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NOTES ON SOUTHERN-HEMISPHERE CIRCULATION

By S. T. A. MIRRLEES, M.A.

Summary.—Data of some of the pre-war expeditions to the South American sector of Antarctica are examined for a possible relation between circulation types and the surface zonal westerly index[1]. Some comparison is made with results of northern-hemisphere investigations and points for future investigations are suggested.

Introduction.—Antarctic exploration has been described as a "spasmodic affair proceeding by great efforts separated by intervals of inertness and inattention . . . the results were seldom fully recorded and published."[2]

Meteorological, and in particular climatological, exploration of Graham Land is now in a better way since the Falkland Islands Dependencies Survey[3] was set up, and, what is more important, has maintained continuously for several years a number of observation posts in latitudes 63–68°S.

When it was announced that the data of the Falkland Islands Dependencies Survey were being prepared for publication it occurred to the writer to examine data of some earlier expeditions to see if any line of investigation might be suggested for work on the more complete data of the Survey.

Data and method of working.—In the appropriate "source books"[4,5] data of mean monthly barometric pressure were available for 1903, 1904 and 1909, at various fixed stations (see Fig. 1). For 1915 there was a "drift station" (Shackleton's expedition) and considerable extrapolation was necessary to "reduce" the data to a fixed position in northern Graham Land. This process of course begs the question of the mean pressure distribution, but is perhaps no more outrageous than some of the extrapolation often involved in work on antarctic climatology. Data of the South American stations shown on the map were also extracted, and a series of charts of monthly pressure anomaly was prepared. Charts for 1935–37 were available from previous work[6].

Preliminary examination of the whole series of charts suggested a type classification on the following lines:—

(i) Since the maps of normal pressure distribution show that the westerlies prevail throughout the year on the west coast of South America only about as far north as 43°S., the term high- or low-index month is used to denote a month in which the gradient of mean monthly pressure

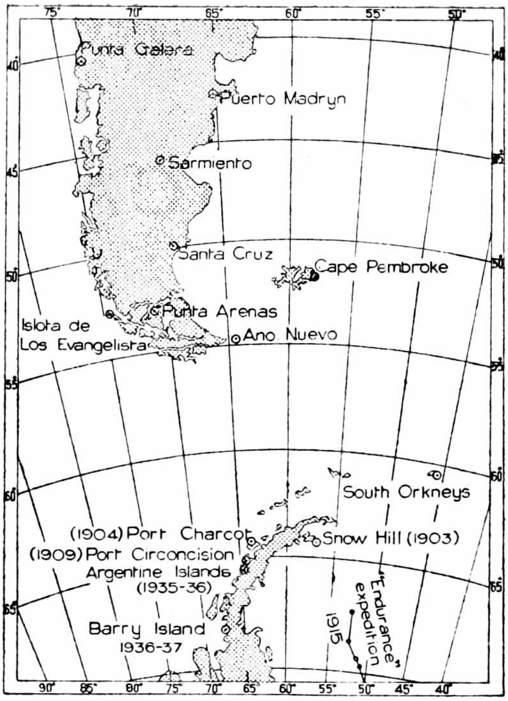

FIG. 1—POSITION OF STATIONS

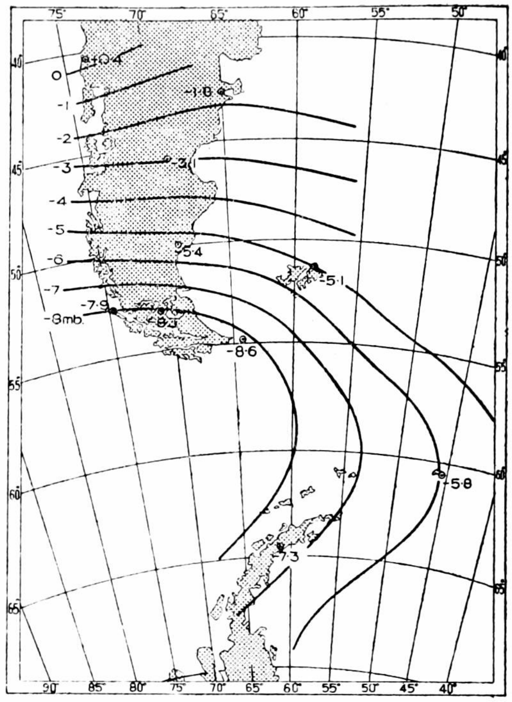

FIG. 2—COMPOSITE CHART OF THE FIVE HIGHEST INDEX W MONTHS

Average isanomalies of March 1903, March 1904, August 1909, March 1935 and December 1936.

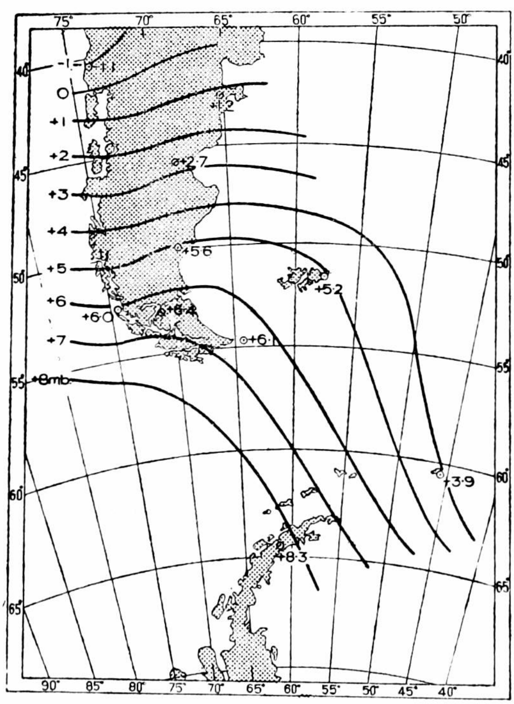

FIG. 3—COMPOSITE CHART OF THE FIVE LOWEST INDEX B MONTHS

Average isanomalies of May, November and December 1904, October 1935 and August 1936.

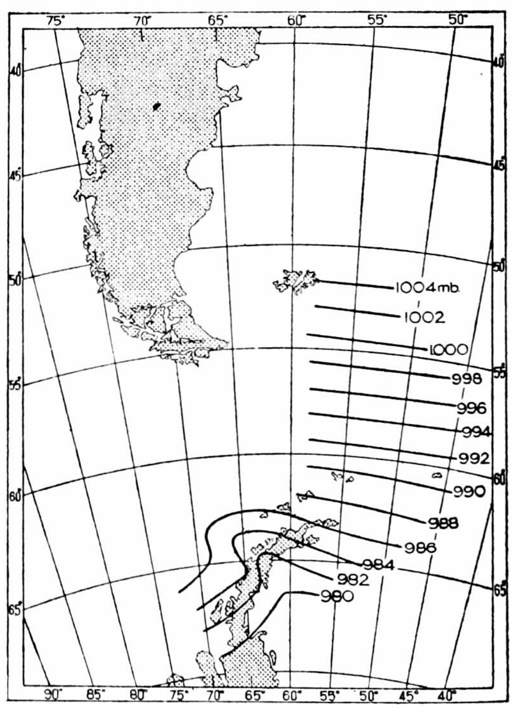

FIG. 4—MEAN MONTHLY SEA LEVEL PRESSURE, OCTOBER 1948

Part of the CLIMAT broadcast.

at mean sea level, Punta Galera – Los Evangelistas, was above or below normal for the time of year.

(ii) Subdivisions were made according as the mean monthly sea-level pressure at certain key stations was above (+) or below (−) normal.

TABLE I—CLASSIFICATION OF TYPES OF MONTHLY PRESSURE ANOMALY

	Type of monthly pressure anomaly at Falkland Islands	South Orkneys	Type indicator
High index ...	−	−	W
		+	X
	+	−	Y
		+	Z
Low index ...	+	−	A
		+	B
	−	−	C
		+	No example

This scheme of types seems adequate for a preliminary investigation, being objective and easily applied. When more complete data are available it would be possible to make a detailed air-mass investigation on dynamical–climatological lines.

Results of the type classification.—The results of the classification process are shown in Tables II, III and IV. Of the 70 months included, there are 41 with high index and 29 with low index. This result suggests that

TABLE II—DISTRIBUTION OF TYPES

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1903	...	...	W	Y	Z	W	Y	Y	Z	Z	Z	Y
1904	A	A	W	B	B	Z	A	X	X	X	B	B
1905	Z	...	...	...	...	...	...	...	...	...	...	...
1909	A	C	B	W	W	W	X	W	B	B	A	...
1915	A	C	B	W	X	W	X	X	Z	Z	Z	C
1935	...	...	W	A	W	X	C	A	C	B	W	W
1936	X	A	C	B	C	W	Z	B	W	W	A	W
1937	B	X	...	...	...	...	...	...	...	...	...	...

TABLE III—SEASONAL DISTRIBUTION OF TYPES

	High-index months W	X	Y	Z	Low-index months A	B	C
	Number of occasions						
Spring	3	2	0	6	2	4	1
Summer	2	2	1	1	5	2	3
Autumn	7	1	1	1	1	5	2
Winter	5	5	2	2	2	1	1

TABLE IV—RELATION OF TYPES TO PRESSURE DIFFERENCE BETWEEN SOUTH ORKNEYS AND GRAHAM LAND

Pressure difference South Orkneys – Graham Land	Type of classification: High-index months W	X	Y	Z	Low-index months A	B	C
	Number of occurrences						
+	13	10	4	10	5	9	4
0	1	...	...	...	...	...	...
−	3	...	...	...	5	3	3

expeditions were in the field mainly in high-index years, or the adopted "normals" may be doubtful, and is a point for future investigation along with the following:—

(i) The seasonal trend is for high-index types in winter and spring, low-index types in summer and autumn.

(ii) Type W (Fig. 2) shows the closest association with season (7 in autumn, 2 in summer).

(iii) Of low-index types, B (Fig. 3) shows a slight predominance over A on the whole year.

In the previous work[6] some indication was found of a tendency for months when pressure over Graham Land was higher than over South Orkneys to be associated with low zonal index. Now, using data of 70 instead of 24 months, a different régime appears (see Table IV). This may be some indication of secular change, and is a point for future investigation.

Comparison with northern-hemisphere investigations.—

(i) Namias[7] finds a suggestion that during the colder parts of the year low-index periods are more persistent than high—according to Table III if periods of one month are considered, the chances are 14 to 4 against a winter month being a low-index month. A point for future investigation is whether there is a 30-day rhythm in pressure, over the area considered, which in certain years may be "in step" with the calendar.

(ii) Brier[8,9] has found a tendency for mean monthly sea-level pressure patterns resembling summer–autumn pressure patterns towards the end of that period (1899–1939) and winter–spring pressure patterns towards the earlier part of the period. Table II shows something of the same kind—of 23 months in 1903–05 there were 16 of high index and 7 of low index whereas in 1935–37 the proportion was 12 to 12.

(iii) Namias[10] has found some indication that low- or high-index patterns are more consistent within the same year than from year to year, e.g. a low-index feature is apt to repeat in the same fashion in the same season. Table II has some indication of this (sequence A, C, B) but without emphasis on "the same season".

Conclusion.—It seems that charts of monthly pressure anomaly afford a means of using the data of early expeditions to Graham Land in conjunction with the data of the Falkland Islands Dependencies Survey for study of circulation patterns and investigation of secular change in these.

CLIMAT broadcasts.—As part of the scheme of the World Meteorological Organization for exchange of data, each meteorological authority makes radio broadcasts of mean surface values of meteorological elements (including pressure) for a selection of stations "as soon as possible after the end of the month and not later than the 5th".

As an instance of the advance in climatological exploration since the first expedition wintered in Graham Land some fifty years ago, it may be noted that the climatologist may (in favourable conditions of radio propagation), by listening on the short-wave band of his domestic radio, have the data for drawing the map of pressure distribution over Graham Land (Fig. 4) "not later than the 5th".

[Dr. J. Pepper comments, with reference to Mr. Mirrlees's suggestion on secular change, that his studies of the region show that the mean monthly pressure in the Graham Land region undergoes very large variation, and he is doubtful if even 10 years' observations suffice for the examination of secular change.—Ed., *M.M.*]

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ACCURACY OF 100-MB. CONTOUR HEIGHTS

By D. H. JOHNSON, M.Sc.

Summary.—Comparison between observed winds and slopes of the 100-mb. pressure surface indicate that the standard error in the measurement of 100-mb. contour height, using radio-sonde data for British land stations, is of the order of 145 ft.

Introduction.—Reports of 100-mb. winds show flow patterns at the 100-mb. level to be smoother than those of the troposphere. If, however, the contours of the 100-mb. surface are drawn to agree strictly with the measurements of contour height, patterns are obtained which are far more irregular and have a much greater variability in space and time than the observed flow. The dominant terms in the expression for the ageostrophic wind depend on the local and spatial accelerations. Since these are small at 100 mb. the ageostrophic winds will also be small. So, knowing the observed winds to be reasonably accurate[1], the large apparent geostrophic departure must be accounted for in terms of contour-height errors. A method of estimating the standard error in measurements of 100-mb. contour height is described below.

Expression for the standard error.—An estimate of the standard error of the contour-height measurements can be obtained simply by comparing the measured contour gradients with the observed winds, due consideration being given to errors, other than those of the contour heights themselves, which may affect the comparison. The problem may be formulated as follows. The value ascribed to the 100-mb. contour height above a given station is obtained from radio-sonde observations of temperature and pressure by integration of the hydrostatic equation. This value is known to contain not only the usual errors of measurement and computation but also errors caused by the fact that the basic observations are not made simultaneously at all levels; they are made over finite intervals of time during which the balloon travels some distance away from the point to which they are taken to refer. The object of the present test is to get an estimate of the total error in the values obtained and not to discriminate between the various component parts.

Observations are required from two adjacent upper air stations at points A and B. Let

V = true wind component perpendicular to AB.
U = measured wind component perpendicular to AB.
ε = error in measured component perpendicular to AB.
J = geostrophic wind component perpendicular to AB.
V' = ageostrophic wind component perpendicular to AB.
x = distance measured along AB.
d = distance between A and B.
h = true height of 100-mb. surface.
H = measured height of 100-mb. surface.
θ = error in measured height of 100-mb. surface.

g and l have their usual significance. Suffixes A, B denote values of the variables at points A, B.

Then $$V = V' + J$$

where $$J = \frac{g}{l}\left(\frac{\partial h}{\partial x}\right)_{100}$$

Taking mean values over the distance AB for a particular occasion

$$\overline{V} - \overline{V'} = \overline{J}$$
$$= \frac{g}{ld}(h_B - h_A)$$

so $$(H_B - H_A) + (\theta_B - \theta_A) = \frac{ld}{g}(\overline{V} - \overline{V'}). \qquad \ldots\ldots (1)$$

Now let η be the difference between the true wind component at any point along AB and the wind component obtained by linear interpolation between the true winds at A and B,

so that $$\overline{V} = \tfrac{1}{2}(V_A + V_B) + \overline{\eta}$$
$$= \tfrac{1}{2}(U_A + U_B) + \tfrac{1}{2}(\varepsilon_A + \varepsilon_B) + \overline{\eta}$$

and from equation (1)

$$(H_B - H_A) - \frac{ld}{2g}(U_A + U_B) = (\theta_A - \theta_B) + \frac{ld}{g}[\tfrac{1}{2}(\varepsilon_A + \varepsilon_B) + \overline{\eta} - \overline{V'}].$$

Now taking the mean-square values of both sides of the equation over a large number, N, of occasions and assuming θ, ε, η and V' to be independent,

$$\frac{1}{N}\Sigma\left[(H_B - H_A) - \frac{ld}{2g}(U_A + U_B)\right]^2 = \frac{2}{N}\Sigma\,\theta^2 + \frac{l^2d^2}{Ng^2}\left(\frac{1}{2}\Sigma\varepsilon^2 + \Sigma\overline{\eta}^2 + \Sigma\overline{V'}^2\right)$$

and the standard error in the measured height

$$\left[\frac{1}{N}\Sigma\theta^2\right]^{\frac{1}{2}} = \frac{1}{2^{\frac{1}{2}}}\left\{\frac{1}{N}\Sigma\left[(H_B - H_A) - \frac{ld}{2g}(U_A + U_B)\right]^2 - \frac{l^2d^2}{Ng^2}\left[\frac{1}{2}\Sigma\varepsilon^2 + \Sigma\overline{\eta}^2 + \Sigma\overline{V'}^2\right]\right\}^{\frac{1}{2}}.$$

Evaluation of the errors.—The first term in the expression for $[(1/N)\Sigma\theta^2]^{\frac{1}{2}}$ has been calculated using 356 pairs of observations for the first nine months of 1952 made by 6 pairs of British radio-sonde stations. The root-mean-square of

$$\left[(H_B - H_A) - \frac{ld}{2g}(U_A + U_B)\right]$$

was 207 ft., implying an upper limit to $[(1/N)\Sigma\theta^2]^{\frac{1}{2}}$ of 145 ft.

It is reasonable to assume that $(1/N)\Sigma\bar{\eta}^2$ is not greater than $(1/N)\Sigma\eta_m{}^2$ where η_m is the error of interpolation at the mid point of AB. Now an estimate, (7 kt.)^2, of $(3/2N)\Sigma\varepsilon^2 + (1/N)\Sigma\eta_m{}^2$ has previously been obtained[1] by comparing an interpolation between winds observed at Aldergrove and Downham Market with the wind observed at Liverpool. This estimate applied to a winter sample of winds and the distance Aldergrove—Downham Market exceeds the distance between any of the pairs of stations used in the present test. So we may safely take the value of the terms $(1/2N)\Sigma\varepsilon^2 + (1/N)\Sigma\bar{\eta}^2$ as being less than (7 kt.)^2; $(1/N)\overline{V'^2}$ will be of the same order as $(1/N)\Sigma(V'_A)^2$ or $(1/N)\Sigma(V'_B)^2$. Representative values of the observed time and space variations of 100-mb. wind over the British Isles are 11 kt./12 hr. and 12 kt./300 miles in winter and less in summer. Since the total geostrophic departure $\mathbf{V}'$ is related to the flow accelerations by the equation

$$l\mathbf{V}' = \mathbf{k} \times \left(\frac{d\mathbf{V}}{dt}\right)_h + 2V_z\,\omega_h$$

where $d/dt = \partial/\partial t + \mathbf{V}.\nabla$, $\mathbf{k}$ is unit vector in the vertical, ω represents the angular velocity of the earth and h, z denote components in the horizontal and vertical respectively, it may be deduced that the ageostrophic wind is unlikely to average more than 3 or 4 kt. Also (5 kt.)^2 is probably a generous allowance for the mean square of the ageostrophic wind components at A or B and so for $(1/N)\Sigma\overline{V'^2}$.

The factor ld/g combined with that required to convert knots to feet per second varies between different pairs of stations from 4 to 5 sec. From these considerations we can estimate that the term $(l^2d^2/Ng^2)[\frac{1}{2}\Sigma\varepsilon^2 + \Sigma\bar{\eta}^2 + \Sigma\overline{V'^2}]$ will be less than 1,850 ft.^{2} So $[(1/N)\Sigma\theta^2]^{\frac{1}{2}}$ will be greater than

$$2^{-\frac{1}{2}}[(207)^2 - 1850]^{\frac{1}{2}} = 142 \text{ ft.}$$

Strictly, the values of U employed in these calculations should refer to points vertically above A and B at 100 mb., but the average spatial variation of U can reasonably be expected to be so small over the 10 to 30 miles the balloon is usually carried away from its station as to have a negligible effect on these results.

It is of interest to compare the 100-mb. standard error with those given by Murray[2] for lower levels, which are contained in Table I.

TABLE I—STANDARD ERRORS IN HEIGHTS OF ISOBARIC SURFACES COMPUTED FROM RADIO-SONDE OBSERVATIONS FOR BRITISH LAND STATIONS

Pressure level (mb.)	700	500	300	200	100
Approximate height (ft.) ...	10,000	18,000	30,000	38,000	53,000
Standard error (ft.)	20	30	70	100	145

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MOBILE DEPRESSION WITH AN UNUSUAL THERMAL STRUCTURE

By C. A. S. LOWNDES

Experience in the use of 1000–500-mb. thickness patterns has led to the recognition of certain types of association between such patterns and particular features and phases of development on surface charts. For example, cyclogenesis is usually accompanied by a distortion of the thickness pattern, with a developing cold trough to the rear and a warm ridge ahead of the surface depression. Later, when the occlusion process is well advanced, the cold trough sometimes overtakes the surface low, which is then usually slow moving and in the process of filling. Thermal gradients in these circumstances are often weak and a cold pool may become associated with the surface low.

A system which formed near Greenland on October 4, 1952, started as a normal depression but subsequently developed a well marked cold trough in phase with the centre. In this case, however, the low did not become stationary or begin to fill up, but after a period of erratic motion continued its south-eastward movement without much change of pressure at the centre (Fig. 1).

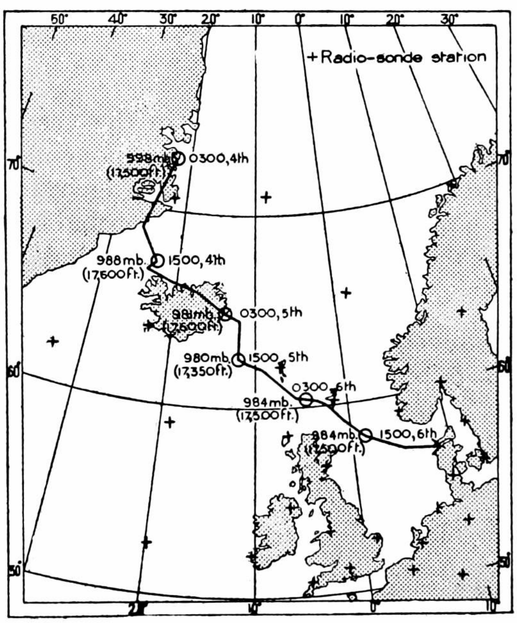

FIG. 1—TRACK OF DEPRESSION

The central M.S.L. pressure and the associated 1000–500-mb. thickness are shown at 12-hr intervals.

Initial development of the depression.—By 0300 G.M.T. on October 4, 1952 a trough of low surface pressure off the east coast of Greenland had developed a closed centre at about 72°N. The new centre (pressure 998 mb.) was situated in a moderate thermal gradient near the "top" of a diffluent ridge in the 1000–500-mb. thickness pattern (Fig. 2). The corresponding patterns for the partial thicknesses of the layers 500–300 mb., 700–500 mb. and 1000–700 mb. were similar, the ridge being more sharply defined in the lower layers (Fig. 2). The depression deepened rapidly and moved (rather at variance with thermal steering) on a southerly track to the north-west of

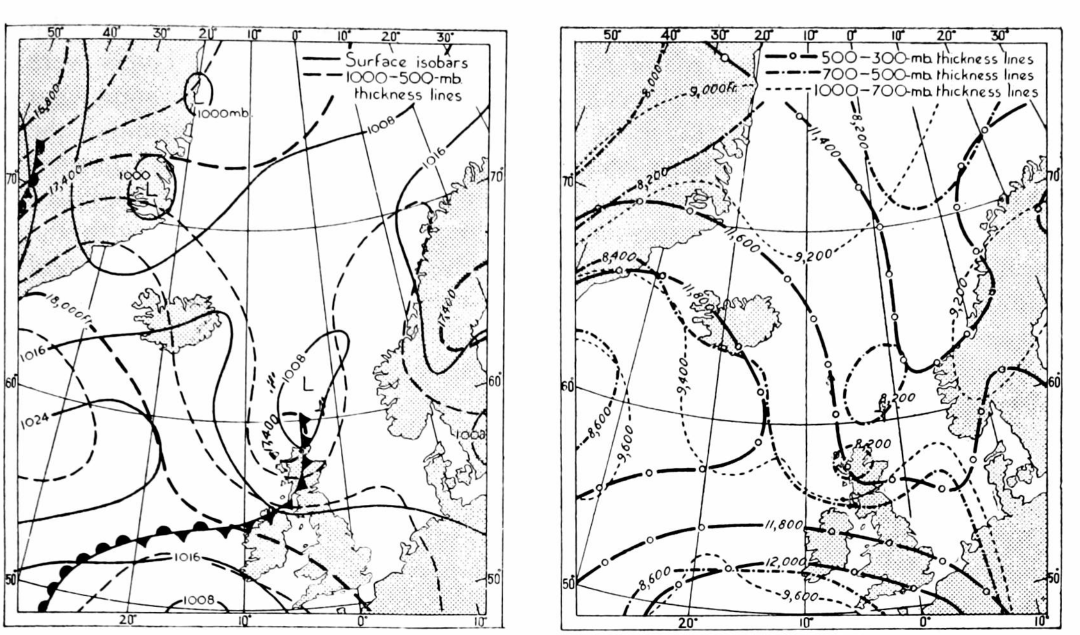

FIG. 2—SYNOPTIC CHART, OCTOBER 4, 0300 G.M.T.

Iceland by 1500, the central pressure falling to 988 mb. During the morning, a cold occlusion moved south-east over Greenland, became slow moving near the east coast, and then moved steadily south across the Denmark Strait, becoming associated with the developing low. The low deepened to 983 mb. by 1800, and continued east-south-east across Iceland without much further intensification and was situated near the east coast of Iceland by 0300 on the 5th. Warm frontogenesis was then occurring between Iceland and Scotland, ahead of the cold occlusion. The associated 1000–500-mb. thickness pattern showed a well developed cold trough to the rear and a warm ridge ahead of the low (Fig. 3).

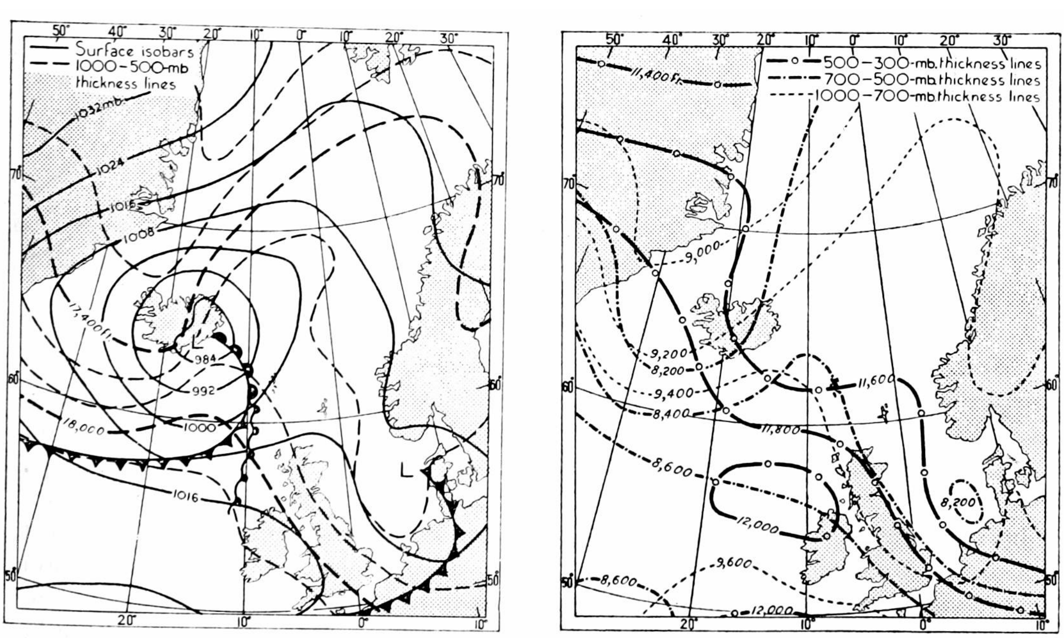

FIG. 3—SYNOPTIC CHART, OCTOBER 5, 0300 G.M.T.

Relative positions of upper air troughs and low pressure at the surface.—The patterns for the 1000–700-mb. and 700–500-mb. layers were very similar, the warm ridge and cold trough in the higher layer being somewhat ahead of that in the lower layer, as is normally found. On the other hand, the 500–300-mb. thickness pattern was rather abnormal; the entire wave pattern at this level was so far in advance of the lower patterns that the cold trough was almost in phase with the warm ridges of the two lower layers and with the surface depression itself (Fig. 3). It is interesting to note that the orientation of the 500–300-mb. thickness pattern at 0300 was much more in keeping with the south-south-east movement of the low during the next 12 hr. The thermal wind below 500 mb. over the depression centre at this time was south-westerly in direction.

By 1500, an equally remarkable transformation had occurred in the 1000–500-mb. pattern, the cold trough of which had apparently moved rapidly south-east so as to overtake the surface low (as had the trough in the 500–300-mb. layer previously) whilst the warm ridge had moved still further ahead and had weakened. This phase-change was largely effected in the 700–500-mb. layer as will be seen from the isopleths (Fig. 4). The normal structure, with the cold trough to the rear and the warm ridge ahead of the surface centre, was still in evidence in the 1000–700-mb. layer.

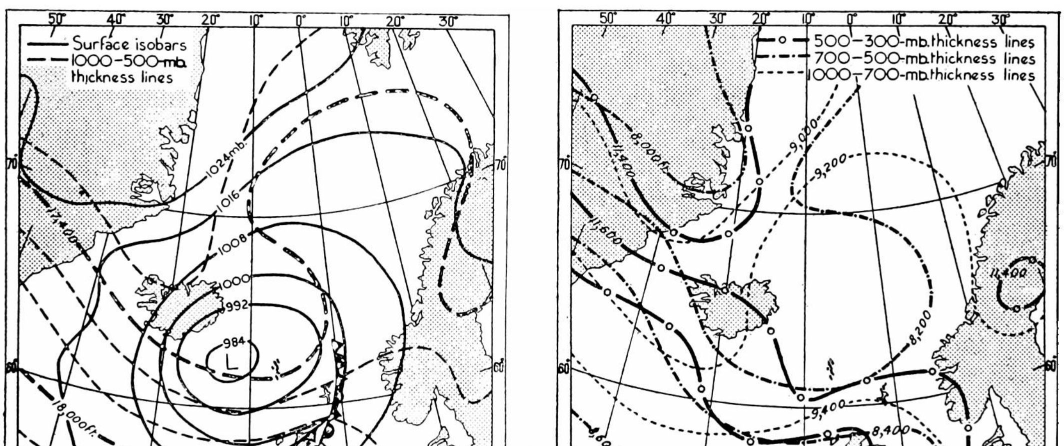

FIG. 4—SYNOPTIC CHART, OCTOBER 5, 1500 G.M.T.

Movement of depression after overtaking of surface depression by upper trough.—During the period 0300 to 1500 on October 5, the greatest 1000–500-mb. thickness change occurred at the depression centre, as the main cold trough in this layer moved into phase with the surface low (Fig. 4). Simultaneously, the centre of the low became detached from the occlusion. Thermal steering would have taken the low north-east, yet it moved almost south-south-east into its own cold trough. The movement of the depression was rather erratic over this period, with symptoms of splitting into two early on, which suggests that the anomalous movement with respect to the 1000–500-mb. pattern may have been due to a re-development further south in the cold air.

The cooling around and ahead of the centre during this period is particularly interesting, because it occurred at a time when the low was of constant depth and when it was moving obliquely across the thickness lines to the warmer side and also south-south-east over a warmer under-surface. Whatever the causes and the nature of the abnormal movement of the low, this remarkable cooling must have been a result of dynamical temperature changes (the lifting of a stable layer) or of ageostrophic cold air advection. It is possible that some cold air was advected (geostrophically) round the southern flank of the low which was then transferred south into it, as previously noted, but this could not have accounted for the magnitude or the extent of the cooling which occurred. This is brought out in Fig. 5 which shows the position of the 1000–500-mb. thickness line for 17,400 ft. at the beginning and end of the period in question, and also where it would have been if it had been advected by the component of the surface geostrophic wind normal to it.*

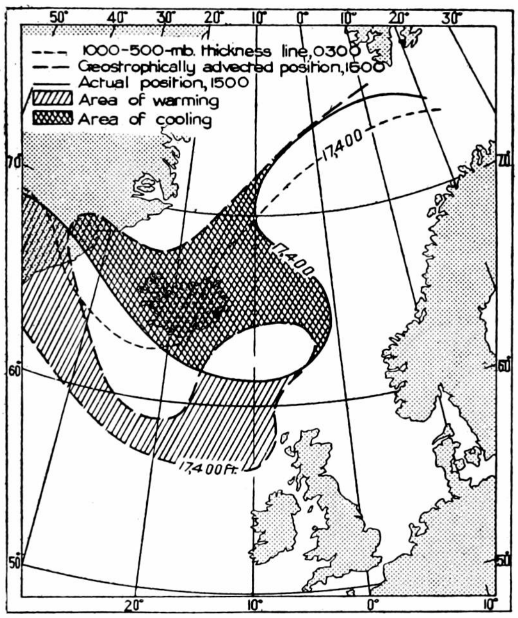

FIG. 5—AREAS OF MAXIMUM NON-ADVECTIONAL WARMING AND COOLING

The shaded segments give an indication of the areas of maximum non-advectional warming and cooling. Warming from below as the cold air moved southwards over the relatively warm sea surface was probably an important agency in the former. Some computations based on the Sutcliffe formula† gave a reasonably good correspondence between the area of maximum vertical ascent required by this theory and the area of maximum cooling. Ageostrophic advection of cold air towards the centre is, however, the essence of the occlusion process and was undoubtedly a contributory factor in the present instance.

Subsequent history.—By 0300 on the 6th, the centre had moved south-east to a position north of Scotland having filled a little and was situated at the "tip" of the trough in the 1000–500-mb. thickness pattern whilst the warm ridge was

* This was done by progressive extrapolation using synoptic charts of the surface isobars at 3-hr. intervals.

† SUTCLIFFE, R. C.; A contribution to the problem of development. *Quart. J. R. met. Soc., London,* **73**, 1947, p. 370.

rapidly developing to the west in spite of the opposing cold air advection (Fig. 6). The partial thickness patterns showed that a cold pool had developed above the surface depression in the 500–300-mb. layer. The trough in the 700–500-mb. pattern was apparently beginning to lag behind the surface centre again at this stage, but later moved forward to become associated with it again. By 1500 the upper cold pool was also apparent in the 700–500-mb. layer whilst that in the layer above had split into two. The thermal gradient in the lowest layer (1000–700 mb.) remained weak throughout.

From this stage, the centre accelerated on an east-south-east track to north Denmark and then slowed down. Before the depression filled, a more normal thermal structure developed in the 1000–500-mb. thickness pattern, namely a cold trough to the rear and a warm ridge ahead. This change was also apparent in the 1000–700-mb. layer, but in the two upper layers the cold pools persisted in association with the centre of surface pressure. The thermal gradients at all levels were weak throughout this period.

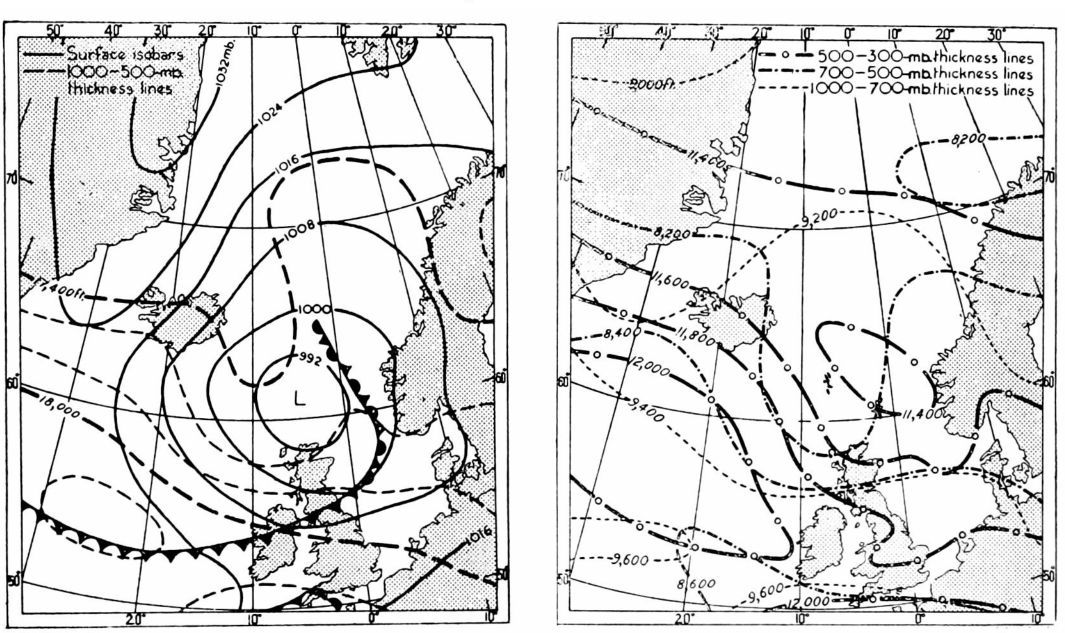

FIG. 6—SYNOPTIC CHART, OCTOBER 6, 0300 G.M.T.

Concluding remarks.—This case-study illustrates how complex the thermal structure of extratropical cyclones can be, and, in particular, points to the possible importance of the 500–300-mb. thickness pattern on some occasions in forecasting. Moreover, the fact that such complex structures and evolutions occur and are possibly significant with respect to surface developments, suggests that no simple cyclone model can provide the basis for a method of forecasting or of deriving numerical solutions of the equations of motion, which will succeed in all cases.

NEW CLIMATOLOGICAL AVERAGES FOR GREAT BRITAIN

By J. GLASSPOOLE, Ph.D.

Station averages are used as a standard for reference, so that the weather of any month or year may be classified in relation to these averages. In the course of time the average over a definite number of years may change. Moreover some of the stations for which averages have been computed cease to report, while new stations may be started. It is therefore useful for a more up-to-date period to be brought into use as the standard for comparison. When this is done it is important to define the differences in the averages for the two periods.

In the *Monthly Weather Report*, 1953, averages of temperature and sunshine for the period 1921–50 were introduced, replacing those for 1906–35. These new averages have now been published[1,2]. Pressure averages at 9h. for 1921–50 are available for inclusion in the *Monthly Weather Report*, 1954, while rainfall averages for 1916–50 will replace those for 1881–1915 when the necessary computations have been carried out.

Temperature.—Serial monthly values of mean temperature at sea level over England and Wales and over Scotland were published by Glasspoole and Hogg[3] covering the period 1901–40, and these values have been continued in the form of departures in the *Monthly Weather Report*. Using these values it is possible to give a comparison of the averages for 1921–50 with those for 1906–35 as set out in Table I.

TABLE I—MEAN TEMPERATURE AT SEA LEVEL

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
	degrees Fahrenheit												
	ENGLAND AND WALES												
1921–50	40·4	40·6	43·6	47·5	52·8	58·2	61·6	61·3	57·6	51·4	45·0	41·6	50·1
1906–35	40·5	40·6	42·9	46·6	53·2	57·7	61·1	60·9	57·0	50·9	44·1	41·5	49·7
	SCOTLAND												
1921–50	39·1	39·5	41·8	44·9	49·7	54·7	58·1	57·4	53·7	48·4	42·8	40·4	47·5
1906–35	39·4	39·6	41·0	44·2	49·6	54·2	57·8	57·1	53·1	48·0	42·2	39·9	47·1

On the basis of this table the period 1921–50 was warmer than 1906–35 by 0·4°F. over England and Wales and over Scotland. The increase in the temperature was most marked in the spring months March and April, and there was a slightly greater increase in the autumn than in the summer. The mean monthly differences, 1921–50 minus 1906–35, for the various seasons are set out in Table II. The seasonal changes are therefore similar over England and Wales and over Scotland.

TABLE II—MEAN MONTHLY DIFFERENCE OF TEMPERATURE, 1921–50 MINUS 1906–35

	Spring Mar.–May	Summer June–Aug.	Autumn Sept.–Nov.	Winter Dec.–Feb.
	degrees Fahrenheit			
England and Wales ...	+0·4	+0·5	+0·7	0·0
Scotland	+0·5	+0·4	+0·5	+0·0

For most stations annual averages for 1921–50 were greater than those for 1906–35 by 0·2–0·6°F. The values were rather less than 0·4°F. in the western half of Scotland, over the English Lake District and from north Wales and the Wash across the Midlands to the south coast between Weymouth and Dover. The difference was therefore rather more than 0·4°F. in the east of Scotland, over much of England north of Derbyshire, over south Wales and much of Devon and Somerset, as well as in parts of East Anglia. The main feature, however, is the uniformity of the difference over the country.

Sunshine.—Serial monthly values of sunshine were published by Hancock covering the period 1909 to 1948[4,5], and in order to enable a comparison to be made Mr. Hancock kindly continued the values back to 1906. These serial values are based on the maps published in the *Monthly Weather Report*, and the general distribution shown on these maps may have changed somewhat as more information became available. Moreover, homogeneous sunshine records are relatively few because of changes caused by diminution in the efficiency of the sphere and by changing exposure, as trees grow etc. General values for England and Wales and Scotland, in the form of departures, have been published in the *Monthly Weather Report* deduced from the means of representative stations in each district. These values are in close accord with those prepared by Mr. Hancock, and they have been used from 1934 onwards, because this series is likely to be continued in the future. A comparison for the two periods is given in Table III.

TABLE III—AVERAGES OF SUNSHINE

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
	hours a day												
	ENGLAND AND WALES												
1921–50	1·51	2·31	3·76	5·02	6·09	6·70	5·82	5·47	4·40	3·18	1·89	1·34	3·96
1906–35	1·55	2·39	3·70	4·99	6·03	6·54	5·92	5·38	4·69	3·17	2·01	1·27	3·98
	SCOTLAND												
1921–50	1·18	2·16	3·27	4·59	5·68	5·80	4·54	4·36	3·60	2·54	1·58	0·93	3·35
1906–35	1·14	2·12	3·34	4·67	5·36	5·83	4·83	4·18	3·78	2·58	1·65	0·92	3·36

On the basis of Table III the period 1921–50 was about as sunny as 1906–35 for the year as a whole and during the winter. It was rather sunnier in the spring but less sunny in the autumn, while in the summer it was sunnier over England and Wales but less sunny over Scotland. The mean daily differences 1921–50 minus 1906–35 for the various seasons are set out in Table IV.

TABLE IV—CHANGE IN SEASONAL AVERAGES OF SUNSHINE, 1921–50 MINUS 1906–35

	Spring Mar.–May	Summer June–Aug.	Autumn Sept.–Nov.	Winter Dec.–Feb.
	hours a day			
England and Wales ...	+0·05	+0·05	−0·13	−0·02
Scotland	+0·06	−0·05	−0·10	+0·03

The seasonal difference in the averages for the two periods in the autumn over England and Wales amounts to the loss, as judged by 1906–35 standards, of about one autumn's sunshine in the 30 yr., 1921–50.

Pressure.—Estimates of the monthly changes of pressure at 9h. in the two periods 1901–30 and 1921–50 were obtained from the mean values for 10 well distributed places over Scotland and 20 over England, Wales and the Isle of Man. Station values were taken where available but occasionally values were estimated from the average monthly maps in order to obtain a better distribution. The estimated values for the two periods are set out in Table V.

TABLE V—AVERAGES OF PRESSURE* AT 9H.

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
	millibars												
	ENGLAND AND WALES												
1921–50	13·7	15·1	15·5	13·7	15·3	16·5	14·6	14·6	15·7	14·1	12·3	14·0	14·6
1901–30	15·2	13·9	12·5	13·3	15·4	16·6	15·6	14·2	16·8	13·3	13·0	11·2	14·3
	SCOTLAND												
1921–50	8·0	11·2	12·8	11·6	14·4	13·9	11·6	11·6	12·0	10·0	8·5	8·9	11·2
1901–30	8·6	8·9	9·2	11·3	14·0	14·7	13·2	10·8	13·7	9·9	8·8	5·9	10·7

* The first two figures are omitted in this table, e.g. 1013·7 is printed as 13·7.

On the basis of Table V the outstanding monthly changes are the higher pressure during 1921–50 in March and December and the lower pressure in January, July and September. The mean monthly differences for the seasons are given in Table VI.

TABLE VI—CHANGE IN SEASONAL AVERAGES OF PRESSURE, 1921–50 MINUS 1901–30

	Spring Mar.–May	Summer June–Aug.	Autumn Sept.–Nov.	Winter Dec.–Feb.
		millibars		
England and Wales ...	+1·1	−0·2	−0·3	+0·8
Scotland	+1·5	−0·5	−0·6	+1·6

The seasonal pressure changes in the two periods were small but the higher pressures during 1921–50 were due mainly to the higher pressures of the winter and spring, which more than balanced the rather lower pressures in the summer and autumn.

From Table V it can be inferred that the mean annual pressure at 9h. for 1921–50 was greater than that for 1901–30 by 0·3 mb. over England and Wales and by 0·5 mb. over Scotland. The difference was only 0·2 mb. from south Wales to the south coast between Land's End and the Isle of Wight, but the values increased to the east coast of England and to the northern half of Scotland, where they exceeded 0·5 mb.

From the monthly maps the pressure gradient between Cape Wrath and Dungeness was estimated for the two periods, and the seasonal changes are set out in Table VII, the plus sign indicating that the pressure gradient for 1921–50 was greater than that for 1901–30.

TABLE VII—SEASONAL CHANGE IN PRESSURE GRADIENT BETWEEN CAPE WRATH AND DUNGENESS, 1921–50 MINUS 1901–30

	Spring Mar.–May	Summer June–Aug.	Autumn Sept.–Nov.	Winter Dec.–Feb.
		millibars		
Change in pressure gradient	−0·01	+1·05	+1·33	−0·28

The two seasonal tables above suggest that in the summer and autumn the pressure gradient was greater in 1921–50 than in 1901–30, while there was a small decrease of pressure over the country; in the winter and spring the gradient was less but the pressure was greater.

Rainfall.—Serial values of monthly and annual rainfall over England and Wales, and over Scotland, were published in *British Rainfall*[6], and these series have been continued in the annual volumes. Using these values a comparison is given in Table VIII of the averages for the two periods 1881–1915 and 1916–50.

TABLE VIII—AVERAGES OF RAINFALL

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
							inches						
							ENGLAND AND WALES						
1916–50	3·83	2·74	2·31	2·38	2·49	2·18	3·10	3·26	3·04	3·70	3·90	3·63	36·56
1881–1915	2·99	2·57	2·67	2·12	2·30	2·44	2·87	3·35	2·54	3·97	3·49	3·92	35·23
							SCOTLAND						
1916–50	5·90	4·00	3·27	3·21	3·14	3·12	4·11	4·41	4·86	5·77	5·32	5·32	52·43
1881–1915	4·90	4·18	4·05	2·99	3·01	2·83	3·78	4·51	4·00	4·90	5·29	5·88	50·32

Table VIII suggests that the mean rainfall was greater during 1916–50 than 1881–1915 by 1·33 in./yr. over England and Wales, and by 2·11 in./yr. over Scotland. This means that the 35 yr. 1916–50 gave as much rain as occurred in 1881–1915 plus that of more than an extra year of the 1881–1915 standard over England and Wales and also over Scotland. The greater rainfall during 1916–50, over that for 1881–1915, was contributed mainly by January, September and November over England and Wales, and by January, September and October over Scotland. There was rather less during 1916–50 in a number of months—March, June, August, October and December over England and Wales and February, March, August and December over Scotland.

The seasonal differences are set out in Table IX. The increase in the rainfall 1916–50 compared with 1881–1915 is mainly attributable therefore to the increase in the autumn and winter.

TABLE IX—SEASONAL DIFFERENCES OF RAINFALL, 1916–50 MINUS 1881–1915

	Spring Mar.–May	Summer June–Aug.	Autumn Sept.–Nov.	Winter Dec.–Feb.
			inches	
England and Wales ...	+0·09	−0·12	+0·64	+0·72
Scotland	−0·43	+0·52	+1·76	+0·26

Parts of the country experienced less rain in 1916–50 than in 1881–1915, i.e. parts of the east of Great Britain, the Midlands and the extreme south-west of England—from the Moray Firth to Aberdeen, around Berwickshire, from Flamborough Head to Great Yarmouth and around Huntingdon and Cambridge, from Hereford to Oxford and over much of Cornwall. Over by far the greater part of the country 1916–50 was wetter, and the excess was more than 5 per cent. over a broad strip along the west coast from Stornoway to Swansea, as well as along the south coast from Torquay to Dungeness. The excess reached 10 per cent. in parts of south Wales, north Wales and in the Oban to Glasgow area.

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SEVERE TURBULENCE AT HIGH LEVELS OVER NEW SOUTH WALES

By U. RADOK

On August 22, 1951, a Canberra jet aircraft flying from Laverton (near Melbourne) to Sydney at a constant pressure altitude of 30,000 ft. (300 mb.) encountered a 30-mile stretch of severe turbulence in clear air over Tumut, New South Wales. Details of the incident were given by the pilot, Wg-Cmdr D. R. Cuming, at the end of a letter reproduced in the *Meteorological Magazine*[1]. Immediately before entering the turbulence it was noticed that the airspeed

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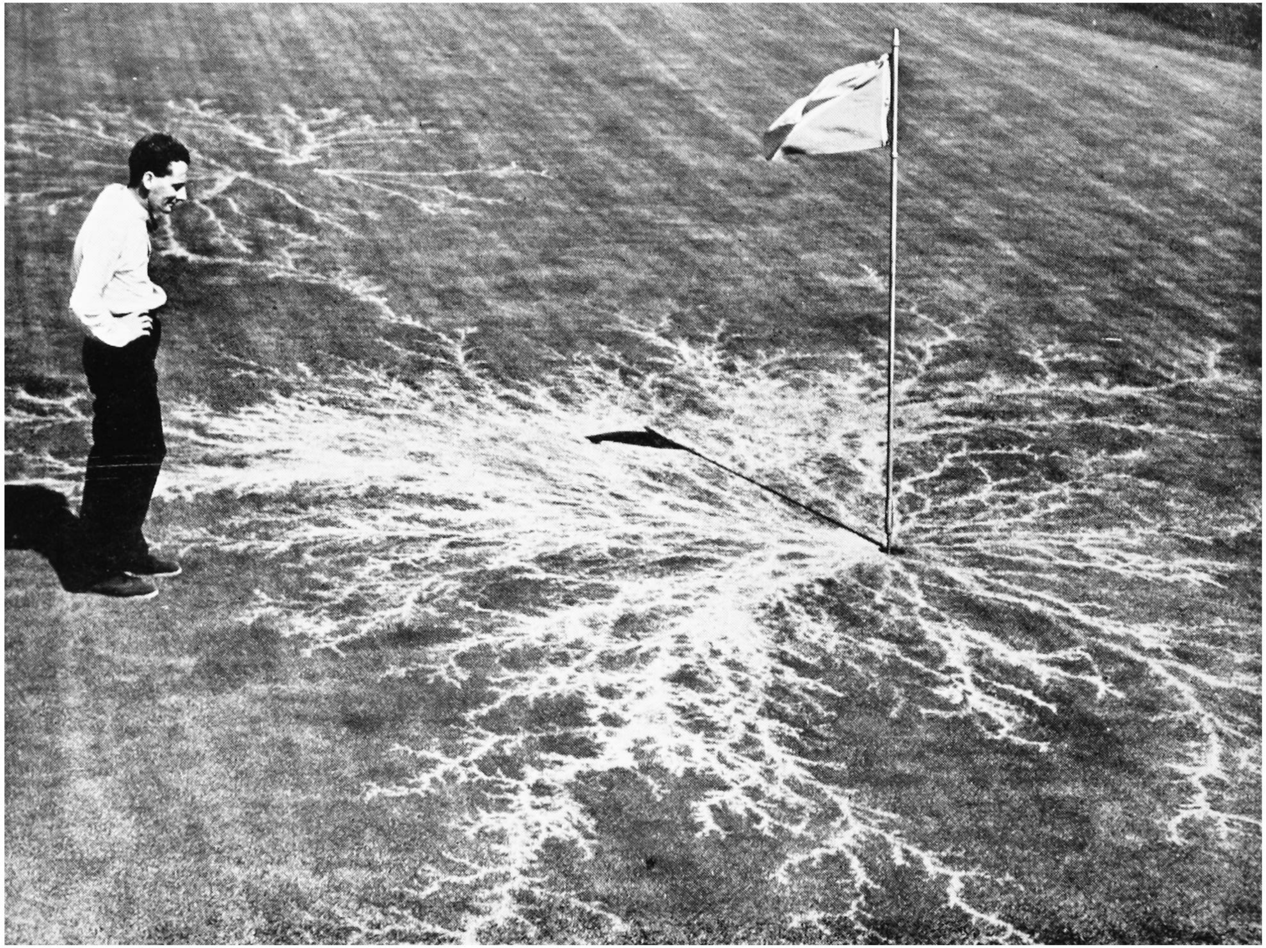
ALTOCUMULUS FROM 27,000 FT. AT 1502, SEPTEMBER 11, 1944
This sheep's back pattern of clouds was observed just north of Münster.

LENTICULAR ALTOCUMULUS CLOUDS SEEN AT

Reproduced by courtesy of Flt-Lt Webb

BALLYKELLY, NORTHERN IRELAND, NOVEMBER 29, 1953

To face p. 49]



(c) *N.G.S. Courtesy National Geographic Magazine*

MARKS LEFT BY LIGHTNING FLASH, CHEVY CHASE CLUB, NEAR WASHINGTON D.C.

dropped while maintaining a constant pressure altitude. This apparent loss of power, which ended with the turbulence, was too pronounced to have arisen from a rise in air temperature, and Wg-Cmdr Cuming therefore attributed it to a tailwind component increasing gradually in a field of horizontal wind shear.

Figs. 1, 2 and 3 provide the meteorological background for the incident. At that time the Australian upper air network was too sparse to reveal, as a rule, finer details.* However, on this occasion the pressure distribution happened to be symmetrical with respect to the eastern Australian radio-sonde stations (see Fig. 1). Thus all upper air observations in the region despite their differences in longitude could legitimately be combined in a single meridional cross-section along 145°E. The temperature curves in Fig. 2 show this very clearly; they suggest, incidentally, that the middle-latitude tropopause continued as an inversion to at least the latitude of Charleville or even Garbutt (where it appeared at the 550-mb. level).

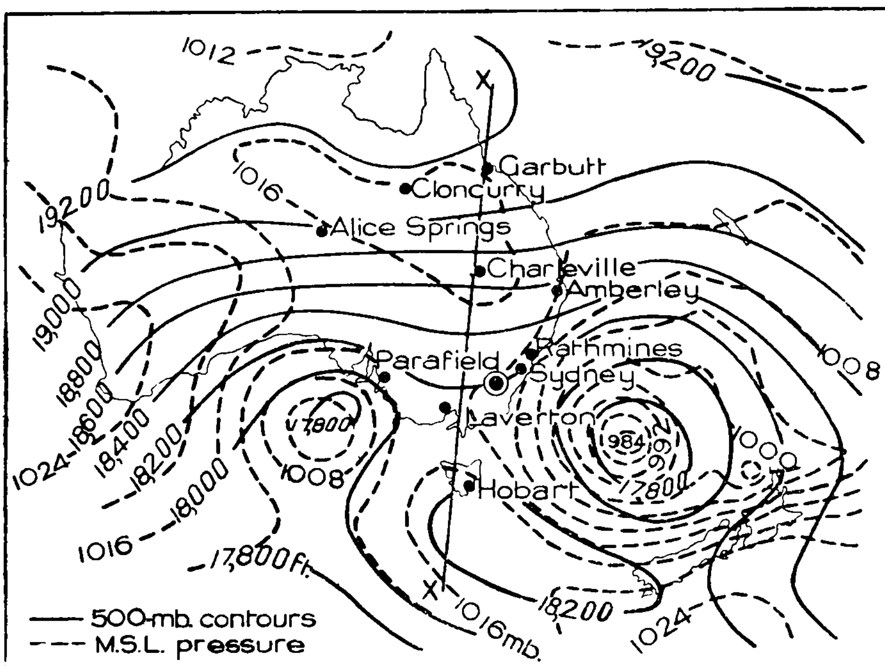


FIG. 1—SYNOPTIC CHART, AUGUST 22, 1951
◉ turbulence

The speed isopleths in the cross-section (Fig. 3) were constructed from the winds at 500 mb. and the isentropic slopes, using the method suggested for zonal sections by Matthewman[2] and modified for meridional ones by Radok and Grant[3]. A check on the geostrophic speeds is provided by the radar-wind observations from Sydney, also shown in the cross-section. The discrepancy of 30 m.p.h. in the maximum speeds seems reasonable, considering the anticyclonic curvature in the longitude of the section and the steeper gradients in the longitude of Sydney. The region of interest, marked by a dot in a circle, thus appears to have been located on the low-pressure side of the entrance to the eastern branch of the jet stream.

* Since then the number of high-level wind observations has been greatly increased, and the routine analysis now extends to the 100-mb. level.

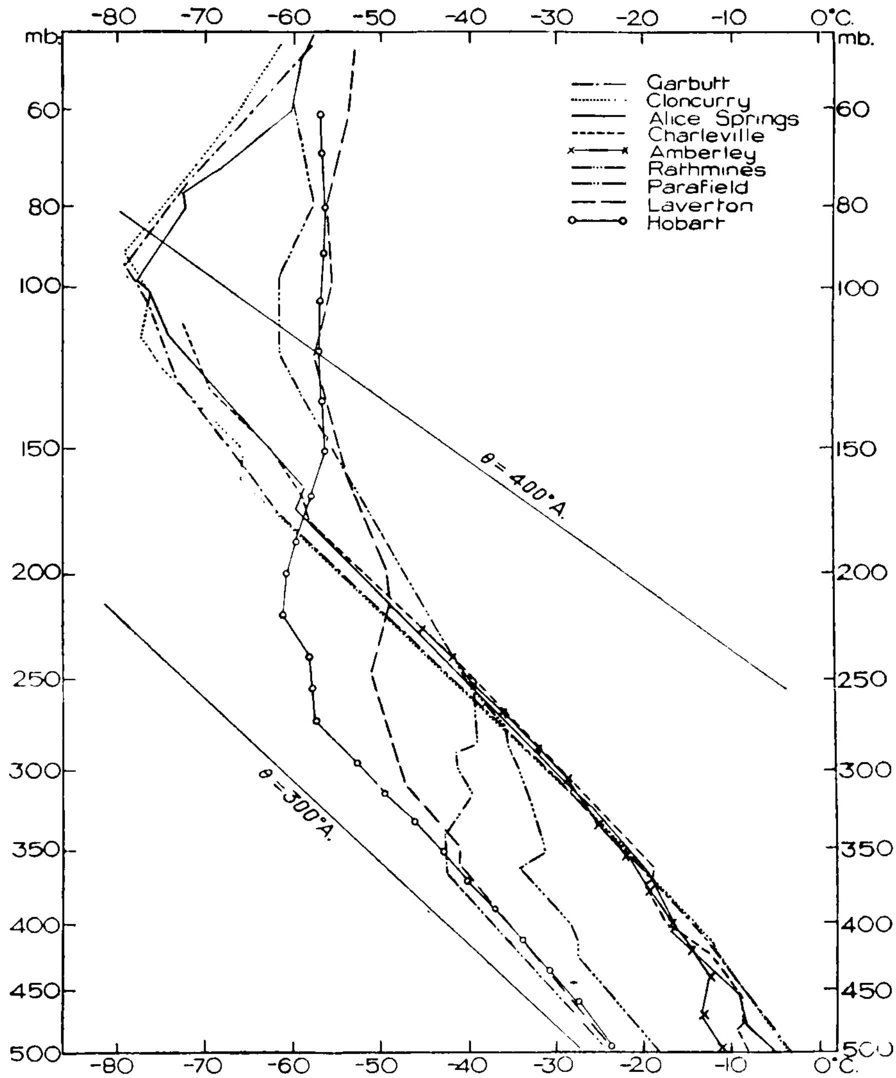


FIG. 2—UPPER AIR SOUNDINGS, AUGUST 22, 1951

Now the low-pressure side of jet streams is well known to be especially prone to turbulence (Bannon[4]), and this fact might be taken as a satisfactory explanation of the incident in question. However, it is hard to evade some curiosity as to why the turbulence was especially severe on this occasion, and moreover restricted entirely to such a narrow area.

It is more than likely that the answer to these questions has been lost irretrievably in the smoothing required for the construction of the cross-section; on the other hand there exists the possibility that the clue to the problem might be found in the surface topography. The map, Fig. 4, shows that at the time the aircraft was flying past the south-west corner of a gap in the Australian Alps, not far from where the ground descends by more than 4,000 ft. to below the 1,000-ft. level. With the stable stratification of the surface layers and the large vertical wind shear suggested by the cross-section the flow further south must have been deformed by the mountains up to considerable heights. The occurrence of severe turbulence in the region of transition to the less affected flow through the mountain gap then becomes intelligible.

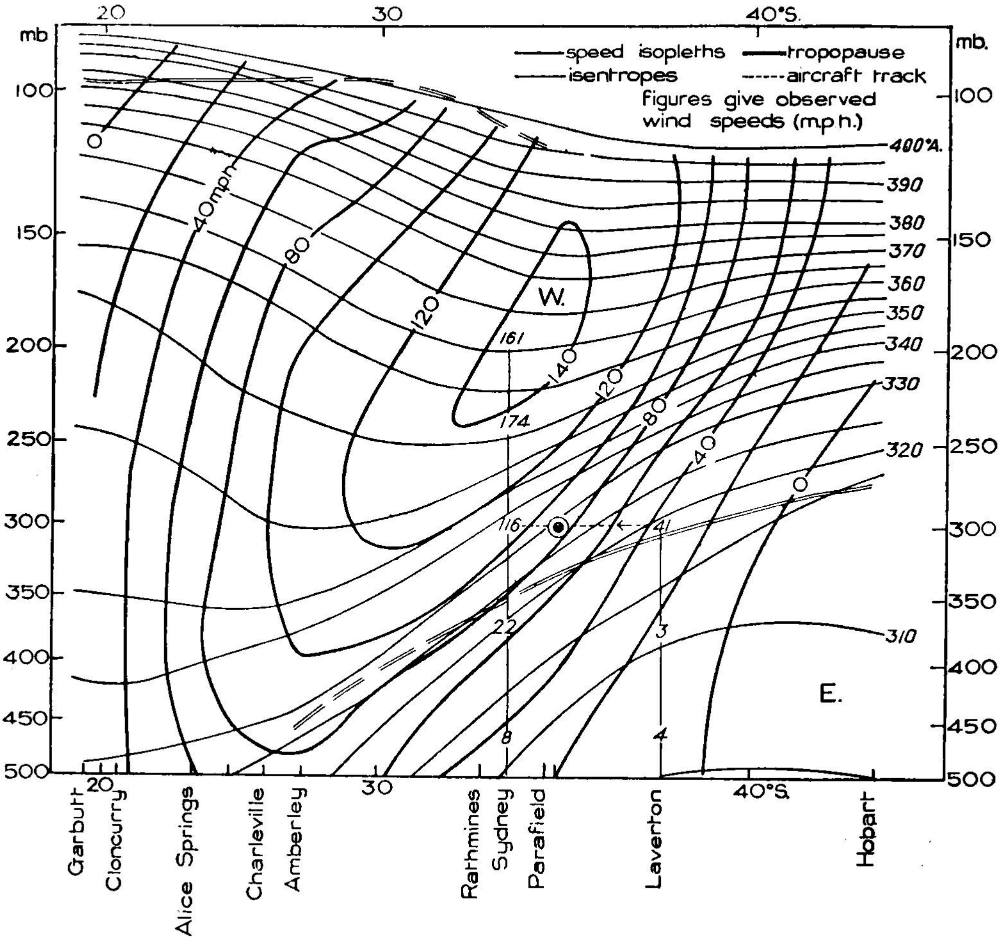


FIG. 3—VERTICAL CROSS-SECTION ALONG LINE XX OF FIG. I

◉ turbulence

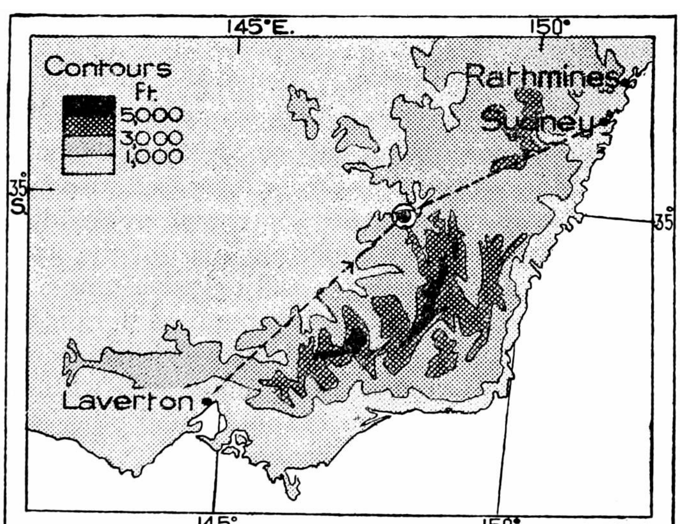


FIG. 4—SOUTH-EAST AUSTRALIA

- - - - - aircraft track

◉ turbulence

The same transition would also account for the tailwind component suspected as cause of the apparent loss of power in the turbulent region. This is otherwise hard to understand since recent work on the flow near jet-stream entrances[5] has confirmed its transversal component directed towards the low-pressure side of the jet, which had already been expected on theoretical grounds.[6]

Acknowledgements.—The writer is indebted to Wg-Cmdr D. R. Cuming for information concerning the incident and suggestions for its interpretation, and to the Director, Meteorological Branch, for the radio-sonde data.

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METEOROLOGICAL OFFICE DISCUSSION

Lake evaporation

The discussion was held on Monday, November 16, 1953 at the Royal Society of Arts.

In his introductory remarks, the Director said that he was pleased to attend his first Discussion since assuming the Directorship, although he had in the past attended many of these Discussions. It was to the benefit of all in a service which is spread far and wide that we should gather together to discuss recent research, for scientists do not readily twinkle in isolation and gleam most strongly in the irradiation of their fellow scientists.

Mr. E. Knighting opened the discussion with a summary of the following report:—

Washington, Department of Interior. Water-loss investigations: Vol. I—Lake Hefner studies technical report. *Circ. U.S. geol. Surv., Washington,* 1952.

At Lake Hefner the water budget can be satisfactorily balanced, because the measurement of inflow and outflow can be measured with fair accuracy; the evaporation can thus be determined with a precision not readily obtainable at most reservoirs. Evaporation is an important item in the water budget and not the small difference of large positive and negative terms, so that it could be used as a control to sieve out the evaporation formulae (based upon turbulence theory and the heat energy budget) which can be used with confidence elsewhere. Using the formulae which agree well with the evaporation as determined by the water budget, the evaporation at other stored-water sites can be computed from meteorological measurements.

Lake Hefner is an almost circular lake lying in flat country about 1,200 ft. above sea level and is about 4 square miles in surface area. Four meteorological stations were set up, three on the periphery of the lake and the fourth on a barge at the centre of the lake. Observations of wind speed, temperature and humidity were made at all four stations at heights of 2, 4, 8 and 16 m. above water-surface level; in addition, at the barge, the incoming solar radiation was measured by an Eppley pyrheliometer, the total incoming radiation by a Gier and Dunkle flat-plate radiometer and the reflected solar radiation by two Eppley pyrheliometers pointing downwards towards the lake. Observations of water-surface temperature were also made and measurements of the water temperature with depth at various parts of the lake; rain-gauges were set up around the periphery of the lake and at the barge station.

Many evaporation formulae based upon the theory of turbulent flow were tested, using the meteorological observations to determine the parameters in these equations. Of these formulae only those of Sverdrup (1937) and Sutton (1949) were found to agree well with experiment; these two predicted the daily evaporation within about 10 per cent. of the mean, whereas the other equations over-estimated the evaporation by a factor of 2 or more. It was also found that variations in lapse rate had little effect upon the daily evaporation and that the flow was always "rough".

An empirical equation was constructed to give the evaporation using the wind speed and vapour pressure at a nearby airport some 13 miles to the south, and the saturated vapour pressure at the lake-surface temperature; the accuracy of this formula was less than that of the two theoretical formulae, but a formula of this type is most valuable because the only non-routine measurement needed is the lake-surface temperature.

The heat-balance method consists of measuring the heat going into or out of the lake with the exception of that used for evaporation and that flowing from the water surface to the air. It had been intended to determine the atmospheric radiation by subtracting the solar radiation as measured by the pyrheliometer from the total incoming radiation as measured by the flat-plate radiometer, but this difference, which should have been sensibly constant, showed a great variation in the day-time, and so the night values obtained from the radiometer were taken as applying to the day-time also. The instruments must be regarded as suspect. The ratio of the heat flowing from water to air to that used in evaporation, known as Bowen's ratio, showed very marked daily fluctuations, but when averaged over a period of days its behaviour became more coherent, suggesting that the evaporation as determined by the energy budget would be more accurate over a period of days than over a single day. The daily evaporation calculated by the energy budget showed a very wide scatter when compared with the evaporation calculated by the water budget; the standard error of estimate decreased as the period for which the evaporation was calculated was increased, and the accuracy obtained by the energy budget for a period of one week was about the same as that obtained by using Sutton's equation for a period of one day.

So far the actual observations recorded at Lake Hefner have not been published, and the report is not specific as to the methods of calculation used in determining the evaporation from the various equations. The barge records are the most important and the most difficult to observe, and possibly more than one barge is desirable. The energy-budget method used at Lake Hefner could not be used elsewhere since it requires just the same water measurements as does the water-budget method, and in addition other complex instrumentation. While some of the radiative items in the budget may be estimated from synoptic observations, such estimations must seriously vitiate the accuracy of the computed evaporation.

Dr. Penman said that the report must be treated with reserve until the actual data were published. There were several inconsistencies, instanced by two tables of monthly evaporation which did not agree, which must be reconciled before an opinion could be offered. The water-budget results cannot be checked at this stage and will have to be accepted. The evaporation equation given by Sverdrup in 1946 is much more acceptable physically than that given in 1937, yet it over-estimated the evaporation by a factor of 2. Previously the Thornthwaite-Holzman formula had been known to give better results than the Sverdrup 1937 formula using the same wind profile. Since nearly all these formulae depended upon the measurement of vapour pressure at two heights, the choice of these heights may be quite important. The technique for measuring water-surface temperature is not adequate since the surface is probably cooler than at ¼ in. below the surface; measurements at Rothamsted had shown differences of 0·7° to 1·0°C. Attention should be drawn to the incorrect curvature of the plot of evaporation against vapour-pressure difference for Sutton's equation as given in the report. With regard to the energy-budget measurements, the solar-radiation measurements seem to be rather high, and an error must be introduced by the swaying of the barge which prevented the pyrheliometer from pointing vertically. Using his own formula, he found values of evaporation which were 10 per cent. too high.

Mr. Ryder pointed out that though the measurements were not sufficiently accurate to test the Thornthwaite-Holzman formula, the figure given in the report did show that there was a fairly clear-cut division between evaporation under stable and unstable conditions, evaporation being over-estimated under stable conditions.

Dr. Sutton said that we must be grateful to the Americans for undertaking a programme of experiments which was beyond the scale available in this country; the actual observations would be very valuable indeed. The report had, however, failed to distinguish between evaporation from a semi-infinite area and an infinite area, and these were two very different things. His formula applies to a semi-infinite area in which there is a distinct leading edge to the area from which evaporation takes place; although it has been applied to a circular area it is not strictly applicable because there must be diffusion sideways as well as in the direction of the mean wind. The results were rather surprising and it would be best to await the publication of the experimental values.

Mr. Bleasdale said that he had carried out a test of Dr. Penman's method of computation of evaporation for the average monthly values as given in diagrammatic form in the report. It was surprising to find that there was little correlation with the evaporation as determined by the water budget, but very good agreement with that determined by the evaporation pans at Lake Hefner. He suggested that the water budget might have been in error owing to the rainfall or the flow in and out being in error. The test of the formulae derived from turbulence theory was confined to days upon which these errors were small, but the errors upon the other days might have been quite large.

Mr. Gold asked if any idea of the variation of the various meteorological elements across the lake could be given. The wind had been measured at four heights, but only the measurements at two heights seemed to have been used. What use was made of the other measurements? He asked also if any comparison had been made with Jeffreys's formula for evaporation from a limited area.

Dr. Glasspoole said that in the report there was no statement as to the forecast value of the annual evaporation over the Lake Hefner area, although he was quite sure that before the work of constructing the dam was authorized some estimate would have been made, based on past experience. Estimates of evaporation were made for every reservoir constructed in England. It would have been of value to know how far the original estimates of annual evaporation were confirmed. The other losses from such areas, due to geological factors, are often even more difficult to forecast, and yet clearly some guess must have been made before it was judged worth-while to build this reservoir. From the report these losses were expected to be negligible, and this was confirmed by the work carried out for this report. This is an important point because what is needed, from a practical aspect, is a more precise estimate of the annual evaporation than is available at present, and in such a form as to be applicable to other areas with precision. Even 1 in. of water over the total area of reservoirs in this country represents a great deal of water—the run-off of the Thames above Teddington is less than 10 in. a year. The final recommendations of the Lake Hefner report were for further study of evaporation from water surfaces. If a similar study could be carried out in this country, then the comparison, with the different climatological conditions here, would cover a range of evaporation from about 50 in. a year at Lake Hefner to 20 in. a year in the south of England. The recommendations also include the collection of water-temperature data in lakes and reservoirs and of wind data at the sites of existing and proposed reservoirs. It should be realized that in this country very little information is apparently available under these two headings. This report seems to be only a first step in solving our hydrological problems, since it deals only with evaporation from a water surface. Most reservoirs have a much larger collecting land area, and there is the further problem of the amount of water stored in the ground, with a variation over a period of years of the same order as the annual evaporation. In addition we want to know how the evaporation varies with different types of ground cover, how it varies over the country, how it varies from wet to dry years, and how the ground storage varies from year to year and during the year. This seems a most valuable report, comparing theory with practical problems of water supply, and he (Dr. Glasspoole) hoped that similar practical investigations might be carried out in this country.

Dr. Robinson remarked that the Gier and Dunkle flat-plate radiometer which was installed at Kew gave an answer within about 5 per cent. when used very carefully. The same is true of most pyrheliometers and such errors were reflected in much larger percentage errors in evaporation. While it was true that very accurate measurements of wind, temperature and radiation terms had been made, they were over periods of 20 min. or so, and no-one had yet tried to achieve such accuracy over a continuous period of a year.

Mr. Knighting answered various points which arose in the course of the discussion, and Dr. Sutton closed by remarking that this report was difficult reading for the non-specialist, which accounted for the relatively few speakers.

Dr. Pasquill in a review of the Lake Hefner Report, written for the *Meteorological Magazine* before the decision to hold this discussion was taken, draws attention to the following points which were not brought out in the course of the discussion:—

(i) The absence of any experimental indication of a transition between "smooth" and "rough" flow at some particular speed. At Lake Hefner the flow is apparently always aerodynamically rough with the roughness parameter varying systematically from 0·58 to 1·15 cm. for wind speeds varying from 1 to 15 m./sec. at a height of 8 m. There has previously been some conflicting evidence about such a transition over the sea.

(ii) Confusion has been added to the complex issue of the influence of stability in the form of the wind profile between 2 and 8 m. On the one hand the results are claimed to show no appreciable stability influence on the form of the wind profile; on the other hand the results apparently lead to a wide range of Deacon's parameter β* with a systematic relation between β and stability consistent with observations over grassland. Publication of the wind-profile results in full will, no doubt, stimulate further critical discussion of their interpretation.

(iii) It is important to remember that the absolute rate of evaporation from a finite area is not necessarily a unique test of the theory. A more penetrating test is provided by the developing distribution of vapour above the evaporating surface, and in future work it would be a great pity not to take the opportunity of making a comprehensive investigation of this feature in company with the other elaborate measurements.

ROYAL METEOROLOGICAL SOCIETY

At the meeting of the Royal Meteorological Society held on December 16, 1953, the President, Dr. O. G. Sutton, in the Chair, a discussion was held in collaboration with the Royal Astronomical Society on the subject of stellar scintillation.

Dr. H. E. Butler and Dr. M. A. Ellison, both of the Royal Observatory, Edinburgh, described detailed observations of scintillation made visually and instrumentally with photo-electric cells. The image of the star varies in colour and total brightness, moves about in an irregular way, changes in area, and the pattern of illumination over the image is neither constant nor uniform. The instrumental observations showed that the periodicity of the fluctuations in brightness increased with altitude of the star but the amplitude decreased. There was little doubt that scintillation was produced by the passage of the light through the earth's atmosphere. On the general connexion of twinkling with weather it was well known to astronomers that the steadiest images were obtained on rather hazy nights and that very clear nights often gave poor "seeing". Experiments with rotating prisms and with parallel slits in the eyepiece of the telescope showed that on many occasions the scintillation consisted of a steadily travelling regular series of peaks of illumination as though it was produced by a regular pattern of small eddies travelling with the wind.

Dr. E. C. Megaw of the Royal Naval Scientific Service discussed the general physics of the fluctuations in the refractive index of the air which were presumably responsible for scintillation. Temperature fluctuations were the more important for light, but the same phenomenon occurred on radio wave-lengths and for them humidity fluctuations were more important. Pressure fluctuations associated with small changes in speed were unimportant.

Dr. J. van Isacker of the Royal Meteorological Institute of Belgium described his mathematical investigations into the relation between atmospheric turbulence and scintillation.

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*DEACON, E. L.; Vertical diffusion in the lowest layers of the atmosphere. *Quart. J. R. met. Soc., London*, 75, 1949, p. 89.

The discussion dealt very largely with the regularly moving patterns of disturbance often observed which appeared to indicate that the turbulence responsible for them was confined to a shallow layer of the atmosphere. Dr. Ellison and Dr. Butler mentioned that on occasion more than one set of steadily travelling patterns could be seen. Mr. Grant described the Meteorological Research Flight observations of temperature anomalies in the free air, which on the smallest observable scale amounted to about 0·5°F. in a distance of 50 ft. This distance, however, was too great for the eddies causing twinkling which, according to the astronomers, have dimensions of the order of inches.

LETTERS TO THE EDITOR

An unusually clear example of lenticular clouds

On Sunday evening, November 29, for about two hours before sunset, the sky over Northern Ireland was covered by 3–4 oktas of lenticular altocumulus. These clouds had marked irisation. To the delicate colouring of the cloud were added the effects of the setting sun which coloured the clouds from the underneath in shades ranging from purple and a fiery red to yellow. The whole colouring was against the pale blue.

Many people saw and commented on the cloud forms and colours, and the photographs in the centre of this Magazine were taken by Flt-Lt Webb, the Station Adjutant at Ballykelly.

F. M. BANCROFT

Ballykelly, December 1953

[Northern Ireland lay in a weak warm sector with a weak cold front lying, at 1800 G.M.T., from Stornoway to a point 100 miles west of Blacksod and thence south-westwards. This front moved eastwards reaching Aldergrove by midnight.

The 0200 G.M.T. Aldergrove temperature sounding showed subsided air above 700 mb., but by 1400 G.M.T. the air above 700 mb. was considerably moister, while the lower layers had dried out a little. The upper winds in the medium levels were 240–270°, about 40 kt.—J. ROSS.]

Optical phenomena observed at Seletar, Singapore on August 19, 1953

At 0700 local time on August 19, 1953 at Seletar, Singapore, S.A.C. Allen noticed that the sun, which had risen to an altitude of 8° azimuth 70° from magnetic north, had developed a pillar above and below it, that below being shorter in length than that above. Also a very small arc of the 22° halo was evident directly above the sun, and it appeared to spread out on its upper side to form the shape of a fan. The cloud at the time was high cirrus and cirrostratus which was tinged reddish brown by the sun.

About 1½ hr. later on the same morning, when the sun had risen to an altitude of 28°, azimuth 72°, more complicated phenomena began to form. By 0845 these had become most pronounced and complete, and after this time gradually disappeared as the cirrus and cirrostratus dispersed, and the sun's altitude increased.

The phenomena shown by Fig. 1 were visible at 0845 but gradually disappeared as the sun rose in the sky and as the cirrus and cirrostratus dispersed; by 0915 none was visible.

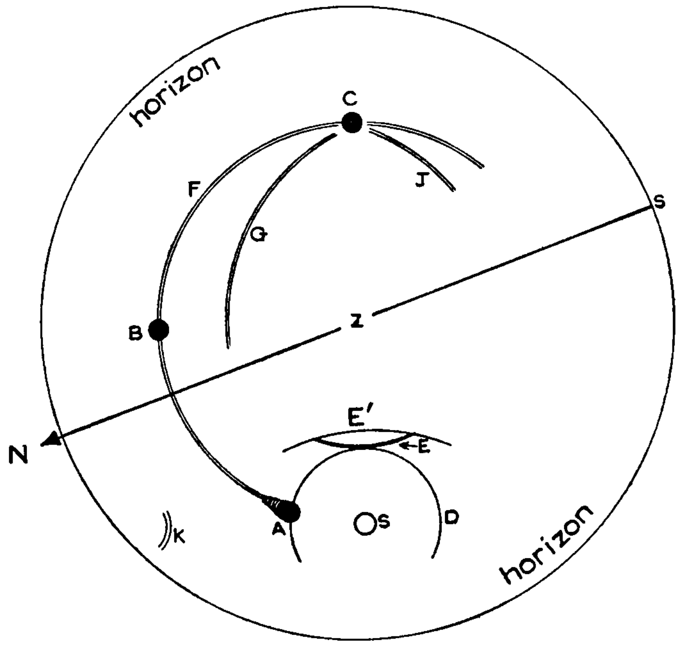

FIG. 1—OPTICAL PHENOMENA AT SELETAR, SINGAPORE, 0845 LOCAL TIME, AUGUST 19, 1953

D A faint and incomplete 22° halo.

E, E′ Arcs of upper contact, the lower one, E, being broader and shorter than the higher, E′. Both contained faintly the colours of the spectrum, red being nearest the sun in both. The lower arc appeared to coincide with the highest point of the 22° halo, and its outer ends to curve gradually into the higher arc. The angular distance, as observed from the ground, between the two arcs was 7°.

F The parhelic circle, which was very distinct and white, was only visible between 50° and 230° (through north) due to the absence of cloud in the other sector.

A A 22° mock sun, at the intersection of the 22° halo and the parhelic circle. It contained very faintly the spectrum colours, red being nearest the sun. The corresponding mock sun on the opposite side of the sun was not visible.

B A 90° mock sun on the parhelic circle, which was not visibly coloured.

C The anthelion or counter sun, which was extremely faint and was also on the parhelic circle, being diametrically opposite the sun.

G An oblique arc through the anthelion, on the western side of the zenith, and visible only as far as 350°.

J The corresponding oblique arc to G, though extremely faint and much shorter.

K A short arc, rainbow coloured, at an elevation of 5°, azimuth 32°. Red in this arc was again nearest the sun.

The cirrus and cirrostratus, of which there was estimated to be just over half coverage, was at a height estimated to be 28,000 ft. The surface wind was calm and the visibility 5–10 miles. All these latter phenomena were observed by S.A.C. Allen and myself.

J. M. BAYLISS

Singapore, September 18, 1953

[It is unusual for such a complex display to be seen in the tropics and some of the phenomena are individually rare. The Parry arc (E′), anthelic arcs (G and J) and the infralateral arc to the 46° halo (K) are rare. The observers have confirmed that the angle to the 90° mock sun (B) on the parhelic circle was measured in azimuth round the circle.—Ed., *M.M.*]

NOTES AND NEWS

High wet-bulb temperatures, Aden, June 1953

June is considered by the inhabitants of Aden to be the most unpleasant month of the year and meteorological records support this opinion. The weather in June 1953 was described by residents of Aden as the most uncomfortable they have experienced for at least 20 yr. It is interesting therefore to compare the records for June 1953 with observations for the same period in previous years.

Table I gives a comparison of the average June temperature and humidity for the 5-yr. period 1948–52 with those of June 1953.

TABLE I—TEMPERATURE AND HUMIDITY, ADEN

	Temperature						Relative humidity
	Mean daily				Extreme		
	Dry bulb	Wet bulb	Max.	Min.	Max.	Min.	Mean daily
	degrees Fahrenheit						%
June 1948–52	90·0	80·6	97·4	83·7	103	79	67
June 1953 ...	90·9	81·8	98·7	85·3	105	82	67

This table does not suggest that June 1953 was much more unpleasant than the average conditions over the past 5 yr. The mean daily wet-bulb temperature was, however, 1·2°F. above the average, which, although small, is quite significant.

The reason why June 1953 was so uncomfortable is that the wet-bulb temperature remained high for longer periods than usual and the relative humidity was also high. Table II shows this more clearly. This table gives the average number of hours in June 1948–52 and the number of hours in June 1953 when the wet-bulb temperature reached or exceeded stated values.

TABLE II—NUMBER OF HOURS WHEN THE WET-BULB TEMPERATURE REACHED OR EXCEEDED CERTAIN VALUES, ADEN

	Wet-bulb temperature						
	82°F.	83°F.	84°F.	85°F.	86°F.	87°F.	88°F.
	number of hours						
June 1948–52 ...	246	138	52	15	2	0·2	...
June 1953 ...	387	249	146	55	10	1	...

Daily maximum wet-bulb temperatures have been recorded at Aden since 1947. Table III shows the average number of days in June 1948–52 and also the number of days in June 1953 when the maximum wet-bulb temperature reached or exceeded stated values.

TABLE III—NUMBER OF DAYS WHEN THE MAXIMUM WET-BULB TEMPERATURE REACHED OR EXCEEDED CERTAIN VALUES, ADEN

	Wet-bulb temperature						
	82°F.	83°F.	84°F.	85°F.	86°F.	87°F.	88°F.
	number of days						
June 1948–52 ...	29	27	22	13	4	1	0·2
June 1953 ...	30	30	25	17	7	2	2

Table III does not show that the conditions were much worse in June 1953 than on the average, but even in a June when the mean daily wet-bulb temperature is below normal the maximum wet-bulb temperature may reach high values. It is common for the wet-bulb temperature, like the dry-bulb temperature, to vary by 2–3°F. in a matter of minutes. The extreme maximum dry-bulb temperature for June 1953 of 105°F. occurred on the 12th, but the highest temperature recorded at any reporting hour on that day was 102°F. The extreme maximum wet-bulb temperature of 88°F. also occurred on the 12th and the highest reading of the wet-bulb at any reporting hour on that day was 86·5°F.

All the temperatures quoted above were recorded in a Stevenson screen. There is, however, little difference between conditions indoors or outdoors at Aden during the hot season, as doors and windows are not as a rule shut during the day. Human comfort during the hot season depends almost entirely on the wet-bulb temperature and wind speed. Conditions are invariably most uncomfortable when the wet-bulb temperature reaches or exceeds 84°. It will be noted from Table II that the number of hours in June 1953 when the wet bulb reached or exceeded 84°F. was 146. It is also of interest to note that the mean relative humidity during these 146 hr. was as high as 73 per cent. which is 6 per cent. above the mean daily relative humidity for June 1953.

C. C. NEWMAN

REVIEWS

Deep-sea research. **1**, No. 1, 10 in. × 6¾ in., pp. 64, *Illus.*, Pergamon Press Ltd, London, 1953. Price: £4 10*s.*, p.a.

Deep-sea research has become much more widely studied since the second world war, particularly by meteorologists in view of the information on past climates which Professor Petterssen, Mr. Ovey and others have shown to be obtainable from the cores of the sediments of the deep oceans. The Brussels meeting of the International Union of Geodesy and Geophysics set up a new Commission specifically to cover deep-sea research with Dr. J. H. D. Wiseman of the British Museum (Natural History) as President and Mr. C. D. Ovey (Geography Department, Cambridge) as Secretary. The new Commission at its first meeting in September 1952 recommended the establishment of a journal.

Now with Professor L. Fage (Paris), Mr. C. D. Ovey and Dr. Mary Sears (Woods Hole, United States) as editors, the Pergamon Press, London have begun publication of a journal specifically devoted to deep-sea research. The first number shows the journal will deal with the structure, physics, and biology of the deep sea and the sea floor and their relations to other sciences.

The journal is to be published quarterly at a subscription price of £4 10s. 0d. a volume.

G. A. BULL

Der Blitz in der Bildenden Kunst. By A. Rieth. 10½ in. × 8 in., pp. 48+68, *Illus.*, Ernst Heimeran Verlag, München, 1953. Price: *DM.* 12.

As is well known to every historically minded student of thunderstorm and lightning phenomena the folklore inspired by the lightning discharge, the symbolism to which it has given rise, and the influence it has exerted on various religious cults have aroused—and continue to arouse—the interest of physicists and meteorologists whether these are professional men or amateurs. It is therefore not altogether surprising to learn that a traveller admiring a painting by del Sarto depicting the lightning miracle of St. Philip suddenly felt an impulse to collect "lightning pictures". The result of his search, which embraces not only various continental art collections but also many learned treatises on lightning, its symbolism and its manifestations, is a beautiful book, itself a work of art, which will not fail to receive an enthusiastic reception alike from meteorologists and art lovers.

The book is divided into a descriptive and an illustrative part comprising 67 art plates. Starting from ancient conceptions and representations, in various parts of the world, of a material thunderbolt which falls from heaven the author traces the pictorial symbolism representing the heavenly fire in the antique cultures of the Middle East, Greece, Rome, and later the Europe of the Middle Ages. He shows how these antique representations are revived in the Renaissance, and how it is left to the Italian masters of the early sixteenth century to introduce, possibly for the first time, a lightning stroke into a landscape, and to make full artistic use of the dark and light of an active thundercloud and its effect on human beings. Continuing this historical survey, the representation of the lightning stroke as a meteorological phenomenon and as a symbol is traced up to the present time with its surrealistic aberrations.

From the artist's world the author turns to modern science. He exemplifies the inherent beauty of lightning photographs and sketches their influence on present-day knowledge of the lightning discharge. Then, leaving the lightning discharge as such, an interesting chapter traces the historical development of beliefs in weather saints and the personal protection afforded by them, and this leads to an account of the history of the lightning conductor.

To the scientific mind the beauty of a lightning photograph may appear supreme. Yet, it is left to the artist to depict the feelings aroused in the human spectator by that awesome spectacle. To anyone interested in this wider aspect of one of the most spectacular meteorological phenomena this book cannot fail to give exquisite pleasure.

R. H. GOLDE

BOOK RECEIVED

A radio-sonde ascent through the Sierra Wave. By E. L. Corton, Jr. *Tech. Memor. U.S. Nav. Ordn. test Sta.* No. 225. 10¼ in. × 8 in., pp. v + 22. *Illus.*, London, 1953. Price: 10*s*. 6*d*.

HONOURS

The following awards were announced in the New Year Honours List, 1954:—

C.B.

Dr. J. M. Stagg, O.B.E., Principal Deputy Director, Meteorological Office.

M.B.E.

Mr. D. F. Bowering, Senior Experimental Officer, Meteorological Office.

METEOROLOGICAL OFFICE NEWS

Academic successes.—To the lists published in the October number should be added:—

General Certificate of Education (Advanced).—R. E. Workman: physics, applied mathematics.

Athletics.—Messrs. M. K. Garrod, I. P. McDonald, W. P. Bird, J. Lomax, D. Limbert and G. F. Burton were members of the Air Ministry team which ran second in the Civil Service Cross-Country Team Championship at Wimbledon on Saturday, December 5. Mr. I. P. McDonald came second and Mr. M. K. Garrod third in the Air Ministry Cross-Country Championship held at Hayes on Saturday, November 28, over a five-mile course. Only three seconds covered the first three men home. The Meteorological Office had six men in the first seven men home and gained first and second places in the team race. Mr. G. F. Burton was placed second in the sealed handicap.

Retirement.—Miss D. G. Chambers retired from the Meteorological Office on January 9, 1954 after 40 years' service. Miss Chambers joined the secretarial staff of the Office in October 1913. From 1921 to 1938 she was the Director's (Sir George Simpson's) personal assistant, and in that capacity did much work for the British National Committee for the International Polar Year 1932–33 and in connexion with the International Meteorological Organization. Miss Chambers was Secretary of the Meteorological Committee from 1935 to 1946.

Miss Chambers was presented by her colleagues with a cheque which she intends to use for items of furniture. In expressing her thanks she recounted interesting and amusing recollections of her early days in the Office when comparatively few women were employed in Government service. It is more than usually fitting that Miss Chambers's retirement should be noted in "Meteorological Office News". She has compiled the items under this heading in the *Meteorological Magazine* since they first appeared in March 1950.

CORRIGENDUM

OCTOBER 1953, PAGE 318, *General Certificate of Education (Advanced level) for* "pure mathematics . . . . F. B. Webster" *read* "pure mathematics, physics, R. C. Friend, P. J. S. Greenaway; pure mathematics, physics, geography, F. B. Webster".

WEATHER OF DECEMBER 1953

Mean pressure was above normal over the whole of Europe except the Iberian peninsula; it was below normal over most of North America, the north-west Atlantic and the region between the Azores and Portugal. A mean pressure of 1032 mb. was reached over south-east Europe, which was as much as 13 mb. above normal. The lowest mean pressure, 985 mb., occurred off the coast of south-east Greenland; this pressure was 13 mb. below normal.

Mean temperature was above normal over most of Europe as a result of the mean pressure distribution favourable to S. or SW. winds; mean temperature was, however, below normal in the countries bordering the eastern Mediterranean. The greatest excess of temperature above normal was 14°F. in the north of Scandinavia. Mean temperature was also above normal in most parts of North America, the excess being generally 5°F.

In the British Isles the weather was unusually mild; it was dry except over much of central and east Scotland and dull on the whole in England and Ireland, but sunnier than usual in Scotland. The mildness was the more remarkable since it followed a very mild November. Until the 18th the dominant type of weather was a mild southerly; owing to the influence of a continental anticyclone, over a large area in the south-east there was little rain but a good deal of drizzle and fog but little sunshine. From the 19th onwards a changeable, mainly westerly type of weather prevailed finally becoming north-west to north.

Southerly winds from low latitudes resulted in exceptionally high temperatures on the 2nd, lasting over the 4th in southern England and East Anglia; 63°F. was reached at St. James's Park, London and at Thetford, Norfolk on the 4th. The exceptional character of the maxima on these days is illustrated by readings at stations with long records; at Falmouth, 59°F. on the 2nd was the highest temperature in December since before 1871, while the same reading at Kew Observatory on the 4th equalled that of December 4, 1931, which was the highest since before 1871. A rainy cold front moved slowly south-east over Scotland on the 2nd becoming almost stationary over the Irish Sea and the Scottish Border on the 3rd when a depression moved north-east along it from south-west of Ireland to the North Sea giving heavy rain in the west and north of the British Isles (1·99 in. at Ardgour House and 1·89 in. at Inveraray Castle Gardens, both in Argyllshire, on the 2nd and 2·22 in. at Kilkeel, County Down and 1·79 in. at Hamilton Water Works, Lanarkshire on the 3rd). There was flooding in parts of Scotland and Ireland. The cold front crossed England on the 4th but in the south-east it only gave drizzle. An anticyclone moved eastward over south Scotland on the 5th and intensified when it reached Poland next day; frost occurred in parts of Ireland and Scotland and valley fog in south Scotland. A dull, mild south-easterly to easterly type of weather followed which lasted with minor variations until the 9th; rainfall was slight from the 5th to the 7th but heavier in the north-west on the 8th and 9th. Subsequently pressure was high on the Continent and low to the west and north-west of the British Isles and mild southerly conditions prevailed; fronts associated with Atlantic depressions caused frequent rain in the west and north but amounts were very small in the south-east. On the 14th a trough moved right across the country and some rain fell in all districts. A new anticyclone developed over the eastern districts of Great Britain on the 15th and was soon absorbed into the anticyclone on the Continent. On the 16th–17th there was keen frost over much of Scotland, particularly the north-east; there was fog in many districts between the 15th and 18th, notably in London and the Midlands on the 15th and 18th. The formation of a small depression over the North Sea early on the 19th, together with a new anticyclone off west Ireland, ended the long southerly spell. Early on the 21st a ridge of high pressure gave frost in south-east England, with renewed fog which recurred on the 23rd. Meanwhile troughs to Atlantic depressions brought rain to the west and north on the 20th and 21st and to most of the country on the 22nd and 23rd, though falls were still small in the south-east. Subsequently a changeable south-west to west type of weather set in finally becoming north-west to north, with somewhat colder weather; rain or showers occurred at times but there were also long sunny periods on some days. In London there was remarkably little sunshine up to the 23rd but five of the seven days 24th to 29th were sunny, and it was one of the sunniest Christmas periods of the century.

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 ...	64	22	+4·6	36	−4	77
Scotland	59	16	+2·9	95	−1	128
Northern Ireland ...	56	23	+3·6	92	−1	74

RAINFALL OF DECEMBER 1953

Great Britain and Northern Ireland

County	Station	In.	Per cent. of Av.	County	Station	In.	Per cent. of Av.
London	Camden Square ...	0·63	26	*Glam.*	Cardiff, Penylan ...	1·73	35
Kent	Dover	1·45	47	*Pemb.*	Tenby	1·39	28
„	Edenbridge, Falconhurst	0·77	23	*Radnor*	Tyrmynydd	2·21	27
Sussex	Compton, Compton Ho.	1·12	27	*Mont.*	Lake Vyrnwy	2·08	29
„	Worthing, Beach Ho. Pk.	0·88	29	*Mer.*	Blaenau Festiniog ...	5·15	41
Hants.	Ventnor Park	0·99	29	„	Aberdovey	1·64	34
„	Southampton (East Pk.)	0·80	22	*Carn.*	Llandudno	1·22	42
„	South Farnborough ...	0·66	23	*Angl.*	Llanerchymedd ...	2·45	56
Herts.	Royston, Therfield Rec.	0·54	23	*I. Man*	Douglas, Borough Cem.	2·65	54
Bucks.	Slough, Upton	0·55	22	*Wigtown*	Newton Stewart ...	4·80	89
Oxford	Oxford, Radcliffe ...	0·70	28	*Dumf.*	Dumfries, Crichton R.I.	2·65	62
N'hants.	Wellingboro' Swanspool	0·62	26	„	Eskdalemuir Obsy. ...	4·38	63
Essex	Shoeburyness	0·63	34	*Roxb.*	Crailing...	1·53	57
„	Dovercourt	0·80	37	*Peebles*	Stobo Castle	3·37	89
Suffolk	Lowestoft Sec. School...	0·88	38	*Berwick*	Marchmont House ...	2·45	87
„	Bury St. Ed., Westley H.	0·86	36	*E. Loth.*	North Berwick Res. ...	2·72	127
Norfolk	Sandringham Ho. Gdns.	1·17	46	*Midl'n.*	Edinburgh, Blackf'd. H.	3·26	139
Wilts.	Aldbourne	1·01	31	*Lanark*	Hamilton W. W., T'nhill	4·71	109
Dorset	Creech Grange... ...	1·03	23	*Ayr*	Colmonell, Knockdolian	4·31	77
„	Beaminster, East St. ...	0·89	19	„	Glen Afton, Ayr San. ...	5·46	85
Devon	Teignmouth, Den Gdns.	0·54	13	*Renfrew.*	Greenock, Prospect Hill	6·92	93
„	Ilfracombe	1·38	29	*Bute*	Rothesay, Ardencraig...	5·35	98
„	Okehampton	1·80	25	*Argyll*	Morven (Drimnin) ...	7·31	93
Cornwall	Bude, School House ...	1·32	30	„	Poltalloch	6·10	96
„	Penzance, Morrab Gdns.	1·11	20	„	Inveraray Castle ...	10·02	101
„	St. Austell	1·58	26	„	Islay, Eallabus... ...	5·59	94
„	Scilly, Tresco Abbey ...	1·87	40	„	Tiree	4·64	89
Somerset	Taunton	0·79	22	*Kinross*	Loch Leven Sluice ...	4·27	108
Glos.	Cirencester	0·98	29	*Fife*	Leuchars Airfield ...	2·80	113
Salop	Church Stretton ...	1·50	42	*Perth*	Loch Dhu	9·49	94
„	Shrewsbury, Monkmore	1·08	44	„	Crieff, Strathearn Hyd.	5·13	115
Worcs.	Malvern, Free Library...	1·37	49	„	Pitlochry, Fincastle ...	5·13	127
Warwick	Birmingham, Edgbaston	1·19	44	*Angus*	Montrose, Sunnyside ...	3·35	121
Leics.	Thornton Reservoir ...	0·97	36	*Aberd.*	Braemar	4·11	115
Lincs.	Boston, Skirbeck ...	0·83	39	„	Dyce, Craibstone ...	2·75	81
„	Skegness, Marine Gdns.	0·78	35	„	New Deer School House	2·66	78
Notts.	Mansfield, Carr Bank...	0·84	29	*Moray*	Gordon Castle	2·96	110
Derby	Buxton, Terrace Slopes	2·43	43	*Nairn*	Nairn, Achareidh ...	2·14	104
Ches.	Bidston Observatory ...	1·26	48	*Inverness*	Loch Ness, Garthbeg ...	5·25	114
„	Manchester, Ringway...	1·26	41	„	Glenquoich	10·39	71
Lancs.	Stonyhurst College ...	2·48	51	„	Fort William, Teviot ...	9·76	96
„	Squires Gate	1·56	50	„	Skye, Broadford ...	6·88	77
Yorks.	Wakefield, Clarence Pk.	1·14	47	„	Skye, Duntuilm ...	5·62	90
„	Hull, Pearson Park ...	1·10	46	*R. & C.*	Tain, Mayfield... ...	2·18	77
„	Felixkirk, Mt. St. John...	1·21	50	„	Inverbroom, Glackour...	5·11	70
„	York Museum	1·31	58	„	Achnashellach	8·18	86
„	Scarborough	1·06	45	*Suth.*	Lochinver, Bank Ho. ...	5·37	96
„	Middlesbrough... ...	0·86	44	*Caith.*	Wick Airfield	2·30	75
„	Baldersdale, Hury Res.	1·60	42	*Shetland*	Lerwick Observatory ...	5·03	105
Norl'd.	Newcastle, Leazes Pk....	0·79	34	*Ferm.*	Crom Castle	3·59	87
„	Bellingham, High Green	1·79	49	*Armagh*	Armagh Observatory ...	3·52	112
„	Lilburn Tower Gdns. ...	1·00	38	*Down*	Seaforde	3·34	81
Cumb.	Geltsdale	2·17	57	*Antrim*	Aldergrove Airfield ...	3·34	97
„	Keswick, High Hill ...	3·50	52	„	Ballymena, Harryville...	3·76	85
„	Ravenglass, The Grove	2·80	61	*L'derry*	Garvagh, Moneydig ...	3·85	96
Mon.	A'gavenny, Plâs Derwen	1·72	35	„	Londonderry, Creggan	3·69	84
Glam.	Ystalyfera, Wern House	1·94	23	*Tyrone*	Omagh, Edenfel ...	3·83	91

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