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Time Variations of the Barometric Coefficient of Cosmic Ray Neutron Component at Morioka, Tokyo and Mt. Norikura during the Period 1970-1973

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Abstract

In this paper, trial calculations of the barometric coefficient by various methods are given using the neutron component observed at Morioka, Tokyo, Mt. Norikura, and Deep River during the period, January 1970 - December 1973. The results of the calculations obtained are discussed in comparison with each other. It was found that the method by multiple correlation is the best one among three methods used here, that is, method by deviation, method by single correlation, and the above one. The variable tendency of the barometric coefficients with solar activity as pointed out by Bachelet et al. and others was not found clearly because of the short period of analysis. It will be possible to derive a significant conclusion about the long-term variation of the barometric coefficients by developing this study over a longer period.

1. Introduction

Many authors [1-6] have pointed out that the barometric coefficients, β, of cosmic ray neutron component are dependent on altitude and latitude of the observing station, and, besides, the values of the coefficients vary significantly during a long period of time. Griffiths et al.[3] and Bachelet et al.[4),6] showed that the time behavior of the yearly mean of β was dependent on solar activity during the last solar cycle. Furthermore, Bachelet et al.[6] showed that such time changes of β are closely related to the modulation of the neutron intensity.

In this paper, to get a clue to search for the time changes of β, trial calculations of β by different methods are given using the neutron component observed at Morioka, Tokyo, Mt. Norikura, and Deep River during the period, January 1970 -

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December 1973. The results of the calculations obtained are discussed in comparison with each other.

Continuous observations of the cosmic ray neutron intensity are being carried out in Morioka (Iwate University) since August 1970. Preliminary results concerning the counting rates, the values of β, and the time variations of the observed intensity were given previously [7-13]. However, the values of β given in the paper[8] were tentatively calculated from the data obtained during early period of observation, that is, first five months, and, moreover, the calculation was made only by the method of deviation which is a simple and less reliable method as will be illustrated in the next section. Therefore, re-calculation of β using the data of longer period by means of more reliable method is needed.

2. Calculation of the barometric coefficient, β

(1) Method by deviation

This is one method to obtain a regression coefficient between daily means of the atmospheric pressure, P, in mb and the cosmic ray neutron intensity, N, in a count by a least square method. In this calculation, P and N are replaced by ΔP and $\Delta N/\overline{N}$, as shown in Fig. 1, in order to remove a systematic error which may occur over a comparatively long period. In Fig. 1, ΔP is the day to day deviation of the barometric pressure in unit of mb, ΔN the day to day deviation of cosmic ray neutron counts, and $\overline{\mathrm{N}}$ the averaged value of the succesive two daily neutron counts. The values of β obtained by this method are indicated by the open triangles in Fig. 2. In case of involving comparatively large intensity variation such as Forbush decreases (for example, such as 1972 August event) in the period considered, the correlation between the corresponding two quantities (ΔP and $\Delta\overline{N}/N$) becomes poor, as shown in Fig. 1. Accordingly, the value of β obtained may be considerably deviated from the reasonable value. In such a case, it will be necessary to remove the effect of such time variations (Forbush decreases). The dotted triangles in Fig. 2 indicate the values of β obtained after removing such an effect by excluding the data of the periods of Forbush decreases.

(2) Method by single correlation

This is a simple method to obtain straightforwardly the value of β using the daily mean values of P and N mentioned above. This method is also a similar to the deviation method mentioned above in the point that the regression coefficient to be obtained may be affected by the effect of Forbush decreases, as mentioned in the above method (1). However, this method is useful in the point that we can simply know beforehand a pattern of variations of the value of β because of easiness of obtaining the β-values. The open circles in Fig. 2 denote the values of β obtained by this method.

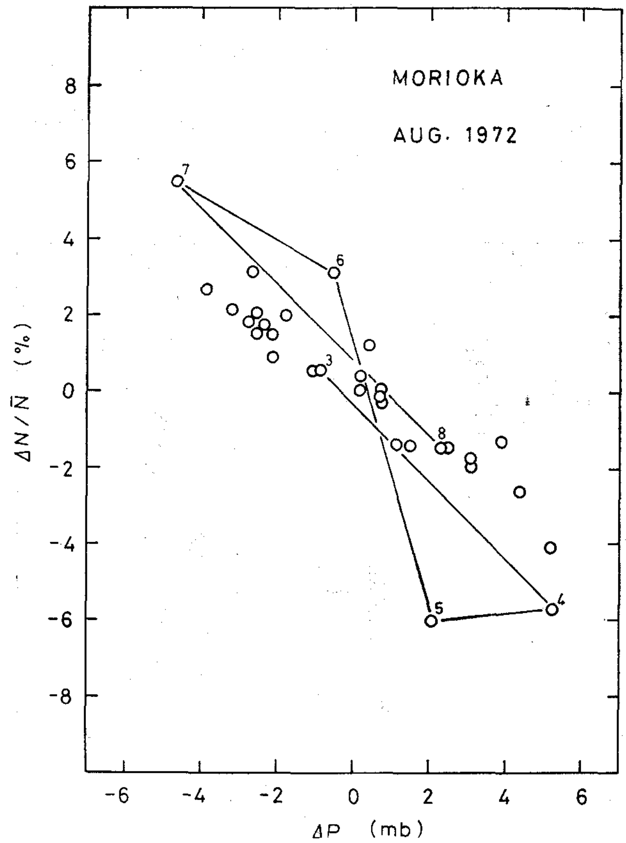

Fig. 1. Diagram for obtaining β.
ΔP; day-to-day deviation of barometric pressure in unit of mb.
ΔN; day-to-day deviation of cosmic ray neutron counts.
$\bar{N}$; averaged value of the successive two daily neutron counts.
The figures (3, 4, 5, …) attached to the open circles in the diagram indicate the dates which correspond to those during the August event.
The regression coefficient, which is calculated by the method of least squares, gives the value of β.

(3) Method by multiple correlation

As mentioned before, the above two methods are likely to lead to the low precession of β because of the effect of the intensity variations of cosmic rays. In this method, to exclude such an effect, the cosmic ray data from a representative cosmic ray station (here Deep River is selected as the station) are used in addition to the values of P and N mentioned before. The values of β obtained from this method are indicated by the double open circles in Fig. 2.

3. Results obtained

Figs. 2-(a), -(b), -(c), and -(d) show the time variations of the monthly values of β at Morioka, Tokyo, and Mt. Norikura for the years, 1970, 1971, 1972,

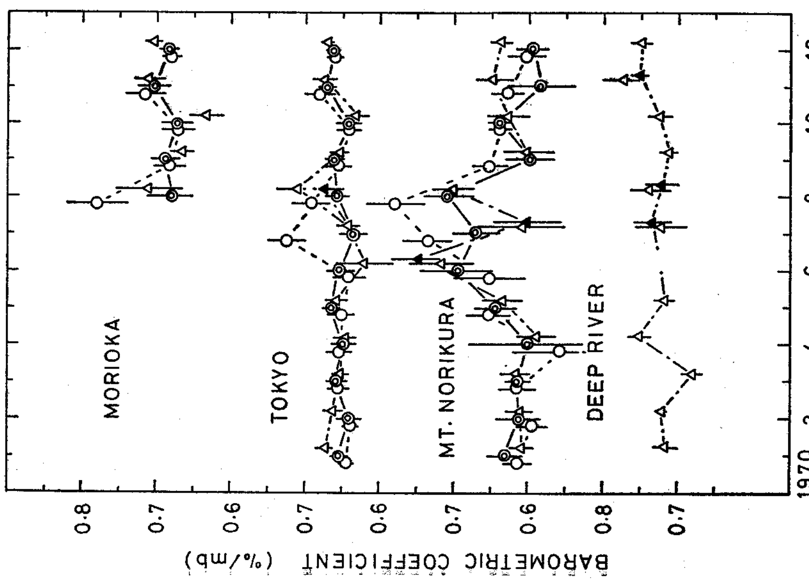

Fig. 2-(a). Monthly values of the barometric coefficient of the Morioka, Tokyo, Mt. Norikura and Deep River neutron monitors in 1970 (for notation see Section 2).

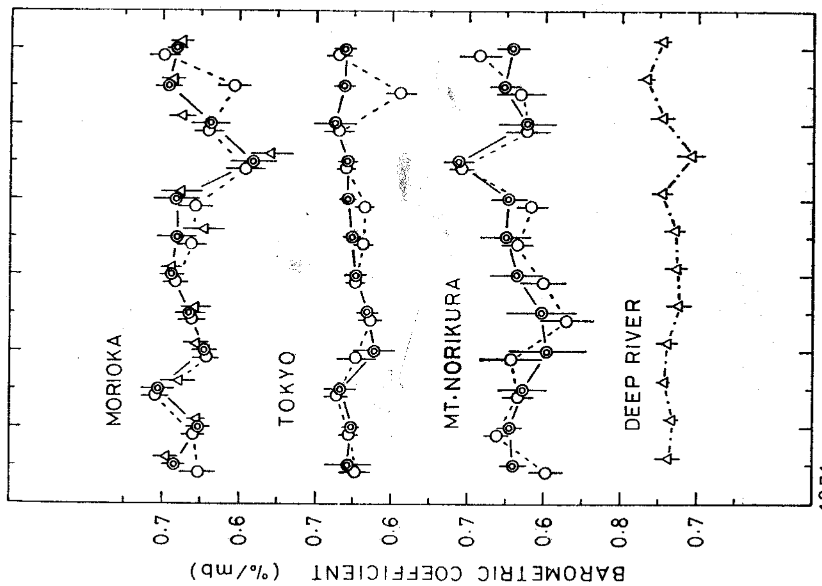

Fig. 2-(b). Monthly values of the barometric coefficient of the Morioka, Tokyo, Mt. Norikura and Deep River neutron monitors in 1971 (for notation see Section 2).

and 1973, respectively, which correspond to the period of continuous observation in Morioka. In each figure, the three methods given in Section 2 are not always used for all stations, because of convenient reason in the calculation. Especially, for Deep River, only the values of β calculated by the deviation method are given for the period January 1970 - August 1973 for comparison with the values of β at

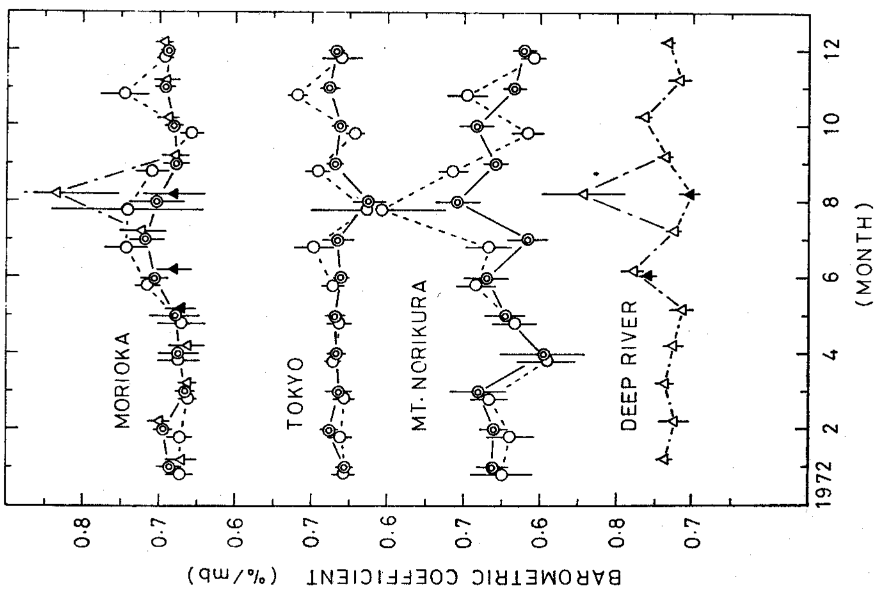

Fig. 2-(c). Monthly values of the barometric coefficient of the Morioka, Tokyo, Mt. Norikura and Deep River neutron monitors in 1972 (for notation see Section 2).

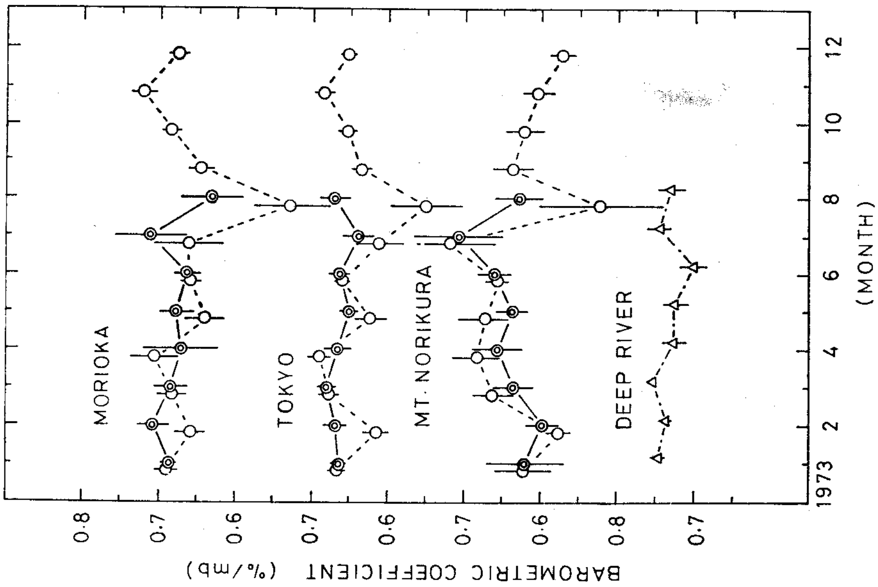

Fig. 2-(d). Monthly values of the barometric coefficient of the Morioka, Tokyo, Mt. Norikura and Deep River neutron monitors in 1973 (for notation see Section 2).

the other stations. In Table 1 are given the yearly means of β-value for 1970, 1971, 1972 and 1973 at each station. For information, in the table, the correlation coefficients are given in the parenthesis below each row of the β-values by the methods of single correlation and multiple correlation.

Table 1. Yearly values of barometric coefficient, β, of the Morioka, Tokyo, Mt. Norikura and Deep River neutron monitors.

Station	Nota-tion*	$-\beta$ (%/mb)			
		1970	1971	1972	1973
Morioka	△▲	0.689±0.022	0.671±0.011	0.685±0.005	—
	○	0.695±0.009 (0.988)	0.657±0.006 (0.985)	0.690±0.007 (0.982)	0.674±0.006 (0.986)
	◎	0.690±0.009 (0.994)	0.664±0.008 (0.988)	0.689±0.005 (0.995)	0.673±0.011 (0.984)
Tokyo	△▲	0.662±0.004	—	—	—
	○	0.660±0.005 (0.990)	0.650±0.005 (0.990)	0.669±0.006 (0.987)	0.652±0.005 (0.992)
	◎	0.660±0.004 (0.996)	0.657±0.006 (0.993)	0.667±0.004 (0.998)	0.655±0.008 (0.991)
Mt. Norikura	△▲	0.625±0.006	—	—	—
	○	0.629±0.009 (0.964)	0.620±0.008 (0.971)	0.661±0.009 (0.965)	0.615±0.008 (0.970)
	◎	0.623±0.010 (0.980)	0.633±0.009 (0.982)	0.652±0.008 (0.987)	0.628±0.015 (0.969)
Deep River	△▲	0.729±0.005	0.739±0.004	0.735±0.004	0.734±0.005

*: for notation see Section 2.
( ): the value of correlation coefficient.

4. Discussion and conclusions

On the whole, each value of β corresponding to each station is near to reasonable one, as is recognized from Fig. 2 and Table 1. The variances of β in Tokyo and Deep River are small as presumed, whereas those at Morioka and Mt. Norikura seem to be somewhat larger than those in the former even in the case of using the method of multiple correlation. The latter may be due to the difference of the counting rates of monitor and the condition of location at each station. Re-examination of the observed cosmic ray data at each station may be necessary.

The mean value of β in Morioka for the period 1970 - 1973, -0.682 ± 0.007 %/mb, which was obtained by the method of multiple correlation, is nearly consistent with the value for 1970, -0.689 ± 0.022 %/mb[8], which was obtained previously by the method of deviation. The mean value of β in Tokyo for the period 1970 - 1973 is -0.662 ± 0.003 %/mb, showing good precession. This will be expected also from the yearly means shown in Table 1.

As for the method of calculation of the β-value, in the case such as 1972 August event which was accompanied by a series of Forbush decreases, it is expected that the β-value is different by the different methods of calculation. For example, as is seen in Fig. 1, the value of β in Morioka for August 1972 obtained from the method of deviation is considerably deviated from the yearly mean and also its correlation coefficient indicates low value. Also in case of using the method of single correlation, the β-value is similar to this. However, as is clear in Fig. 2, such a deviation of β-value due to the effect of the August event is almost completely excluded by using the method of multiple correlation. Furthermore, even by the method of deviation, such a deviation can be excluded to a considerable extent, provided that cosmic ray data corresponding to the periods of Forbush decreases during the event are properly excluded. However, in this case, considerable ambiguity will be accompanied from the procedure of excluding the cosmic ray data.

On the other hand, the mean value of β, -0.637 ± 0.008 %/mb, at Mt. Norikura throughout the period 1970 - 1973 is unexpectedly small. This may be due to the effect of wind velocity on the mountain, as pointed out by Lockwood and Calawa[14], Chiba and Kodama[15], and Kawasaki[16]. It will be necessary to reexamine this later. The errors of β-value are also bigger than those at the other stations due to the big variances throughout this period. The variances of the values of β at Deep River are considerably small in comparison with those at the other stations. As mentioned before, these values are obtained only by the deviation method. If the method of multiple correlation is applied, better correlation and smaller variance will be expected. The mean value of β obtained here for the period 1970 - 1973, -0.735 ± 0.002 %/mb, is consistent with the value, -0.740 %/mb (-0.987 %/mm), which was shown in the reference[17] within limit of error.

In this study, the variable tendency of the β-value as shown by Bachelet et al. and others is not seen perhaps because of short period of analysis. By calculating the monthly values of β at the three stations selected tentatively, a measure of variance of the β-values during the period 1970 - 1973 was estimated. The degree of deviation of the β-values due to the effect of Forbush decreases was also found and, in addition, it was found that such a deviation is almost completely excluded by applying the method of multiple correlation. These will be the fruitful results in this study. It will be possible to derive a significant conclusion about the long-term variation of β by developing this study over a longer period.

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