ANALYSIS OF VISUAL AURORAL OBSERVATIONS AT HALLEY BAY, 1967

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Abstract. Visual observations made on the aurora at quarter-hourly intervals are analysed. Diurnal variations in occurrence of the various forms are obtained and variation in position of quiet homogeneous arcs is found. Comparison is made with the results of similar analyses for previous years.

The position of the Halley Bay station in 1967 was lat. 65·7°S., long. 24·2°E. geomagnetic. The geomagnetic pole (lat. 75·8°S., long. 111°E. geographic) was at an azimuth of 160·9° and the magnetic pole was 179° east of true north. Local midnight is 1 hr. 45 min. after midnight U.T. and geomagnetic midnight 3 hr. after midnight U.T.

Visual observations on the aurora were continued during 1967, those used in this analysis being made at the quarter, half, three-quarter and full hour U.T. They were not, as in most previous years, the responsibility of one person but became part of the geophysical programme and were made by J. Jamieson, W. R. Laidlaw and G. McWilliam.

To allow comparison with earlier years (Evans and Thomas, 1960; Sheret, 1963; Blackie, 1964; Blundell, 1965, 1967; Sievwright, 1967*a*, *b*; Shaw, 1968), the old classification system of auroral forms (Störmer, 1930) has been used in the analysis, although the system of the *International auroral atlas* was used in recording the observations.

Analysis of Results

Observations were made on 196 nights when the sun was more than 12° below the horizon. On 36 of these the sky was completely obscured throughout the night by cloud or drifting snow, whereas it remained clear and dark throughout on 12 nights. Aurorae were seen on 83 nights. The Fabry-Perot interference filters, which have been found useful by previous observers, were not in use and the number of nights on which it might have been possible to detect auroral light through cloud is not known. On only two of the 12 clear dark nights was no aurora seen and on both of these nights the sun was more than 12° below the horizon for only a few hours. Aurorae were overhead (within 0·5° of the latitude of the station) on 16 nights. Overhead aurorae should have been observed, if present, unless the sky was completely obscured and thus were seen on 10 per cent of possible nights. On the basis of these values it appears that there was no marked increase from solar minimum (I.Q.S.Y.) values.

Observations made in clear dark conditions are summarized in Table I. The four observations made in each hourly interval were those at a quarter past, half past, a quarter to and on the hour (e.g. 18–19 U.T. includes observations made at 18.15, 18.30, 18.45 and 19.00 U.T.). Table II includes all observations made with the sun more than 12° below the horizon.

The rows of Tables I and II give the following information:

a. Number of observations.
b. Number of observations with aurorae present.
c. Number of observations with active forms present.
d. Number of observations with overhead aurorae present.
e. Number of observations with diffuse surfaces present.
f. Number of observations with glows present.
g. Number of observations with quiet homogeneous arcs present.

Rows *b′* . . . . *g′* give the respective percentage frequencies using the values in row *a* of each table.

The final column in each table gives the total number of observations for the year and the respective percentage frequencies.

All the types of pulsing and activity described in the *International auroral atlas* were seen during the year and are included in the active forms of row *c*.

TABLE I. DIURNAL VARIATIONS
(Clear dark periods)

U.T.	17	18	19	20	21	22	23	00	01	02	03	04	05	06	07	08	09	10	11	12	*Totals*
a			3	9	41	70	78	99	92	86	90	77	72	57	53	34	32	4			897
b			3	6	17	28	46	64	76	64	65	60	53	40	34	13	5				574
c						1	7	10	11	10	9	8	6	15	7						84
d						1	4	7	5	1			1	9	5						33
e				1	4	1	1	6	16	11	6	5	4	8	4	1	2				70
f			3	6	13	9	11	10	8	4	10	2	7	3	1						87
g						10	14	14	15	17	12	16	12	9	16	5					140
																					(per cent)
b′		100·0	66·7	41·5	40·1	59·0	64·6	82·6	74·4	72·2	77·9	73·6	70·2	64·2	38·2	15·6					64·0
c′					1·4	9·0	10·1	12·0	11·6	10·0	10·4	8·3	26·3	13·2							9·4
d′					1·4	5·1	7·1	5·4	1·2			1·4	15·8	9·4							3·7
e′			11·1	9·8	1·4	1·3	6·1	17·4	12·8	6·7	6·5	5·6	14·0	7·5	2·9	6·3					7·8
f′		100·0	66·7	31·7	12·9	14·1	10·1	8·7	4·7	11·1	2·6	9·7	5·3	1·9							9·7
g′					14·3	17·9	14·1	16·3	19·8	13·3	20·8	16·7	15·8	30·2	14·7						15·6

TABLE II. DIURNAL VARIATIONS
(Sun more than 12° below horizon)

U.T.	17	18	19	20	21	22	23	00	01	02	03	04	05	06	07	08	09	10	11	12	*Totals*
a		18	47	118	337	516	660	726	754	760	760	748	722	624	547	479	330	141	9	1	8,297
b			3	12	23	45	95	142	198	188	183	179	148	111	104	80	47	21	6	1	1,586
c						1	12	16	30	22	17	16	16	23	11	9	3	4			180
d						1	5	9	19	11	11	14	14	21	14	8	5	3			135
e				3	3	6	23	44	71	65	47	59	64	45	43	35	15	12	2		537
f			3	6	13	14	16	16	16	15	28	19	16	7	5	4	4	2			184
g						10	21	30	33	30	32	33	20	19	18	5					251
																					(per cent)
b′			6·4	10·2	6·8	8·7	14·4	19·6	26·3	24·7	24·1	23·9	20·5	17·8	19·0	16·7	14·2	14·9	66·7	100·0	19·1
c′						0·2	1·8	2·2	4·0	2·9	2·2	2·1	2·2	3·7	2·0	1·9	0·9	2·8			2·2
d′						0·2	0·8	1·2	2·5	1·4	1·4	1·9	1·9	3·4	2·6	1·7	1·5	2·1			1·6
e′				2·5	0·9	1·2	3·5	6·1	9·4	8·6	6·2	7·9	8·9	7·2	7·9	7·3	4·5	8·5	22·2		6·5
f′			6·4	5·1	3·9	2·7	2·4	2·2	2·1	2·0	3·7	2·5	2·2	1·1	0·9	0·8	1·2	1·4			2·2
g′						1·9	3·2	4·1	4·4	3·9	4·2	4·4	2·8	3·0	3·3	1·0					3·0

Row *d* includes all observations when auroral light was present between 60° and 120° above the southern horizon.

Diffuse surfaces, row *e*, are patches and also veils and non-identifiable forms whose lower borders were above the horizon.

Glows, row *f*, consist of veils and non-identifiable forms whose lower borders did not extend above the horizon.

Fig. 1 shows for each year from 1956 to 1967 the variation in percentage frequency of occurrence in clear dark periods of all aurorae and of overhead aurorae. The percentage occurrence of all aurorae has changed little in recent years but the 1967 value is slightly higher than that for 1966. The occurrence of overhead aurorae also has altered only slightly in recent years but the rising trend since 1965 is maintained.

Fig. 2 similarly gives the values for quiet homogeneous arcs, active forms and diffuse surfaces. Arcs occurred less frequently than in 1966 and again the level of occurrence since 1963 has not changed much. This can also be said of diffuse surfaces (the 1964 value was surprisingly high) but the upward trend since 1965 has continued. Active forms were less common than in 1966 but they occurred more frequently than in the years from 1961 to sunspot minimum in 1965.

Flaming was observed on 50 occasions in 1967. 19 of these observations were made in clear dark conditions, a percentage occurrence of 2·1. These are nearly ten times the corresponding values for 1966 and the total number of occurrences was greater than that for any year since 1962. The variations for 1957–67 are shown in Fig. 3.

Colour class *a* (red type A) was never recorded in 1967. Colour class *b* (red type B) was seen on 12 occasions, colour class *d* on four and class *e* on 11, in one of these occurring along with blue coloration. The occurrences of red types A and B since 1956 are shown in Fig. 4. The variation is irregular but it appears that colour is frequent only in years near sunspot maximum.

The diurnal variations in occurrence of the forms listed in Tables I and II are shown in Figs. 5 to 10. Solid lines show the variations in clear dark periods (Table I), while dotted lines show those in all conditions (Table II). The observations were made regularly between the hours of 20.00 and 09.00 U.T. Outside these times observations were usually made only if aurorae were present. The values for hours between 20.00 and 09.00 U.T. are shown on the graphs.

When the diurnal variation of occurrence of all aurorae shown in Fig. 5 is studied, it is seen that the maximum value on both curves occurs at hour 00.00–01.00 U.T. In all other years the maximum in the curves obtained from clear dark observations does not occur before local midnight and it is usually around geomagnetic midnight. (In 1957 and 1958 the percentage was 100 for much of the night but the period of maximum occurrence was fairly symmetrical about 03.00 U.T.) There is a secondary maximum at 03.00–04.00 U.T. on the clear dark curve but this is not apparent on the curve obtained from all observations, so that a shift towards the evening has occurred.

The diurnal variations in active aurorae are shown in Fig. 6. On the clear dark curve there is a large peak in the morning at hour 05.00–06.00 U.T. and a smaller one in the curve at hour 00.00–01.00 U.T. On the curve obtained from all observations, the two peaks are of equal importance. The earlier of the peaks occurs at the time of the maximum in the diurnal variation of occurrence of all aurorae but the morning peak shows that the aurorae are more active at this time.

The diurnal variation in occurrence of overhead aurorae (Fig. 7) in clear dark conditions suggests that there was a period around geomagnetic midnight when overhead aurorae were unusual. This seems unlikely in view of the movement of quiet arcs relative to the station and it is reassuring to observe that the curve for all conditions, while bimodal, does not follow the clear dark curve in the period around 03.00 U.T. The maximum on the clear dark curve coincides with that for active aurorae (Fig. 6), while the smaller peak is very close to the time of the smaller peak on the active aurorae curve. The two curves (Figs. 6 and 7) for all conditions are similar. Between 03.00 and 06.00 U.T. the frequency of occurrence of overhead aurorae was about 90 per cent of that of active aurorae, suggesting that during this period the region of active aurorae moved closer to the station, although at that time the aurora was not especially active.

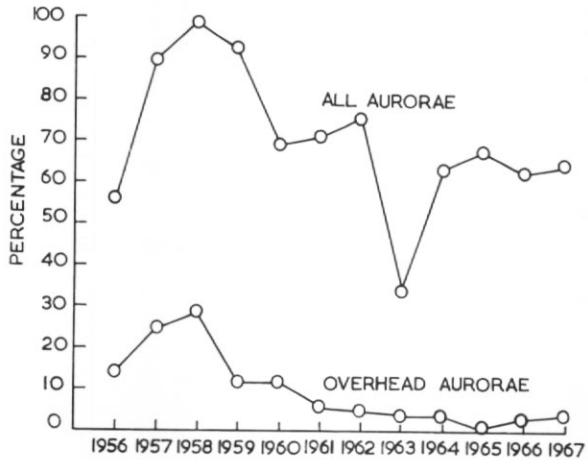

Fig. 1. Occurrence of all aurorae and overhead aurorae, 1956–67.

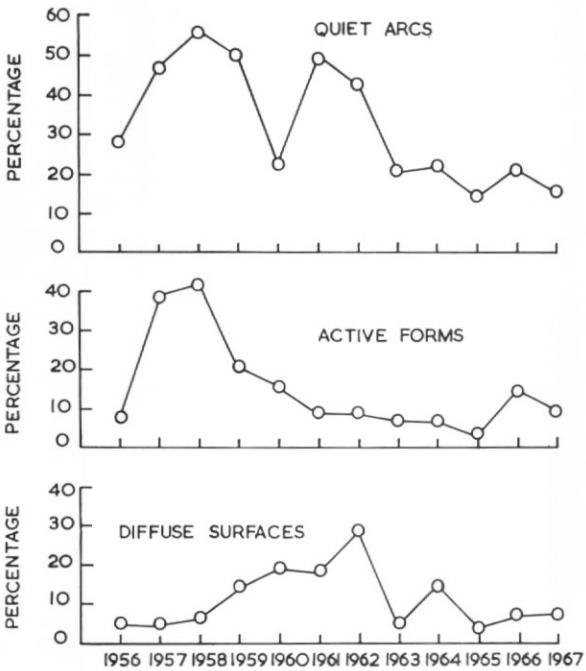

Fig. 2. Occurrence of various auroral forms, 1956–67. Values for active forms and diffuse surfaces in 1959 are for all clear periods, including moonlit periods.

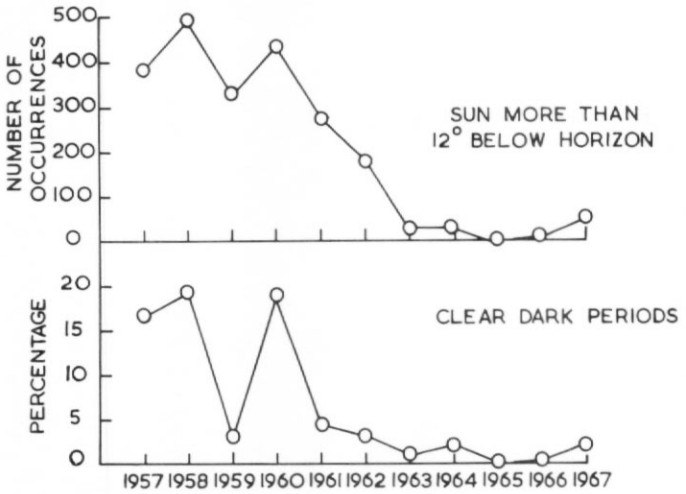

Fig. 3. Occurrence of flaming, 1957–67.

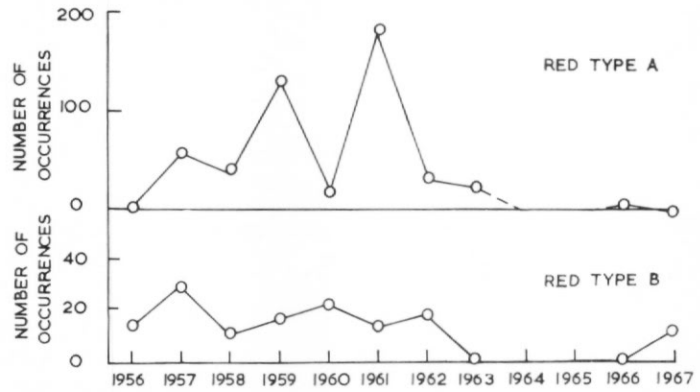

Fig. 4. Occurrence of red types A and B, 1956–67.

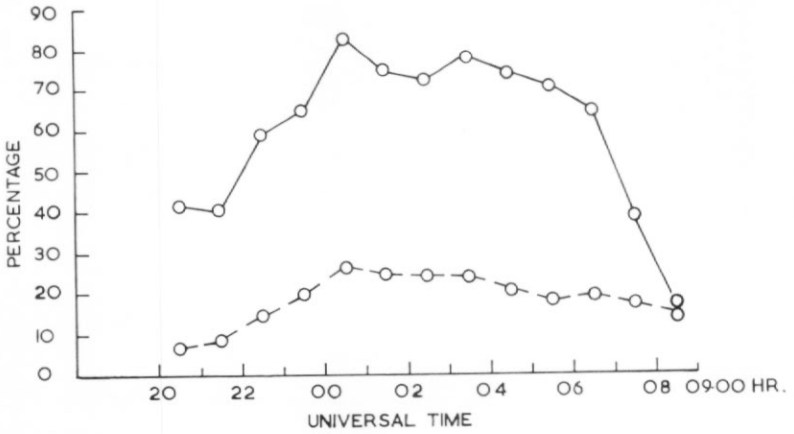

Fig. 5. Diurnal variation of all aurorae, 1967.

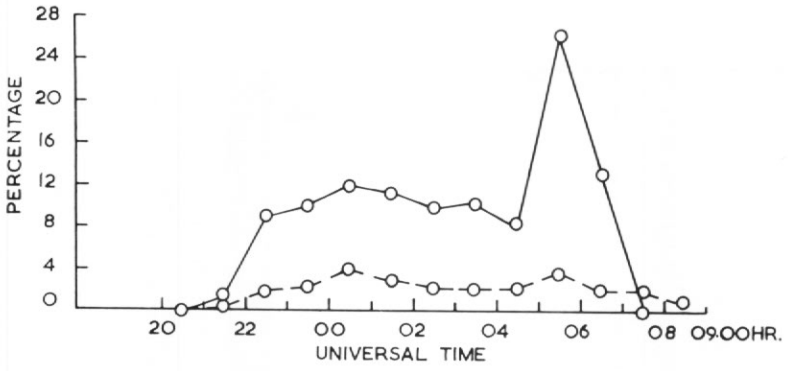

Fig. 6. Diurnal variation of active aurorae, 1967.

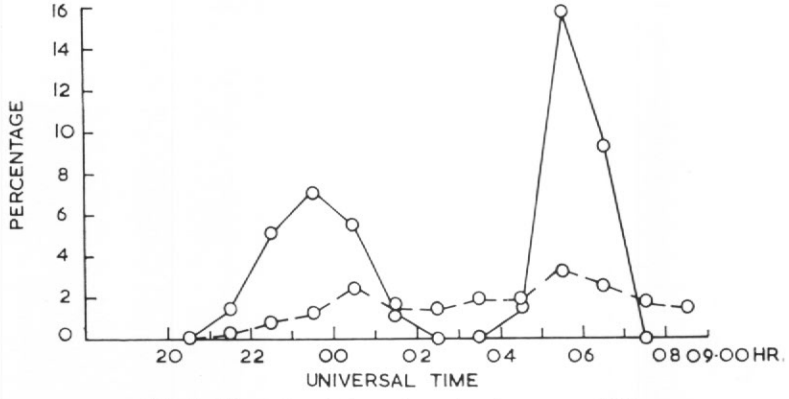

Fig. 7. Diurnal variation of overhead aurorae, 1967.

The diurnal variations in occurrence of diffuse surfaces shown in Fig. 8 are irregular. The maximum in the clear dark curve is at hour 00.00–01.00 U.T. and there is a subsidiary maximum at hour 05.00–06.00 U.T. The latter coincides with maxima in the corresponding curves for active and overhead aurorae. From the curves obtained from all observations it is seen that diffuse surfaces are unusual early in the night but from 23.00 to 08.00 U.T. the frequency of occurrence is about 7·5 per cent. In most previous years diffuse surfaces became more frequent in the morning hours. Since 1963, however, this tendency has not been as marked. It is possible that, following the introduction of the new classification system in 1964, forms not earlier considered to be diffuse surfaces have been included in this category.

Since 1960 the diurnal variation in occurrence of glows has been found for each year except 1966. The variation for 1967 is shown in Fig. 9. There is a decrease in frequency throughout the night except for a period around 03.00 U.T. This is the time at which the auroral belt is expected to be farthest from the pole so an increase in the occurrence of glows at this time suggests that aurorae inside the main auroral belt were being observed. The pattern of high values early in the night followed by a decrease is unlike that found during I.Q.S.Y. but it resembles the variation found in earlier years. The general occurrence of glows thus seems to have been a feature of only the quietest years.

The diurnal variations in occurrence of quiet homogeneous arcs are shown in Fig. 10. On the clear dark curve there is a rapid rise from zero to a level about which the frequency of occurrence varies relatively little (except at hour 06.00–07.00 U.T.) until it drops to zero again at hour 08.00–09.00 U.T. This is unusual, resembling only the corresponding curve for 1964. The curve drawn by using all observations also rises quickly to a level near which it remains until 07.00 U.T.

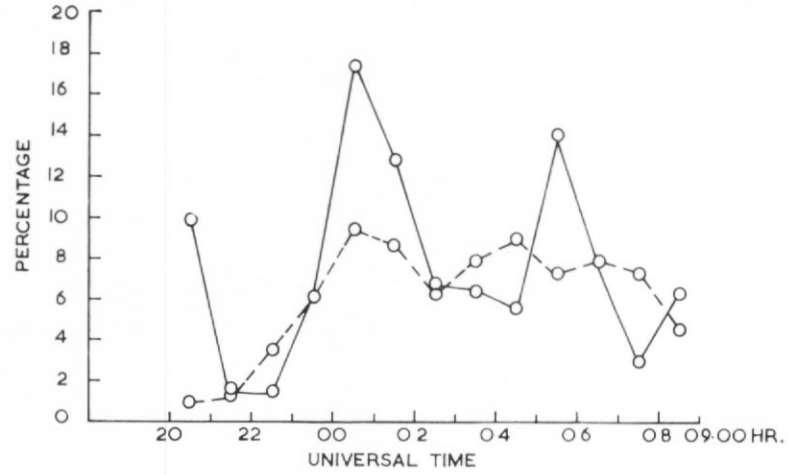

Fig. 8. Diurnal variation of diffuse surfaces, 1967.

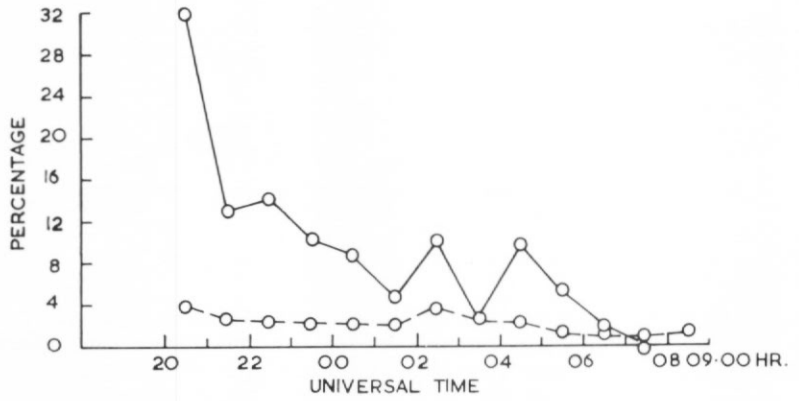

Fig. 9. Diurnal variation of glows, 1967.

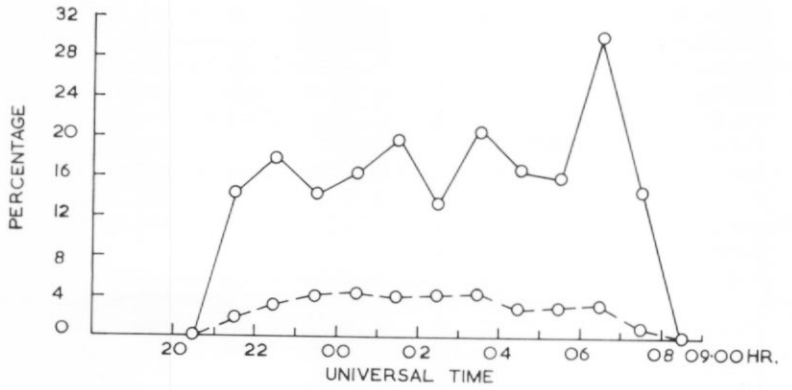

Fig. 10. Diurnal variation of quiet homogeneous arcs, 1967.

The distributions of arcs in geomagnetic latitude and azimuth are shown as histograms in Fig. 11. The median geomagnetic latitude (obtained by converting the median elevation, assuming a height of 100 km.) was 72·3° with interquartile values of 71·0° and 73·2°. The distribution is thus no broader than in a number of previous years. The median azimuth was 172·5° east of true north with interquartiles of 166·6° and 180·7°. This is a greater spread in azimuth than has been previously observed.

The variations in median latitude and azimuth during 1956–67 are shown in Fig. 12. Also indicated are the interquartile ranges. In latitude there has been a gradual and possibly systematic change in the median value since 1962. From 1956 to 1960 there was an apparently systematic change (Sheret (1963) commented on the change for 1956 to 1959). The discontinuity, if it be so, between 1960 and 1962 is not understood. The variation in co-latitude since 1962 follows that of activity on the sun with a lag of about 2 years. The variation in years near sunspot maximum cannot be explained in this way. The high latitudes during the I.G.Y. are especially difficult to understand; it might be that the arcs seen during the most active years were representative of the inner edge of the auroral oval rather than the whole oval. The yearly values have not been corrected for changes in the diurnal variation in occurrence from year to year. A correction was applied by Sievwright (in press) for the years up to

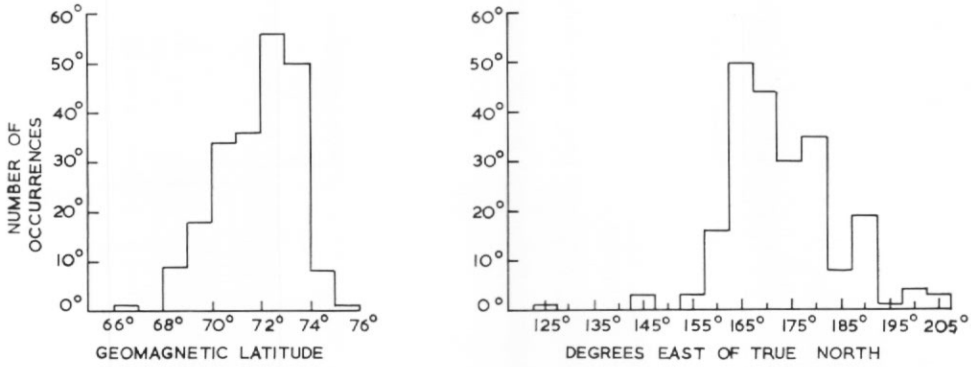

Fig. 11. Geomagnetic latitudes and azimuth distribution of quiet homogeneous arcs in 1967.

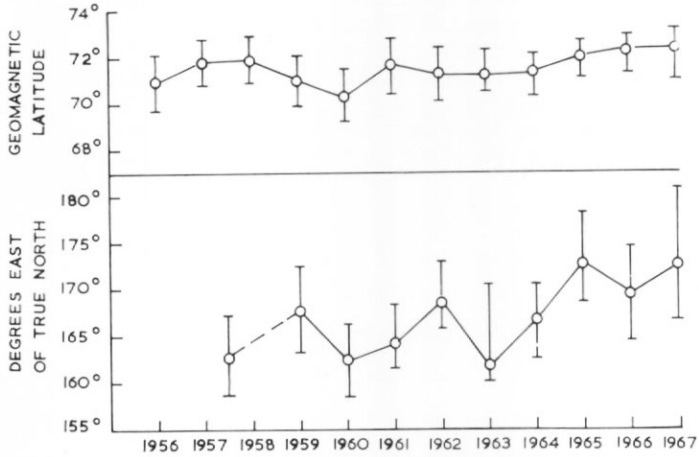

Fig. 12. Median latitudes and median azimuth positions of quiet homogeneous arcs, 1956–67.

1965 and the semblance of systematic variation disappeared. Since it is possible to draw on the latitude plot a horizontal line passing within all the interquartile ranges, no systematic change can be considered established.

In the case of azimuth, the variation is irregular. However, the median value for each of the last 3 years is higher than that of any earlier year and it is possible that a solar-controlled or secular variation is present.

The diurnal variations in position during 1967 are shown in Fig. 13. The variation in latitude is a familiar one with the lowest value being reached at hour 03.00–04.00 U.T., the arcs being found nearer the pole in the evening and the morning. The variation in azimuth does not show the increase throughout the night which is the normal pattern at the station. The azimuth is surprisingly high for hours 02.00–03.00 and 03.00–04.00 U.T. Outside these hours there is a slight increase from evening to morning.

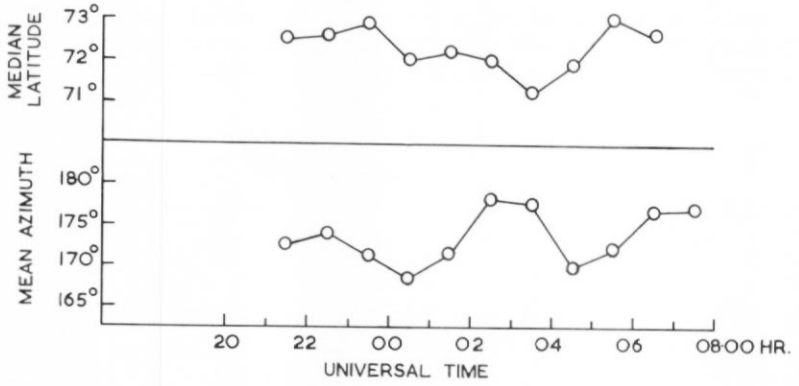

Fig. 13. Diurnal variations in median geomagnetic latitude and mean azimuth of quiet homogeneous arcs in 1967.

Conclusions

The general level of occurrence of all auroral forms and of quiet forms showed little evidence of change from those of the quiet sun years. However, activity increased a little and it was accompanied by more frequent coloration of the displays.

The diurnal-variation curve for all aurorae was shifted towards the evening but activity was more frequent in the morning than earlier in the night.

Quiet arcs were, unusually, seen with much the same frequency for most of the night. The positions occupied by arcs were not exceptional, although their distribution in azimuth was slightly broader than has often been found, and the systematic variation throughout the night was not evident. On the basis of the Halley Bay observations, a solar-controlled variation in position of quiet homogeneous arcs is not yet certain.

MS. received 26 November 1968

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