



Study on the Quiet Conditions in the Interplanetary Medium and Its Association with Diurnal Variation of Cosmic Ray Intensity

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Abstract: The influence of varying interplanetary condition is studied using A_p index on the observed daily variation of cosmic rays for the period 1989-2002 onwards. We have determined the statistical distribution of the diurnal variation with low A_p events. Attempt have been made to study the variational features of the diurnal time of maximum as well as its amplitude on continuous low A_p days selected under two criteria (i) selection of quiet A_p events with fixed $A_p \leq 8$ for 6 or more days occurring successively; (ii) selection of A_p value based on iteration process (for a set of continuous days) instead of fixed value of A_p ; for six days. Study of diurnal anisotropy on specified criteria shows that the phase of diurnal anisotropy in the later period shifts to early hours in 1995-96. It is also found that the characteristics of daily variation in cosmic ray intensity are quite comparable for the two different criteria of days, during the period of investigation. The results for each year for both types of A_p days are analysed. We draw the conclusion that fixed A_p values serve better for further composition with the annual average values. We have also looked into the trend between the average of fixed value of A_p and the annual average for each year. The diurnal amplitude remains quite similar as annual amplitude for the low A_p (quiet days) on annual average for low A_p events. The amplitude of annual average for iterated A_p events have high magnitude while fixed A_p events have low magnitude in comparison with annual average for the entire period of study.

Keywords: Cosmic rays, solar activity, diurnal variation, A_p Index, quiet days.

I. Introduction

Geomagnetic activity variation is the time variation in the magnetic field of the earth and is linked through solar interplanetary magnetospheric phenomena. We generally find that such variations are a consequence of fluctuation in surrounding the Earth. Different kinds of solar processes affecting the interplanetary medium, in turn produce variations in geomagnetic field, as well as modulate the cosmic ray intensity both on long and short term bases. It is now established fact that even the short term presence of southward component (B_z) of the interplanetary magnetic field (IMF- B_z) has been found to be an important catalytic parameter generating large disturbances in the geomagnetic field [4]. Many geomagnetic indices (K_p, A_p, Dst etc.) are used to reflect geomagnetic activity. These indices give indications of the severity of magnetic fluctuations, and hence the level of disturbances in the ionosphere. The continuous occurrence of high/most high values of the geomagnetic field disturbance index A_p , indicates the disturbed conditions/most disturbed phase in the interplanetary medium. Similarly to look for undisturbed periods of continuous days (i.e. quiet conditions in the interplanetary medium), we have analysed continuous days of low values of A_p index.

Past studies on cosmic ray isotropic and anisotropic variation during quiet periods have indicated significant changes in its intensity and amplitudes [10]. They have reported higher cosmic ray intensity during such event (quiet) periods for the interval 1976 to 1986. Tiwari et al [2] critically analysed the diurnal anisotropy for low A_p groups and find that dispersion from one group to another for low values of A_p index indicate quiet periods there by signifying quiet condition of the interplanetary medium. Singh et al [12] and the references therein used low/high wave train events of diurnal amplitude of cosmic ray variation they found that HAEs and LAEs do not reveal any correlation with the solar wind speed (V) or geomagnetic index (A_p) on annual average basis. Also the high speed solar wind streams do not play any significant role in causing these HAEs and LAEs. The days of low and high diurnal amplitudes occur continuously as train of days almost with equal probability during the entire solar cycle. The tendency of higher rate of occurrence of high amplitude wave trains is significantly low during low sunspot activity period. Nevertheless, the total numbers of events are much larger for low diurnal amplitude wave trains. To find out undisturbed period of continuous days (i.e. quiet conditions in the interplanetary medium) one can choose continuous days of low values of A_p index. The anisotropic modulation in CR intensity on long/short term basis has been studied for diurnal anisotropy and for higher harmonics in CR intensity, satisfying different criteria. Kumar et al ([14],[5]) studied the diurnal anisotropy on geomagnetically quietest days (60QD); Whereas, ([7], [1],[9]) have opted All Days (AD) for such analysis. Solar wind and IMF play an important role in controlling the electrodynamics of the heliosphere [15].

Solar wind speed V and IMF parameters, such as B , spiral angle and tilt are important for the transport of energetic cosmic ray particles in the heliosphere, for the modulation of CR and creation of CR anisotropy in the interplanetary space [16]. Alania et al [17] studied the on relation of the long period galactic cosmic rays intensity variations They noticed that the magnitude of the GCR anisotropy vector is larger in the positive IMF sector and that the phase shifts towards early hours.

II. Data and Method of Analysis

We have performed here a systematic study to observe the short-term changes in cosmic ray intensity during the geomagnetic quiet periods for the interval 1989 to 2002, covering a part of ascending phase of solar cycle 23. Using A_p values, events of continuous quiet periods have been selected, which seems to be a good indicator of the interplanetary medium quiet conditions. For our analysis, we have selected low A_p continuous days, as per selection criteria given below.

- Quiet A_p events with fixed $A_p \leq 8$ for 6 or more days occurring successively[11];
- A_p value selection based on iteration process (for a set of continuous days) instead of fixed value of A_p ; for six days. [18]

Based on the two selection process mentioned above for continuously occurring low A_p days, the averages for each events for the first harmonics of the daily variation of the cosmic rays have been calculated separately. Moreover, the overall average of all the events has also been obtained. For comparison, we have taken the yearly average harmonic values, fixed A_p values and for iterated set of events for each year. A closer look to the result obtained reveals that the averages differ to a great extent from one event to another event in the same year. Both for first and second harmonic of the daily variation of cosmic rays, the averages are also quiet significantly changed in the two cases because of different number of events.

Finally pressure corrected data obtained from KIEL neutron monitor(Geographic latitude=54.34 N, Geographic longitude =10.12E, Altitude=54m, Vertical cut off rigidity=2.36GV) has been harmonically analysed through Fourier technique after applying trend correction and removing UT associated days, to obtain the first and second harmonic amplitude and phase.

III. Results and Discussion

Attempt have been made to study the variational features of the diurnal time of maximum as well as its amplitude on different groups of days selected under different criteria depending on A_p values. Fig.1 and Fig 2 show the no. of events and the no. of days involved in both type of quiet days (fixed and iterated). It is observed that during solar minima i.e. in 1996-97, the no. of days as well as no. of events are higher than the other years however considerable number of more days are associated with the fixed A_p events. Fig. 2(a) shows the cross-plot between average A_p of fixed days versus A_p average of iterated events days. We find a good correlation ($r = 0.66$) during the entire period of study. The cross-plot between both type of A_p averages to the annual average of the corresponding year is shown in fig. 2(b). We found that iterated A_p average is better correlated to the yearly average ($r = 0.46$) than the fixed A_p events averages($r = 0.28$).

We have compared the I- Harmonic amplitude of diurnal variation and phase of the two types of A_p events with the annual average [Fig. 3 (a, b)] and we find that fixed A_p events show a large changes during solar minima i.e. 1995, 1996. The phase shifted to earlier hours during solar minima in both two types of days as compared with the annual average.

The cross-plot of Fig. 4(a) reveals that Fixed versus iterated A_p I-Harmonic amplitudes have considerable correlation coeff. ($r = 0.40$).The yearly amplitude plotted against both type of events i.e. fixed and iterated A_p show a very good correlation ($r = 0.67$) with the fixed A_p amplitudes and a considerable good correlation($r = 0.49$) with the iterated A_p events is observed [fig.4(b)].

In a similar manner, the correlation for the diurnal phase of fixed A_p versus iterated A_p ($r = 0.94$), Yearly A_p versus fixed A_p ($r = 0.85$) and yearly A_p versus iterated A_p ($r = 0.81$) show the very good correlation as shown in Fig.5(a,b). From these figures (4, 5) we can conclude that the low A_p events and amplitude/phase are well correlated with the annual average values.

The solar wind velocity and IMF B are plotted for both fixed and iterated values for the period under study [fig.6 (a,b)]. From the figures it is observed that the V and B both are significantly correlated for both type of A_p events. The frequency histograms of solar wind velocity for V and B have been plotted in Fig.7(a, b). It can be observed from these figures that majority of the A_p events have occurred when the solar wind velocity lies in the interval 300-400 km/s. Very few A_p events occurred when solar wind velocity is 450 and above. It is also observed that most of the low A_p events occurred when IMF B oscillates between 3.5 to 7.5.

IV. Conclusion

1. Diurnal phase for low A_p events in both criteria (fixed & iterated) varies with the diurnal phase on annual average basis. The direction of observed diurnal variation for low A_p events lies along the ~ 9 h and 15 h direction. The annual average phases are concentrated mostly in the 12 h to 15 h direction.

2. On an annual average basis during solar activity minima of 1996, 1997, the yearly average diurnal phase shifted to earlier hours. In contrast, we have found that the annual average diurnal amplitudes show a significant decrease during the solar activity minima and found maximum during the declining phase of the solar cycle for both the criteria.
3. The diurnal amplitude remains quite similar as annual amplitude for the low Ap (quiet days) events on an annual average basis. The amplitude of annual average for iterated Ap events have high magnitude while fixed Ap events have low magnitude in comparison with annual average for the entire period of study.
4. The amplitude as well as direction of diurnal anisotropy is well correlated with solar cycle during low Ap days. The occurrence of low Ap events is geomagnetic activity dependent and hence the interplanetary conditions disturbances are responsible for modulation of cosmic rays.
5. It is clear from the study that low continuous Ap events are most suitable for the study of geomagnetic undisturbed period instead of choosing other parameters for the study of quiet interplanetary conditions.

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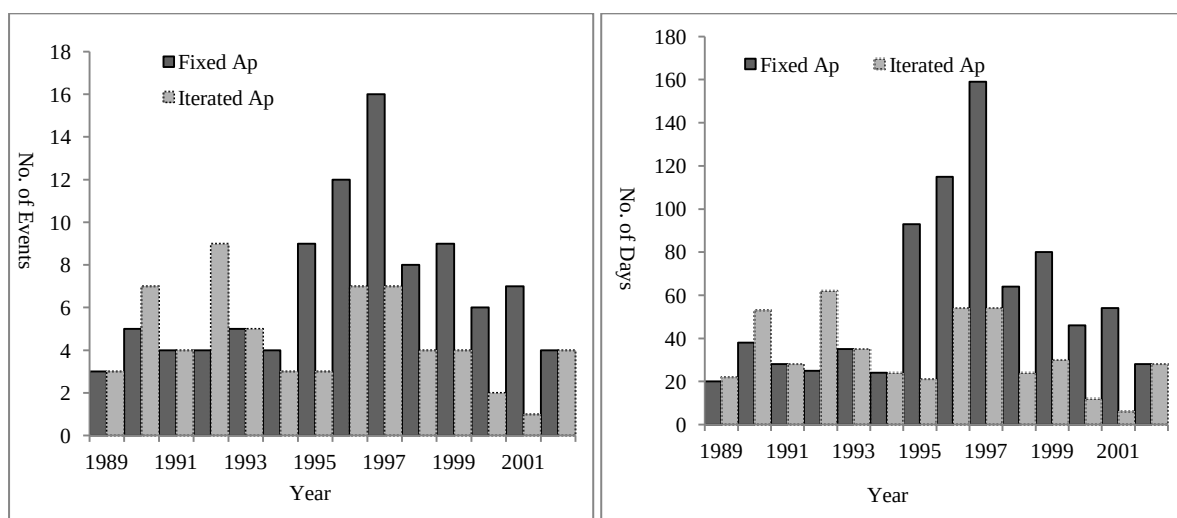


Figure-1: Shows the Histogram plot for the (a) No. of events per year, (b) No. of days associated per year, of two types of Ap for the year 1989 to 2002.

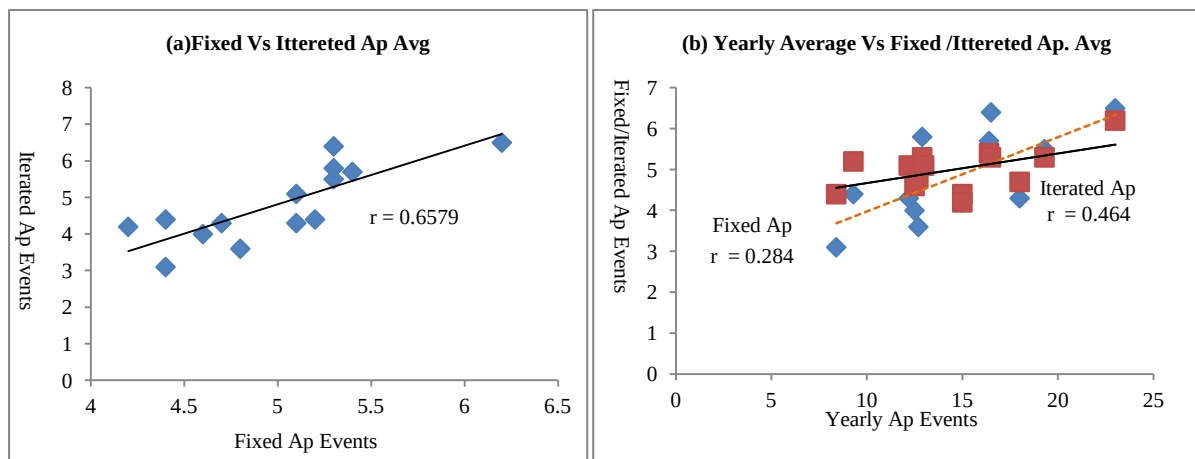


Figure-2: Shows the Cross plot between averages of (a) fixed Ap events vs Iterated Ap events (b) Yearly average vs. Fixed/Iterated Ap events for the year 1989 to 2002.

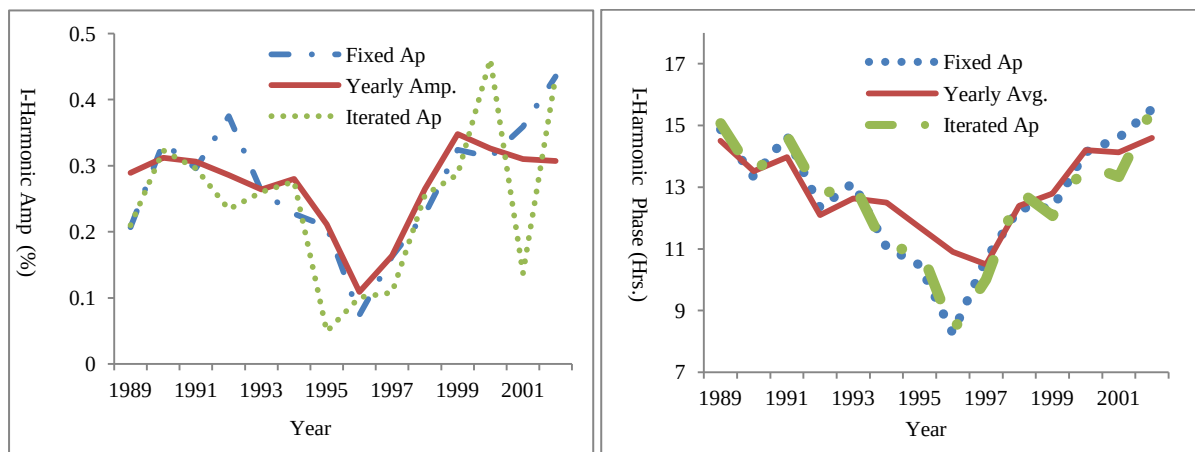


Figure:3 (a) Shows the comparison of amplitude of first harmonic for three types of days(Fixed, Iterated, and annual averages (b) Shows the comparison of Phase (Hrs.) of first harmonic for three types of days(Fixed, Iterated, and annual averages

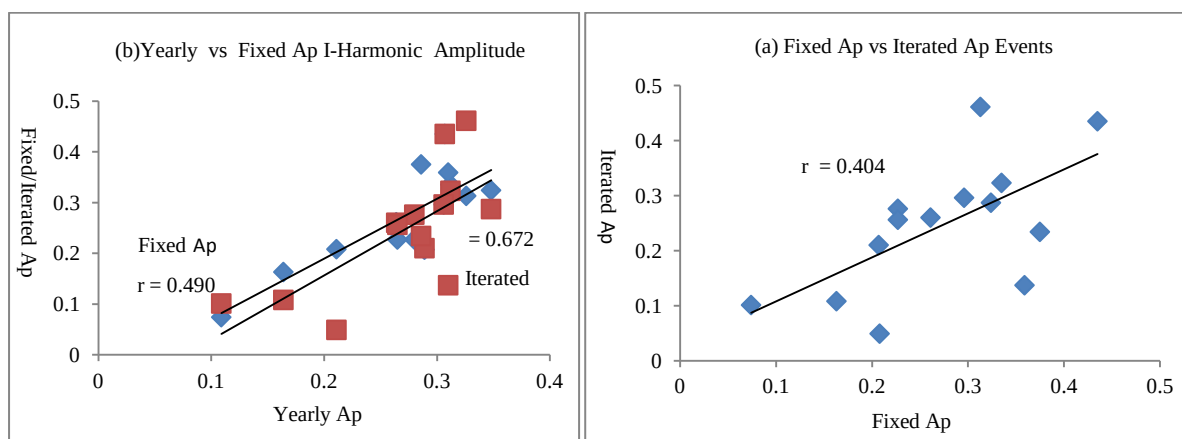


Figure-4: Shows Cross Plot between Average of (a) Fixed Ap events I-Harmonic Amplitude (%) vs. Iterated Ap events I- Harmonic amplitude (%) (b) I-Harmonic Amplitude (%) of Yearly Average vs. Average of Fixed Ap/Iterated Ap events for the period 1989 to 2002

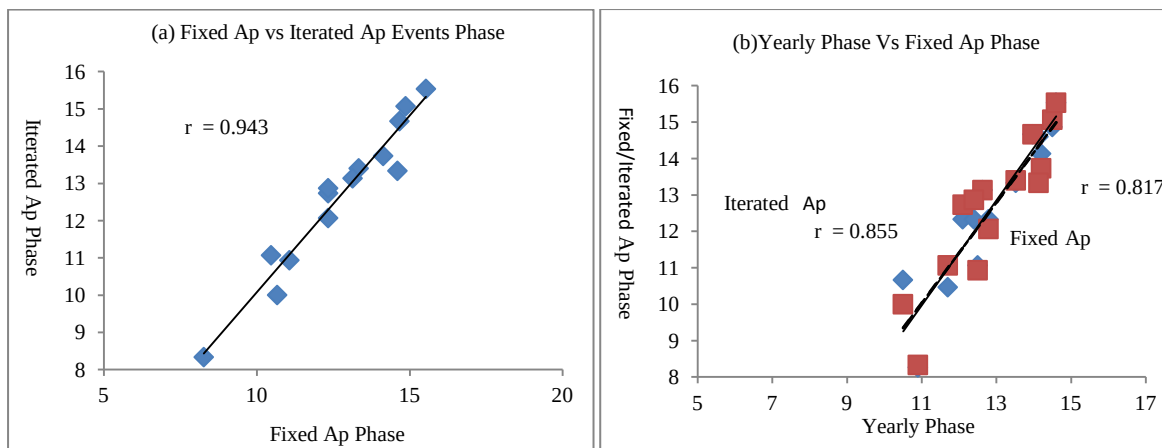


Figure-5: Shows Cross Plot between Average of (a) Fixed Ap events I-Harmonic Phase(Hrs.) VS. Iterated Ap events I- Harmonic Phase (Hrs.) (b) I-Harmonic Phase (Hrs.) of Yearly Average VS I-Harmonic Average Phase (Hrs.), of Fixed/Iterated Ap event for the year 1989 to 2002.

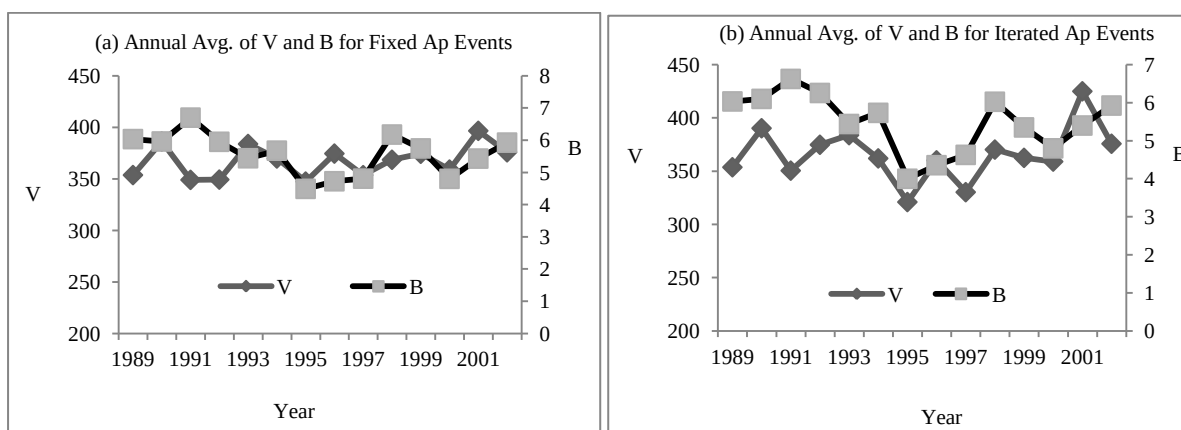


Fig. 6 (a, b) Show the Variation of Solar wind velocity (V) and IMF Bsc. For both type of Events (Fixed/Iterated).

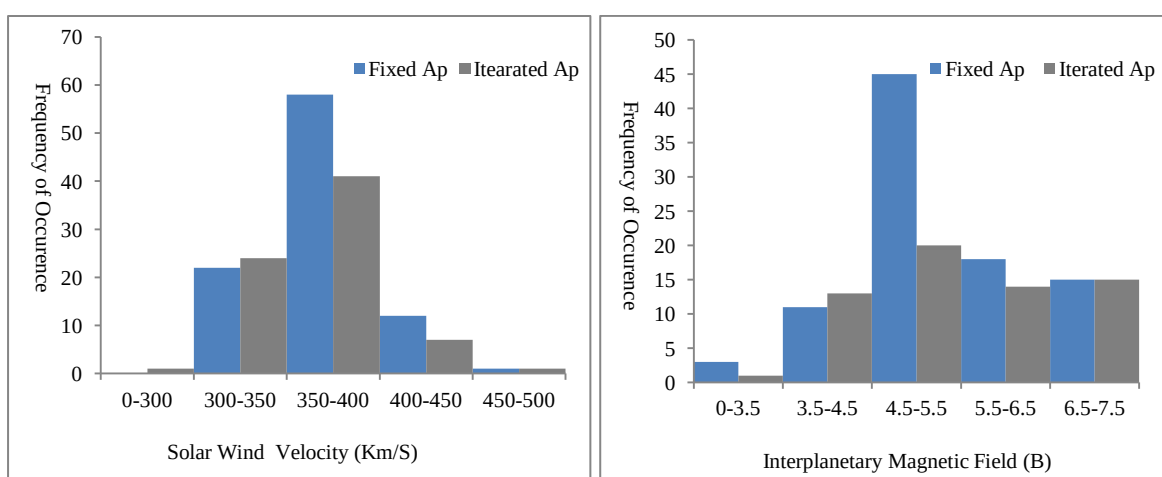


Figure-7: Frequency histogram of (a) solar wind velocity (b) Interplanetary Magnetic field B for all the Ap events (Both types Fixed & Iterated) during 1989-2002.