Cosmic-Ray Research for Space Weather Monitoring and Forecasting

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Abstract

Based on 47 ground-based neutron-monitor counts and the solar wind data recorded by the Advanced Composition Explorer, the characteristics of magnetic clouds and their influences on cosmic rays in November 2004 have been discussed. By using the wavelet decomposition, clearer definitions of the initial phase, main phase, and recovery phase of the Forbush decrease event are proposed, and the onset time of the main phase precedes the arrival time of the first cloud by about 3 hours. Maybe it would become valuable information to predict the space weather. About 45% of the onset times of the recovery phase of the Fds were clustered at 04:00 UT on 10 November, independent on the station position. Comparison with time variations from different neutron monitors reveals the global simultaneity of this Fd event. The interplanetary disturbance was asymmetric when it reached the Earth, being inclined to the southern hemisphere. The CMEs which caused the geomagnetic storms should have moved to the magnetopause southward and interacted with the magnetosphere continuously. Our analysis has clearly demonstrated that the sheath region between the shock and the magnetic cloud, particularly the enhanced turbulent magnetic field, results in the scattering of cosmic-ray particles, and causes the following Forbush decrease. Maybe it is the most effective mechanism to produce a transient depression in cosmic-ray variations.

Characteristics of Magnetic Clouds

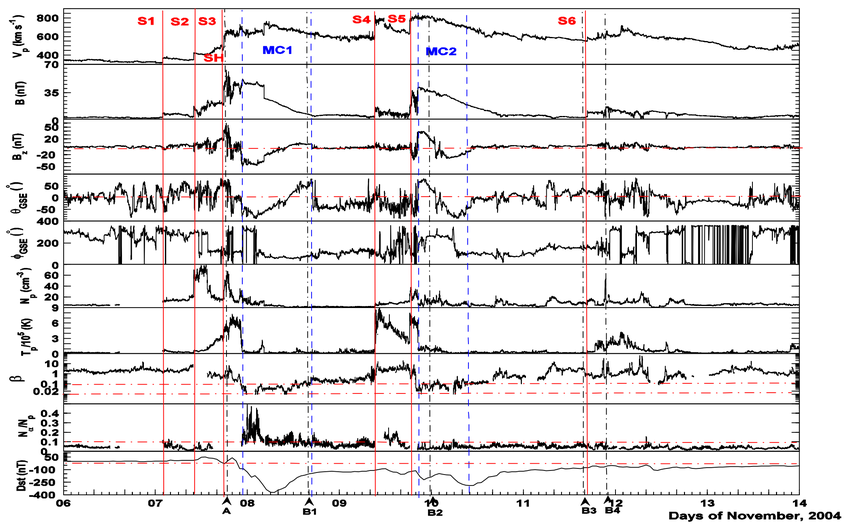

Figure 1 Time variations of parameters characterizing the solar wind and interplanetary medium observed by ACE and Wind from 6 to 13 November 2004.

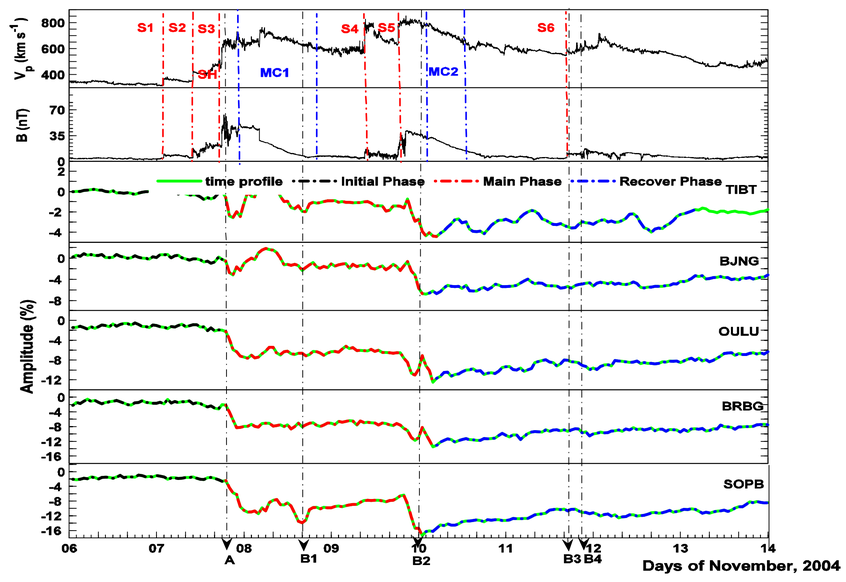

Figure 2 Time profiles of the solar-wind plasma speed (*V*p), magnetic field strength (*B*), and hourly intensity profiles of the TIBT, BJNG, OULU, BRBG and SOPB neutron monitors.

Definition of Three Phases in a Forbush Event

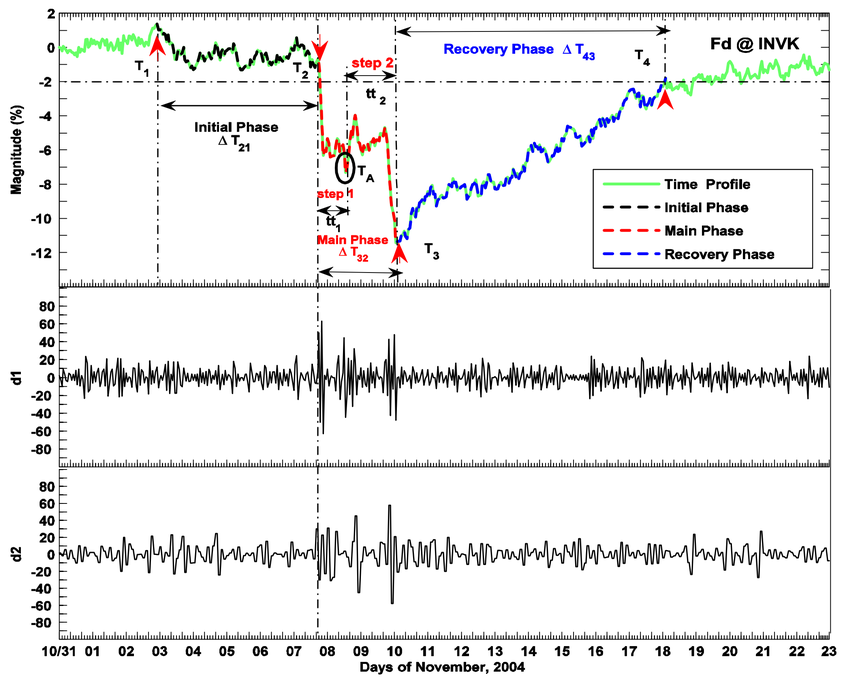

Figure 3 A representative diagram defining the initial phase, main phase, and recovery phase in a Forbush event.

Methods: Wavelet Decomposition and Lomb-Scargle Algorithm

$$P_N(w)=\frac{1}{2s^2}\left\{\frac{\left[\sum_j (X(t_j)-\bar{X})\cos w(t_j-t)\right]^2}{\sum_j \cos^2 w(t_j-t)}+\frac{\left[\sum_j (X(t_j)-\bar{X})\sin w(t_j-t)\right]^2}{\sum_j \sin^2 w(t_j-t)}\right\}$$

$$\tan(2wt)=\left(\sum_j \sin 2wt_j\right)/\left(\sum_j \cos 2wt_j\right)$$

Distribution of 47 ground-based NM stations

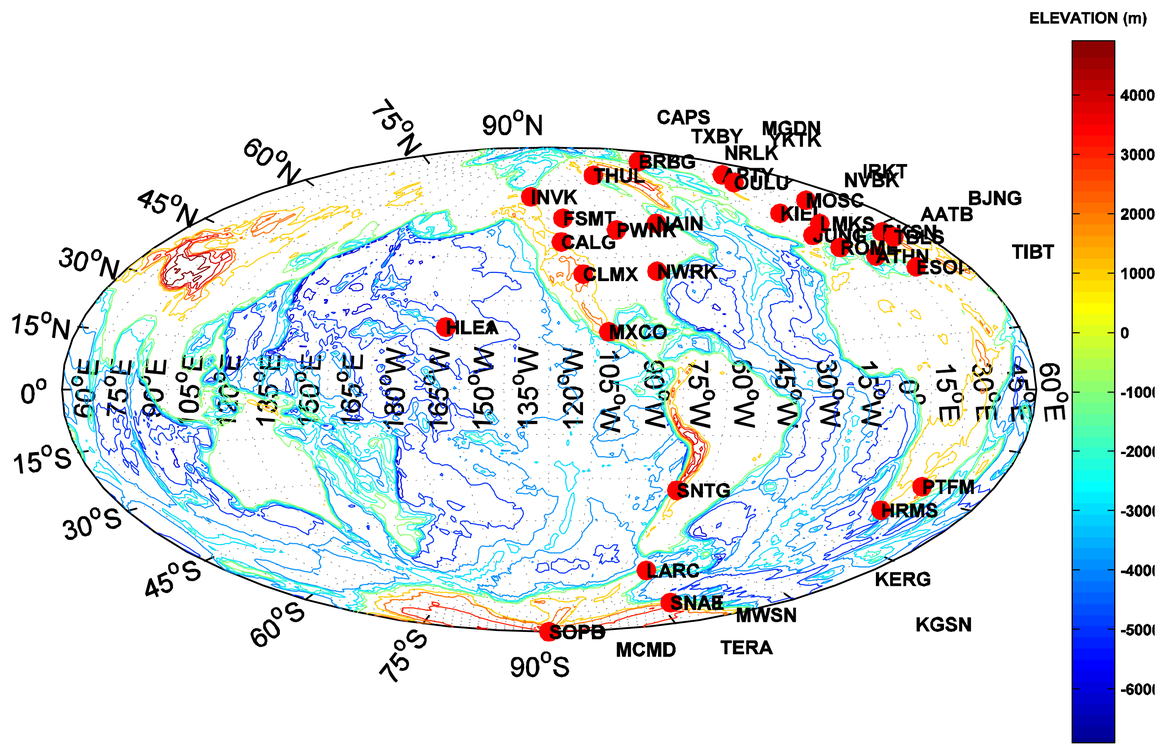

Figure 4 The geographic distribution of 47 ground-based stations which registered a counting rate drop from 1 to 28 November 2004.

References:

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Summary

Øi) By using the wavelet decomposition, the catastrophe points in the counting rate of cosmicrays are identified, and the earliest one of several catastrophe points seen in the wavelet decomposition in the selected time window is defined as the onset time of the main phase in a Fd event. Hence, clearer definitions of the initial phase, main phase, and recovery phase are proposed.

Øii) The onset time of the main phase preceded the arrival time of the first cloud by about 3 hours and a large fraction of them (39/47) was found to originate from the sheath region as indicated by large fluctuations in magnetic field vectors at 19:00 UT on 7 November 2004, regardless of the station location. It is consistent with the conclusion that the CR decrease starts earlier than the arrival of the cloud and is due to the shock in front of the cloud.

Øiii) About 45% of the onset times of the recovery phase of the Fds was clustered at 04:00 UT on 10 November, independent on the station position. Comparison with time variations from different neutron monitors reveals the global simultaneity of this Fd event.

Øiv) The interplanetary disturbance was asymmetric when it reached the Earth, being inclined to the southern hemisphere. The CMEs which caused the geomagnetic storms should have moved to the magnetopause southward and interacted with the magnetosphere continuously.

Ø v) Our analysis in this paper has clearly demonstrated that the sheath region between the shock and the magnetic cloud, particularly the enhanced turbulent magnetic field, results in the scattering of cosmic-ray particles, and causes the following Fds. Maybe it is the most effective mechanism to produce a transient depression in cosmic-ray variations. This conclusion is in accordance with the hypothesis made by Badruddin, Venkatesan, and Zhu (1991).

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