Large-scale Heliospheric Magnetic Field and Drift Effects During Forbush Decrease

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Abstract

In this paper we have studied the effects of gradient and curvature drifts during Forbush decrease (FD) phenomena. For this purpose hourly neutron monitor counts, with respect to start time of the classical FDs, have been subjected to superposed epoch analysis separately for decreases observed during 1960s, 1970s, 1980s and 1990s. The results are compared with model predictions including drifts. Some drift models predict larger amplitude and faster recovery (smaller recovery time) during $A > 0$ epoch as compared during $A < 0$ epoch. Our results regarding the amplitude of FDs, during different polarity states of the heliospheric magnetic field (HMF), do not provide clear experimental evidence about a significant role of gradient and curvature drifts during the main phase of FD. However, the difference in recovery time of FDs during $A > 0$ and $A < 0$ polarity conditions provide some evidence that drifts play an important role in cosmic ray modulation. Absence of observational evidence about significant drift effects during main phase is possibly due to the presence of magnetically turbulent region during this phase; such region may not be conductive for the drift effects to be observed.

1. Introduction

The aim of this work is to study the effect of large scale HMF polarity and drifts on the time profile of Forbush decreases specially its recovery characteristics. Results obtained after the analysis have been discussed in the light of simulation of Forbush decreases including drift effects.

2. Methods

Isolated classical Forbush decreases during the periods, 1961-1968, 1971-1979, 1981-1989 and 1991-1999, excluding the periods of polarity reversal, are selected by visual inspection of hourly cosmic ray intensity graphs of Calgary neutron monitor (cut off rigidity = 1.09 GV) on the basis of following criteria.
(i) There should be a rapid decrease (within $\leq$ 24 hour) followed by a slow recovery, up to $> 70\%$ of pre-decrease level within $\sim$10 days.
(ii) The amplitude of decrease in count rate should be $\geq 3\%$ and $< 10\%$.

pp. 3605–3608

(iii) There should be no sharp decrease/GLE three days before or ten days after the onset of the Forbush decrease under consideration.

The period covered two $A > 0$ cycle such as 1971-1979 and 1991-1999, and two $A < 0$ periods such as 1961-1968 and 1981-1989 when the solar polarity is reversed.

After selecting all classical Forbush decreases falling within the criteria mentioned above, we applied the superposed epoch analysis on the pressure corrected hourly cosmic ray intensity recorded at Calgary neutron monitor by taking the onset time (hour) of each Forbush decrease as zero hour. The analysis is carried out separately for four periods 1961-1968, 1971-1979, 1981-1989 and 1991-1999. The date for recovery were fitted by assuming an exponential recovery. The recovery rate is then calculated in all the four periods considered.

3. Results

The average profiles of Forbush decreases during sixties, seventies, eighties and nineties are shown in Fig. 1. From an examination of these figures, qualitative inferences about a few features of the time profiles, relevant to simulation of Forbush decreases, during $A < 0$ (1960s, 1980s) and $A > 0$ (1970s and 1990s) are as follows.

No clear differences in the amplitude of decrease during $A < 0$ and $A > 0$ epochs is observed; recovery rate is slower during periods sixties and eighties ($A < 0$) than seventies and nineties ($A > 0$).

The data for the recovery were fitted to an equation

$$I = I_0 + A \exp(-t/t_0)$$

Where I_0 is the 'normal' intensity in percent, I, also in percent, is the intensity at time t and A is the decrease amplitude. The characteristic recovery time t_0 corresponds to the time for the decrease to decay to e^{-1} times its amplitude. The calculated values for the rate of decrease (dI/dt) at times when Forbush decreases have recovered to various levels are plotted in Fig. 2. It is evident from this figure that, throughout, the recovery rate during $A > 0$ (1970s and 1990s) is faster than during 1960s and 1980s.

4. Discussion

In $A > 0$ polarity state when the northern hemisphere HMF pointed away from the sun, cosmic rays drift towards the earth from over the solar poles, and under such circumstances, the cavity left behind by propagating disturbances in the equatorial region will be filled at a faster rate and consequently the recovery time will be smaller.

This recovery time will be larger when polarity reverses ($A < 0$); under such

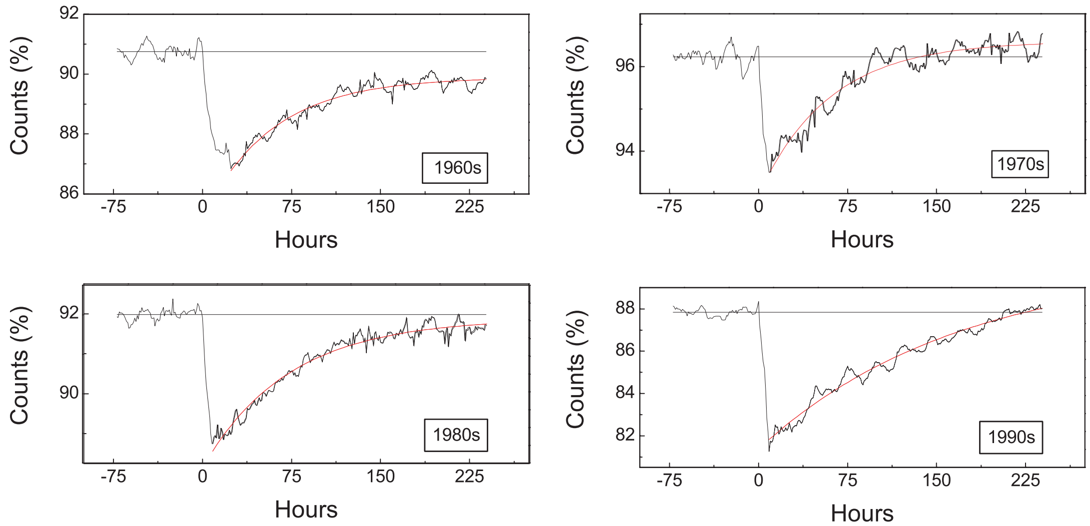

Fig. 1. Three FD events (square, circle, triangle) alongwith their average profile (inverted triangle) before (upper panel) and after (lower panel) the correction for solar cycle effect.Figure 2. Mean superposed intensity alongwith the 95% confidence interval for minimum intensity (vertical bar) and mean intensity (upper and lower horizontal bars) alongwith the mean intensity (middle horizontal bar) before (upper panel) and after (lower panel) the correction for solar cycle effect.

condition particles drift towards earth from the equatorial region and drifting particles will primarily encounter the disturbance head on and the filling process is retarded in this situation. This is the consequence of drift-dominated models [4-7]. Two-dimensional model simulation of FDs including drift effects [1, 2], predict larger recovery time in $A < 0$ condition of HMF. The amplitude of FD is predicted to be almost same in both the polarity states [2] or it is larger during $A > 0$ than $A < 0$ condition [1]. The role of drift in the phenomenon of Forbush decrease has been studied by only few workers [3-6] and experimental evidences are inconclusive as regards the role of drifts during this phenomenon.

5. Conclusions

We did not find a clear difference in amplitudes of decrease in two polarity states of the heliosphere ($A < 0$ and $A > 0$). The recovery rate is faster in $A > 0$ epoch as compared to $A < 0$ epoch. It is faster through out the recovery phase during seventies, nineties in comparison to recovery rate in sixties and eighties. The results concur with some earlier results [4, 6], are in accord with the simulations of Forbush decreases (including drifts [1, 2]) that

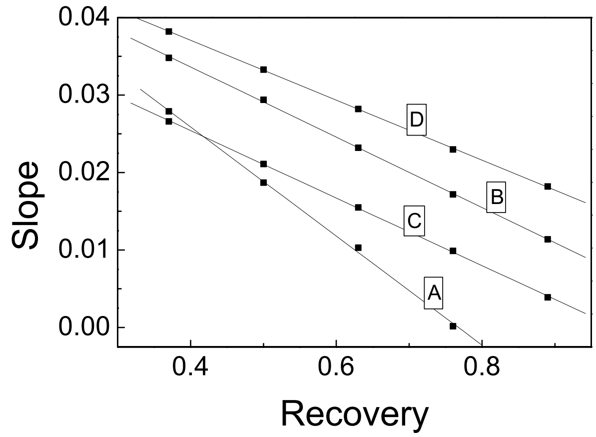

Fig. 2. Recovery rate (dI/dt) at various levels of recovery during sixties(A), seventies(B), eighties(C) and nineties(D).

6. References

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