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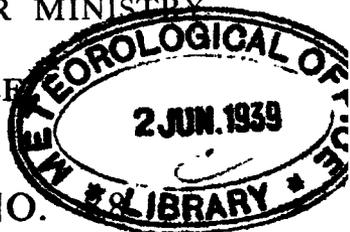
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FOG ON THE MAINLAND AND COASTS OF SCOTLAND

By F. E. DIXON, B.A.

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FOG ON THE MAINLAND AND COASTS OF SCOTLAND

By F. E. DIXON, B.A.

Since 1889 systematic observations of fog have been made at all the lighthouses round the coasts of Scotland, and the lightkeepers, under an instruction by the Commissioners of the Northern Lighthouses, enter each day in a log particulars of the occurrences of fog and the number of hours the fog prevailed. The lighthouses are distributed all along the coast, the only area not represented in their records being the narrower waters of the Firth of Clyde. In 1902 Alexander Buchan (1)* discussed the information accumulated by 65 lighthouses for the twelve years 1889-1900, giving tables of the gross number of hours of fog recorded at each place and a brief discussion of the results. Recently somewhat similar summaries for the ten years 1925-34 have been made at the Edinburgh Meteorological Office from the records of 84 lighthouses now existing.

Visibility observations with reference to fixed marks are made also at a large number of climatological stations on the mainland and islands of Scotland. These also have been summarised in so far as they include cases of visibility less than 1 Km.

The objects of the present paper are, to present the summarised data, to discuss the geographical distribution and the seasonal variation, and—in so far as the lighthouse observations are concerned—to compare the features of the period 1925-34 with those of the period 1889-1900, i.e. to assess the changes in the 35-year interval separating the mean points of the two periods.

The lighthouse fog statistics, being based on continuous observation throughout the 24 hours, cannot be related in any simple manner to the figures obtained at climatological stations, where observations are made only at set hours. A further difference in the observations is that whereas at standard meteorological stations a definite criterion is used (visibility < 1 Km.), at lighthouses any atmospheric obscurity that, in the opinion of the lightkeeper, necessitates the sounding of a fog signal is entered as fog. There is thus a personal equation in the lighthouse fog records, but the frequent interchange of staff leads to a considerable uniformity in the standards adopted.

At several lighthouses more than 200 ft. above sea level† the amount of "fog" reported is considerably in excess of the totals for neighbouring stations at a lower level. This excess is due to the inclusion of many cases of low cloud. Barra Head (629 ft.) is a notable example, 1,017 hours of fog per annum being recorded; Monach, equally exposed but only 28 ft. above M.S.L., has an average of 177 hours. Similarly in the south-west the mean annual totals for Mull of Galloway (272 ft.) and Killantringan (107 ft.) are

* The numbers in brackets refer to the bibliography on p. 18.

† The heights published are approximately those of the bases of the lighthouses.

421 hours and 173 hours respectively. As no figures are available which would assist in eliminating the occurrences of low cloud, ten high-level stations which show this characteristic excess have been omitted in the computation of district averages. In the north-east coastal district, where the heights of lighthouses vary between 68 and 331 ft., and where there seems to be no consistent variation of duration of fog with height, all the records have been used. Sule Skerry was omitted, since it is too isolated to be considered as belonging to any of the districts dealt with.

Table I shows the average monthly and annual duration of fog at each of the 84 lighthouses for the period 1925–34, also the annual mean for 1889–1900 derived from Buchan's data, and the percentage ratio of the 1925–34 annual mean to the 1889–1900 mean. In considering this table it was noted that the lighthouses could readily be grouped into districts, the boundaries of which are in most cases quite definite—with special characteristics in regard to total amount. Buchan had evidently noted the same point. The mean monthly values for these districts are given in Table II and in graphical form in Fig. 1.

Table III includes the average number of days per year on which fog was observed at the morning observation (0700 or 0900) at all the Scottish meteorological stations for which reliable statistics of visibility exist. Ten-year averages were obtained wherever possible, the period 1927–36 being used as that for which most data were available, but some stations have only recently commenced visibility observations, and at other stations evidence was found that changes of observer had resulted in changes of practice. These changes are not necessarily due to bad observing, but to different treatment of such occurrences as valley fog. An observer may be in a valley in which fog is lying, but from a point only a few feet higher mountains 30 miles away may be easily distinguished. Hence a change of site which would only negligibly affect other meteorological readings may cause a very large change in the amount of fog recorded. Stations affected in this way have not been included in the present paper. The averages which were obtained from less than ten years' observations are printed in brackets.

Table IV comprises district averages for each month for the land stations, the groups being those shown in Table III. The data are also set out graphically in Fig. 2.

Distribution of fog in recent years.—The average numbers of days of fog per annum at the Scottish meteorological stations are given on the map (Fig. 3), and isopleths have been drawn to show the general distribution. On the same map the stippling and hatching round the coasts show the distribution of total annual duration of fog at the lighthouses. (Those experiencing a large amount of low cloud have been omitted.)

It is clear that industrial pollution is an important factor in determining the amount of fog. The Glasgow and Greenock area is

TABLE I.—DURATION OF FOG (IN HOURS) AT 84 LIGHTHOUSES ON THE SCOTTISH COASTS AND ISLANDS

No.	Lighthouse*	Height Ft.	Mean values, 1925-34												Annual mean, 1889- 1900	Annual mean, 1925- 34	as per- centage of period 1889- 1900
			Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.			
1	St. Abb's Head†	212	6	21	33	39	50	46	20	22	5	6	8	295	262	113	
2	Barnsness ..	20	15	37	31	27	27	29	10	10	7	15	9	238	..	..
3	Rass Rock ..	?	40	60	58	36	39	40	19	21	16	44	46	456	..	..
4	Fidra ..	54	30	63	75	28	33	35	16	17	9	26	37	394	245	161	
5	Inchkeith ..	190	96	108	102	51	47	41	37	35	32	96	94	779	419	186	
6	Isle of May ..	183	10	39	55	37	37	41	23	22	8	13	19	342	313	110	
7	Bell Rock ..	0	3	15	26	29	29	23	14	14	4	2	5	193	220	88	
8	Montroseness ..	18	11	23	35	24	38	30	15	13	3	6	5	226	285	79	
9	Todhead ..	114	3	9	20	25	34	27	38	20	2	1	1	188	..	..
10	Girdleness ..	89	24	17	30	33	40	33	30	20	6	11	14	296	264	112	
11	Buchanness ..	39	7	12	23	24	43	37	42	26	2	3	4	243	266	91	
12	Rattray Head ..	0	4	8	19	21	37	22	42	24	2	2	3	200	..	..
13	Kinnaird Head..	62	9	16	19	20	36	27	25	11	3	4	4	203	226	90	
14	Coveasa Skerries	55	4	7	13	5	20	15	13	17	8	3	4	112	167	67	
15	Chanorly ..	19	7	11	14	7	16	6	11	7	2	2	7	103	103	100	
16	Cromarty ..	?	7	10	13	9	9	8	7	4	2	5	9	89	89	100	
17	Tarbetness† ..	62	5	11	38	9	38	9	13	14	3	0	6	150	133	113	
18	Clythness ..	133	1	3	16	19	25	23	29	10	2	1	0	152	..	..
19	Nosshead ..	129	0	6	18	22	33	34	59	42	3	1	1	282	281	83	
20	Duncansby Head	200	3	11	21	26	43	43	82	48	15	5	2	304	304	..	
21	Pentland Skerries	70	3	12	25	27	41	40	78	47	17	5	6	304	264	115	
22	Dunnet Head ..	331	3	13	18	24	45	41	79	46	21	4	9	308	385	80	
23	Holburn Head ..	68	1	3	11	5	19	13	25	18	3	2	1	103	177	58	
24	Stroma ..	54	2	7	13	16	30	31	64	39	13	4	3	223	..	..
25	Caytick Head ..	68	3	6	15	14	26	28	46	32	11	3	2	189	92	..	
26	Hoy High ..	29	0	4	12	7	17	14	33	26	12	3	0	130	162	71	
27	Hoy Low ..	40	2	3	8	8	12	15	40	14	10	2	2	117	181	65	
28	Coginsey ..	324	2	7	12	16	37	37	75	44	18	3	2	259	..	..

29	Hellyar Holm ..	35	7	19	39	19	35	27	67	43	18	9	10	3	296	223	85
30	Awakerry ..	27	2	5	7	11	25	21	57	41	15	3	3	0	190	239	82
31	Start Point ..	22	2	7	6	9	24	23	64	37	12	5	3	3	195	264	89
32	Noup Head† ..	206	6	19	34	94	48	35	96	48	29	16	9	3	377	264	89
33	N. Ronaldshay..	22	3	14	12	11	31	30	67	35	18	6	3	5	235	264	89
34	Sule Skerry† ..	40	0	3	9	8	19	19	37	22	6	2	0	0	126	..	..
35	Fair Isle (South)	44	0	2	7	8	23	28	68	31	14	3	1	0	185	..	..
36	Fair Isle (North)†	286	1	9	9	12	39	42	87	47	25	9	3	2	285	621	90
37	Sumburgh Head†	262	12	20	26	32	71	67	147	75	50	34	10	12	556	238	60
38	Bressay ..	69	2	6	6	9	21	16	47	21	13	4	2	0	143	197	91
39	Whaleby ..	?	5	6	8	8	26	21	53	21	13	8	2	0	180	180	91
40	North Unst ..	187	2	4	4	8	25	22	41	29	10	12	3	3	163	366	45
41	Flannan Is.†	270	11	15	27	23	33	55	79	39	32	26	10	16	368	153	47
42	Butt of Lewis ..	77	2	2	5	4	9	13	13	14	3	3	2	2	72	28	57
43	Stornoway ..	28	0	0	3	1	3	2	1	3	2	1	0	0	16	62	..
44	Tiunpan Head..	129	1	3	7	1	11	13	10	11	2	1	1	2	100	170	59
45	Glas Island ..	57	1	3	9	5	10	17	24	13	10	5	1	2	177	254	70
46	Monach ..	28	7	15	22	7	19	17	24	16	19	14	6	11	88	141	62
47	Ushenish ..	184	1	5	9	7	12	14	20	8	8	1	2	1	1,017	1,323	76
48	Barra Head† ..	629	68	65	96	84	66	85	172	112	84	85	40	60	305	519	59
49	Cape Wrath† ..	346	7	13	18	16	41	44	72	48	15	13	7	11	101	174	58
50	Stourhead ..	174	2	5	7	3	11	17	28	13	10	3	2	0	35	43	195
51	Rudh Re ..	53	1	0	5	1	7	4	10	6	1	0	0	0	84	..	..
52	Rona ..	202	0	2	10	2	16	10	22	17	4	1	0	0	95	18	78
53	Neist Point ..	79	0	8	8	9	9	14	22	8	11	5	1	0	14	72	42
54	Kyleakin ..	54	0	0	1	0	5	2	4	4	1	0	1	0	30	..	..
55	Ornsay ..	36	0	4	4	2	3	3	6	3	1	3	0	0	110	147	75
56	Ardnamurchan..	79	2	9	7	7	9	15	25	10	12	9	2	3	11	58	19
57	Sound of Mull ..	26	0	1	1	1	2	0	2	0	2	1	0	2	57	71	80
58	Lismore ..	38	1	6	5	3	4	4	16	5	6	4	1	2	153	146	69
59	Hyskeir ..	31	2	15	12	10	9	10	40	17	20	9	4	5	101	100	184
60	Skerryvore ..	0	0	9	7	7	13	15	21	8	12	7	1	1	134	..	..
61	Dhuheartach ..	40	0	1	9	11	13	17	31	12	15	8	2	3	..	..	..

‡ Mean for 5 years only.

† Not included in district averages.

* The spellings adopted are those normally used by the lighthouse keepers.

TABLE I—continued

No.	Lighthouse*	Height Ft.	Mean values, 1925-34												Annual mean, 1925- 34	Annual mean, 1889- 1900	1925-34 as per- centage of period 1889- 1900
			Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.			
62	Fladda ..	22	1	2	3	3	6	6	19	6	7	5	0	2	60	89	67
63	Rhuvaal ..	69	1	10	9	9	11	13	27	11	8	12	2	7	120	98	129
64	Rhinnis of Islay ..	74	2	15	14	13	17	27	41	17	14	8	2	4	174	252	69
65	Lochindaun ..	45	0	10	9	7	5	8	15	8	5	4	1	2	74	210	35
66	McArthur's Head ..	173	9	20	18	10	9	9	19	10	9	9	6	11	139	51	272
67	Skervuile ..	10	0	3	7	2	3	3	6	5	3	2	0	0	34	35	97
68	Mull of Kintyre†	270	6	15	17	19	24	26	47	23	14	6	2	4	203	191	106
69	Sanda ..	134	1	5	9	13	14	16	11	10	5	3	0	1	88	97	91
70	Devaar ..	76	2	7	14	12	15	13	19	11	11	5	2	4	115	139	83
71	Pladda ..	53	7	15	21	6	9	5	5	3	7	7	3	5	93	57	163
72	Holy Island ..	68	12	18	37	9	13	8	5	3	12	9	15	15	156	116	135
73	Turnberry ..	40	1	4	12	2	4	2	2	0	6	4	1	2	40	128	31
74	Ailsa Craig ..	35	1	6	11	4	5	4	2	3	2	5	1	2	46	115	40
75	Loch Ryan ..	13	1	19	12	2	3	1	3	3	2	5	3	5	59	88	67
76	Corsewall ..	48	2	9	14	8	8	6	7	6	7	2	2	4	75	146	51
77	Killantringan ..	107	4	18	16	15	23	19	30	19	12	8	1	8	173	..	..
78	Mull of Galloway†	272	18	43	46	37	57	50	63	38	27	10	13	19	421	412	102
79	Little Ross ..	136	22	42	20	16	21	8	11	4	8	11	18	25	206	114	181
80	Point of Ayre ..	35	8	30	18	10	15	10	4	4	3	6	8	12	128	337	38
81	Maughald Head†	230	11	36	24	20	28	24	27	17	10	8	8	17	230	..	..
82	Douglas Head ..	62	4	16	14	12	15	16	13	6	5	3	1	5	110	272	40
83	Langness ..	38	4	17	13	11	16	17	13	10	4	4	1	3	113	167	68
84	Chicken's Rock	0	8	24	21	22	30	29	27	17	11	6	2	4	201	179	112

* The spellings adopted are those normally used by the lighthouse keepers.

† Not included in district averages.

Fog in Scotland

TABLE II.—DISTRICT AVERAGES OF DURATION OF FOG (IN HOURS) AT 73 LIGHTHOUSES ON THE SCOTTISH COASTS AND ISLANDS

Dis- trict Letter	District	Light- house Nos.	Mean values, 1925-34												Annual mean, 1925- 34	1925-34 as per- centage of 1889- 1900*
			Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.		
A	Firth of Forth	2-6	38	61	64	36	37	32	39	21	21	14	39	41	443	155
B	East coast ..	7-13	9	14	25	25	37	28	34	22	15	3	4	5	221	92
C	Moray Firth	14-17	6	10	19	7	19	9	11	11	4	4	4	4	112	92
D	North-east coast	18-23	2	8	18	21	34	32	58	38	13	3	4	2	233	86
E	Orkney ..	24-31, 33	3	8	14	12	26	25	67	35	14	5	3	2	204	82
F	Shetland ..	35, 38-40	2	3	6	11	24	22	62	25	13	7	2	1	168	61
G	Outer Hebrides	42-47	2	5	9	4	11	13	15	11	7	4	2	3	86	61
H	North-west coast	50-55	1	3	6	3	9	8	15	8	5	2	1	0	61	75
I	West coast (Mull)	56-61	1	9	7	7	8	10	23	9	6	2	2	3	96	79
J	West coast (Islay)	62-67	2	10	10	7	9	11	21	9	11	7	2	4	100	82
K	Firth of Clyde	69-74	4	9	17	8	10	8	7	5	5	5	4	5	89	83
L	South-west coast	75-77, 79	7	22	15	10	14	9	13	8	7	7	6	11	129	98
M	Isle of Man ..	80, 82-84	6	22	17	14	19	18	14	9	6	5	3	6	139	58
D, E, F	North ..	..	2	7	14	15	28	27	56	34	5	5	3	2	206	78
G, H	North-west ..	..	1	4	7	3	10	11	15	9	6	3	1	1	71	65
I, J	West ..	..	2	9	8	7	8	11	22	9	7	2	2	3	97	81
K, L, M	South-west ..	..	5	16	17	10	14	11	11	7	6	4	4	7	115	73
	All coasts ..	..	6	13	17	13	20	18	29	17	10	5	5	6	159	86

* These figures are the percentages between the 1889-1900 averages and those for 1925-34 for the same stations.

much the worst affected, fog occurring at Glasgow on 84 mornings a year. The prevailing westerly winds spread the atmospheric pollution across to the east coast, intensifying the effect of local industries as far north as Aberdeen. Unfortunately there is a large area in the south of Scotland for which no records are available, but the figures for Dumfries, Eskdalemuir and Kelso all suggest that this area is less free from smoke pollution than the north of Scotland.

Of the sea areas the Firth of Forth is much the foggiest and, except for the Moray Firth, the east and north coasts and Orkney and Shetland all experience more fog than any of the western areas. The freedom of the Moray Firth area from fog may be explained by the fact that all winds, except the north-easterly which only rarely brings the conditions necessary for the formation of sea fog, cross high mountains before reaching the Firth, and thus can scarcely reach the Firth in a humid condition. Reverting to the land areas it is noteworthy that Inverness is another industrial centre, but the pollution is confined to a small district, and the neighbouring stations of Nairn and Fortrose support the evidence from the lighthouses that the Moray Firth coast is remarkably free from fog.

The other areas experiencing more than 5 days of fog a year are in Orkney and Shetland and the north-east corner of the Scottish mainland. In all three cases incursion of sea fog is the probable cause.

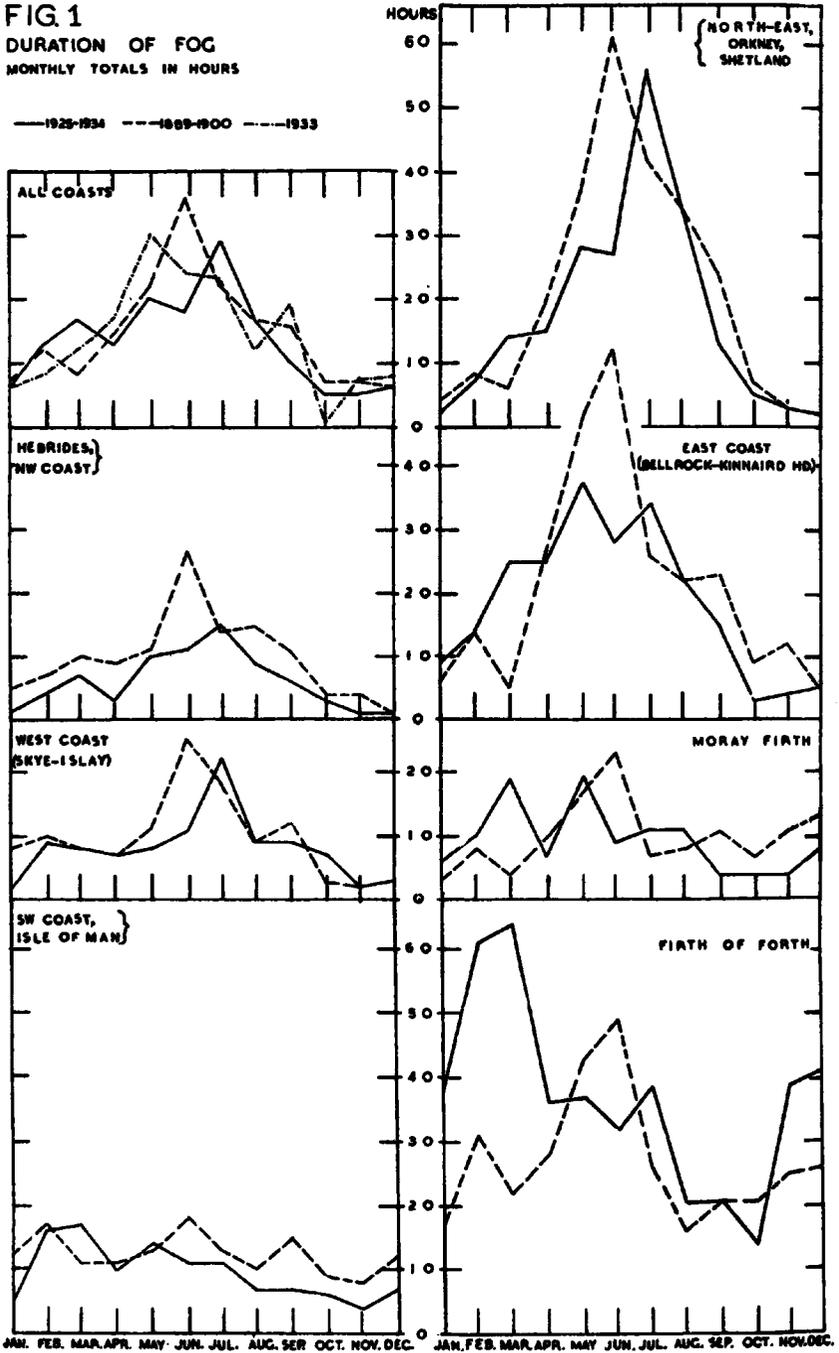
North of the Clyde, the western districts of Scotland, including the islands, are almost entirely free from fog, as officially defined, no place reporting as many as five occurrences per annum. The explanation is threefold. First, the atmosphere is free from pollution; secondly, it is the area in which sea fog is least prevalent, and thirdly, the mountainous nature of the country probably assists convection enough to prevent air becoming sufficiently "stagnant" for more than valley fog to form.

Season of maximum fog.—As shown by the italicised figures in Table I at nearly all the lighthouses the month experiencing the most fog is February, March, May or July. Two stations with June maxima and two with August maxima are isolated exceptions. Fig. 4 shows the areas with maxima in different months.

The month of most fog is May at the majority of the lighthouses on the east coast, but in the Forth area fog is most prevalent in February and March. Bell Rock is on a district boundary, having equal amounts in April, May and June. With negligible exceptions all the lighthouses in the north and those on the west coast as far south as Islay have a summer maximum in July, and this is true for the most exposed places even further south. The less exposed places in south-west Scotland experience most fog during the late winter; to the north of Galloway this late winter maximum occurs in March and to the south in February.

Unfortunately there is no lighthouse on the west coast of the Isle of Man but striking differences are found between the records

FIG. 1
DURATION OF FOG
MONTHLY TOTALS IN HOURS



of the five lighthouses to the east and south. Point of Ayre and Maughold have definite February maxima; Douglas Head and Langness, on the boundary between districts with winter maximum and summer maximum, both have equal amounts in February and June, while Chicken's Rock to the south has most fog in May.

Season of minimum fog.—Owing to the small amounts of fog recorded at most lighthouses between September and January the month which is freest from fog is difficult to define. On the average the minimum is in October in the east, November in the west and December or January in the north.

Annual variation.—The continuous curves in Fig. 1 show the monthly averages for 1925–34 for the districts arranged in geographical order. These curves show that in every district there is actually evidence of three maxima, one in February or March, another in May and a third in July; but in the different districts there are notable differences in the relative magnitudes of these maxima.

The outstanding features of the incidence of fog in each district are :—

FIRTH OF FORTH—High values almost throughout the year; greatest from November to March, and lowest in October.

EAST COAST—High throughout spring and summer but almost negligible in winter.

MORAY FIRTH—Freer from fog than the remainder of the east coast. The four stations have rather different seasonal variations.

NORTH-EAST COAST, ORKNEY AND SHETLAND—Except for June the increase from January to July is continuous; from October to January very little fog is experienced.

NORTH-WEST COAST AND HEBRIDES—Most of the observing stations are in moderately sheltered positions and record little fog. The March and July maxima are well marked.

WEST COAST (SKYE—ISLAY)—Similar to the north-west coast but the July maximum is higher and the secondary maximum is earlier.

SOUTH-WEST COASTS AND ISLE OF MAN—Similar in seasonal variations to the Firth of Forth with an unsteady decrease from February to November, but the total amount is less than one-third.

Table IV and Fig. 2 give the district averages for fog frequency at land stations. In the northern area and in the Moray Firth the month to month variation is similar to that for the lighthouses, as is to be expected since there is little atmospheric pollution and most of the fogs will originate at sea; in central Scotland, away from urban influence, fog is so rare that the figures available do not suggest any marked seasonal variation, but the other areas show interesting features.

Near the east coast all stations have most fog in winter, and this difference from the lighthouse records is due chiefly to the difference in the times of observing. At the land stations in this area the observations quoted are for 0900 (except at Leuchars) by which time many of the summer fogs have cleared (see below under Diurnal Variation), but the lighthouses are observing continuously, and report all occasions of fog irrespective of the time of occurrence.

TABLE III.—AVERAGE NUMBER OF DAYS PER ANNUM WITH FOG AT MORNING OBSERVATION AT STATIONS USING FIXED VISIBILITY OBJECTS, 1927-36

<i>North and west islands—</i>		<i>Firth of Clyde—</i>		<i>Firth of Forth—</i>	
Lerwick*	.. 8.5	Rothesay ..	15.5	Inchkeith*	.. 14.4
Kirkwall ..	5.8	Helensburgh ..	28.2	Dunfermline ..	(22.1)
Wick*	.. 9.5	Greenock ..	58.5	Stirling ..	37.6
Stornoway*	2.4	Renfrew* ..	27.2	Edinburgh ..	(29.2)
Duntulm ..	(4.3)	Paisley ..	27.2	N. Berwick ..	5.9
Tiree*	.. 3.5	Glasgow ..	83.9	Dunbar ..	10.6
<i>Moray Firth—</i>		<i>East Scotland—</i>		<i>South Scotland—</i>	
Fortrose ..	1.6	Aberdeen ..	14.7	Kilmarnock	11.1
Inverness ..	6.5	Stonehaven ..	(5.2)	Troon ..	(14.6)
Nairn ..	2.5	Montrose ..	5.1	Strathaven ..	(14.2)
Forres ..	(2.3)	Kettins ..	8.3	Balerno ..	(11.8)
		Arbroath ..	15.6	Boghall ..	16.9
<i>Central Scotland—</i>		Leuchars* ..	7.7	Kelso ..	10.3
Fort Augustus	6.8	St. Andrews	4.8	Eskdalemuir	9.2
Braemar ..	(2.2)			Dumfries ..	15.4
Dalwhinnie*	(4.3)				
Glenbranter	5.0				
Oban ..	0.7				

NOTE.—The observations are for 0900 except at those stations marked with an asterisk where they are for 0700.

In the Firth of Forth the foggiest months are November to March for both lighthouses and other meteorological stations, suggesting that the lighthouses are affected by the land fog which is commonest in winter. The only difference is that the lighthouses have most fog in March and land stations have their maximum amount in November.

The land stations in the Clyde area show a seasonal variation both greater and more regular than that for any other district. In

TABLE IV.—DISTRICT AVERAGES OF FOG FREQUENCY AT LAND STATIONS
Average number of days per month with fog at morning observation.

District	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
North and west islands	0.1	0.2	0.5	0.3	0.7	0.7	1.2	1.0	0.8	0.1	0.1	0.1
Moray Firth ..	0.5	0.4	0.5	0.1	0.4	0.2	0.2	0.2	0.3	0.2	0.3	0.2
Central Scotland	0.4	0.2	0.5	0.3	0.3	0.1	0.3	0.1	0.3	0.3	0.5	0.5
East Scotland ..	1.0	1.2	1.5	0.5	0.7	0.3	0.4	0.4	0.6	0.4	0.9	1.0
Firth of Clyde ..	6.0	5.8	5.5	1.5	1.1	0.3	0.4	1.1	3.1	3.1	6.2	5.8
Firth of Forth ..	2.7	2.3	1.9	0.7	1.5	1.0	0.5	0.8	1.1	1.2	3.7	2.9
South Scotland ..	1.9	2.0	1.5	0.5	0.6	0.4	0.4	0.3	0.8	0.5	1.9	2.2
Mainland ..	2.1	2.0	1.9	0.6	0.8	0.4	0.4	0.5	1.0	0.9	2.3	2.1

the five months, November to March, one day in five is foggy but in the remaining seven months only one in twenty. As near the Firth of Forth, November is the foggiest month.

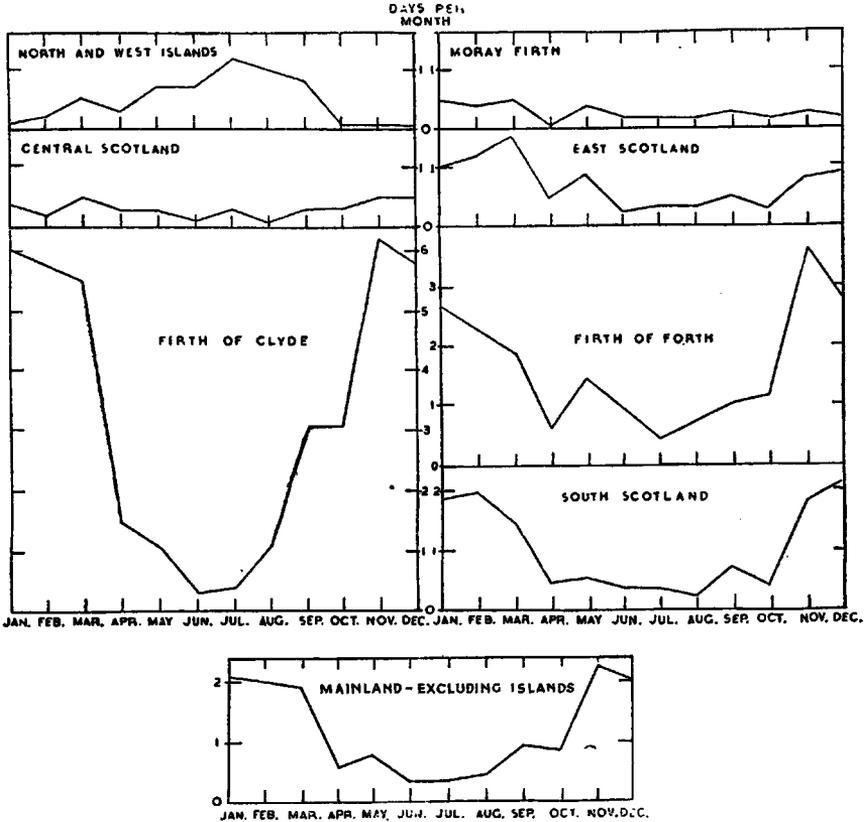


FIG. 2.—FOG AT LAND STATIONS. NUMBER OF DAYS PER MONTH WITH FOG AT MORNING OBSERVATION—1927-36

The southern area shows a similar variation to the Firth of Clyde, although the total amount is much less.

Diurnal variation.—At the Observatories at Eskdalemuir and Aberdeen the visibility is recorded six times each day, at 0700, 0900, 1300, 1500, 1800 and 2100. Observations at 0700, 1300 and 1800 are made at other stations, of which Inchkeith*, Stornoway, Wick and Lerwick also observe at 0100. Summaries of the records for 1927 to 1936 are given in Table V, and the Eskdalemuir and Aberdeen averages are reproduced in Fig. 5.

At both Lerwick and Wick there is more fog at 0700 than 0100 during most of the year, but less in winter, although fog is then so rare that the decrease has no practical significance. At Inchkeith,

* The Inchkeith station is now closed.

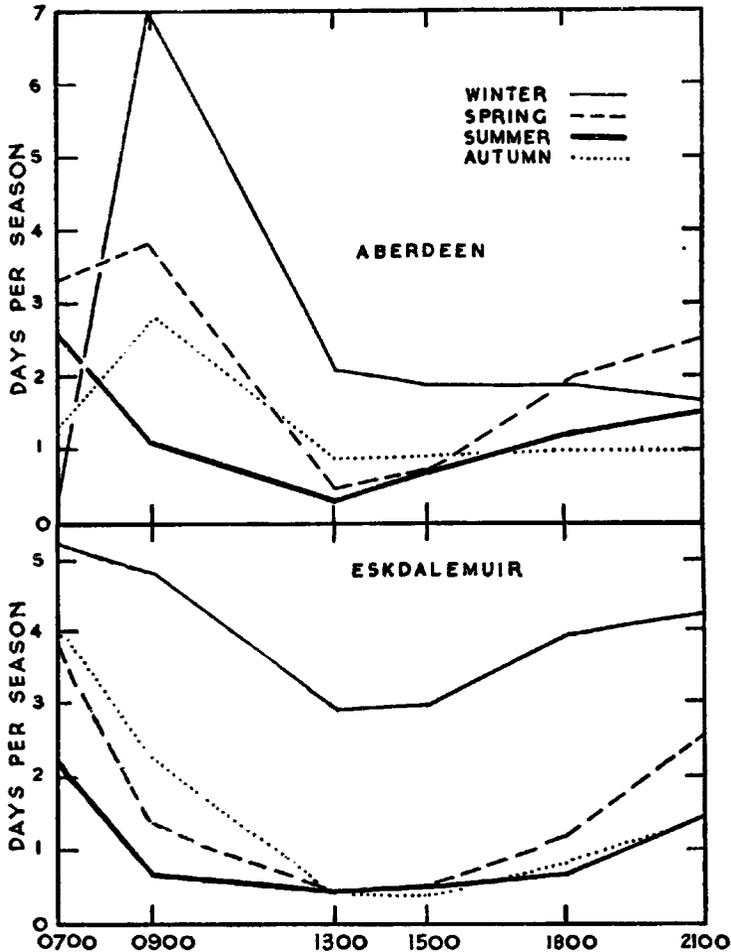


FIG. 5.—DIURNAL VARIATION OF FOG FREQUENCY 1927-36

although the difference is least in winter, the 0700 figure is the greater during the year.

The changes from 0700 to 0900 are apparently as great as those between 0900 and 1300; this is particularly the case at Aberdeen, where the increase from 0700 to 0900 in winter is exceptionally large. Increases also occur in the equinoctial months but in summer the interval from 0700 to 0900 is the time of greatest improvement of visibility. In all seasons visibility improves between 0900 and 1300. Though at Eskdalemuir the improvement between 0700 and 1300 is apparently continuous throughout the year, at Aberdeen the difference in the curves for winter and summer is very striking. Inspection of the figures for individual months (not published) shows that more fogs occur at 0700 than at 0900 from April to September, and the difference is greatest in July; during the other six months



FIG.3—ANNUAL DURATION OF FOG AT LIGHTHOUSES AND NUMBER OF DAYS PER ANNUM WITH FOG AT MORNING OBSERVATION AT LAND STATIONS. Isopleths are drawn for 5,10,20,40,60 and 80 days per annum.



FIG. 4 - MONTH OF MOST FOG 1925-34

the change is reversed and in December and January, although 0700 is the clearest of the six times at which observations are made, 0900 is the foggiest.

The difference between the diurnal variations at Eskdalemuir and Aberdeen is in agreement with Aitken's deductions from observations near Falkirk (2). He found that with clear skies, fog thickened after sunrise only when the atmosphere was polluted with the products of combustion, and it was this observation which led to his discovery that ultra-violet radiation increases the number of hygroscopic nuclei. At Eskdalemuir the atmosphere is pure and the diurnal variation seems to be independent of the time of sunrise, but at Aberdeen the connexion is very marked.

TABLE V.—DIURNAL VARIATION OF FOG FREQUENCY. AVERAGE NUMBER OF DAYS PER SEASON, 1927-36

Station	Time G.M.T.	Winter, Dec.-Feb.	Spring, Mar.-May	Summer, June-Aug.	Autumn, Sept.-Nov.	Station	Time G.M.T.	Winter, Dec.-Feb.	Spring, Mar.-May	Summer, June-Aug.	Autumn, Sept.-Nov.
Lerwick ..	0100	0.1	1.8	4.4	0.9	Leuchars ..	0700	1.6	1.9	1.9	2.3
	0700	0.0	2.4	5.0	1.1		1300	1.0	0.0	0.3	0.3
	1300	0.0	1.0	1.6	0.6		1800	1.2	1.1	0.3	0.8
	1800	0.3	1.1	3.5	0.9						
Wick ..	0100	0.3	1.5	3.9	0.9	Inchkeith ..	0100	2.3	3.6	2.5	1.5
	0700	0.2	2.4	5.4	1.5		0700	2.8	5.2	4.2	2.2
	1300	0.0	1.6	3.0	0.3		1300	2.5	2.0	1.0	1.5
	1800	0.4	1.2	2.4	0.4		1800	1.5	1.6	1.6	1.5
Stornoway ..	0100	0.0	0.3	1.0	0.5	Renfrew ..	0700	7.4	6.6	2.2	11.0
	0700	0.1	0.5	0.8	1.0		1300	12.4	2.0	0.3	6.7
	1300	0.1	0.0	0.4	0.0		1800	8.3	1.2	0.6	5.4
	1800	0.1	0.5	0.4	0.3						
Tiree ..	0700	0.3	1.2	1.4	0.6	Eskdalemuir	0700	5.2	3.9	2.2	4.0
	1300	0.1	0.5	0.2	0.1		0900	4.8	1.4	0.7	2.3
	1800	0.4	0.7	0.8	0.4		1300	2.9	0.4	0.4	0.4
							1500	3.0	0.5	0.5	0.4
Aberdeen ..	0700	0.4	3.3	2.6	1.3		1800	3.9	1.2	0.7	0.8
	0900	7.0	3.8	1.1	2.8	2100	4.2	2.6	1.5	1.5	
	1300	2.1	0.5	0.3	0.9						
	1500	1.9	0.7	0.7	0.9						
	1800	1.9	1.9	1.2	1.0						
	2100	1.7	2.5	1.5	1.0						

Climatological stations normally observe at the same hour (G.M.T.) throughout the year and, therefore, if subject to atmospheric pollution, experience a seasonal variation of fog frequency due to the changes in time of sunrise, superposed on the real variation. Some stations observe an hour earlier in summer than in winter and this will decrease the amplitude of the spurious variation.

Another factor is latitude, the difference between the times of sunrise in winter and summer being greatest in high latitudes. The complication introduced by the constancy of the hour of observation will therefore be less important at most British stations than at Aberdeen.

At the stations where no data are published for any hour between 0700 and 1300 it is impossible to discuss the incidence of maximum, but it is noteworthy that in winter Renfrew has more fog at 1300

than at 0700, and that at Inchkeith the decrease between those hours is only quite small. These are the stations most affected by atmospheric pollution.

During the afternoon there is usually a decrease in visibility, the chief exceptions being at Renfrew, Wick and Inchkeith.

Changes between 1889-1900 and 1925-34.—General.—The last two columns of Table I show the average annual duration of fog for the period 1889-1900, extracted from Buchan's paper, and the 1925-34 figures expressed as percentages of the earlier values; the areas, according to the changes shown, are indicated in Fig. 6. Table VI includes the district monthly values for each district for 1889-1900.

It is seen that the districts in which fog has increased are chiefly those which now have the greatest amount in winter, namely the Firth of Forth, parts of the south-west coast, and the north side of the Moray Firth, the increases in the last mentioned being only very slight. The land areas adjoining these districts have become increasingly urbanised in the last half century and have experienced an increase in industrial activity and associated atmospheric pollution. Similarly at Girdleness, near Aberdeen, slightly more fog has been recorded in recent years than formerly.

Other stations with increased fog and those with the least decrease have a mainly southerly exposure, e.g. Mull of Kintyre, Mull of Galloway, Little Ross, Chicken's Rock, Barra Head and Sumburgh Head. Consistently with this there is a tendency for places with a northerly exposure to have less fog than formerly; North Unst has decreased 55 per cent. and Butt of Lewis 53 per cent.

The most sheltered lighthouses show less consistent variations. Sound of Mull has a considerably decreased total but the amount at McArthur's Head has more than doubled, whereas at other stations the changes are negligible.

Incidence of maximum, 1925-34 and 1889-1900.—Comparison of Fig. 7 with Fig. 4 reveals important differences, the chief being that, at all but a few stations, the summer month with most fog in 1889-1900 was June and not July. On the east coast, only four stations had their maximum in May and, even in the Forth area, none experienced its greatest amount during the winter. Of all the 65 lighthouses considered by Buchan, only one, North Unst in the far north, had a July maximum; and in the south-west the area of winter fog was much smaller than now, including only the east coast of the Firth of Clyde, the south coast of Galloway excluding the Rhinns, (Little Ross having a December maximum), and part of the north-east coast of the Isle of Man; Lochindaal (Islay) also had a February maximum.

Annual variation, 1925-34 and 1889-1900.—In Fig. 1 the dotted lines show the 1889-1900 monthly averages. It is seen that there

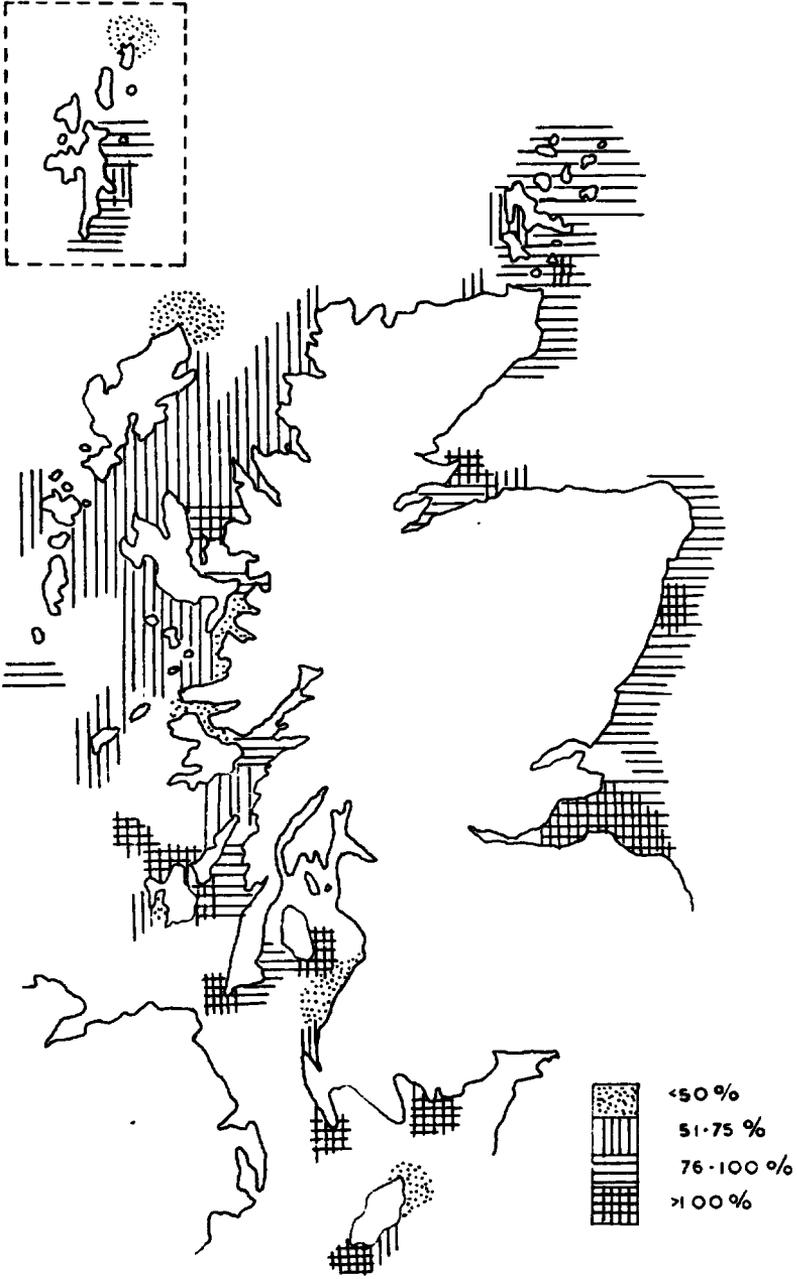


FIG. 6 - FOG DURATION - 1925-34 MEAN AS PERCENTAGE OF 1889-1900 MEAN



FIG.7- MONTH OF MOST FOG 1889 -1900

Fog in Scotland

TABLE VI.—DISTRICT AVERAGES OF DURATION OF FOG (IN HOURS) AT 58 LIGHTHOUSES ON THE SCOTTISH COASTS AND ISLANDS, 1889-1900

District Letter	District	Lighthouse Numbers	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
A	Firth of Forth	4-6	17	31	22	28	43	49	26	16	21	21	25	26	325
B	East coast ..	7, 8, 10, 11, 13	6	14	5	26	47	58	26	22	23	9	12	5	253
C	Moray Firth	14-17	3	8	4	10	17	23	7	8	11	7	11	13	122
D	North-east coast	19, 21-23	6	13	6	23	41	67	47	37	24	5	4	3	276
E	Orkney ..	25-27, 30, 31, 33	4	6	3	15	36	59	35	28	22	3	1	2	214
F	Shetland ..	38-40	2	3	9	18	35	60	51	42	27	14	6	1	268
G	Outer Hebrides	42, 43, 45-47	6	8	12	11	14	34	16	19	15	4	6	2	147
H	North-west coast	50, 52, 54, 55	3	6	6	7	6	17	11	10	7	3	1	0	77
I	West coast (Mull)	56-58, 60, 61	6	8	8	8	9	27	16	8	10	3	2	1	106
J	West coast (Islay)	62-67	9	11	8	7	13	24	20	9	13	3	3	4	123
K	Firth of Clyde	69-74	8	13	7	7	7	15	8	9	14	6	7	7	108
L	South-west coast	75, 76, 79	12	14	9	8	7	12	9	7	10	9	6	12	115
M	Isle of Man ..	80, 82-84	16	30	17	20	24	28	25	15	20	15	12	17	239
D, E, F	North ..	..	4	8	6	19	37	61	42	34	24	7	3	2	247
G, H	North-west ..	..	5	7	10	9	11	27	14	15	11	4	4	1	118
I, J	West ..	..	8	10	8	7	11	25	18	9	12	3	2	3	116
K, L, M	South-west ..	..	12	19	11	11	13	18	13	10	15	9	8	12	151
	All coasts ..	..	7	12	8	14	22	36	22	17	16	7	7	6	174

are changes in the annual variation other than the alteration in the month of greatest fog. In all districts in 1889-1900 the summer maximum was not only earlier but more pronounced than in the period 1925-34. The February-March secondary maximum was well marked, but there was another in September of which there is little evidence in recent years.

The greatest changes in the 35-year interval have occurred in the east, particularly in the south-east. In the Firth of Forth there has been a considerable increase in winter and spring and a slight decrease in summer. Elsewhere there have been decreases during the winter and early summer which have more than compensated for the increase in July.

Relation to other meteorological factors.—Since the data dealt with above are monthly or annual means it is only possible to consider broadly the relation to other meteorological factors. It was expected that, as fog is most persistent under anticyclonic conditions, variations similar to those of the fog frequency might be found in the records of pressure. Fig. 8 includes the monthly mean pressure at Aberdeen for the two periods under discussion. Averages were computed for other stations, but the figures were found to be very similar and they are therefore not reproduced here. Three maxima, namely in February, June and September, are common to the two curves and comparison with Fig. 1 shows that these maxima of pressure coincide with those of fog duration for the earlier period. There is, however, no change in mean pressure corresponding to the shift of the summer maximum of fog to July in the later period.

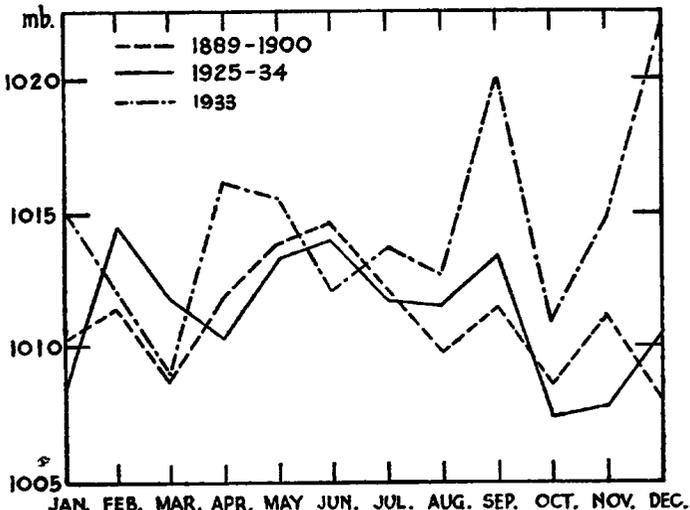


FIG. 8.—PRESSURE AT ABERDEEN; MONTHLY MEAN VALUES

Amongst other weather elements for Scotland as a whole one striking difference between the periods 1889-1900 and 1925-34 was

in rainfall. The earlier period was normal in the sense that it included as many wet years as dry years, but the later one was rather wet, and 1933 was the only year of the 10 in which less than the average rainfall was recorded; 1933 was in fact an outstandingly fine year, and it was obvious that it would be of interest to consider the fog averages for 1933 separately. The monthly values of fog and of pressure are shown in Fig. 1 (all coasts) and Fig. 8 respectively; it is seen that 1933 has a still earlier (May) summer maximum of fog than 1889-1900.

In 1933 the higher pressures during the winter and September were associated with increased fog, and the deficiencies in February and March also apply to both fog and pressure. The resemblance between the curves in summer is less striking, but in both the maximum was two months earlier in 1933 than in the average for the decade 1925-34. From this consideration of pressure and fog in 1889-1900, in 1925-34 and in 1933 it appears that pressure, or the frequency of anticyclonic conditions, has an important association with the amount of fog, but that other agencies must be considered during the summer months.

In regard to air temperature, Geddes (3) showed that there has been an increase at Aberdeen during the last 50 years, chiefly during the winter months, but comparison of averages for the actual periods now under discussion shows that there has also been a large increase in July and a small decrease in June. The actual figures in degrees Fahrenheit, are :—

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
1889-1900	38.0	37.7	39.9	43.4	47.5	53.3	56.1	56.1	52.8	46.6	43.3	39.5	46.2
1925-34	39.4	39.3	40.8	43.4	47.7	53.1	57.7	56.8	52.8	47.3	42.6	40.5	46.8
Difference	+1.4	+1.6	+0.9	0.0	+0.2	-0.2	+1.6	+0.7	0.0	+0.7	-0.7	+1.0	+0.6

Since the sea temperature tends to vary with that of the air, though with a time lag of about a month, it is clear that taking the periods as a whole the average excess of air over sea temperature has decreased in June and increased in July. Similarly in September, although the air temperature has not changed, the sea temperature has probably increased slightly.

It is well established that sea fog is most likely to form when the excess of air over sea temperature is high. Hence the change, between 1889-1900 and 1925-34, from June to July of the summer maximum of duration of fog and the decreased prevalence in September are probably both explained by the changes which have occurred in the air-sea temperature difference.

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BIBLIOGRAPHY

1. BUCHAN, A. ; *Edinburgh, J. Scot. met. Soc., Third Series*, **12**, 1902, p. 3.
2. AITKEN, J. ; *Edinburgh, Proc. roy. Soc.* **32**, 1911-2, p. 183 and reprinted in "Collected Scientific papers of John Aitken, LL.D., F.R.S.", Cambridge at the University Press, p. 512.
3. GEDDES, A. E. M. ; *London, Quart. J. R. met. Soc.*, **61**, 1935, p. 347.

APPENDIX—LOW CLOUD

Since low cloud and fog are different forms of the same phenomenon the following notes on the frequency of low cloud at a few Scottish stations are appended with particular reference to the annual and diurnal variations.

The average frequencies of cloud below 600 ft. and below 1,000 ft. as estimated by the observers, are given in Table VII. The large numbers for Eskdalemuir are due to the high level (800 ft. above M.S.L.) of the station.

TABLE VII.—LOW CLOUD ; AVERAGE NUMBER OF OCCURRENCES PER SEASON, 1927-3 ;

Station.	Hour G.M.T.	Below 600 ft.				Below 1,000 ft.			
		Winter	Spring	Summer	Autumn	Winter	Spring	Summer	Autumn
Aberdeen	7	1.2	5.9	7.7	4.2	6.6	14.5	16.6	9.7
	13	2.2	3.6	3.6	2.3	9.3	9.5	8.9	9.1
	18	1.7	5.2	4.9	3.0	7.4	11.6	11.1	9.4
Leuchars	7	2.0	10.8	12.3	3.9	9.0	16.9	18.4	10.9
	13	3.8	5.9	6.2	3.3	10.9	12.0	11.4	8.3
	18	2.6	7.7	5.9	3.9	11.1	13.6	11.0	9.7
Renfrew	7	5.8	3.4	3.9	7.9	12.7	11.7	16.6	16.1
	13	5.1	1.5	1.2	3.0	13.5	6.1	6.2	8.5
	18	3.2	1.2	2.1	3.6	12.0	5.5	7.0	9.7
Eskdalemuir ..	7	16.8	16.0	16.0	14.5	31.7	27.4	28.9	30.3
	13	15.2	4.9	4.2	6.4	28.8	12.9	10.4	17.8
	18	14.3	7.7	5.8	9.1	28.7	15.6	12.9	19.4

Seasonal variation.—Low cloud is most common in spring and summer at Aberdeen and Leuchars when considerably more cloud is experienced than at Renfrew, but Renfrew has more in winter and autumn, the excess being greatest at the 0700 observation. For cloud below 1,000 ft. at 0700 even Renfrew has a summer maximum, but the cloud clears rapidly during the morning. At Eskdalemuir low cloud is commonest in winter and autumn, although for the lowest cloud autumn is the season with the least amount for the 0700 observation.

Diurnal variation.—There is more low cloud at 1300 than at 0700 at both Aberdeen and Leuchars in winter, and this is true for cloud below 1,000 ft. at Renfrew. Otherwise the amount generally decreases during the morning, especially in summer. Between 1300 and 1800 there is a further clearance in winter at all stations with the exception of cloud below 1,000 ft. at Leuchars. Leuchars is also the exception in summer when it experiences an afternoon

decrease, the other three stations all reporting definite increases. Similarly in spring, Aberdeen, Leuchars and Eskdalemuir have more cloud at 1800 than 1300, the difference being greater than in summer, but at Renfrew a slight clearance occurs. Autumn is the only season with similar variations at all stations, a small increase in low cloud being experienced during the afternoon.

Occurrences of low cloud at Wick, Aberdeen, Leuchars and Inchkeith during the summer months of 1931-6 have also been investigated in relation to wind direction and speed. It is found that sea breezes are the winds most frequently associated with low cloud at all the stations considered, especially at 1300 and 1800. At 0700 many cases occur with calms and light airs, and are probably the result of night radiation. At 1300 and 1800 winds of force 2 and 3 (Beaufort Scale) are experienced with most of the occurrences considered, but it is found that low cloud can persist even with winds of force 5.

An interesting feature of this low cloud experienced on the east coast of Scotland is its seaward extent. It has been found that when low cloud or fog occur at Montrose, Leuchars and Inchkeith, associated with an easterly wind, the Isle of May has longer periods of fog and Bell Rock still longer periods.

