TRANSIENT COSMIC RAY INCREASE ASSOCIATED WITH A GEOMAGNETIC STORM

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ABSTRACT

On the basis of worldwide network data of cosmic ray nucleonic component, the transient cosmic ray increase due to the depression of cosmic ray cutoff rigidity during a severe geomagnetic storm has been investigated in terms of the longitudinal dependence. Multiple correlation analysis among isotropic and diurnal terms of cosmic ray intensity variations and Dst term of the geomagnetic field is applied to each of various station's data. It is shown that the amplitude of the transient cosmic ray increase associated with Dst depends on the local time of the station, and that its maximum phase is found in the evening sector. This fact is consistent with the theoretical estimation based on the azimuthally asymmetric ring current model for the magnetic DS field.

1. Introduction. The depression of cosmic ray cutoff rigidities and the alteration of the asymptotic direction of approach of cosmic rays during geomagnetic storms have been widely investigated by several authors throuth analysis of cosmic ray data or using trajectory-tracing technique (Yoshida et al., 1968; Debrunner et al., 1979; Flückiger et al., 1981). A particular interest is paid to the longitudinal or local time asymmetry of the cutoff rigidity depression or the storm-time cosmic ray increase, in connection with the asymmetric ring current which causes disturbed daily variation of geomagnetic field (Cummings, 1966; Kudo et al., 1984).

In this paper the storm-time cosmic ray increase for mountain stations is analyzed using 28 severe geomagnetic storm events occurred in 1966-1978. In this way the multiple correlation analysis is applied among isotropic and diurnal components of cosmic ray intensity and geomagnetic Dst term, and then the cosmic ray modulation term due to other origins except the lowering of cutoff rigidity is composed. The amplitude is obtained as a function of longitude of the stations.

2. Method of Analysis. The first step of the analysis is to separate the storm-time increase from other kinds of cosmic ray variations during geomagnetic storms. In the previous paper (Tanskanen et al. 1983) we reported that the observed cosmic ray variation during severe geomagnetic storms, CR(t), is reasonably separated into three components, i.e., the diurnal and the isotropic components A(t) and Iso(t), and the Dst depen-

dent component, Dst(t).

$$CR(t)=A(t)+c \cdot Iso(t)+d \cdot Dst(t)$$
$$\text{where} \quad A(t)=a \cdot \cos\omega t+b \cdot \sin\omega t \qquad \omega=2\pi/24hr$$

The isotropic component Iso(t) is an average of neutron monitor data from Thule and McMurdo to analyze the data from the sea-level stations. An average of Thule and Alert is used to analyze the data from the mountain stations since they are all distributed in the northern hemisphere. The coefficients a,b,c and d are obtained by the multiple correlation analysis based on one hour values covering three days centered at the Dst minimum day. The composed cosmic ray intenstiy, CR'(t), is defined by using some of the coefficients as follows.

$$CR'(t)=A(t)+c \cdot Iso(t)$$

The storm-time increase, STI, in unit of %/100nT is determined subtracting CR'(t) from CR(t). Some examples are shown in Figure 1.

3. Local Time Asymmetry of the Storm-Time Increase. The local time dependence of STI is analyzed by using the cosmic ray data from a number of stations distributed over a whole range of longitude on the earth. In the previous paper (S.Kudo et al., 1984), the sea-level stations below 5GV cutoff rigidity are used. After excluding the rigidity dependence of STI we obtained the local time asymmetry of STI from about 30 stations.

The phase and amplitude of the local time asymmetry of the storm time increase are obtained for six events. The histograms of the frequecy distribution of phases of the six events show that the asymmetry is located in the evening sector in the interval of several hours close to the Dst minimum time. The amplitude of the asymmetry averaged over the six events is kept almost constant at 1%/100nT for the same interval of time.

In Figure 2 the observed storm-time increases of the six events are illustrated together with the theoretical expectations. The black circles are the average values of observed STI of the stations with 4 GV cutoff rigidity, and the arrows denote the amplitudes of the asymmetry. The white circles are the theoretical estimations of the average storm time increase for Kiel, Jungfraujoch and Rome, which are obtained from the theoretical curve for the rigidity dependence of the storm-time increase (Kondo,1961). The theoretical values of the amplitude of asymmetry are estimated by using the result of Flückiger et al.'s work (1981), in which they calculated the depression of cutoff regidity based on a partial ring current model. It is seen that the observed values of STI are comparable with the theoretical expectations in magnitude.

4. Analysis on Mountain Stations. The local time dependence of STI on mountain stations is analyzed by using 28 events which occur in various UT hours. The method adopted for the sea-level stations is not applicable for mountain stations because they have various altitudes and the number of stations are limited. In this paper 28 events listed in Table 1 are used.

A typical example is shown in Figure 3, where STI in unit of %/100nT are plotted against UT of the Dst minimum time. Three hour average values of STI centered at the Dst minimum time are used in the present analysis.

The conversion of unit from % to %/100nT is made by multipling STI(%) by 100/ΔDst, where Δ Dst is the difference of Dst between its flat level and the average over three hours around the Dst minimum time. The large increase near 18h LT(the arrow) show the local time asymmetry of STI. The other European mountain stations with between 4 and 5 GV cutoff rigidity, Lomnicky-Stit, Zugspitze, Pic-du-Midi, have the same tendency in the local time dependence. On the other hand the mountain stations with higher or lower cutoff rigidities, for example Mt.Norikura(11.4 GV) and Climax(3.0 GV), do not show such an evident asymmetry of the storm-time increase. The STI of Rome is also plotted in Figure 3. The phase of the asymmetry is close to 18h LT.

5. Discussion and Summary. We have obtained the local time asymmetry of the storm-time increase from the worldwide neutron monitor data. In section 2 the method for analyzing the data from a number of sea-level stations with cutoff rigidity lower than 5 GV has been shown briefly. The amplitudes of the asymmetry are consistent with the theoretical expectations, and the phases are located in the evening sector. In section 3 another method has been used to analyze the data from mountain stations or individual stations. The two methods are mutually connected with an equation between LT, UT and the longitude of stations, *LT=UT+(longitude/15degrees)*. It is evident that the data from European mountain stations show the local time asymmetry in the storm-time increase, and that the observed amplitude of asymmetry of Jungfraujoch and Rome are consistent with the theoretical expectations shown in Figure 2. We are making further analysis of the data from individual stations.

6. Acknowledgements. The authors express their sincere thanks to all the stations for sending neutron monitor data to WDC-C2. The present analysis is made on these invaluable data.

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EVENT NUMBER	DATE YEAR	MONTH	DAY	Dst MINIMUM UT(hour)	nT
1	1966	3	14	6	-132
2	1966	5	26	23	-112
3	1966	8	30	24	-111
4	1966	9	4	3	-229
5	1967	1	14	6	-176
6	1967	2	16	14	-120
7	1967	5	26	4	-418
8	1967	6	6	3	-172
9	1968	4	5	23	- 95
10	1969	2	2	24	-175
11	1969	3	24	2	-240
12	1969	9	30	3	-132
13	1970	3	8	23	-268
14	1970	12	14	10	-142
15	1971	12	17	21	-167
16	1972	6	18	4	-190
17	1972	8	9	12	-154
18	1972	9	14	6	-146
19	1973	4	1	23	-188
20	1974	9	15	20	-149
21	1974	10	13	15	-105
22	1975	11	9	19	-114
23	1976	1	10	24	-164
24	1976	3	26	9	-229
25	1976	4	1	9	-221
26	1978	7	4	17	-114
27	1978	8	28	10	-242
28	1978	9	29	11	-241

Table 1 List of severe geomagnetic storms from 1966 to 1978.

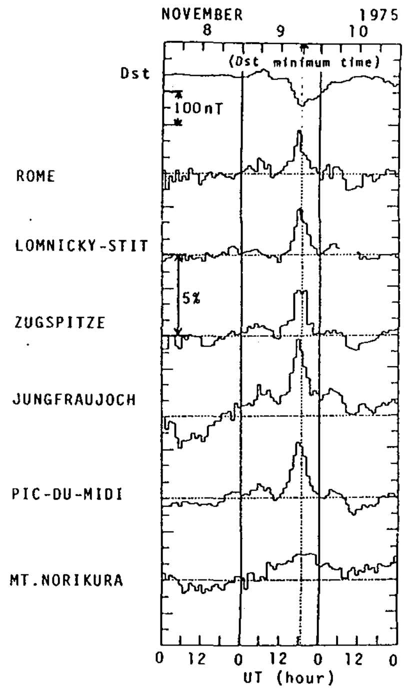

Fig. 1 The storm time increase (STI) for some stations during the geomagnetic storm in November 9, 1975. The topmost curve is the time variation of the geomagnetic Dst(t) (Sugiura).

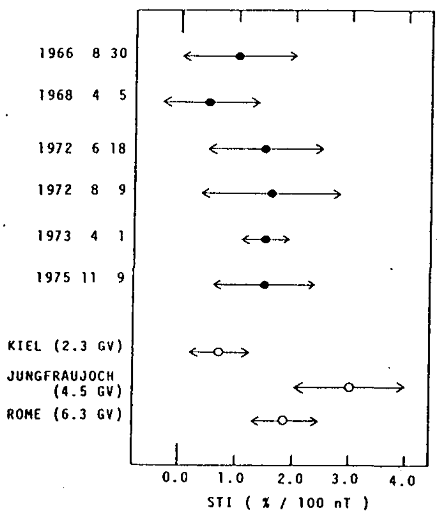

Fig. 2 The observed storm time increase of six events and the theoretical expectations for Kiel, Jungfraujoch and Rome.

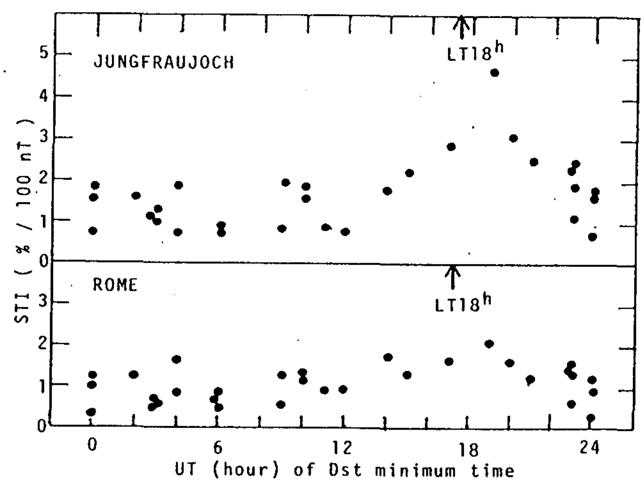

Fig. 3 The local time dependence of the storm time increase for Jungfraujoch and Rome obtained from 28 events listed in Table 1.