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WATER-FOG POINT—A FURTHER TEST

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Summary.—The following note reports the results of a test of Saunders's method[1] for forecasting the water-fog point. The test was aimed primarily at ascertaining the result of applying the method simultaneously to different locations. An account is given of the experience obtained at Northolt Airport in the use of the method. Some remarks are also made regarding the differing approaches towards fog forecasting in general, as seen from the work of other writers.

Introduction.—One of the present writers, in an article[1] published in 1950, described the results of an investigation leading to a practical method of forecasting the water-fog point by the use of representative tephigram ascents. The method has been used almost exclusively by forecasters at Northolt Airport since that time with an encouraging degree of success. For example, investigations carried out, for other purposes, during the last four winters into the accuracy attained in forecasting visibility show that a considerable improvement took place during that period. It is believed that use of the method played a definite part in the improvement.

One would expect the water-fog point to be more or less constant for a given air mass. Experience strongly suggests that in radiation-fog situations this is true, and that local variations in fog development arise from differences in the degree of night cooling rather than in spatial variations of the fog-point temperature. This does not hold, of course, near coasts with on-shore winds. Hence, over areas where there has been fairly uniform heating, the fog point can be regarded within close limits as a fixed property of the air mass, with local topographical and soil variations being manifest in night-cooling differences. Local differences in the occurrence and density of radiation fog are thus believed to be almost entirely due to local variations in the cooling rate.

It was decided to test the above conception of the approximate constancy of the fog-point temperature within a given air mass, and at the same time to examine the usefulness of the fog-point method when applied simultaneously to different locations. Before reporting the results of this test, it seems desirable to comment on the adopted definition of the water-fog point (T_f).

Definition of fog point.—In assessing the value of any method for forecasting radiation fog it is essential to define with great care what is to be regarded as the fog point. To say that it is the "temperature at which fog forms" is too vague and may lead to many uncertainties which largely invalidate any test. First, it must be clearly recognized that smoke fog is not at all closely associated with relative humidity and must be dealt with by different methods from water fog. This is no mere academic distinction. Visibility in most smoke fogs is in the range 600–1,000 yd. whilst in most water fogs it is below 500 yd. In the former, aircraft using modern aids can land safely. In the latter, they often cannot. Any definition used for testing a method of forecasting radiation fog should therefore exclude smoke fog. Secondly, on radiation nights the temperature at ground level is commonly several degrees below that at screen level and shallow fog patches may form, even when at screen level the temperature is appreciably above the fog point of the air mass. It is therefore suggested that, for purposes of this sort, the fog point should be defined as "the screen-level temperature at which the general visibility falls within the fog range with relative humidity 95 per cent. or more, or at which with visibility in the fog range relative humidity rises to 95 per cent. or more". These aspects are mentioned since it is the fog point as here defined which is yielded by the method under discussion, and it is important to keep this in mind in studying the usefulness of the method.

Test of the fog-point method.—The test was applied to the period August 1–October 5, 1950. This period was specially selected in the hope that seasonal lack of domestic smoke would ensure that any fog would be mostly water fog; and in fact there was only one occasion when fog was first reported with relative humidity less than 95 per cent. The trial was restricted to inland stations in England which report hourly temperatures and for which night minima appear in the *Daily Weather Report.* On each afternoon when radiation fog was possible, the fog points were calculated from the 1500 G.M.T. Larkhill, Liverpool and Downham Market ascents using Saunders's method[1] and were plotted on a chart. An estimate was then made of the forecast fog point for each of the selected stations making due allowance for any unmistakable advective effects over the area. Where fog developed, the screen-level temperature at the time of fog formation (i.e. the actual fog point) was plotted, occasions of ground fog alone being disregarded for this purpose. When there was no fog in a potentially foggy area, the night minimum temperature was plotted.

Results of the test.—The results were analysed as follows:—

Radiation fog reported (55 occasions)	
(i) Actual T_f within ± 1°F. of forecast T_f	40
(ii) Actual $T_f >$ forecast $T_f + 1$	11
(iii) Actual $T_f <$ forecast $T_f - 1$	4
No fog within potentially foggy area (93 occasions)	
(iv) $T_{min} >$ forecast T_f	78
(v) $T_{min} \leqslant$ forecast T_f	15

We are perhaps justified in regarding the 40 occasions under (i) as successful cases, since hourly temperatures only could be used and it was not possible to arrive at the actual fog point precisely. On this assumption, and using the method of assessing the usefulness of forecasts described by Crossley[2], we find that the "useful effort" for forecasts of fog (i.e. the proportion of them which would have proved correct) was 75 per cent., whilst the "useful effort" for forecasts of no fog was 88 per cent. These percentages would of course have been much higher if a continuous period had been treated in this way, instead of a selection comprising only potentially foggy periods. They are therefore very encouraging.

Cases under (ii), (iii) and (v) appear at first to constitute failures of the method and we therefore proceed to examine them briefly.

Of the 11 fog occasions under (ii), 8 occurred in southern England on two nights when marked advective changes from the south-west took place. On both nights the radio-sonde ascents revealed a rise in dew point between 1500 and 2100 G.M.T. This rise was greater at 900 mb. than at 950 or 1000 mb., thus decreasing the hydrolapse. On 2 of the remaining 3 occasions the fog developed after rain had fallen at the stations concerned, whereas the afternoon ascent used in the analysis had not been made in rain.

On the 4 occasions under (iii), there were 2 on which the radio-sonde ascent used had been affected by rain but not the station concerned.

Among the 15 cases under (v), there were 5 in which, in a special sense, there was no representative ascent. For example, on one occasion with a westerly air stream there was no fog at stations to the lee of the Welsh hills although the forecast fog point was reached. Its value, however, had been derived from Larkhill and Liverpool ascents, neither of which was representative of air modified by passage over the hills.

In short, on most of the occasions when the method of forecasting fog would have been unsuccessful, and these are comparatively few, the failure of the method can be ascribed to the forecast fog points not applying to the air over the stations during the evening. There is nothing to indicate that the process of derivation of the fog point itself is in any way at fault; the difficulty is to ensure that the process is applied to a truly representative ascent.

We may justifiably conclude that when this method is applied to cases of water fog at a variety of stations, the accuracy is not appreciably less than that obtained in the original work[1] for stations in the London area. In the latter work, occasions when there were no representative ascents were excluded so that the basic relation could clearly be demonstated. The forecast and actual fog points were then found to be within 1°F. on 44 occasions out of 48.

General experience of the method.—The encouraging results obtained from the use of the method at Northolt during 2½ years' experience have already been mentioned, and some more specific comments on this experience, and that of other stations, may be of interest.

First, it appears now to be well substantiated that, given a representative ascent, the constructions of Types I and IIIA in Fig. 4 in the paper by Saunders[1] yield satisfactory results. Provided T_f is above the freezing point, water fog forms when T_f is reached at screen level. We have seen too that there is no obvious restriction as to locality.

Secondly, it follows from the approximate constancy of the fog point for a given air mass that the construction may also be used when the cooling is due to processes other than radiation. Thus it may be used equally for sea fog or other advection fog where, through passage over a colder underlying surface, the screen-level temperature of the air mass falls to T_f.

Three types of difficulty or sources of possible error have been encountered as follows:—

(*a*) *Advection.*—Sometimes advective change of dew point occurs in the upper part of the mixed layer, say at 2,000–3,000 ft., where the wind speed may be 20–25 m.p.h., whilst the surface wind is still light enough for fog. Thus, moister or drier air may readily be advected at this level, and T_f raised or lowered accordingly, with perhaps little or no change of surface dew point. To guard against errors from this cause, all upwind ascents must be considered. For example, in a south-westerly situation T_f for southern England may be derived from the Larkhill ascent, but Camborne also must be watched at relevant levels for moister air which may arrive in time to affect the fog point. A correction should be made if necessary.

(*b*) *"Inversion" case.*—The construction in the so-called "inversion" case (Type II in Fig. 4 in the paper by Saunders[1]) is less well established than the other categories. This is partly because it is mainly the midwinter case when there are often heavy smoke concentrations near London to complicate matters, and partly because it is often not possible to obtain the slope of the representative dew-point curve near the surface with sufficient precision—the number of dew points given on ascents is sometimes inadequate to establish the dew-point curve properly. Further investigation into this case is desirable, preferably based on non-smoky areas.

(*c*) *Effect of rain.*—The case in which rain falls during the radio-sonde ascent, but not at the station for which the fog point is required, is always troublesome and there is no obvious solution. The reverse case, where the ascent is made in dry air but there is rain at the station during the evening, is also difficult, but it has been noted that if the precipitation is of the shower type and provided there is still some surface wind after precipitation ceases, the dry-air value of T_f applies.

We may conclude that further research on the water-fog point is most needed in the "inversion" case and in the effect of rain.

Work of other writers.—It is a matter of some interest to note the choice adopted by various writers of parameters for use in forecasting fog. For example, Craddock[3] has shown that the fog point can be expressed approximately in terms of surface temperature and dew point, ignoring variations in the vertical, whilst Briggs[4] recently used temperature lapse and hydrolapse but ignored surface values. The neglect of obviously significant parameters must impose limitations on the value of any method, and it seems reasonable to suppose that the use of lapse rate of potential dew point together with surface temperature and dew point as in the present method is the better approach. This choice of parameters is indirectly supported by the work of Swinbank[5]. Swinbank does not deal explicitly with the fog point but determines the time of fog formation from two diagrams in which the other variables are mean square wind shear (effectively the square of the gradient wind speed), mean difference between 1800 dry-bulb and dew-point temperatures, and hydrolapse. In the present method wind is regarded as best allowed for in forecasting the cooling, and the parameters employed are thus only different forms of those used by Swinbank.

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SIGNIFICANCE OF MEAN CONTOUR CHARTS

By A. F. CROSSLEY, M.A.

In the issue of this Magazine for February 1952, Mr. R. W. James[1] has given a comprehensive discussion of the significance of mean flow charts. In particular he examines the relationship between the true mean wind and the wind derived from a mean isobaric chart for the same period. When the seasonal charts of pressure contours, now published in "Upper winds over the world"[2], were being prepared, it was realized that the mean wind as deduced from these charts would not be identical with the true mean. The method by which this result was reached is an extension of that used by James, and moreover has the advantage that it enables the mean ageostrophic departure arising from the "space acceleration" to be readily evaluated.

To avoid repetition we need consider only horizontal frictionless flow in the free air, for which the equations of motion may be written in Cartesian co-ordinates as:—

$$\left.\begin{aligned} \frac{\partial u}{\partial t} + u\frac{\partial u}{\partial x} + v\frac{\partial u}{\partial y} - 2\,\Omega\, v \sin\phi &= g\frac{\partial h}{\partial x} \\ \frac{\partial v}{\partial t} + u\frac{\partial v}{\partial x} + v\frac{\partial v}{\partial y} + 2\,\Omega\, u \sin\phi &= g\frac{\partial h}{\partial y} \end{aligned}\right\} \qquad \ldots\ldots\ldots(1)$$

Here u and v are the horizontal wind components at time t in the direction of the rectangular axes of x and y, and h is the height of a given pressure surface above some standard level, while other symbols have their customary meaning. We shall also require the reduced equation of continuity,

$$\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} = 0. \qquad \ldots\ldots\ldots(2)$$

To obtain the mean motion, we must take the mean value of each term in these equations over the required period. Using a bar to denote a mean value with respect to time, and an accent to denote the departure of an individual value from the mean, we write

$$u = \bar{u} + u', \quad v = \bar{v} + v'.$$

Since we are considering seasonal charts, it follows as in James's paper that we may take

$$\overline{\frac{\partial u}{\partial t}} = \overline{\frac{\partial v}{\partial t}} = 0.$$

We also have

$$\overline{u\frac{\partial u}{\partial x}} = \tfrac{1}{2}\frac{\partial}{\partial x}\overline{u^2} = \tfrac{1}{2}\frac{\partial}{\partial x}(\bar{u}^2 + \overline{u'^2})$$

since $\overline{u'} = 0$ by hypothesis. Now the vector departures of the actual wind from the mean wind have an approximately circular distribution[2]. Thus if $\mathbf{V}$ denotes the vector wind on a particular occasion, then $\mathbf{V} = \overline{\mathbf{V}} + \mathbf{V}'$ where the components of $\mathbf{V}'$ are u' and v'. The standard vector deviation of $\mathbf{V}$ is $\sqrt{(\overline{\mathbf{V}'^2})}$ and is denoted by σ. Since the distribution of $\mathbf{V}'$ is symmetrical about the point which represents the extremity of the vector $\overline{\mathbf{V}}$, we have

$$\overline{u'^2} = \overline{v'^2} = \tfrac{1}{2}\sigma^2.$$

We then have

$$\overline{u\frac{\partial u}{\partial x}} = \bar{u}\frac{\partial \bar{u}}{\partial x} + \tfrac{1}{2}\,\sigma\frac{\partial \sigma}{\partial x}.$$

Similarly

$$\overline{v\frac{\partial v}{\partial y}} = \bar{v}\frac{\partial \bar{v}}{\partial y} + \tfrac{1}{2}\,\sigma\frac{\partial \sigma}{\partial y}.$$

Also, from equation (2),

$$\begin{aligned} v\frac{\partial u}{\partial y} &= \frac{\partial}{\partial y}(uv) - u\frac{\partial v}{\partial y} \\ &= \frac{\partial}{\partial y}(uv) + u\frac{\partial u}{\partial x}, \end{aligned}$$

so that

$$\overline{v\frac{\partial u}{\partial y}} = \frac{\partial}{\partial y}(\bar{u}\bar{v}) + \bar{u}\frac{\partial \bar{u}}{\partial x} + \tfrac{1}{2}\,\sigma\frac{\partial \sigma}{\partial x},$$

since from symmetry $\overline{u'v'} = 0$. Then, with use of equation (2) again after taking mean values, we have

$$\overline{v\frac{\partial u}{\partial y}} = \bar{v}\frac{\partial \bar{u}}{\partial y} + \tfrac{1}{2}\,\sigma\frac{\partial \sigma}{\partial x}.$$

Similarly

$$\overline{u\frac{\partial v}{\partial x}} = \bar{u}\frac{\partial \bar{v}}{\partial x} + \tfrac{1}{2}\,\sigma\frac{\partial \sigma}{\partial y}.$$

We can now write down the result of taking mean values of the equations (1) with respect to time, namely

$$\left.\begin{aligned} \bar{u}\frac{\partial \bar{u}}{\partial x} + \bar{v}\frac{\partial \bar{u}}{\partial y} - 2\,\Omega\,\bar{v}\sin\phi &= g\frac{\partial \bar{h}}{\partial x} - \sigma\frac{\partial \sigma}{\partial x} \\ \bar{u}\frac{\partial \bar{v}}{\partial x} + \bar{v}\frac{\partial \bar{v}}{\partial y} + 2\,\Omega\,\bar{u}\sin\phi &= g\frac{\partial \bar{h}}{\partial y} - \sigma\frac{\partial \sigma}{\partial y} \end{aligned}\right\} \quad\ldots\ldots\ldots(3)$$

These are the equations of mean horizontal motion in rectangular co-ordinates. If the mean motion is such that the second-degree terms are negligible, then it is given by the equations

$$\left.\begin{aligned} -\,2\,\Omega\,\bar{v}\sin\phi &= g\frac{\partial \bar{h}}{\partial x} - \sigma\frac{\partial \sigma}{\partial x} \\ 2\,\Omega\,\bar{u}\sin\phi &= g\frac{\partial \bar{h}}{\partial y} - \sigma\frac{\partial \sigma}{\partial y} \end{aligned}\right\} \quad\ldots\ldots\ldots(4)$$

Now the geostrophic wind is defined as

$$u_G = \frac{g}{l}\frac{\partial h}{\partial y}, \quad v_G = -\frac{g}{l}\frac{\partial h}{\partial x},$$

where l is written for $2\Omega\sin\phi$. Therefore the mean geostrophic wind is given by

$$\overline{u_G} = \frac{g}{l}\frac{\partial \bar{h}}{\partial y}, \quad \overline{v_G} = -\frac{g}{l}\frac{\partial \bar{h}}{\partial x},$$

and is obtained by applying the geostrophic scale to the mean contour charts.

Eliminating the contour gradients from equations (4), we obtain for the components of the mean wind the expressions:—

$$\left.\begin{aligned} \bar{v} &= \bar{v}_G + \frac{\sigma}{l}\frac{\partial\sigma}{\partial x} \\ \bar{u} &= \bar{u}_G - \frac{\sigma}{l}\frac{\partial\sigma}{\partial y} \end{aligned}\right\} \qquad \ldots\ldots\ldots(5)$$

The true mean wind in this case is therefore the vector sum of the mean geostrophic wind and an ageostrophic departure which is proportional to the gradient of σ^2, and is directed along the lines of equal σ with the lower values of σ to the left (to the right in the southern hemisphere). Where the contours and the isopleths of σ coincide, then the geostrophic and σ contributions to the mean wind are in the same or opposite directions according as the gradients of $\bar{h}$ and of σ are in the same or opposite directions.

From the published charts of the distribution of σ at various pressure levels it may be inferred that the greatest value of the gradient of σ^2 in any part of the world occurs between about 300 and 200 mb. in the neighbourhood of both the British Isles and the Aleutian Isles. The corresponding value of σ in each case is about 50 kt., and of the gradient about 5 kt. in 200 nautical miles. Since l is 0·4 radians/hour in latitude 50°, the greatest value of the ageostrophic departure is therefore about 3 kt. The corresponding value given by James is 1 kt., but this was inferred from observations over the British Isles for only one month (May 1948) and for the 800-mb. level only. The figure of 3 kt. now derived implies an error in the geostrophic approximation of about 10 per cent. between 300 and 200 mb. in the regions mentioned, where the mean geostrophic wind is of the order of 30 kt., which is comparatively light for these levels. At 700 mb. the mean geostrophic wind is often down to about 10 kt. over wide areas, while the ageostrophic component may amount to about 1 kt., again giving errors in the neighbourhood of 10 per cent.

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FOG AND LOW STRATUS AT PRESTWICK AIRPORT, WITH NOTES ON THE DIURNAL VARIATION OF SURFACE WIND AND TEMPERATURE

By N. E. DAVIS, M.A.

Prestwick Airport (55°31′N., 4°36′W., height 30 ft.) has the reputation of being one of the most fog-free airfields in Great Britain. This reputation is in no way diminished by the detailed consideration made in this note of the diurnal variation of fog, low stratus, wind and temperature at Prestwick.

Diurnal variation of poor visibility.—The visibilities reported at each hour of each day for the four years August 1946 to July 1950 were examined, and a record was made of the number of occasions when the visibility was less than or equal to 220, 440, 880, and 1,100 yd. Table I shows the distribution of these occasions according to months irrespective of hour, and Table II shows the distribution according to hours irrespective of month for the two seasons October to March and April to September; there were too few cases of fog to show the distribution according to months separately.

TABLE I—MONTHLY VARIATION OF FOG AT PRESTWICK AIRPORT

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept	Oct.	Nov.	Dec.	Year	Mean
	number of occasions in four years													hr./yr.
⩽ 220 yd. ...	...	...	10	...	1	3	...	5	...	1	2	3	25	6
⩽ 440 yd. ...	1	1	16	...	1	3	...	8	...	3	7	6	46	11
⩽ 880 yd. ...	4	2	26	...	1	3	4	12	...	4	13	8	77	19
⩽ 1,100 yd. ...	11	2	34	...	2	7	8	14	2	5	15	15	115	29

The outstanding feature of Table I is the size of the total: 115 hr. of fog out of a possible 35,066 (0·3 per cent.) as compared with London Airport[1] and Northolt Airport[2] which had totals of 2,672 and 2,696 respectively for the same period. Fog for the most part occurs in the months November to January, June to August and also in March. The high total for March is in part due to 15 hr. of bad visibility during the blizzards of March 1947.

In the summer half year fog is confined to the hours around or just after sunrise and sunset, but in the winter half year, there is very little diurnal variation.

Fog at Prestwick Airport may be ascribed to three factors: radiation, advection and smoke. Of these, advection is by far the most important. Smoke from the main source of pollution—the Forth-Clyde Valley—has to cross a range of hills to reach Prestwick and only exceptionally would reduce visibility to fog limits. Radiation fog forming over the airfield is rare. Normally a light land breeze (generally ESE.) blows over the airfield at night in conditions of slack gradient and is sufficient to prevent the formation of radiation fog. However, in circumstances in which a light gradient wind opposes the land breeze and conditions are otherwise suitable, radiation fog may form over the airfield. About two or three fogs a year—nevertheless lasting several hours—form in this manner.

Except for these few, all fogs at Prestwick Airport are due to the advection of fog over the airfield. This is of three types: advection of radiation fog formed locally, advection of sea fog and advection of frontal or pre-frontal fog. The movement of locally formed radiation fog may result in a rapid deterioration of visibility from several thousand yards to a few hundreds in a matter of minutes. Most of the early morning fogs in summer are of this type. Sea fog arrives in a similar manner though it may be preceded by low stratus cloud. The evening fogs in summer are sea fogs.

The fogs which occur in winter are mostly of the frontal advective type. Normally they are preceded by low stratus cloud which falls to ground level. However, owing to the long night and low elevation of the sun at noon in midwinter, it is possible for radiation fog to form either directly over the airfield or near by, and subsequently drift over the airfield at any time—except for a short period around 1400 G.M.T.—provided conditions are otherwise suitable.

However, since fog at Prestwick has a frequency of only 0·3 per cent. it is not a serious obstacle to aircraft operations. A greater hazard is low stratus cloud. In the immediate vicinity of the airfield hills rise to 400 ft.; the radio-range masts are on a hill nearly 550 ft. high $2\frac{1}{2}$ miles from the airport and near the approach to runway 26, while hills over 2,000 ft. occur within a radius of 12 miles. Frequent low cloud would thus present a considerable drawback to

TABLE II—DIURNAL VARIATION OF FOG AT PRESTWICK AIRPORT

Time	April-September				October–March			
	≤220 yd.	≤440 yd.	≤880 yd.	≤1,100 yd.	≤220 yd.	≤440 yd.	≤880 yd.	≤1,100 yd.
	Number of occasions in four years							
0000	...	...	...	...	...	...	2	4
0100	...	...	...	...	1	2	3	4
0200	...	...	1	2	1	1	2	3
0300	1	2	3	5	1	1	2	3
0400	5	5	5	6	1	1	3	4
0500	2	2	4	5	1	2	3	5
0600	1	1	1	4	2	2	2	2
0700	...	1	1	1	1	1	1	1
0800	...	1	1	2	1	2	2	2
0900	...	...	1	1	1	2	3	3
1000	...	...	...	...	1	2	2	4
1100	...	...	...	...	...	1	2	4
1200	...	...	...	...	1	2	2	3
1300	...	...	...	...	1	2	2	2
1400	...	...	...	...	...	2	2	2
1500	...	...	...	...	...	1	1	2
1600	...	...	...	...	...	1	1	4
1700	...	...	...	...	2	2	3	4
1800	...	...	...	...	...	2	2	3
1900	...	...	...	2	...	1	2	4
2000	...	...	1	2	...	1	3	5
2100	...	...	1	2	...	...	5	5
2200	...	...	1	1	...	2	4	5
2300	...	...	...	...	1	1	3	4
All hours	9	12	20	33	16	34	57	82

TABLE III—DIURNAL VARIATION OF LOW CLOUD AT PRESTWICK AIRPORT

Time	Winter				Summer				Year			
	≤200 ft.	≤400 ft.	≤600 ft.	≤1,000 ft.	≤200 ft.	≤400 ft.	≤600 ft.	≤1,000 ft.	≤200 ft.	≤400 ft.	≤600 ft.	≤1,000 ft.
	Number of occasions in four years											
0000	4	16	26	62	2	16	22	56	6	32	48	118
0100	1	9	20	51	6	16	25	63	7	25	45	114
0200	1	11	22	53	5	13	24	69	6	24	46	122
0300	2	8	15	51	6	21	35	89	8	29	50	140
0400	3	11	23	55	8	26	44	99	11	37	67	154
0500	4	10	25	59	9	25	51	110	13	35	76	169
0600	6	12	20	61	14	32	55	133	20	44	75	194
0700	2	12	22	70	10	27	55	134	12	39	77	204
0800	6	13	29	90	9	22	53	136	15	35	82	226
0900	10	19	28	92	7	17	41	118	17	36	69	210
1000	8	17	31	86	4	13	33	107	12	30	64	193
1100	1	17	32	87	1	11	23	94	2	28	55	181
1200	3	12	24	81	1	9	22	86	4	21	46	167
1300	3	8	28	85	3	12	23	76	6	20	51	161
1400	4	9	27	84	1	9	22	64	5	18	49	148
1500	2	7	25	85	4	10	21	73	6	17	46	158
1600	3	10	28	90	3	8	26	74	6	18	54	164
1700	4	13	28	94	1	8	22	72	5	21	50	166
1800	4	13	21	81	...	9	25	72	4	22	46	153
1900	2	11	21	69	2	8	24	68	4	19	45	137
2000	5	12	21	57	4	8	23	78	9	20	44	135
2100	5	12	16	63	3	11	19	62	8	23	35	125
2200	3	13	21	65	1	10	19	58	4	23	40	123
2300	3	11	25	57	2	8	18	61	5	19	43	118
Total	89	286	578	1,728	106	349	725	2,052	195	635	1,303	3,780
Mean	22	72	145	432	27	87	181	513	49	159	326	945

flying. There is, however, a marked diurnal variation in its frequency. This is considered in the following section.

Diurnal variation of low cloud.—The lowest cloud height reported at each hour of each day for the four years August 1946 to July 1950 was examined, and a record was made of the number of occasions when the cloud base was less than or equal to 200, 400, 600 and 1,000 ft. Tables giving the distribution of these occasions for each month separately were compiled but are not reproduced here. Table III summarizes the data for the two seasons October–March and April–September and for the year as a whole. Each figure in the table gives the number of times in four years when the lowest cloud base was less than or equal to the prescribed value for each hour of the day. The last two lines give the total number of hours of low stratus per season for the four years and the mean number per season respectively. Fig. 1 shows isopleths of percentage frequency of cloud ⩽1,000 ft. The isopleths have been smoothed to allow for departures of the four years from normal. The isopleths of frequency of cloud ⩽200, ⩽400 and ⩽600 ft. follow a similar pattern, but the frequencies are only 1 twentieth, 1 sixth and 1 third as great respectively at all times and seasons, except that the proportion of cloud ⩽200 ft. rises to 1 tenth in the mornings at the time of maximum frequency and is rather less than 1 twentieth in the afternoons.

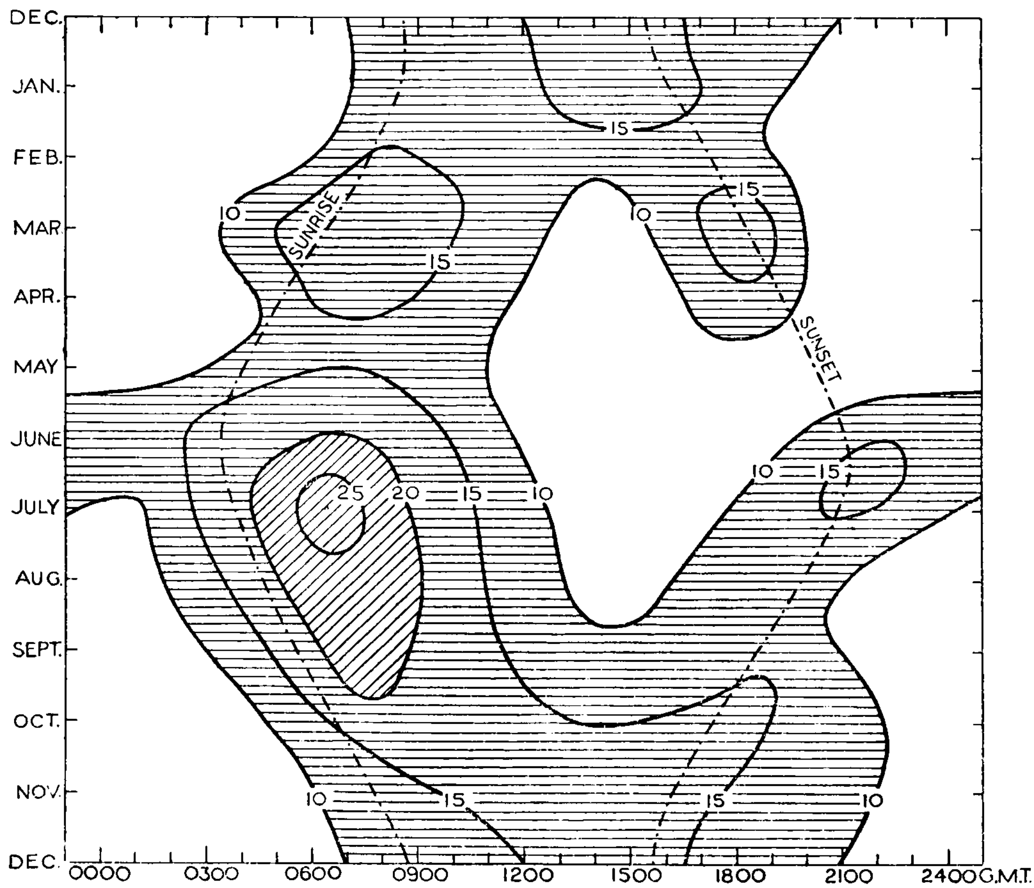

FIG. 1—PERCENTAGE FREQUENCY OF CLOUD AT OR BELOW 1,000 FT. AT PRESTWICK AIRPORT

The salient features in the variation of low cloud at Prestwick Airport to be deduced from these tables are as follows:—

(i) Considerable irregularity of diurnal variation

(ii) Relatively low frequency of low cloud in spring and relatively high frequency in summer and autumn

(iii) High frequency of low cloud about 2 hr. after sunrise throughout the year but especially in midsummer

(iv) Relatively low frequency during the middle of the afternoon in midsummer

(v) Increase of frequency about sunset

(vi) Relatively low frequency during the middle of the night.

These variations are to be explained by consideration of the stability of the lowest layers and their moisture content. These in turn depend on the amount of incoming radiation, the sea temperature, the local wind direction and the general synoptic situation.

The fact that the general synoptic situation is to a great extent responsible for the presence or absence of low cloud is the reason for the irregularities in the tables. The greater the number of frontal passages in a month the greater—in a broad sense—the number of occasions of low cloud. Table IV gives the mean-sea-level pressure at Prestwick for each month for the period, the normal (1901–30) pressure, the departure from normal and the number of occasions of cloud below 1,000 ft.

Subnormal pressure is associated with greater depressional activity, more frequent frontal passages, and consequently a greater frequency of low cloud. This is confirmed by Table IV, for, apart from March, the frequency of low cloud is greater for those months with negative departures of pressure. The isopleths given in Fig. 1 have been smoothed on the lines indicated by Table IV.

If a rough correction is made by adding 16 occasions for each millibar above normal and subtracting 16 for each millibar below normal, Table IV shows that,

TABLE IV—MEAN-SEA-LEVEL PRESSURE AT PRESTWICK AND ITS RELATION TO CLOUD AMOUNT

Period: August 1946–July 1950

	Mean-sea-level pressure			Occasions of cloud ≤ 1,000 ft.	
	Average (1946–50)	Normal (1901–30)	Difference from normal	Actual (1946–50)	Corrected
		millibars			
January	1010	1011	−1	346	330
February	1013	1011	+2	183	215
March	1015	1010	+5	322	402
April	1009	1012	−3	330	282
May...	1016	1014	+2	192	224
June...	1014	1015	−1	407	391
July...	1014	1014	0	402	402
August	1014	1012	+2	337	369
September	1013	1015	−2	384	352
October	1017	1011	+6	277	373
November	1009	1010	−1	324	308
December	1011	1008	+3	276	324
Year...	1013	1012	+1	3,780	3,972

apart from March, cloud below 1,000 ft. is relatively less frequent from February to May and more frequent from June to October. This is contrary to the usual experience of coastal stations in that low stratus cloud is more frequently experienced in the spring when the sea temperature is relatively low, and less frequently in the autumn. At Prestwick, however, the synoptic situation normally more than outweighs the sea-temperature effect. In spring, south-westerly weather types are at a minimum, while the air masses of westerly and north-westerly types are more unstable than usual, so that Prestwick, which is protected by hills from low stratus from other directions experiences a minimum of low cloud. In summer and autumn south-westerly types are the most frequent in Scotland, so that Prestwick tends to have a maximum of low cloud. Further, the frequency of light gradient winds is at a maximum in summer, and sea breezes which tend to bring in low stratus (especially in the evening) are most frequent.

The exceptional March figure can now be explained by the fact that, though pressure was much higher than usual, south-westerly types were rather frequent especially in March 1950, so that Prestwick might be described as receiving a double amount of low cloud. An increase of the south-westerly type would increase the frequency of low cloud in any case, but occurring at a time when the sea temperature is relatively low, an exceptionally high total of low cloud is produced.

The diurnal variation of low cloud would be expected to show a maximum about sunrise when the stability of the lowest layers is at a maximum, and a minimum in the middle of the afternoon. The diurnal variation of low cloud at Prestwick is in the main, however, to be accounted for by variations in the local wind direction which cause variations in the moisture content of the lowest layers.

In conditions of slack gradient at night an ESE. land breeze blows across the airfield descending from hills to the east and south-east. Consequently the moisture content of the lower layers is generally below saturation and the formation of low stratus is unlikely. This land breeze dies out shortly after sunrise and is replaced by air from the sea, with a consequent maximum in the frequency of low stratus about 2 or 3 hr. after sunrise. In the depth of winter insolation is insufficient to produce convection to disperse the stratus, though the base may lift to above 400 ft., and it persists all day until the land breeze sets in again some hours after sunset. In summer, however, convection is sufficient to lift the base of the stratus in the afternoon and the frequency of very low cloud is at a minimum. Towards sunset, convection dies down while the sea breeze still persists, so that low stratus again forms. At midsummer, the night is short and the land breeze may not blow so that low stratus may persist all night. In the other summer months the setting in of the land breeze about 2 hr. after sunset produces a reduction in the frequency of low stratus.

Diurnal variation of surface wind.—The diurnal variation of surface wind has been generally indicated in the previous paragraphs; Table V illustrates the variation. This table gives the number of occasions per thousand of the various wind speeds and directions at 0300 and 1500 G.M.T. in winter and summer.

Whenever the gradient is slack, an ESE. wind blows over the airfield from about 2 hr. after sunset to just after sunrise, and a W. or WSW. wind from

TABLE V—DIURNAL AND SEASONAL VARIATION OF SURFACE WIND AT PRESTWICK AIRPORT

Period: 1946–50

Mean Speed	NNE.	NE.	ENE.	E.	ESE.	SE.	SSE.	S.	SSW.	SW.	WSW.	W.	WNW.	NW.	NNW.	N.	All directions
kt.	Number of occasions per thousand																
December–February																	
0300 G.M.T.																	
0																	62
1– 3	5	5	12	16	16	13	7	3	3	...	2	2	...	2	5	3	94
4– 6	6	12	7	16	20	21	12	8	5	8	...	4	...	7	7	1	134
7–10	6	18	22	14	26	29	9	21	14	8	17	12	14	10	12	7	239
11–16	...	7	14	17	15	20	10	32	31	33	25	26	12	12	4	...	258
17–21	2	2	5	1	13	6	6	15	9	13	19	18	9	7	4	...	129
22–27	...	...	2	...	2	2	...	6	5	6	25	9	13	2	1	...	73
28–33	...	...	...	...	2	...	...	...	...	2	...	2	...	...	...	...	6
34–40	...	...	...	...	...	...	...	...	...	...	2	2	...	...	...	...	4
1– 6	11	17	19	32	36	34	19	11	8	8	2	6	...	9	12	4	228
7–16	6	25	36	31	41	49	19	53	45	41	42	38	26	22	16	7	497
>16	2	2	7	1	17	8	6	21	14	21	46	31	22	9	5	...	212
1500 G.M.T.																	
0																	27
1– 3	4	...	3	11	14	8	4	2	2	3	4	8	1	2	...	...	66
4– 6	4	3	9	8	13	16	12	4	...	...	9	6	3	2	4	4	97
7–10	8	26	15	18	29	27	22	18	11	17	8	10	17	13	7	6	252
11–16	3	15	17	17	24	21	10	33	21	40	37	14	20	22	14	2	310
17–21	...	6	3	7	10	6	3	14	19	22	33	26	15	3	3	...	170
22–27	...	...	...	1	6	1	4	8	7	8	13	9	2	4	...	...	63
28–33	...	...	...	...	2	...	...	...	...	2	3	6	...	3	3	...	19
34–40	...	...	...	...	...	...	...	...	...	2	...	...	...	...	...	...	2
1– 6	8	3	12	19	27	24	16	6	2	3	13	14	4	4	4	4	163
7–16	11	41	32	35	53	48	32	51	32	57	45	24	37	35	21	8	562
>16	...	6	3	8	18	7	7	22	26	34	49	41	17	10	6	...	254
June–August																	
0300 G.M.T.																	
0																	157
1– 3	8	9	12	25	28	16	6	2	...	...	5	6	2	8	5	...	132
4– 6	11	16	18	15	34	25	9	2	4	7	5	4	2	...	6	5	163
7–10	17	30	22	13	19	12	35	29	11	30	19	21	24	19	5	1	307
11–16	4	11	8	2	6	5	16	24	17	26	43	15	14	10	7	...	208
17–21	...	4	...	1	1	...	...	3	1	2	9	6	...	4	...	...	31
22–27	...	...	...	...	...	...	...	...	...	...	...	...	2	...	...	...	2
1– 6	19	25	30	40	62	41	15	4	4	7	10	10	4	8	11	5	295
7–16	21	41	30	15	25	17	51	53	28	56	62	36	38	29	12	1	515
>16	...	4	...	1	1	...	...	3	1	2	9	6	2	4	...	...	33
1500 G.M.T.																	
0																	4
1– 3	...	...	...	...	...	...	...	...	...	...	2	...	...	2	...	...	4
4– 6	...	2	...	4	...	...	...	...	...	3	14	32	13	5	1	1	75
7–10	10	14	4	7	14	13	18	7	8	52	97	116	51	18	2	4	435
11–16	2	5	12	4	8	8	16	25	19	62	91	59	37	20	...	...	368
17–21	...	...	4	1	2	5	2	20	4	10	7	9	17	7	...	...	88
22–27	...	3	4	...	...	...	1	9	4	1	...	...	2	...	...	...	24
28–33	...	...	...	...	...	...	...	...	...	...	2	...	...	...	...	...	2
1– 6	...	2	...	4	...	...	...	...	...	3	16	32	13	7	1	1	79
7–16	12	19	16	11	22	21	34	32	27	114	188	175	88	38	2	4	803
>16	...	3	8	1	2	5	3	29	8	11	9	9	19	7	...	...	114

about 2 hr. after sunrise to about sunset. The remarkable feature especially in summer is the concentration of light winds from an easterly point at 0300 and from a westerly point at 1500.

In winter, daylight is short, and the sun is at a low elevation and sets about 1600 G.M.T. so that there is frequently insufficient heating to prevent the land breeze in conditions of slack gradient from blowing at any time. In summer, on the other hand, the reverse is true, so that light W. winds may persist well into the night.

Diurnal variation of temperature.—Fig. 2 shows curves of the diurnal variation of screen temperature for the 4 months, January, April, July and October, and the table gives the standard deviation of the temperature at certain hours.

The essential features of this figure are:—

(i) Small fall of temperature at night in January and October

(ii) Relatively rapid rise of temperature in April mornings and late maximum

(iii) Slow rise of temperature on July mornings.

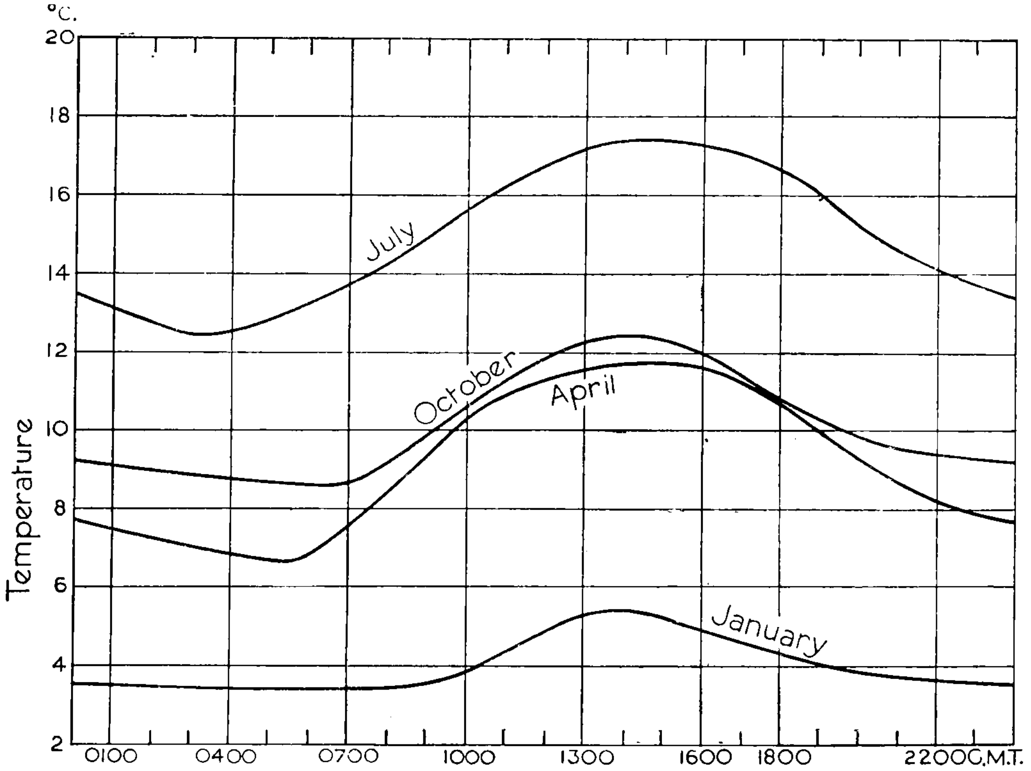

FIG. 2—DIURNAL VARIATION OF TEMPERATURE AT PRESTWICK

The temperature curves had already been worked up for the 5-year period 1942–46, and though the curves might suffer slight translation up or down if based on another period, their form would be retained.

	Standard deviation at							
	0100	0400	0700	1000	1300	1600	1800	2200
	degrees Centigrade							
January... ...	4·2	4·2	4·0	3·8	3·1	3·3	3·6	4·1
April	2·6	2·8	2·4	2·2	2·6	2·6	2·4	2·2
July	1·8	2·0	1·6	1·8	2·2	2·6	2·4	1·7
October... ...	3·1	3·2	3·3	2·6	2·2	2·2	2·4	2·8

January and October are cloudy months for the most part so that outward radiation is much reduced. Further when clear skies and light winds occur together at night, the land breeze blows with great regularity, and so, as stagnation is prevented, temperature tends to be kept up.

April is a month with minimum low-cloud amounts, consequently temperature shows a quicker rise than in other months, but the sea breeze tends to set in regularly so that a flat and delayed maximum occurs.

July is generally a cloudy month especially shortly after sunrise when low stratus cloud is most frequent; as a consequence temperature rises very slowly after sunrise. Though the low cloud tends to break and lift during the morning, the sea breeze causes a rather flat maximum.

The airfield and the aircraft operator.—From the aircraft operator's point of view the worst time for operations is the period 1–3 hr. after sunrise, in summer especially, when very low cloud and occasionally fog are most liable to occur. As fog is exceptional, services in and out of Prestwick will not be subject to much delay or diversion on account of low cloud or poor visibility provided the aircraft are fully equipped with instrumental landing aids for a safe descent to low levels.

REFERENCES

1. DAVIS, N. E.; Fog at London Airport. *Met. Mag., London,* **80,** 1951, p. 9.
2. SAUNDERS, W. E., and SUMMERSBY, W. O.; Fog at Northolt Airport. *Met. Mag., London,* **80,** 1951, p. 255.

SEVERE TURBULENCE OVER THE INNER HEBRIDES

By H. S. TURNER, B.A.

The writer, in an article[1] published in April 1951, drew attention to a number of cases of standing waves to the lee of high ground encountered by pilots of British European Airways Corporation and the associated meteorological conditions were discussed. A recent occurrence of extremely severe turbulence followed by powerful vertical currents, in circumstances pointing to the existence of a standing wave, is described in this note.

The aircraft, a B.E.A. Dakota, was flying from Glasgow to Benbecula on the morning of December 21, 1951, and the severe turbulence was encountered approximately over the island of Rhum. Some of the passengers were thrown out of their seats with such force that injuries were sustained and extensive damage was done to the cabin interior. Previously, at 8,500 ft. the captain had noted alternate up- and down-currents of 500–1,000 ft./min., the periodic time of the oscillations being approximately 4 min. He then descended to about 5,500 ft. and at 1010 G.M.T. entered an 8 oktas stratocumulus layer near Rhum. At 1013 the violent turbulence occurred, lasting for less than a minute and was followed immediately afterwards by a vigorous up-current of at least 2,000 ft./min. for 1–2 min.

The area in question was subject to a strong south-westerly current in advance of an approaching warm front. The tephigrams for the 0800 G.M.T. ascents at Stornoway and Aldergrove, illustrated in Fig. 1, indicated stability of the air mass apart from a shallow layer near the surface. The upper air temperature observations, in fact, indicated that vertical currents were unlikely to arise from air-mass instability. Conditions were thus favourable for a standing wave, namely a fast-flowing and markedly stable air stream with a shallow unstable layer underneath.

The source of origin of the waves cannot be determined with certainty, but it seems most likely that the steady up-and-down motion was due to standing waves set up by the mountains of Northern Ireland, or possibly the small islands off the coast of Scotland or the mainland itself. The motion, however, was not observed until the aircraft had passed Ardnamurchan Point. Allowing for the speed of the aircraft and the angle between its track and the air stream, this would involve a wave-length of about 6 miles which is consistent with what is normally found in these cases. As regards the severe turbulence, this might well have occurred at one of the troughs of a separate train of waves set up by the island of Rhum itself and possibly reinforcing the other wave-train. This could also then account for the powerful vertical current which followed. The fact that the severe turbulence was distinct from the strong up-current makes it unlikely that orographic convection was responsible.

Alternative explanations to the one given involve a degree of instability not shown in the ascents. Obvious instability (see Fig. 1), ceased at 925 mb. but

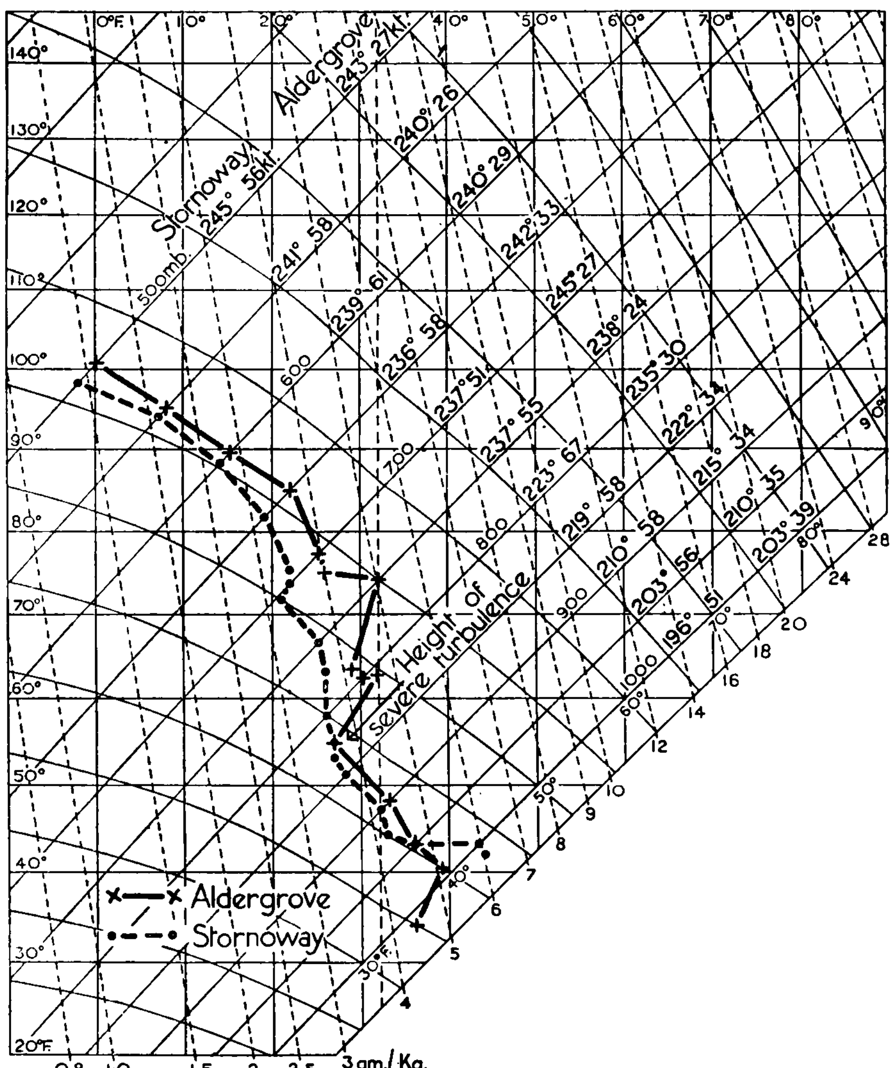

FIG. 1—TEPHIGRAM FOR STORNOWAY AND ALDERGROVE ASCENTS, 0800 G.M.T., DECEMBER 21, 1951

DUSTSTORM NEAR MAFRAQ, JORDAN

Photographs taken from 10,000 ft. at 1400 G.M.T. on April 17, 1951 (see p. 248).

FIG. 1—APPROACHING THE FOG BELT

FIG. 2—THE SOUTHERN EDGE OF THE FOG BELT

BELT OF SEA FOG OVER THE NORTH SEA

(See p. 249)

FIG. 3.—VERTICAL VIEW OF THE FOG BELT

FIG. 4.—OVER THE MIDDLE OF THE FOG BELT

BELT OF SEA FOG OVER THE NORTH SEA

(See p. 249)

To face p. 241]

FIG. 5—NORTHERN EDGE OF THE FOG BELT

FIG. 6—LEAVING THE FOG BELT

BELT OF SEA FOG OVER THE NORTH SEA

(see p. 249)

modifications in the air stream might have created a saturated adiabatic lapse rate up to the height at which severe turbulence was experienced. It is difficult, however, to believe that rising currents of any convective origin, ascending at 2,000 ft./min. and lasting more than a minute, could have been met at this height, which was the base of a much more stable layer.

Our knowledge of the precise mechanism of standing waves remains somewhat sketchy, and, as it would appear that they can on some occasions be of significance, aviation would benefit if pilots of powered aircraft reported cases as they occur for study by the meteorologist.

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CUMULONIMBUS CLOUDS OVER SUMATRA

By R. FROST, B.A.

Until recently very little information has been available about cloud development above 25,000 ft. in the region of the intertropical front, and although there were theoretical grounds for thinking that cumulonimbus clouds might extend up to 55,000 ft., the level at which the tropopause is reached over the equator, the only observations (which are little known) in support of this appear to be those of van Bemmelen[1], who made photographic measurements of cumulonimbus clouds over Batavia from two points, and found that the tops of these clouds were in most cases above 33,000 ft. and occasionally reached 50,000–53,000 ft.

In view of the introduction by British Overseas Airways of Comet aircraft operating at 40,000 ft. on the London–Singapore route, the following confirmatory observations of cumulonimbus development over Malaya and Sumatra may be of interest to forecasters for this route.

During the period April 18 to June 18, 1950, calculations of the heights of certain cumulonimbus clouds over Malaya and Sumatra were made by an R.A.F. Transport Command pilot from measurements of the angle of elevation of the clouds with a bubble sextant, and simultaneous observations of the range of the clouds on the aircraft radar.

In general a number of measurements were made over about 10 miles of run towards the cloud and the mean of such observations taken. The scatter of the results indicated that the mean would be in error by less than 1,100 ft. The mean heights of the tops are given in Table I. It can be seen from this table that many cumulonimbus clouds had tops well above 40,000 ft., the highest occurring at 54,600 ft.

TABLE I—MEASURED CLOUD-TOP HEIGHTS OVER SUMATRA AND MALAYA, 1950

Date	Time	Mean height	No. of obs.	Date	Time	Mean height	No. of obs.
		ft.				ft.	
May 4	1238	43,310	1	June 1	1402	38,310	5
	1655	44,500	1		1525	47,960	7
May 19	1523	34,000	2		1615	47,520	7
May 24	1530	22,540	1		1715	48,760	7
May 26	1641	29,200	1		1750	41,770	5
May 30	1445	36,970	1	June 2	1435	40,236	6
	1510	40,600	3		1508	41,660	5
May 31	1515	38,570	6		1640	54,600	4
	1800	37,370	6	June 10	1330	44,100	5

In August 1951 during the flight of an R.A.F. Canberra bomber to Australia the pilot reported that in the tropics, especially around Sumatra, the tops of the cumulonimbus clouds were well above 45,000 ft. Over the west coast of Sumatra and on the direct route between Ceylon and Singapore he found a solid area of cumulonimbus cloud (which he was fortunately able to bypass to the north) which did not appear to have any breaks below 50,000 ft.

I am indebted to Sqdn-Ldr Thirlwell, the pilot of the Transport Command aircraft, and to Wg-Cmdr Cumming, the pilot of the Canberra, for these observations. A note on the meteorological observations made by Wg-Cmdr Cumming during this flight is published in the July 1952 *Meteorological Magazine* on p. 218.

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1. BEMMELEN, W. VAN; Die Erforschung des tropischen Luftozeans in Niederländisch-Ost-Indien, *Luftfahrt u. Wiss., Berlin*, 1913, Heft 5, p. 48.

SOME EFFECTS OF THE COHERENCE OF METEOROLOGICAL TIME-SERIES

By R. P. WALDO LEWIS, M.A., M.Sc., and D. H. McINTOSH, M.A., B.Sc.

It is now generally realized that statistical formulæ based on the assumption of random sampling from a set of uncorrelated values cannot automatically be applied to geophysical and meteorological time-series (such as a sequence of daily pressure or temperature readings) which often have a considerable amount of coherence (alternative names are conservation, persistence, auto-correlation, or autoregression). In particular, if the standard deviation of the individual terms of a coherent series is σ, then the standard deviation σ_n of the set of means of n consecutive terms is not $\sigma/\sqrt{n}$, as given by the theory of random sampling, but some other number. Brooks and Carruthers[1] quote an example from daily pressure readings at Kew in the winter of 1938–39: standard deviation of the individual readings was 11·1 mb., whereas that of the means of two consecutive readings was not $11\cdot 1/\sqrt{2} (= 7\cdot 8$ mb.) but 10·4 mb.

Chapman and Bartels[2] consider n consecutive terms of a series as being equivalent to n' random terms, each repeated n/n' times, and find a relation between n/n', σ and σ_n'

$$n/n' \equiv \varepsilon(n) = n\sigma_n^2/\sigma^2 = \text{"equivalent number of repetitions"}.$$

It is often convenient to have a formula for σ_n in terms of the correlation coefficients $r_1, r_2, r_3, \ldots\ldots\ldots$ between successive terms, terms two apart, terms three apart,.........and so on. If the original series is $u_1, u_2, \ldots\ldots\ldots u_N$ (N very large) where the u's may without loss of generality be taken to be departures from a mean,

$$r_1 = \frac{u_1u_2 + u_2u_3 + \ldots\ldots\ldots + u_{N-1}u_N}{(N-1)\sigma^2}$$

$$r_2 = \frac{u_1u_3 + u_2u_4 + \ldots\ldots\ldots + u_{N-2}u_N}{(N-2)\sigma^2}$$

....

The expression for r_p contains a factor $N - p$ in the denominator, but for small p we may replace this by N, since N is supposed large; r_p will in practice diminish with increasing p, usually becoming inappreciable after r_4 or r_5.

Consider a mean of n consecutive terms given by

$$m_{nx} = \frac{u_x + u_{x+1} + \dots\dots\dots + u_{x+n-1}}{n}$$

On squaring, this gives

$$\begin{aligned} n^2 m_{nx}^2 = & (u_x^2 + u_{x+1}^2 + \dots\dots\dots + u_{x+n-1}^2) \\ & + 2(u_x u_{x+1} + u_{x+1} u_{x+2} + \dots\dots\dots + u_{x+n-2} u_{x+n-1}) \\ & + 2(u_x u_{x+2} + u_{x+1} u_{x+3} + \dots\dots\dots + u_{x+n-3} u_{x+n-1}) \\ & + \dots\dots\dots \end{aligned}$$

On the right-hand side there are n terms in the first bracket, $n - 1$ in the second, $n - 2$ in the third, etc. Summing both sides for $x = 1, 2, \dots\dots\dots (N - n)$ and dividing by N, if N is very much larger than n, we have

$$n^2 \sigma_n^2 = n\sigma^2 + 2(n-1)r_1\sigma^2 + 2(n-2)r_2\sigma^2 + \dots\dots\dots + 2r_{n-1}\sigma^2$$

or $$\sigma_n^2 = \frac{\sigma^2}{n}\left[1 + \frac{2}{n}\left\{(n-1)r_1 + (n-2)r_2 + \dots\dots\dots + r_{n-1}\right\}\right] \quad \dots\dots\dots(1)$$

In a recent paper Brooks[3] gives a modification of equation (1) on the assumption that $r_n = r_1^n$. As this is not always true, however, it is advisable to leave equation (1) as it stands. For example, if we construct a coherent series by taking 3-term running means of a random series,

$$r_1 = 0{\cdot}67$$

$$r_2 = 0{\cdot}33 \neq r_1^2 = 0{\cdot}45.$$

For $n \geqslant 3$ $\quad r_n = 0 \neq r_1^n \; (r_1^3 = 0{\cdot}30, r_1^4 = 0{\cdot}20, \dots\dots\dots).$

The "equivalent number of repetitions" is given by the coefficient of σ^2/n i.e.

$$\varepsilon(n) = 1 + \frac{2}{n}\left\{(n-1)r_1 + (n-2)r_2 + \dots\dots\dots + r_{n-1}\right\} \quad \dots\dots\dots(2)$$

The expression (2) may be used to estimate the number of effectively independent terms to which a number n of coherent terms is equivalent. In this case, n is frequently the total number of terms available, and we have to estimate the r's from this limited sample instead of from the theoretical total of N terms. Knowledge of the number of independent terms is necessary for assessing the significance of various statistics, such as the correlation coefficient between two coherent series.

As an example we consider the departures of the Edinburgh daily mean temperature for 1950 from the corresponding 50-year average. For these $r_1 = 0{\cdot}76$, $r_2 = 0{\cdot}54$, $r_3 = 0{\cdot}37$, $r_4 = 0{\cdot}27$, $r_5 = 0{\cdot}21$ and $\sigma = 4{\cdot}8$°F. (these values of $r_2 \dots\dots\dots r_5$ compare with $r_1^2, \dots\dots\dots r_1^5$, namely 0·58, 0·44, 0·34, 0·25, implied in Brooks's formula). If we consider 30-day means, expression (2) gives (ignoring terms in r_6 and beyond)

$$\varepsilon(30) = 5{\cdot}0.$$

It is noteworthy that the daily mean temperatures for one month yield only about six (30/5) independent values. (Compare the "persistence length" of three days for daily temperature readings made at a fixed hour—an obviously less coherent series—mentioned by Carruthers[4] in a recent paper.) We therefore have, from equation (1),

$$\sigma_{30} = 4{\cdot}8\sqrt{(5{\cdot}0/30)} = 2{\cdot}0\text{°F}.$$

Actual calculation from the 336 30-day running means over the whole year gives $\sigma_{30} = 1 \cdot 8°F.$ while the standard deviation of the 12 monthly means (i.e. of separate blocks of about 30 values) is 2·4°F.—in fair agreement considering the smallness of the sample. These values of σ_{30} compare with a value of $4 \cdot 8/\sqrt{30}$ or 0·9°F., calculated on the basis of independence between successive daily values.

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1. BROOKS, C. E. P., and CARRUTHERS, N.; Statistical methods in climatology. London, 1944, p. 15.
2. CHAPMAN, S., and BARTELS, J.; Geomagnetism. Vol. II. Oxford, 1940, p. 584.
3. BROOKS, C. E. P.; The variability of means of a series of observations. *Met. Mag., London,* **77,** 1948, p. 283.
4. CARRUTHERS, N.; The accuracy of a mean of *n* temperature observations as an estimate of the mean temperature for a particular month. *Met. Mag., London,* **78,** 1949, p. 65.

METEOROLOGICAL RESEARCH COMMITTEE

The Meteorological Research Committee held its 63rd meeting on March 26. The Committee considered reports from Sub-Committees. The Chairman, Prof. G. M. B. Dobson, announced that he would cease to be Chairman of the Committee after the meeting, and the Director of the Meteorological Office stated that Sir David Brunt had accepted an invitation to succeed Prof. Dobson as Chairman of the Committee.

The twentieth meeting of the Synoptic and Dynamical Sub-Committee of the Meteorological Research Committee was held on May 14, 1952.

The Committee reviewed long-range forecasting methods and also considered a paper by Mr. Sawyer and Mr. Bushby[1] on a baroclinic model suitable for numerical integration.

A paper by Mr. G. W. Hurst[2] dealing with the profile of a jet stream observed on January 18 was received with interest as it suggested a possible technique for measuring jet streams over desert areas where no radar network existed.

ABSTRACTS

1. SAWYER, J. S. and BUSHBY, F. H.; A baroclinic model atmosphere suitable for numerical integration. *Met. Res. Pap., London,* No. 715, S.C. II/104, 1952.

Authors adopt as a model a baroclinic fluid in which the thermal wind is constant in any vertical column and its speed is proportional to the vertical pressure difference through the layer. With certain assumptions a system of 3 simultaneous differential equations is derived to compute the rates of change of height of a contour surface, thickness 1,000 mb. to that surface, and average vertical velocity throughout the column. A method of solution is given but to forecast values 24 hours ahead would be very laborious without electronic computing machinery.

2. HURST, G. W.; The profile of a jet stream observed 18th January, 1952. *Met. Res. Pap., London,* No. 722, S.C. II/107, 1952.

On June 18, 1952, an aircraft flew at 30,000 ft. from Yarmouth to Pembroke and back on a more southerly track, crossing a well marked northerly jet stream. Vertical photos were taken every 12 seconds; the winds calculated from these fixes are presented in diagrams. They show a rapid increase from 80 kt. in longitude 0° to nearly 180 kt. between 2¼° and 3°W., and a slow decrease to 160 kt. in 5°W.

BOOK RECEIVED

Geophysical Notes, **4,** 1951, Nos. 1–8, 10 in. × 7 in., Geophysical Institute, Tokyo University, Tokyo, 1951.

ERRATUM

June 1952, PAGE 184, line 46; *for* "maximum" *read* "latter".

ROYAL METEOROLOGICAL SOCIETY

The Annual General Meeting was held on April 23, 1952, with the President, Sir Charles Normand, in the Chair.

The Buchan Prize for 1947–51 was awarded to Dr. G. D. Robinson, the Hugh Robert Mill medal for 1952 to Dr. J. Glasspoole, and Darton Prizes to Dr. H. L. Penman, Mr. J. M. Craddock, Mr. A. J. Whiten, and to Messrs. E. G. Bowen and K. A. Davidson jointly.

Presidential Address—Atmospheric ozone and the upper air conditions

Sir Charles Normand opened his address by pointing out that although all the ozone brought to normal surface pressure and temperature would form a layer about 3 mm. thick compared with a corresponding thickness of 8 Km. for the atmosphere as a whole, yet it effectively cut short the ultra-violet end of the solar spectrum, a fact of great biological importance. More important to the meteorologist is the relation between ozone and weather, from which it seems that ozone may be acting as an indicator of air movements in the stratosphere.

Dobson long ago established an inverse correlation between the amount of ozone and the surface pressure. The relation between the amount of ozone and the meteorological situation was now being investigated by the Ozone Commission (of which Sir Charles is Secretary) of the International Association of Meteorology. Dobson spectro-photometers have been brought into use at a number of stations in western Europe for examination of the variations of ozone with place. With this apparatus readings of the amount of ozone can be made by using the radiation coming through clouds if direct observation of the sun is impossible. However, the ozone observational network outside the British Isles was incomplete in 1951, and so the address dealt mainly with the observations made at Oxford. Sir Charles showed the relations between ozone amount and the structure of the troposphere over long periods with parallel curves and correlation coefficients, and used 300-mb. contour charts to illustrate typical individual cases of high and low ozone amounts. The observations confirm Dobson's conclusion of ozone tending to be low above anticyclones and high above depressions, but the main result has been the striking anti-parallelism between ozone content and the thickness of the 500–300-mb. layer and the heights of the 300-mb. surface and of the tropopause. In terms of the long-wave pattern of the zonal flow in the upper troposphere, ozone is high in the troughs and low in the ridges.

The changes appear to be explicable in terms of vertical currents in the stratosphere above tropospheric disturbances since ozone content increases with height to a maximum between 20 and 30 Km. and then decreases. This raises the question of the determination of the vertical distribution of ozone and Sir Charles discussed methods of finding it. Rocket- and balloon-carried spectrographs can be used to record the changes in the solar spectrum with height but are very expensive in use. A much simpler method is the one due to Dobson and Götz of observing from the ground the changes in intensity of two lines in the ultra-violet spectrum of the zenith radiation as the altitude of the sun or moon increases or decreases near rising and setting.

The address will be published in the *Quarterly Journal of the Royal Meteorological Society.*

At a meeting of the society on May 21, 1952, the President, Sir Charles Normand, in the Chair, the following papers were read:—

*Goody, R. M.—A statistical model for water-vapour absorption**

This paper in physical research is, Dr. Goody claimed, an effort to solve one small part of the problem of radiation in the atmosphere. The radiation spectrum of water vapour in the infra-red consists of a large number of lines, the observed wave-lengths of which agree very well with those calculated from the molecular structure by means of the quantum theory. Schnaidt's method of calculating the absorption or transmission of these lines could not be used since it assumed regular spacing of the absorption lines, and for water vapour the spacing was seemingly very haphazard.

Dr. Goody started with an arbitrary line shape (intensity of absorption plotted against wave-length) and an expression for the total transmission in a wave-band, making the simplifying assumption that the absorption lines have a random distribution. By trying an exponential form for the probable intensity of a line and, following Prof. Cowling, using the Lorentz shape for each line he could then calculate the total transmission in a wave-band, and could compare his results with the data calculated by Prof. Cowling in a few special bands (in one case with four different pressures). Except for the wave-band 300–350 $cm.^{-1}$ agreement was very good, all the points (Cowling's data) appearing to lie on the curves given by Dr. Goody's equations.

Mr. Curtis followed Dr. Goody's account with a description (to be published shortly) of how he had applied the equations to a path along which the pressure varies. With typical water-vapour distributions the agreement with observed data was good, but application to the absorption and transmission by ozone was not so good, and he thought more success would be obtained by graphical methods.

Dr. Scorer was surprised that Dr. Goody should be disappointed with the fit of one of the curves; it fitted better than many curves he had seen in meteorology. Prof. Sheppard asked if there was any sound information on the line shape. Dr. Goody replied that it was the accurate balance between two measurements that was required which meant greater accuracy was required in his formula; with regard to line shape, information in all other regions was consistent in all grades of spectroscopy, i.e. the Lorentz shape held up to heights of 30 Km. where the Doppler effect becomes important.

Thompsom, B. W.—An essay on the general circulation of the atmosphere over south-east Asia and the west Pacific†

In the absence of Mr. Thompson, who was in Hongkong, this paper was read by Mr. G. S. P. Heywood, Director of the Royal Observatory, Hongkong. This paper is a preliminary survey based on observations during the period September 1947–September 1949 when information was (and still remains) very sparse, particularly in the upper air and over China. With the help of reports from transport aircraft it has proved possible to draw up model charts for each season of the year showing typical conditions (neither mean nor actual) at the surface, 2,000 ft. and 10,000 ft. At the two upper levels conditions are represented by flow charts, the 10,000-ft. chart being the more likely to be accurate since

Quart. J. R. met. Soc., London,* **78, 1952, p. 165.
†*Quart. J. R. met. Soc., London,* **77**, 1951, p. 569.

transport flights usually took place at that height. The most important features of these charts are the comparatively shallow cold northerlies over China in winter associated with the Siberian anticyclone (winter monsoon), the North Pacific trades, the upper westerlies from northern India, the movement northwards of the westerlies from the Indian Ocean during spring and early summer (summer monsoon), the convergence zones between similar and dissimilar air masses which appeared and disappeared, and the formation of typhoons. Mr. Thompson also thought that the classical intertropical front of India in July was in reality the polar front of Asia.

Mr. Durst said that Dr. Hare had produced similar model circulation maps during the war, but they had not been published because the results did not differ from those published previously by Chinese workers. He did not remember seeing the "classical" position before; Hare's position was very similar to Thompson's. There then followed some discussion on the nature of the intertropical front or convergence zone and the origin of the air on either side of it. Mr. Sawyer said that the intertropical front followed the thermal equator. Dr. Forsdyke said a very large part of the supply of air in the Indian monsoon does come from the South Indian Ocean and extended to a height of at least 10,000 ft.; further east there was a weaker gradient across the equator, and he would not be surprised at the occurrence of limited convergence zones as described in Thompson's paper.

Mr. Veryard thought the jumpiness of the intertropical front (which he had observed in the Sudan) could be explained by the shallowness of the underlying warm moist air. Sir Charles Normand drew attention to the major properties of air in north-west India—the difference in humidities—and to the formation of cyclones in the Bay of Bengal preceded by westerly winds to the south of the main easterly current and squally weather.

Mr. Heywood, in conclusion, doubted whether Mr. Thompson had read the Chinese reports, but he had the advantage of more upper air information. Regarding the nature of the westerlies from India, since they had a very long sea track by the time they reached Hongkong, it did not seem to matter where the air had originated.

LETTER TO THE EDITOR

Speed of development and localization of thunder clouds

An interesting example of the rapidity with which thundery activity can develop and of its localized character in the initial stages occurred at Elmdon Airport, Birmingham, on Sunday, May 18, 1952. The synoptic situation and upper air temperature favoured the development of thunderstorms soon after the critical temperature (75°F.) at the surface was reached. The freezing level was 10,500 ft.

During the morning the sky was clear apart from some fragments of cirrus cloud and a small cumulus cloud "permanently" over the cooling towers at the Power Station, Hams Hall, but at 1230 G.M.T. very small flat cumuli formed at 3,500–4,000 ft. when the critical temperature was reached. About five minutes later two of these clouds over the western side of the airfield quickly developed vertically to an estimated height of 12,000–15,000 ft. These "twin" clouds were comparatively close to each other and covered much less than 1 okta of the sky, but from 1246 G.M.T. onwards short lightning flashes were distinctly observed (thunder clearly heard) between the protuberances at or near the top of each cloud and between the clouds. The development of these clouds was not quite simultaneous, and it seemed that the presence of the second cloud provided the trigger action.

At 1255 there was another development about 2–3 miles to the west, but this was on a larger scale and covered about 1–2 oktas of the sky. Heavy rain (very large drops) and some hail were first observed at 1315 G.M.T. There followed further outbreaks and the general thundery conditions lasted about two hours.

A. W. BERRY

Elmdon, May 20, 1952

NOTES AND NEWS

Auroral arch of January 29, 1952

At 1930 G.M.T. on January 29, 1952, a well defined auroral arch, with a dark segment below, was visible from the meteorological office at Shawbury. At 2000 the arch extended from 310° to 050° true, and was of a moderately bright, homogeneous white colour. The arch had a sharply defined lower edge, and extended from 7° to 10° above the horizon in the centre, with a glow of lesser intensity extending to roughly 15° above the horizon. The arch remained quiescent but decreased slightly in intensity until 2040 when it began to pulsate and occasionally very faint white rays could be seen extending upwards.

At 2045 another arch developed above the original one, extending from 265° to 020° true, the elevation of the ends being 20° and of the centre 25° above the horizon.

By 2055 the arches had degenerated into a diffuse glow extending from roughly west-north-west to north-north-east and elevation 25° above the horizon. This glow gradually decreased in intensity until 2130 when it disappeared altogether, and continuous observation of the phenomenon ceased.

Visibility during the period of observation was between 10 and 15 miles, with 1 okta altocumulus at 10,000 ft. and 3–4 oktas cirrus and cirrocumulus to the south. Measurements of elevation and bearing were made with a theodolite on the meteorological office roof, using Polaris as azimuth.

C. A. ROBINSON
D. J. GEORGE

Duststorm near Mafraq

The two photographs facing p. 240 were taken at 1400 G.M.T. on April 17, 1951, from an aircraft of R.A.F. Station, Shawbury, flying at 10,000 ft. between Malta and Habbaniya. The position, 32°24′N., 36°49′E., is near Mafraq, Jordan, and the top of the rising dust layer shown was estimated to be at 11,000 ft.

Meteorological observations from the desert regions of Jordan and western Iraq are too scanty for this duststorm to be associated with any particular feature of the synoptic situation. Between April 15 and 20, 1951, however, the Levant and western Iraq came under the influence of a series of fronts, the first of which reached Sinai early on April 15, and subsequently became very slow-moving on reaching western Iraq; showers and scattered thunderstorms were reported in the area, and much rising dust in Iraq.

The phenomenon of dust rising to 10,000 ft. or more over central and southern Iraq due to frontal systems approaching from the west is not infrequent during the months of October and November and again from March to May or June. Well marked sandstorms further to the west are relatively rare owing to the harder nature of the surface; at Rutba for instance Coles* has shown that the frequency of duststorms is low compared with other stations in Iraq.

Sea fog

The photographs in the centre of this Magazine illustrate a belt of sea fog over the North Sea on April 30, 1942. They were all taken from a height of 6,000 ft. from a Rhombus meteorological reconnaissance aircraft within a few miles of 54°45′N., 2°30′E. at about 1300 G.M.T. The belt was 10–50 miles wide, lying in a direction east-south-east to west-north-west with top about 500 ft. above sea level. Except for the vertical views the photographs show the appearance of the fog on the starboard side of the aircraft as it flew across the belt on a course of 030° true.

There had been an easterly wind current across the North Sea for nearly a week with almost cloudless weather from the 25th onwards. As the wind backed to east-north-easterly cloud developed, the first sign of low cloud being this belt of sea fog; cirrostratus was visible at this time to the east. A minor front passed through eastern districts of England during the evening of May 1 and the cloudless spell was over.

Heavy rainfall in Devon on May 19, 1952

Major J. M. Salusbury-Trelawny has forwarded some interesting details of the heavy rain experienced at Cotleigh House, four miles east-north-east of Honiton, on May 19, 1952.

At 1550 G.M.T., an unobtrusive brown-coloured cloud appeared over the hill, a few points south of due west. In less than five minutes rain started falling, and immediately developed into a torrential downpour with hailstones over half an inch in diameter. Rain ceased entirely by 1640.

The track of the storm, which was accompanied by a great deal of thunder and lightning, was nowhere more than 1½ miles wide, and it passed to the south-east, petering out about two miles away. A great deal of soil was washed off neighbouring fields and 4-ft. high walls were demolished.

This fall of 2·56 in. in under 50 min. ranks as "very rare" in the classification used in *British Rainfall*, where such a fall is regarded as likely to occur once in about 300 years at an individual station. There are, however, other comparable falls on record for south-west England.

July 28, 1948: 3·08 in. in 50 min. at Halford (Dyche), 12 miles north of Taunton.

June 21, 1933: 2·75 in. in 45 min. at Temple Combe, 10 miles east-north-east of Yeovil.

June 23, 1946: 2·35 in. in 45 min. at Cullompton, 12 miles west of Honiton.

*COLES, F. E.; Dust-storms in Iraq. *Prof. Notes met. Off., London*, **6**, No. 84, 1938.

During the day pressure was almost uniform at about 1018 mb. over the whole of the British Isles with anticyclones to the north-east and south-west. What surface wind there was seemed to drift from the west or north in the western parts and from the east in the eastern parts of England. There had been a warm anticyclone over the country during the preceding week but this had collapsed slowly leaving warm stagnant air behind. This was moderately dry above 3,000 ft., but in the south of England was very moist at low levels, dew points of 57–60°F. being common (at Boscombe Down a dew point of 66°F. was recorded at 1200 G.M.T. implying a moisture content of 13–14 gm./Kg.). The air mass was unstable, provided the surface temperature reached 74°F., and, since the weather was initially fine, this temperature was reached in many places away from the coast and local thunderstorms occurred. There was a cold front drifting westwards over the North Sea, but this did not affect England until the following day when a tornado was experienced at Tibshelf in Derbyshire.

North Greenland Expedition

The Norwegian M.V. *Tottan* sailed from Deptford on July 8, 1952, carrying the British North Greenland Expedition, and the following message was sent to Commander C. J. W. Simpson, R.N., Leader of the Expedition:

> "The Meteorological Office wish you bon voyage and every success in North Greenland."

The Meteorological Office has lent Mr. R. A. Hamilton to act as Deputy Leader and Chief Scientist of the Expedition. The equipment taken on the *Tottan* included 87 packages of meteorological stores supplied by the Instruments Division of the Meteorological Office.

The Expedition is to operate from a main base in Queen Louise Land about 50 miles inland from the east coast and from a smaller station at 9,000 ft. near the centre of the ice-cap in latitude 77°N. (approximately). An extensive programme of geophysical and glaciological research is to be undertaken. The meteorological work will be largely, though not exclusively, associated with the requirements of the glaciological investigations.

Professor of Meteorology, University of London

Sir David Brunt, M.A., Sc.D., Secretary of the Royal Society, is retiring from the chair of Meteorology in the University of London (Imperial College of Science and Technology).

Asst. Prof. P. A. Sheppard, B.Sc., F.Inst.P., Reader in Meteorology in the University, has been appointed to succeed Sir David as Professor with effect from October 1, 1952.

Sir David Brunt is a member of the Meteorological Committee and Chairman of the Meteorological Research Committee. Asst. Prof. Sheppard is Chairman of the Instruments Sub-Committee of the Meteorological Research Committee.

REVIEWS

The terrestrial atmosphere. By N. C. Gerson*. *Sci. Progress, London,* **40,** 1952, pp. 245–254.

Mr. Gerson's article is a highly condensed survey of selected characteristics of the earth's atmosphere, mainly at levels beyond those reached by modern

*of the Geophysics Research Division, A. F. Cambridge Research Center, Cambridge, Mass.

sounding balloons. A brief general sketch of a subdivision of the atmosphere into six shells according to properties is followed by sections dealing with the constituents, temperature, electron densities, aurora, airglow and air motion in the ionosphere. These topics are, of course, not mutually independent. Knowledge of the constituents, and their condition, of the attenuated regions of the atmosphere results from study of the emission spectra of the aurora and of the airglow at night and twilight. Deductions as to the temperature above about 100 Km. depend largely on the evidence provided by ground-based radio and spectrographic measurements, though discrepancies exist between the inferences drawn from the two classes of evidence. The radio data and the observed occurrence of aurora at heights of about 1,000 Km. lead to estimates of temperatures of 2,000–3,000°A. at 300–400 Km.

It is convenient to have in a general scientific review this compact presentation of current knowledge and opinion concerning the higher layers of the atmosphere where complexity, if different in character and origin, appears to be not less in degree than in the lower, presumably more earth-influenced, layers in which most meteorologists are normally more immediately interested. Notable progress in the exploration of the upper atmosphere by a variety of indirect methods has been made in the past two or three decades. It is to be expected that developments on these lines in conjunction with the new facility for obtaining measurements with instruments conveyed to great heights will greatly increase our knowledge and, not improbably, reveal fresh problems.

H. W. L. ABSALOM

The climate of Blue Hill according to air masses and winds. By Photios P. Karapiperis, *Harvard met. Stud.*, No. 9, 10 in. × 7 in., pp. 105, Harvard University Press, Cambridge Mass., 1951. Price: $1.25.

This investigation is in two parts. Part I is a study of seasonal surface winds (direction and speed) which accompany different air masses at Blue Hill Meteorological Observatory (42°13′N., 71°07′W.) in New England. The observations of wind were obtained from a 3-cup anemometer at the hour ending 0100, 52 ft. above the ground at Blue Hill from December 1947 to November 1950. The winds were divided (*a*) with respect to eight directions subdivided into maritime (between ENE. and S.), continental (between WSW. and N.) and transitional (NNE. and NE., SSW. and SW.) according as the underlying surface over which the air flowed was respectively wholly oceanic, land, or partly land and partly ocean, and (*b*) into speeds 1–15 m.p.h., 16–30 m.p.h., over 30 m.p.h., and according as the flow of the air from a particular direction was or was not maintained for a distance exceeding 200 miles. The six air masses, cA arctic continental air, cPk polar continental air colder than surface over which it is moving, cP polar continental air, cPw polar continental air warmer than surface, mP polar maritime air and mT tropical maritime air, used were those published once a day in the Washington *Daily Weather Map* of 0130. The two air masses cP and cPw were grouped together.

From the results of Part I Karapiperis deduces "that persistent winds and, to a fair degree, strong winds from a certain direction are fairly closely related to the occurrence of air masses whose source regions are in their directions". The closeness of the connexion between air mass and wind direction can be gauged from a study of Table 4 which shows that at 0130 in autumn the probability of continental winds of 16–30 m.p.h. being associated with air masses (cP and cPw), cPk, and mP is respectively 21, 74 and 5 per cent. This appreciable departure from one-to-one correspondence between air mass and wind direction and speed must, to some extent, invalidate Karapiperis's conclusion that "it is possible to study air-mass climatology without depending on the availability or homogeneity of air-mass data". Accordingly, Part II, which is a study, by seasons at 0700 and 1300, of the influence on the climate at Blue Hill during the ten years 1941–50 of the same categories of wind direction (maritime, continental and transitional) and speeds dealt with in Part I, but omitting travel greater than 200 miles from the same direction, cannot, as Karapiperis considers, "provide a valid substitute for a strictly air-mass climatic study".

The climatic elements examined in Part II are those of wind, temperature, relative humidity, cloudiness and fog (mainly low stratus since the Observatory is at a height of 635 ft.), precipitation and visibility. Seasonal values are given in tables, illustrated by diagrams, as percentage frequencies of the total number of observations at each of the hours 0700 and 1300. Only broad class intervals of each element are used: 18°F. for temperature, 25 per cent. for relative humidity.

The results of Part II lead Karapiperis to the conclusion that "Once the wind is forecasted the rest of the weather picture is shown here" [in Part II]. This conclusion needs examination. Let it be supposed that it is autumn and that continental winds (i.e. winds from between WSW. and N.) 16–30 m.p.h. are expected and that it is desired to forecast (*a*) temperature (*b*) relative humidity at 0700 and (*c*) the amount of precipitation (rain and snow) of the hour before 0700. Tables 10, 14 and 25 show respectively that the approximate probability of occurrence (*a*) of temperature lying between 15° and 32°F., 33° and 50°F., 51° and 68°F., and 69° and 86°F. to be respectively 24, 52, 20 and 4 per cent.; (*b*) of relative humidity having values between 100 and 76 per cent., 75 and 51 per cent. and between 50 and 26 per cent, to be respectively 46, 53 and 1 per cent.; and (*c*) of precipitation amounting to between trace and 0·04 in., between 0·05 and 0·09 in., and equal to and greater than 0·10 in. to be respectively 70, 23 and 7 per cent. Such information can hardly be said to be of assistance to the forecaster on this occasion or to a climatologist for planning purposes.

J. E. BELASCO

Southern Rhodesia Rainfall Handbook, and Supplement No. 1. Prepared by the Department of Meteorological Services. 13 in. × 8 in., pp. 30 and 55, *Illus.*, Government Printing and Stationery Department, Salisbury, Southern Rhodesia. 1951. Prices: 7*s.* 6*d.* and 2*s.* 6*d.*

The success of many of the development schemes in the rapidly expanding economy of Southern Rhodesia depends on the provision of adequate water supplies. Therefore a knowledge of the rainfall and its variations is essential.

This Handbook discusses the rainfall records of some 300 stations selected for their position, reliability and length of record—the 30-year period 1916–45 has been chosen where possible. Further handbooks will be published, dealing with special aspects of the rainfall and supplements will be issued giving details of monthly and annual rainfall and number of rain days—Supplement No. 1 for the eastern area has been issued with this handbook.

The average annual rainfall chart, discussed in Chapter II, reflects the orographic features of Southern Rhodesia and the climatic features of South Africa where there is a general diminution of rainfall from the east coast to the west and from north to south. The well marked seasonal distribution of rainfall is described; much of the rain in the early part of the season from September to November comes from thunderstorms and showers.

Chapter III discusses the variability of monthly and annual rainfall with a series of diagrams for 25 stations showing means, medians and quartiles of the rainfall distribution. An interesting analysis has been made of 10-day periods of rain for four stations, and it is shown that the rainfall for a particular 10-day period is likely to be below the long-term average of the 10-day period, especially in October. The length of the records is too short for the consideration of secular trends, but there is some evidence of a diminution of rainfall in parts of the eastern areas. No periodicity in the rainfall has been established.

Chapter IV describes an experiment on the variation of rainfall over small distances. Over the Colony as a whole the conclusion was reached that about 75 per cent. of the variation of the rainfall is common to all stations.

Chapter V deals with the incidence of rainfall. Sequences of dry and wet days were analysed, and it is shown that once a wet or dry spell has lasted 3 days the chance is about 3 to 1 that it will persist. The intensity of rainfall at Salisbury was investigated (over a period of 18 years) with the interesting result that it could be described as being divided about equally into one third of light, one third moderate, and one third heavy rainfall (light being taken as less than 0·25 in./hr. and heavy as more than 1 in./hr.). Bulawayo rainfall shows similar features.

The statistical basis of the arguments in the previous chapters is given in Chapter VI. In the section on "Heavy daily falls", it is suggested that the formula (due to Brooks and Carruthers) for the maximum daily fall, R, expected once in Y years, might be tested: it is $R = K(1 + \log Y)$ where K = mean annual maximum rainfall in a day. It is also suggested that in Chapter III percentiles would be worth giving and in Chapter IV that the variation of rainfall with position might be investigated by the use of regression coefficients, with latitude, longitude and altitude as independent variates.

J. PEPPER

METEOROLOGICAL OFFICE NEWS

Birthday Honours.—We congratulate Mr. A. G. King on the award to him of the B.E.M. Mr. King was associated with the production of the *Daily Weather Report* for over 50 years and had been in charge of the Meteorological Office Unit of H.M. Stationery Office since its formation in 1920. This unit was transferred to the Central Forecasting Office, Dunstable, in 1940. Mr. King retired in September, 1951.

Staff losses.—The office has lost the services of four of its Principal Scientific Officers, namely, Messrs. O. M. Ashford, J. L. Galloway, A. H. Gordon and G. J. W. Oddie. The first three have been seconded to the Secretariat of the World Meteorological Organization at Geneva, and the last named to the International Civil Aviation Organization at Montreal. We wish them all success in their new spheres.

Another Principal Scientific Officer whose services are lost to the office temporarily is Mr. R. A. Hamilton. He has joined the British North Greenland Expedition as Chief Scientist.

Ocean weather ships.—The cricket team of o.w.s. *Weather Observer* visited Hillhead High School, Glasgow—which "adopted" the ship some time ago—with the object of playing against the school, but bad weather prevented the match. The ship presented to the school a trophy shield embossed with the ocean-weather-ship crest for the inter-house relay race.

Sports and Athletics.—A good year of sport culminated in many successes at the Air Ministry and Ministry of Civil Aviation annual sports meeting at The White City on July 2. The Bishop Shield was won by the Office (for the fourth successive year) with a total score of 126 points. The achievements of the staff in winning every swimming event, gaining points in football and in ladies' netball contributed much to this success. The runners-up were the Ministry of Civil Aviation, who scored 66 points. The Jones Memorial Cup, awarded for the highest number of points at the annual sports meeting, was won by the Office for the third consecutive year, the outstanding win being the men's relay race in record time for these meetings. The Social and Sports Committee will circulate a list of individual successes to all branches and local offices.

The Social and Sports Club of the Office at Harrow held its third annual athletic meeting at Alperton in the evening of June 25. The high light of the evening was the tug-of-war which was won by a scratch team made up of officials on the spot, a result which caused some consternation in tug-of-war circles and considerable excitement amongst the spectators. Mrs. R. G. Veryard kindly presented the medals and certificates.

Flight Officer (Mrs.) J. K. Frith (R.A.F.V.R.–Met.) has been selected to shoot for Great Britain at the International Archery Championship meeting being held at Brussels from July 19 to July 26.

WEATHER OF JUNE 1952

Mean pressure was high over Europe and most of the Atlantic east of 40°W., generally 2 mb. above normal. Mean pressure was low from Scandinavia to Greenland and over North America, the greatest deficit of pressure, 7 mb., occurring between Norway and Iceland. The highest mean pressure, 1024 mb., was recorded in the Azores; mean pressure decreased steadily north-eastwards from the Azores to 1006 mb. in the Norwegian Sea.

Mean temperature over Europe and the Mediterranean was generally 2–6°F. above normal. The mean temperature varied from 50–55°F. in Scandinavia to 60–70°F. in west Europe and 70–80°F. in the Mediterranean region. In the south-east of the United States the mean temperature was between 80° and 85°F., about 9°F. above normal.

In the British Isles, broadly speaking, the weather was wet in the west and north and dry in the south and east. Temperature was changeable during the first three weeks, but the last week was warm, particularly the last three days.

On the 1st and 2nd a depression moved north-east over the British Isles causing rain and local thunderstorms, with a gale on our south-west coasts. Thereafter an anticyclone moved quickly north-east from Spain to central Europe, while a depression south of Iceland moved slowly east and associated troughs of low pressure crossed the British Isles. Scattered showers were recorded in Scotland and Ireland on the 3rd and rain or showers, heavy in places, on the 4th and 5th; thunderstorms were experienced locally in England on the 5th and 6th. Temperature rose in south and east England on the 5th, reaching 78°F. at Camden Square, London. The duration of bright sunshine exceeded the average in all districts during the first week. On the 8th a shallow depression off north-west Ireland moved east-south-east causing widespread rain in southern districts. Subsequently a belt of high pressure extended from the Azores across the southern districts of the British Isles to Germany and a short spell of fair, warm weather prevailed over much of the country, though cloudy conditions with some rain occurred in the north of Scotland. Temperature reached 80°F. at Camden Square on the 12th. On the 12th and 13th a small depression over the Bay of Biscay moved to southern England and then turned north-east. Thunderstorms occurred widely in southern England and the Midlands on the 13th, the storms being severe locally, notably in the Bristol, Torquay and Bognor areas; at Long Ashton near Bristol, 2·21 in. was registered. A cool rather unsettled period ensued, which lasted until the 21st. On the 14th and 15th pressure was low over Scandinavia and high to the north-west of the British Isles; cool northerly winds prevailed with scattered rain or showers. On the 17th and 18th a depression off the west of Scotland moved east and became less intense, while an associated trough moved across England; rain occurred widely and there was local thunder. On the 19th and 20th a small depression west of Iceland moved south-east and on the 21st another depression westward of Scotland moved east-south-east to the North Sea. Further rain occurred, heavy in places (3·24 in. at Blaenau Festiniog and 3·16 in. at Llechwedd Quarry, both in Montgomeryshire, on the 21st), but falls were slight in the south. In the north of Scotland the period 7th–16th was unusually dull; at Duntuilm, Isle of Skye, the total sunshine for the ten days was only 6·2 hr., the lowest there for any ten days in June since records were first begun in 1934. Frost occurred locally on the night of the 15th–16th; at Ross-on-Wye the temperature on the grass fell to 30°F., a most unusual occurrence there for mid June. Subsequently the Azores anticyclone spread north-east and a belt of high pressure lay over southern districts maintaining fair, warm weather for the remainder of the month. Atlantic depressions moving north-east caused rain at times, however, in northern districts, chiefly on the 24th and 28th. Except in the north and north-west of Scotland the last week was warm, the last four days being very warm. For example, temperature rose to 85°F. at Bournemouth on the 27th, 86°F. at Greenwich Observatory on the 28th, 89°F. at Camden Square and Greenwich and 88°F. at Southend on the 29th, and 89°F. at Camden Square and Greenwich and 88°F. at Southend, East Malling and Scarborough on the 30th.

The general character of the weather is shown by the following provisional figures:—

	AIR TEMPERATURE			RAINFALL		SUNSHINE
	Highest	Lowest	Difference from average daily mean	Percentage of average	No. of days difference from average	Percentage of average
	°F.	°F.	°F.	%		%
England and Wales ...	89	31	+1·1	86	0	98
Scotland	78	24	−0·6	130	+4	80
Northern Ireland ...	76	33	0·0	98	+3	84

RAINFALL OF JUNE 1952

Great Britain and Northern Ireland

County	Station	In.	Per cent. of Av.	County	Station	In.	Per cent. of Av.
London	Camden Square ...	1·59	79	*Glam.*	Cardiff, Penylan ...	2·29	91
Kent	Folkestone, Cherry Gdn.	0·81	41	*Pemb.*	Tenby	3·42	143
,,	Edenbridge, Falconhurst	1·26	57	*Mer.*	Aberdovey	3·62	133
Sussex	Compton, Compton Ho.	1·78	71	*Radnor*	Tyrmynydd	3·92	120
,,	Worthing, Beach Ho. Pk.	1·22	70	*Mont.*	Lake Vyrnwy	2·79	87
Hants.	Ventnor Cemetery ...	1·29	68	*Mer.*	Blaenau Festiniog ...	9·38	144
,,	Southampton (East Pk.)	1·20	60	*Carn.*	Llandudno	1·43	75
,,	Sherborne St. John ...	1·70	80	*Angl.*	Llanerchymedd ...	2·53	107
Herts.	Royston, Therfield Rec.	1·15	51	*I. Man*	Douglas, Borough Cem.	2·55	105
Bucks.	Slough, Upton	1·14	55	*Wigtown*	Newton Stewart ...	3·14	119
Oxford	Oxford, Radcliffe ...	1·33	59	*Dumf.*	Dumfries, Crichton R.I.	2·80	111
N'hants.	Wellingboro' Swanspool	1·14	54	,,	Eskdalemuir Obsy. ...	4·35	138
Essex	Shoeburyness	1·40	80	*Roxb.*	Kelso, Floors	1·91	91
,,	Dovercourt	1·39	79	*Peebles*	Stobo Castle	2·65	91
Suffolk	Lowestoft Sec. School ...	1·54	85	*Berwick*	Marchmont House ...	2·65	115
,,	Bury St. Ed., Westley H.	1·58	75	*E. Loth.*	North Berwick Res. ...	2·16	130
Norfolk	Sandringham Ho. Gdns.	0·98	45	*Midl'n.*	Edinburgh, Blackf'd. H.	2·43	121
Wilts.	Aldbourne	1·81	78	*Lanark*	Hamilton W. W., T'nhill	2·46	112
Dorset	Creech Grange... ...	1·36	59	*Ayr*	Colmonell, Knockdolian	2·44	96
,,	Beaminster, East St. ...	1·67	74	,,	Glen Afton, Ayr San. ...	3·24	108
Devon	Teignmouth, Den Gdns.	1·75	91	*Renfrew.*	Greenock, Prospect Hill	4·21	135
,,	Cullompton	1·36	64	*Bute*	Rothesay, Ardencraig ...	4·32	141
,,	Ilfracombe	2·38	110	*Argyll*	Morven (Drimnin) ...	4·39	145
,,	Okehampton Uplands...	2·33	84	,,	Poltalloch	3·71	122
Cornwall	Bude, School House ...	1·92	96	,,	Inveraray Castle ...	5·47	138
,,	Penzance, Morrab Gdns.	1·33	60	,,	Islay, Eallabus	4·42	169
,,	St. Austell	1·34	52	,,	Tiree	3·48	136
,,	Scilly, Tresco Abbey ...	1·11	64	*Kinross*	Loch Leven Sluice ...	2·76	126
Glos.	Cirencester	1·92	80	*Fife*	Leuchars Airfield ...	2·24	134
Salop	Church Stretton ...	...	...	*Perth*	Loch Dhu	4·93	118
,,	Shrewsbury, Monksmore	2·11	101	,,	Crieff, Strathearn Hyd.	2·61	99
Worcs.	Malvern, Free Library...	2·23	96	,,	Pitlochry, Fincastle ...	2·20	105
Warwick	Birmingham, Edgbaston	1·55	67	*Angus*	Montrose, Sunnyside ...	2·08	125
Leics.	Thornton Reservoir ...	1·87	87	*Aberd.*	Braemar	1·86	95
Lincs.	Boston, Skirbeck ...	1·83	101	,,	Dyce, Craibstone ...	3·04	163
,,	Skegness, Marine Gdns.	0·78	43	,,	New Deer School House	2·79	140
Notts.	Mansfield, Carr Bank ...	1·73	77	*Moray*	Gordon Castle	2·31	113
Derby	Buxton, Terrace Slopes	3·58	111	*Nairn*	Nairn, Achareidh ...	1·64	93
Ches.	Bidston Observatory ...	1·80	82	*Inverness*	Loch Ness, Garthbeg ...	2·85	125
,,	Manchester, Ringway...	2·29	95	,,	Glenquoich	7·02	143
Lancs.	Stonyhurst College ...	3·94	128	,,	Fort William, Teviot ...	5·20	146
,,	Squires Gate	2·67	128	,,	Skye, Duntuilm ...	4·23	163
Yorks.	Wakefield, Clarence Pk.	1·22	57	,,	Skye, Broadford ...	6·71	171
,,	Hull, Pearson Park ...	2·02	98	*R. & C.*	Tain, Tarlogie House ...	1·16	63
,,	Felixkirk, Mt. St. John...	2·09	95	,,	Inverbroom, Glackour...	4·50	160
,,	York Museum	1·71	83	,,	Achnashellach	5·28	140
,,	Scarborough	1·28	70	*Suth.*	Lochinver, Bank Ho. ...	3·72	174
,,	Middlesbrough... ...	1·04	55	*Caith.*	Wick Airfield	2·92	162
,,	Baldersdale, Hury Res.	1·49	68	*Shetland*	Lerwick Observatory ...	3·66	204
Norl'd.	Newcastle, Leazes Pk....	1·71	81	*Ferm.*	Crom Castle	2·93	108
,,	Bellingham, High Green	2·12	92	*Armagh*	Armagh Observatory ...	2·27	90
,,	Lilburn Tower Gdns. ...	1·62	78	*Down*	Seaforde	2·22	80
Cumb.	Geltsdale	3·23	120	*Antrim*	Aldergrove Airfield ...	2·55	106
,,	Keswick, High Hill ...	2·99	103	,,	Ballymena, Harryville...	2·97	102
,,	Ravenglass, The Grove	3·13	120	*L'derry*	Garvagh, Moneydig ...	2·20	87
Mon.	Abergavenny, Larchfield	2·12	87	,,	Londonderry, Creggan	2·94	104
Glam.	Ystalyfera, Wern House	4·64	123	*Tyrone*	Omagh, Edenfel ...	3·21	114