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RIGIDITY RESPONSES OF IONIZATION CHAMBERS DERIVED FROM COSMIC RAY TIME VARIATIONS

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ABSTRACT

The coupling coefficient which connects the cosmic ray variation in space with that observed at the ground is obtained for the ionization chamber. The differential coefficients with respect to the zenith angles are averaged with weights corresponding to the zenith angle dependence of a spherically symmetric chamber at sea level and mountain elevation. The resultant coefficients satisfactorily accord with the results of the neutron monitors and the multi-directional muon telescopes for the cases of great Forbush decreases.

1. Introduction

The continuous registration of cosmic ray intensity in early stage of research was realized by the ionization chamber (Compton et al., 1934). Though the muon telescopes (Miyazaki, 1954) and the neutron monitors (Simpson et al., 1953) are main instruments of the continuous observation now, the chambers have been most stable detectors for the long term variations of cosmic rays. The data from the world network of Carnegie Institution (Forbush et al, 1948, 57, & 69) are still useful to the researchers.

The Institute of Physical and Chemical Research developed ionization chambers in 1930's just after the report of Compton Model-C meter (Compton et al. 1934). We call it IPCR-type or Nishina-type ion chamber (Nishina et al., 1937; Ishii, 1944; Miyazaki, 1954). We have five identical chambers. They are at Sapporo (vertical cutoff rigidity, 8.22 GV), Mt. Norikura (11.39 GV, 2770 m above sea level), Tokyo (11.61 GV), Hong Kong (16.23 GV), and Kochi (12.66 GV, planned).

Though the accuracy of observation is not so high as that of the neutron monitors and the large area muon telescopes, the data can be used even for transient variations as great Forbush decreases. In order to use the data, it is necessary to know the coupling coefficients. The coupling coefficients connect the cosmic ray variations in space with those observed by the detectors at the ground through the response functions and the variation spectrum of primary cosmic rays. As for the coefficients of anisotropies, the asymptotic directions are also requested.

In this paper, we deal with only the isotropic component in cases of Forbush decreases. We assume a single power-law spectrum with exponent of -1.0 upto 100 GV. The coefficients are obtained from existing differential coefficients with respect to the zenith angle. They are examined by well known great Forbush decreases on August 5, 1972 and February 15, 1978. The result is very satisfactory. Some problems concerning the use of the ion chamber are described.

2. Numerical estimation

Since the shape of ion chamber is spherical as Compton Model-C meter and ASK-1 (Dorman, 1957) or cylindrical with one hemispherical end (Nishina-type), it can be approximated that the cross sectional area is independent of the zenith angle. The zenith angle dependence of the cosmic ray flux at low altitudes is given by $\cos^2 z$, and the flux, I, observable by a chamber can be estimated from the vertical flux, j_o, by,

$$I = 2\pi j_o \int_0^{\pi/2} \cos^2 z \sin z \, dz. \tag{1}$$

That the ion chamber is effective to larger zenith angles than that of the muon telescope is displayed in Fig.1. In the figure, the zenith angle dependence of muon telescope is approximated by higher power of cosine term as,

$$(n + 1) \cos^n z \sin z, \tag{2}$$

which results the integral over hemisphere to be unity.

The differential coupling coefficient for a certain zenith angle is picked up from that of the multi-directional muon telescope at Nagoya (Fujimoto et al.,1976, 77) and at Mt. Norikura. It is plotted as a curve A in Fig.2. Then the coupling coefficient for an ion chamber is obtained by,

$$C = 3.0 \int_0^{\pi/2} A(z) \cos^2 z \sin z \, dz. \tag{3}$$

The integrand is plotted in Fig.2 as B. The coefficient at sea level is 0.16 for the variation spectrum of,

$$f(P) = (P/10 \text{ GV})^{-1.0} \quad \text{upto 100 GV}, \tag{4}$$

and 0.20 for Mt. Norikura.

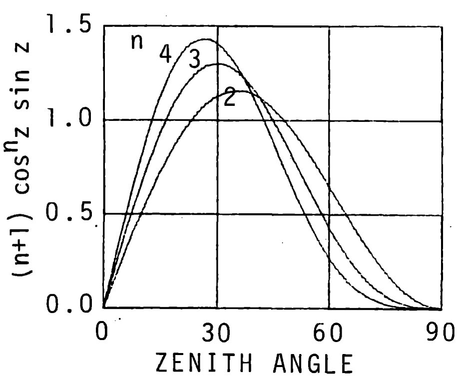

Fig.1. The response to zenith angle. The curve, n = 2 corresponds to an ion chamber. The curves with higher n correspond approximately to muon telescopes. The curves are normalized so that the areas under respective curves are unity.

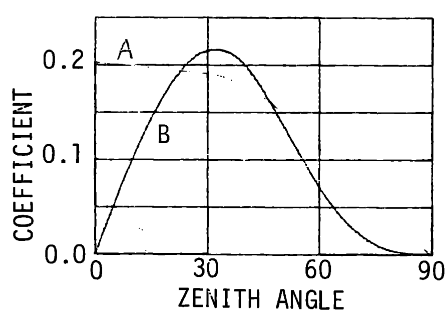

Fig.2. The differential coupling coefficient with respect to zenith angle (curve A) and that effective to an ion chamber, for sea level muons at Nagoya/Tokyo.

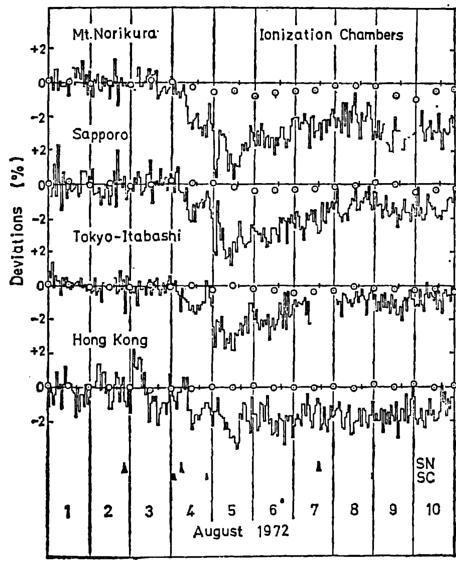

Fig.3. Variations of cosmic ray intensity observed by Nishina-type ion chambers at the time of a great Forbush decrease on 5 August 1972. Small circles indicate equivalent variations by the atmospheric temperature effect.

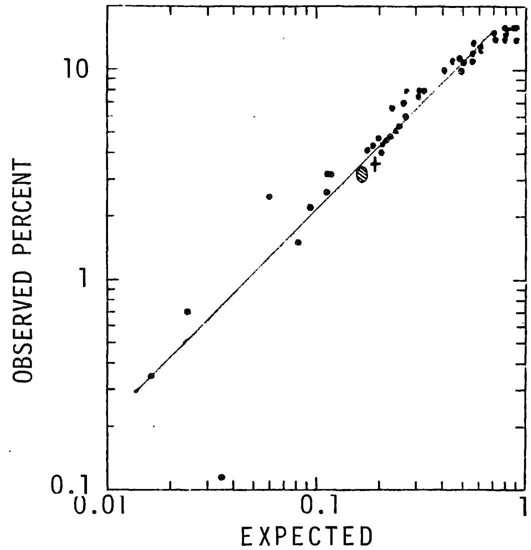

Fig.4. The observed amplitudes of the depression during 1000-1400 UT on 5 August 1972 with respect to the expected isotropic coupling coefficients. If the points line on the 45° line, the fitness is good. The cross is for Mt.Norikura, and the ellipse for Tokyo/Hong Kong.

3. Forbush decreases

There are two great Forbush decreases occurred recently: on 5 August 1972 and on 15 February 1978. The maxmimum depression of the 1972 event was at 0000-0200 UT in most of the cases of neutron intensity. The second maximum was at 1000-1400 UT. In higher rigidities, however, the minimum had a tendency to unify to one (Chuang et al., 1973; Miyazaki et al.,1973) as depicted from their figure in Fig.3 above. Therefore we take the period of the second minimum for any of the neutron monitors and the muon telescopes as well as the chambers, and plotted the amplitudes of depression in Fig.4. In the same way, the case of the 1978 event is shown in Fig.5. In either cases, the points of the ion chambers are well on the fitness lines between the observed and the expected values.

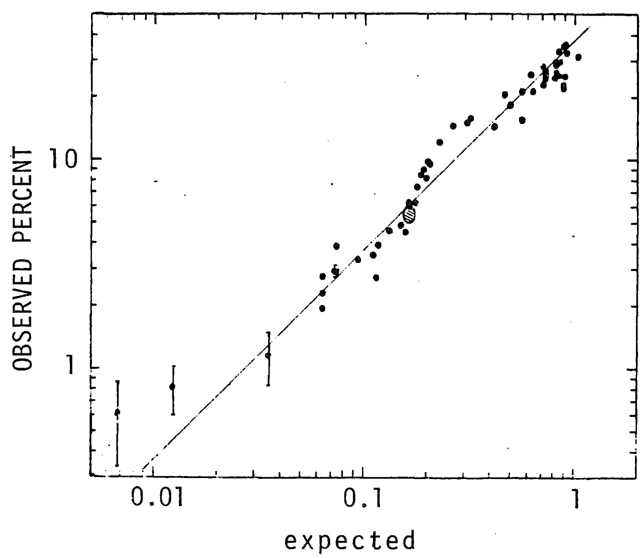

Fig.5. The observed amplitudes of the depression on 15 February 1978 (Wada et al.,1979). The times of maximum depression for individual components and stations are taken.

The result of ASK-1, the 1000 liter chamber, at Yakutsk in the 1972 event (Filippov et al.,1973) does not contradict with the present indication in Fig.4.

4. Conclusion

The coupling coefficients of the ion chamber for the isotropic variation have been estimated and examined by existing Forbush decreases. It is concluded that the coupling coefficients can be obtained if the zenith angle dependence is taken properly.

The ion chambers can be used for the continuous registration of cosmic ray intensity from now also. For that, there are some problems which should be taken into account. The most serious is the drift in the level of output current. The long term drift was noted by Forbush (1954). The 50 liter chambers in USSR had the same trouble (Dorman, 1957). In our case, the leakage of high pressure inner gas should be overcome. Some chamber was kept in a constant pressure for more than ten years, then it started to leak. Both the current level and the conversion factor from the current to percentage values are changing continuously.

In the meantime, we changed the recording system from a static electrometer-film system to a vibrating reed electrometer-pen recorder system. Recently we have made a device which registers digital output of current on paper tape every one minute. The bursts are subtracted from the one minute differences during the offline computer processing. It will be reported elsewhere.

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