High amplitude anisotropic wave trains and interplanetary disturbances

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Abstract. The present work deals with the study of cosmic ray intensity, solar wind plasma and interplanetary magnetic field parameters variation due to interplanetary magnetic clouds during an unusual class of high amplitude anisotropic wave train events. The high amplitude anisotropic wave train events in cosmic ray intensity has been identified using the data of ground based Deep River neutron monitor and studied during the period 1981-94. Even though, the occurrence of high amplitude anisotropic wave trains does not depend on the onset of interplanetary magnetic clouds. But the possibility of occurrence of these events cannot be overlooked during the periods of interplanetary magnetic cloud events. It is observed that solar wind velocity remains higher (> 300) than normal and interplanetary magnetic field B remains lower than normal on the onset of interplanetary magnetic cloud during the passage of low amplitude wave trains. It is also noted from the superposed epoch analysis of cosmic ray intensity and geomagnetic activity for high amplitude anisotropic wave train events during the onset of interplanetary magnetic clouds that the increase in cosmic ray intensity and decrease in geomagnetic activity start not at the onset of magnetic clouds but after few days. The north south component of IMF (Bz), IMF (B), proton density (N), proton temperature (T) and latitude angle reaches to their maximum, whereas solar wind velocity (V) and longitude angle reaches to their minimum on the day of magnetic cloud event during the passage of high amplitude anisotropic wave trains. The cosmic ray intensity and Dst index both are found to decrease with the increase of solar wind velocity and reaches to their minimum on the days of high-speed solar wind streams during HAEs.

Keywords: interplanetary magnetic cloud, solar wind, geomagnetic activity

1 Introduction

Numerous research have been undertaken to find out a possible origin for large amplitude anisotropic wave train events (HAEs) of cosmic ray intensity. Hashim and Thambyahpillai [1] and Rao et al. [2] have shown that the enhanced diurnal variation of large amplitude events exhibits a maximum intensity in space around the anti-garden-hose direction (2000 h) and a minimum intensity around the garden-hose direction (0900 h). Mavromichalaki [3] has shown that the
enhanced diurnal variation was caused by a source around 1600 h or by a sink at about 400 h. A number of high amplitude anisotropic wave train events have been observed with a significant shift in the diurnal time of maximum to co-rotational/1800 Hr direction or later hours [4 and references therein]. Suggestions have been made that the enhanced diurnal variation is produced by a depression of cosmic ray intensity in the garden hose direction; this is due to occurrence of solar flares on the invisible side of the solar disk [1, 5]. A significant increase is observed in the amplitude of first three harmonics (diurnal/semi-diurnal/tri-diurnal) during the passage of high speed solar wind stream, whereas the direction of the anisotropy have no time variation characteristics associated with solar wind velocity and north south component of interplanetary magnetic field for three neutron monitoring stations located at different geomagnetic cutoff rigidities and altitudes [6].

Interplanetary magnetic clouds belong to one of the several classes of transient flows in the solar wind. Magnetic clouds as ideal force free objects (cylinders or spheres) are ejected near the Sun and followed beyond the Earth's orbit. It is found that the decrease in cosmic ray intensity, which are associated with magnetic cloud preceded by a shock, are very high and these decrease starts few days earlier than the arrival of cloud at Earth. From the study of the time profile of these decrease, it is found that the onset time of a Forbush type decrease produced by a shock associated cloud starts nearly at the time of arrival of the shock front at the Earth [7, 8] and the recovery is almost complete with in a week. Forbush decreases associated with shock-associated cloud are caused by magnetic field variations associated with interplanetary disturbances [8].

### 2 Data and analysis

The pressure-corrected data of the Deep River Neutron Monitor (NM) station (data from http://spidr.ngdc.noaa.gov/NeutronMonitor) has been subjected to Fourier analysis for the period 1981 – 1994 after detrending. While performing the analysis of the data, all those days discarded having more than three continuous hours of data missing.

### 3 Discussion

The cosmic ray intensity, interplanetary magnetic field and solar wind plasma parameters along with Dst index have been plotted in figure 1 to show an example of interplanetary positive magnetic cloud (magnetic field is directed northward) without shock occurred on July 6, 1982 at 0200 UT during these events. It is clearly seen from figure 1 that cosmic ray intensity is found to remain statistically constant prior to arrival of cloud and then decreases 4 days after the arrival of cloud and reaches to its lowest on +8 day and then increases gradually onwards. The north south component of interplanetary magnetic field (Bz) increases slowly prior to onset of cloud and reaches to its maximum on the arrival day of cloud and then decreases for one day and remains statistically constant during the passage of cloud.
A sharp decrease in solar wind velocity is observed, which starts 6 days prior to the arrival of magnetic cloud and continues up to -1 day and then increases gradually with some depressions and reaches to its highest value on +8 day, which is the period of high speed solar wind streams. The interplanetary magnetic filed (B) decreases sharply 10 days prior to the cloud and reaches to its minimum on -2 day. The B then increases to its maximum on the day of the arrival of cloud and then decreases gradually afterwards. The disturbance storm time index Dst is found to remain statistically constant prior to arrival of cloud upto +5 day on the onset of magnetic cloud. The decrease in Dst index starts 5 days after the arrival of cloud and reaches to its lowest on +8 day and then increases gradually onwards. One of the significant observation from these plots is that north south component of IMF (Bz), IMF (B), proton density (N), proton temperature (T) and latitude angle reaches to their maximum whereas solar wind velocity (V) and longitude angle reaches to their minimum on the day of magnetic cloud event.

To study the effect of these interplanetary magnetic clouds on cosmic ray intensity and geomagnetic activity index (Ap) during the passage
Fig 4: Superposed epoch results of geomagnetic activity index (Ap) due to interplanetary magnetic clouds along with statistical error bars (I) during high amplitude anisotropic wave trains.

of HAEs, we have adopted the Chree analysis of superposed epoch for days –10 to +10 and plotted in Fig 2 & 3 as a percent deviation of cosmic ray intensity and Ap index along with statistical error bars (I) during the period 1981-94. We can see from this plot that increase in cosmic ray intensity start not at the onset of cloud but after 3 days. The cosmic ray intensity remains statistically constant few days before and after the onset of magnetic cloud and increases sharply after the passage of the magnetic cloud during HAEs.

It is noted from the shape of the plot that deviations in geomagnetic activity is almost similar before and after few days (i.e. for 6 days) of the arrival of cloud. Thus the decrease in geomagnetic activity during the passage of HAEs starts not at the onset of cloud but after few days.

4 Conclusions

Even though, the occurrence of high amplitude anisotropic wave trains does not depend on the onset of interplanetary magnetic clouds. But the possibility of occurrence of these events cannot be overlooked during the periods of interplanetary magnetic cloud events.

The superposed epoch analysis of cosmic ray intensity and geomagnetic activity for high amplitude anisotropic wave train events during the onset of interplanetary magnetic clouds reveals that the increase in cosmic ray intensity and decrease in geomagnetic activity start not at the onset of magnetic clouds but after few days.

The north south component of IMF (Bz), IMF (B), proton density (N), proton temperature (T) and latitude angle reaches to their maximum, whereas solar wind velocity (V) and longitude angle reaches to their minimum on the day of magnetic cloud event during the passage of high amplitude anisotropic wave trains.

5 References