Gradient of Cosmic-Ray Intensity Perpendicular to the Ecliptic Plane.

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Summary. - Cosmic-ray gradients perpendicular to the ecliptic (cross-gradients) can be estimated, in principle, from the seasonal variation of cosmic-ray intensity, because the earth deviates from the solar equatorial plane by about ±7° heliolatitude (equivalent to ±1/6 A.U.) during a year. However, such estimates can be greatly vitiated by long-term cosmic-ray changes specially when these are nonlinear. Neutron monitor data for the period 1958-67 are critically examined for such an effect. The long-term changes were tolerably linear only during Sept. '63-May '65 and analysis for this period yields an extrapolated cross-gradient less than (4±2)%/A.U. For other periods the method is unreliable. The method is applicable only to heliolatitudes within ±7° corresponding to distances of ±1/6 A.U. and hence gives no information for regions beyond.

1. - Introduction.

With the help of space probes it has been possible in recent years to get some idea about the gradient of cosmic-ray intensity in interplanetary space. However, these estimates are confined to the ecliptic plane only and refer only to radial gradients. No direct information is available about gradients perpendicular to the ecliptic plane. For the recently proposed explanations of some cosmic-ray phenomena (Subramanian and Sarabhai (1), LIETTI and QUENBY (2)) such a gradient is a prerequisite.

(2) B. Lietti and J. J. Quenby: Paper (Mod. VIII-58) read at the Tenth Int. Cosmic-Ray Conference, Calgary, 1967.
A possible way of getting some idea about a gradient perpendicular to the ecliptic plane is by utilizing the fact that the axis of rotation of the sun is not perpendicular to the ecliptic plane but is inclined at an angle of about 7°. Hence, the earth, during its rotation round the sun, plunges in and out of the solar equatorial plane twice a year. On March 7 and September 7, the earth is in the equatorial plane. On June 7, it is farthest north and on December 7 it is farthest south, both by about 7°. Hence, changes in cosmic-ray intensity over a period of about 3 months on either side of the March 7 and September 7 epochs should, in principle, reveal a gradient of cosmic-ray intensity perpendicular to the ecliptic plane at least to an angular distance of 7°. Such a study was carried out by DORMAN et al. (3) who have concluded that a "cross-gradient of the cosmic rays in the vicinities of the Earth's orbit ((13±11)%/1 A.U.) is of the same order as the radial gradient".

Unfortunately, such a study is apt to be vitiated by some major pitfalls. These arise due to the fact that cosmic-ray intensity may vary over a 3-month period for reasons totally unconnected with the heliolatitude effect referred to above. Thus, it is known that cosmic-ray intensity varies with an 11-year cycle. For high-latitude sea-level neutron monitors, the effect can be as large as 25% over a period of few years or about (1±2)% over a few months and hence is comparable to a cross-gradient of about (8±16)%/A.U. ((1±2)% over 7° which is roughly $\frac{1}{2}$ A.U.). In the present communication, an attempt has been made to examine this aspect critically and see if any worthwhile conclusions can be drawn.

2. Experimental data.

The data used are for the neutron monitor at Climax. Figure 1 shows the maximum values, minimum values and monthly means of cosmic-ray intensity over successive months for the period 1958-1967. The maximum values will be the least affected by short-term phenomena like Forbush decreases and hence represent truly the long-term changes of cosmic-ray intensity.

Now, to study the heliolatitude effect, it is necessary to correct for the long-term changes adequately. This can be done satisfactorily only if the changes are linear, that is, the rate of change is constant over a substantially long period. As can be seen from Fig. 1, the changes are very violent and change sign very frequently. Only during the limited 20-month period September 1963-May 1965 is the change tolerably linear. Therefore, for this period, further analysis was carried out as follows.