High-speed Solar-wind Streams from Coronal Holes and Modulation of Cosmic Ray Diurnal Anisotropy

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Abstract

We analyze the solar modulation of cosmic ray diurnal anisotropy for the year 1974, an epoch with considerable high-speed solar-wind streams (HSSs) activity, which show pronounced 27-day recurrence. Coincidentally, enhanced diurnal wave trains of cosmic ray intensity also persist with a 27-day recurrence. On close inspection of both data of neutron monitor (NM) and muon telescope (MU), we remark that the modulation of the diurnal anisotropy by the HSS may occur through two different processes; one is that many already reported that with the development of the HSS the diurnal waves are enhanced, and are observed by both NM and MU, and the other is our finding that along with the decline in the HSS the diurnal waves are again enhanced, and are rather observed by NM.

1. Introduction

The year 1974 is an interesting epoch with a remarkable 27-day recurrence in the occurrence of the HSSs. This is seen from Figure 1. These HSSs arise from long-lived coronal holes which are located in both hemispheres of the sun and show the solar equatorial extension for this period. Coincidentally, enhanced diurnal wave trains of the cosmic ray intensity variations also persist with a 27-day recurrence, as observed for example by the NM at Deep River (effective primary rigidity $P_m \sim 10$ GV) and by the MU at Nagoya (vertical; $P_m \sim 60$ GV) and shown in Fig. 1. In the figure, the daily intensity variations of the hourly means, taken as deviations from the 24-hur running averages, are displayed. Iucci et al. (1983) and Dorman et al. (1984) investigated these diurnal wave trains with the presence of the HSS during 1974 using NM data at Deep River, and Munakata et al. (1987, referred to Paper I) followed them. They showed that the modulation of the diurnal anisotropy in space by the HSS is appreciable and significant; the amplitudes are enhanced, the phases are also modulated and are invariant in ~ 18 hr direction, and the rigidity spectrum exhibits slightly positive. Swinson et al. (1980) carried out another kind of analysis of enhanced diurnal waves trains for 1974 using the MU data at Nagoya. However, the role of the HSS in cosmic ray

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modulation, specifically in terms of the daily variation of cosmic ray intensity variation, has not yet fully understood. In this report, on close inspection of the cosmic ray data in a wide range of rigidities; 17 NMs in world network and 17 components of MU at Nagoya, whose P_m ranges from ~ 10 GV to ~ 120 GV, we remark that the modulation of the diurnal anisotropy by the HSS in 1974 may occur through two different rigidity dependent processes. Examples are given in Fig.2, in which the intensity variations for NMs at Deep River and Tokyo and for MU at Nagoya are shown, along with the solar-wind velocity data; (a) for Bartels rotation No. 1926 and (b) for No. 1928.

2. Results and discussions

By the best-fitting between the observed and the theoretically predicted variations, the diurnal anisotropy in free space were examined day by day. The calculations were performed with the same procedure in those in Paper I, by assuming that the anisotropy is uni-directional and has a power law spectrum P^{γ} with the upper cut-off rigidity P_u (GV); the following values were tried; $\gamma = -0.5, 0.0 + 0.5$ and $P_u = 50, 100, 500$ GV. The amplitude and phase and also its spectrum were determined for each day. The daily distribution thus obtained is shown in Fig. 3 for Bartels rotations 1920-1933, in which as the spectrum of the anisotropy changes from day to day, the amplitude corresponds to 10 GV. The phases are obtained in around 18 hr direction not only in the HSS but in almost all of the days in 1974.
It is seen in Fig. 3 that the modulation of the anisotropy in space by the HSS is remarkable during the high wind speed regions as already discussed by many. We here remark that the modulation characterized by enhanced amplitudes again occur during the period of the decline of the HSS, and that this has been rather observed by NM; the spectrum exhibits negative. It is seen that these enhanced diurnal waves may be associated with the recovery of the cosmic ray intensity variations (see Fig. 2). Recall that the phases are invariant in 18 hr direction, which may be different from those during Forbush decreases, whose phases are ~ 12 hr direction. In interpreting these results, the so-called convection-diffusion model in the stationary conditions may be a plausible one even in such quasi-stationary states.

References

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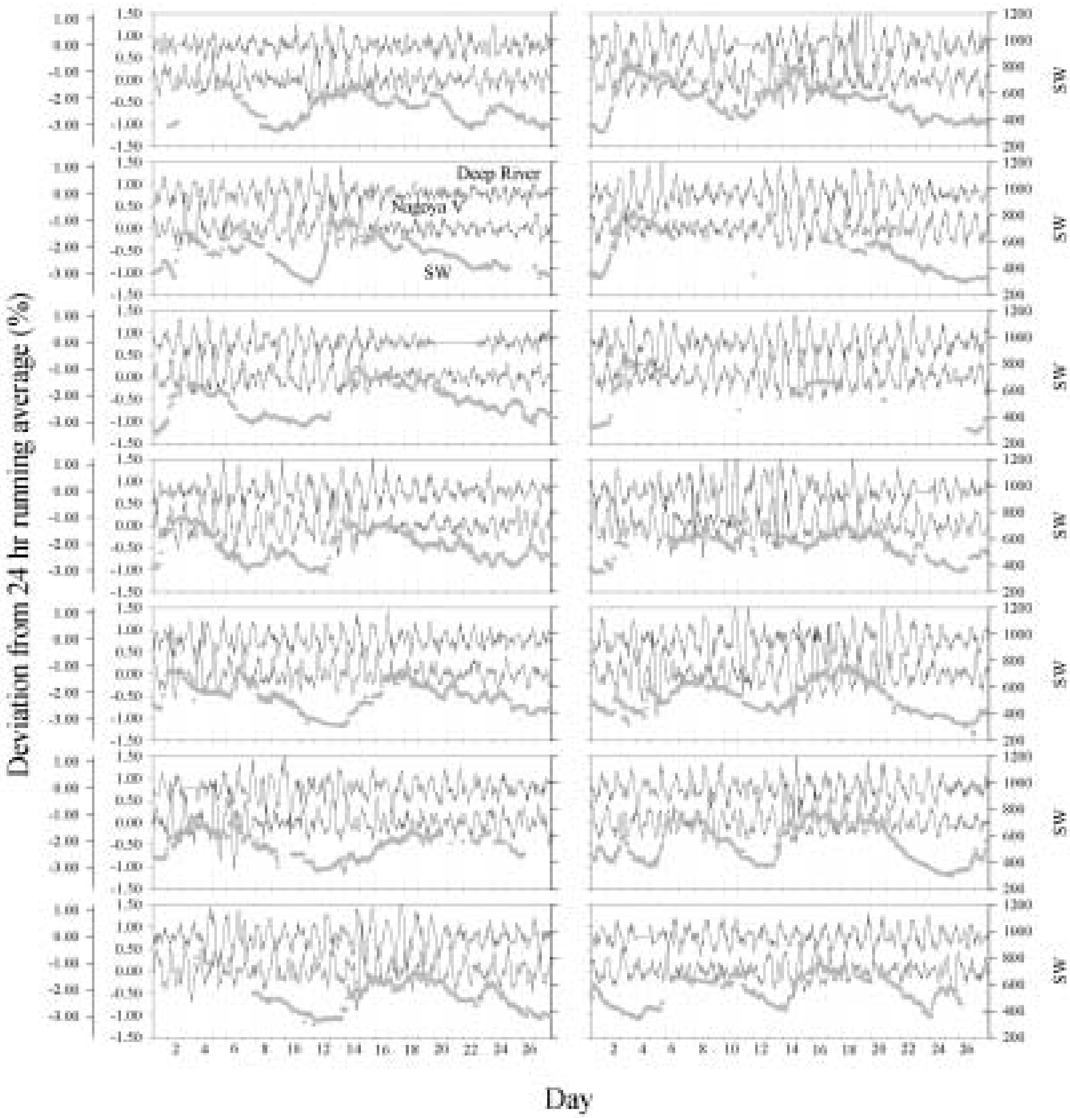

Fig. 1. 27-day pattern of high-speed solar-wind streams (HSSs), together with cosmic ray intensity variations observed by NM at Deep River and by MU (vertical component) at Nagoya for Bartels solar rotations 1920-1933 for the year 1974. Cosmic ray data are shown by the hourly mean values, taken as deviations from the 24-hour running averages.

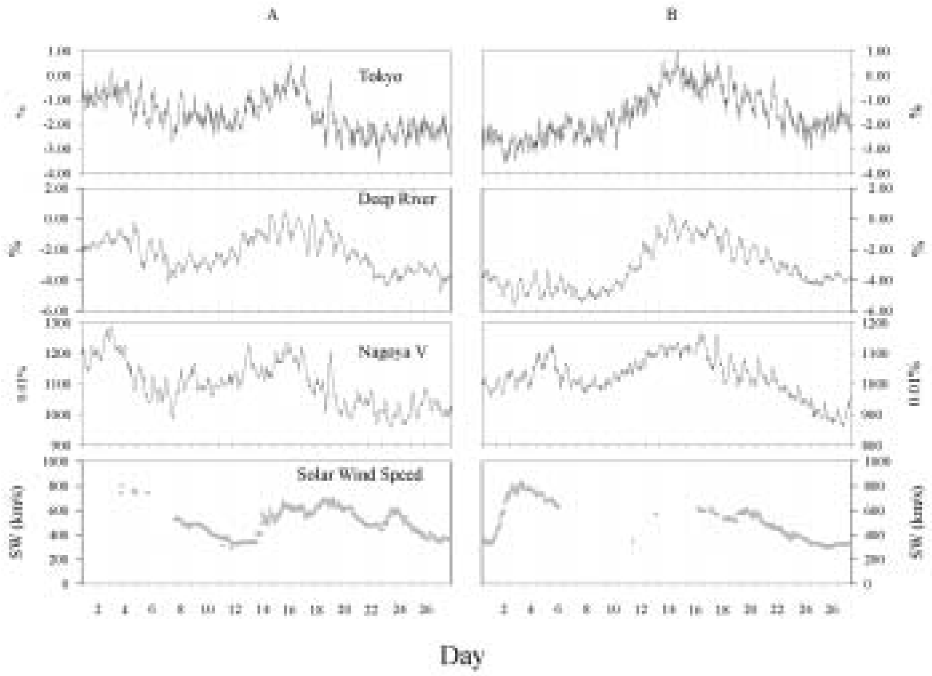

Fig. 2. Examples of cosmic ray intensity variations observed by NMs at Deep River (high latitude) and Tokyo (low latitude) and by MU at Nagoya (vertical component), along with the solar wind bulk velocity; (a) for solar rotation No. 1926 (May 29-June 24, 1974) and (b) for No. 1928 (July 22-August 17, 1974).

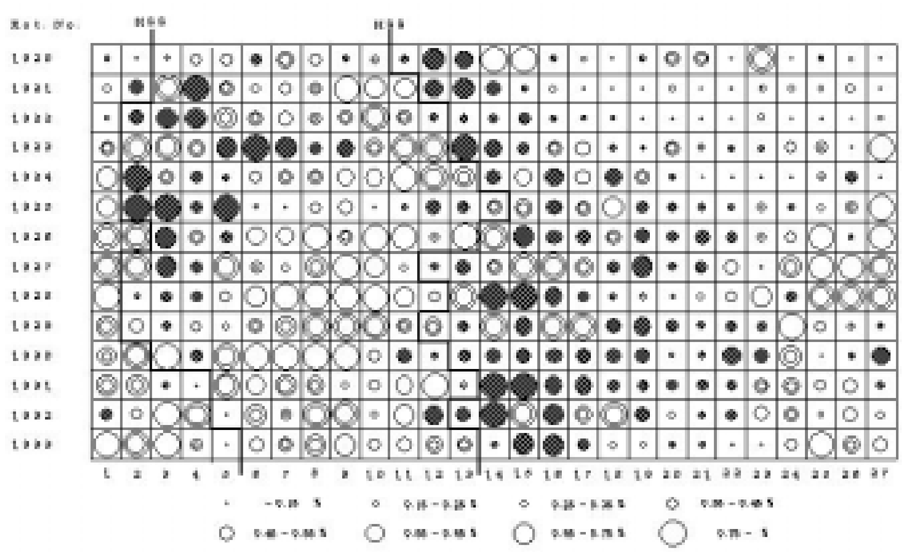

Fig. 3. Daily distribution of the amplitude and its spectrum of the diurnal anisotropy in free space determined by the best-fitting for solar rotations 1920-1933. Open, solid and double circles represent, respectively, the negative- ($\gamma < 0$), the positive- ($\gamma > 0$) and the flat- ($\gamma = 0$) spectrum, and the amplitude is shown by the size (diameter) of each circle as is given in the figure. The starting day of two series of HSSs is also plotted by the heavy line.