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Effect of interplanetary disturbances on cosmic ray daily variation at neutron monitor energies

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The solar modulation of galactic cosmic rays is also reflected in the record of neutron monitors in terms of daily variation, with significant amplitudes at 24-hours periodicity. The long term daily variation has been investigated for the recent period from 1989 to 2004, using geomagnetic disturbance index Ap, both on an annual average basis as well as on short term basis. Here Ap index has been used as a proxy for the solar induced interplanetary disturbances. It is found that, in general on an annual average basis, both the diurnal amplitude as well as the diurnal phase is significantly lower in the years of low Ap values, during the period 1989 to 2004. Such a result was also reported for the earlier periods. However, anomalous and contrary results for the diurnal variations have been obtained when the daily values of Ap are distributed in five groups with the first group representing low Ap condition (i.e. quite periods) and the last group naturally representing the disturbed conditions. Further choice of low Ap days occurring continuously support these results.

1. Introduction

The analysis uses data obtained from various neutron monitor stations for the years 1989 to 2004 which spans a large range of the interplanetary disturbances. The large and systematic changes observed in the daily variation of cosmic ray intensity indicate that significant changes do occur in interplanetary space, sometimes for continuous periods, affecting the spatial distribution of cosmic ray intensity as well as producing simultaneous geomagnetic disturbances [1 -3]. The long-term daily variation has been investigated in this paper, using geomagnetic disturbance index Ap. Here Ap index has been used as a proxy for the solar induced interplanetary disturbances. It is found that the diurnal amplitude as well as the diurnal phase are significantly lower in the years of low Ap values, during the period 1989 to 2004. Days have also been divided in groups according to the value of Ap, as well as according to their continuous occurrence for few days. The quiet periods are the first two groups of Ap, whereas the last group of Ap represents the disturbed geomagnetic condition/ disturbed state of interplanetary medium.

2. Discussion

The results are reported for a systematic study to observe both the long as well as the short-term changes in the cosmic ray daily variation during the gamogenetically quiet periods, for the interval 1989 to 2004, which also cover a part of the ascending phase of solar cycle 23. The year 2003 is unique, because of high magnitudes of geomagnetic field disturbances and its more frequent occurrence. In fact, when events of continuous quiet periods have been selected, by using Ap values, we have found not a single event of $Ap \leq 8$ occurring continuously for 6 days, in the year 2003. In general, the year 2003 alone is exceptionally disturbed, with very less disturbances observed before and after this year. For our analysis we have divided days according to increasing values of Ap index, in five groups (Gp1: 0-8, Gp2: 9-17 Gp3: 18-26, Gp4: 27-53, Gp5: $\geq$54). Annual averages of the daily variation have been obtained separately for each of five groups

of Ap index for a number of neutrons monitoring stations for the entire period of 1989 - 2004. The diurnal vectors obtained for all these five groups and for all the years for the two stations Kiel and Haleakala are depicted in figure1 and figure2 respectively.

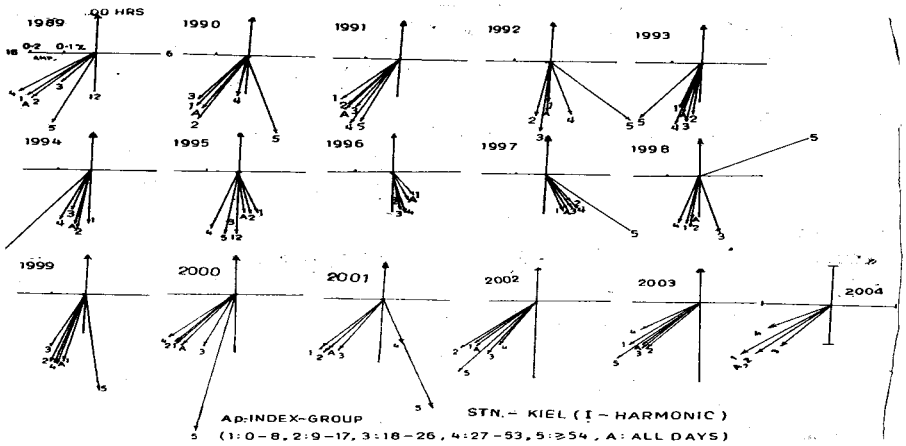

Figure 1. shows the average diurnal vector for the years 1989 to 2004 for various Ap groups, for station Kiel (low cutoff rigidity)

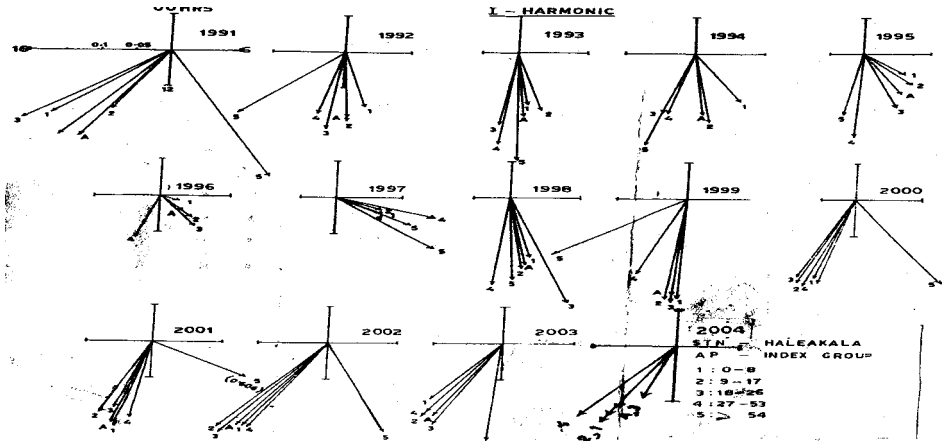

Figure 2. shows the average diurnal vector for the years 1991 to 2004 for various Ap groups, for station Halekala (high cutoff rigidity)

Both of these figures reveal that the diurnal amplitudes increases for higher group of Ap index. i.e. the more disturbed interplanetary conditions are associated with larger diurnal amplitudes. When the analysis is performed on annual average basis, similar variations are observed. As for as the variations in the diurnal phase is conserved, we find that the diurnal phase shifts to higher values from group 1 to 5,(i.e. low Ap to high Ap), during the years of 1993 to 1996 for Kiel, and 1992 to 1997 for Haleakala neutron monitor station. This is also observed on annual average basis. However, for all other periods, the diurnal phase shifts in the opposite direction. i.e. for the group of low Ap, the diurnal phase is in later hours and for the group of higher Ap, the diurnal phase is shifted to earlier hours.

The choice of continuously occurring days of low Ap values signifies that the interplanetary medium is stable for few days with least interplanetary disturbances. As such days with Ap ≤ 8 and occurring for at least 8 days continuously have been selected for all the years from 1989 to 2004. The average diurnal amplitude and phase for each such event and for each year (for all the event days) have been obtained. The detailed results obtained are depicted in figure 3 showing from bottom number of events, total number of

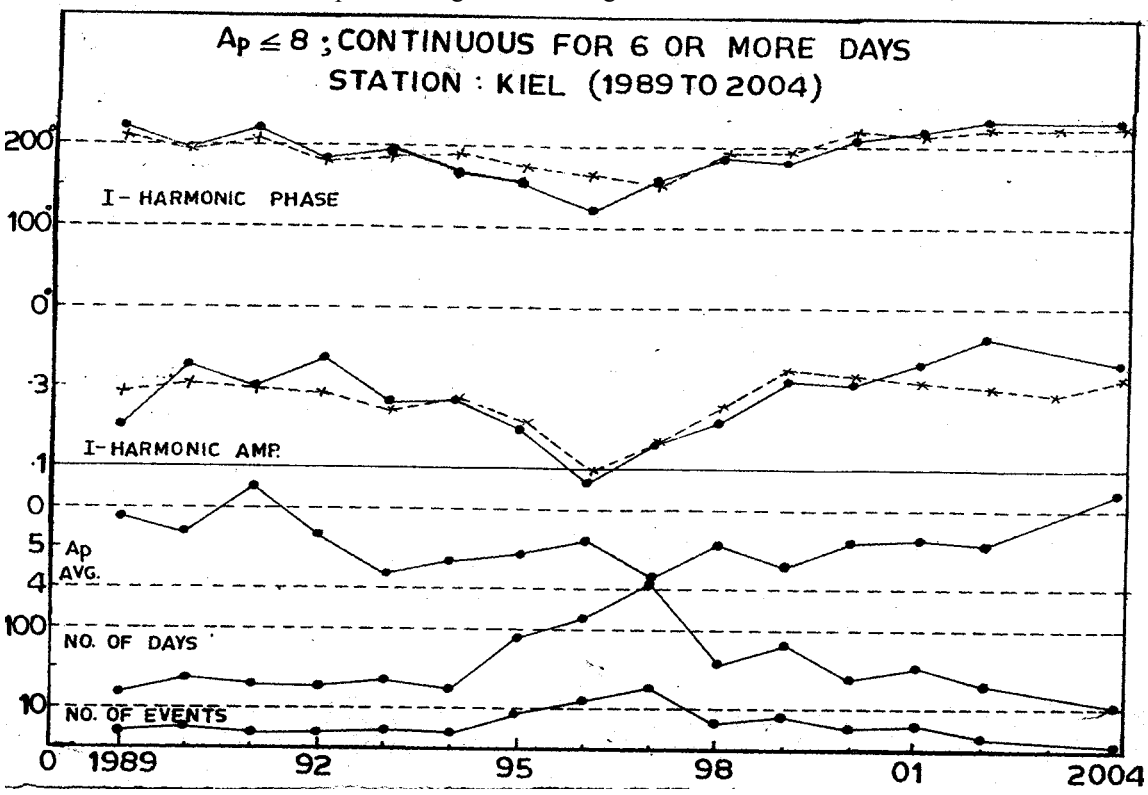

Figure 3. Shows the yearly numbers/ averages of various parameters related to continuously occurring low Ap days for the years 1989 to 2004. The bottom line diagram depicts the number of events of low Ap days in each year. The total number of days of these events in a year is then depicted and thereafter the Ap average of these days only. The top two panels depict the annual average diurnal variations for these event days(shown by dot and thick lines) as well as for All days(cross with dashed lines) respectively for diurnal amplitude(in %) and diurnal phase- top panel (in degrees). Not a single event occurred in the year 2003.

days for all the events in each year, the events annual average diurnal amplitudes and phase as well as the annual averages for all days(excluding only UT effected days), for the Kiel station. The figure clearly reveals the diurnal phase shift to lower values for the years 1994 to 1996, supporting the earlier findings presented here by using groups of days of Ap. Similar behaviour is seen for diurnal amplitudes during the years 1995 and 1996, but the difference is not very significant.

3. Conclusions

From the results on the diurnal variation presented on the basis of the annual average of all days, distributions made using geomagnetic disturbance index Ap, and the continuously low Ap days, the diurnal phase is found to
shift to early hours during the years 1994 to 1996, quite significantly in all the cases Nevertheless, for other periods (particularly before 1992 and after 1997) such a relationship is not observed. Eventhough the new results are in tune with that reported earlier [4-5], however, the contrary findings need more thorough investigations.

4. Acknowledgment

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