# ANALYSIS OF VISUAL AURORAL OBSERVATIONS AT HALLEY BAY, 1965

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ABSTRACT. A statistical analysis is made of visual auroral observations at the Halley Bay station in 1965. The diurnal variations in occurrence of the various auroral forms are given, and the positions of quiet arcs in geomagnetic latitude and azimuth have been determined. A comparison is made with the results of previous years.

IN 1965, the position of the Halley Bay station was lat. 75°31′S., long. 26°44′W. in geographical coordinates or lat. 65·7°S., long. 24·2°E. in geomagnetic coordinates (taking the coordinates of the geomagnetic pole as lat. 78·5°S., long. 111°E.). The direction of the geomagnetic pole is 160·9° east of true north and the magnetic pole lies 179° east of true north. Local midnight is 1 hr. 45 min. after midnight U.T. and geomagnetic midnight is 3 hr. after midnight U.T.

As in 1964, the observations were carried out by the author. Those used in this analysis were made at 15 min. intervals whenever the sun was more than 12° below the horizon (except during the darkest months when the period of observation was normally from 18.15 to 10.00 U.T. and for a time in April when other commitments at the station curtailed observations in the morning hours).

In recording the observations the classification system of the *International auroral atlas* was used. However, in the analysis the forms have been grouped according to the older system of the *Photographic atlas of auroral forms* in order that a comparison with the results of previous years could be made.

## ANALYSIS OF RESULTS

The sun was more than 12° below the horizon on 200 nights in 1965. Observations were made on each of these nights. On 18 nights the sky was completely obscured by cloud or drift snow but, although this figure compares favourably with that for 1964, the sky was clear and dark on only eight nights. Aurorae were seen on 99 nights and they were detected on a further 25 with the aid of Fabry-Perot interference filters transmitting the 5577 Å line of monatomic oxygen. No clear dark night occurred during which aurorae were absent. Aurorae reached the overhead position on six nights, i.e. 3·3 per cent of possible nights if it is considered that overhead aurorae could be seen provided that the sky was not completely obscured. Although there were more aurorae than in 1964, fewer of these reached the overhead position.

The diurnal variations of the various auroral forms, using only observations made in clear dark periods, are given in Table I. Observations made in each hourly interval refer to observations made at quarter past, half past, quarter to and on the hour (i.e. 21.00–22.00 U.T. includes observations made at 21.15, 21.30, 21.45 and 22.00 U.T.). The data in Table II are similar but all observations made while the sun was more than 12° below the horizon are included.

The individual rows of Tables I and II list the following:

*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 last column in each table gives the total number of observations made during the year with the various forms present and the respective percentage frequencies.

Row *c* includes all the types of activity and pulsing recorded at 15 min. observations during the year, namely conditions $a_2$, $a_4$ and $p_3$, also activity not well described by any of the condition symbols of the *International auroral atlas*, denoted in the records by *a*.

TABLE I. DIURNAL VARIATIONS
(Clear dark periods)

| U.T. | 18 | 19 | 20 | 21 | 22 | 23 | 00 | 01 | 02 | 03 | 04 | 05 | 06 | 07 | 08 | 09 | 10 | *Totals* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *a* | 32 | 55 | 64 | 49 | 57 | 62 | 84 | 87 | 92 | 92 | 86 | 83 | 82 | 75 | 74 | 51 | | 1,125 |
| *b* | 4 | 15 | 27 | 18 | 38 | 48 | 68 | 70 | 76 | 83 | 72 | 62 | 59 | 53 | 43 | 21 | | 757 |
| *c* | | 1 | 1 | | | 2 | 2 | 2 | 4 | 4 | 1 | 3 | 7 | 7 | 2 | | | 36 |
| *d* | | | | | | | | 1 | | | | | | 3 | 1 | | | 5 |
| *e* | | | 2 | | 2 | 2 | 1 | 3 | 5 | 7 | 2 | 2 | 6 | 10 | 4 | | | 46 |
| *f* | | 4 | 6 | 4 | 4 | 5 | 11 | 4 | 10 | 7 | 8 | 5 | | 2 | 2 | | | 72 |
| *g* | | | 1 | 2 | 6 | 6 | 11 | 13 | 17 | 25 | 29 | 20 | 18 | 12 | 1 | | | 161 |
| *b′* | 12·5 | 27·3 | 42·2 | 36·7 | 66·6 | 77·4 | 80·9 | 80·4 | 82·6 | 90·2 | 83·7 | 74·7 | 72·0 | 70·6 | 58·1 | 41·2 | | (per cent) 67·3 |
| *c′* | | 1·8 | 1·6 | | | 3·2 | 2·4 | 2·3 | 4·3 | 4·3 | 1·2 | 3·6 | 8·5 | 9·3 | 2·7 | | | 3·2 |
| *d′* | | | | | | | | 1·1 | | | | | | 4·0 | 1·4 | | | 0·4 |
| *e′* | | | 3·1 | | 3·5 | 3·2 | 1·2 | 3·4 | 5·4 | 7·6 | 2·3 | 2·4 | 7·3 | 13·3 | 5·4 | | | 4·1 |
| *f′* | | 9·1 | 9·4 | 8·2 | 7·0 | 8·1 | 13·1 | 4·6 | 10·9 | 7·6 | 9·3 | 6·0 | | 2·7 | 2·7 | | | 6·4 |
| *g′* | | | 1·6 | 4·1 | 10·5 | 9·7 | 13·1 | 15·7 | 18·5 | 27·2 | 33·7 | 24·1 | 22·0 | 16·0 | 1·4 | | | 14·3 |

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

| U.T. | 18 | 19 | 20 | 21 | 22 | 23 | 00 | 01 | 02 | 03 | 04 | 05 | 06 | 07 | 08 | 09 | 10 | *Totals* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *a* | 361 | 477 | 569 | 638 | 705 | 752 | 787 | 800 | 791 | 764 | 722 | 641 | 588 | 511 | 414 | 316 | | 9,836 |
| *b* | 14 | 31 | 49 | 67 | 110 | 160 | 210 | 229 | 239 | 237 | 201 | 187 | 159 | 133 | 83 | 41 | | 2,150 |
| *c* | | 1 | 1 | 1 | | 4 | 17 | 20 | 11 | 5 | 1 | 3 | 15 | 13 | 4 | | | 96 |
| *d* | | | 3 | 3 | | | 5 | 9 | 5 | | | | 4 | 4 | 1 | | | 34 |
| *e* | | | 2 | 1 | 2 | 2 | 3 | 6 | 10 | 5 | 2 | 3 | 16 | 14 | 4 | | | 70 |
| *f* | 2 | 8 | 11 | 14 | 22 | 18 | 34 | 27 | 34 | 27 | 23 | 15 | 6 | 3 | 3 | | | 247 |
| *g* | | | 1 | 6 | 15 | 15 | 18 | 29 | 33 | 54 | 64 | 46 | 35 | 20 | 6 | 2 | | 344 |
| | | | | | | | | | | | | | | | | | | (per cent) |
| *b′* | 3·9 | 6·5 | 8·6 | 10·5 | 15·6 | 21·3 | 26·7 | 28·6 | 30·2 | 31·0 | 27·8 | 29·2 | 27·0 | 26·0 | 20·0 | 13·0 | | 21·9 |
| *c′* | | 0·2 | 0·2 | 0·2 | | 0·6 | 2·2 | 2·5 | 1·4 | 0·7 | 0·1 | 0·5 | 2·6 | 2·5 | 1·0 | | | 1·0 |
| *d′* | | | 0·5 | 0·5 | | | 0·6 | 1·1 | 0·6 | | | | 0·7 | 0·8 | 0·2 | | | 0·3 |
| *e′* | | | 0·4 | 0·2 | 0·3 | 0·3 | 0·4 | 0·8 | 1·3 | 0·7 | 0·3 | 0·5 | 2·7 | 2·7 | 1·0 | | | 0·7 |
| *f′* | 0·6 | 1·7 | 1·9 | 2·2 | 3·1 | 2·4 | 4·3 | 3·4 | 4·3 | 3·5 | 3·2 | 2·3 | 1·0 | 0·6 | 0·7 | | | 2·5 |
| *g′* | | | 0·2 | 0·9 | 2·1 | 2·0 | 2·3 | 3·6 | 4·2 | 7·1 | 8·9 | 7·2 | 6·0 | 3·9 | 1·4 | 0·6 | | 3·5 |

Row *d* includes all observations of aurorae when luminescence was present between 60° and 120° elevation.

In Fig. 1 the percentage frequencies of occurrence during clear dark periods of all aurorae and overhead aurorae (last column of rows *b'* and *d'* in Table I) are compared with the values for 1956 to 1964. In the case of all aurorae, there has been little change from the 1964 value but that change is to a higher value. On the other hand, overhead aurorae have become extremely rare, the percentage frequency now being less than 0·5 per cent. This represents a decrease by almost a factor of ten from the already low value for 1964.

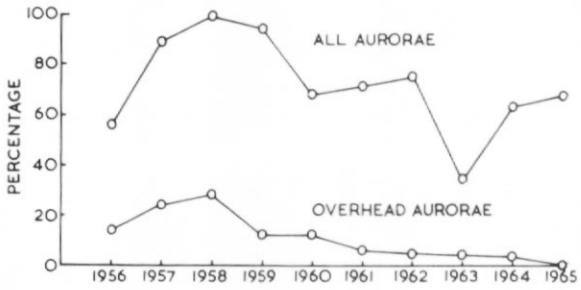


Fig. 1. Occurrence of all aurorae and overhead aurorae, 1956–65.

Fig. 2 similarly compares the values for quiet arcs, active forms and diffuse surfaces. The frequency of occurrence of quiet arcs is lower than in any year since observations were first made in 1956. The decrease since 1964 is substantial.

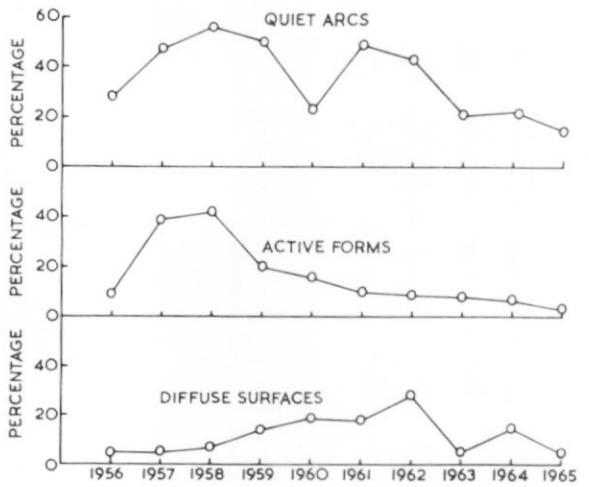


Fig. 2. Occurrence of various auroral forms, 1956–65. Values for active forms and diffuse surfaces in 1959 are for all clear periods, including moonlit periods.

Active forms occurred for little more than 3 per cent of the clear dark periods. This again is a marked decrease from the 1964 value and it carries the downward trend evident since 1958 to a value well below any hitherto recorded.

The frequency with which diffuse surfaces occurred dropped from the value for 1964 to the level of the values for 1956–58 (and 1963; but see Sievwright (1967)).

Flaming was never observed at any of the 15 min. observations and hence in Fig. 3, which compares the percentage frequency of occurrence of flaming for 1956–65, both curves drop to zero for 1965. However, flaming was observed for a short period at 07.07 U.T. on 4–5 May.

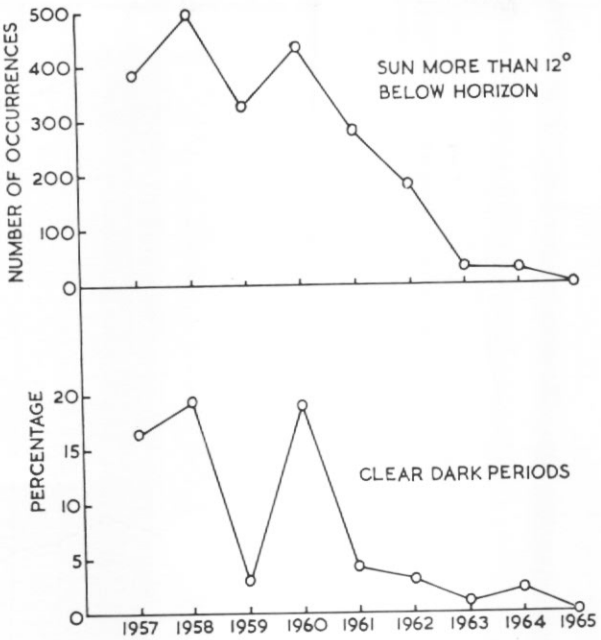


Fig. 3. Occurrence of flaming, 1957–65.

Flickering was observed on a number of occasions and it should be noted that weak flaming might escape notice when flickering is present. However, it is certain that flaming occurred less frequently in 1965 than in any year since the Halley Bay station was established.

Red type A was never recorded in 1965. Since, during the bright active display of 27–28 September, other station personnel reported seeing red coloration at a time when the author did not record either type A or type B, it appears certain that the lack of recorded red coloration is due to the author's defective colour vision.

All values for previous years are taken from Sievwright (1967).

Figs. 4–9 give the diurnal variations of the various forms using the values in rows $b' \ldots g'$ of Tables I and II. Values from Table I are plotted as open circles joined by full lines while those from Table II are plotted as open circles joined by broken lines.

The diurnal variation of all aurorae is shown in Fig. 4. The curve reaches a maximum in hour 03.00–04.00 U.T. This is an hour later than in 1964 but it is still earlier than in previous years. The curve rises to a value only a little less than its maximum by hour 00.00–01.00 U.T. and it remains at that level for some further hours. It thus appears that there has been a shift from morning hours to evening hours when quiet sun years are compared with years with greater sunspot activity.

In the case of active aurorae (Fig. 5) the shift to morning hours noted in 1964 is maintained although the effect is not so marked. When all periods with the sun more than 12° below the horizon are considered, the curve of diurnal variation is bimodal, the morning peak being accompanied by a peak of equal size near local midnight. The size of this peak is due to aurorae occurring in late September, at which time observations could be made for only an hour or so around local midnight. Since cloud was present during these displays, the effect is not seen in the curve for clear dark periods.

The diurnal variations of overhead aurorae shown in Fig. 6 are unlikely to be of great significance, as the total number of occurrences involved is in each case very small. The peak around local midnight is again due to displays in late September but, in view of the correspondence between active and overhead aurorae suggested by Sievwright (1967), the morning peak may be of greater significance.

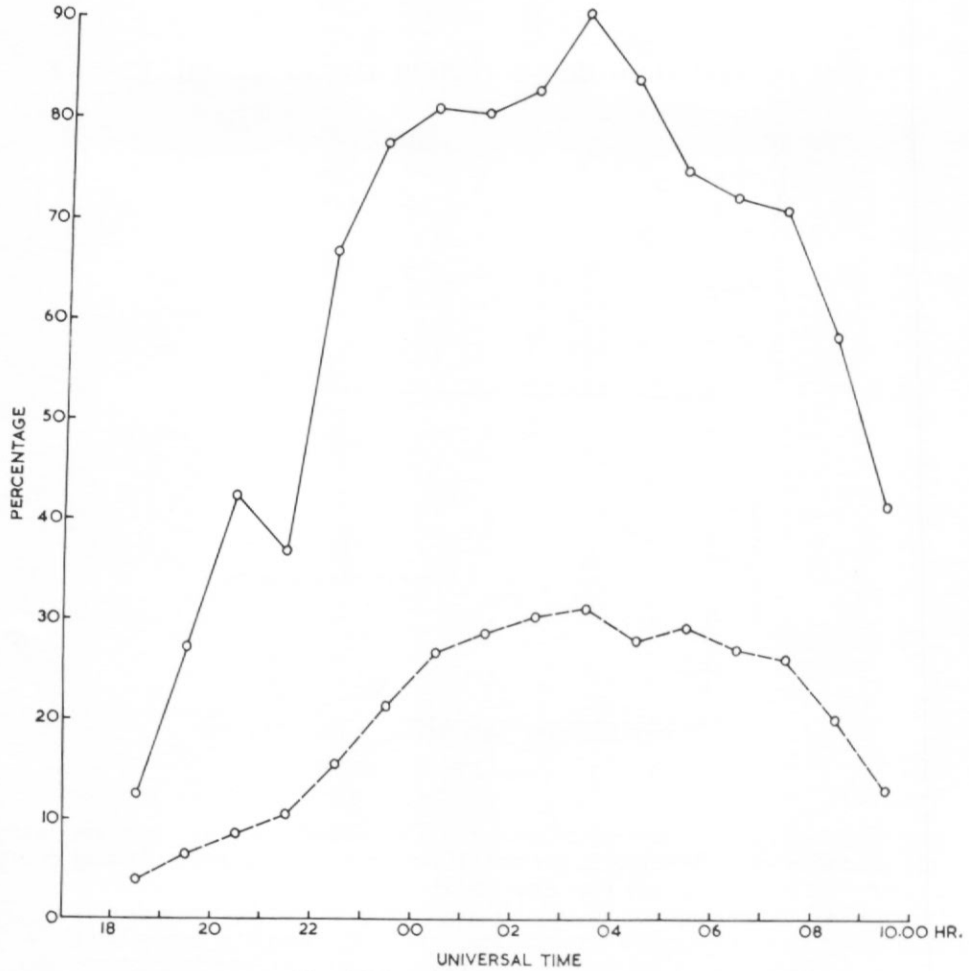


Fig. 4. Diurnal variation of all aurorae.

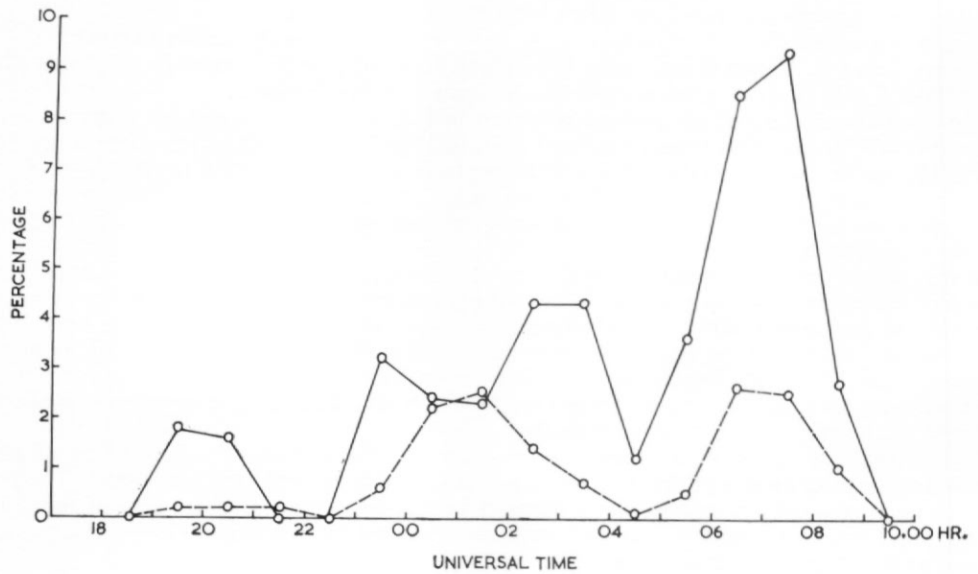


Fig. 5. Diurnal variation of active aurorae.

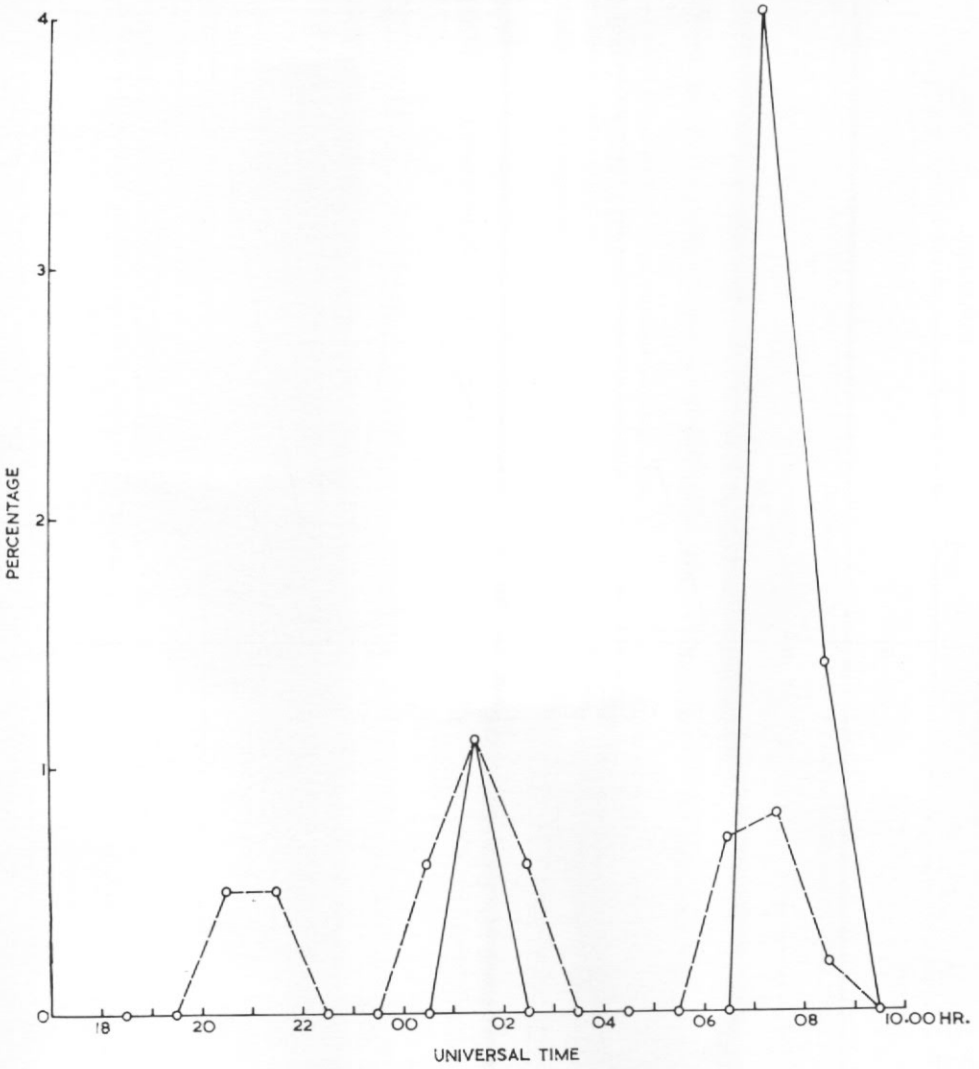


Fig. 6. Diurnal variation of overhead aurorae.

The diurnal variations in the occurrence of diffuse surfaces are shown in Fig. 7. As in most years for which observations are available, the percentage frequency of occurrence of diffuse surfaces increases through the night to a maximum in the late morning hours.

From Fig. 8 it is evident that in 1965 glows occurred fairly frequently except in the late morning hours. If all periods with the sun more than 12° below the horizon are considered, the diurnal variation is similar to that for all aurorae but shifted towards the evening hours. In 1965 glows were thus a more general feature of the aurorae as seen from Halley Bay.

From Fig. 9, in which the diurnal variation of quiet arcs is plotted, it can be seen that quiet arcs tend to occur more often after than before midnight. This tendency has been apparent for a number of years, the effect being seen very clearly in 1961 and 1962 (Blundell, 1966). The shift of the curve in 1964 towards evening hours is not maintained.

The distribution of quiet arcs in "geomagnetic latitude" and azimuth is given in Fig. 10, while the distribution in time and latitude is shown in Table III. From Fig. 10 it can be seen

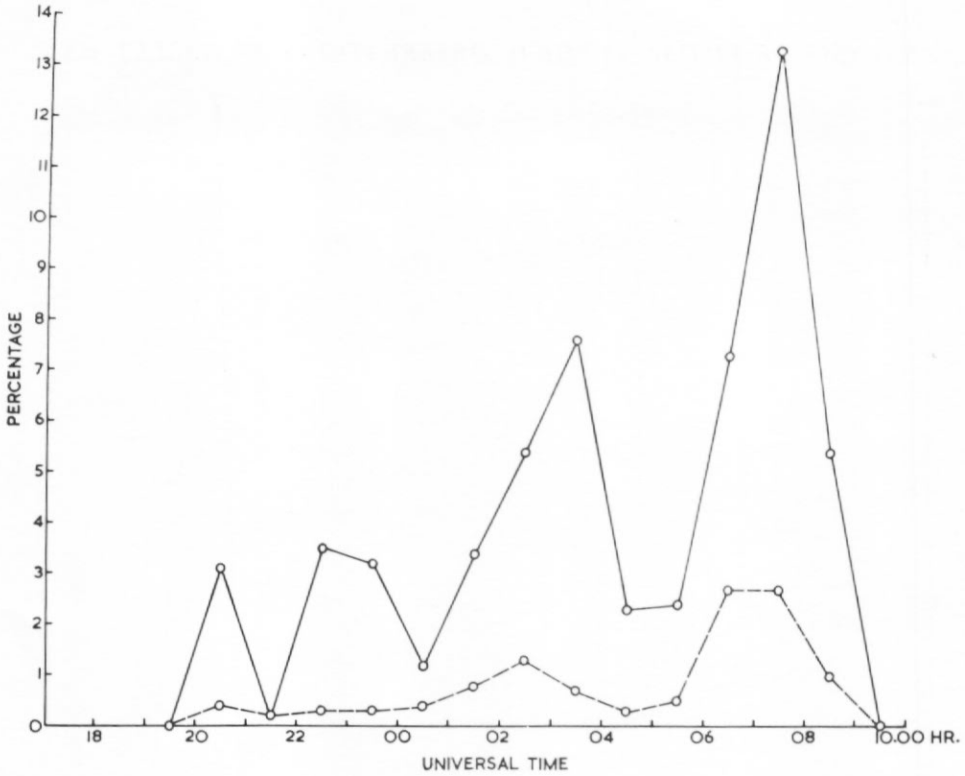


Fig. 7. Diurnal variation of diffuse surfaces.

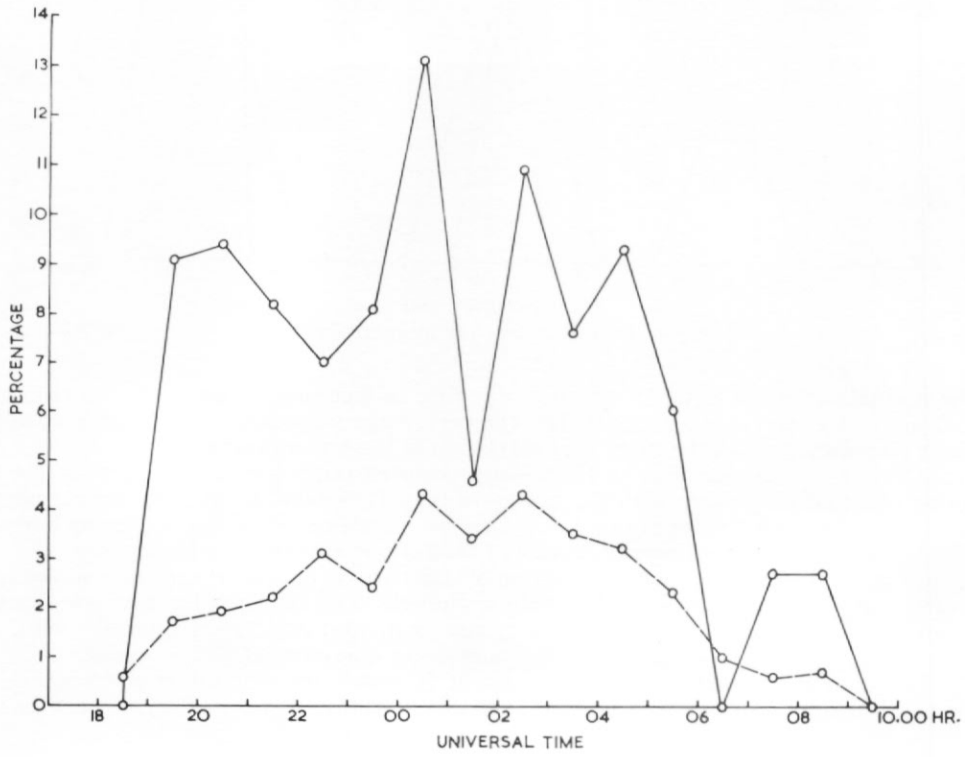


Fig. 8. Diurnal variation of glows.

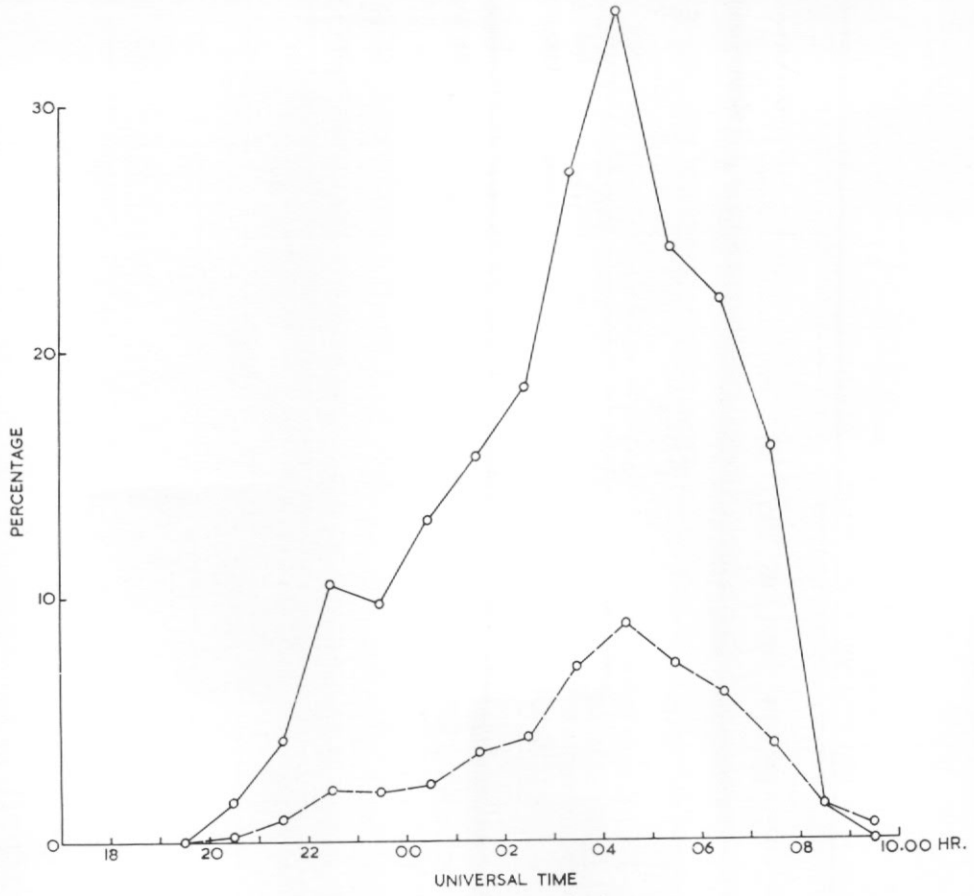


Fig. 9. Diurnal variation of quiet arcs.

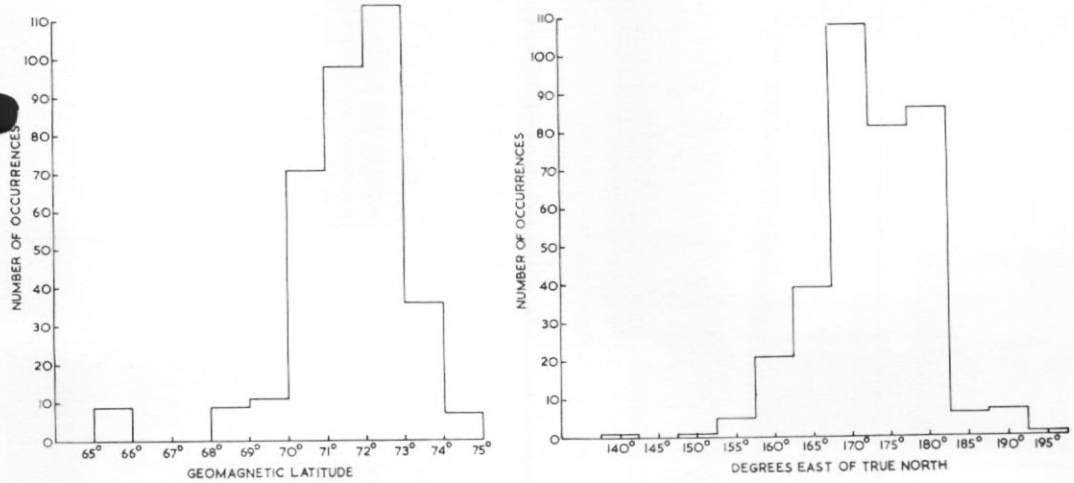


Fig. 10. Geomagnetic latitude and azimuth distribution of homogeneous arcs, 1965.

TABLE III. VARIATION OF QUIET ARCS WITH TIME AND GEOMAGNETIC LATITUDE

| *Elevation* (degrees) | U.T. | 20 | 21 | 22 | 23 | 00 | 01 | 02 | 03 | 04 | 05 | 06 | 07 | 08 | 09 | 10 | *Totals* | *Geomagnetic latitude* (degrees south) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | | | | | | | | | | | | | | | | | | 75 |
| 2 | | | | | | | 2 | 1 | 1 | | | | | 1 | 2 | | 7 | 74 |
| 3 | | | | 3 | 4 | 1 | 3 | 1 | 2 | 1 | 4 | 5 | 4 | 4 | 2 | 2 | 36 | 73 |
| 4–5 | | | 1 | 1 | 4 | 7 | 6 | 12 | 9 | 17 | 16 | 13 | 19 | 7 | 2 | | 114 | 72 |
| 6–7 | | | | 1 | 2 | 2 | 2 | 8 | 8 | 20 | 22 | 20 | 7 | 6 | | | 98 | 71 |
| 8–10 | | | | 3 | 3 | 3 | 5 | 3 | 10 | 12 | 20 | 5 | 4 | 3 | | | 71 | 70 |
| 11–15 | | | | | | | 1 | 1 | 1 | 4 | 1 | 2 | | 1 | | | 11 | 69 |
| 16–23 | | | | 1 | | 4 | | 1 | 1 | | 1 | 1 | | | | | 9 | 68 |
| 24–40 | | | | | | | | | | | | | | | | | 0 | 67 |
| 41–90 | | | | | | | | | | | | | | | | | 0 | 66 |
| 91–140 | | | | | | | 1 | 4 | 2 | 2 | | | | | | | 9 | 65 |
| *Median latitudes* (degrees south) | | | | 72·4 | 71·9 | 72·3 | 71·9 | 71·8 | 71·8 | 71·8 | 71·9 | 72·4 | 72·4 | | | | | |

that, although the distribution in latitude is little different from that in previous years, arcs between 70° and 73° contributing greatly to the total, the azimuths of the centres of the quiet arcs have shifted towards the west.

The diurnal variation of median "geomagnetic latitude" and mean azimuth of quiet arcs is shown in Fig. 11. The variation in latitude has the same character as found in previous years

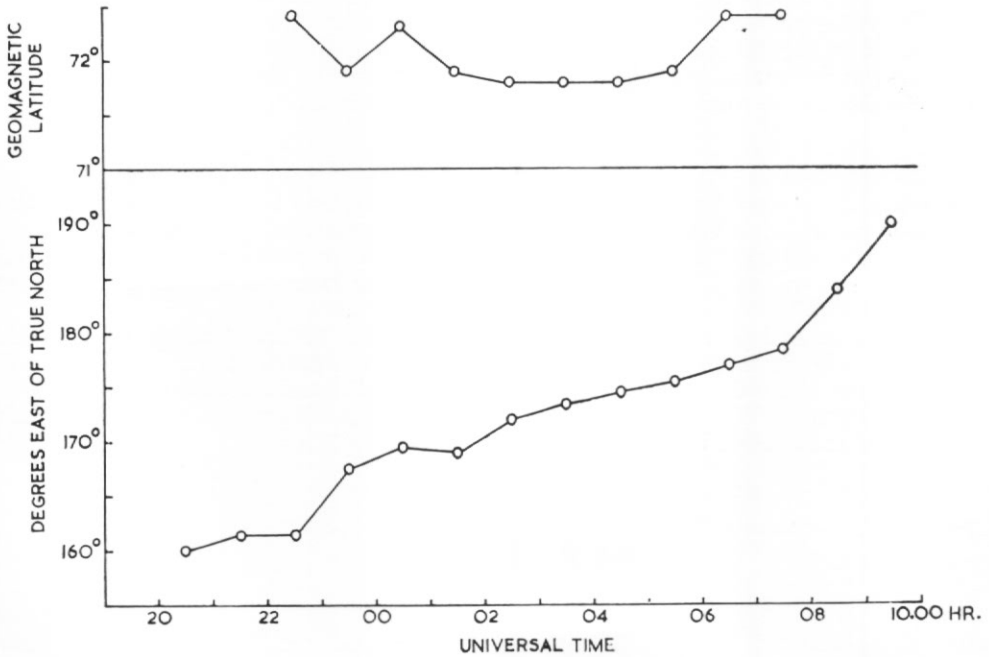


Fig. 11. Diurnal variations of median geomagnetic latitudes and mean azimuth of homogeneous arcs.

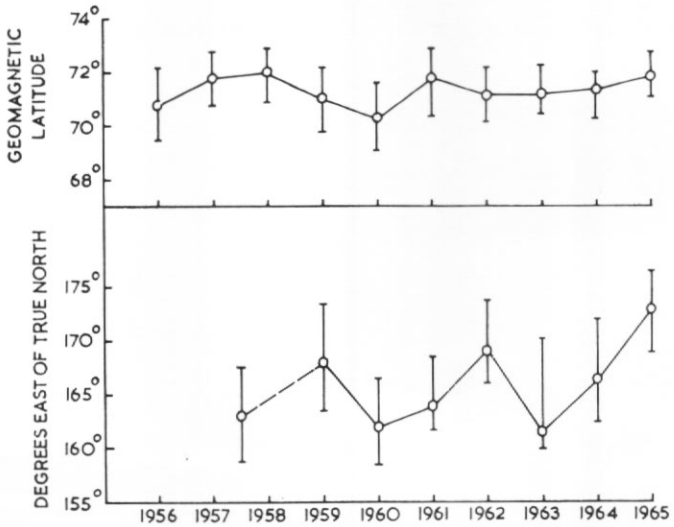


Fig. 12. Median latitudes and median azimuth positions of homogeneous arcs.

but the range in latitude is small. In azimuth, the variation follows a now familiar pattern but the range is larger than previously observed.

The median geomagnetic latitude for the year was 71·9°S. with interquartile values of 71·1° and 72·8°. The median azimuth was 173·0° east of true north with interquartile values of 169·0° and 176·5°. These values and the corresponding ones for the years 1956 to 1964 are plotted in Fig. 12. In latitude, there is little variation from the level of the past four years and the value for 1965 is very close to those obtained for sunspot maximum years. In the case of azimuth the variation is somewhat different. The median azimuth in the years 1957–58 to 1964 varied in an apparently irregular manner but the value for 1965 is considerably greater than any previously determined. This suggests a tendency for the median azimuth east of true north to increase as the solar cycle progresses from its maximum to its minimum.

## Conclusions

Although aurorae were little less frequent at Halley Bay than in most years except those near sunspot maximum, overhead and active aurorae were extremely rare in 1965.

The position of the quiet arc zone as defined by the median position for the year of quiet homogeneous arcs was very close to that found during the International Geophysical Year 1957–58.

Although the diurnal variation of all aurorae suggests that aurorae tended to occur earlier during the night in the International Quiet Sun Year than in previous years, active aurorae, overhead aurorae and diffuse surfaces were all morning phenomena. Glows have become a more general feature of the aurorae seen from Halley Bay. Quiet arcs still tend to occur more frequently after than before local midnight.

*MS. received 23 September 1966*

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