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Study of anisotropic variation of cosmic rays intensity with solar activity

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ABSTRACT

The annual average values of amplitudes and phases of first two harmonics of cosmic ray anisotropy have been derived by using the harmonic analysis technique for the period 1989 to 2004, which covers mostly the major period of solar cycles 22 and 23. In this paper we have taken the pressure corrected hourly data for Kiel neutron monitor station (cut off rigidity ≈ 2.29 GV) to derive the harmonic component of cosmic ray daily variation and compared with the data of Halekala neutron monitor (cut off rigidity ≈ 13.2 GV) for the period 1991 to 2004. From the analysis it has been concluded that the diurnal amplitude and phase of daily variation of cosmic rays have been found to be correlated with solar activity. However, the semi-diurnal amplitude and phase are inversely correlated with solar activity for both the stations.

Keywords: Cosmic Ray, Anisotropic Variation, Solar Parameter

1. INTRODUCTION

The anisotropic variations in cosmic ray intensity which are observed only in the heliosphere can be easily detected by the ground based detectors [1-6]. Among the various cosmic ray intensity variations, 27-day variations, Forbush decreases and solar daily variations have been widely investigated by number of researchers [6-8]. The large differences in the diurnal and semi-diurnal variation of cosmic ray intensity indicate that large changes occur in interplanetary space for continuous periods, which are associated with the spatial distribution of cosmic ray intensity as well as geomagnetic disturbances. The amplitudes and phases of first two harmonics of cosmic ray daily variation and their average characteristics have been particularly emphasized in a series of papers [9-10]. Since the realization of "in situ" observations; the convection-diffusion and the interplanetary magnetic field (IMF) gradient as well as curvature drift phenomena in galactic cosmic ray particles; all together manifest itself as a time variation in the count rate of the monitor, a phenomena called solar daily variation or cosmic ray anisotropies [11-15].

In this paper we have collected the data of diurnal and semi-diurnal amplitudes and phases of cosmic ray anisotropies for the period 1989-2004 of Kiel neutron monitor (a high-latitude station) and for the period 1991-2004 of Haleakala (a low-latitude) neutron monitor station and correlated with sunspot number (Rz) covering the previous solar cycle 22 and present solar cycle 23.

2. METHOD OF ANALYSIS

Generally, cosmic ray intensity shows significant anisotropic variation on a day-to-day basis with most probable amplitude of 0.4% to 0.5% at high and low latitude neutron monitor stations. During the period 1989 to 2004, covering the major portion of solar cycles 22 and 23, the amplitudes and phases of the first two harmonics of the daily variation of high energy cosmic rays have been obtained on a day-to-day basis by using the pressure corrected hourly data of neutron monitors, well distributed particularly in latitudes, to cover different cut-off rigidities. Such data enable us to study the rigidity-dependent variations. These observational results for first and second (diurnal and semi-diurnal) harmonics have been compared with the solar and geomagnetic parameters. The hourly pressure corrected cosmic ray neutron monitor data of Kiel (a high-latitude station with low cut-off rigidity) and Haleakala (a low-latitude station with high cut-off rigidity) neutron monitor stations have been obtained from the website www.cosmic ray neutron monitor data NGDC/WDC STP, Boulder-Cosmic Rays. The amplitudes and Phases (time of maximum) of the anisotropic variation of cosmic rays have been derived from these data by simple harmonic analysis. The annual average is calculated from individual daily vectors after rejecting the days with universal time (UT) associated cosmic ray variations. The daily values of

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solar and geomagnetic parameters have been taken from Solar Geophysical Data Books.

3. DISCUSSION AND CONCLUSIONS

The solar activities play a significant role in modulating the cosmic ray intensity. It modifies interplanetary and geomagnetic parameters. The cosmic ray daily variations which are due to spinning motion of the earth, are particularly described in this analysis. In fact, the largest amplitudes are observed during the declining phase of solar activity (**Figures 1** and **2**). In other words, we infer that the semi-diurnal amplitude for Kiel and Haleakala neutron monitor stations are negatively correlated with sunspot numbers, (**Figures 3** and **4**) which is opposite to that found for the diurnal amplitudes.

Nevertheless, the semi-diurnal phase *i.e.* the time of maximum for Kiel and Haleakala is positively correlated (Kiel r = 0.84, Haleakala r = 0.53) with sunspot number, as was also the case for the diurnal phase. The results are presented here for the recent periods.

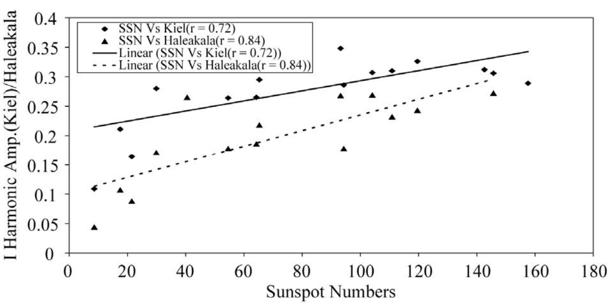

Figure 1. The crossplot between the first harmonic (diurnal variation) annual average amplitude (for Kiel as well as for Haleakala in %) with sunspot numbers, for the interval 1989-2004 for Kiel and 1991-2004 for Haleakala. The best fit lines are also shown.

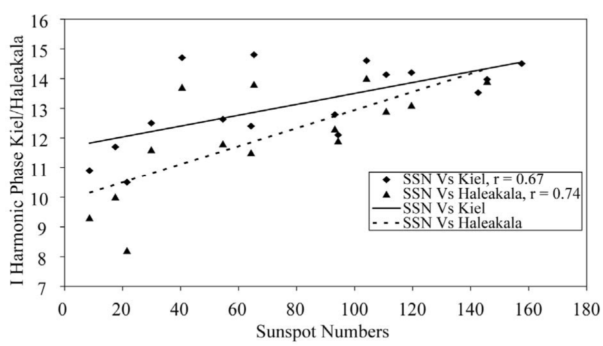

Figure 2. The crossplot between the first harmonic (diurnal variation) annual average phase values (in hours) for (Kiel/Haleakala) neutron monitor with sunspot numbers for the interval 1989-2004 for Kiel and 1991-2004 for Haleakala. The best fit lines are also shown.

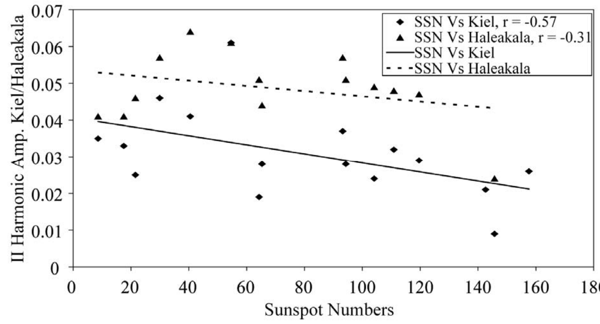

Figure 3. The crossplot between the second harmonic (semi-diurnal variation) annual average amplitudes in (%) for Kiel/Haleakala neutron monitor with sunspot numbers, for the interval 1989-2004 for Kiel and 1991-2004 for Haleakala. The best fit lines are also shown.

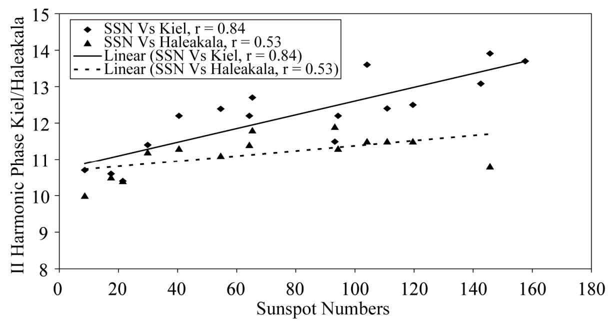

Figure 4. The crossplot between the second harmonic (semi-diurnal variation) annual average phase values (in hours) for Kiel as well as for Haleakala neutron monitor station with sunspot numbers for the interval 1989-2004 for Kiel and 1991-2004 for Haleakala. The best fit lines are also shown.

1) Significant positive correlations of amplitudes and phase for both the stations as well as for the solar parameter (*Rz*) have been found for diurnal variation. From the analysis, it is observed that the diurnal amplitude and phase show a significant correlation with sunspot activity.
2) The amplitude as well as the time of maximum of the diurnal phase has been found to increase with the increase of sunspot numbers, *i.e.* diurnal amplitude as well as phase is generally high during high solar activity period. The negative correlations of the semi-diurnal amplitudes with sunspot number signify that during maximum sunspot activity periods, the semi-diurnal amplitudes have least magnitudes.
3) The semi-diurnal amplitude for Kiel and Haleakala neutron monitor stations are negatively correlated with sunspot number, which is opposite to that found for the diurnal amplitudes.
4) Nevertheless, the semi-diurnal phase *i.e.* the time of maximum for Kiel and Haleakala is positively correlated (Kiel r = 0.84, Haleakala r = 0.53)

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with sunspot number, as was also observed in case of the diurnal phase.

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