DISTRIBUTION OF AURORAS IN THE SOUTHERN HEMISPHERE

III. COMPARISON WITH NORTHERN HEMISPHERE

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Summary

While the distribution of auroras in the southern hemisphere is well represented in terms of each of the parameters θ_1, θ_2, and θ_3 (introduced in Part II), the northern hemisphere distribution is not satisfactorily represented in terms of θ_1. In terms of θ_2 or θ_3, and within the limits of accuracy of the data, the distributions in the two hemispheres are conjugate. To carry this investigation further, much more accurate data and more refined concepts are required.

I. Introduction

In Part II of this series (Bond and Jacka 1962) the distribution of probability of occurrence of overhead auroras in the southern hemisphere during the International Geophysical Year was found to be well represented in terms of each of three different parameters related to the geomagnetic field. These were:

- θ_1, the co-latitude referred to the axis of the eccentric dipole representation of the field;
- θ_2, defined in terms of projections from circles in the equatorial plane, along the lines of force, onto the Earth's surface;
- θ_3, defined in terms of the longitudinal invariant of charged particle motion in the field.

The maximum probability isoaurore closely follows the isolines $\theta_1 = 21 \cdot 25°$, $\theta_2 = 21 \cdot 1°$, or $\theta_3 = 22 \cdot 5°$.

In the present paper the corresponding isolines in the northern hemisphere are compared with the data of Fel'dstein (1960) and Gartlein and Sprague (1960).

II. Comparison of Data

(a) *The Maximum Probability Isoaurore*

Fel'dstein (1960) has delineated the isoaurore of maximum frequency of half-hourly intervals during which overhead aurora occurred in the northern hemisphere. The interval used in Part II was the whole night. Before comparing the two hemispheres it was therefore necessary to examine the relationship between the interval used and the location of the maximum frequency isoaurore.

The southern hemisphere data were originally collated in hourly intervals. From these basic data the hourly interval auroral frequencies, π%, were evaluated as the ratio of number of clear intervals (those throughout which cloud cover was less than 5/8) with overhead aurora to the total number of such hourly intervals.

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The frequencies $\pi\%$ are plotted against θ_3 in Figure 1, which shows a considerable spread of points near the maximum. As this may be due to bias introduced through non-availability of data, values for stations near the maximum were re-estimated by a method similar to that used to estimate the nightly probabilities P in Part II.

The data were divided into classes according to the value of the planetary geomagnetic disturbance index K_p and the hour (00–01, 01–02, . . . , 23–24 h UT). For each K_p-time class the relative frequency $\phi(K_p, t)$ of auroras was determined. It was now assumed that the frequencies $\phi(K_p, t)$ were representative of the whole population of one-hourly intervals between evening and morning nautical twilights.

Denoting by $\nu(K_p, t)$ the total number of hours (clear or cloudy) in a K_p-time class the estimate

$$\Pi = \Sigma\, [\nu(K_p, t)\, .\, \phi(K_p, t)]/\Sigma\, \nu(K_p, t)$$

of the probability of occurrence of overhead aurora during an hour was thus determined. These estimates are indicated on Figure 1 for Mawson and Syowa.

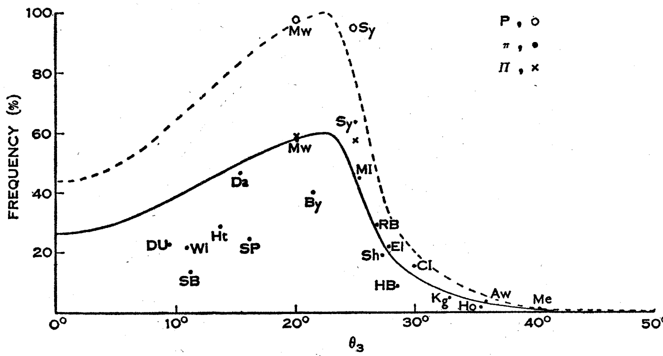

Fig. 1.—Hourly percentage frequency of overhead aurora against "co-latitude" θ_3, southern hemisphere. (For station name symbols see Part II, Table 1).

The hourly probability (full line) curve of Figure 1 was drawn by scaling down the ordinates of the nightly probability (dashed line) curve in the ratio Π/P estimated for Mawson.

Low values of π at certain stations, as observed, are to be expected. At Byrd, from about April 20 to August 20, darkness persists throughout the 24 hours, with low frequency of aurora during the 12 hours about noon. At the South Pole darkness does not ensue during March or September, which are months of high auroral frequency at stations near the maximum frequency isoaurore. Cape Hallett, Dumont d'Urville, Scott Base, and Wilkes are situated well inside the maximum frequency isoaurore, where auroral occurrence is often sporadic and of short duration.

Because of these factors the data are somewhat inhomogeneous; however, it is apparent that the location of the maximum *hourly* probability isoaurore is not displaced significantly from that of the maximum *nightly* probability isoaurore. For purposes of comparison with Fel'dstein's data it will be assumed that the maximum *half-hourly* probability isoaurore is likewise not significantly displaced from the maximum *nightly* probability isoaurore.

When the half-hourly frequency data of Fel'dstein are plotted against θ_3 there is a slightly greater spread of points around the maximum than in the case of the southern hemisphere hourly data. However, the curve $\theta_3 = 22 \cdot 5°$, as in the southern hemisphere, provides a satisfactory fit to the data.

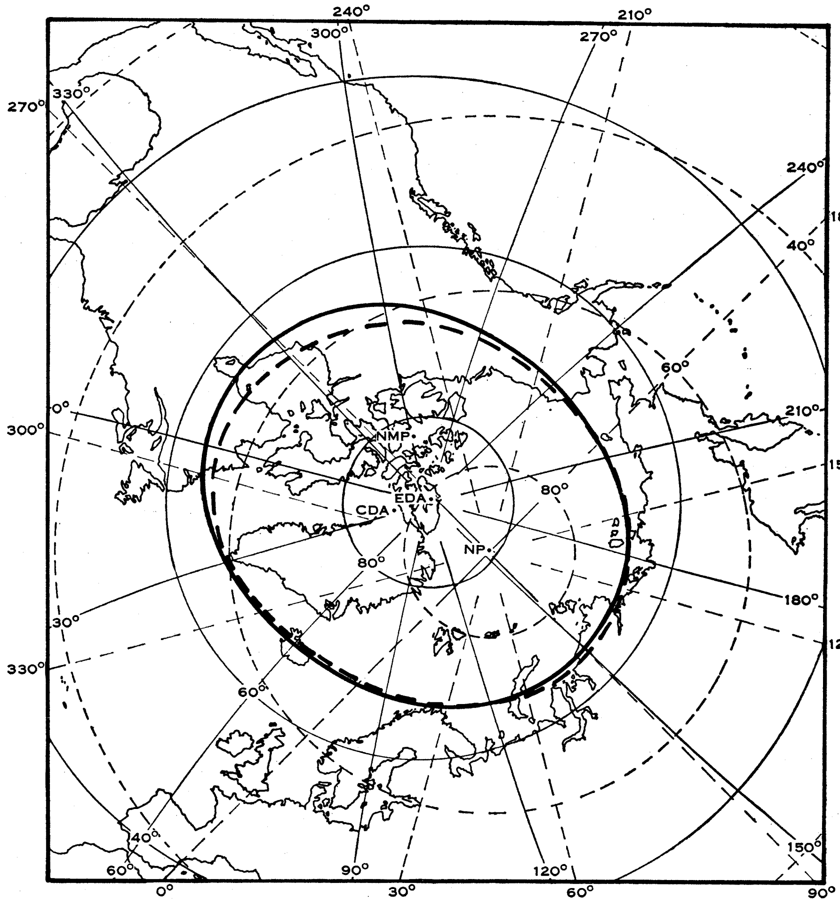

Fig. 2.—Fel'dstein's isoaurore (dashed line) compared with the conjugate to the southern hemisphere curve $\theta_3 = 22 \cdot 5°$. (NP, North Geographic Pole; NMP, North Magnetic Pole; CDA, centred dipole axis; EDA, eccentric dipole axis.)

Fel'dstein's maximum frequency isoaurore, denoted F, is reproduced in Figure 2 with the curve $\theta_3 = 22 \cdot 5°$. Curves of $\theta_1 = 21 \cdot 25°$, and $\theta_2 = 21 \cdot 1°$ (not shown) were also drawn and the displacements $\theta_i - \theta_F$ measured at 10° intervals of eccentric dipole longitude (Cole 1963).

It was found that, in the northern hemisphere, the θ_1 isoline does not satisfactorily represent the maximum frequency isoaurore. The differences $\theta_2 - \theta_F$ and

$\theta_3 - \theta_F$ are probably less than the uncertainty in location of the isoaurore F from the observational data.

(*b*) *The 50% Probability Isoaurores* ($K_p = 1$, $K_p = 5$)

Gartlein and Sprague (1960) have delineated the 50% probability isoaurores in the northern hemisphere for intervals during which the planetary geomagnetic disturbance index attained the values $K_p = 1$ and $K_p = 5$.

To compare these curves with southern hemisphere data it is assumed that, at points equatorwards of the maximum probability isoaurore, auroras occurred on all nights during which they were observed at points nearer the Equator. This

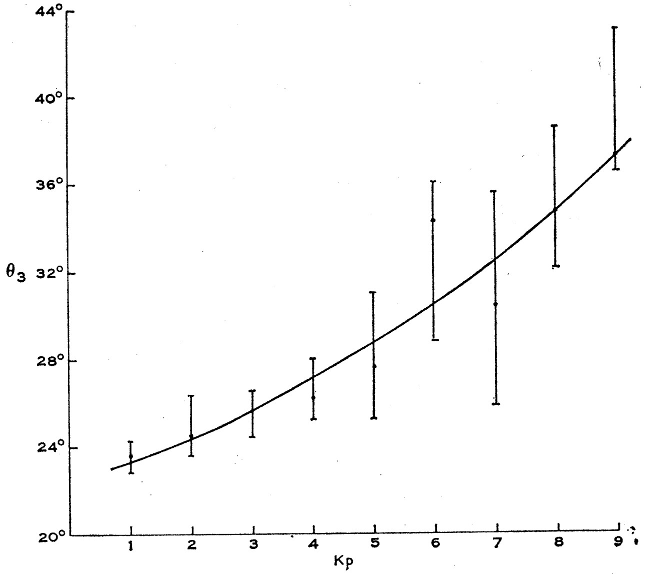

Fig. 3.—The co-latitude θ_3 of the 50% probability isoaurore for intervals of each value of K_p. The error tails include the range 25–75% probability.

permits the use of an extract from the data of Bond (1960), referring to gg. longitude 152°, to construct Figure 3 which shows the co-latitude θ_3 of the 50% probability isoaurores as a function of K_p. A smooth curve was drawn through the plotted points guided by the straight-line relationship (fitted by least squares) and the considerations which follow. Auroras over co-latitudes $\theta_3 = 20°$ to $35°$, giving median points in the range $\theta_3 = 23 \cdot 6°$ to $27 \cdot 6°$, were observed from Macquarie Island. Departures from the curve of points near the ends of this range may be accounted for by the tendency to underestimate the frequency of auroras occurring at low elevations. This is due to poorer visibility and to the lower luminosity of auroras viewed in this situation as compared with those observed roughly "edge on" at high elevations. Similar considerations apply to the more southerly observations from southern Tasmania.

In Part II it was shown that isolines of θ_3 represented well the average isoaurores for the IGY period, during which the most frequent value of K_p was 3. It is now assumed that for those nights during which K_p had the values 1 and 5 the isoaurores can be represented by isolines of θ_3. From Figure 3 it is apparent that, for $K_p = 1$, the 50% probability isoaurore lies at $\theta_3 = 23 \cdot 3°$ and for $K_p = 5$ at $\theta_3 = 28 \cdot 8°$.

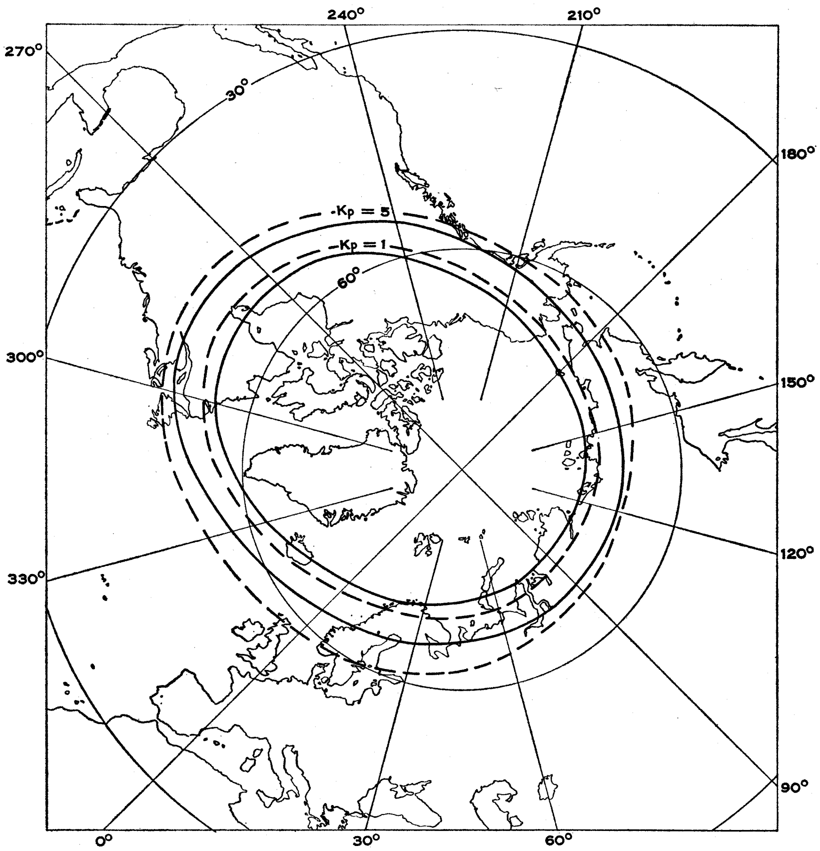

Fig. 4.—The 50% auroral incidence isoaurores for intervals when $K_p = 1$ and $K_p = 5$ (Gartlein and Sprague 1960) compared with the conjugates to the southern hemisphere isoaurores $\theta_3 = 23 \cdot 3°$ and $\theta_3 = 28 \cdot 8°$ of 50% auroral incidence for intervals when $K_p = 1$ and $K_p = 5$ respectively.

In Figure 4 the curves $\theta_3 = 23 \cdot 3°$ and $\theta_3 = 28 \cdot 8°$ are compared with the 50% probability isoaurores estimated for the northern hemisphere by Gartlein and Sprague (1960). From Figure 3, for $K_p = 1$, the semi-interquartile range is approximately 1°, and for $K_p = 5$ approximately 2°. Assuming similar accuracy for the Gartlein and Sprague curves, agreement between the two sets of curves is considered reasonable. However, the lower latitude of the Gartlein and Sprague curves may be due, at least partially, to the low density of visual observers and considerable cloud cover in regions to the north of their curve, since only overhead aurora were included in their analysis. Alternatively, the northern curves are biased in favour of observations during the northern winter, while the southern curves are biased in favour of observations during the southern winter. This may be important.

Again, when the data are represented in terms of θ_2, the two sets of curves show closely similar relationships.

III. Discussion

While the isoaurores of the southern hemisphere are well represented by the isolines of θ_1, θ_2, or θ_3, in the northern hemisphere, where the high latitude geomagnetic field is somewhat less like that of a dipole, θ_1 does not provide a satisfactory representation. In terms of either θ_2 or θ_3, and within the limits of accuracy of the data, the distributions in the two hemispheres appear conjugate.

It is noted, however, that from an examination of a limited amount of data, Jacka (1961) found that individual occurrences of auroras over Macquarie Island and College (approximately conjugate in terms of θ_2 or θ_3) were statistically independent.

To determine whether θ_2 or θ_3 provides the better representation of the distribution of auroras will require much more accurate data. Also some refinement of the concept of θ_2 is probably desirable to judge its significance in relation to those theories which attribute the aurora to precipitation of charged particles directly (i.e. without geomagnetic trapping) from a solar wind. One might consider projections, along the geomagnetic field lines, from curves of constant field strength (rather than circles) in the equatorial plane.

As discussed in Part II, isolines of θ_3 should represent the isoaurores if auroras are excited by particles precipitated, via a longitude-independent mechanism, from the geomagnetically trapped radiation. The co-latitude type parameter θ_4, defined by $L \sin^2\theta_4 = 1$, where L is that parameter introduced by McIlwain (1961), closely approximates θ_3 and has the advantage of being derived from a somewhat more elegant concept.

IV. Acknowledgments

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V. References

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