nearly constant regardless of the grade of the magnetic storm, while the energy spectrum of them varies with the grade of magnetic storm when the cosmic ray storm is accompanied with the small one. That these results are not due to the change in geomagnetic cut-off at the earth is clear from the procedure by which the results (ii) and (iii) were obtained. It is, therefore, concluded that the cause of these results probably lies in interplanetary space, and that it is tied up directly with the solar corpuscular emission. Detailed discussions about these will be given later.

Acknowledgments

The author is very gratefull to Dr. Y. Miyazaki and the members of Cosmic Ray Laboratory, the Institude of Physical and Chemical Research, for their many stimulating discussions and valuable advices. He also wishes to express his sincere gratitude to Prof. Y. Kato of Tohoku University for his kind advice and encouragement and to the members of IGY cosmic ray observatories around the world who presented the precious data through World Data Centre.

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JOURNAL OF THE PHYSICAL SOCIETY OF JAPAN Vol. 17, SUPPLEMENT A-II, 1962
INTERNATIONAL CONFERENCE ON COSMIC RAYS AND THE EARTH STORM Part II

II-4-8. On Cosmic-Ray Intensity Increase during Geomagnetic Storm*,**

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Studies were made on worldwide cosmic-ray intensity increases which were observed during geomagnetic storms. From statistical analysis of these events, the following results were obtained. This intensity increase was found to be a characteristic feature of cosmic-ray variation associated with severe geomagnetic storm. On the other hand, this intensity increase was not observed when the cosmic-ray storm was not associated with large geomagnetic storm.

Assuming this intensity increase was caused by decrease of the magnetic cut off rigidity by depression of the geomagnetic field, the dependence of the increment on latitude was calculated. The observed increments at various stations were in good agreement with theoretical expectation. Thus it was concluded that this storm time increase is caused by the shift of the magnetic cut off rigidity. Observed neutron intensity variations during the cosmic-ray storms associated with large geomagnetic storms are strongly affected by this storm time increase. So in order to study the intensity variations during these storms, correction for this increase is necessary.

It was reported at the Moscow Meeting[1] that the cosmic-ray intensity increases were observed during cosmic-ray storms on Sept. 13, 1957 and Feb. 11, 1958. This storm time increase was found to be due to the shift of cut off rigidity during geomagnetic storm.

* This paper was combined with (II-4-5), (II-4-6) and (II-4-7), and presented by I. Kondo in II-4-32.

** Full text will be published in Rep. Ionosphere, Space Res. Japan, **15** (1961).

In the present paper, further studies are made on the intensity increase during geomagnetic storm. Not only for the cases reported at the Moscow Meeting, this intensity increase was found to exist during large geomagnetic storm.

58 geomagnetic storms during I.G.Y. were classified into 2 groups according to whether they are preceded by Type IV solar radio outburst or not. These groups are further divided into three subgroups by the size of the geomagnetic storm. The cosmic-ray neutron intensities observed at 5 mountain and 4 sea level stations were used to obtain the intensity variation during these storms by Chree's method. The minima of the horizontal intensity of the geomagnetic field at Kakioka were used as the epochs and the results are shown in Figs. 1, 2 and 3.

As seen from Figures, the cosmic-ray intensity decrease was not so large at low and middle latitudes when the geomagnetic storm was large (subgroups A_1 and A_2). In contrast, large cosmic-ray decrease was observed at high latitudes for the magnetic storms of group A. For small magnetic storms associated with Type IV radio outbursts (subgroup A_3), all stations observed large intensity decrease. When the large geomagnetic storms not associated with Type IV outbursts occurred, the neutron intensity increased at low and middle latitudes while increase or decrease was not observed at high latitude stations (subgroup B_1).

These facts strongly indicate that the cosmic-ray intensity increase is a characteristic feature of severe geomagnetic storm, but not a characteristic feature of the cosmic-ray storm. The decrement of the neutron intensity was calculated from curves in Fig. 1

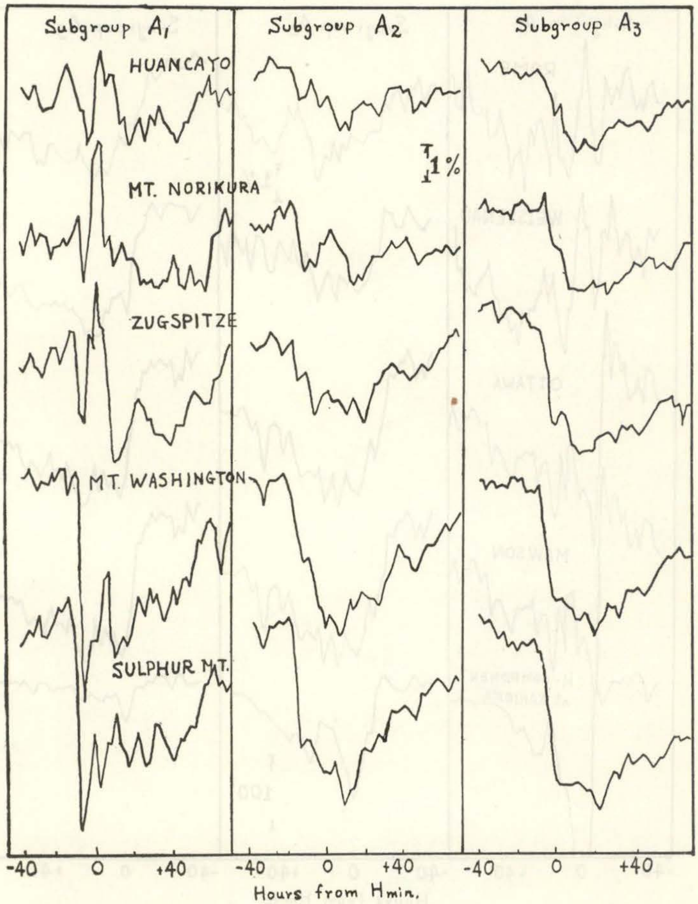

Fig. 1. Cosmic-ray neutron intensity variation during geomagnetic storms associated with Type IV solar radio outbursts. (mountain stations).

and plotted against the geomagnetic cut off rigidity at each station in Fig. 4 a. The obtained rigidity dependence differs from each other for subgroups of A. This figure shows that while the decrease at the high latitude stations is not so different from storm to storm, the decrement at middle and low latitudes is affected by the storm time increase.

Results of theoretical calculation for this intensity increase reported at Moscow Meeting was used to correct the observed intensity variation for this effect. This theoretical calculation was made under the assumption that this intensity increase is due to the shift of the geomagnetic cut off rigidity by depression of the geomagnetic field during the magnetic storm. The corrected intensity variation was found to have similar shape at all stations regardless of the latitude of station and the size of the geomagnetic storm as shown in Fig. 5. The rigidity dependence of the decrement was corrected and plotted in Fig. 4 b in which the dependence shows almost same shape for each subgroup.

Rigidity dependence of the decrement of cosmic-ray intensity was also investigated for relation to the position of the solar flare on the sun which produced the magnetic storm. As shown in Fig. 6, after correction for the storm time increase effect, the decrements show similar rigidity dependence regardless of the position of the solar flare on the sun. The magnitude of the decrement, however, shows a dependence to the position of the flare on the sun, *i.e.*, the solar flares occurred in the eastern heliographic longitudes produce larger cosmic-ray intensity decrease.

The above results strongly support the existence of the storm time increase as the

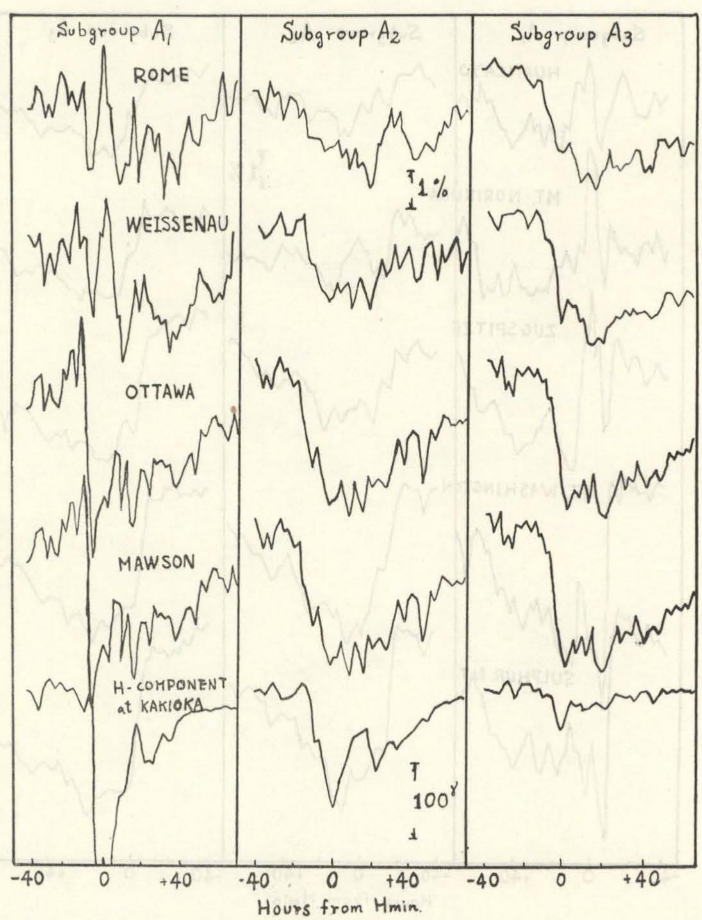

Fig. 2. Cosmic-ray neutron intensity variation during geomagnetic storms associated with Type IV solar radio outbursts. (sea level stations).

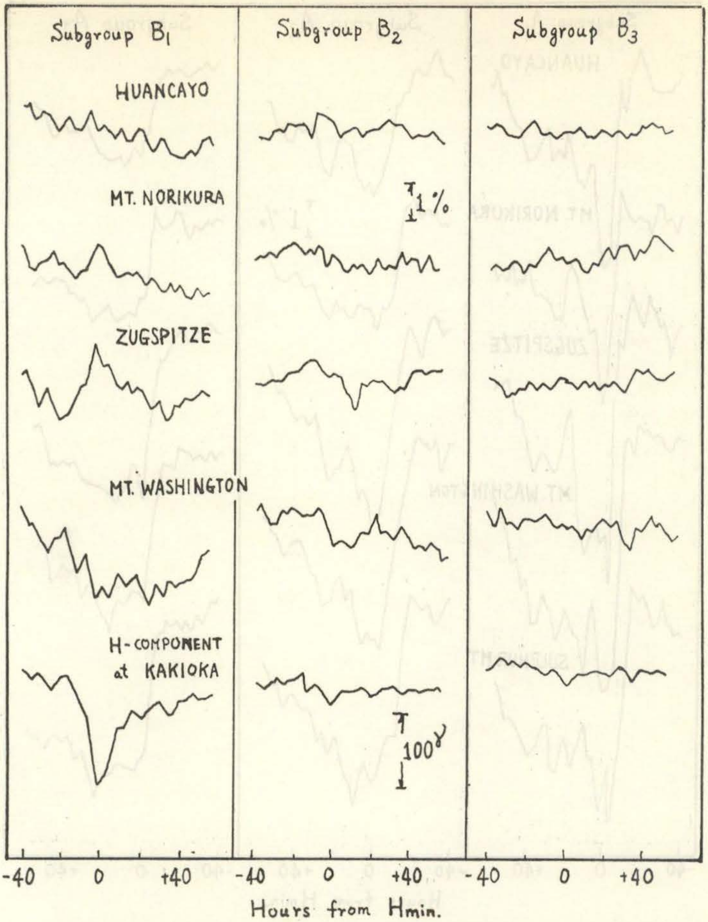

Fig. 3. Cosmic-ray neutron intensity variation during geomagnetic storms not associated with Type IV solar radio outbursts. (mountain stations).

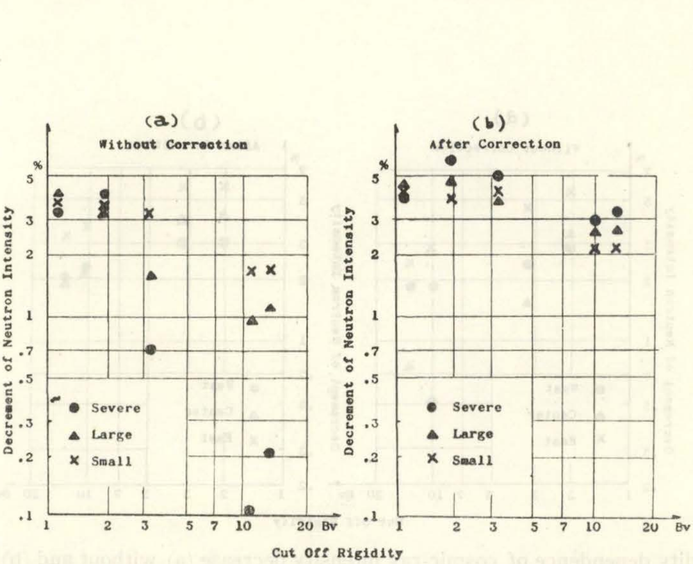

Fig. 4. Rigidity dependence of cosmic-ray intensity decrease; (a) Observed decrements for magnetic storms of group A. (b) Decrements corrected for the storm time increase effect.

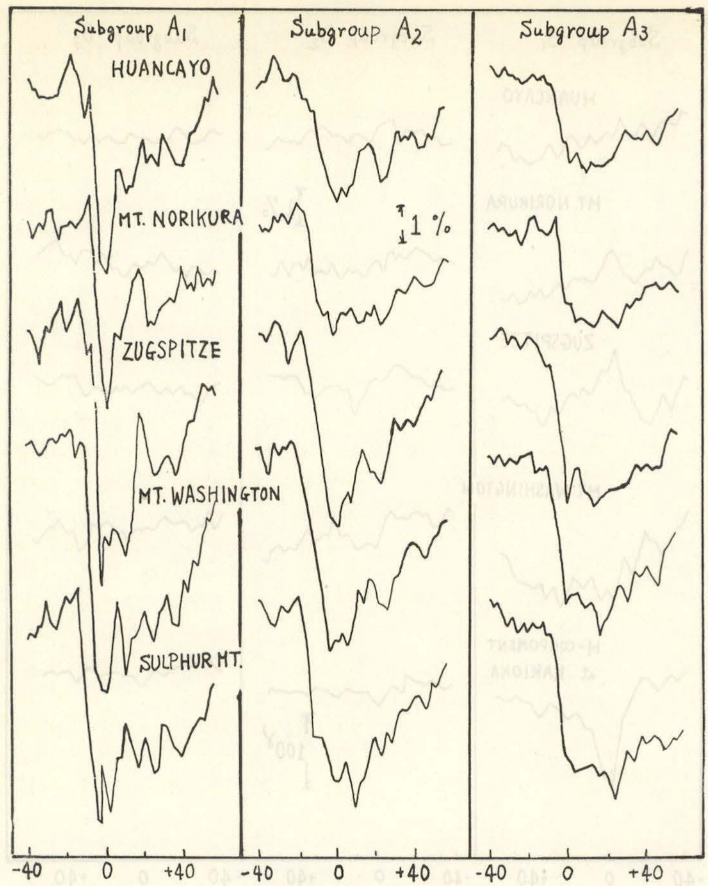

Fig. 5. Cosmic-ray neutron intensity variation during geomagnetic storms, corrected for the storm time increase effect.

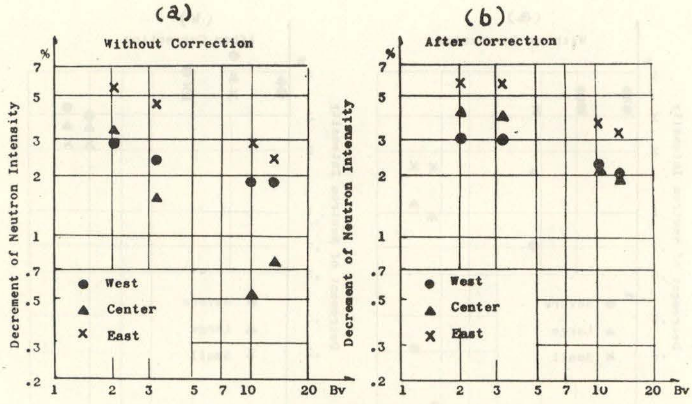

Fig. 6. Rigidity dependence of cosmic-ray intensity decrease (a) without and (b) after correction for the storm time increase effect. West, Center and East denote the position on the sun of the solar flare responsible for the cosmic-ray storm.

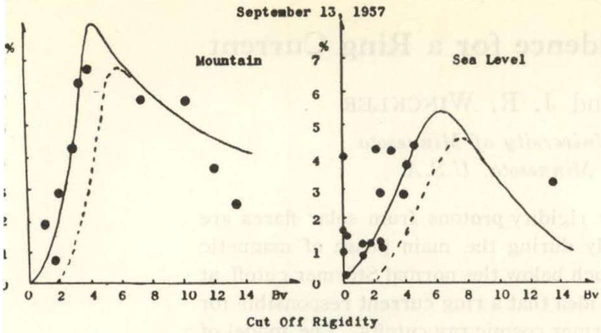

Fig. 7. Dependence of the increments of cosmic-ray intensity on cut off rigidity. Smooth curves show theoretical expectation for $\Delta H=300\gamma$ and radius of ring current is larger than 10 earth radii. Dotted line shows what happens when the radius of ring current is 5 earth radii.

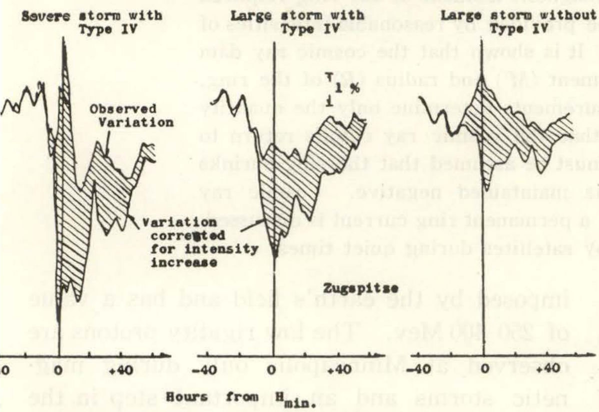

Fig. 8. Observed intensity variation of neutron component at Zugspitze and the effect of the intensity increase by the shift of cut off rigidity during geomagnetic storms.

result of the shift of the cut off rigidity due to the depression of the geomagnetic field. Minnesota group reported the evidence which shows the change of cut off rigidity during geomagnetic storm from balloon experiment. Dr. Kellogg made a study and from his results estimation was made on the magnetic moment and the radius of the ring current which produced the depression of the geomagnetic field. On a rare case, he found no reduction in cut off rigidity which he attributed to smaller radius of the ring current. This conclusion can be checked by the neutron monitor at latitude 40°–50° where as shown in Fig. 7 the increment of neutron intensity depends strongly on the radius of the ring current.

The cosmic-ray intensity variation observed at the earth during large geomagnetic storm is deviated from that would be observed at a point outside of the geomagnetic field due to the storm time increase effect. The effect of this increase is illustrated for the intensity variation observed at Zugspitze in Fig. 8. Thus the correction for this effect is very important in the study of the modulation effect on cosmic-ray intensity.

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