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Study of high amplitude anisotropic wave trains along with interplanetary plasma parameters

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Abstract - The first three harmonics (diurnal/semi-diurnal/tri-diurnal) of high amplitude anisotropic wave trains of cosmic ray intensity over the period 1991-1994 have been investigated for Deep River neutron monitoring station. Our study reveals that the diurnal time of maximum i.e. phase remains in the corotational/18 Hr direction, whereas the time of maximum for semi-diurnal anisotropy has no definite trend as compared to the quiet days (days on which the transient magnetic variations are regular and smooth) annual average for majority of the HAE events. The phase of the tri-diurnal anisotropy significantly shift towards later hours as compared to the quiet day annual average. It is noticed that these events are not caused either by the high-speed solar wind streams or by the sources on the Sun responsible for producing these streams such as polar coronal holes. The amplitude of tri-diurnal anisotropy for HAE events is observed to remain high for negative polarity of north-south component of interplanetary magnetic field (Bz), whereas it is found to remain slightly low for positive polarity of Bz showing a negative correlation. The amplitude of the tri-diurnal anisotropy is observed to increase with the decrease in the value of disturbance storm time index (Dst) showing a negative correlation.

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1. Introduction

Existence of high and low amplitude anisotropic wave trains has been revealed through the long-term study of cosmic ray intensity. Periods of unusually large amplitude often occur in trains of several days. The average characteristics of cosmic-ray diurnal anisotropy are adequately explained by the co-rotational concept [1-3]. This concept supports the mean diurnal amplitude in space of 0.4% along the 1800 Hr direction using the worldwide neutron monitor data. However, the observed day-to-day variation both in amplitude and time of maximum, and the abnormally large amplitudes or abnormally low amplitudes of consecutive days, cannot be explained in co-rotational terms. Moreover, the maximum intensity of diurnal anisotropy has not appeared in the direction of 1800 Hr, which is the nominal co-rotational phase [4-5].

Many workers used a new concept for the interpretation of the diurnal variation [6-8]. McCraken et al. [9] first suggested the extension of this new concept from the solar cosmic events to the observed diurnal variation and theoretical formulation provided by Forman and Gleeson [10]. Several workers have attempted to find the possible origin of the 'large amplitude wave trains' of cosmic ray neutron intensity to develop a suitable realistic theoretical model, which can explain the diurnal anisotropy in individual days.

Hashim and Thambyahpillai [11] and Rao et al. [6] have shown that the enhanced diurnal variation of large amplitude events exhibits a maximum intensity in space around the anti-garden-hose direction (2000 Hr) and a minimum intensity in space around the garden-hose direction (0900 Hr). Kane [12] and Bussoletti [13] have noticed that quite often an enhanced intensity is presented along the corotational direction and it is not correlated with the garden-hose direction. The diurnal anisotropy is well understood in terms of a convective-diffusive mechanism [10]. Mavromichalaki [14] has observed that the enhanced diurnal variation was caused by a source around 1600 Hr or by a sink at about 0400 Hr. It was pointed out that this diurnal variation by the superposition of convection and field-aligned diffusion due to an enhanced density gradient of ≈ 8% AU^{-1}.

2. Analysis of Data

Using the long-term plots of the cosmic ray intensity data as well as the amplitude observed from the cosmic ray pressure corrected hourly neutron monitor data using harmonic analysis the High amplitude wave train events (HAE) have been selected on the basis of following criteria:

High amplitude wave train events of continuous days have been selected when the amplitude of diurnal anisotropy remains higher than 0.4% on each day of the event for at least five or more days.

On the basis of above selection criteria we have selected 16 high amplitude wave train events during the period 1991-94

3. Results and Discussion

The amplitude (%) and phase (Hr) of cosmic ray diurnal/semi-diurnal/tri-diurnal anisotropy along-with the respective quite day annual average value is plotted and shown in Fig 1 (a-c) for all the HAE events. The amplitude of the diurnal anisotropy as depicted in Fig. 1 is observed to remain significantly high as compared to the quiet day annual average value throughout the period, whereas, the phase remains in the co-rotational direction for majority of the event. Further, the amplitude of the semi-diurnal anisotropy is significantly large as compared to the quiet day annual average values for majority of the events, whereas, the phase has no definite trend for the semi-diurnal anisotropy. Furthermore, the amplitude of the tri-diurnal anisotropy is significantly higher for all HAEs as compared to the quiet day annual average value throughout the period. As it is quite apparent from these plots that the tri-diurnal time of maximum has a tendency to shifts towards later hours as compared to quiet day annual average value for majority of the events; which is in agreement with the low amplitude wave trains where it has also shift towards later hours for the majority of the events.

The amplitude (%) and phase (Hr) of cosmic ray diurnal/semi-diurnal/tri-diurnal anisotropy along - with the variation in associated value of Bz component of interplanetary magnetic field is plotted (figs not shown here) and calculated the correlation coefficient between these parameters as shown in Table 1. The amplitude of the diurnal anisotropy for majority of the HAE events is observed to remain significantly high, whereas, the phase is found to remain in the corotational direction statistically. No significant correlation between the amplitude of semidiurnal anisotropy and Bz has been observed for HAE events. The phase is observed to shift towards earlier hour as the polarity of Bz component of IMF directed from negative to positive values showing a negative correlation as depicted in Table 1.

The amplitude of tri-diurnal anisotropy for HAE events is observed to remain high for negative polarity of Bz, whereas it is found to remain slightly low for positive polarity of Bz showing a negative correlation. The phase of the tri-diurnal anisotropy does not show significant correlation with Bz due to large scattering of points.

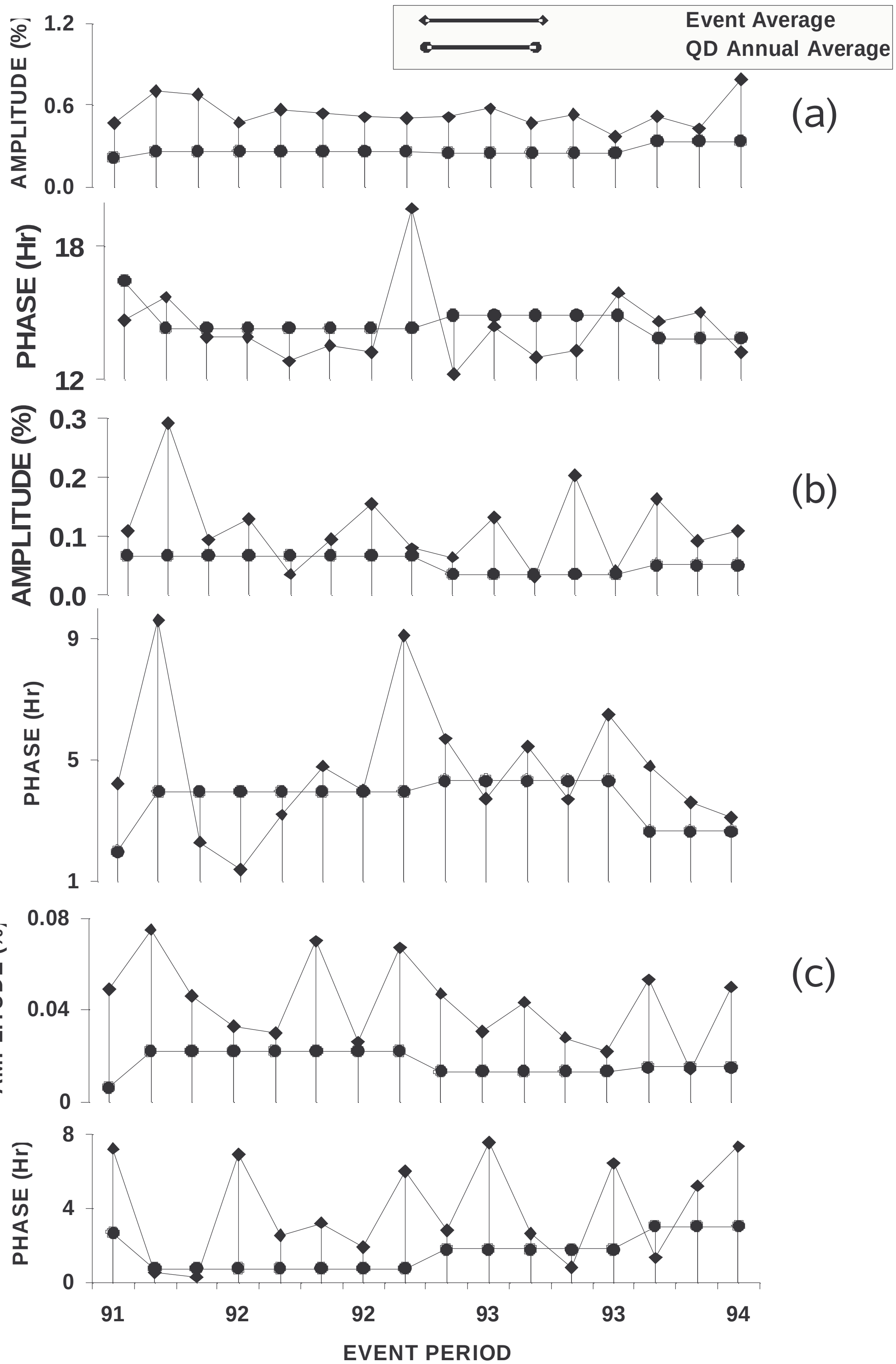

Fig. 1. Amplitude and phase of the (a) diurnal, (b) semi-diurnal and (c) tri-diurnal anisotropy for HAEs along with the quiet day annual average values during the period 1991-94.

Table 1. Correlation coefficient (r) of diurnal/semi/tri-diurnal amplitude and phase with Bz, Dst and Ap index.

Correlation Coefficient (r)	**Bz**	**Dst**	**Ap**
Diurnal amplitude	0.24	**- 0.48**	0.31
Diurnal Phase	- 0.03	- 0.01	- 0.21
Semi-diurnal amplitude	0.08	- 0.26	0.09
Semi-diurnal Phase	**- 0.45**	- 0.02	- 0.21
Tri-diurnal amplitude	- 0.13	- 0.34	- 0.20
Tri-diurnal Phase	0.14	- 0.14	**- 0.53**

The amplitude (%) and phase (Hr) of cosmic ray diurnal/semi-diurnal/tri-diurnal anisotropy along-with the variation in associated value of disturbance storm time index (Dst) is plotted (figs not shown here) and calculated the correlation coefficient between these parameters as shown in Table 1. The amplitude of the diurnal anisotropy for HAE events is observed to increase with the decrease of Dst-index showing a negative correlation. The amplitude of the semi-diurnal anisotropy is found to slightly increase with the decrease in the value of Dst-index showing weak negative correlation. The amplitude of the tri-diurnal anisotropy is observed to increase with the decrease in the value of Dst-index showing a negative correlation. The weak correlation has been observed with Dst-index for diurnal, semi-diurnal and tri-diurnal phase of HAE events. The amplitude (%) and phase (Hr) of cosmic ray diurnal/semi-diurnal/tri-diurnal anisotropy along-with the variation in associated value of geomagnetic activity index (Ap) is plotted (figs not shown here) and calculated the correlation coefficient between these parameters as shown in Table 1. The weak correlation has been observed with Ap-index for diurnal, semi-diurnal anisotropy vectors and tri-diurnal amplitude for the HAE events. However, the phase of tri-diurnal anisotropy for HAE events is found to shift towards earlier hours with the increase of Ap-index showing a significant negative correlation.

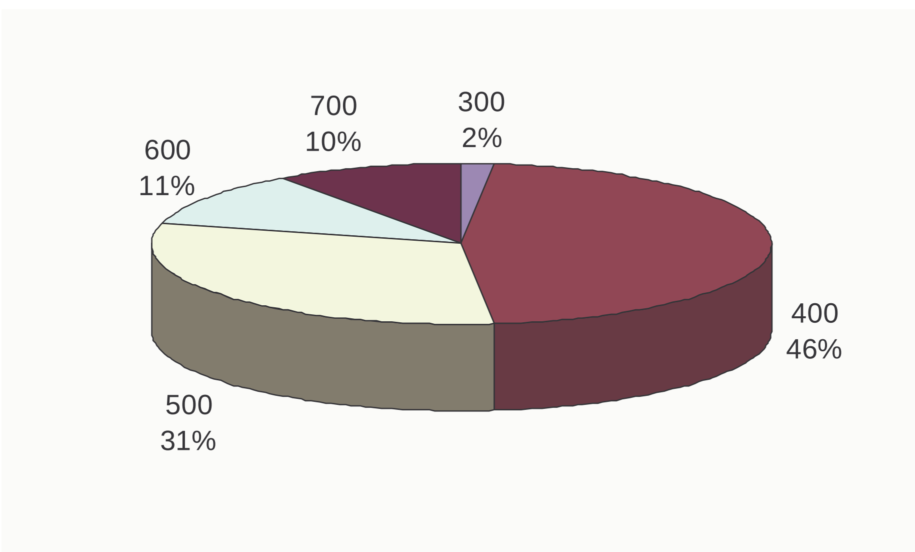

Fig. 2. The pie diagram of the solar wind velocity for all HAEs.

The frequency pie diagram of solar wind velocity for all HAEs has been plotted in Fig 2. It is quite observable from these plots that the majority of the HAE events have occurred, when the solar wind velocity lies in the interval 400-500 km/s i.e., being nearly average. Usually, the velocity of high-speed solar wind streams (HSSWSs) is 700 km/s [15].

Therefore, it may be deduced from these plots that HAE events are not caused either by the HSSWS or by the sources on the Sun responsible for producing the HSSWS such as polar coronal holes (PCH) etc. Thus, we may infer that HAEs are weakly dependent on solar wind velocity, which is in agreement with earlier findings [15] and significantly contradicts with the earlier results reported by Iucci et al. [16] and Dorman et al. [17], that the solar diurnal amplitude is enhanced during the HSSWSs coming from coronal holes.

Conclusions

The diurnal time of maximum remains in the corotational direction as compared to the quiet day annual average for majority of the HAE events.

The phase of semi-diurnal anisotropy has no definite trend in case of HAE. However the phase of tri-diurnal anisotropy for HAE has shifted to later hours as compared to the quiet day annual average values for majority of the events.

No significant correlation between the amplitude of semi-diurnal anisotropy and Bz has been observed for HAE events. The phase is observed to shift towards earlier hour as the polarity of Bz component of IMF directed from negative to positive values showing a negative correlation. The amplitude of tri-diurnal anisotropy for HAE events is observed to remain high for negative polarity of Bz, whereas it is found to remain slightly low for positive polarity of Bz showing a negative correlation.

The phase of the tri-diurnal anisotropy does not show significant correlation with Bz due to large scattering of points.

The occurrence of HAE is dominant when the solar wind velocity is being nearly average. This reveals that HAE events are not caused either by the HSSWS or by the sources on the Sun responsible for producing the HSSWS such as polar coronal holes (PCH) etc. Thus, we may infer that HAEs are weakly dependent on solar wind velocity.

The amplitude of the diurnal anisotropy for HAE events is observed to increase with the decrease of Dst-index showing a negative correlation.

The amplitude of the semi-diurnal anisotropy is found to slightly increase with the decrease in the value of Dst-index showing weakly negative correlation.

The amplitude of the tri-diurnal anisotropy is observed to increase with the decrease in the value of Dst-index showing a negative correlation.

The weak correlation has been observed with Dst-index for diurnal, semi-diurnal and tri-diurnal phase of HAE events.

The weak correlation has been observed with Ap-index for diurnal, semi-diurnal anisotropy vectors and tri-diurnal amplitude for the HAE events. However, the phase of tri-diurnal anisotropy for HAE events is found to shift towards earlier hours with the increase of Ap-index showing a significant negative correlation.

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