VARIATIONS OF INTENSITY OF THE AURORA AT MACQUARIE ISLAND

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Summary

Observations of intensity of the aurora at Macquarie Island (geomagnetic co-ordinates 61 °S., 243 °E.) are examined. The intensity is found to be dependent on geomagnetic planetary disturbance index K_p but the form of this dependence is different for different auroral forms. After eliminating the effects of variation of K_p the residual diurnal and annual variations of intensity are small and irregular.

I. INTRODUCTION

The nocturnal variation of auroral "activity" has been examined by a number of workers (cf. Vegard 1912 ; Fuller 1933 ; Davies 1935) but agreement among them is very poor. The annual variation of auroral activity has been shown to exhibit maxima at the equinoxes and minima at the solstices (cf. Chapman and Bartels 1940, p. 474). A high correlation between auroral activity and magnetic activity has been claimed by some workers and denied by others (cf. Rooney 1934, p. 109). In these studies various measures of auroral activity have been used—in some cases the intensity, in some the frequency of occurrence, and in others a measure depending on intensity, area of sky covered, and type of aurora.

In an earlier paper (Jacka 1953) it was pointed out that the geomagnetic planetary disturbance index K_p was devised to measure the "intensity" of the solar particle stream producing the aurora and it will be inferred from the discussion of that paper that the definition of the term "intensity" must depend on the formulation of a satisfactory theory of the aurora and magnetic disturbance. It is considered that a study of the variations of intensity of the aurora and its dependence on K_p may contribute to this end.

For this purpose Parsons and Fenton's (1953) observations, which cover the period May 1950 to April 1951, have been examined. These observations were made at the Australian National Antarctic Research Expedition station at Macquarie Island (geomagnetic coordinates 61 °S., 243 °E.). The intensity I of the brightest display observed during each hour of G.M.T. is considered. These intensities were visually estimated on the usual 0–4 scale (cf. La Cour 1932) ; consequently they are very roughly proportional to the logarithms of the photometric intensities.

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II. Nocturnal Variation of Auroral Intensity

The mean nocturnal variation of I is shown in Figure 1 with the mean nocturnal variation in K_p derived from data associated with the same hours of observation. The values of K_p are taken to the nearest integer and are ascribed to each hour of the standard 3-hr periods. Mean magnetic midnight (as defined

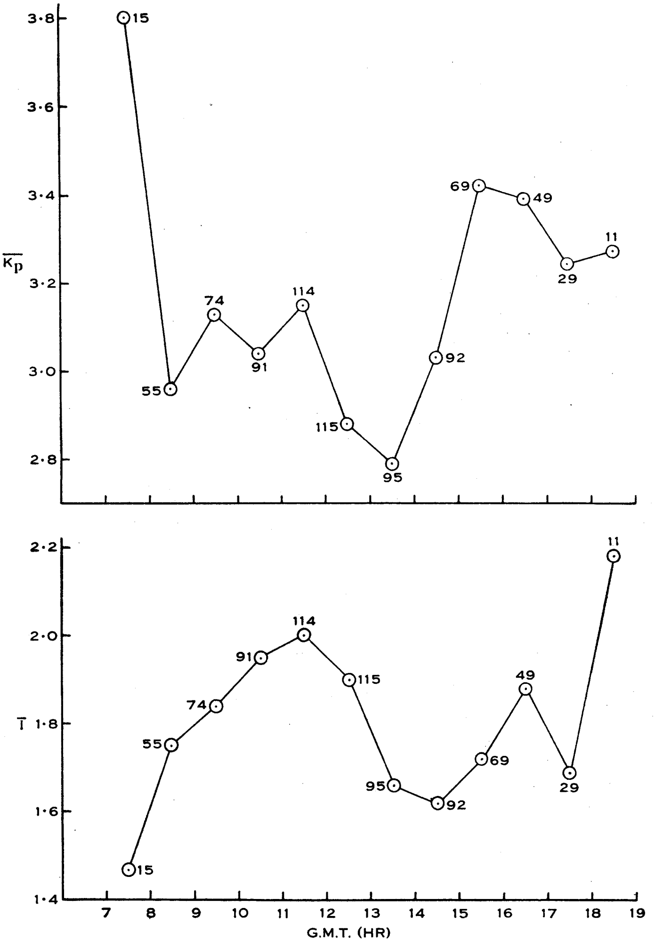

Fig. 1.—Nocturnal variation of intensity of the aurora, I, and K_p. (The numbers near the points indicate the number of observations used in computing the point.)

by McNish (1936)) is at 12·4 hr G.M.T. and geographic midnight at 13·4 hr G.M.T.

Figure 2 shows the mean value of I associated with each value of K_p, the straight line

$$I_{E1}=0\cdot 57+0\cdot 39K_p \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

through the points being fitted to the raw data by the least squares method.

Ordering the observations chronologically, we find

$$d=\Sigma(\Delta Z)^2/\Sigma Z^2=1\cdot 27<d_{L(5\%)}\simeq 2,$$

indicating serial correlation of the error term of the regression model significant at the 5 per cent. level (cf. Durbin and Watson 1951). (Z is deviation from regression, ΔZ's are first differences of Z.)

The mean $I-I_{E1}$ for each hour is shown in Figure 3. The distribution of points here suggests a relation of the form

$$I_{E2}=\alpha+\beta_2 K_p+\beta_3 \sin \frac{2\pi(t-9)}{8}, \quad \ldots\ldots\ldots\ldots\ldots \quad (2)$$

t being the mid point of the hour (G.M.T.) of observation. The least squares estimates and 95 per cent. confidence limits of the coefficients are $\alpha^*=0\cdot 56$,

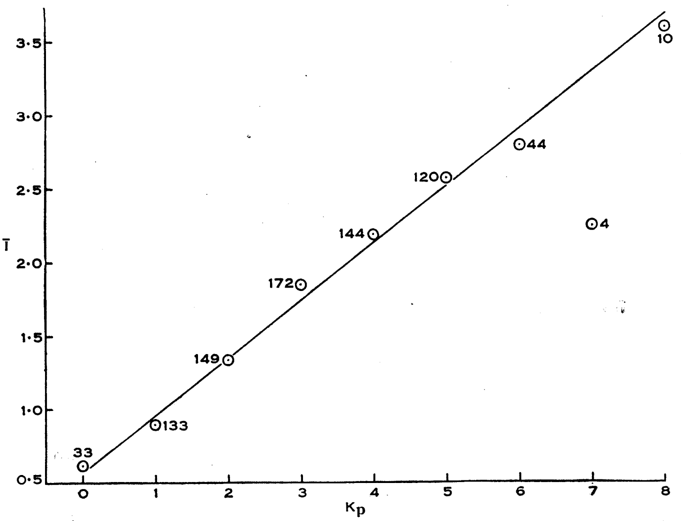

Fig. 2.—Dependence of intensity of the aurora, I, on K_p. (The numbers near the points indicate the number of observations used in computing the point.)

$\beta_2^*=0\cdot 39\pm 0\cdot 04$, $\beta_3^*=0\cdot 14\pm 0\cdot 09$. Again, however, $d=1\cdot 36<d_{L(5\%)}\simeq 2$, indicating serial correlation of the error term. The significance of the estimates above is, therefore, doubtful especially in the case of β_3^* (cf. Durbin and Watson 1950). The curve $0\cdot 14 \sin \{2\pi(t-9)/8\}$ is shown in Figure 3.

From the physical point of view the regression model is unsatisfactory if the error term is serially correlated. In attempting to improve the regression model the following possibilities should be considered:

(1) The intensity I may be dependent on some factor, other than K_p and t, which is not highly correlated with K_p or t.

(2) The observers' estimates of I may not be consistent; they may tend to be high for a while—say a few hours—then low for a while and so on.

(3) It may be that the relation between I, K_p, and t is different for different auroral forms and that the form of the brightest display during each hour shows

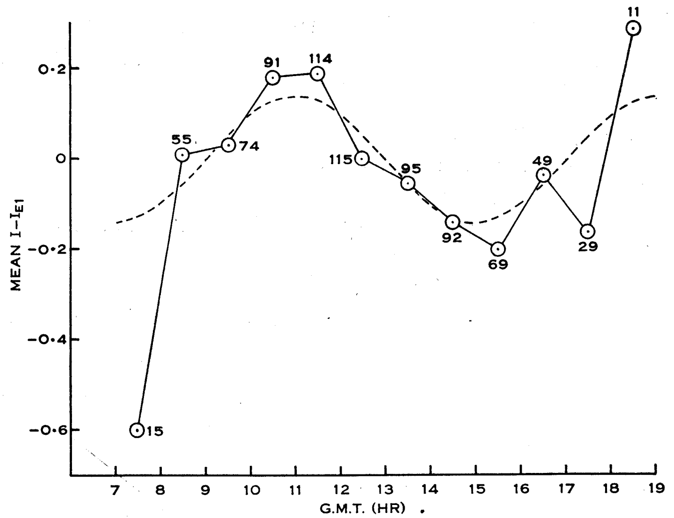

Fig. 3.—Nocturnal variation of deviations $I—I_{E1}$ of observed intensity from regression of I on K_p. The dotted curve is that of $0 \cdot 14 \sin \{2\pi(t—9)/8\}$. (The numbers near the points indicate the number of observations used in computing the point.)

some tendency to conservation. In fact, an examination of the observers' log (Parsons and Fenton 1953) shows quite clearly that a conservation of the form of the brightest display for several hours is quite common.

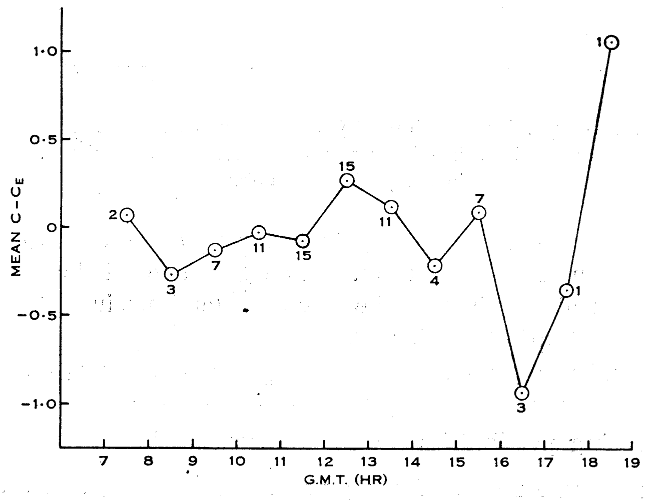

Fig. 4.—Nocturnal variation of deviation $C—C_E$ of observed corona intensities from regression on K_p. (The numbers near the points indicate the number of observations used in computing the point.)

In order to examine the plausibility of this last point the observations on "coronas" and on "homogeneous arcs" (H.A.) were examined. Denoting by C the intensity of the brightest corona during each hour in which a corona was observed we find

$$C_E = 1\cdot18 + (0\cdot29 \pm 0\cdot17)K_p, \quad \ldots\ldots\ldots\ldots\ldots \quad (3)$$

the limits being the 95 per cent. confidence limits of the coefficient of K_p. Serial correlation of the error term is not significant at the 5 per cent. level;

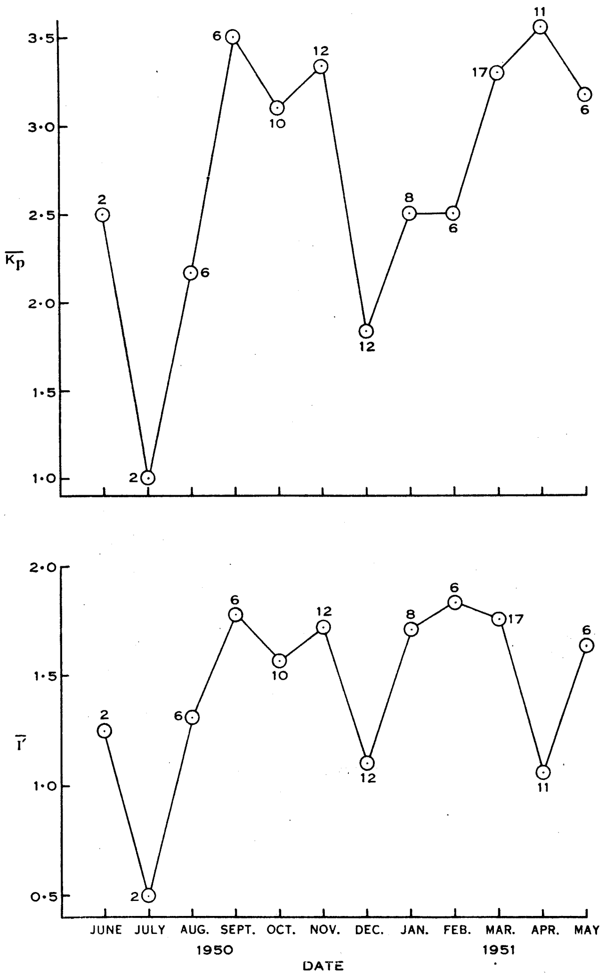

Fig. 5.—Annual variation of monthly mean auroral intensity I' and K_p. (The numbers near the points indicate the number of observations used in computing the point.)

$d = 1\cdot73 > d_{U(5\%)} = 1\cdot66$. (This is not surprising in view of the fact that the observations, 80 in all, were made over a period of 1 year so that there were rarely two or more observations during one night). The variation (which may not be significant) of $C - C_E$ with time of night is shown in Figure 4; its form is markedly different from that of $I - I_{E1}$ shown in Figure 3.

Denoting by A' the mean intensity of all H.A. observed during the one hour we find the regression of A' on K_p and also of A' on K_p and L' (mean latitude of H.A.) is not significant at the 5 per cent. level.

Point (3) above, then, does offer at least a partial explanation of the failure of the regression models considered above. In order to describe the variations of intensity of the aurora we must consider the dependence of intensity on K_p and t for each auroral form and also, separately, describe the sequence and concurrence of forms characteristic of the place of observation. That the

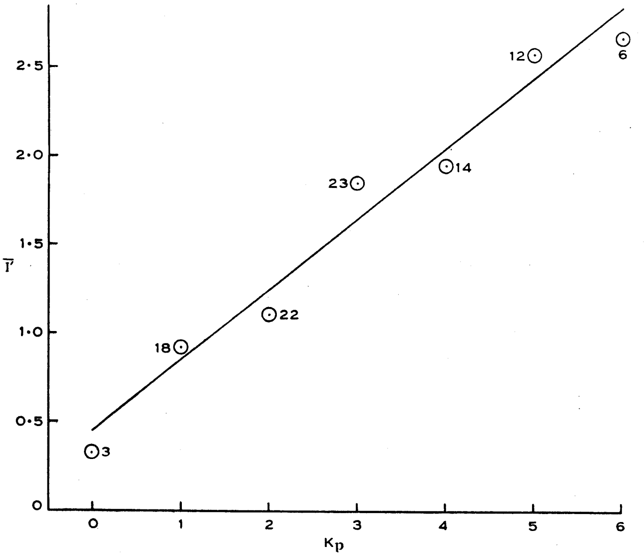

Fig. 6.—Dependence of intensity of aurora, I', on K_p. (The numbers near the points indicate the number of observations used in computing the point.)

sequence of forms is dependent on the place of observation is clear from the fact that the probability distribution of geographic position is different for different forms (cf. Jacka 1953, p. 227).

It is considered that these findings may explain the poor agreement among previous workers on the diurnal variation of auroral activity.

III. Annual Variation of Auroral Intensity

In order to study the annual variation of intensity of the aurora the mean values I' of the values of I for the hours 12–13, 13–14, and 14–15 hr G.M.T. were calculated for each day. In cases where only two values of I were available in this 3-hr period I' was taken as the mean of these; in cases where only one value was available this was not included in the sample.

Figure 5 shows the annual variation in monthly mean of I' and also of K_p for corresponding 3-hr periods. Figure 6 shows the mean I' associated with each value of K_p, the straight line

$$I'_E = 0\cdot45 + (0\cdot40 \pm 0\cdot10)K_p \quad \ldots\ldots\ldots\ldots \quad (4)$$

through the points being fitted to the raw data by the least squares method. The limits are the 95 per cent. confidence limits of the coefficient of K_p. In this case serial correlation of the error term is not significant at the 5 per cent. level; $d=1 \cdot 90 > d_{U(5\%)}=1 \cdot 69$.

The monthly mean values of $I'-I_E'$ are plotted in Figure 7; this shows the annual variation of intensity of the aurora after elimination of the effects of variation of K_p. The variation is small and irregular and may well be due to errors in estimating the intensity.

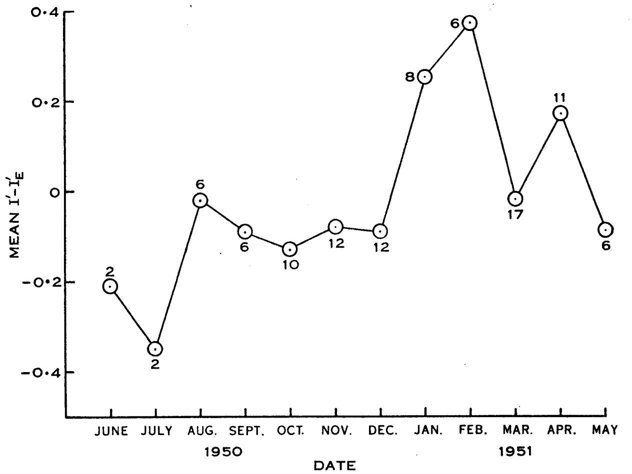

Fig 7.—Annual variation of deviations $I'-I_E'$ of observed intensity from regression on K_p. (The numbers near the points indicate the number of observations used in computing the point.)

IV. Conclusions

Even though visual estimates of the intensity of the aurora are very rough and subjective it appears likely that an application of the methods used above on such estimates may lead to descriptions of the variations of intensity of different auroral forms which would be of use in formulating a satisfactory physical theory of the phenomenon. The possibility should not be overlooked, of course, that the magnetic disturbance index K at the place of observation may provide more relevant information on the auroral intensity than does K_p.

V. Acknowledgments

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