



STUDY OF THE AVERAGE CHARACTERISTICS OF DIURNAL VARIATION OF COSMIC RAY INTENSITY FOR THE PERIOD OF 1986-2010

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Abstract : *In the present report, we have analyzed the average characteristics of diurnal variation of cosmic ray intensity for the period of 1986-2010 for Beijing and Kiel neutron monitor stations. We have performed an average characteristics analysis to establish the amplitude and phase modulation for first harmonic of the cosmic ray anisotropy. It has been concluded from the analysis that the diurnal amplitude is mostly concentrated in between the amplitude values of 0.2% to 0.4%, whereas the phase of diurnal anisotropy is concentrated in the belt of 100 to 240 degrees. A good positive correlation has been found between diurnal amplitudes (corr. = 0.62) and between annual averaged diurnal phases (corr. = 0.68) for both the stations. It is also seen that the diurnal amplitudes are significantly larger, by a factor of two, at high/middle latitude station (Kiel) as compared to that of low/middle latitude station (Beijing). The widths of distributions are minimum in the periods of maximum solar activity and maximum during the period of solar minimum.*

Keywords: cosmic rays, diurnal variation, solar cycle.

I. Introduction

The average characteristics of diurnal variation of cosmic ray intensity have been investigated by several investigators from long ago ([1],[2],[4],[5],[7]). The solar modulated anisotropic variations in cosmic ray intensity can be easily detected by the ground based detectors. These anisotropies are generated due to the spin motion of the earth ([1],[6],[3]).

The solar daily variation of cosmic ray intensity is a reflection of the continuously changing conditions in the interplanetary space. The systematic and significant deviations in amplitude/phase of diurnal of cosmic rays from the average values are known to occur in association with strong geomagnetic activity [2]. The significant amplitudes and phases of the diurnal variation and their average characteristics have been investigated for last four decades. Their occurrence and extra terrestrial nature are well established phenomena of cosmic ray modulation studies. In earlier studies it has been established that the diurnal variation of cosmic ray anisotropy has two significant components of the variability. On long term basis these components are 11-year and 22-year period of solar activity.

The diurnal variation of cosmic ray intensity was interpreted initially on the basis of an outward radial convection and inward diffusion along with IMF. The balance between convection and diffusion generates an energy independent anisotropic flow of cosmic ray particles [2]. It has been suggested by [8] that the anisotropy in cosmic radiation is caused by the acceleration or deceleration of particles in an electric field produced by solar stream.

In the present analysis, we have studied to derive the average characteristics of the amplitude and phase of the diurnal variation of cosmic ray anisotropy.

II. Experimental data and analysis

In the present study, we have taken the pressure corrected hourly values of Kiel (cut-off rigidity 2.32 GV, a middle/high latitude station) and Beijing (cut-off rigidity 10.07 GV, a low/middle latitude station) neutron monitors. The amplitudes and phases of diurnal variation of cosmic rays have been derived on a day to day basis by using the technique of harmonic analysis for the period of 1986 to 2010 covering the solar cycles 22 and 23. This technique has been adopted to calculate the vector components of daily variations after removing long-term variations by the method of 24-hours moving average. The annual average for each station for the diurnal variation has been derived from individual daily harmonics after rejecting the universal time affected days. Such rejection eliminates the days of large interplanetary disturbances.

III. Results and Discussion

The results of our analysis are shown by linear plots in figure 1, by vectorial representation in figure 2 and by histographic representation in figure 3. We have also established the relation of average characteristics of diurnal variation of cosmic ray intensity between low and high cut-off rigidity neutron monitor. The long term trend of diurnal vectors of Kiel and Beijing neutron monitor station can also be easily seen in our analysis. The average amplitudes are shown in the form of linear diagram in figure 1 for neutron monitors Beijing and Kiel for the entire study period (1986 to 2010) encompassing solar cycle-22&23 and some part of solar cycle-24. The minimum amplitudes are appeared during minimum solar activity periods and maximum amplitudes are appeared during maximum solar activity periods for both the stations. A good positive correlation ($\text{corr.} = 0.62$) has found for diurnal amplitudes for both the stations. It is also seen that the diurnal amplitudes are significantly larger, by a factor of two, at high/middle latitude station (Kiel) as compared to that of low/middle latitude station (Beijing). The amplitudes are 0.1% or less during solar minima periods, while the amplitudes are 0.3% or more during solar maxima periods.

Similar plot for the time variation of the annual average values of the time of maximum (phase) of first harmonic for the same neutron monitor stations for the same study period is shown in figure 1. The phase is significantly earlier during the minimum solar activity period of 1986, 1996, 1997 and 2007 to 2008. Moreover, the spread in phase has significantly increased during the minimum solar activity periods. It is also seen from the figure that the phase is earliest (75 degree) during the initial period (2008-2009) of solar cycle-24. We have also found that there is smaller change in diurnal phase at high/middle latitude (Kiel) and significantly much larger change at low latitude (Beijing). We have found a good positive correlation ($\text{corr.} = 0.68$) between annual averaged diurnal phases for above two stations.

The vectorial representations are quite important to distinguish the complete variability from one period to another. Using the annual average diurnal amplitudes ($R1$ in %) and phases (ϕ_1 in degree), the vector addition diagram are drawn from 1986 to 2010 for the Kiel and Beijing neutron monitors in figure 2. The annual average values for diurnal vector have been plotted end-to-end for the entire period of study. From the figure it is noticed very clearly that the diurnal phase has continuously changed to earlier hours from 1992 to 1997 and from 2004 to 2005 for both the stations with somewhat decreasing amplitudes. The overall values are shown in the figure by the dashed lines for both the station (Kiel and Beijing). The overall average vectors for the entire period for Kiel & Beijing stations have been deduced and are found to be:

Kiel: Average amplitude (1986-2010): $R1 = 0.239\%$, Average phase (1986-2010): $\phi_1 = 205^\circ$

Beijing: Average amplitude (1986-2010): $R1 = 0.184\%$, Average phase (1986-2010): $\phi_1 = 173^\circ$

The day-to-day variability for the amplitude and phase for diurnal variation of cosmic ray intensity can be better represented by generating frequency distribution in the form of histographic diagram of the days by choosing sets of intervals. Figure 3 depict the frequency of occurrence of daily values of the amplitude (in %) phase (in degree) of diurnal anisotropy using the hourly data of the Beijing neutron monitor station for the period of 1986 to 2010. A well defined peak around 0.3% can be easily seen for the amplitude in most of the years. There is a left-ward shift with maximum frequency around 0.2% for the years 1986, 1987, 1995, 1996, 1999, 2002 and 2009, while we have found right-ward shift with maximum frequency 0.4% for the years 1990, 1993, 1994, 2001 and 2006. The shift of the overall distribution towards lower phase values is clearly evident. The width of distributions are minimum in the periods of maximum solar activity (1989-1990 and 2001-2001) and maximum during the period of solar minimum (1986-1988, 1996-1998, and 2007-2008).

IV. Conclusion

1. The diurnal amplitudes are significantly larger at high/middle latitude station as compared to that of low/middle latitude station. The amplitudes are lower during solar minima periods than that of solar maxima periods. We have also concluded that there is smaller change in diurnal phase at high/middle latitude and significantly much larger change at low latitude.
2. A well defined peak about 0.3% can be easily seen for the amplitude in most of the years. The shift of the overall distribution towards lower phase values is clearly evident. The widths of distributions are minimum in the periods of maximum solar activity and maximum during the period of solar minimum.
3. It is concluded that the diurnal amplitude is mostly concentrated in between the amplitude values of 0.2% to 0.4%, whereas the phase of diurnal anisotropy is concentrated in the belt of 100 to 240 degrees.
4. The results presented support the theories of long-term variability of diurnal variation and clearly reveal the 11-year periodicity.

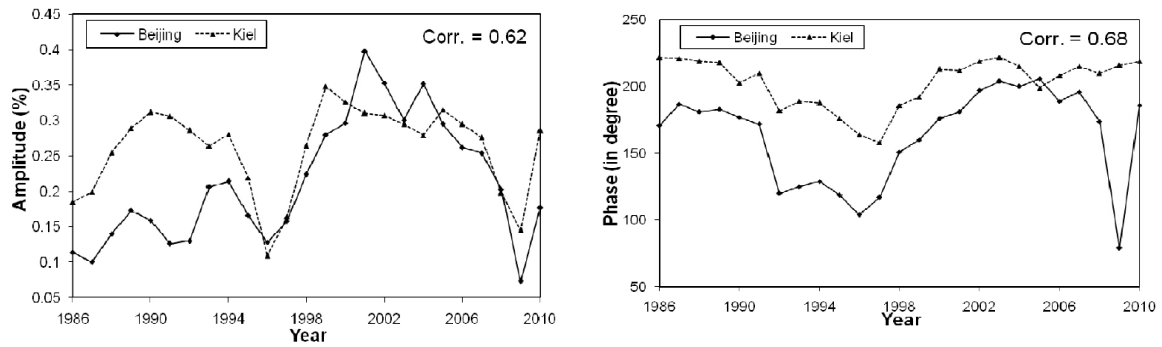


Figure 1. The variation of the annual average amplitudes and phase of first harmonic of daily variation of cosmic rays for two different neutron monitor stations for the period 1986-2010.

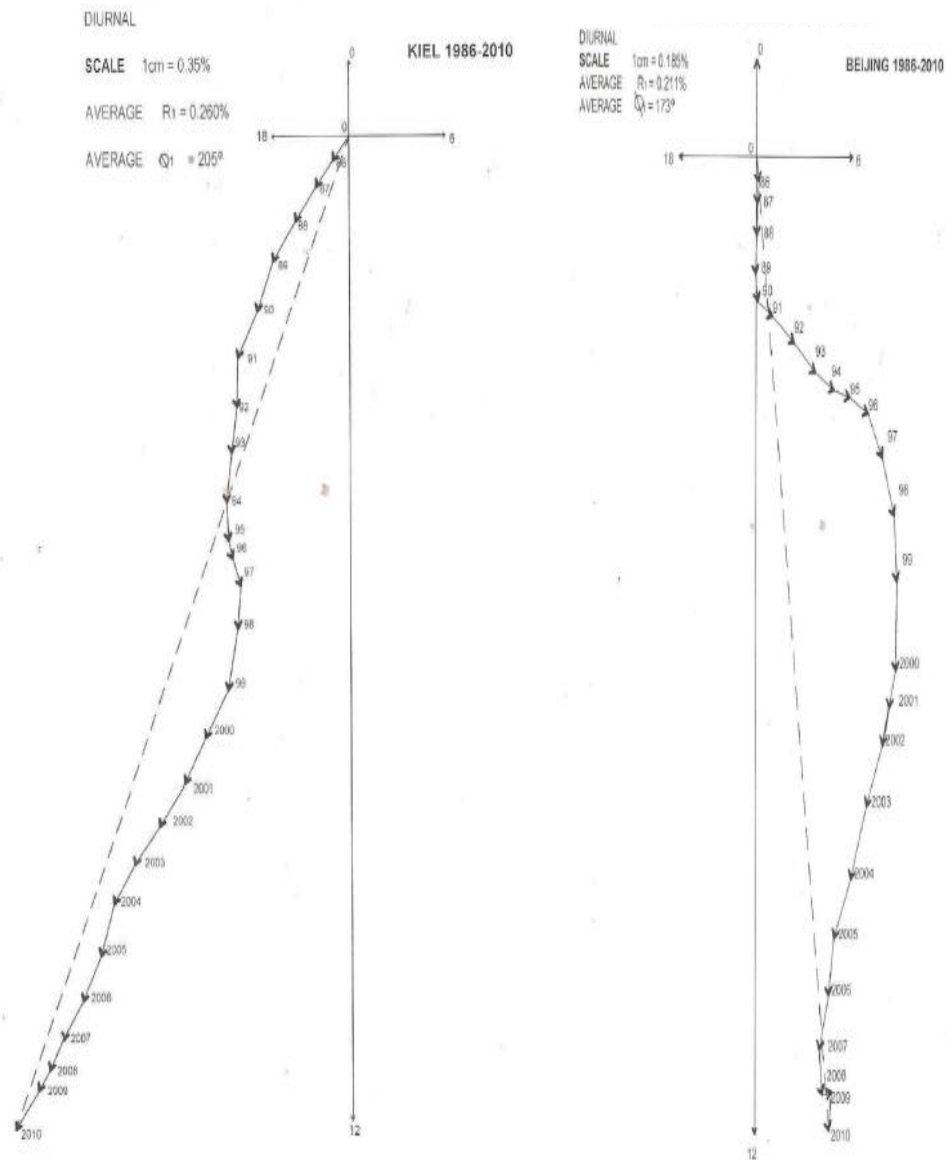


Figure-2.: The vector addition representation of the annual average vector of first harmonic of the daily variation of cosmic rays for the data of Kiel and Beijing neutron monitor for the interval 1986-2010.

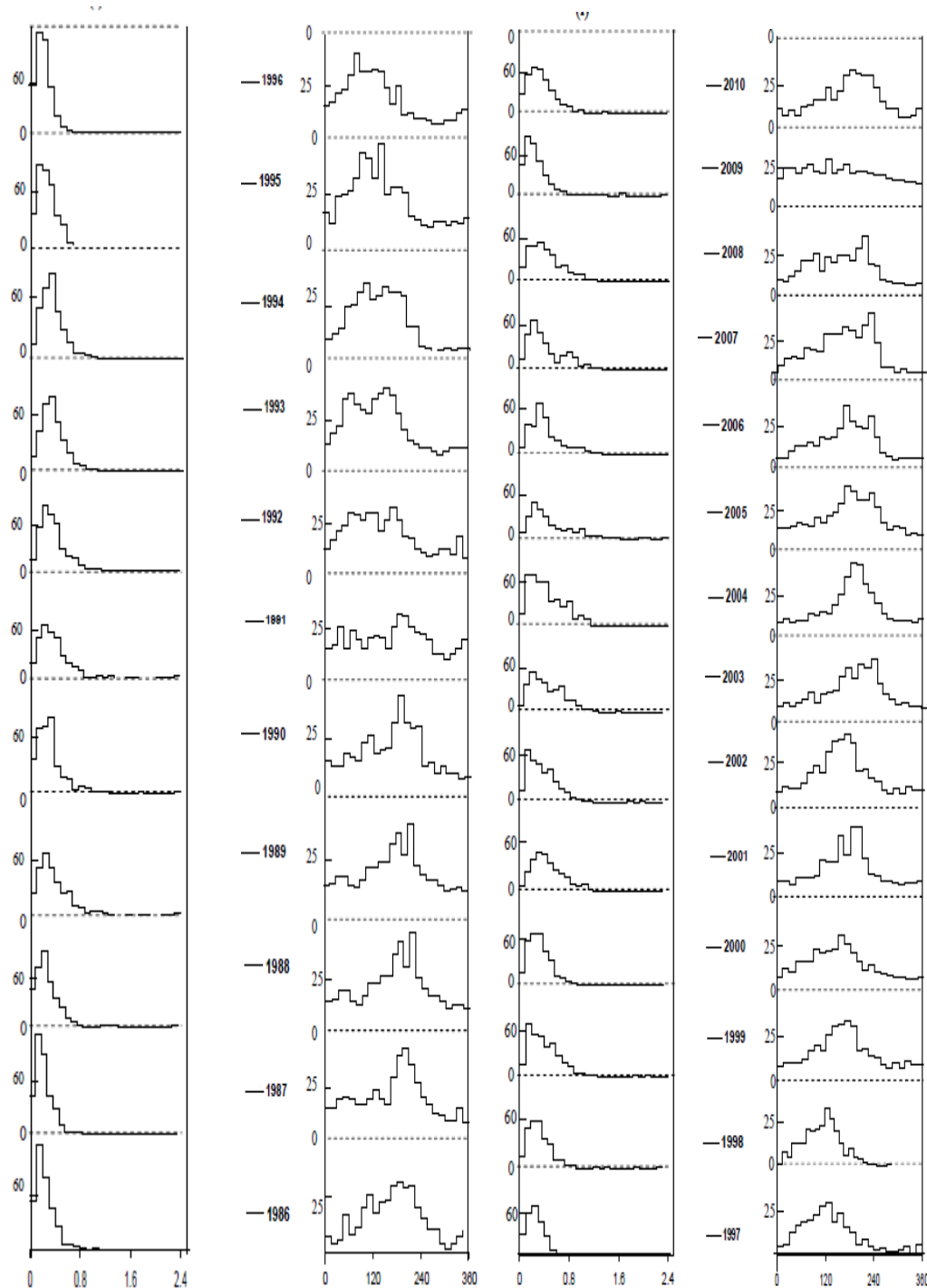


Figure 3: The frequency of occurrence of daily values of the amplitude (in %) and phase (in degree) of diurnal anisotropy using the hourly data of the Beijing neutron monitor station for the period of 1986-2010.

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