

# DIURNAL VARIATION OF COSMIC RAY NEUTRON INTENSITY

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## ABSTRACT

A neutron monitor is in operation at Gulmarg Research Observatory since July, 1958. The details of the apparatus are given. The dependence of the diurnal amplitude of neutron intensity on geomagnetic planetary index  $K_p$  is studied. It is shown that there is no apparent relation between the two. It is also shown that the diurnal amplitude tends to be higher on days of low mean intensity and tends to be lower on days of high mean intensity.

## INTRODUCTION

The study of diurnal variation of cosmic ray intensity is important as it is believed to be caused by the anisotropy of primary cosmic radiation. Firor *et al.* (1954) have shown that the diurnal amplitude is largely energy dependent, being larger when measured with a low energy detector, i.e. a neutron monitor, than when measured with a high energy detector such as a meson telescope. It is now accepted that the amplitude of diurnal variation varies with time and such amplitude variations are world-wide. The dependence of the amplitude and phase on the magnetic disturbances have also been studied extensively with charged particle detectors and also with neutron monitors. Firor *et al.* (1954) find that the diurnal amplitude measured with the neutron detector increases on days of high geomagnetic planetary index  $K_p$ . Sittkus (1955) on the other hand shows that days of large diurnal amplitude are not always associated with magnetically disturbed days. Hogg as quoted by Sekido *et al.* (1950) has found that the phase of the maximum diurnal amplitude on international disturbed days is earlier than that of international quiet days while the amplitude remains constant. Wada (1950) also obtained a similar result with a large aperture counter telescope.

A preliminary report on the relation between the daily amplitude and geomagnetic activity as observed with the neutron monitor at Gulmarg (9,000 ft. Geomagnetic latitude  $24.7^\circ$  N.) is presented in this paper. Data of neutron monitors at Climax (11,000 ft., Geomagnetic latitude  $48^\circ$  N.), Huancayo (11,000 ft., Geomagnetic latitude  $0.6^\circ$  S.) and Rio de Janeiro (sea level, Geomagnetic latitude  $13^\circ$  S.) were also used.

## APPARATUS

A neutron monitor is in operation at Gulmarg Observatory since July, 1958. Although our instrument is not of I.G.Y. standard, the design is similar to that described by Simpson (1955). It consists of two  $\text{BF}_3$  counters of active length 17" and  $1\frac{1}{2}$ " in diameter, filled with commercial  $\text{BF}_3$ . The pulses from the counters are fed to a linear amplifier (Model 204 C, Atomic Instrument Co.) through a pre-amplifier (Model 810, Baird Atomic Co.). After selection of the suitable height the pulses are scaled by a scale of 8. The mechanical recorder which counts the pulses is photographed together with a clock by a 35 mm. camera every hour. The schematic diagram in Fig. 1 shows the arrangement of  $\text{BF}_3$  counters and the associated electronic circuitry. The pressure data are obtained by means of a Friez micro-barograph placed near the apparatus.

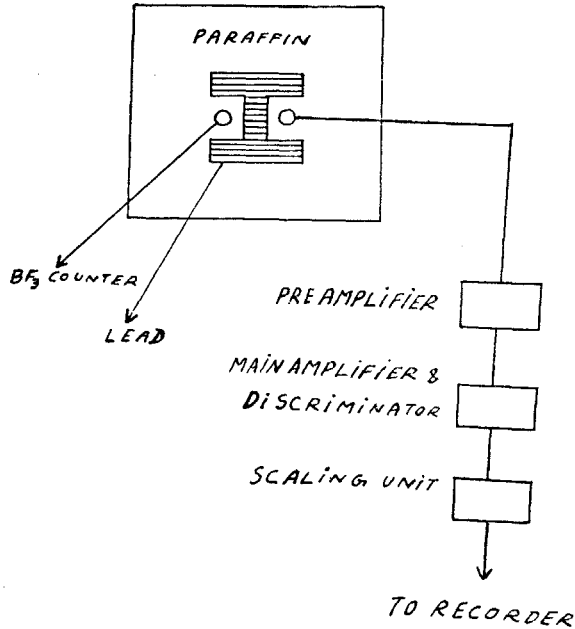


FIG. 1. Schematic diagram showing the arrangement of  $\text{BF}_3$  counters and the associated electronic circuitry.

#### ANALYSIS OF THE DATA

A correlation between daily mean neutron intensity and daily mean pressure gives a value of 0.73 per cent per mb. for the pressure co-efficient. The pressure co-efficients for neutron intensity at four different stations are shown in Table 1. The value of the pressure co-efficient is the same at all the stations. Consequently our data are corrected to 737 mb., the mean pressure at Gulmarg. As there is no heating arrangement of the roof the data are also corrected for the snow effect with a co-efficient of  $-2.1$  per cent per foot of snow during days of snow fall. The data for a single day consists of 12 bi-hourly values.

TABLE 1

Author	Station and height	Pressure co-efficient/mb.
Present work ..	Gulmarg, 9,000 ft. ..	0.73%
" ..	Rio de Janeiro, sea level ..	0.72%
Simpson <i>et al.</i> ..	Climax, 11,000 ft. ..	0.72%
Lockwood & Yingst	Mount Washington, 6,252 ft.	0.73%

The daily amplitudes are determined by the following method. The value of  $(D-N/D+N) 100$  is taken as representing the daily per cent amplitude, where  $D$  represents the sum of intensities during the 6 bi-hourly day-time intervals 0600 to 1800 hrs. local time and  $N$  represents the sum of the 6 bi-hourly values of intensity during the night intervals 0000 to 0600 and 1800 to 2400 hrs. Three days' running averages are used both in the case of Kp values and per cent amplitudes to minimize errors.

DIURNAL AMPLITUDES

The diurnal amplitudes for groups of days on which the  $K_p$  values remain within the given interval are calculated and are given in Table 2. Similarly the amplitudes are calculated for Huancayo and Climax data. No apparent relation

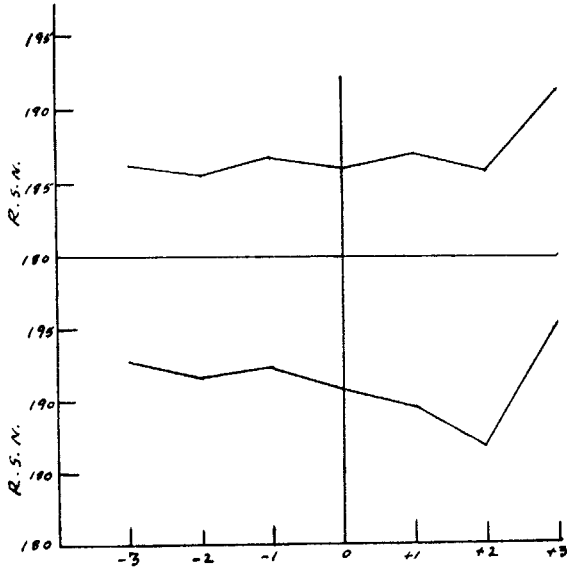


FIG. 2a. Average relative sun-spot number from -3 to +3 days. The zero day in the upper curve represents the day of minimum amplitude and the zero day in the lower curve represents the day of maximum amplitude.

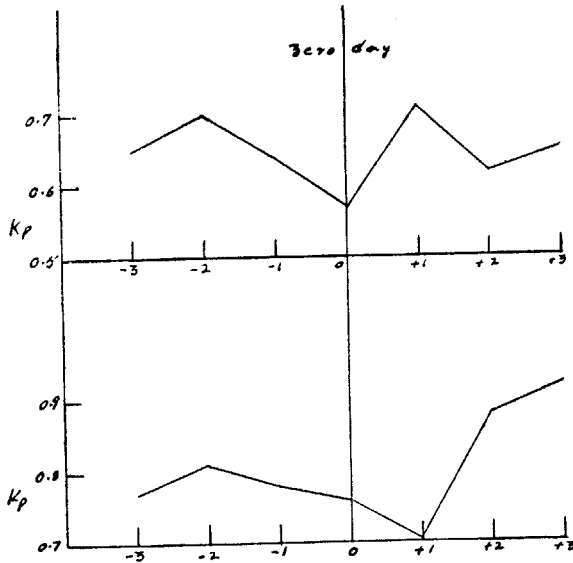


FIG. 2b. Average  $K_p$  values from -3 to +3 days. The zero day in the upper curve represents the day of minimum amplitude and the zero day in the lower curve represents the day of maximum amplitude.

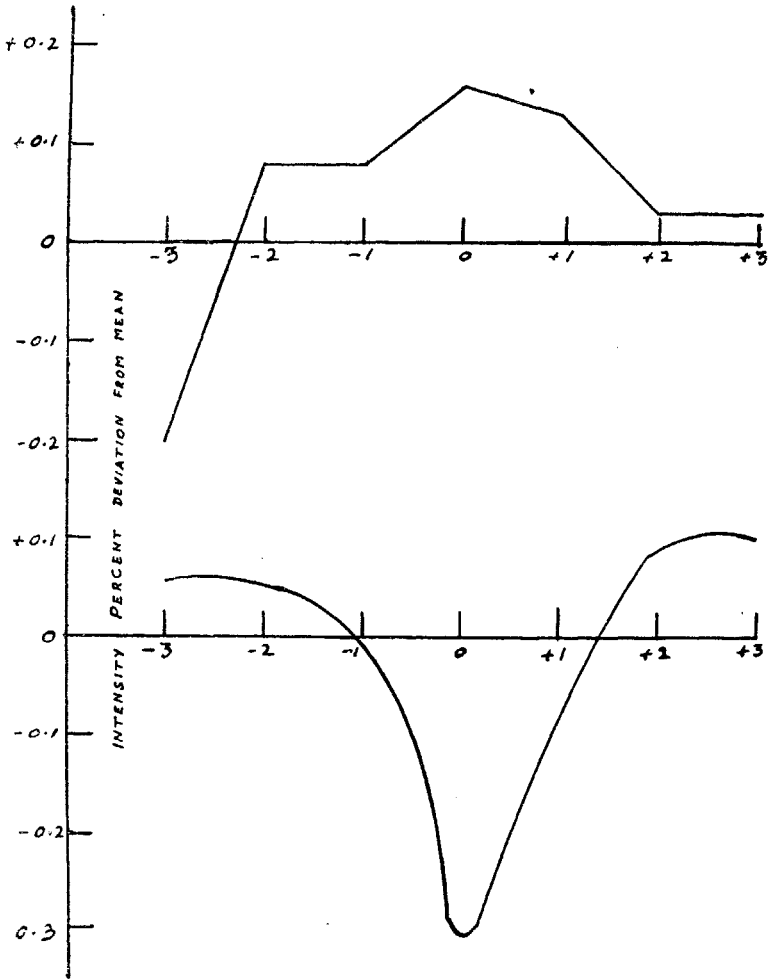


FIG. 2c. Average daily mean intensity from  $-3$  to  $+3$  days. The zero day in the upper curve represents the day of minimum amplitude and the zero day in the lower curve represents the day of maximum amplitude.

is found between the Kp values and the amplitudes. The results reported here are in agreement with those of Sittkus (1955) and Sekido *et al.* (1950).

TABLE 2

Kp intervals	Amplitudes, Climax	Amplitudes, Huancayo	Amplitudes, Gulmarg
1.8-2.0	0.50%	1.04%	0.87%
1.4-1.6	0.42%	0.50%	0.40%
1.0-1.2	0.80%	0.80%	0.29%
0.6-0.8	0.48%	0.22%	0.72%
0.0-0.2	0.72%	0.54%	0.49%

The daily amplitudes at Gulmarg are correlated with the daily amplitudes at Rio de Janeiro. A significant correlation co-efficient of 0.58 indicates the world-wide nature of these amplitudes.

The superposed epoch method is employed in determining the probable association in time between the Kp values and the amplitudes. The average value of Kp on all the days (termed zero day) on which the amplitude is maximum is obtained together with the similar averages for each of the three preceding days (termed -1, -2, -3) and for the three succeeding days (termed +1, +2, +3). Similarly the Kp averages are found for days of minimum amplitude. By the same method the relationship between the daily neutron intensity and the amplitude as well as the daily relative sun-spot number and amplitude are obtained. There seems to be no dependence of the daily amplitude on the magnetic figure, i.e. Kp, and on the relative sun-spot number. But the intensity shows a decrease of  $0.3 \pm 0.03$  per cent on the day when the amplitude is maximum and it shows an

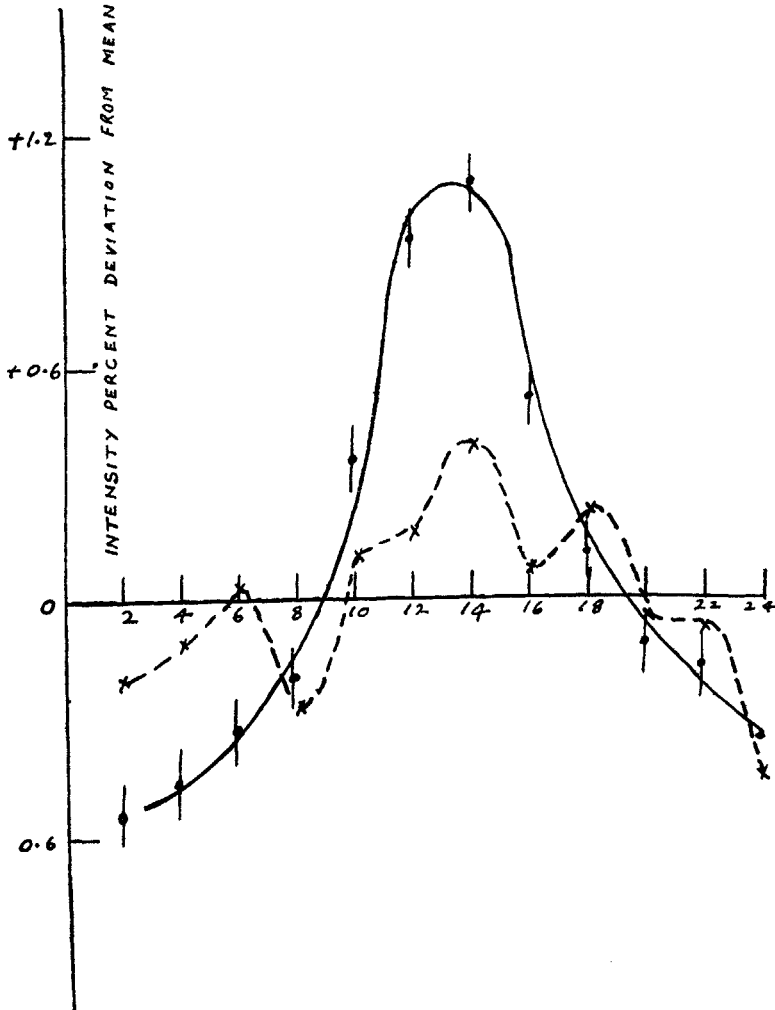


FIG. 3a. Diurnal variation of cosmic ray neutron intensity during the period October and November, 1958.

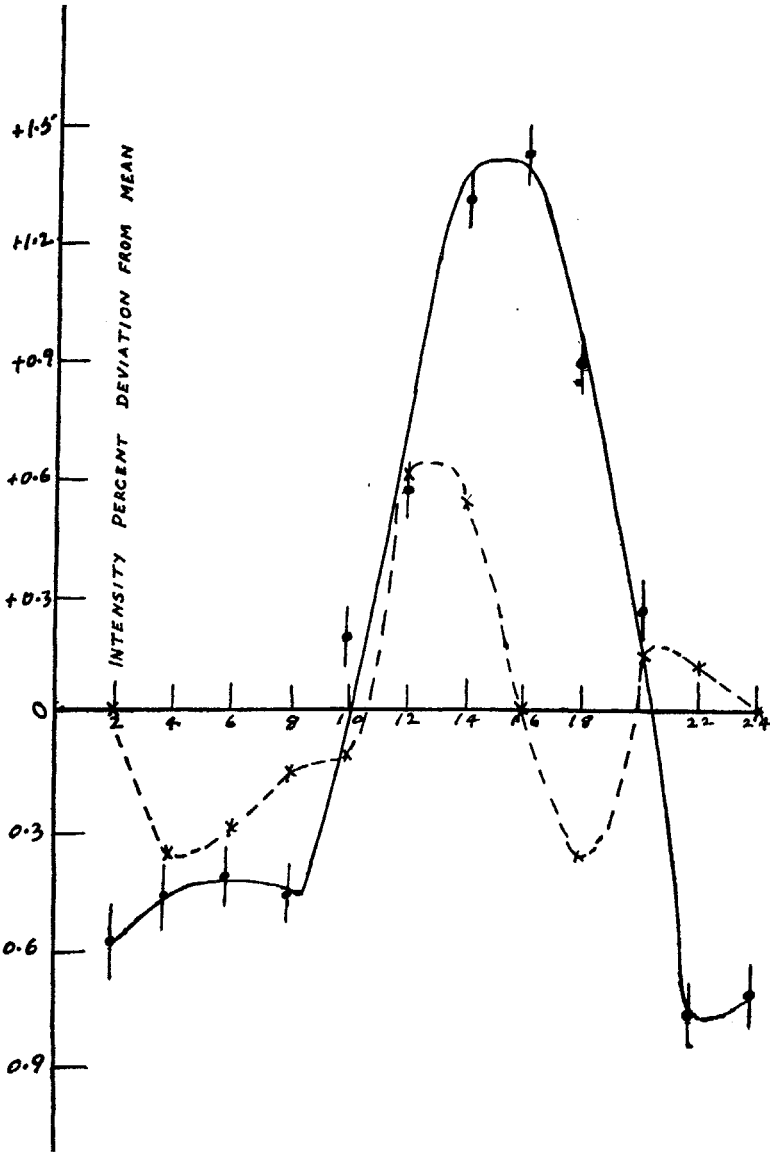


FIG. 3b. During the days when the daily mean intensity deviates from the mean of all days by  $-1$  per cent or more.

increase of  $0.16 \pm 0.03$  per cent on the day when the amplitude is minimum. Fig. 2 shows the results.

The dependence of the diurnal amplitude on latitude and altitude during cosmic ray storms can be used to see if neutrons come from the sun. The average value of the amplitude is obtained during the period October and November, 1958, and also during the days when the daily mean intensity deviates from the mean of all days by  $-1$  per cent or more at Gulmarg and Rio de Janeiro. The diurnal variations are shown in Fig. 3. The ratio of amplitudes at the two stations is nearly the same in both the cases.

## DISCUSSION

Firor *et al.* (1954) have shown that the diurnal variation in neutron intensity is not caused by the emission of neutrons from the sun. This fact can be further illustrated from the altitude dependence of the diurnal variation. The latitude factor between  $13^\circ$  and  $24^\circ$  is approximately 1.2 as obtained from the measurements of Simpson and Fagot (1953). Therefore a 1 per cent amplitude at Rio de Janeiro should be 1/1.2 per cent at Gulmarg. Although the altitude factor for cosmic ray neutrons between sea level and 9,000 ft. is approximately 5 as shown by Curtiss and Gill (1952), the amplitude is not affected. So the amplitude at Gulmarg should be 1/1.2 per cent neglecting the absorption due to oblique incidence. But the ratio is approximately  $2.0 \pm 0.3$  between Gulmarg and Rio de Janeiro, and thus the variation is not caused by the emission of neutrons from the sun.

Our results do not show any dependence of the diurnal amplitude on the Kp values of the day. Sarabhai and Kane (1953) find a positive correlation between diurnal amplitude and magnetic character figure. They also find that the diurnal amplitude has got a high partial correlation with sun-spot number. Results reported here do not warrant their conclusions. Krishna (1956) dividing the days according to Kp values finds no change in the amplitudes. He, however, attributes it to the weak solar activity during which his experiment was performed. It is obvious from our results that even during days of considerable solar activity there is no significant relation between Kp value and the amplitude. The fact that the diurnal amplitude tends to be greatest when the average intensity decreases and the amplitude tends to be smaller during days of high average intensity is of considerable interest as it supports the view that cosmic ray anisotropy is caused by the electric fields set up by the ionized beams emanating from the sun. Yoshida and Kondo (1954) from a study of the 27-day recurrence tendency in the amplitude, daily mean intensity, and magnetic storms find that the recurrence tendency in the amplitude and the daily mean intensity are more persistent than magnetic storms. Simpson (1954) shows that a magnetic disturbance is not always followed by a decrease of cosmic ray intensity.

It has been suggested by Nagashima (1951 and 1953) that the anisotropy in cosmic radiation is caused by the acceleration or deceleration of particles in an electric field produced by a solar stream. The solar streams also cause magnetic disturbances as suggested by Chapman (1937). The high values of amplitudes in Table 2 sometimes coincide with high Kp values, and other times not. This indicates that occasionally the solar stream can produce anisotropy in cosmic radiation and also magnetic disturbance. But sometimes it is only effective in producing a cosmic ray storm but not a magnetic disturbance. Yoshida and Kondo (1954) also show that the solar stream can produce both a magnetic and cosmic ray disturbance on its first appearance but when it reappears again in the vicinity of the earth after one or two solar rotations it can no longer produce a magnetic storm but it is effective in creating a cosmic ray storm.

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