Cosmic ray intensity is known to exhibit a solar diurnal variation with an average amplitude of about 0.3–0.4% and a space direction of about 18 hours. Long-term changes in the amplitude and phase [Sarabhai and Kane, 1953; Thambyahpillai and Elliot, 1953; McCracken and Rao, 1965; Duggal et al., 1967; Forbush, 1969; Quenby and Hashim, 1969], as well as day-to-day changes [Yoshida, 1958; Duggal and Pomerantz, 1962, Kane, 1966], have been reported. Theoretically, these changes have been fairly well explained on the basis of the corotation mechanism [Parker, 1964, 1967; Axford, 1965], which is essentially a Compton-Getting effect and which, when correctly taken into account [Gleeson and Axford, 1968], gives a maximum possible amplitude of about 0.6%. Several peculiar configurations of the interplanetary medium can also cause departure from this average picture. Thus, diffusion perpendicular to the magnetic field lines ($K_r \rightarrow K_s$) and/or transverse gradients would reduce the amplitudes [Parker, 1967]. Even during quiet periods, a random walk of magnetic field lines could give significant values of $K_r$ [Jokipii and Parker, 1969]. During disturbed periods, several parameters can cause deviations from the average picture [Axford, 1965]. The non-spherical nature of the solar wind cavity would produce radial flow in the solar equatorial plane [Quenby and Hashim, 1969]. Gradients perpendicular to the ecliptic plane can give first and second harmonics of amplitudes of about 0.3% and 0.2%, respectively [Subramanian and Sarabhai, 1967; Lietti and Quenby, 1968].

To study the finer details of the diurnal variation, data from several neutron monitors were studied for the period 1953–1969. In agreement with other workers, we found that, except for the quiet sun year 1954 when amplitudes were negligibly small, the amplitudes have remained essentially constant around about 0.3%, with a space direction of about 18 hours. The day-to-day and month-to-month scatter was rather large, however, yielding a monthly rms vector error of about 0.03–0.05%. This was almost 10–15% of the average amplitude and implied that long-term changes of less than 20–30% could not be detected with much reliability.

This also raises the question of whether the corotation mechanism is a permanent feature at all, on which the day-to-day irregularities are superimposed. To check this, the quiet period of 1965–1966 and the disturbed period of 1966–1967 were selected for study. In each, groups of consecutive days on which the amplitudes of the first harmonic of the neutron monitor intensity at Deep River were roughly similar were grouped together. The average daily variation curves are shown in Figure 1(a) for October 1965 to January 1966 and in Figure 1(b) for December 1966 to February 1967. The number of days and average values of the first harmonic amplitude $r, (%)$ are indicated. As can be seen, there are several groups of consecutive days on which the average amplitudes are negligibly small (0.1% or less), both in quiet and disturbed periods.

It seems, therefore, that the corotation mechanism can be inoperative for several days at a stretch, and that the monthly average diurnal variation of amplitudes of about 0.3% is not a physically meaningful quantity but is only a vector average of heterogeneous quantities varying in amplitude from 0 to 1% or more. As such, averages over more than 1 or 2 weeks...
cannot possibly be of much physical significance.

Because here we are dealing with a large day-to-day variability, it would be more meaningful to study the characteristics of this variability than its mathematical averages. One common and popular approach is to study the amplitude and phase of the daily harmonics. This technique, however, presupposes a definite pattern of the daily variation and yields no information as to whether the deviations are increases or decreases. Another approach would be to compare data from two stations that are expected to show similar isotropic changes but different diurnal effects. Neutron monitors at Deep River and Alert form a convenient pair, because the first is chiefly looking in the ecliptic plane and the second is chiefly looking outside. The difference (Deep River minus Alert) could be considered as an absolute measure of the anisotropy. Mathews et al. [1969] used this quantity to prove that the anomalous diurnal variation on some days was caused by decreases from the garden hose direction. Hashim and Thambyahpillai [1969] reached a similar conclusion.

A major difficulty of studying such a difference is that instrumental drifts in any one or both instruments would pollute the difference. On inspection, however, it was found that after about every 10-15 days the diurnal variations at both Deep River and Alert were negligible. If intensities for such days were set as 100% levels and intensities for the next few days were expressed as percentages of these levels, separately for Deep River and Alert, the difference (Deep River minus Alert) for these days would be expected to have little pollution due to instrumental vagaries.

Using the data for Deep River and Alert given by Steljes [1966 and subsequent volumes], periods were chosen when the mean intensities at both stations were essentially steady and the diurnal variation amplitudes were negligibly small (0.3% or less). These were set as 100% levels, and, after expressing the succeeding values as percentages of these values, the hourly deviations (Deep River minus Alert) were obtained. The occurrence of positive and negative deviations of different magnitudes at different hours (local time Deep River) were studied, and the following was noticed.

1. There are days, generally occurring in bunches of 2 or more and roughly 10-15 days apart, when diurnal amplitudes are negligibly small. In terms of the random-walk picture of interplanetary magnetic field lines proposed by Jokipii and Parker [1969], this effect would imply certain interplanetary conditions, such that the diffusion of cosmic rays perpendicular to the average interplanetary field is quite large \((K_1 \rightarrow K_4)\) and the corotation mechanism ceases to be operative.

2. On other days, diurnal wave trains of moderate amplitudes (about 0.5%) or abnor-
nally large amplitudes (even exceeding 1%) can occur, and both increases in the 18-hour direction and decreases in the garden hose direction are noticed. This effect implies that (a) the estimate of a maximum amplitude of 0.6 for the corotation mechanism is wrong; (b) the estimate is correct, but some additional mechanism is contributing on such days to the 18-hour component; or (c) there is definitely an additional sink in the garden hose direction.

3. On days of very disturbed interplanetary conditions, (such as Forbush decreases) a variety of diurnal patterns is obtained, different from event to event and from day to day in the same event, with no correlation with any phase (main phase or recovery) of the Forbush decrease. Since shock-wave fronts causing such events do not have any fixed patterns of magnetic field configurations, such a random behavior of diurnal variation is understandable.

What are causes of these abnormal diurnal variations? During 1966–1968, there were at least 9 major events when diurnal amplitudes exceeded 0.6% for about a week and 1.0% for at least a day or two. Details are given in Table 1.

As can be seen, more than half of the events were associated with quiet or moderately disturbed conditions of mean intensity. By assuming that these large amplitude wave trains are mainly due to decreases in the garden hose direction, Hashim and Thambyahpillai [1969] have attributed these to a possible connection of the earth through the interplanetary field lines to a region of depleted cosmic ray intensity behind some shock fronts that usually give a Forbush decrease but have somehow missed the earth.

However, this does not explain the increases in the 18-hour direction for which evidence is presented in this paper.

In conclusion, the findings of the present analysis may be summarized as follows.

1. The day-to-day variability of the diurnal variation of cosmic ray intensity is very large indeed. Amplitudes vary from zero to several percent. Low, medium, or high amplitudes last for only a few days at a time. As such, only daily values or averages over a few days should be expected to give a meaningful representation of interplanetary conditions. Averages over long periods (monthly or yearly averages) will have only mathematical significance and no physical meaning.

2. There are groups of days when amplitudes are almost zero and the corotation mechanism seems to be inoperative. During disturbed periods such a situation is understandable, but during quiet periods the situation is intriguing, because it would imply that for a few days conditions are so quiet that the random walk of field lines produces appreciable perpendicular diffusion, whereas, for the next few days, the random walk effect is reduced, and the corotation mechanism starts being effective. This is followed by another set of days when random walk is again predominant.

3. Medium amplitudes (about 0.6% or less) are best explained on the basis of present theories.

4. For certain groups of days there is definite evidence of (a) large increases (about 1–2%) from the 18-hour direction, far in excess of the upper limit of about 0.6% for the corotation mechanism; and (b) large decreases (about 1–2%) from roughly the garden hose (9 hour) direction. Both these do not find a satisfactory explanation in the present theories. None of these occurred during the quiet sun period 1964–1965. But their occurrence during 1966–1968 was not confined to stormy periods and was mostly during comparatively quiet conditions, as judged from cosmic ray mean intensity changes. Thus, connection of the earth with remote disturbed regions is suggested. Actual identification of such regions must be attempted. Other mechanisms, which will give substantial extra azimuthal streaming, will also have to be discovered.

### TABLE 1

<table>
<thead>
<tr>
<th>Interval</th>
<th>Mean Intensity Changes</th>
</tr>
</thead>
<tbody>
<tr>
<td>December 31, 1965, to</td>
<td></td>
</tr>
<tr>
<td>January 6, 1966</td>
<td>moderate</td>
</tr>
<tr>
<td>May 1–10, 1966</td>
<td>quiet</td>
</tr>
<tr>
<td>September 8–13, 1966</td>
<td>moderate</td>
</tr>
<tr>
<td>February 1–8, 1967</td>
<td>moderate</td>
</tr>
<tr>
<td>April 8–15, 1967</td>
<td>moderate</td>
</tr>
<tr>
<td>May 25–30, 1967</td>
<td>violent</td>
</tr>
<tr>
<td>February 23–27, 1968</td>
<td>quiet</td>
</tr>
<tr>
<td>October 30 to Nov. 6, 1968</td>
<td>violent</td>
</tr>
<tr>
<td>November 12–18, 1968</td>
<td>violent</td>
</tr>
</tbody>
</table>
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REFERENCES


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