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II-4-19. Asymptotic Directions and Cut-off Rigidities in the Geomagnetic Field*

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A simulation of the geomagnetic field using spherical surface harmonics up to and including the sixth degree is in markedly better agreement with the observed geomagnetic field than is the dipole approximation. Consequently, a digital computer has been used to numerically integrate the equations of motion of a cosmic ray in one such simulation (the Finch and Leaton 48 coefficient simulation being used). In practice, the trajectory of a negative particle of the required rigidity was computed by the Runge-Kutta step by step integration process, the initial point being a point 20 km above the point of interest on the earth's surface. The asymptotic directions of approach were evaluated at 25 earth radii, and at other intermediate points.

For comparison, the asymptotic directions of approach were evaluated for the centred dipole approximation to the geomagnetic field. The asymptotic directions specified by the geographic latitude and longitude relative to Greenwich are compared in Fig. 1. The arrow head points to the point which corresponds to the determination made using the Finch and Leaton field. Differences of 10° are quite common, and will be of significance in any careful study of cosmic ray effects. Near the cut-off rigidity the difference are often quite great. (cf. Deep River, Kodaikanal).

Asymptotic directions for numerous cosmic ray observatories have been calculated using the Finch and Leaton field simulation, and will be supplied on request.

Determining the trajectories for many rigidities, upper and lower limits for the vertical cut-off rigidity at a high latitude station can be found. For Port aux Francais in the Kerguelen Islands, the limits $1.27 \leq N_V \leq 1.30$ GV were obtained. The Quenby and Webber approximation yields 1.74 GV. The increments observed during the isotropic phase of the cosmic ray flare effect of November 15, 1960 are displayed in Fig. 2 as a function of vertical cut-off rigidity calculated using the Quenby and Webber approximation. All the points, except that corresponding to Port aux Francais, lie on a single curve. The enhancement observed at Port aux Francais is great as those observed at stations with

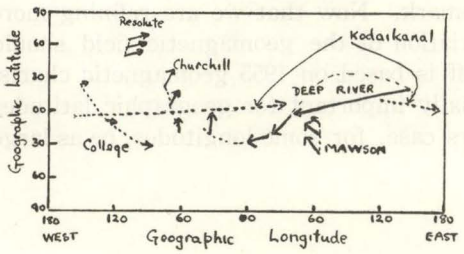

Fig. 1.

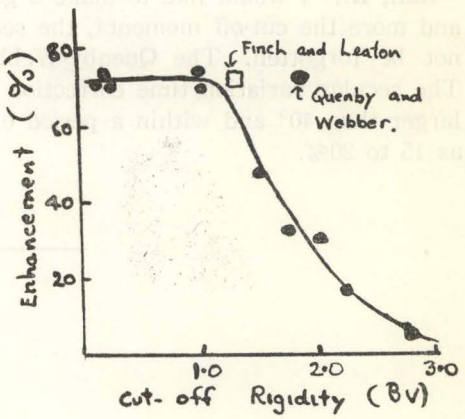

Fig. 2.

* A portion of the calculations reported here were performed using the facilities of the National Aeronautics and Space Agency computation centre at Greenbelt, Maryland, U.S.A.

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cut-off rigidities considerably low than 1.74 GV. Plotting the enhancement against the value estimated using the Finch and Leaton field, a good fit is obtained to the curve defined by the remainder of the points.

The discrepancies between the Quenby and Webber value, and the value calculated using the trajectory tracing programme are smaller (less than 0.2 GV) at other high latitude cosmic ray observatories.

Port aux Francais is near the Cape Town anomaly. The fact that the trajectory tracing value is consistent with the experimental observations while the Quenby and Webber approximation results in an incorrect estimate of the cut-off rigidity implies that

(1) the magnetic field as estimated from surface measurements is adequate to explain the observed cosmic ray effects even near the Cape Town anomaly.

(2) The Quenby and Webber approximation breaks near the Cape Town anomaly. This is not surprising, for the line of force through Port aux Francais is in all probability considerably different from a dipole-like line of force.

Discussion

Kane, R.P.: (1) I think it is necessary to check that whereas the revised calculation gives a better fit for this one stations, it does not produce nonagreement for other stations which show at present agreement with Quenby and Webber's calculations.

(2) In that case, the very good agreement by considering permanent geomagnetic field alone should be considered as positive proof that effects due to ring currents are negligible (by this I imply ring currents which are transient and not those which may be permanently present).

McCracken, K.G.: A limited number of calculations performed for other stations show the deviations from the Quenby and Webber cut-off rigidities to be smaller than in the case of Port aux Francais. This suggests that in the regions of the world where there are no small scale irregularities in the geomagnetic field, the Quenby and Webber values are essentially correct.

Elliot, H.: In connection with the threshold rigidity at Port aux Francais, the revised value in the Quenby-Webber treatment would be in much better agreement with your value than is the one given by Quenby-Webber.

In reply to Dr. Kane's point about the existence of a ring current, I believe that the neutron observations at sea level are hardly sufficiently sensitive to reveal the presence.

Pomerantz, M.A.: Conservatively speaking, it should be noted that only one of several remaining points needs to be displaced somewhat to disturb the apparent agreement produced by the detailed computation of the Port aux Francais cut-off.

Gall, R.: I would like to make a general remark. Now that we are refining more and more the cut-off momenta, the secular variation of the geomagnetic field should not be forgotten. The Quenby-Webber cut-off is based on 1955 geomagnetic charts. The secular variation time correction is especially important for geographic latitudes larger than 40° and within a period of 10 years case, for some longitudes, be as large as 15 to 20%.