COUPLING FUNCTIONS FOR LEAD AND LEAD-FREE NEUTRON MONITORS FROM THE LATITUDINAL MEASUREMENTS PERFORMED IN 1982 IN THE RESEARCH STATION "ACADEMICIAN KURCHATOV"

Alekanyan T.M., Dorman L.I., Yanke V.G.
Institute of Terrestrial Magnetism, Ionosphere and Radio Wave Propagation, USSR Academy of Sciences, I42092 Troitsk, Moscow Region, USSR

Korotkov V.K.
SVKNII, Magadan, USSR

Abstract. The latitudinal behaviour of intensities and multiplicities was registered by the neutron monitor 2 NM and the lead-free neutron monitor 3 SND (slow-neutron detector) in the equator-Kaliningrad line in the Atlantic Ocean. Coupling coefficients for 3 SND show the sensitivity of this detector to primary particles of cosmic rays of energies on the average lower than for 2 NM. As multiplicities increase, the coupling coefficients shift towards higher energies.

The data of latitudinal expeditions have given information on the planetary CR distribution, but mainly from the results of measurements of the summary intensity registered by the neutron monitor, e.g./I,2/. But the available results for measurements of multiplicities are contradictory /3,4/, although it is obvious that large multiplicities must be connected on the average with high energies of primary particles with the exception of a first multiplicity, where the influence of the muon component can be observed. It is also reasonable to specify the known results /5,6/ for the lead-free neutron monitor NMD (Neutron maderated detector) and to compare them with the data for the standard neutron monitor NM-64.

The approximation of the dependence of the recorded intensity I on the geomagnetic cutoff rigidity R has the form /I-6/

$$I = I_o \left[1 - \exp\left(-\alpha R^{-\kappa}\right)\right] . \qquad (I)$$

It appears impossible to determine simultaneously three parameters, I_o, α, k in (I) by the method of least squares because of divergency of the iteration process. Therefore, one usually determines the parameter I_o from expedition measurements and then calculates and k by solving the system of equations $\ln\ln[I_o/(I_o-I)] = \ln\alpha - k\ln R$, where I are experimental data. But this method turns out invalid for multiplicities because a statistical accuracy of measurements rapidly decreases, as multiplicity increases, and because in many cases the data of measurements in polar zones are absent. Besides, we cannot use part of the data, for which $I \geqslant I_0$ because of statistical difference.

The aim of this papaer is the development of the method of simultaneous calculation of all the parameters in (I) and practical application of this method.

The planetary distribution of CR was measured by the detectors on the research ship "Academician Kurchatov" from 6 to 22 of April, 1982 in the Atlantic Ocean in the northern hemisphere. The standard two-counter neutron monitor 2 NM and the three-counter lead-free neutron monitor 3 NMD were used for measurements. Correction due to atmospheric pressure variation was made similarly to /7/. The correction due to variations of extraterrestrial origin was introduced according to the Kiel station; the dependence of the amplitude of variations on the geomagnetic cutoff rigidity was also determined by analogy with /7/. The geomagnetic cutoff rigidities were calculated according to /8/. The results of latitudinal measurements are shown in Fig.I.

The successive approximation method /9/ is proposed for finding the parameters of the approximation (I). The expansion of (I) in a Taylor series with an accuracy to first-order terms at the point of the initial approximation of paramaters has the form

$$I=[I_o(1-e^{-\alpha R^{-\kappa}})]_o+(1-e^{-\alpha R^{-\kappa}})_o\Delta I_o+(I_o R^{-\kappa}e^{-\alpha R^{-\kappa}})_o\Delta\alpha+(I_o\alpha R^{-\kappa}e^{-\alpha R^{-\kappa}}\ln R)_o\Delta\kappa, \quad (2)$$

where the expressions in brackets are taken at the point of the initial approximation $I_o=I_o^{(o)}$, $\alpha=\alpha^{(o)}$, $k=k^{(o)}$. Then one minimizes the sum of the squares of the differences of the calculated values of I according to (2) and experimental values of I

$$S=\Sigma\,(q\Delta I_o+I_o\tau\Delta\alpha-I_o\alpha\tau\ln\tau\Delta\kappa-I_o q-I)=min \quad (3)$$

where $q=1-exp(-\alpha R^{-\kappa})$, $\tau=R^{-\kappa}exp(-\alpha R^{-\kappa})$. The condition of the minimum (3) $\partial S/\partial I_o=0$, $\partial S/\partial\alpha=0$, $\partial S/\partial\kappa=0$ gives the system of equations

$$\begin{cases}\Delta I_o\Sigma q^2+I_o\Delta\alpha\Sigma q\tau-I_o\alpha\Delta\kappa\Sigma q\tau\ln R=\Sigma q\,(I-I_o q)\\ \Delta I_o\Sigma q\tau+I_o\Delta\alpha\Sigma\tau^2-I_o\alpha\Delta\kappa\Sigma\tau^2\ln R=\Sigma\tau\,(I-I_o q)\\ \Delta I_o\Sigma q\tau\ln\tau+I_o\Delta\alpha\Sigma\tau^2\ln R-I_o\alpha\Delta\kappa\,\Sigma\,(\tau\ln R)^2=\Sigma\tau\,(I-I_o q)\ln R\end{cases} \quad (4)$$

the solution of which $\Delta I_o, \Delta\alpha, \Delta k$ determines the following approximation of the parameters $I_o^{(1)}=I_o^{(o)}+\Delta I_o$, $\alpha^{(1)}=\alpha^{(o)}+\Delta\alpha$, $\kappa^{(1)}=\kappa^{(o)}+\Delta\kappa$. This cycle of operations is repeated for subsequent approximations until stable values of the parameters I_o, α, k are obtained. The results of the calculations are shown in Fig.I (solid curve) for all the recording channels: total intensity of the neutron monitor 2 NM, multiplicities m=I-5, $\geqslant$ 6 and a lead-free monitor. The successive approximation method proved convergent only for multiplicities $m \geq 6$, which is explained by a low statistical accuracy of measurement of higher multiplicities. For comparison the calculated curves in Fig.2 are normalized for R=0. The polar coupling coefficients calculated in line with /I-3/ as $W(R)=\alpha K R^{-K-1} \exp(-\alpha R^{-K})$ are shown in Fig.3. The table presents the parameters I_0, α, k, as well as the maximal values of the coupling coefficients W_{max} and the corresponding values of the rigidities R_{max}.

	I_0	α	k	R_{max}, GV	W_{max}, %/GV
2NM	42930	8.3I8	0.866	4.76	4.55
3NMD	59076	6.550	0.800	3.80	4.99
m=I	28592	7.I55	0.808	4.2I	4.58
m=2	448I.8	I0.255	0.95I	5.43	5.99
m=3	I055.5	I3.483	0.978	6.96	3.76
m=4	325.63	20.298	I.060	9.I5	3.23
m=5	63.56	42.83	I.29I	II.77	3.30

The measurements give the form of multiplicity distribution

$$I_m = C \exp(-\varkappa m^{\delta}), \tag{5}$$

where I_m is the number of cases of recording of multiplicity m; $C, \varkappa, \delta$ are the distribution parameters. In a particular case of the use of multiplicities I,2,4 it is easy to obtain explicit expressions for determining the parameters

$$\delta = \ln[\ln(I_2/I_4)/\ln(I_1/I_2)]/\ln 2, \quad \varkappa = \ln(I_1/I_2)/(2^{\delta}-1), \quad C = I_1 e^{\varkappa}. \tag{6}$$

From Fig.4 it follows that these parameters are functionally connected with one another, in this case $\varkappa=(1{,}87\pm0{,}01)\delta^{1{,}226\pm0{,}008}$, $C=(5{,}77\pm0{,}04)\cdot10^4\exp(0{,}81\pm0{,}01)\varkappa$. This means that a change in the cutoff rigidity leads to an interdependent change in the multiplicity distribution parameters. The dependence of these parameters on the geomagnetic cutoff rigidity is shown in Fig. 5. If δ (R) is represented by a straigt line according to Fig. 4, $\varkappa$ (R) and C(R) are represented according to (6), then it is easily verified that the expression is not transformed into (I), i.e. δ (R) has a more complicated form. It can be obtained if (I) is substituted into (6) and then (6) into (5). The δ (R) thus obtained is illustrated in Fig.5 by a dashed line.

The main results: I. Coupling coefficients shift towards higher rigidities as multiplicity increases; 2. The lead-free monitor NMD is sensitive to lower energies than NM-64. 3. The multiplicity distribution parameters are functionally connected. 4. All the parameters of (I) are determined by the successive approximation method.

REFERENCES : I. E.A.Andreev et al. Cosmic rays, I974,NI4,p.34
2.T.M.Alekcanjan et al.,Proc.I7 ICRC,Paris,I98I,v.4,p.266.
3.T.M.Alekcanjay et al.Proc.I6 ICRC,Kioto,I979,v,4,p.3I5.

SH 6.1-1

4. T.M.Alekcanjan et al. Cosmic Rays,I978,NI8,p.72.
5. T.M.Alekcanjan et al.ProcI6 ICRC,Kioto,I979,v.4,p.32I.
6. L.I.Dorman et al.Proc.I6 ICRC,Kioto,I979,v.4,p.325.
7. M.Kadama and A.Inaue.Yare Scientific Reports,Japan,I970, Ser.A.N O.9,p.I.
8. M.A.Shea and D.T.Smart. J.Geophys.Res.I967,v.22,N 07,p.202I
9. B.P.Demidovich et al.Numerical methods of analysis. Fizmatgiz, I962.

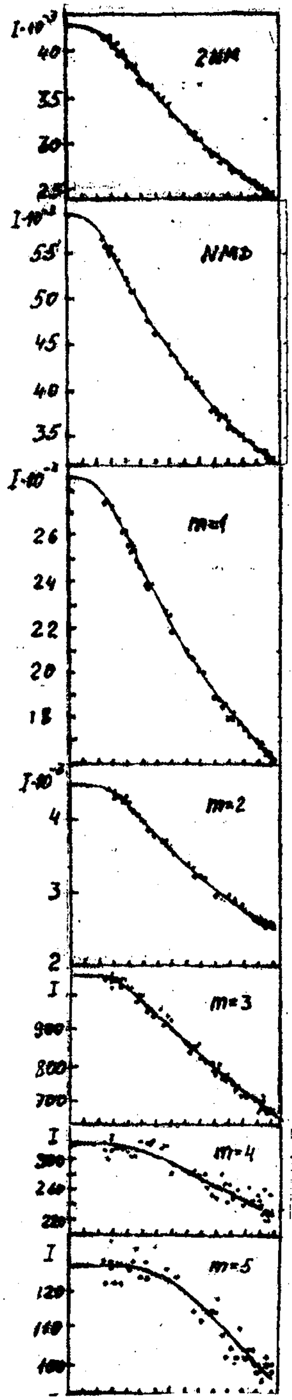

Fig.1

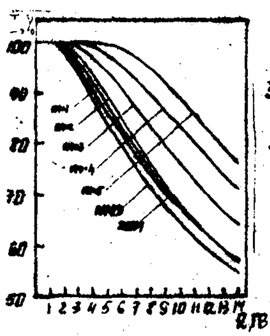

Fig.2

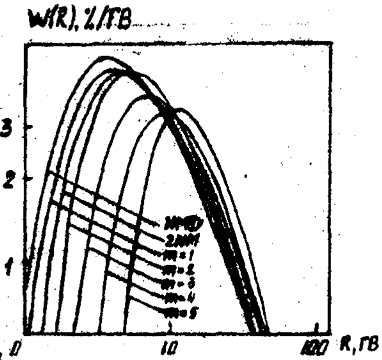

Fig.3

Fig.4

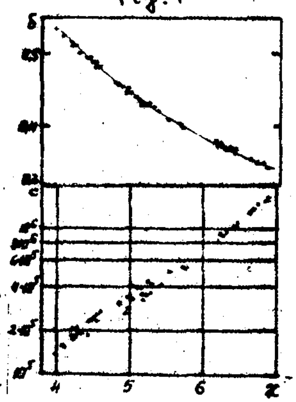

Fig.5