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Globally Non-Simultaneous Forbush Decrease Events

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Abstract: It is generally believed that Forbush Decrease (FD) events happen simultaneously over the globe of the Earth. However, there have been reports on non-simultaneous FD events. We investigate the properties of non- simultaneous FD events in order to determine what solar wind conditions lead to global simultaneity of FD events. We examined the hourly data of the Oulu Neutron Monitor (NM) station from 1997 to 2006. We have selected 93 FD events that have greater than 3.5 % intensity reductions. Global simultaneity was determined by comparing the time profiles of these FD events with those recorded by other NM stations at Inuvik and Magadan. Most FD event onsets (62 out of 93) are observed simultaneously by each NM station in universal time (UT) regardless of the location of the station, whereas some other FD events are not simultaneously detected, but at similar local times (LT). The stronger FD events tend to be simultaneous events, but the weaker FD events non-simultaneous. The latter occurs only if the main phase of the FD is superposed in phase with the declining phase of diurnal variation, which has the maximum around noon and the minimum around midnight.

Introduction

Forbush Decrease (FD) events [1] are typical examples of abrupt change. The FD events are considered to be caused by the exclusion of GCR by intense interplanetary magnetic field (IMF) structures such as interplanetary shocks (IP shocks) accompanied by the sheath and its driver, magnetic clouds (MCs).

Although previous studies have mainly focused on generation mechanisms of FD events, mechanisms of FD generation have still not been agreed upon. The suggested mechanisms are diffusion ([2], [3]), drift ([4], [5], [6]) and a third view of the compromise ([7], [8]).

Most of FD events are recorded simultaneously by globally distributed NM stations ([9], [10]). Even though some of FD events do not occur simultaneously ([11], [12]), their extraordinary features have never been studied in detail. Thus, the purpose of the paper is to investigate the statistical properties of the non-simultaneous local time dependent FD events and the solar wind conditions causing such FD events.

Data and Results

1. FD selection and Simultaneity

Event threshold GCR intensity data of each NM station are normalized to the monthly average of each station. The variation rate (%) from the monthly average GCR intensity (zero level) is used instead of the flux value. We identified the FD events from the hourly averaged GCR intensity data at Oulu NM station during the ten years from 1997 to 2006. The criteria of determining FD events are: (1) the magnitude in GCR intensity decrease during the main phase is more than 3.5 %, (2) the minimum GCR intensity of the FD main phase should be lower than −1.5 %.

Table 1: Configurations of Inuvik, Oulu, & Magadan NM stations

NM Station	Latitude, Longitude	Cut-off rigidity	Local Time
Inuvik	68.35N, 133.72W	0.18 GV	UT−09h
Oulu	65.02N, 25.50E	0.81 GV	UT+02h
Magadan	66.10N, 151.00E	2.10 GV	UT+10h

In order to investigate the global simultaneity of the FD events by comparing the profiles of FD events observed by different NM stations, two

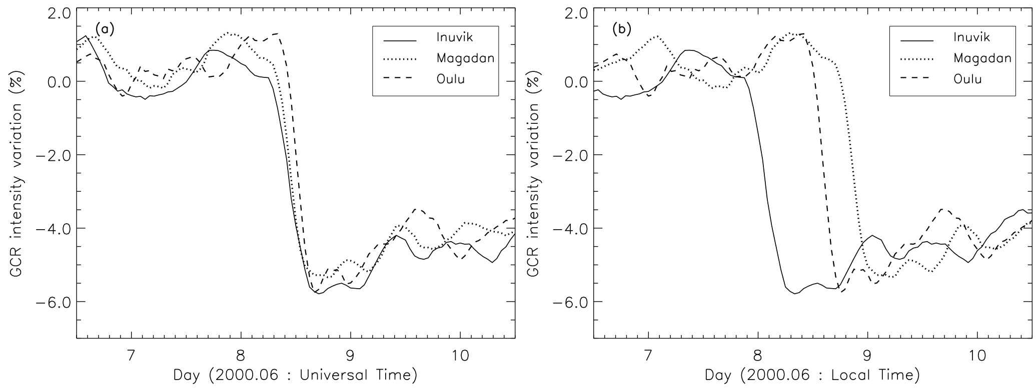

Figure 1: The GCR intensity profiles of a simultaneous FD event occurred on June 8, 2000 in UT recorded by three NM stations at Inuvik, Magadan, and Oulu (a) in UT and (b) in LT. The solid, dashed, dotted lines represent Inuvik, Oulu, Magadan NM station, respectively.

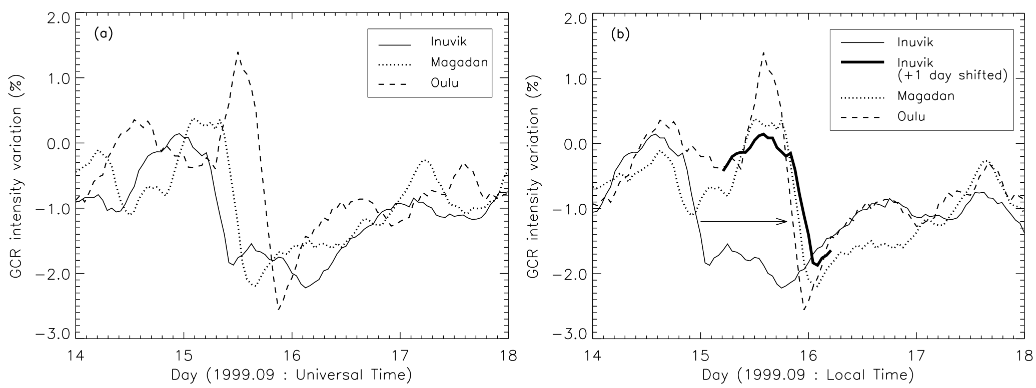

Figure 2: The GCR intensity profiles of a non-simultaneous FD event occurred in September 15, 1999 in UT (a) in UT and (b) in LT as like Figure 1. The bold line depicts the one-day-shifted profile of Inuvik NM station.

more NM stations were chosen by the location. In order to reduce the geomagnetic cut-off rigidity effect due to latitude difference, we selected NM stations at similar high-latitudes, and fairly evenly separated in longitude. The configurations of the Oulu, Inuvik, and Magadan NM stations are summarized in Table 1.

Figure 1 shows an example of an FD event that occurred on June 8, 2000 in UT. The profiles of the time-varying GCR intensities at the three NM stations are shown in Figure 1-a in UT. Figure 1 reveals the global simultaneity of this particular event from overlapped main phases of the FD event. However, the profiles presented in LT in Figure 1-b show that the main phases are separated by as much time as their local time separation.

Figure 2 shows example of an FD event that occurred on September 15, 1999. In this case, the main phases occur in sequence with some time intervals in UT in Figure 2-a. The main phases when plotted in LT all overlap in Figure 2-b. The profile of Inuvik NM station is not coincident with those of other NM stations by one day. But, the FD main phase observed in Inuvik NM station happened at the same LT as with the other two NM stations, if the profile is shifted by one day.

We call the FD event *simultaneous* if the main phases of the FD events are recorded at the same UT regardless of the station location. On the contrary, the other events would be called the *non-simultaneous* FD event if the main phases of the FD events are recorded at the same LT of the stations.

2. Results

The statistical results such as number of events and the GCR intensity decrease magnitude are summarized in Table 2. The intensity of the FD event is expressed by the magnitude of the GCR intensity decrease during the main phase. The GCR intensity decrease rate of the main phase is higher in the simultaneous FD event (mean = 6.9 %) than the non-simultaneous FD event (mean = 4.8 %).

Table 2: Classification of FD events by simultaneity during the period of 1997-2006

	Forbush Decrease event class	
	simultaneous	non-simultaneous
Number of FD events	62	31
Average of GCR intensity	-6.9 ± 3.4 %	-4.8 ± 1.4 %
decrease during main phase	-6.2 ± 3.0 % for all 93 FDs	

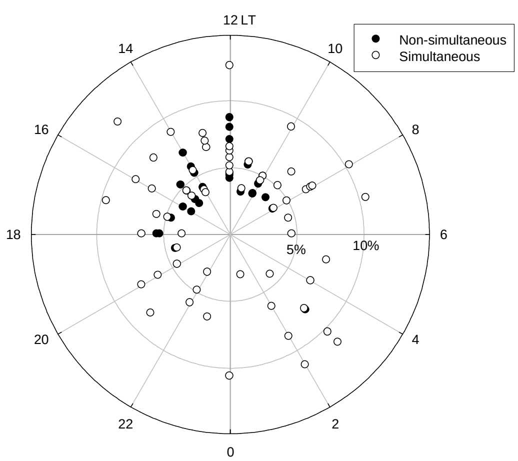

Figure 3: Distributions of the times of GCR intensity maximum (onset time of FD main phase) in local time of Oulu NM station in the polar coordinates. The radial component represents the magnitude of GCR intensity variation during the main phase of FD event. The angular position marks the local time at the Oulu NM station. The symbols of empty circle (○) represent the simultaneous FD events, and the symbols of filled circle (●) indicate the non-simultaneous FD events.

Table 3: Distribution of the local onset time of two kinds of FD events and the Fisher's exact test statistic

Category	local onset time of maxim intensity	
	simultaneous FD	non-simultaneous FD
dayside	42	29
nightside	20	2
probability of the same distribution	0.35 %	

The distributions of the FD main phase onset local times at Oulu NM station for both the simultaneous and the non-simultaneous FD events are indicated in Figure 3. The main phase onset local times are well dispersed all over the day for the simultaneous FD events. However, for the non-simultaneous FD events, the main phase onset local times are found only in local day. The GCR intensity decrease of non-simultaneous FD events are in phase with the declining part of the diurnal modulation with amplitude of ~ 1 %.

We use Fisher's exact test, which is for two small samples in two mutually exclusive bins yielding a 2×2 contingency table as shown in Table 3. The local onset times of FD main phases are categorized into dayside or nightside events. In Table 3, we set the 2×2 contingency table from the data given in Figure 3. The calculated probability that two distributions are identical is about 0.35 %. The result shows that two onset time of FD main phase distributions of the simultaneous FD events and of the non-simultaneous FD events are significantly different from each other, with a confidence level of 99.65 %.

A strong FD event would appear as a signal simultaneously in the records of all NM stations. However, a weaker FD event could be observed only if the FD main phase is superposed in phase with the declining phase of diurnal variation. Thus, the weaker FD events may be seen as the non-simultaneous FD events only in cases where they are in phase with the declining phase of the diurnal variation.

Summary

1. Most of the FD events (62 out of 93) are detected by the three separate stations simultaneously

in universal time. The rest of the FD events are detected simultaneously at the same local time. There clearly exist two distinctive kinds of FD events, simultaneous FD events and non-simultaneous FD events.

2. The GCR intensity decrease rate of the main phase is higher in the simultaneous FD event (mean = 6.9 %) than the non-simultaneous FD event (mean = 4.8 %).

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