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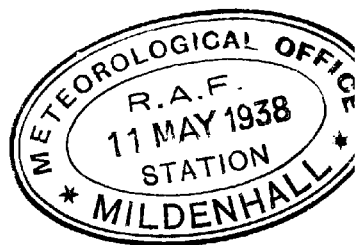
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AURORAL OBSERVATIONS
at
LERWICK OBSERVATORY
1924-9

By A. W. LEE, M.Sc.

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AURORAL OBSERVATIONS AT LERWICK OBSERVATORY, 1924-9

By A. W. LEE, M.Sc.

Data.—In 1921 an observatory was established near Lerwick (latitude $60^{\circ} 8' \text{ N.}$, longitude $1^{\circ} 11' \text{ W.}$) for study of geophysical and meteorological phenomena in the most northerly regions of the British Isles. Details of the work undertaken and a description of the observatory site appear in the *Observatories' Year Book* for 1923 and subsequent years.

Observations of aurora have been made since the Observatory opened, but in the earlier years meteorological conditions were recorded only for nights when aurora occurred. More complete observations are available from 1924. The sky is now inspected regularly, except during the four summer months, at intervals of 15 to 30 minutes from 19h. to 23h., G.M.T. There are observations at later hours, usually during auroral displays. Annual summaries of the observations are published in the *Observatories' Year Book*, which also contains a general auroral table for Scotland compiled from the records of all stations making regular meteorological observations.*

TABLE I.—NUMBER OF OBSERVATIONS AT 18h. AND 01h. OF
SPECIFIED CLOUD AMOUNTS AT LERWICK, 1924-9.

Time.	18h.					1h.				
Cloud Amount.	0	1-3	4-6	7-9	10	0	1-3	4-6	7-9	10
Sept. ..	2	21	29	54	44	6	36	21	36	51
Oct. ..	0	24	20	41	70	2	39	20	34	60
Nov. ..	0	32	24	28	66	4	26	27	37	56
Dec. ..	2	26	40	32	55	1	24	38	36	56
Jan. ..	0	24	25	35	71	1	24	25	32	73
Feb. ..	0	12	24	39	66	3	20	25	29	64
Mar. ..	0	12	28	51	64	2	24	23	31	75
Apr. ..	0	13	41	56	40	3	39	23	41	44
Total ..	4	164	231	336	476	22	232	202	276	479

Lerwick is very favourably situated for auroral investigations owing to its high latitude, but unfortunately it is located in a region where comparatively few nights are clear enough for the necessary observations to be taken. Table I has been extracted from the *Monthly Weather Report* to show the number of occurrences of specified cloud amounts at 18h. and 1h. during the

* Similar general auroral summaries for 1917 to 1921 are published in the *Geophysical Journal*.

five auroral seasons, 1924-9. The table shows that the number of overcast nights is very nearly equal at 18h. and 1h., in each case being about 40 per cent. of all nights. The summaries for November, December, and January show no pronounced change in distribution between 18h. and 1h., but in the other months, especially April, the sky is clearer at 1h. During overcast nights it is obviously impossible to determine whether aurora occurs or not, and with the sky more than half clouded the observations are frequently unreliable.

The present paper aims at using the available data for study of the incidence of aurora throughout the hours and months, and includes a comparison between the occurrence of aurora and magnetic disturbance.

Assignment of Hourly "Auroral Character Figures."—For the present investigation the data relating to each evening during the five auroral seasons, 1924-5 to 1928-9, have been divided into five periods by throwing the time of individual observations to the nearest hour. Thus the data employed for 20h., 21h., and 22h. refer to observations in 60-minute intervals centring at that time, the data for 19h. and 23h. refer to the periods 19h. to 19h. 30m. and 22h. 30m. to 23h. respectively.

Each "hour," defined as above, has been awarded an "auroral character figure" according to the following scheme.

"0" represents no observation of aurora despite reasonably favourable conditions.

"1" denotes that auroral forms without ray structure were seen at least once, and that neither ray structure nor flaming aurora was seen.

"2" denotes one or more observations of aurora showing ray structure or of flaming aurora.

Aurora of character "2" frequently extended to the zenith or even to the south of Lerwick, but that of character "1" usually only occurred to the north.

No entry is made for hours when conditions were unfavourable for observations of aurora owing to cloudiness, moonlight, twilight, or other causes.

The scheme of tabulation was adopted in 1926 under slightly different nomenclature, but on receipt of an advance copy of the "Auroral Atlas"* which Professor Størmer has prepared for international use, the wording of the definitions was amended.

Distribution of Hourly Character.—For each month the numbers of hours characterised as "0", "1", and "2" appear in Table II. During 1,480 hours, or 24 per cent. of the total, conditions were favourable for observation; aurora was seen on 40 per cent. of these favourable occasions.

* Awaiting publication.

TABLE II.—DISTRIBUTION OF "HOURLY AURORAL CHARACTER",
1924-9.

Season	1924-5								1925-6							
Month	S	O	N	D	J	F	M	A	S	O	N	D	J	F	M	A
No. of "0" hours ..	10	39	21	25	11	14	21	8	12	19	21	22	14	12	40	21
No. of "1" hours ..	3	10	1	0	8	9	2	1	20	20	17	3	4	12	20	21
No. of "2" hours ..	3	2	0	0	3	5	0	0	6	1	4	0	5	4	6	2
Total hours used	16	51	22	25	22	28	23	9	38	40	42	25	23	28	66	44

Season	1926-7								1927-8							
Month	S	O	N	D	J	F	M	A	S	O	N	D	J	F	M	A
No. of "0" hours ..	22	56	47	37	33	29	27	21	36	23	16	29	42	24	9	14
No. of "1" hours ..	1	8	21	8	20	14	12	15	11	12	12	25	9	14	2	2
No. of "2" hours ..	5	10	0	1	0	0	2	0	6	7	2	8	2	3	1	1
Total hours used	28	74	68	46	53	43	41	36	53	42	30	62	53	41	12	17

Season	1928-9								Total for 5 years	
Month	S	O	N	D	J	F	M	A		
No. of "0" hours ..	18	9	16	23	17	16	9	9	892	
No. of "1" hours ..	19	31	33	9	0	8	13	10	460	
No. of "2" hours ..	11	8	6	5	0	1	7	1	128	
Total hours used	48	48	55	37	17	25	29	20	1,480	

The distribution of "character" throughout the months and hours appears in Tables III and IV. From Table III it is seen that the frequency of aurora is high from September to November and from February to April, much lower in December and January.

TABLE III.—MONTHLY FREQUENCIES OF "HOURLY AURORAL CHARACTER", 1924-9.

Hours of observation : 19-23h.

Month	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.
No. of " 0 " hours ..	98	146	121	136	117	95	106	73
No. of " 1 " hours ..	54	81	84	45	41	57	49	49
No. of " 2 " hours ..	31	28	12	14	10	13	16	4
Total	183	255	217	195	168	165	171	126
Frequency of Aurora (1 or 2)—per cent. ..	46	43	44	30	30	42	38	42
Frequency of " 2 " hours —per cent.	17	11	6	7	6	8	9	3

TABLE IV.—HOURLY DISTRIBUTION OF CHARACTER FIGURES, 1924-9.

Hour (G.M.T.)	19h.	20h.	21h.	22h.	23h.
No. of " 0 " hours ..	158	204	202	187	141
No. of " 1 " hours ..	43	78	112	117	110
No. of " 2 " hours ..	13	24	38	30	23
Total	214	306	352	334	274
Frequency of Aurora (1 or 2)—per cent.	26	33	43	44	49
Frequency of " 2 " hours —per cent.	6	8	11	9	8

According to Table IV there is on the average a pronounced increase in the frequency of aurora, (characters " 1 " and " 2 " combined) from 19h. to 21h., followed until 23h. by a more gradual increase ; the frequency of character " 2 " shows a maximum at 21h. In connexion with the total number of observations it must be remembered that the periods covered for 19h. and 23h. are only 30 minutes, against 60-minute intervals for the other hours ; also, that during some months observations during the earlier hours were unreliable owing to twilight.

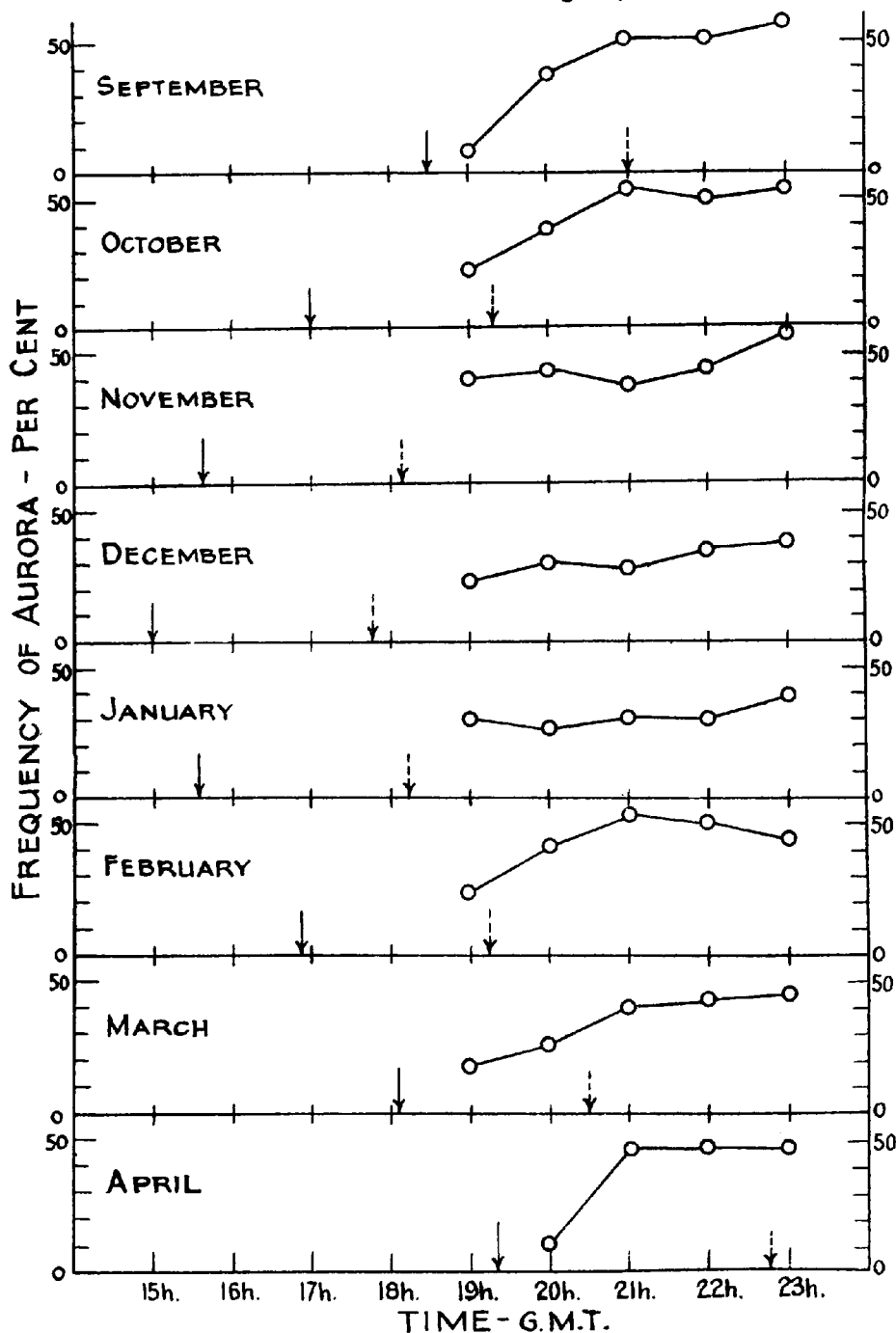
Figure 1.

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LERWICK. DIURNAL VARIATION OF AURORA, 1924-29 CHARACTER '1' OR '2'

↓ = Indicates time of sunset

↓ = Indicates end of twilight (Sun 18° below horizon)



The hourly distribution of auroral frequency for each month is summarised in Table V, and plotted in Fig. 1. The diagram also shows the mid-monthly times of sunset and of the ending of astronomical twilight, i.e., the instant when the true zenith distance of the sun's centre is 108° *. Although the increasing frequency from 19h. to 21h. in September, March, and April may be largely attributed to twilight obscuring weak aurora in the earlier hours, such an explanation would not apply in October or February.

TABLE V.—MONTHLY FREQUENCY OF AURORA
(CHARACTER 1 OR 2), 1924-9.

Per cent.

Month	19h.	20h.	21h.	22h.	23h.
Sept. 	8	37	50	51	57
Oct. 	22	38	53	49	53
Nov. 	40	43	38	44	58
Dec. 	23	30	28	34	38
Jan. 	29	26	30	30	39
Feb. 	24	41	53	50	44
Mar. 	17	26	40	43	45
Apr. 	—	11	47	47	47

The data indicate that, for the whole season, the truest representation of auroral frequency month by month is obtained from the observations for 22h. The monthly frequency of aurora for 22h. is similar to that obtained from all hours in showing values for December and January considerably lower than those for other months.

Assignment of Daily "Auroral Character Figures."—Daily character figures have also been assigned and indicate:—

"0" that no aurora was observed on that day and that there were at least three hours of character "0."

"1" that auroral forms without ray structure occurred, and that the types with ray structure were not seen.

"2" that auroral forms with ray structure or flaming aurorae occurred on that day.

Auroral activity in the early morning hours has been credited to the previous day when allotting daily character figures.

Distribution of Daily Character.—The number of days in each month of character "0", "1", and "2", together with seasonal values of the average auroral character, are given in Table VI. In Table VII appears the distribution of character for each season, and the frequency of aurora.

* See *Nautical Almanac*.

TABLE VI.—DISTRIBUTION OF "DAILY AURORAL CHARACTER",
1924-9.

[illegible][illegible]

Season	1928-9								Total for 5 years
Month	S	O	N	D	J	F	M	A	
No. of " 0 " days	1	0	1	3	3	3	1	1	152
No. of " 1 " days	6	7	8	2	0	2	7	6	148
No. of " 2 " days	5	6	5	3	0	1	3	1	67
Total days used	12	13	14	8	3	6	11	8	367
Seasonal average character ..	1.15								

TABLE VII.—SEASONAL DISTRIBUTION OF DAILY CHARACTER, 1924-9.

Season	No. of " 0 " days	No. of " 1 " days	No. of " 2 " days	Total No. of days classified	Frequency of aurora (1 or 2)
1924-5	32	11	6	49	$\frac{\%}{35}$
1925-6	25	40	14	79	68
1926-7	46	37	8	91	49
1927-8	36	22	15	73	51
1928-9	13	38	24	75	83
Total for 5 seasons	152	148	67	367	59

1,211 days are included in the five seasons, but on only 367 days, or 30 per cent. of the total, were conditions such that reliable observations of aurora could be taken. Some auroral activity was observed on 59 per cent., and the more spectacular forms on 18 per cent., of these days.

TABLE VIII.—MONTHLY DISTRIBUTION OF DAILY CHARACTER, 1924-9.

Month	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.
No. of " 0 " days ..	15	24	19	28	23	13	17	13
No. of " 1 " days ..	15	24	22	10	12	20	23	22
No. of " 2 " days ..	17	14	8	7	4	6	8	3
Total	47	62	49	45	39	39	48	38
Frequency of aurora (1 or 2)—per cent. ..	68	61	61	38	41	67	65	66
Frequency of " 2 " days —per cent.	36	23	16	16	10	15	17	8

The monthly distribution of daily character and frequency of aurora is set out in Table VIII. The frequencies of aurora obtained from the hourly and daily characterization show similar variation from month to month, but the values given by the hourly character are lower than the daily values. This systematic difference between hourly and daily frequencies is caused by the exclusion from the daily characterization of quiet days on which there were less than three hours of character " 0 ".

Magnetic Disturbance and Aurora.—Magnetographs are maintained at the Observatory for recording declination, horizontal force and vertical force. In common with other observatories equipped for continuous registration, the records for each day are examined and a magnetic character figure is awarded :—

“ 0 ” to indicate magnetically quiet conditions,

“ 1 ” denoting moderate magnetic disturbance, and

“ 2 ” denoting large magnetic disturbance.

TABLE IX.—DISTRIBUTION OF AURORAL CHARACTER ACCORDING TO MAGNETIC CHARACTER.

Daily Auroral Character		0			1			2		
Daily Magnetic Character		0	1	2	0	1	2	0	1	2
1924-5 .. ..	..	24	8	0	4	6	1	2	2	2
1925-6 .. ..	..	18	7	0	9	26	5	0	10	4
1926-7 .. ..	..	35	10	1	7	26	4	1	3	4
1927-8 .. ..	..	20	16	0	5	16	1	0	12	3
1928-9 .. ..	..	10	2	1	6	30	2	2	12	10
Total ..	..	107	43	2	31	104	13	5	39	23

The distribution of daily auroral character according to magnetic character is shown in Table IX. The table shows 152 occurrences of auroral character “ 0 ”. Of these, there were 107 on days of magnetic character “ 0 ”, 43 on days of magnetic character “ 1 ”, and 2 on days of magnetic character “ 2 ”. Auroral character “ 0 ” was associated with magnetic character “ 2 ” on September 21, 1926, and February 28, 1929; on each night the sky was fairly clear from 20h. to 23h. and aurora should have been noted if there had been any at the time of the observations. On the earlier date aurora was seen at Baltasound (about 45 miles north by east of Lerwick) at 20h., and also at Turnberry in Ayrshire from 24h. to 0h. 30m. February 28, 1929, was the third day of a large magnetic storm, but the disturbance subsided around 19h. and magnetic conditions after dark were no longer favourable for aurora; a vigorous auroral display was observed in Shetland on the night of February 27-28.

There were 67 days of auroral character “ 2 ” 5 on magnetic “ 0 ” days, 39 on magnetic “ 1 ” days, and 23 on magnetic “ 2 ” days. The incidence is greatest on the magnetic “ 1 ” days, indicating that moderate magnetic disturbance may frequently be associated with aurora showing ray structure.

The 5 cases of active aurora on magnetically quiet days were:—September 3 and 25, 1924, October 1, 1926, October 10 and 11, 1928. Magnetic character “0” was awarded at Eskdalemuir Observatory on each of these dates except September 25, 1924, and at Stonyhurst Observatory on each date except October 10, 1928. The ray formations were always of short duration, but reports from other stations confirm the occurrence of aurora on four of the five dates.

Summary.—Meteorological conditions at Lerwick Observatory were favourable for observations of aurora on 30 per cent. of the evenings in the auroral seasons 1924-9. Aurora was observed to occur on 59 per cent. of these favourable evenings.

The frequency of aurora is high from September to November and from February to April, lower in December and January. Throughout the evening the frequency increases considerably from 19h. to 21h. then more gradually until 23h.; the frequency of aurora showing ray structure is greatest at 21h.

In general aurora and magnetic disturbance go together. There were, however, five occasions on which active aurora was observed but the magnetograms showed no disturbance.

