Abstract

Multiplicity measurements using the NM-64 neutron monitor have been carried out continuously at Syowa Station, Antarctica, and concurrently once a year along a definite sea-level route between Japan and Syowa Station. The Syowa data obtained during the period from March 1967 to February 1969 are analyzed, together with those from the first two of the latitude surveys which are in progress since 1966. The barometric coefficient and the rigidity response function of the cosmic-ray neutron component are derived as a function of multiplicities from $m=1$ to $m\geq6$. The multiplicity spectrum is investigated in the cases of the cosmic modulation phenomena such as solar proton event, Forbush decrease and diurnal variation. It is shown that the barometric coefficients and the magnitudes of intensity variations as observed in the solar proton and Forbush decrease events are decreasing with increasing multiplicity, while no significant multiplicity effect is recognized in the diurnal variation. A possibility of distinguishing the various modulation spectra of the primary cosmic radiation on the basis of the multiplicity measurements is examined quantitatively. By taking into account the behavior of higher multiplicities and the accuracy in low rigidity part of the differential response functions, the limitation of the NM-64 neutron monitor in the multiplicity work is discussed.

1. Introduction

Recently a new study of cosmic ray modulation has been advanced considerably by detecting the multiple neutrons produced in the neutron monitor. HUGHES and MARSDEN (1966) suggested that the detected multiplicity spectrum would reflect the energy dependence of the time variation of the primary cosmic radiation. In fact, the multiplicity measurements have been performed with the IGY neutron monitor (BACHELET *et al.*, 1964, 1965; KENT *et al.*, 1966; DYRING and SPORRE, 1966a, b), the NM-64 neutron monitor (GRIFFITHS *et al.*, 1968; BLOMSTER and TANSKANEN, 1969; AGRAWAL *et al.*, 1969; SMIRNOV and USTINOVICH, 1969; LOCKWOOD and SINGH, 1969) and the Lockheed neutron monitor which was specially designed so as to be sensitive to very high multiplicities (NOBLES *et al.*, 1967; WOLFSON *et al.*, 1968). However, the whole range of primary energy to which the different types of neutron monitors respond is not given quantitatively yet, particularly for each of the various time-dependent phenomena of the cosmic radiation.

It is generally believed that the neutron monitor with high counting rates located in high latitudes is very suitable for the multiplicity measurements. In such case, a physical interpretation of the detected multiplicity spectrum in the light of the primary energy spectrum requires the response functions for different multiplicities which can be deduced from the latitude survey. At Syowa Station, Antarctica, the multiplicity measurement using the NM-64 neutron monitor is being made continuously since March 1967. In concurrence with this work, another regular work of the latitude survey using the same type of multiplicity meter is carried out along a definite sea-level route between Japan and Syowa Station once a year since 1966. Preliminary results obtained from the both measurements were already reported (KODAMA and OHUCHI, 1968; ISHIDA and KODAMA, 1969). The aim of this work is to search quantitatively the availability of the multiplicity work for cosmic ray modulation studies and its limitation, on the basis of the multiple neutron data obtained at Syowa Station before February 1969 and from the first two latitude surverys during December 1966 - April 1968.

2. Multiplicity Measurements

2.1. NM-64 neutron monitor at Syowa Station

At Syowa Station (69°00′S, 39°35′E), the continuous observation of cosmic ray intensity using the NM-64 neutron monitor was started in March 1967. 10-min counting rates of events of six different multiplicities from 1 to more than 6 were recorded by the multiplicity meter as shown in Fig. 1. By the operation of an address scaler consisting of six-stage ring counter, the number of multiple neutrons produced by a primary particle incident on the monitor is determined according to the number of particles arriving within a definite gate time of one millisecond, in which the first triggering pulse is included. Then a signal of the multiple event thus designated is sent from the address scaler to one of the following six scaler units when the gate is closed. The dead time of the electronic equipment such as mixing and scaling circuits is less than 5 microseconds, but

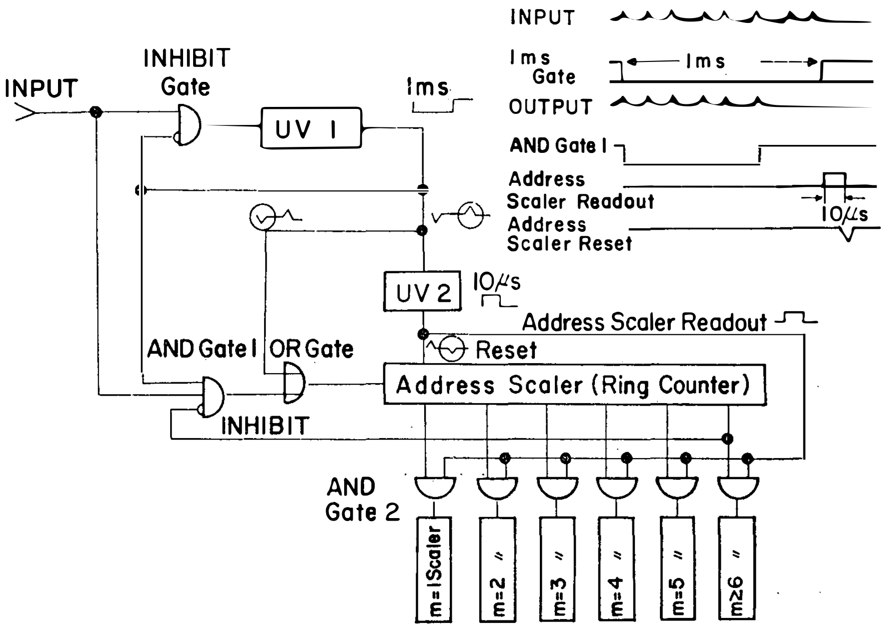

Fig. 1. Block diagram of the multiplicity meter.

that of the preamplifier set in the counter assembly is 20 microseconds which was given originally by CARMICHAEL (1964).

The number of neuton counters actually used was three until February 1968 and thereafter increased to ten, and then finally to twelve after February 1969. A duplex set of the recording instruments was installed inside a specially constructed observation room so as to minimize some unfavorable intensity fluctuations as caused by the change of meteorological factors near the ground. In fact, the maximum height of the snow drift piled up around the observation building was far below the bottom level of the monitor and no snow effect on the roof was found due to strong winds. The room temperature was well controlled by the electric heater and oil furnace automatically so that it was kept in the range of $\pm 1^{\circ}C$ throughout a year. In Fig. 2 is shown an example of the hourly counting rate observed as a function of multiplicity, in response to the different number of neutron counters operated.

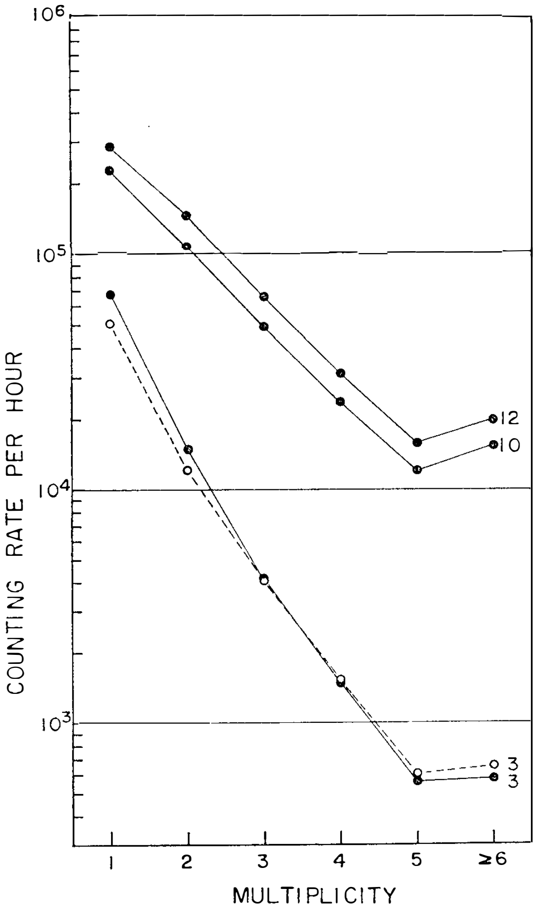

Fig. 2. Intensity distributions of the multiple neutron events detected at Syowa Station. Numerical figures attached to each curve indicate the number of operated neutron counters. The counting rates in three, ten and twelve counters were obtained during July-September, 1967, November 18, 1968 and February 25, 1969, respectively. All values are normalized to 1000 mb. Open circles show the result obtained aboard the FUJI during her stay at Syowa Station from January to February, 1967.

2.2. Latitude survey

A shipborne neutron monitor installed aboard the new icebreaker FUJI is the

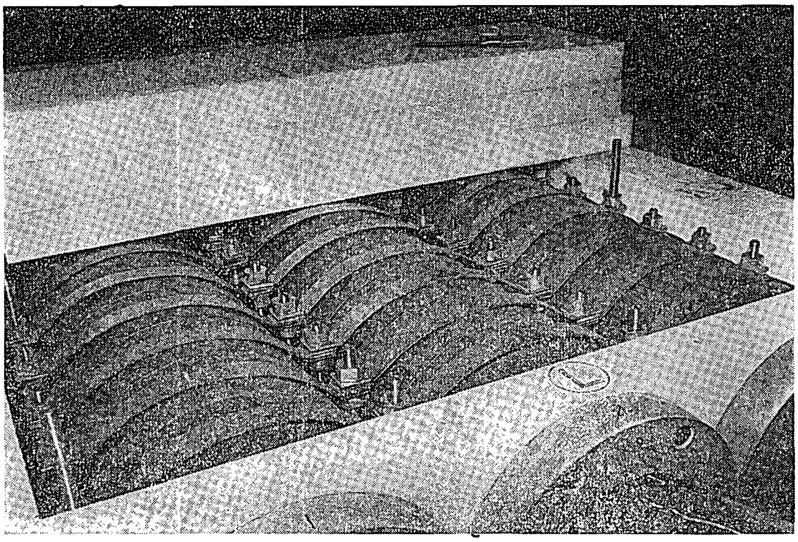

Fig. 3. Structure of the shipborne neutron monitor. Lead rings are secured by aluminum bolts and stainless steel belts.

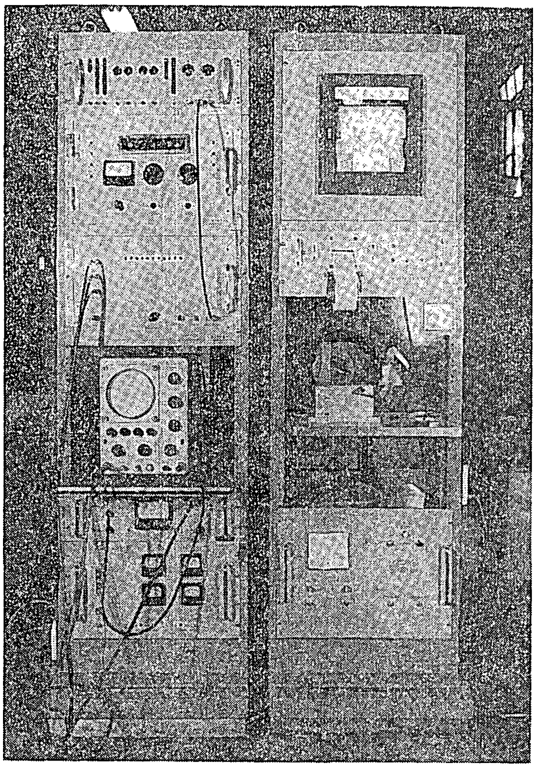

Fig. 4. A whole view of the readout equipment with recording system.

NM-64 neutron monitor with three counters which are surrounded by lead rings alone, so as to be more sensitive to high multiplicity events (HATTON and CARMICHAEL, 1964) and because of the limited space on board. The construction of the shipborne monitor is shown in Fig. 3. The thickness of the polyethylene reflector set in the both sides and the bottom was 15 cm, after the mobile monitor of CARMICHAEL *et al.* (1969). The amount of the absorption materials above the monitor was kept almost constant, being about 8g/cm^2, during the voyage.

From the above circumstances, the shipborne neutron monitor gave the absolute counting rate slightly different from that of of the Syowa 3-NM-64 neutron monitor, as indicated by a dashed curve of Fig. 2. Particularly, a feature of the shipborne monitor, as being more sensitive to higher multiplicities, can be recognized. The readout and recording equipment is of almost the same type as that of the Syowa monitor and its general view is given in Fig. 4.

The latitude survey has been done twice along a definite route as indicated in Fig. 5 during the period of 1966-1968, regularly from November to April of the next year. The route of the outward voyages (denoted by Survey-1A, -2A) is quite different from that of the homeward voyages (denoted by Survey-1B, -2B). The former crossed almost perpendicularly the iso-rigidity contour lines in the Pacific and Indian Oceans, while the latter intersected them at a considerably oblique angle in the Indian Ocean and was very close to the survey route of the

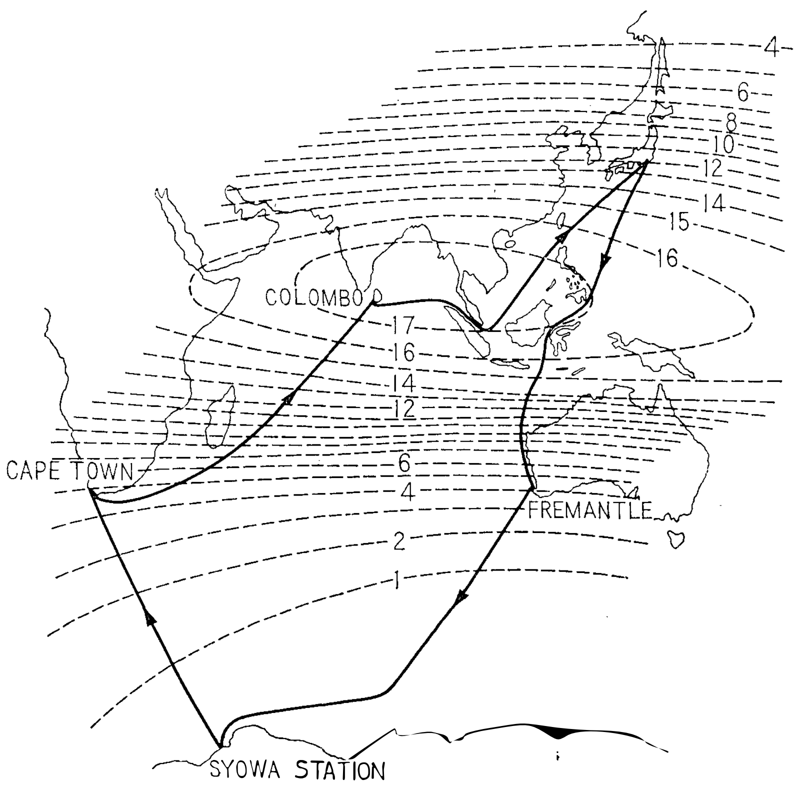

Fig. 5. The voyage route along which the present surveys were carried out. Broken lines show the contours of the KONDO and KODAMA threshold rigidity in unit of GV.

SOYA (KODAMA, 1968). Consequently, it took about twelve and thirty days to pass through the entire range of the threshold rigidities 1–17 GV in the forward and homeward voyages, respectively. This fact means that the intensity-rigidity curve based on the data from the homeward voyage has better statistical accuracy than that from the forward voyage.

For deducing the attenuation coefficient and the response function, the data from the three surveys were analyzed independently, except Survey–2A from which the data were not available due to some instrumental failures. The data on January 28 and 29, 1967, the days when a solar proton event occurred, were excluded from the present analysis of the response function. The data obtained at Fremantle, Cape Town and Colombo where the FUJI stayed for a time were also excluded, because of the unexpectedly large fluctuations in the observed neutron intensity.

The observed counting rates were corrected for the world-wide intensity variation using the Deep River neutron data and for the barometric pressure using the barometric coefficients calculated according to the procedure as described in the next section. Next, the detected multiplicity distribution has to be corrected for the gate time of the multiplicity meter and overlapping events, because it depends on the width of the gate time which can be selected arbitrarily. The method proposed by DEBRUNNER and WALTHER (1968) was applied to these corrections, where the mean lifetime of the thermalized neutrons in the shipborne monitor was determined to be 0.3 milliseconds from the experimental measurement. The relation of the corrections to the change of the neutron lifetime and the gate time is discussed in Appendix I. Daily mean values of the observed counting rates, before and after correcting for barometric pressure, the gate time and overlapping events, are compiled in Appendix II.

3. Barometric Coefficients of Multiple Neutrons

3.1. Coefficients at Syowa Station

In order to deduce the response function necessary for multiple neutron studies from the original intensity-latitude curve, the barometric coefficients for the various multiplicities must be determined as a function of threshold rigidity. Table 1 gives the barometric coefficients calculated by means of the regression analysis using the bi-hourly data obtained during the period from March to December 1967. Upper half a) of Table 1 gives the values obtained before correcting for the gate time and overlapping events, while lower half b) for the values after the corrections. It is seen from Table 1 that fluctuations of the coefficients from month to month are not very large excepting somewhat smaller values in April and November, but a considerable difference is found between the corrected and uncorrected coefficients.

Total counting rates of neutrons detected by the neutron counters were not

Table 1. The barometric coefficients of the multiple neutrons observed at Syowa in 1967, in unit of %/mb. The both values corrected and uncorrected for the gate time and overlapping events are listed.

a) Before correction

Month	$m=1$	$m=2$	$m=3$	$m=4$	$m=5$	$m\geq6$	TC
Mar. 1967	.68	.87	.91	.95	.94	.87	.77
Apr.	.55	.69	.73	.78	.74	.79	.62
May	.75	.87	.91	.94	.93	.88	.81
June	.70	.83	.86	.88	.89	.84	.77
July	.72	.86	.89	.92	.93	.87	.79
Aug.	.69	.81	.86	.89	.89	.86	.75
Sept.	.67	.79	.83	.85	.88	.86	.74
Oct.	.70	.82	.87	.89	.88	.87	.76
Nov.	.62	.76	.74	.79	.82	.82	.69
Dec.	.70	.82	.86	.88	.88	.88	.77
Mean	.70±.01	.82±.02	.87±.02	.88±.03	.90±.03	.87±.02	.76±.02

b) After correction

Month	$m=1$	$m=2$	$m=3$	$m=4$	$m=5$	$m\geq 6$	TC
June 1967	.75	.81	.81	.82	.82	.71	.77
July	.77	.83	.84	.86	.88	.76	.80
Aug.	.73	.78	.80	.84	.86	.77	.76
Sept.	.72	.77	.79	.80	.84	.78	.74
Oct.	.74	.79	.82	.84	.83	.79	.77
Mean	.74	.80	.81	.83	.86	.76	.77

TC: total counting rate

recorded experimentally but calculated with the following expression:

$$\sum_{m=1}^{5} mN_m + 6.6N_{\geq 6}$$

where N_m is the counting rate of event of multiplicity m and 6.6 is the effective multiplicity for events of $m\geq 6$, which was determined from the experimental results of HATTON and CARMICHAEL.

3.2. Rigidity dependence

The rigidity dependence of the barometric coefficient can be deduced using

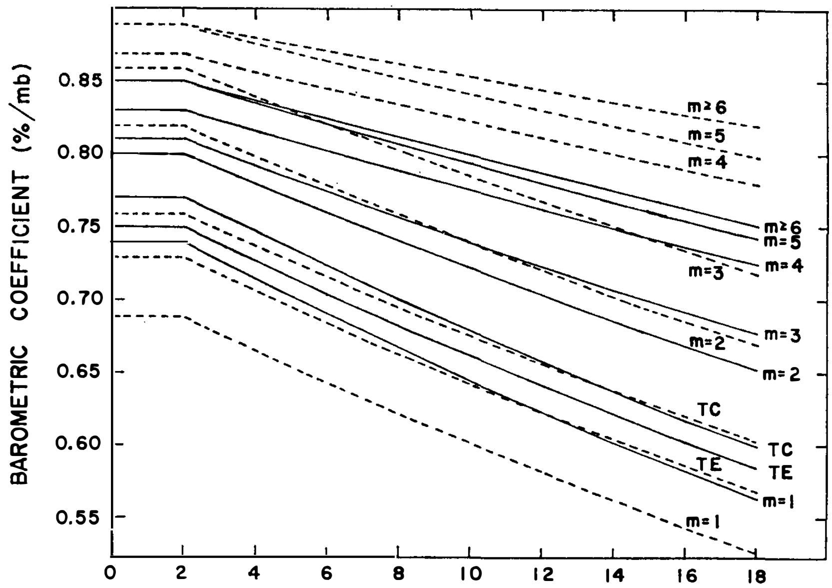

Fig. 6. The barometric coefficients of the six different multiplicities from $m=1$ to $m\geq 6$ as a function of threshold rigidity. Dashed and solid curves correspond to the values before and after correcting for the gate time and overlapping events, respectively. TE denotes total event and TC total count.

the latitude survey data, assuming an exponential law of rigidity P as denoted by $\beta_P=\beta_O \cdot \exp(-(P-2)/P_O)$, where β_O and P_O are independent variables but it seems to be $\beta_P=\beta_O$ at $P \leq 2$ GV. Determination of two parameters of β_O and P_O was tried by the least square calculations repeated for a number of pairs of β_O and P_O to minimize scattering of daily mean values from the assumed exponential curve. However, this method could not give a unique solution best fitted to experimental data, because some of the calculation results based on several pairs of β_O and P_O showed almost the same minimum variance.

Next, the following conventional method was applied. Assuming the barometric coefficients of Table 1 obtained at Syowa Station as β_O, one could reduce the number of parameters to one, P_O only, in the calculations to find out the intensity-rigidity curve with the minimum scattering. It was ascertained that a pair of β_O and P_O thus obtained did not contradict one of the best pairs presumed by the first method. The barometric coefficients finally determined as a function of threshold rigidity are represented by solid curves in Fig. 6, where broken curves are the coefficients uncorrected for the gate time and overlapping effects.

In both cases, the correction for the time variation of the primary cosmic

Table 2. The corrected barometric coefficients of various multiplicities at selected cosmic ray stations and interpolated one from the curves shown in Fig. 6.

Station		Coefficient (%/mb)	Interpolated	Difference
Leeds 2.2 GV	$m=1$	0.71±0.01	0.74	0.03
Oct. 1966–May 1967	$m\geq4$	0.85±0.01	—	—
	$m\geq6$	0.87±0.02	0.85	−0.02
Palo Alto 4.7 GV	$m=1$	0 67±0.01	0.71	0.04
	$m=2$	0.72±0.02	0.77*	0.05
	$m=3$	0.78±0.02	0.79	0.01
1965	$m=4$	0.78±0.03	0.81	0.03
	$m=5$	0.74±0.05	0.83	0.09
	$m=6$	0.83±0.07	(0.83)	(0.00)
Itabashi 11.5 GV	$m=1$	0.62±0.01	0.63	0.01
	$m=2$	0.64±0.02	0.71*	0.07
	$m=3$	0.66±0.02	0.73*	0.07
Oct.–Nov. 1966	$m=4$	0.66±0.05	0.77	0.11
	$m=5$	0.68±0.07	0.79	0.11
	$m\geq6$	0.75±0.06	0.79	0.04
Ahmedabad 15.9 GV	$m=1$	0.50±0.03	0.59*	0.09
	$m=2$	0.64±0.04	0.67	0.03
Jan.–Mar. 1969	$m=3$	0.67±0.04	0.69	0.02
	$m=4$	0.73±0.05	0.74	0.01
	$m=5, 6$	0.78±0.08	(0.76)	(−0.02)

ray intensity has been done before deducing the barometric coefficients, utilizing the intensity variation at Deep River, taking into account the latitude effect of the variation. This latitude effect was approximated by an exponential curve based on a ratio of the magnitude of the intensity variation at Deep River (1.0 GV) to that at Itabashi (11.5 GV). The ratio of 1.67 derived from the variations during December 1966 was applied. Assuming no latitude effect at rigidities less than 2 GV, the correction factor at a point of rigidity P and at the time of t is expressed by $\mathrm{DR}(t)\cdot 0.6^{(P-2)/9.5}$, where $\mathrm{DR}(t)$ is the magnitude of the intensity variation at Deep River.

To check a reliability of thus obtained rigidity dependence of the barometric coefficients, a comparison of it with the coefficient at the other cosmic ray stations was tried. Table 2 gives the barometric coefficients obtained at four stations of Leeds (Griffiths *et al.*, 1968), Palo Alto (Nobles *et al.*, 1966), Itabashi (Kodama and Ishida, 1967) and Ahmedabad (Rao, 1969), together with the interpolated one from the present curves at corresponding threshold rigidities. As seen in the column of 'difference' in Table 2, the present coefficients interpolated do not contradict the station values within an error of 0.1%/mb except a few examples, as indicated by asterisk marks, which seem to be significantly different from the station values even when the errors involved in the interpolated values are taken into account. The coefficients for lower multiplicities might be somewhat too large, if the station values are correct. However, since the actually observed range of the barometric pressure variation was less than about 15 mb throughout the whole voyage, the uncertainty as introduced to the differential response curve due to the above-mentioned ambiguity of the barometric coefficient was not so serious after all. Even if an error of 0.1%/mb was assumed in the coefficient, it was proved by calculations that the error as introduced in the response curve was not beyond 1% for any multiplicities.

4. Response Functions of Multiple Neutrons in Different Years

The intensity-rigidity curve for each of the six different multiplicities was deduced with the least square method applying a polynomial expression to the survey data. Before correcting daily mean values of bi-hourly counting rate for the gate time and overlapping effects, they were corrected for both the world-wide intensity variation and the barometric pressure according to the procedure described in the preceding section.

In Fig. 7 is shown the multiplicity dependence of the finally deduced intensity-rigidity curve for Survey-1A, where the integral counting rate at 15 GV was

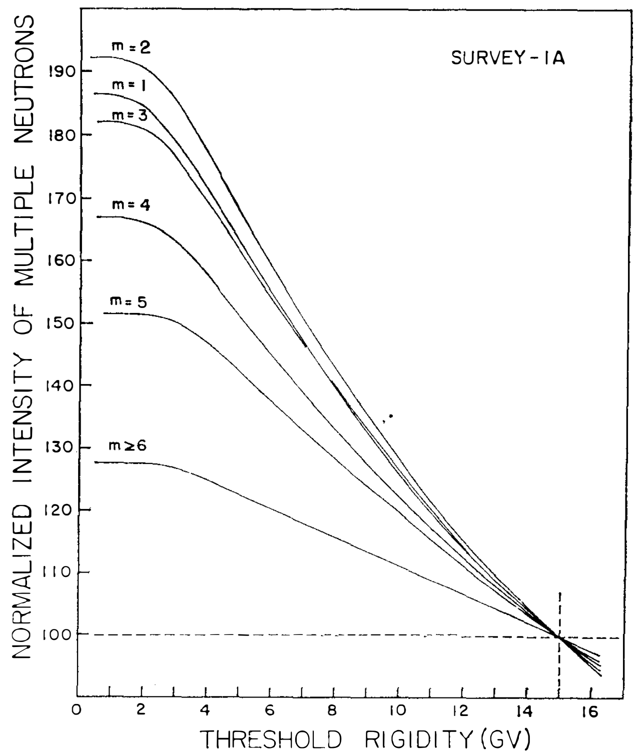

Fig. 7. Least square fitted intensity-rigidity curves of the six different multiplicity events. All intensity values are relative to 100 at 15 GV.

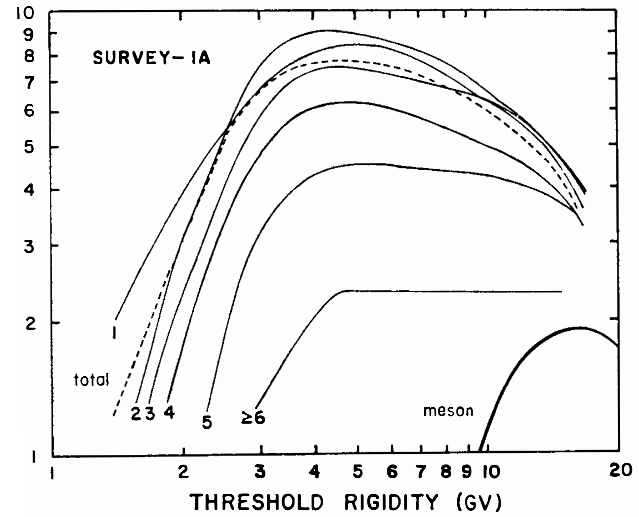

Fig. 8. Differential rigidity response curves of the six different multiplicity events, where a dashed curve is for total counting rate. The period of survey from which the response curves were deduced is from December 1 to December 26, 1966.

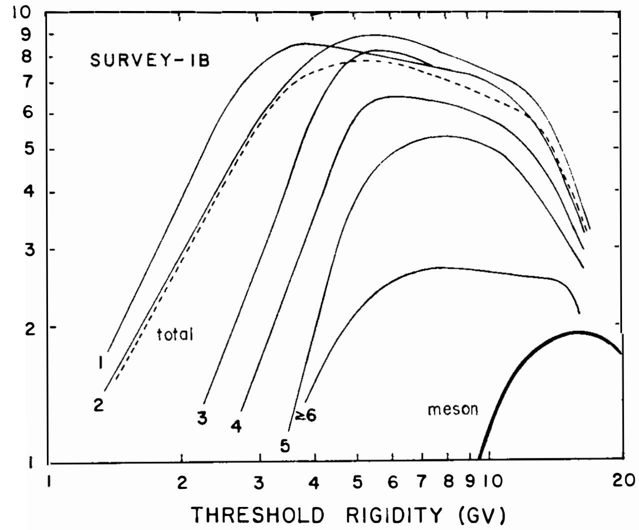

Fig. 9. Differential rigidity response curves of the six different multiplicity events, where a dashed curve is for total counting rate. The period of survey from which the response curves were deduced is from February 15 to April 6, 1967.

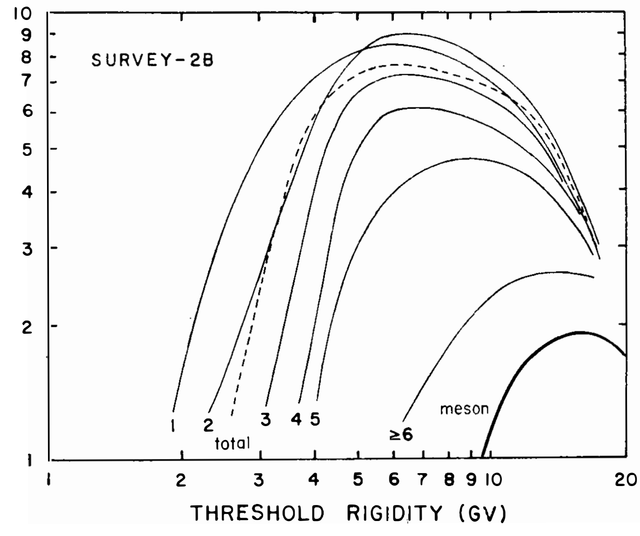

Fig. 10. Differential rigidity response curves of the six different multiplicity events, where a dashed curve is for total counting rate. The period of survey from which the response curves were deduced is from February 19 to March 29, 1968.

Table 3. The integral and differential response functions of multiple neutron components at sea level during 1966–1968.

A) Survey-1A (Dec. 1966)

GV	Multiplicity											
	1		2		3		4		5		≥6	
	int.	dif.	int.	dif.	int.	dif.	int.	dif.	int.	dif.	int.	dif.
1	186.81		192.39		182.18		167.24					
		2.30		1.60		1.16		0.67				
2	184.50		190.79		181.02		166.57		151.74		127.84	
		5.55		5.43		4.61		3.01		1.34		0.64
3	178.96		185.36		176.41		163.56		150.40		127.20	
		7.34		8.31		7.11		5.76		3.31		1.90
4	171.61		177.05		169.30		157.80		147.09		125.30	
		8.14		9.08		7.73		6.60		4.49		2.30
5	163.48		167.97		161.57		151.20		142.60		123.00	
		8.29		8.87		7.51		6.43		4.79		2.30
6	155.19		159.10		154.06		144.77		137.81		120.70	
		8.04		8.36		7.20		6.08		4.70		2.30
7	147.15		150.47		146.86		138.69		133.11		118.40	
		7.59		7.85		6.90		5.71		4.58		2.30
8	139.56		142.89		139.96		132.98		128.53		116.10	
		7.06		7.43		6.70		5.40		4.40		2.30
9	132.50		135.46		133.26		127.58		124.13		113.80	
		6.52		7.07		6.43		5.18		4.29		2.30
10	125.98		128.39		126.83		122.40		119.84		111.50	
		6.03		6.69		6.37		4.92		4.20		2.30
11	119.95		121.70		120.46		117.48		115.64		109.20	
		5.57		6.19		6.06		4.70		4.09		2.30
12	114.38		115.51		114.40		112.78		111.55		106.90	
		5.16		5.59		5.48		4.49		3.96		2.30
13	109.22		109.92		108.91		108.29		107.59		104.60	
		4.78		5.03		4.74		4.25		3.86		2.30
14	104.44		104.89		104.18		104.04		103.73		102.30	
		4.44		4.89		4.18		4.04		3.73		2.30
15	100.00		100.00		100.00		100.00		100.00		100.00	

>15 GV: $P\,(\mathrm{GV})^{-\beta}$

	1	2	3	4	5	≥6
β	1.64	1.69	1.59	1.60	1.56	1.31

A) Survey-1B (Feb.-Apr. 1967)

GV	Multiplicity											
	1		2		3		4		5		≥6	
	int.	dif.	int.	dif.	int.	dif.	int.	dif.	int.	dif.	int.	dif.
1	194.83		195.93		181.68							
		1.70		1.45		0 52						
2	193.13		194.49		181.15		164.07		150.17			
		6.42		4.93		2.70		1.51		0.10		
3	186.71		189.56		178.45		162.56		150.07			
		8.57		7.18		4.79		2.82		1.25		
4	178.14		182.38		173.66		159.74		148.82		127.98	
		9.14		8.47		6.48		4.24		2.60		1.23
5	169.00		173.90		167.18		155.50		146.22		126.75	
		8.89		9.05		7.63		5.40		4.12		2.00
6	160.11		164.85		159.55		150.10		142.10		124.75	
		8.40		9.12		8.19		6.10		5.11		2.59
7	151.71		155.73		151.37		144.00		136.99		122.16	
		7.98		8.85		8.23		6.32		5.40		2.90
8	143.73		146.88		143.14		137.68		131.59		119.26	
		7.58		8.38		7.86		6.28		5.41		2.96
9	136.15		138.50		135.28		131.40		126.18		116.30	
		7.17		7.80		7.25		6.10		5.24		2.95
10	128.98		130.70		128.03		125.30		120.94		113.35	
		6.75		7.21		6.57		5.83		4.96		2.91
11	122.23		123.49		121.46		119.47		115.98		110.44	
		6.28		6.64		5.94		5.54		4.63		2.86
12	115.95		116.85		115.52		113.93		111.35		107.58	
		5.78		6.11		5.47		5.11		4.22		2.70
13	110.17		110.74		110.05		108.82		107.13		104.88	
		5.42		5.62		5.15		4.62		3.77		2.55
14	104.75		105.12		104.90		104.20		103.36		102.33	
		4.75		5.12		4.90		4.20		3.36		2.33
15	100.00		100.00		100.00		100.00		100.00		100.00	

>15 GV: $P(GV)^{-\beta}$

β	1.68	1.71	1.69	1.59	1.49	1.32

C) Survey-2B (Feb.-Apr. 1968)

GV	Multiplicity											
	1		2		3		4		5		≥6	
	int.	dif.	int.	dif.	int.	dif.	int.	dif.	int.	dif.	int.	dif.
1	187.33											
		0.59										
2	186.74		186.40		173.47							
		4.46		1.21		0.40						
3	182.28		185.19		173.07		156.49					
		6.72		4.96		3.06		0.58				
4	175.56		180.23		170.01		155.91		143.70			
		7.88		7.25		5.50		3.24		1.31		
5	167.68		172.98		164.51		152.67		142.36		122.31	
		8.32		8.45		6.74		4.80		3.14		0.93
6	159.36		164.53		157.77		147.87		139.25		121.38	
		8.31		8.89		7.22		5.63		4.20		1.70
7	151.04		155.64		150.55		142.24		135.05		119.68	
		8.06		8.81		7.27		5.96		4.72		2.12
8	142.99		146.83		143.28		136.28		130.33		117.56	
		7.67		8.41		7.10		6.00		4.87		2.27
9	135.32		138.42		136.18		130.28		125.46		115.29	
		7.21		7.85		6.84		5.85		4.79		2.40
10	128.11		130.57		129.34		124.43		120.67		112.89	
		6.72		7.24		6.57		5.60		4.59		2.49
11	121.39		123.33		122.77		118.83		116.08		110.40	
		6.20		6.63		6.27		5.27		4.34		2.56
12	115.19		116.70		116.50		113.56		111.74		107.84	
		5.64		6.07		5.95		4.91		4.11		2.60
13	109.55		110.63		110.55		108.65		107.63		105.25	
		5.06		5.56		5.54		4.52		3.93		2.62
14	104.49		105.07		105.01		104.13		103.70		102.62	
		4.49		5.07		5.01		4.13		3.70		2.62
15	100.00		100.00		100.00		100.00		100.00		100.00	

>15 GV: $P(GV)^{-\beta}$

β	1	2	3	4	5	≥6
β	1.65	1.71	1.69	1.59	1.54	1.39

normalized to 100 for easy comparison with the results by other authors. The threshold rigidities corresponding to the position of the ship were interpolated from the table of the threshold rigidity given by KONDO and KODAMA (1965). The rigidity values thereby obtained are also listed in Appendix II, together with the geographical coordinates of the ship position. The numerical figures of the response functions, integral and differential, in the cases of Survey-1A, -1B and -2B are listed in Table 3, and their differential rigidity response is drawn in Figs. 8, 9 and 10, respectively.

As clearly seen from Figs. 8, 9 and 10, the differential response functions depend largely upon the multiplicity in the range from $m=1$ to $m\geq 6$. However, a significant difference between $m=1$ and $m=2$ curves seems to be contrary in sense to the physical interpretation that the present monitor may detect neutrons produced by the nucleonic component alone. It is reasonable that this discrepancy suggests the existence of the muon contribution at the $m=1$ event, because this contribution should reduce, to a certain degree, the latitude effect of the nucleonic component. A distinct separation from the 'total count' response curve (broken line) can be found in higher multiplicities greater than 4. One of them, probably $m=8$ or 9, would be superimposed on the response function of the muon component drawn in thick line (WEBBER, 1962). In other words, the multiplicity measurement gives a fine structure of the response function between the ordinary neutron and meson components.

Comparing three diagrams of Figs. 8, 9 and 10 with one another, the solar cycle dependence of the response function can be recognized. Namely, the positions of the lower cut-off and peak points of the curves are shifted little by little toward higher rigidity side with increasing solar activity. Whereas no significant dependence is found in the higher rigidity region greater than 15 GV, as seen from the values of the power exponent β listed in Table 3. However, the whole range of the latitude effect observed in both Survey-1B and -2B is somewhat greater than that of Survey-1A. This fact is the result inconsistent with the increase of solar activity and still remains a question.

5. Application of Observed Multiplicity Spectrum to the Study of Primary Time Variations

The counting rate of events of the multiplicity m in the neutron monitor at a time t, at sea level and a vertical threshold rigidity P_c, is denoted by

$$N_m\ (P_c,\ t)=\int_{P_c}^{\infty} S_m(P)\cdot dJ(P,\ t)/dP\cdot dP, \qquad (1)$$

where $dJ(P, t)/dP$ is the primary rigidity spectrum and $S_m(P)$ is the specific yield function. Then the differential response function is defined by

$$dN_m(P,\ t)/dP=S_m(P)\cdot dJ(P,\ t)/dP. \qquad (2)$$

Since the quantities of $dN_m(P, t)/dP$ are given by the actual latitude survey up to a specific threshold rigidity of P_1, eq. (1) is expressed by

$$N_m(P,\ t)=\int_{P_c}^{P_1} dN_m(P,\ t)/dP\cdot dP+K_m(P_1,\ t)\int_{P_1}^{\infty} P_m{}^{-\beta}(P,\ t)\cdot dP, \qquad (3)$$

where the second term on the right hand side gives the response spectrum assumed in the rigidity range greater than P_1 and $K_m(P_1, t)$ is a constant for normalization, being $(dN_m(P_1, t)/dP)\cdot P_1{}^{\beta_m}$. From eq. (3), β_m can be calculated using the observed values of $N_m(P, t)$ and is given in the lowest line of each of Table 3. Assuming a power law spectrum to an event of time variations, the fractional change of the counting rate is given by

$$dN_m(P,\ t)/N_m(P,\ t)=\int_{P_c}^{P_1} dN_m(P,\ t)/dP\cdot P^{-\gamma}\cdot dP+K_m(P,\ t)\int_{P_1}^{\infty} P_m{}^{-\beta-\gamma}\cdot dP. \qquad (4)$$

Normalizing to the total count, the ratio of the fractional change for any multiplicity to that for the total count (suffixed with T) is expressed by

$$R_m(P,\ t)=dN_m/N_m(P,\ t)/dN_T/N_T(P,\ t). \qquad (5)$$

The amounts of intensity change of the cosmic radiation can be calculated from eq. (4) as a function of time, using the differential response functions as listed in Table 3. The actual calculations would be tried for the time-dependent cosmic ray phenomena as described below.

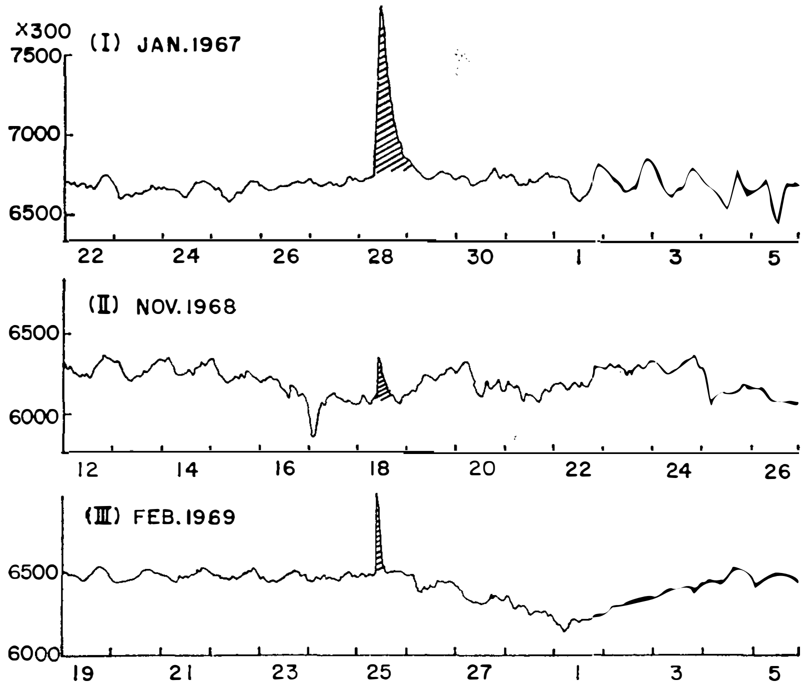

Fig. 11. Time variations on hourly counting rate of the Deep River neutron intensity before and after the solar proton event indicated by hatched area.

5.1. Solar proton event

In general, the energy spectrum of the energetic solar protons associated with the solar flare is softer than that of the galactic cosmic radiation. Therefore, the data obtained in such event should be effective to yield a more detailed information about the behavior of the multiplicity distribution.

There occurred three events of the cosmic ray small increases amounting to about 10% in size on the ground level during the current solar cycle. Fig. 11 shows hourly counting rates of the neutron intensities observed at Deep River during two weeks before and after the respective dates of January 28, 1967, November 18, 1968 and February 25, 1969 when a solar proton event occurred. All of them were accompanied by the solar flare of importance *less than 2*. This fact seems to be an interesting feature in comparison with a number of solar proton events accompanied by the flare importance *greater than 3* during the last solar cycle. Some studies on this point will be given elsewhere.

As regards the above three events, 10-min readings for six different multiplicities from $m=1$ to $m \geq 6$ obtained at Syowa Station are shown in Figs. 12, 13 and 14, respectively. The fact that the range of intensity fluctuations is different from event to event is ascribed mainly to the difference in the size of the neutron monitor operated during the respective periods. To demonstrate the difference in the multiplicity spectrum detected in these events, the maximum intensity en-

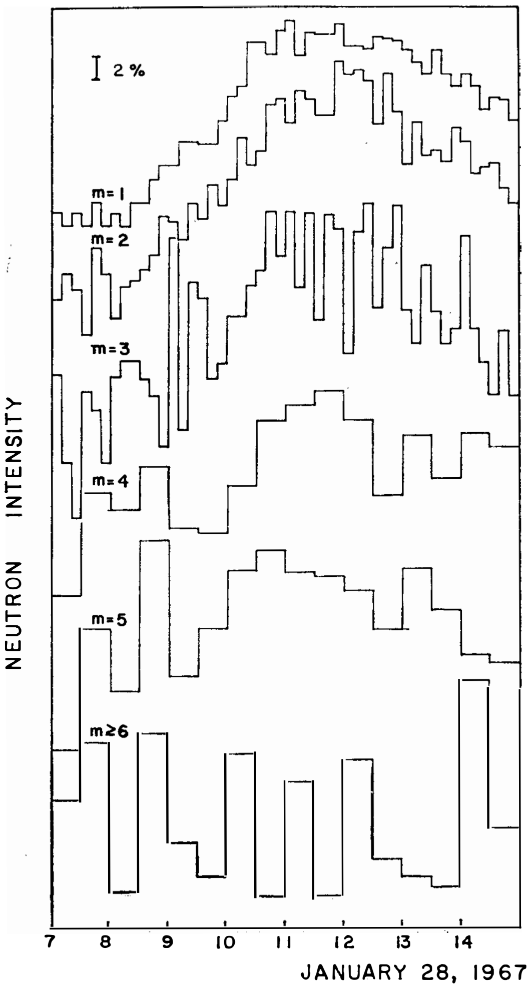

Fig. 12. Variations of 10-min counting rates for the various multiplicities at Syowa Station, where 30-min values are plotted for multiplicities greater than 4.

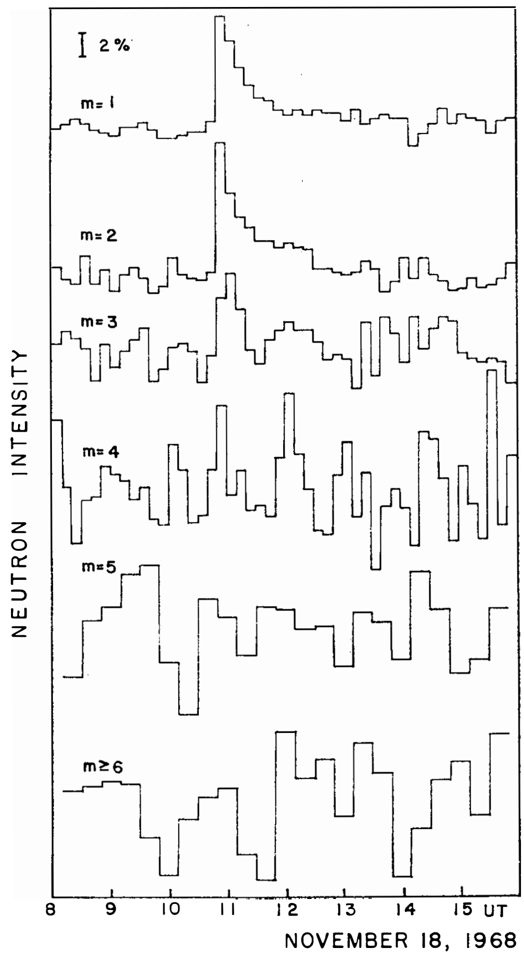

Fig. 13. Variations of 10-min counting rates for the various multiplicities at Syowa Station, where 20-min values are plotted for multiplicities greater than 5.

hancements are plotted as a function of multiplicity in Fig. 15.

One of the three events, the January event, was an increase event of diffusion type so that the multiplicity spectrum of the observed enhancements could be analyzed without taking into account the local time dependence of the incident particles on the earth (KODAMA, 1967; LOCKWOOD, 1968; BLOMSTER and TANSKANEN, 1969).

As seen in Fig. 16, the multiplicity dependence of the observed increase did not contradict that calculated from an assumption of the exponent $\gamma=5$ which was reported by LOCKWOOD (1968). However, it is rather hard to determine uniquely from the experimental data only which one of the various exponent values is best fitted to the data.

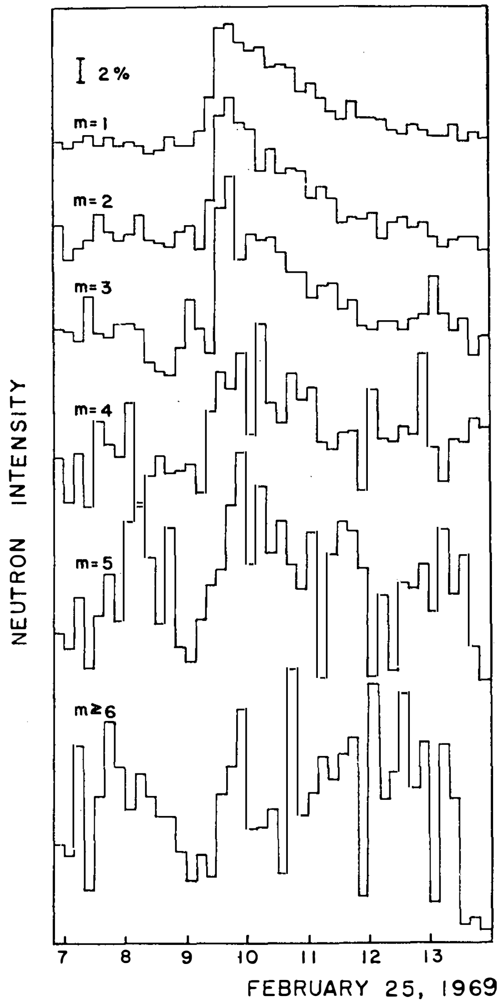

Fig. 14. Variations of 10-min counting rates for the various multiplicities at Syowa Station.

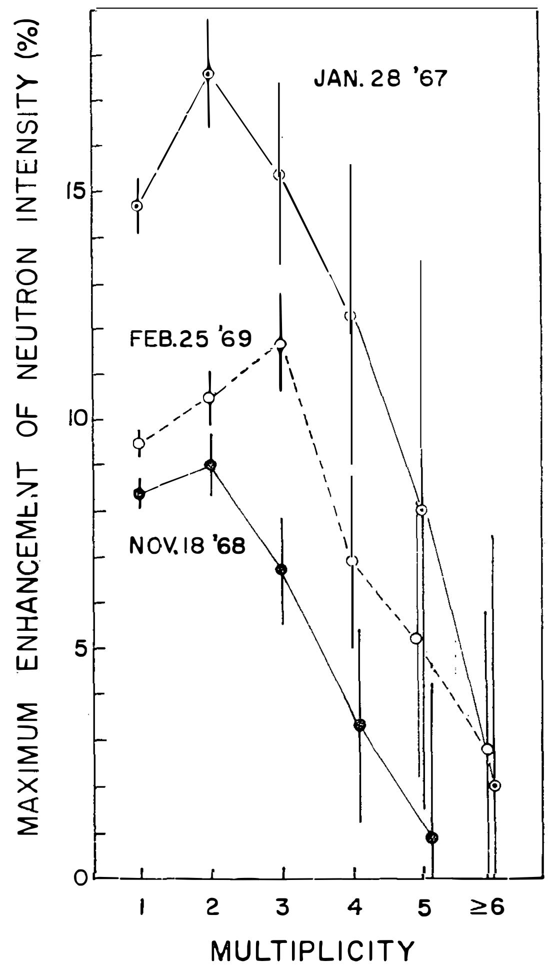

Fig. 15. Multiplicity spectra of the maximum amounts of the neutron enhancements in three solar proton events.

Table 4. The threshold rigidity corresponding to observed multiplicities in the solar proton event of January 28, 1967 and the calculated median nucleon energy of HUGHES *and* MARSDEN *(1966).*

Multiplicity	1	2	3	4	5	6
Rigidity (GV)	1.1±0.1	≥1.0	1.0±0.4	1.5±0.5	$1.9^{+1.9}_{-0.6}$	4.4±2.4
Median energy (GV)	0.11	0.24	0.52	1.0	1.7	<2.6

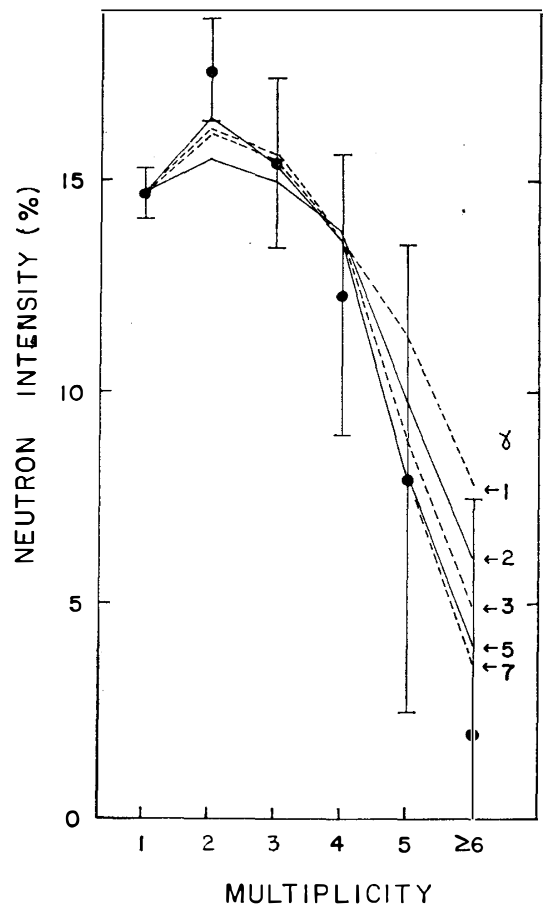

Fig. 16. The maximum enhancements of the multiple neutron intensities in the solar proton event of January 28, 1967. Observed (circles) and calculated (lines) values are plotted as a function of multiplicity, after normalization at m=1 event. The responsefunctionfrom Survey-1A are applied for the calculation. γ denotes the exponent of the assumed power spectrum.

Utilizing the amount of the increase observed at a number of cosmic ray stations distributed over the world, it is possible to estimate the threshold rigidity corresponding to each multiplicity from a comparison with the amount of the enhancement in the multiplicity measurement. These results are summarized in Table 4, together with the median nucleon energy calculated by HUGHES and MARSDEN (1966). The latter implies that the multiplicity spectrum as observed actually would not be distinguishable for lower multiplicities less than 3 due to the atmospheric cutoff at sea level. The former result is consistent with this expectation despite of the difference in the monitor geometry.

In the cases of the November and February events, the world-wide distribution of the neutron intensities checked from data of a number of cosmic ray stations showed an inherent character of anisotropic arrival of solar protons to the earth (MATHEWS and WILSON, 1969; TANSKANEN, 1969). Therefore, it is not so simple to determine the spectrum from these data alone, but the power law exponent estimated using the data observed in the three North American stations, Deep River, Durham, Dallas, located near the first impact zone is found to be 4.8±0.4 and 4.6±0.4 for the November and February events, respectively. Since

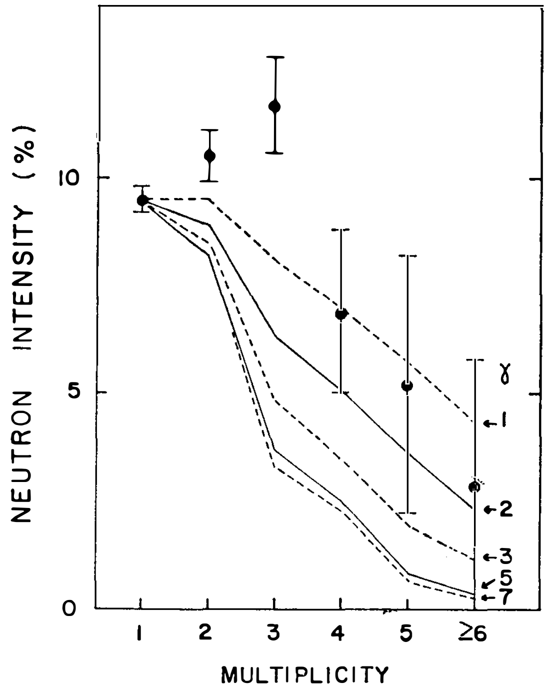

Fig. 17. The maximum enhancements of the multiple neutron intensities in the solar proton event of November 18, 1968. Observed (circles) and calculated (lines) values are plotted as a function of multiplicity, after normalization at m=1 event. The response functions from Survey-2B are applied for the calculation. γ denotes the exponent of the assumed power spectrum.

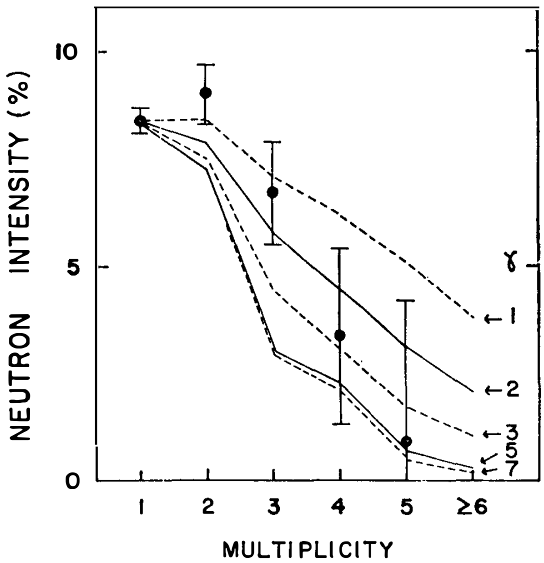

Fig. 18. The maximum enhancements of the multiple neutron intensities in the solar proton event of February 25, 1969. Observed (circles) and calculated (lines) values are plotted as a function of multiplicity, after normalization at m=1 event. The response functions from Survey-2B are applied for the calculation. γ denotes the exponent of the assumed power spectrum.

the width of the asymptotic longitude at Syowa Station is not beyond about 20° even for the entire rigidity interval from 1 GV to infinity (HATTON and CARSWELL, 1963), such anisotropy effect seems to be faint on deducing multiplicity dependence of the intensity enhancement. As seen in Fig. 17 and Fig. 18, no definite value of the exponent can be given by the comparison of the maximum increments observed by multiplicity meter with the calculated curves. This is due to a fairly large error included in the observed values and also probably attributed to a considerable uncertainty of the response function in the low rigidity portion where the function form becomes more serious with steeper variation spectrum. Hence, a much larger amount of intensity increment, at least ten-fold errors, seems to be necessary for higher multiplicities, for the purpose of deducing a more reliable energy spectrum of solar protons.

5.2. Forbush decrease

Seven Forbush decreases over 3% in size happened at Syowa Station in 1967 as listed in Table 5. To see clearly an overall multiplicity spectrum of the Forbush decrease, all of them were superposed by normalizing at the time of the corresponding sudden commencement in the geomagnetic horizontal component.

Fig. 19 illustrates thus obtained intensity variations for the different six multiplicities relative to the total counting rate during the decreasing phase of the Forbush event. It is seen from the figure that the amount of the decrease becomes smaller with increasing multiplicity, excepting $m=2$ event where the highest gradient may be attributed to less muon contribution than in $m=1$ event, as well as the cases of the latitude effect and the solar proton event. A value of the

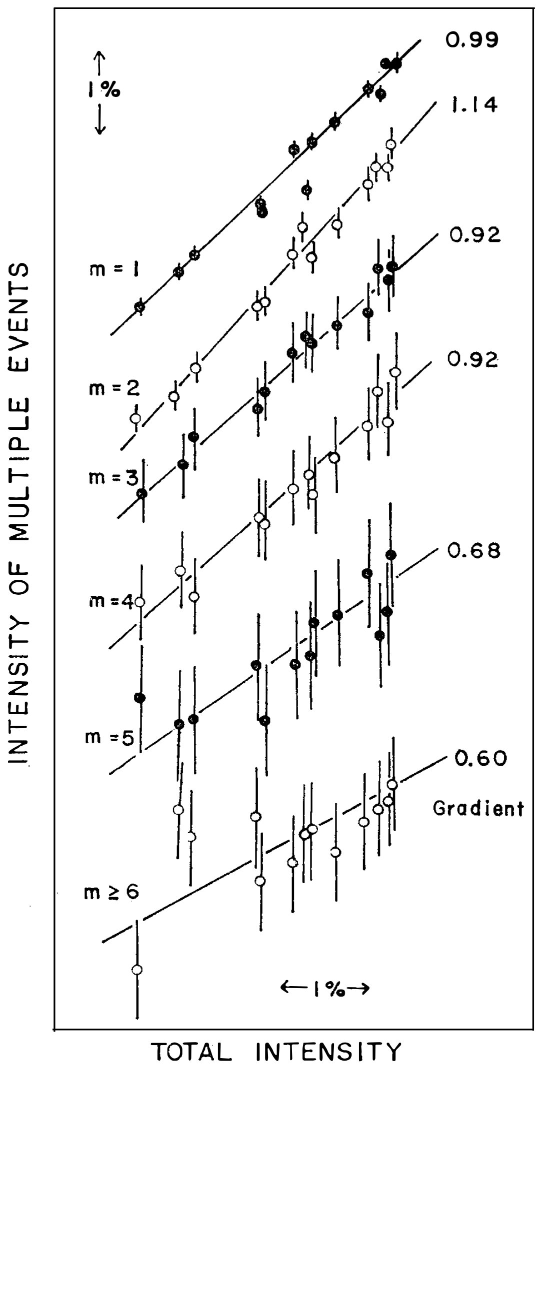

Fig. 19. Bi-hourly intensity variations of the various multiplicity events relative to that of the total counting rate during the decreasing phase of the Forbush decrease which was averaged over seven events in 1967.

Table 5. List of the Forbush decreases recorded at Syowa Station in 1967.

Starting time of F. D.	Sudden commencement	Amount of maximum decrement in %
April 4, 04h UT	April 4, 0304 UT	3. 6
May 1, 23h	May 1, 1906	5. 1
May 24, 23h	May 24, 1725	9. 3
June 6, 00h	June 5, 1914	4. 9
September 19, 21h	September 19, 1958	4. 5
October 28, 18h	October 28, 1638	4. 5
December 30, 15h	December 29, 2224	3. 7

gradient for $m \geq 6$ as indicated in Fig. 19 almost coincides with 0.549 ± 0.025 given by GRIFFITHS *et al.* (1968). WOLFSON *et al.* (1968) reported that the Forbush decrease was significantly detected up to around $m=50$ in the case of the Lockheed neutron monitor.

5.3. Diurnal variation

The first harmonics of the diurnal variation for the various multiplicities were

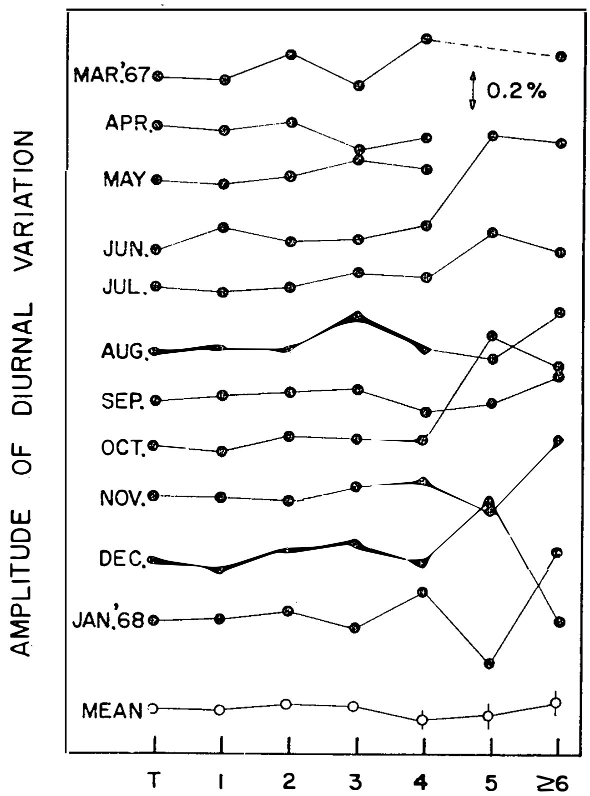

Fig. 20. The amplitudes of the first harmonics of the diurnal variations at Syowa Station. Monthly (solid) and yearly (open) mean values are plotted as a function of multiplicity.

calculated on the monthly basis. In Fig. 20, thereby obtained amplitudes are plotted as a function of multiplicity. Taking into account the standard deviations included in each of the monthly mean values, amounting to about 0.2% for $m=5$, or $m \geq 6$, it is concluded that there is no significant dependence of the amplitude upon the multiplicities less than six. The diurnal phase too was independent of the multiplicity within statistical accuracy. It is reasonable that the multiplicity spectrum is rather flat over the present rigidity range, since the variational spectrum exponent of the diurnal variation is given as almost zero (for example, McCRACKEN and RAO, 1965). In principle, however, the multiplicity spectrum extended to much higher multiplicity would give the upper limit of the rigidity above which the diurnal variation diminishes. The measurement using the Lockheed type of neutron monitor may have a possibility to do so (WOLFSON, 1969), but the NM-64 neutron monitor would not be suitable for such purpose.

6. Discussion

For discussions on the detected multiplicity spectrum, it is convenient to consider intensity variations of the multiple neutrons relative to the total counting rate, because most of the existing neutron monitors record only the total counting rate. Fig. 21 shows the ratios of intensity changes obtained from every different multiplicity. A power exponent common to all of the three phenomena can not be found but the different values of the exponents, 5.0, 0.6 and 0.0 are reasonably fitted to the solar proton events, Forbush decrease and diurnal variation, respectively. LOCKWOOD and SINGH (1969) gave the exponent of 0.7 for the Forbush

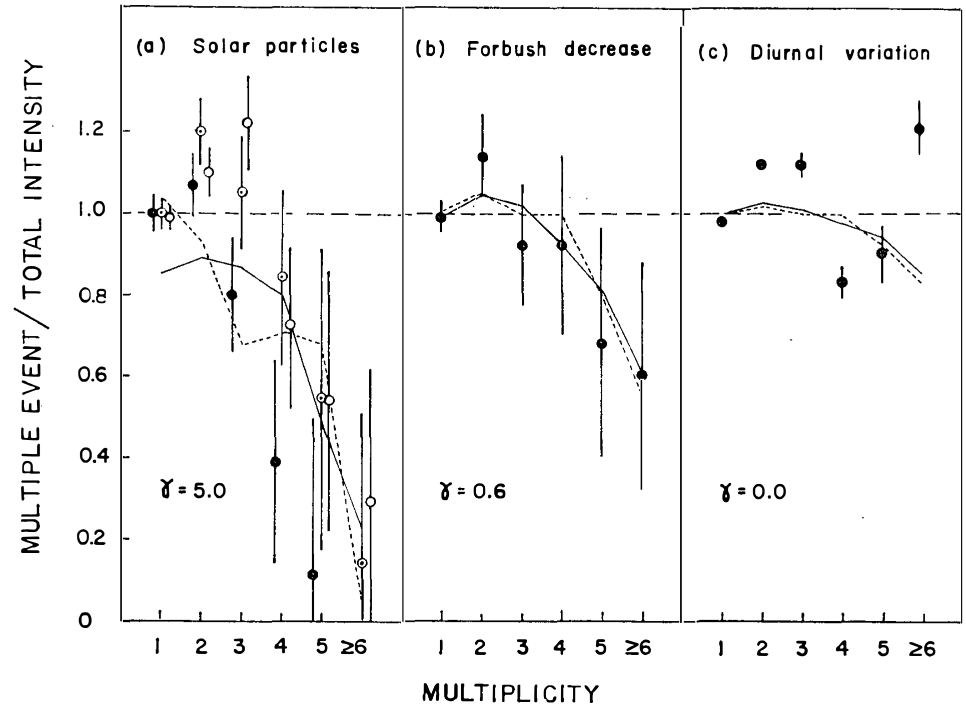

Fig. 21. Ratios of the intensity changes of the various multiplicity events to that the total counting rate in three different time-dependent phenomena. Observed (circles) and calculated (lines) values are plotted, where the latter was given by using the power exponent remarked and the related response functions.

decrease through a similar analysis to the present work. As it is known in the case of the solar proton event of January 28, 1967, when the cosmic ray neutron intensity increase was detected on the ground level where the threshold rigidity was less than 5 GV, the variational spectra seem to be weighted to the lower rigidity side. Therefore, the uncertainty of the calculated exponent of the variational spectrum γ is mainly attributed to the accuracy of the differential response function itself in the lower part of the rigidity, particularly around the latitude knee, where a little larger error is unavoidable due to disturbances in the barometric pressure. It is concluded from Fig. 21 that the low multiplicities of less than 3 would produce no significant intensity changes differing from that of the total counting rate unless the modulation is sharp rigidity dependent, while a larger change takes place in higher multiplicities where poorer statistics cannot be avoided for the NM-64 neutron monitor.

Strictly speaking, the detected multiplicity distribution depends upon the geometry of the neutron monitor. As seen in Fig. 2, the distribution obtained by the monitor having ten or twelve counters is found to enhance the proportion of high-multiplicity events rather than by the small sized neutron monitors. Accordingly, the above-mentioned application of the response functions deduced using the 3-NM-64 monitor to the study of time variations observed using the 10- or 12-NM-64 monitor does not always mean the complete procedure of analysis. However, it is rather meaningless to discuss quantitatively such a small discrepancy, because of the present poor statistics in high-multiplicity events. Also, a possible change of the lifetime of neutrons depending on the monitor geometry gives no serious influence to the detected multiplicity distribution (cf. Appendix I).

The fractional rate of events of higher multiplicities increases with increasing altitude (KODAMA and ISHIDA, 1967). Hence, the multiplicity measurement may be effective at mountain altitude rather than at sea level. However, the counting rate for multiplicities greater than 10 at 3800 meter elevation is approximated by a steep power law spectrum of $m^{-3.3}$ even in the case of the Lockheed monitor (NOBLES *et al.*, 1966). From these circumstances, probably a considerably huge size of the NM-64 neutron monitor will be necessary for the study with enough statistical accuracy of the Forbush decrease and the diurnal variation as represented by relatively hard spectrum. Of course, it would be better if the deadtime of the preamplifier could be reduced from 20 microseconds to 5 microseconds or less (STELJES, 1967).

One of the fundamental problems on multiplicity measurements is related to the parent particles by which the secondary neutrons detected in the neutron monitor are produced. Most of the detected neutrons surely arise from the lead blocks of the neutron monitor, but some of them seems to be coming from outside of the monitor, for example, as part of the extensive air shower. It is rather reasonable to interpret that the event of high multiplicities amounting to order of hundred may be accompanied by the air shower. A distinct separation of the neutrons by the inside multiple production from those by the outside is impossible in the conventional observation. However, it is of importance to determine, experimentally or theoretically, the fractional contribution of the both effects to the multiplicity distribution as detected by the NM–64 neutron monitor.

7. Conclusion

A possibility of discriminating the various variational rigidity spectra of the primary cosmic radiation by means of the multiplicity work was recognized and its effectiveness was represented by higher multiplicities greater than $m=4$. Accordingly, measurements of many more high mulitiplicities may be useful for determining a possible upper threshold rigidity of the cosmic ray modulation such as the Forbush decrease or the diurnal variation. However, it is likely that higher multiplicities show relatively smaller contribution to the counting rate response of the monitor. Consequently, both the statistics of higher multiplicities and the accuracy of the response function in low rigidity range would give an actual limitation of this kind of multiplicity work.

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References

AGRAWAL, S. P., S. K. RAY, and U. R. RAO (1969): Multiplicity measurements at Ahmedabad. Int. Conf. Cosmic Rays, Budapest.

BACHELET, F., P. BALATA, E. DYRING, and N. IUCCI (1964): On the multiplicity effect in a standard cosmic-ray neutron monitor. Nuovo Cim., **31**, 1126–1130.

BACHELET, F., P. BALATA, and N. IUCCI (1965): Some properties of the radiation recorded by the IGY cosmic-ray neutron monitors in the lower atmosphere. Nuovo Cim., **40**, 250–260.

BACHELET, F., E. DYRING, and N. IUCCI (1968): Multiplicity measurements on the IGY and NM-64 neutron monitors. Can. J. Phys., **46**, S1057–S1060.

BLOMSTER, K. A., and P. J. TANSKANEN (1969): The influence of snow and water on the different multiplicities as observed in a neutron monitor NM-64 in Oulu. Int. Conf. Cosmic Rays, Budapest.

CARMICHAEL, H. (1964): Cosmic Rays, IQSY Instruction Manual, No. 7, IQSY Secretariat, London.

CARMICHAEL, H., M. BERCOVITCH, J. F. STELJES, and M. MAGIDIN (1969): Comic-ray latitude surveys in North America in summer, 1965. Can. J. Phys., **47**, 2037–2050.

DEBRUNNER, H., and U. WALTHER (1968): Multiplicity measurements on the IGY neutron monitor at Jungfraujoch. Can. J. Phys., **46**, S1140–S1144.

DYRING, E., and B. SPORRE (1966a): The latitude effect of the neutron multiplicity as detected by a shipborne neutron monitor. Ark. Geofys., **5**, 67–77.

DYRING, E., and B. SPORRE (1966b): Multiplicity measurements on the Uppsala IGY-neutron monitor. Ark. Geofys., **5**, 79–85.

GRIFFITHS, W. K., C. V. HARMAN, C. J. HATTON, P. L. MARSDEN, and P. RYDER (1968): The intensity variations of selected multiplicities in the Leeds NM-64 neutron monitor. Can. J. Phys., **46**, S1044–S1047.

HATTON, C. J., and D. A. CARSWELL (1963): Asymptotic directions of approach of vertically incident cosmic rays for 85 neutron monitor stations. Atomic Energy of Canada Limited, AECL-1824.

HATTON, C. J., and H. CARMICHAEL (1964): Experimental investigation of the NM-64 neutron monitor. Can. J. Phys., **42**, 2443–2472.

HUGHES, E. B., and P. L. MARSDEN (1966): Response of a standard IGY neutron monitor. J. Geophys. Res., **71**, 1435–1444.

ISHIDA, Y., and M. KODAMA (1969): Report of cosmic-ray neutron observation in the 8th Japanese Antarctic Research Expedition 1967–1968. Antarctic Rec., **35**, 1–21.

KENT, D. B., H. COXELL, and M. A. POMERANTZ (1968): Latitude survey of the frequency of multiple events in an airborne neutron monitor. Can. J. Phys., **46**, S1082–S1086.

KODAMA, M. (1967): Multiple neutron production in the solar cosmic ray increase of January 28, 1967, in Syowa Base, Antarctic. Rep. Ionosph. Space Res. Japan, **21**, 59–62.

KODAMA, M. (1968): Geomagnetic and solar modulation effects of sea-level cosmic ray intensity — summary of cosmic ray latitude surveys aboard the expedition ship SOYA during 1956–1962 —. JARE Sci. Rep., Ser. A, No. 5.

KODAMA, M., and T. OHUCHI (1968): Latitude survey of neutron multiplicity using a shipborne NM-64 neutron monitor. Can. J. Phys., **46**, S1090–S1093.

KODAMA, M., and Y. ISHIDA (1967): Multiplicity measurements of cosmic ray neutron monitors in low latitude, Rep. Ionosph. Space Res. Japan, **21**, 55–58.

KODAMA, M. and A. INOUE (1970): to be published.

KONDO, I., and M. KODAMA (1965): Geographic distribution of vertical threshold rigidities. Proc. Int. Conf. Cosmic Rays, London, **1**, 558–563.

LOCKWOOD, J. A., and P. SINGH (1969): Cosmic-ray modulation during Forbush decrease in 1968–1969. Int. Conf. Cosmic Rays, Budapest.

LOCKWOOD, J. A. (1968): Cosmic-ray solar flare effect of January 28, 1967 as recorded by neutron monitors. J. Geophys. Res., **73**, 4247–4260.

MATHEWS, T., and B. G. WILSON (1969): Solar flare increases in cosmic ray observed at Sulphur Mountain and Calgary between November 1968 and 1969. Int. Conf. Cosmic Rays, Budapest.

MCCRACKEN, K. G., and U. R. RAO (1965): A survey of the diurnal anisotropy. Proc. Int. Conf. Cosmic Rays, London, **1**, 201–205.

NOBLES, R. A., R. A. ALBER, E. B. HUGHER, L. L. NEWKIRK, G. T. REYNOLDS, and M. WALT (1966): Neutron multiplicity monitor operations at sea level and 3800 meter elevation, Lockheed Palo Alto Res. Lab.

RAO, U. R. (1969): Private communication.

SMIRNOV, V. S., and V. T. USTINOVICH (1969): Threshold rigidities and coupling constants of a neutron supermonitor and a mulitiplicity meter. Int. Conf. Cosmic Rays, Budapest.

STELJES, J. F. (1967): The amplifier-discriminator designed for the NM-64 neturon monitor, Atomic Energy of Canada Limited, AECL–2680.

TANSKANEN, P. J. (1969): Cosmic-ray solar-flare increase of November 18, 1968. Int. Conf. Cosmic Rays, Budapest.

WOLFSON, C. J., L. L. NEWKIRK, R. A. NOBLES, G. T. REYNOLDS, and M. WALT (1968): Variations in cosmic-ray spectra during Forbush events in 1966. Can. J. Phys., **46**, S875–S878.

WOLFSON, C. J. (1969): Private communication.

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Appendix I

According to the theoretical calculation method of DEBRUNNER and WALTHER (1968), it was investigated how the corrections for the gate time of a multiplicity meter and overlapping events within a definite gate time depend upon both the lifetime of the thermalized neutrons and the width of the gate time. In Fig. 22, fractional changes of counting rates before and after the corrections, for each of the six different multiplicity events, are shown as functions of the lifetime and gate time. It can be seen from the figure that the amount of the corrections scarecely changes with the lifetime but is slightly subject to the gate time. The corrections were checked experimentally by altering in the gate time of 3–NM–64 neutron monitor at Mt. Norikura (KODAMA and INOUE, 1970).

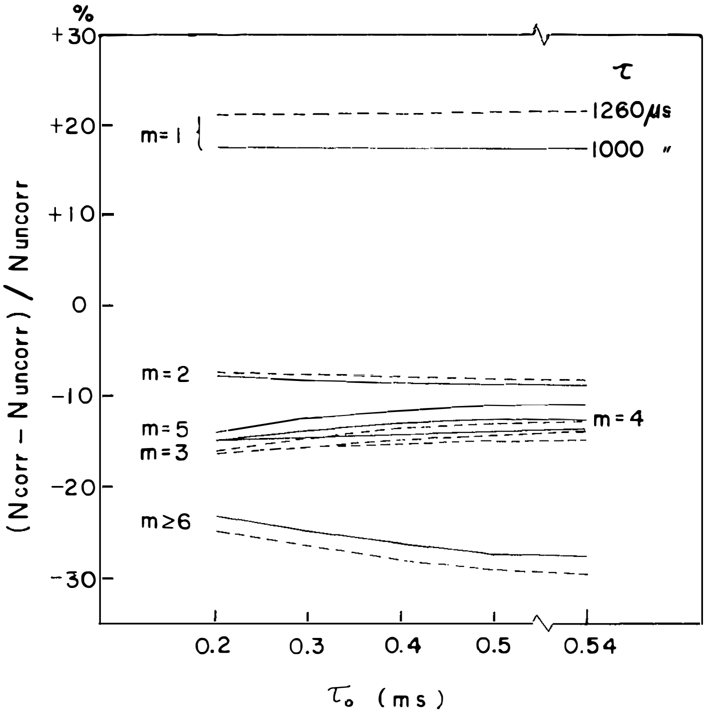

Fig. 22. Fractional changes of counting rates of the different multiplicity events before and after correcting for the gate time and overlapping events. τ_0 and τ are the mean lifetime of neutrons and the width of the gate time, respectively.

Appendix II

Daily mean values of bi-hourly counting rates of the six different multiplicity events from $m=1$ to $m\geq 6$ observed aboard the FUJI are compiled with the geographical factors. A column of TOTAL EVENT is given by a simple summation of all the events. Two groups of values, (A) uncorrected and (B) corrected for the barometric pressure, gate time and overlapping events, are listed in turn, where all values are uncorrected for a possible change, if any, in the absolute intensity level between the different surveys.

Table (A). 3–NM–64 neutron daily average of bi-hourly counting rate, aboard FUJI.

SURVEY-1A

YEAR	MON	DAY	N	MULTIPLICITY $m=1$	$m=2$	$m=3$	$m=4$	$m=5$	$m\geq 6$	TOTAL EVENT	PRESSURE mb	RIGIDITY	GEOG. LAT.	GEOG. LONG.
1966	12	1	12	55525	12087	4008	1608	728	878	74834	1018.2	12.16	34.39	138.52
66	12	3	12	46742	10230	3483	1379	642	804	63280	1022.7	15.00	25.37	134.40
66	12	4	12	47425	10169	3443	1372	648	800	63857	1017.0	15.86	21.06	132.22
66	12	5	12	47142	10188	3435	1377	650	799	63590	1012.2	16.43	16.37	130.20
66	12	6	12	47025	10215	3449	1400	665	807	63561	1010.1	16.83	11.51	128.33
66	12	7	12	47333	10200	3489	1409	656	812	63899	1008.5	17.00	6.47	126.23
66	12	8	12	47550	10471	3523	1426	664	847	64481	1006.9	16.99	2.43	122.13
66	12	9	12	48333	10605	3614	1449	672	848	65521	1006.1	16.72	− 0.55	119.06
66	12	10	12	50383	10888	3736	1494	682	881	68064	1005.8	16.03	− 5.34	117.47
66	12	11	12	52183	11445	3847	1531	719	883	70608	1006.6	15.02	−10.04	115.29
66	12	12	12	55567	12302	4147	1637	764	927	75342	1008.3	13.40	−15.02	114.29
66	12	13	12	61142	13643	4549	1800	817	983	82933	1011.0	10.82	−19.58	113.32
66	12	14	12	71075	16136	5333	1997	890	1015	96446	1013.0	7.29	−25.05	112.45
66	12	15	12	79150	18011	5873	2194	962	1045	107236	1014.6	4.88	−30.07	114.13
66	12	22	12	85242	19696	6367	2359	1029	1116	115808	1010.1	4.02	−32.35	114.29
66	12	23	12	87742	20389	6583	2456	1039	1132	119342	1012.9	3.12	−35.54	111.04
66	12	24	12	91033	21093	6779	2495	1063	1110	123573	1012.5	2.18	−39.49	108.14
66	12	25	7	97829	23017	7423	2735	1150	1275	133429	1001.8	1.64	−42.44	106.05
66	12	26	10	95900	22282	7091	2588	1102	1196	130159	1006.0	1.08	−46.34	103.04

SURVEY-1B

YEAR	MON	DAY	N	MULTIPLICITY $m=1$	$m=2$	$m=3$	$m=4$	$m=5$	$m\geq 6$	TOTAL EVENT	PRESSURE mb	RIGIDITY	GEOG. LAT.	GEOG. LONG.
1967	2	15	11	113018	25817	8120	2951	1262	1275	152443	990.9	0.62	−67.13	30.26
67	2	16	11	106264	24374	7707	2861	1192	1247	143644	995.3	0.70	−68.15	23.30
67	2	17	12	100817	23119	7303	2710	1135	1214	136298	1002.1	0.83	−68.54	12.28
67	2	18	12	104075	23911	7580	2755	1195	1248	140763	998.8	0.99	−69.08	2.52
67	2	19	12	124217	29363	9367	3420	1448	1499	169313	972.5	1.08	−69.00	358.59
67	2	20	12	125217	29596	9508	3487	1483	1560	170850	971.5	1.10	−69.21	357.14
67	2	21	12	116358	27016	8631	3158	1351	1389	157903	984.7	1.10	−69.29	357.03
67	2	22	12	117275	27211	8566	3121	1324	1380	158876	985.1	1.11	−69.29	356.43
67	2	23	12	116533	27053	8581	3116	1316	1371	157970	985.6	1.42	−66.50	356.47
67	2	24	12	118875	27841	8883	3224	1365	1408	161596	981.5	1.88	−62.47	357.03
67	2	25	11	117864	27504	8820	3247	1409	1411	160254	981.5	2.27	−58.48	358.32
67	2	26	12	112442	25813	8294	3011	1286	1325	152171	988.7	2.44	−56.17	1.15
67	2	27	12	104133	23844	7547	2753	1156	1208	140641	1000.1	2.60	−55.24	359.09

Table (A). Continued.

SURVEY-1B (Continued)

YEAR	MON	DAY	N	MULTIPLICITY $m=1$	$m=2$	$m=3$	$m=4$	$m=5$	$m \geqq 6$	TOTAL EVENT	PRESSURE mb	RIGIDITY	GEOG. LAT.	LONG.
1967	2	28	12	104575	23926	7558	2712	1149	1194	141114	1000.7	2.65	−55.09	358.51
67	3	1	12	104308	23694	7517	2702	1143	1166	140530	1000.7	2.63	−54.45	0.13
67	3	2	12	101100	23090	7304	2645	1136	1169	136443	1002.5	3.03	−51.10	0.49
67	3	3	12	99167	22869	7311	2691	1150	1216	134403	1000.6	3.34	−47.39	3.42
67	3	4	12	94758	21918	7133	2609	1126	1204	128747	1002.6	3.62	−44.13	6.51
67	3	5	12	86467	19898	6468	2355	1039	1135	117362	1013.6	3.89	−40.53	10.38
67	3	6	12	83642	19268	6298	2321	1012	1104	113644	1014.8	4.41	−37.25	14.08
67	3	7	12	85017	19403	6310	2307	1013	1090	115140	1010.6	4.95	−28.27	17.35
67	3	14	12	80683	18331	5972	2243	978	1062	109269	1018.8	4.92	−34.13	18.35
67	3	15	12	80383	18329	5987	2216	961	1067	108943	1019.9	4.73	−34.46	22.59
67	3	16	9	81456	18530	6036	2256	958	1021	110256	1017.0	4.99	−33.40	27.36
67	3	17	12	82850	18847	6137	2290	1019	1067	112209	1011.0	5.62	−31.29	32.42
67	3	18	12	81100	18411	5963	2255	978	1065	109771	1008.8	6.29	−29.20	37.54
67	3	19	12	76575	17398	5702	2159	962	1057	103853	1009.2	7.27	−27.04	43.01
67	3	20	12	71533	16074	5292	2030	902	1040	96871	1010.7	8.42	−24.49	47.58
67	3	21	12	68150	15116	5013	1913	869	984	92046	1010.6	9.44	−22.35	53.03
67	3	22	12	64700	14318	4756	1852	815	939	87379	1011.6	10.56	−20.21	57.54
67	3	23	12	60617	13318	4419	1730	784	912	81780	1010.8	11.77	−17.05	61.55
67	3	24	12	57000	12447	4142	1614	749	881	76832	1009.7	12.98	−13.42	65.54
67	3	25	12	54525	11813	3941	1550	728	870	73427	1008.5	14.15	−10.26	69.34
67	3	26	12	51775	11155	3729	1492	702	857	69709	1009.7	15.18	− 6.49	73.07
67	3	27	12	49717	10705	3638	1439	670	820	66989	1009.2	16.19	− 2.13	75.30
67	3	28	12	48358	10361	3499	1412	668	816	65114	1008.2	16.95	2.26	77.27
67	3	29	6	47600	10250	3497	1400	656	813	64215	1008.8	17.37	5.54	79.21
67	4	3	8	47188	10098	3455	1387	653	818	63597	1009.2	17.40	6.04	80.44
67	4	4	12	46900	9989	3415	1370	649	811	63133	1009.2	17.52	6.00	84.45
67	4	5	12	46917	10105	3438	1369	654	832	63313	1007.8	17.60	6.13	89.47
67	4	6	12	46917	10031	3415	1381	654	799	63197	1007.4	17.60	6.06	94.47
67	4	7	12	46825	10035	3410	1372	649	801	63092	1008.8	17.49	4.11	99.15
67	4	8	12	47575	10150	3418	1362	635	802	63942	1009.5	17.29	1.42	103.29
67	4	9	12	47650	10197	3452	1375	649	820	64142	1008.4	17.30	2.52	108.11
67	4	10	12	47675	10221	3435	1387	661	816	64195	1008.2	17.32	4.37	112.52
67	4	11	12	47167	10083	3456	1355	634	809	63505	1009.5	17.36	8.10	116.19
67	4	12	12	46875	10122	3407	1361	649	815	63228	1011.5	17.17	12.48	118.48
67	4	13	12	47900	10261	3460	1366	653	805	64445	1011.8	16.71	17.54	120.21
67	4	14	12	48817	10418	3496	1386	655	810	65581	1014.4	15.99	22.06	123.57
67	4	15	12	50242	10744	3631	1430	664	815	67525	1016.7	15.05	26.25	128.21
67	4	16	12	51375	11133	3739	1487	683	845	69262	1018.6	14.02	30.19	132.25
67	4	17	12	53008	11392	3807	1488	681	831	71206	1023.9	12.82	33.21	136.10
67	4	18	12	54792	11763	3900	1538	715	837	73546	1027.7	11.79	35.31	139.38

Table (A). Continued

SURVEY-2B

YEAR	MON	DAY	N	MULTIPLICITY $m=1$	$m=2$	$m=3$	$m=4$	$m=5$	$m\geq6$	TOTAL EVENT	PRESSURE mb	RIGIDITY	GEOG. LAT.	LONG.
1968	2	19	12	102883	23425	7318	2647	1114	1075	138463	995.1	1.66	−64.41	357.29
68	2	20	12	97467	22036	6903	2524	1046	1041	131015	1003.1	2.05	−61.00	357.57
68	2	21	9	99500	22662	7067	2569	1091	1067	133956	999.6	2.38	−57.10	0.06
68	2	22	12	108642	25053	7902	2886	1210	1202	146895	986.1	2.62	−53.54	2.39
68	2	23	12	104392	23970	7632	2817	1209	1170	141189	991.5	2.98	−50.10	4.32
68	2	24	12	92542	21261	6801	2487	1074	1074	125238	1006.5	3.31	−46.20	7.40
68	2	25	12	87650	20269	6478	2435	1050	1089	118971	1010.2	3.67	−42.15	11.07
68	2	26	12	81775	18813	5962	2251	981	1047	110828	1018.1	4.04	−38.42	15.42
68	2	27	12	78592	18043	5821	2169	942	1012	106577	1021.6	4.55	−36.09	15.50
68	2	28	12	80033	18555	5906	2278	1003	1093	108868	1016.0	5.13	−33.35	17.12
68	2	29	12	80783	18759	6063	2329	1012	1110	110056	1013.0	5.08	−33.36	17.59
68	3	7	12	83608	18910	6048	2253	985	1009	112814	1013.4	4.91	−34.12	18.34
68	3	8	12	80892	18381	5913	2197	946	982	109310	1018.3	4.72	−34.48	22.59
68	3	9	12	78850	17856	5670	2128	925	955	106384	1020.7	5.04	−33.19	28.28
68	3	10	12	80650	18299	5888	2221	973	1009	109041	1013.7	5.72	−31.05	32.41
68	3	11	12	78075	17749	5786	2186	975	1015	105786	1010.7	6.44	−28.56	38.45
68	3	12	12	73342	16628	5428	2091	939	1019	99445	1010.6	7.46	−26.43	43.59
68	3	13	12	70500	16007	5318	2053	929	1024	95830	1007.3	8.57	−24.32	49.01
68	3	14	12	67467	15307	5102	2005	901	1023	91804	1006.1	9.62	−22.23	53.55
68	3	15	12	64383	14498	4809	1910	875	981	87457	1007.0	10.70	−20.09	58.21
68	3	16	12	60308	13554	4534	1773	822	975	81967	1006.4	11.86	−16.59	62.15
68	3	17	12	56450	12543	4221	1682	781	913	76589	1006.4	12.89	−13.59	66.13
68	3	18	12	53167	11683	3922	1587	733	877	71969	1007.4	14.15	−10.23	69.55
68	3	19	12	51433	11323	3799	1531	729	873	69688	1005.4	15.27	− 6.27	73.22
68	3	20	12	49208	10723	3621	1493	698	846	66588	1005.5	16.30	− 1.39	75.50
68	3	21	12	47833	10433	3514	1447	686	845	64759	1006.4	17.00	2.31	78.23
68	3	22	12	47442	10301	3505	1417	665	844	64174	1005.8	17.37	6.21	79.45
68	3	28	12	46967	10201	3440	1399	660	802	63469	1007.4	17.52	5.59	85.15
68	3	29	12	46933	10148	3429	1409	664	807	63390	1007.7	17.60	6.08	90.41
68	3	30	12	46750	10115	3461	1399	655	816	63196	1007.9	17.59	5.56	95.44
68	3	31	12	47092	10301	3448	1429	651	822	63743	1008.3	17.42	3.12	100.34
68	4	1	12	47008	10140	3462	1395	663	805	63473	1009.2	17.32	2.21	104.45
68	4	2	12	46375	9986	3390	1387	652	787	62577	1010.4	17.48	6.22	107.52
68	4	3	12	46308	9949	3355	1343	645	803	62403	1011.4	17.47	10.20	111.12
68	4	4	12	46450	10028	3382	1377	645	781	62663	1011.9	17.22	13.54	114.53
68	4	5	12	47208	10208	3433	1405	657	806	63717	1012.6	16.82	17.18	118.47
68	4	6	12	47092	10142	3408	1392	658	782	63473	1016.8	16.23	20.49	122.37
68	4	7	12	47450	10227	3425	1394	643	784	63923	1019.4	15.50	24.26	126.23
68	4	8	12	48867	10477	3483	1392	658	760	65637	1021.7	14.69	27.59	130.08
68	4	9	12	51875	11249	3769	1507	704	847	69951	1019.9	13.51	31.45	133.53
68	4	10	11	56182	12437	4175	1672	776	924	76166	1013.7	12.40	34.08	138.68

Table (B). 3–NM-64 neutron daily average of bi-hourly counting rate, aboard FUJI *corrected for pressure, gate time and overlapping events.*

SURVEY-1A

YEAR	MON	DAY	N	MULTIPLICITY $m=1$	$m=2$	$m=3$	$m=4$	$m=5$	$m\geq6$	TOTAL EVENT	PRESSURE mb	RIGIDITY	GEOG. LAT.	LONG.
1966	12	1	12	58521	12301	4061	1632	741	875	78105	1018.2	12.16	34.39	138.52
66	12	3	12	50403	10767	3659	1452	679	833	67747	1022.7	15.00	25.37	134.40
66	12	4	12	49432	10285	3472	1384	657	796	66009	1017.0	15.86	21.06	132.22
66	12	5	12	47752	9977	3350	1341	635	769	63828	1012.2	16.43	16.37	130.20
66	12	6	12	47071	9870	3317	1344	640	766	63019	1010.1	16.83	11.51	128.33
66	12	7	12	46960	9750	3321	1337	623	762	62771	1008.5	17.00	6.47	126.23
66	12	8	12	46751	9910	3314	1337	623	787	62749	1006.9	16.99	2.43	122.13
66	12	9	12	47292	9975	3380	1349	626	782	63434	1006.1	16.72	− 0.55	119.06
66	12	10	12	49214	10201	3483	1386	633	811	65757	1005.8	16.03	− 5.34	117.47
66	12	11	12	51240	10780	3601	1427	671	815	68563	1006.6	15.02	−10.04	115.29
66	12	12	12	55136	11702	3919	1542	721	862	73904	1008.3	13.40	−15.02	114.29
66	12	13	12	61805	13203	4371	1726	785	927	82826	1011.0	10.82	−19.58	113.32
66	12	14	12	73022	15793	5173	1928	863	961	97739	1013.0	7.29	−25.05	112.45
66	12	15	12	82476	17798	5742	2137	941	991	110075	1014.6	4.88	−30.07	114.13
66	12	22	12	86212	18770	5986	2205	966	1017	115178	1010.1	4.02	−32.35	114.29
66	12	23	12	90626	19850	6321	2348	995	1051	121192	1012.9	3.12	−35.54	111.04
66	12	24	12	93816	20430	6471	2369	1013	1021	125124	1012.5	2.18	−39.49	108.14
66	12	25	7	93471	20459	6485	2370	996	1080	124949	1001.8	1.64	−42.44	106.05
66	12	26	10	94441	20479	6410	2324	992	1047	125746	1006.0	1.08	−46.34	103.04

SURVEY-1B

YEAR	MON	DAY	N	MULTIPLICITY $m=1$	$m=2$	$m=3$	$m=4$	$m=5$	$m\geq6$	TOTAL EVENT	PRESSURE mb	RIGIDITY	GEOG. LAT.	LONG.
1967	2	15	11	100113	20859	6428	2315	992	976	131844	990.9	0.62	−67.13	30.26
67	2	16	11	97055	20468	6352	2341	975	995	128316	995.3	0.70	−68.15	23.30
67	2	17	12	96637	20544	6378	2353	986	1027	128005	1002.1	0.83	−68.54	12.28
67	2	18	12	97444	20660	6432	2318	1009	1025	128994	998.8	0.99	−69.08	2.52
67	2	19	12	96326	20423	6347	2383	965	987	127633	972.5	1.08	−69.00	358.59
67	2	20	12	96522	20440	6407	2314	981	1022	127999	971.5	1.10	−69.21	357.14
67	2	21	12	98604	20778	6499	2351	1005	1012	130463	984.7	1.10	−69.29	357.03
67	2	22	12	99690	20983	6457	2327	988	1009	131664	985.1	1.11	−69.29	356.43
67	2	23	12	99413	20956	6503	2334	985	1007	131404	985.6	1.42	−66.50	356.47
67	2	24	12	98500	20870	6509	2331	986	999	130433	981.5	1.88	−62.47	357.03
67	2	25	11	97665	20626	6471	2353	1021	1001	129376	981.5	2.27	−58.48	358.32
67	2	26	12	98159	20537	6476	2323	993	1000	129667	988.7	2.44	−56.17	1.15
67	2	27	12	98529	20836	6475	2343	985	1001	130265	1000.1	2.60	−55.24	359.03

Table (B). Continued.

SURVEY-1B (Continued)

YEAR	MON	DAY	N	MULTIPLICITY $m=1$	$m=2$	$m=3$	$m=4$	$m=5$	$m\geqq 6$	TOTAL EVENT	PRESSURE mb	RIGIDITY	GEOG. LAT.	LONG.
1967	2	28	12	99382	20993	6514	2316	984	993	131274	1000.7	2.65	−55.09	358.51
67	3	1	12	99082	20770	6478	2307	979	968	130673	1000.7	2.63	−54.45	0.13
67	3	2	12	97271	20570	6394	2298	991	987	128587	1002.5	3.03	−51.10	0.49
67	3	3	12	94126	20127	6326	2310	989	1018	124986	1000.6	3.34	−47.39	3.42
67	3	4	12	91149	19637	6295	2282	987	1028	121456	1002.6	3.62	−44.13	6.51
67	3	5	12	89715	19473	6252	2262	1004	1062	119764	1013.6	3.89	−40.53	10.38
67	3	6	12	87436	19055	6156	2256	988	1044	116923	1014.8	4.41	−37.25	14.08
67	3	7	12	86318	18559	5963	2166	956	999	114977	1010.6	4.95	−28.27	17.35
67	3	14	12	86633	18698	6029	2259	989	1038	115604	1018.8	4.92	−34.13	18.35
67	3	15	12	87004	18866	6100	2251	980	1052	116203	1019.9	4.73	−34.46	22.59
67	3	16	9	86415	18643	6009	2238	953	982	115212	1017.0	4.99	−33.40	27.36
67	3	17	12	84285	18090	5822	2162	966	981	112321	1011.0	5.62	−31.29	32.42
67	3	18	12	81242	17396	5567	2096	911	966	108205	1008.8	6.29	−29.20	37.54
67	3	19	12	76823	16521	5357	2019	903	966	102612	1009.2	7.27	−27.04	43.01
67	3	20	12	72361	15453	5041	1927	858	968	96622	1010.7	8.42	−24.49	47.58
67	3	21	12	68838	14536	4784	1819	829	918	91737	1010.6	9.44	−22.35	53.03
67	3	22	12	65687	13882	4578	1779	783	885	87601	1011.6	10.56	−20.21	57.54
67	3	23	12	61171	12862	4239	1656	752	858	81548	1010.8	11.77	−17.05	61.55
67	3	24	12	57085	11946	3950	1534	714	827	76071	1009.7	12.98	−13.42	65.54
67	3	25	12	54167	11252	3732	1463	689	811	72133	1008.5	14.15	−10.26	69.34
67	3	26	12	51776	10725	3567	1424	671	808	68984	1009.7	15.18	− 6.49	73.07
67	3	27	12	49533	10264	3472	1369	639	771	66064	1009.2	16.19	− 2.13	75.30
67	3	28	12	47899	9876	3319	1335	633	764	63845	1008.2	16.95	2.26	77.27
67	3	29	6	47296	9812	3333	1330	624	764	63177	1008.8	17.37	5.54	79.21
67	4	3	8	47009	9696	3305	1322	624	772	62744	1009.2	17.40	6.04	80.44
67	4	4	12	46697	9588	3265	1305	620	766	62255	1009.2	17.52	6.00	84.45
67	4	5	12	46353	9615	3256	1291	618	778	61931	1007.8	17.60	6.13	89.47
67	4	6	12	46238	9516	3225	1300	617	745	61663	1007.4	17.60	6.06	94.47
67	4	7	12	46519	9609	3251	1305	618	754	62073	1008.8	17.49	4.11	99.15
67	4	8	12	47475	9762	3273	1301	607	759	63190	1009.5	17.29	1.42	103.29
67	4	9	12	47236	9733	3280	1302	616	769	62954	1008.4	17.30	2.52	108.11
67	4	10	12	47214	9745	3259	1313	627	764	62941	1008.2	17.32	4.37	112.52
67	4	11	12	47052	9698	3311	1294	607	766	62741	1009.5	17.36	8.10	116.19
67	4	12	12	47293	9868	3307	1320	631	781	63206	1011.5	17.17	12.48	118.48
67	4	13	12	48430	10018	3365	1326	636	773	64552	1011.8	16.71	17.54	120.21
67	4	14	12	50138	10348	3460	1371	650	791	66752	1014.4	15.99	22.06	123.57
67	4	15	12	52349	10836	3651	1438	670	808	69737	1016.7	15.05	26.25	128.21
67	4	16	12	54187	11378	3809	1517	699	848	72412	1018.6	14.02	30.19	132.25
67	4	17	12	57839	12078	4026	1578	725	864	77059	1023.9	12.82	33.21	136.10
67	4	18	12	61329	12813	4239	1680	786	893	81667	1027.7	11.79	35.31	139.38

Table (B). Continued.

SURVEY-2B

YEAR	MON	DAY	N	MULTIPLICITY $m=1$	$m=2$	$m=3$	$m=4$	$m=5$	$m\geqq 6$	TOTAL EVENT	PRESSURE mb	RIGIDITY	GEOG. LAT.	GEOG. LONG.
1968	2	19	12	93628	19636	6020	2159	910	852	123327	995.1	1.66	—64.41	357.29
68	2	20	12	93969	19735	6080	2210	916	883	123863	1003.1	2.05	—61.00	357.57
68	2	21	9	93609	19741	6044	2182	929	880	123477	999.6	2.38	—57.10	0.06
68	2	22	12	92878	19545	6036	2180	913	887	122625	986.1	2.62	—53.54	2.39
68	2	23	12	92811	19570	6116	2237	961	904	122751	991.5	2.98	—50.10	4.32
68	2	24	12	91385	19628	6184	2246	974	941	121405	1006.5	3.31	—46.20	7.40
68	2	25	12	88801	19319	6086	2278	985	989	118478	1010.2	3.67	—42.15	11.07
68	2	26	12	87434	19094	5973	2253	987	1016	116719	1018.1	4.04	—38.42	15.42
68	2	27	12	86080	18844	6014	2237	976	1011	115100	1021.6	4.55	—36.09	15.50
68	2	28	12	84245	18546	5825	2247	992	1046	112879	1016.0	5.13	—33.35	17.12
68	2	29	12	83320	18329	5848	2242	976	1040	111753	1013.0	5.08	—33.36	17.59
68	3	7	12	86548	18485	5840	2169	953	942	114933	1013.4	4.91	—34.12	18.34
68	3	8	12	86591	18681	5941	2202	952	953	115284	1018.3	4.72	—34.48	22.59
68	3	9	12	85744	18490	5805	2178	951	945	114061	1020.7	5.04	—33.19	28.28
68	3	10	12	83556	17947	5707	2147	944	947	111244	1013.7	5.72	—31.05	32.41
68	3	11	12	79152	17033	5491	2066	925	935	105616	1010.7	6.44	—28.56	38.45
68	3	12	12	74218	15978	5162	1983	893	944	99192	1010.6	7.46	—26.43	43.59
68	3	13	12	69714	15023	4943	1899	862	929	93404	1007.3	8.57	—24.32	49.01
68	3	14	12	66175	14267	4711	1843	829	924	88788	1006.1	9.62	—22.23	53.55
68	3	15	12	63490	13619	4478	1773	813	895	85101	1007.0	10.70	—20.09	58.21
68	3	16	12	59198	12701	4215	1641	763	891	79442	1006.4	11.86	—16.59	62.15
68	3	17	12	55354	11767	3932	1561	726	836	74206	1006.4	12.89	—13.59	66.13
68	3	18	12	52449	11057	3688	1488	688	812	70208	1007.4	14.15	—10.23	69.55
68	3	19	12	50123	10581	3526	1415	675	798	67153	1005.4	15.27	— 6.27	73.22
68	3	20	12	47989	10040	3370	1385	647	776	64239	1005.5	16.30	— 1.39	75.50
68	3	21	12	46896	9838	3294	1352	642	782	62831	1006.4	17.00	2.31	78.23
68	3	22	12	46334	9671	3273	1318	619	778	62022	1005.8	17.37	6.21	79.45
68	3	28	12	46288	9681	3247	1317	622	747	61925	1007.4	17.52	5.59	85.15
68	3	29	12	46351	9653	3246	1330	627	754	61982	1007.7	17.60	6.08	90.41
68	3	30	12	46214	9634	3281	1322	619	764	61854	1007.9	17.59	5.56	95.44
68	3	31	12	46666	9839	3274	1355	617	771	62543	1008.3	17.42	3.12	100.34
68	4	1	12	46806	9735	3309	1330	633	759	62589	1009.2	17.32	2.21	104.45
68	4	2	12	46502	9670	3269	1335	629	749	62164	1010.4	17.48	6.22	107.52
68	4	3	12	46679	9693	3255	1301	627	769	62330	1011.4	17.47	10.20	111.12
68	4	4	12	46957	9802	3292	1339	629	751	62774	1011.9	17.22	13.54	114.53
68	4	5	12	47946	10026	3358	1374	644	778	64127	1012.6	16.82	17.18	118.47
68	4	6	12	49010	10244	3431	1404	666	777	65515	1016.8	16.23	20.49	122.37
68	4	7	12	50166	10515	3512	1433	663	793	67054	1019.4	15.50	24.26	126.23
68	4	8	12	52415	10934	3626	1454	691	779	69861	1021.7	14.69	27.59	130.08
68	4	9	12	55157	11597	3873	1552	727	856	73730	1019.9	13.51	31.45	133.53
68	4	10	11	57631	12278	4099	1640	763	891	77299	1013.7	12.40	34.08	138.08