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NIGHT COOLING AT THE TWO-INCH SOIL LEVEL

By W. E. SAUNDERS, B.Sc.

Two recent papers have suggested methods for forecasting the clearance or otherwise of fog[1] and frost[2] following the arrival of a cloud sheet during a radiation night. Both methods make use of the 2 in. soil temperature, which may conveniently be measured with the 2 in. bent-stem earth thermometer. If only a very short-range forecast of the behaviour of the fog or frost is required, the only reading which is necessary in addition to the normal routine of an airfield outstation will be a reading of the 2 in. soil temperature at the time the cloud arrives. If, however, the time of arrival of the cloud is forecast in advance, at least approximately, it will be useful to have a technique for forecasting the night cooling curve at the 2 in. level, so that an earlier forecast may be made of the probable effects of the arrival of cloud on existing fog or frost.

In the present note use is made of hourly observations taken at Exeter of the 2 in. soil temperature. To show the general form of the cooling curves four periods have been selected, in which there were nearly clear skies and in which conditions changed little from night to night. The mean hourly 2 in. soil temperatures for five nights from each of these four periods have been plotted in Figure 1. The general features are that the amount of the diurnal variation of 2 in. soil temperature is about 19°F during hot summer weather, decreasing to about 11°F during ordinary winter conditions. During a very cold spell the 2 in. temperature varies from a little above to slightly below freezing. The gradual decrease in the amount of cooling at 2 in. as the initial temperature becomes lower simply reflects what occurs at screen level, where the amount of cooling becomes less for two reasons: the net radiative heat loss decreases with decreasing temperature, and the higher the initial temperature the less likelihood there is of cooling being reduced by the greater latent heat release for hoar frost than for dew. The further sudden decrease in the diurnal variation as the temperature falls near freezing is also to be expected on theoretical grounds—Stewart[3] has shown that the heat flow is about six times greater with freezing soil than in the non-freezing case. The curves are smooth, with flattened maxima and minima which are not noticeably displaced in time from those at screen level. At Exeter, where the soil is clay, there is no sign at the 2 in. soil level of the marked change in cooling rate during the evening, which is a strong feature at grass level. It is interesting to note that the change of rate was apparent at the 2 in. level in the temperature curves produced in an earlier paper[4] for a station in Texas, the difference presumably being due to a much lighter type of soil in Texas.

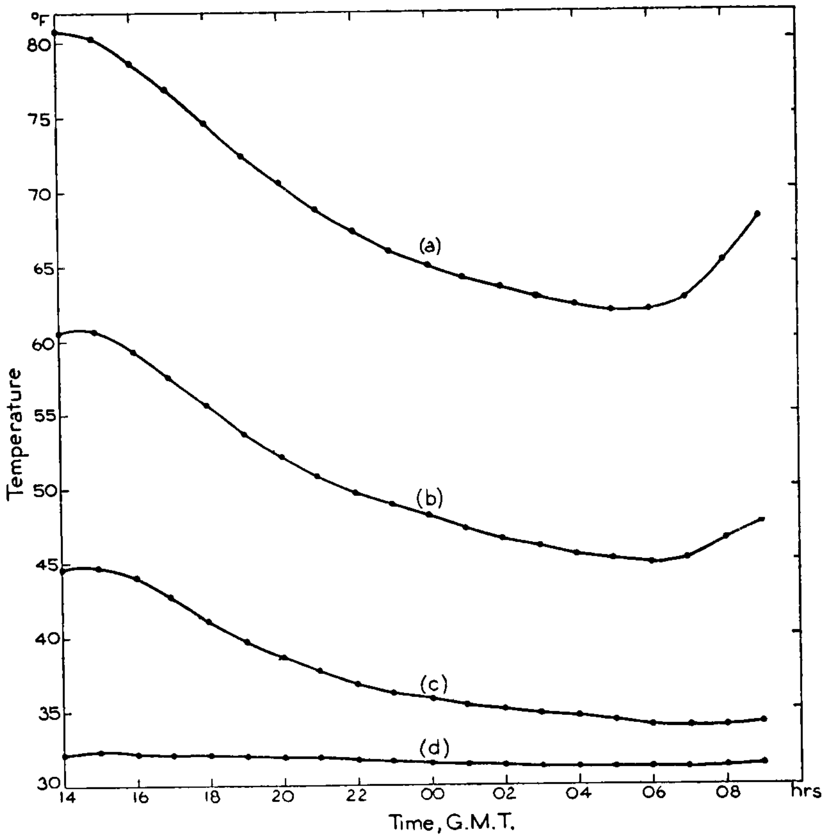

FIGURE I—NIGHT COOLING CURVES AT THE 2 IN. SOIL LEVEL UNDER CLEAR SKIES

(*a*) mean for 5, 6, 7, 10 and 12 July 1955
(*b*) mean for 10, 15, 22, 23 and 28 April 1954
(*c*) mean for 3, 14, 15, 17 and 19 March 1955
(*d*) mean for 31 January, 1, 2, 3 and 4 February 1954

Heat conduction theory suggests that the temperature at a depth of 2 in. at any given time can be determined as a function of the known temperatures above and below that level, provided adequate allowance is made for the nature of the soil and changes in the state of the soil. The nature of the soil is taken into account by basing the work initially on only one site. The most frequent change in the state of the soil in the United Kingdom is between dry and wet during the summer half-year, and between wet and frozen in the winter. There were not enough cases of snow cover at Exeter to deal separately with snow.

For the purpose of developing a forecasting technique for the minimum temperature ($T_{2\,min}$) at a depth of 2 in. (more strictly for the lowest hourly 2 in. temperature, but the difference is not important) the 2 in. minimum has been expressed in terms of the minimum air temperature (at screen level) and the 8 in. earth temperature. At Exeter routine observations of the 8 in. temperature were made twice daily, at 0900 and 2100 G.M.T., using a bent-stem thermometer. At this level the diurnal variation of temperature is very small compared with that at a depth of 2 in. and there are only very small changes from day to day in the 0900 G.M.T. 8 in. temperature. The 8 in. value (T_8) used in this work was therefore that read at 0900 G.M.T. on the morning preceding the night whose cooling was being considered. The screen minimum temperature (T_{min}) and the 8 in. soil temperature are not entirely unrelated variables, and in order to relate them to the lowest 2 in. temperature a method found useful in another connexion[4] was used: T_8 and T_{min} were replaced by two other expressions, $\frac{1}{2}(T_8+T_{min})$ and T_8-T_{min}, and the relation between these and $T_{2\,min}$ was examined.

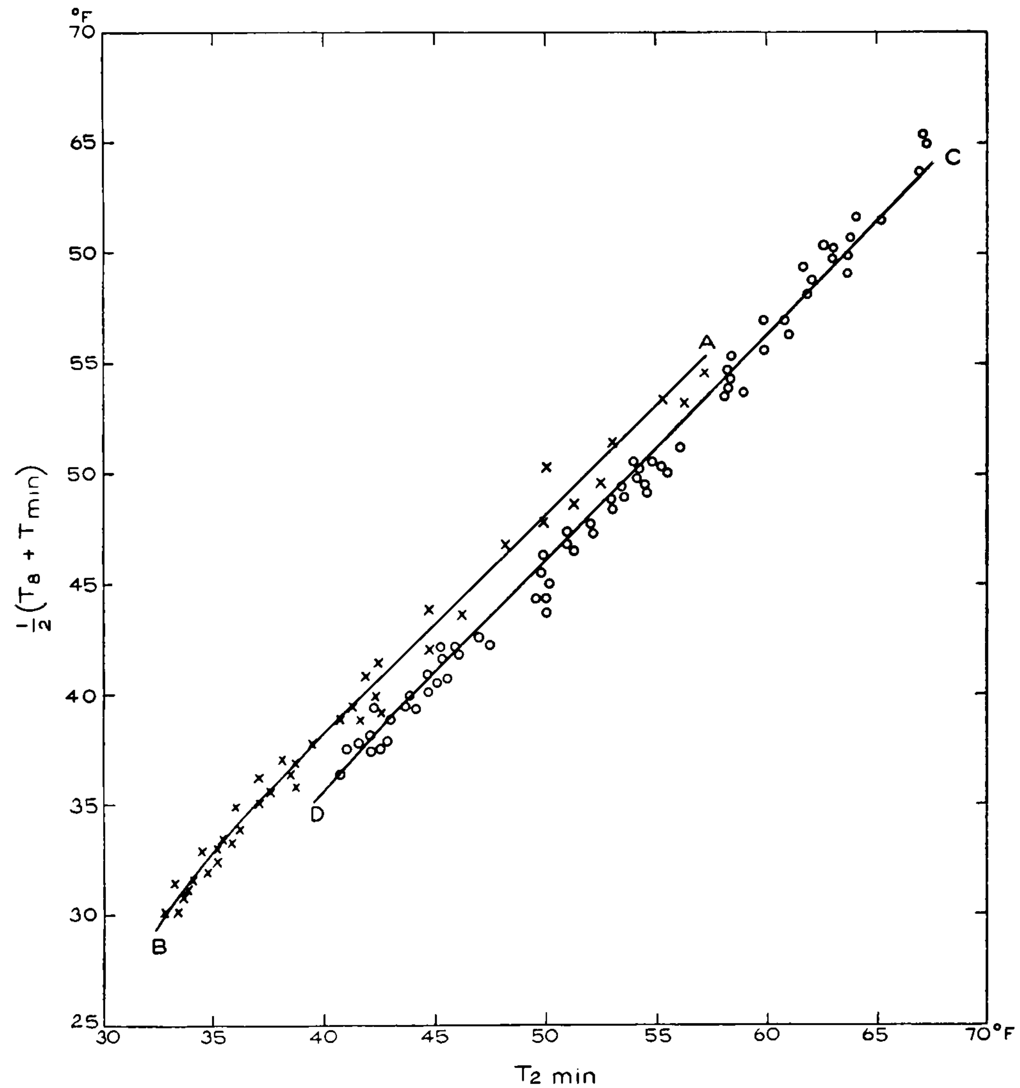

FIGURE 2—RELATIONSHIP BETWEEN SCREEN MINIMUM TEMPERATURE, 8 IN. SOIL TEMPERATURE, AND THE LOWEST 2 IN. SOIL TEMPERATURE, ON CLEAR NIGHTS

× denotes wet ground; o denotes dry ground
AB and CD are mean cases for "×" and "o" cases respectively.

The relation between $\frac{1}{2}(T_8+T_{min})$ and $T_{2\,min}$ is shown in Figure 2, the occasions being separated according as the ground was wet or dry. In effect this meant that all cases except for those with snow cover, during the winter half-year, were included as wet ground, while in summer use was made of the routine reports of the state of ground. It is seen from Figure 2 that this method of analysis leads to an almost complete separation between wet- and dry-ground cases. The relation between $\frac{1}{2}(T_8+T_{min})$ and $T_{2\ min}$ is seen to be practically linear except near freezing where, no doubt, latent heat release in the soil begins to reduce the amount of cooling at a depth of 2 in. The relationship between T_8-T_{min} and $T_{2\ min}$ was found to be very slight, and was not used.

Figure 2 was based on Exeter data for clear nights with light winds in the three years 1954–56. The relation expressed by AB and CD was tested against the data for all similar nights in 1957, 36 cases giving the forecast $T_{2\ min}$ with mean standard error 0·9°F, and in 1958, when 24 cases gave mean standard error 1·1°F. It follows that Figure 2 can be used for forecasting $T_{2\ min}$ with about the same order of accuracy as the screen temperature can be forecast. In using Figure 2 for forecasting purposes, T_{min} is of course the forecast screen minimum for the night.

Similar methods could be developed for forecasting the 2 in. soil temperatures at other times during the night, but it is thought to be adequate for the present purpose to insert on Figure 1 the actual 1400 or 1500 G.M.T. 2 in. temperature and the value of $T_{2\ min}$ forecast from Figure 2, and to sketch in the cooling curve for the night by reference to the existing curves on Figure 1. For this purpose a copy of Figure 1 may conveniently be mounted under perspex. The forecast 2 in. temperature for any required time may then be read off the curve.

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A METHOD OF FITTING ISOBARIC CONTOURS TO THE GRADIENT WIND

By C. J. BOYDEN, B.A.

Various methods exist for calculating the gradient wind from the pressure gradient and the curvature of the flow. These are somewhat complex for use in daily forecasting even when approximations are used in order to shorten the computation. There appears to be no method, however, which provides a quick solution to the reverse problem of spacing the contours or isobars so as to fit a flow of known velocity and curvature. On every chart, particularly where upper air observations are sparse, the analyst has to use observed winds as gradient winds in order to space contours in the vicinity; the cyclostrophic component is often too large to be ignored. It is a common practice to make a rough allowance for the curvature of the flow, which is usually known with fair accuracy from the general pattern, and to apply this as an adjustment to the spacing which would be appropriate to the observed wind if it were geostrophic. This note describes a method making a simple and quick estimate of this adjustment.

The notation used is as follows:

Δz = height difference between neighbouring contours

n_1 = distance between neighbouring contours to give a gradient wind v or a geostrophic wind u

n_2 = distance between neighbouring contours to give a geostrophic wind v

r = radius of curvature of the flow

f = Coriolis parameter

θ = angle through which a parcel of air would turn if it continued on its initial circular track for time t with velocity v

ϕ = latitude.

The equations for gradient and geostrophic flow are as follows:

$$g\frac{\Delta z}{n_1} = fv + \frac{v^2}{r} = fu$$

$$g\frac{\Delta z}{n_2} = fv$$

$$\therefore \frac{n_2}{n_1} = 1 + \frac{v}{fr} = \frac{u}{v} \qquad \ldots\ldots (1)$$

Consider a parcel of air moving with velocity v along a circular path of radius r, as shown in Figure 1. As it moves from A to B along an arc of length vt,

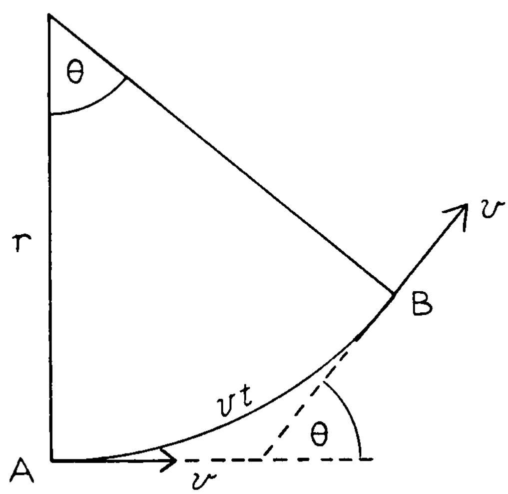


FIGURE 1—MOTION OF A PARTICLE ALONG A CURVED PATH

the direction of motion changes through an angle $\theta = vt/r$. Hence equation (1) can be written

$$\frac{n_2}{n_1} = 1 + \frac{\theta}{ft}.$$

If θ is measured in degrees and t in hours, this becomes, expressed as a percentage,

$$\frac{n_2}{n_1} = 100 + \frac{\theta}{0 \cdot 3t \sin\phi}. \qquad \ldots\ldots (2)$$

Thus n_2/n_1 can be evaluated solely from the latitude and the rate of turning of the moving parcel of air. In using formula (2) it is convenient to make the denominator of the right-hand fraction equal to unity so that θ becomes equal to the percentage increase of n_2 over n_1. Moreover, for practical purposes it is usually satisfactory to choose a value of t which is a whole number. Related values of ϕ and t are as follows:

φ in degrees	t in hours
72	$3\frac{1}{2}$
56	4
48	$4\frac{1}{2}$
42	5
37	$5\frac{1}{2}$
33	6

The method is applied as follows:

(i) Visualize on the chart the circular path along which the air is moving (the reported wind is assumed to be the gradient wind).

(ii) Note the position the air would reach after t hours at reported velocity v, t being determined by the latitude of the observation.

(iii) Note the number of degrees of wind direction change during this movement, a backing counting as positive and a veering as negative.

(iv) Add this number as a percentage adjustment to the reported wind and space the contours accordingly by using the geostrophic scale. (The adjustment gives n_2/n_1, which by equation (1) is equal to the ratio of the geostrophic to the gradient wind).

An example is illustrated in Figure 2. The wind reported by Ocean Weather Ship "K" (45°N, 16°W) is 250 degrees 50 knots, and if the present flow continued for nearly five hours ($t = 5$ corresponds to latitude 42 degrees) the air would follow a circular path to L, arriving there from 210 degrees. The percentage adjustment to be applied is 40 per cent ($= 250 - 210$). The geostrophic wind at "K" is therefore 70 knots, and contours A and C are spaced accordingly.

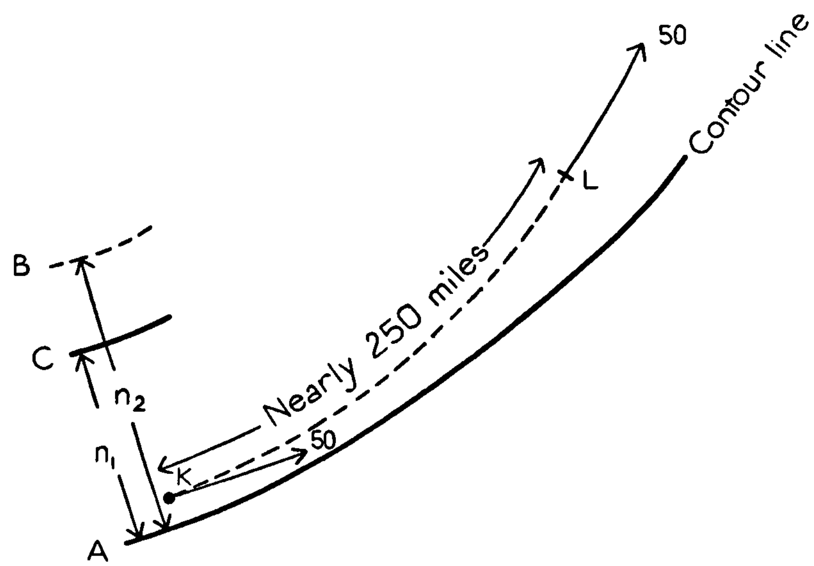


FIGURE 2—EXAMPLE SHOWING METHOD OF OBTAINING SPACING OF CONTOURS

It will be noted that r is the radius of curvature of the trajectory. On many occasions it is satisfactory to regard this as equal to the curvature of the contours, the movement of the contours being ignored. The percentage correction is obtained more precisely by taking the curvature of the flow to be that of the contours near the point of observation, and then using the observed wind speed minus the component of velocity of the local contour pattern measured in the direction of that wind.

UNEXPECTED RAINFALL AT WATNALL, 18 MAY 1958

By G. E. PARREY, B.Sc.

On 18 May 1958 a seemingly weak warm front lay in the zone indicated in Figure 1. The early morning charts showed very little rain and both Watnall and the Central Forecasting Office, Dunstable, forecast a mainly dry day with sunny periods for the areas of England and Wales expected to be affected by the front. This forecast was substantially correct except for parts of Nottinghamshire, Derbyshire, north Staffordshire and an area around Grantham (Lincolnshire). There were also substantial falls in north Wales but this note is concerned only with the rain which fell in the north Midlands.

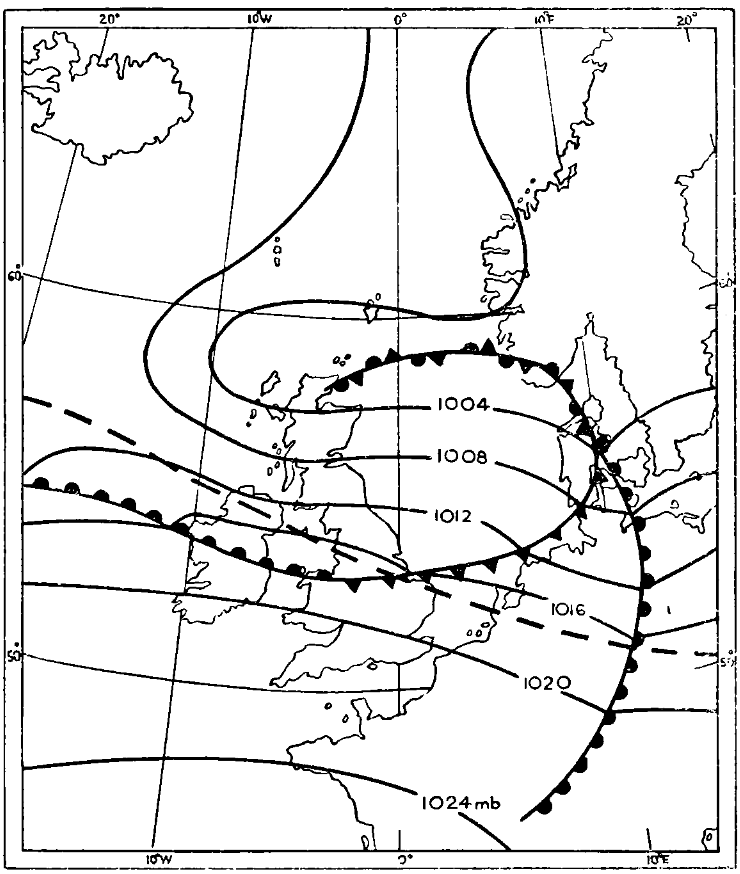


FIGURE 1—SURFACE CHART, 0600 G.M.T., 18 MAY 1958

The broken line indicates the frontal position at 1800 G.M.T., 18 May 1958.

At Watnall a total of 8·2 millimetres (0·32 in.) of rain fell between 0900 and 2100 G.M.T. on the 18th, chiefly in three $1\frac{1}{2}$-hour periods between 0900 and

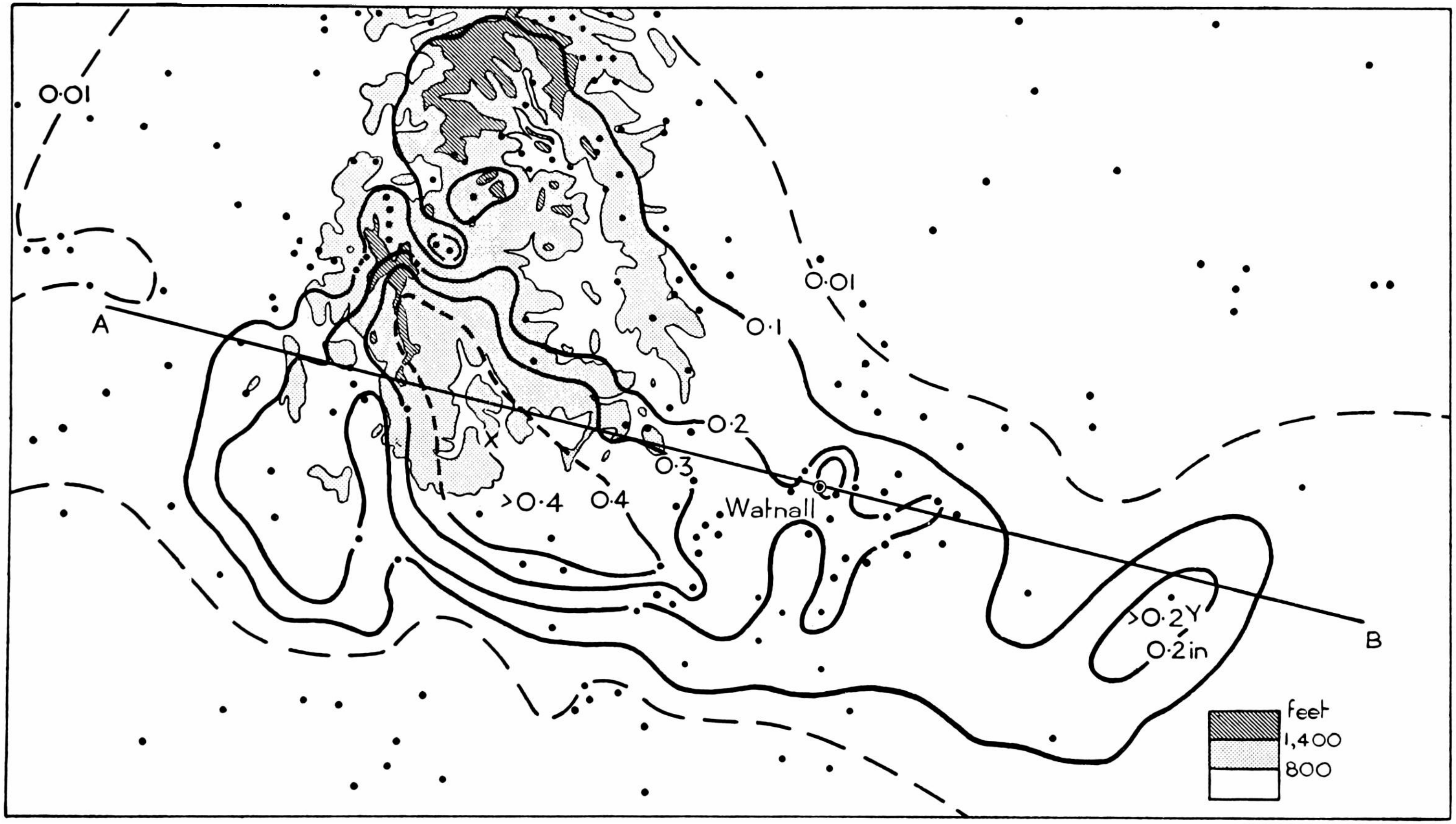


FIGURE 2—RAINFALL 0900 G.M.T., 18 MAY TO 0900 G.M.T., 19 MAY 1958
The dots represent stations whose rainfall reports were used to draw the isopleths.
Scale: 15 miles to 1 inch.

1030 G.M.T., 1300 and 1430 G.M.T. and between 1730 and 1900 G.M.T. During each period there was continuous moderate or heavy rain.

Figure 2 shows the distribution of rainfall during the period 0900 G.M.T., 18 May, to 0900 G.M.T., 19 May 1958, all of which can be ascribed to the warm front. It will be seen that there is a marked area of rainfall to the lee of the southern end of the Pennines. The windward slopes of the hills in fact show negligible amounts of rain. Figure 3 shows a cross-section of the terrain along the line AB of Figure 2 which runs approximately 285°–105° true through Watnall. The general wind flow during the day was from between 280° and 290° and it has been noted in the past that with such wind direction, the Watnall area has experienced more rain, in both frontal and showery situations, than would normally be expected.

FIGURE 3—CROSS-SECTION OF TERRAIN ALONG LINE AB OF FIGURE 2

Corby[1] has shown that under suitable conditions, ascending motion may occur in the lee of a mountain range and it was thought that the rainfall under discussion might be accounted for by a lee-wave effect such as Corby has described.

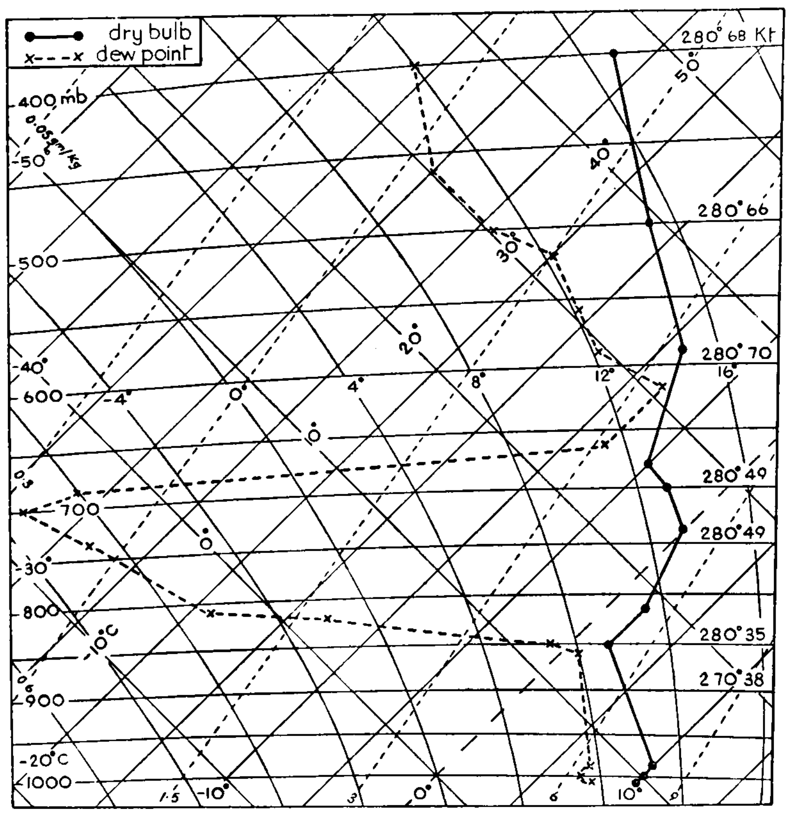


FIGURE 4—TEPHIGRAM AND UPPER WINDS FOR LIVERPOOL, 2300 G.M.T., 17 MAY 1958

As is well known Scorer's parameter should decrease with height for lee waves to be possible. Using the method described by Corby[1] the variation of l^2 with height was computed from the Liverpool upper air observations of 2300 G.M.T., 17 May, and 1100 G.M.T., 18 May. It will be seen from the values which are plotted in Figure 6 that l^2 did in fact decrease with height.

In addition to the rainfall maximum in the Watnall area, there are two other maxima: at X where over 0·40 in. of rain was recorded in the 24 hours

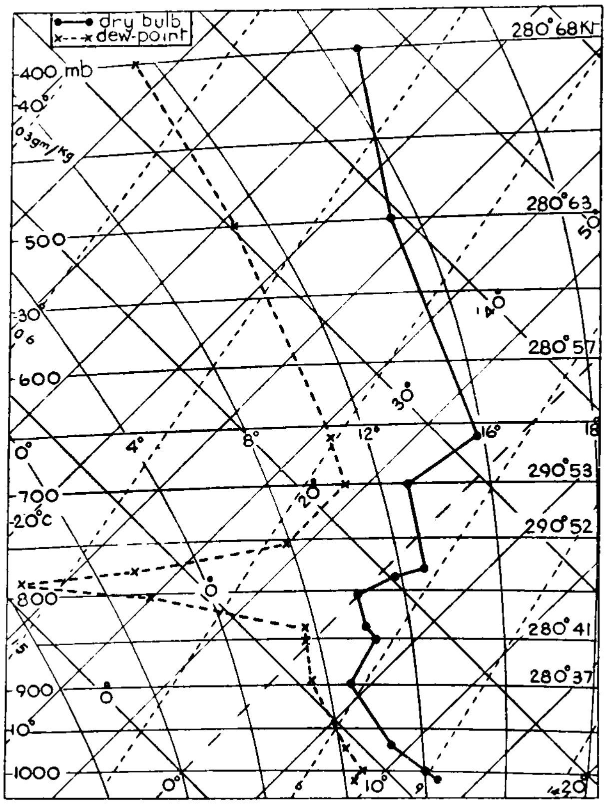
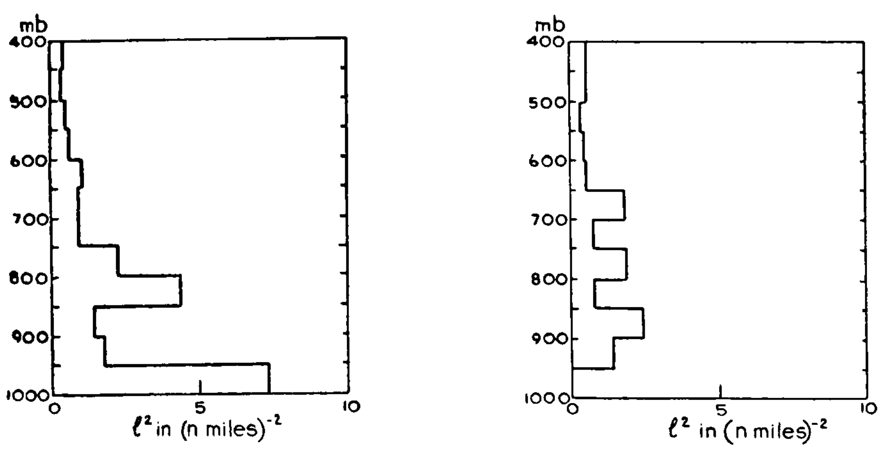


FIGURE 5—TEPHIGRAM AND UPPER WINDS FOR LIVERPOOL, 1100 G.M.T., 18 MAY 1958



(a) 2300 G.M.T., 17 MAY

(b) 1100 G.M.T., 18 May

FIGURE 6—PROFILES OF l^2 FOR LIVERPOOL 17 AND 18 MAY 1958

commencing 0900 G.M.T., 18 May, and at Y where over 0·20 in. was recorded. Thus, on or near the line AB, there are three rainfall maxima to the lee of the main Pennine ridge, approximately equidistant, and having rainfall values which decrease downwind.

It is impracticable to calculate precisely the wavelength and amplitude of the airstream but the main factor determining the wavelength is the upper wind speed. The stronger the wind, the longer the wavelength. Large-amplitude waves are also associated with strong upper winds. With winds of between 50 and 70 knots above 700 millibars, it is likely that fairly powerful waves were present to the lee of the southern Pennines on the day in question. The rainfall maxima at X, Watnall and Y are approximately 20 nautical miles apart. Corby[1] states that the length of lee waves may be up to 20 miles or so. The rainfall distribution suggests that the wavelength was in fact of this order.

In conclusion, it is suggested that the criteria for lee waves may well repay study when considering either frontal or instability rainfall in the Watnall and other similarly placed areas, especially when there is a solid air flow across the range of hills.

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THE UNUSUALLY WARM, DRY AND SUNNY WEATHER OF MAY TO SEPTEMBER 1959 IN THE BRITISH ISLES

By R. E. BOOTH

The prolonged fine, warm weather in England and Wales which lasted with but minor breaks from May to September 1959, has been rivalled in only four previous such periods this century—1911, 1921, 1933 and 1949—which is not to say however that these were the only good summers during that time. Therefore it is considered suitable to place on record some of the outstanding features of this period in 1959 and to compare them, and the summer months, with other years.

The period May to September was predominantly anticyclonic, breaks being of relatively brief duration and occurring during the first week and last few days of June, the last week of July, the second week of August and for one or two days about 20 September. The anticyclones mostly occurred as north-eastward extensions of the Azores high but were sometimes centred east of the British Isles, bringing air from the Continent, and were only rarely over or near our northern districts. The south experienced longer periods of anticyclonic weather than the north. North and west Scotland had more than average rainfall during June and July, whereas all districts in England and Wales had below average rainfall almost every month from May to September as shown in Table I.

Mean pressure was above the average for every month from May to September throughout the British Isles. The amount by which mean pressure at 0900 G.M.T. exceeded the average for the month varied from just over 10 millibars at Wick in September to just under two millibars at Stornoway in June and July.

Afternoon temperatures exceeded 80°F over a wide area at some period during each month. In May the temperature rose above this figure over much of the Midlands and south-east England during the second week, while 80°F was

TABLE I—PERCENTAGE OF AVERAGE RAINFALL EACH MONTH FROM MAY TO SEPTEMBER 1959 IN VARIOUS DISTRICTS OF THE BRITISH ISLES

District	May	June	July *per cent*	August	September
N. Scotland	60	111	119	76	48
E. Scotland	32	106	76	21	23
W. Scotland	45	105	135	22	38
N.E. England	26	94	76	21	18
E. England	37	77	93	68	5
Midlands	45	68	79	52	6
S.E. England	40	46	62	46	5
N.W. England and N. Wales	74	101	99	31	13
S.W. England and S. Wales	70	97	106	78	5
Northern Ireland	48	89	106	33	45

frequently exceeded in June after the 11th and 80°F or more was recorded on 15 days in July; on two of these it rose to 90°F or above. This latter temperature was exceeded over a large area extending from Kew to Cleethorpes on the 5th,

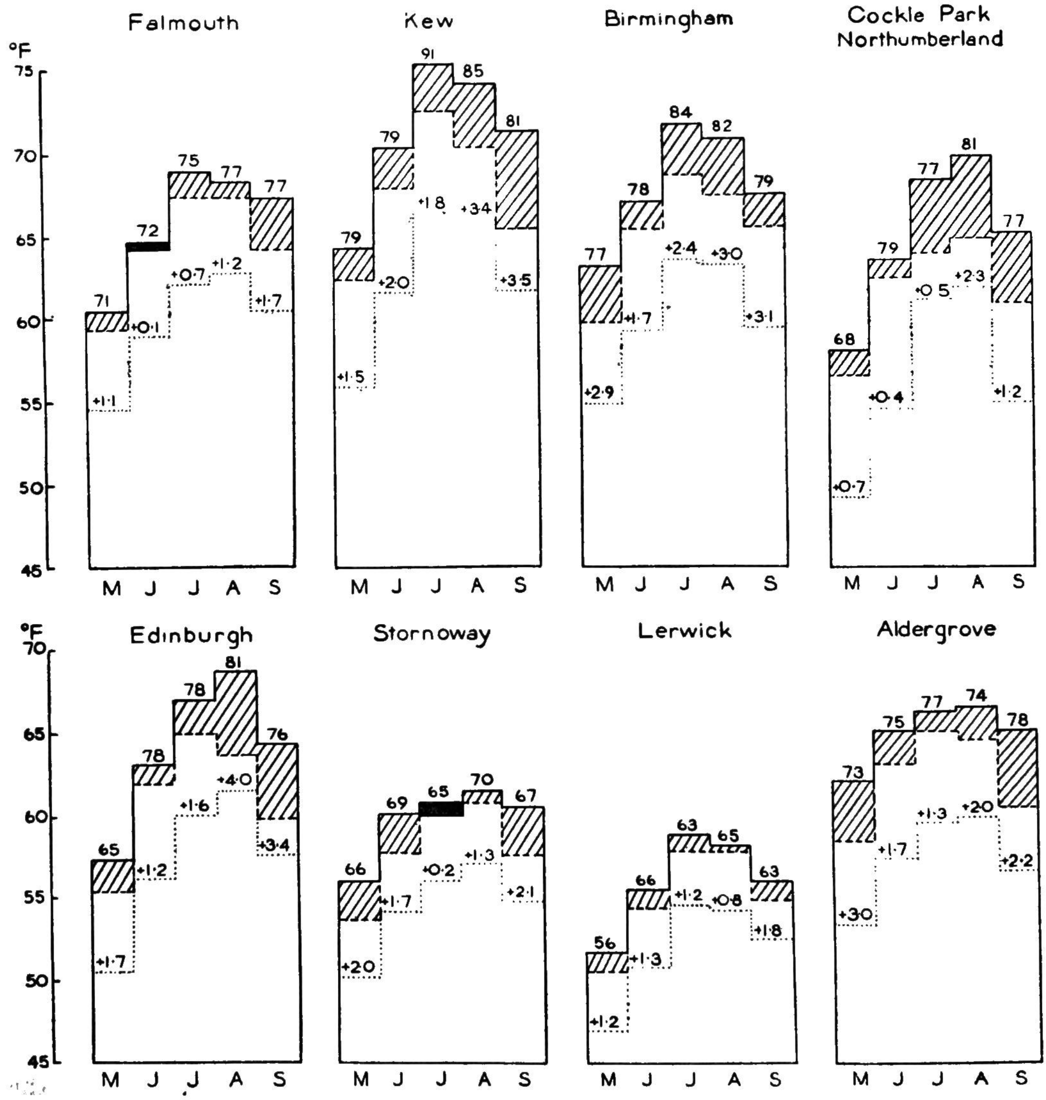

FIGURE I—MONTHLY VARIATION OF TEMPERATURE, MAY–SEPTEMBER, 1959

96°F being recorded at Gunby, Lincolnshire. In August temperature rose above 80°F on six days and did not fall below 60°F on 13 nights, while in September 80°F was exceeded in some parts of the country every day from the 6th to 12th. In south-east England the mean maximum temperature for the month was 2–3°F above average in May and June, 3–4°F in July and August and nearly $6\frac{1}{2}$°F in September. In northern England and in Scotland the corresponding figures were a little lower.

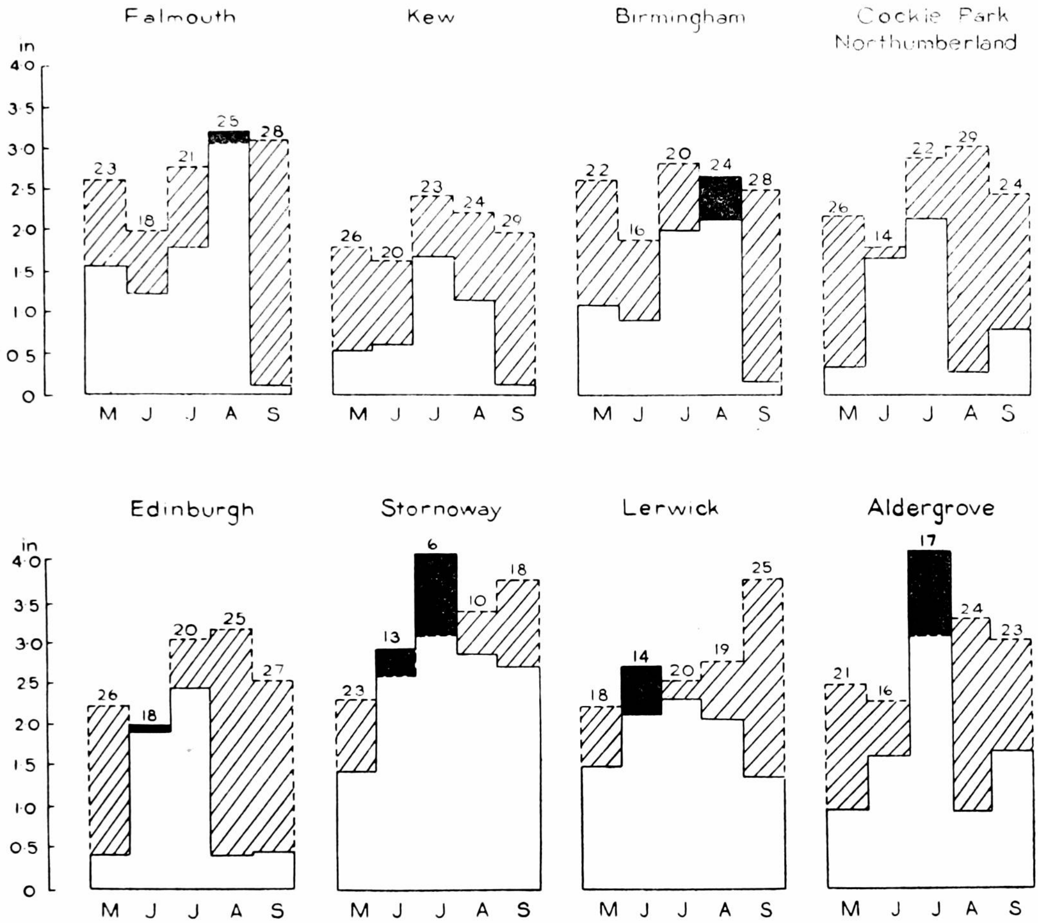

FIGURE 2—MONTHLY VARIATION OF RAINFALL, MAY–SEPTEMBER, 1959

Sunshine was above average almost everywhere during each of the five months. In England and Wales it ranged from 115 per cent of the average in June to 146 per cent of the average in September. In Scotland it was only 94 per cent of the average in July but rose to 134 per cent in September. During the latter month most of the south coast resorts had their sunniest September since 1911, while at some it was the sunniest of the century.

As will be seen from Table I, September was an exceptionally dry month, especially in south and east England. A few stations in the Midlands and East Anglia had no measurable rain from 14 August until the end of September, a period of 48 days, while Lowestoft and Finningley ended on 10 October a period without measurable rain lasting 57 days. The longest drought reliably recorded in the British Isles was during the late spring and early summer of 1893, when some places had no measurable rain for 60 days.

The histograms in Figures 1–3 show the monthly variation of temperature, rainfall and sunshine at eight widely separated stations in the British Isles. In each diagram the average of the daily observations during each of the five months May to September 1959 is shown by a full horizontal line and the corresponding long-term averages for the particular month by a broken line.

Thus in Figure 1 the hatched area between the full and broken lines shows the amount by which mean maximum temperature for the month exceeded the 1921–50 average daily maximum temperature and the black areas the amount by which it was below average. The mean temperature for the month, ½(mean max. + mean min.), is shown by a dotted line with the departure from the 1921–50 average temperature (positive in every case) immediately above it. The maximum temperature attained in each month is also shown.

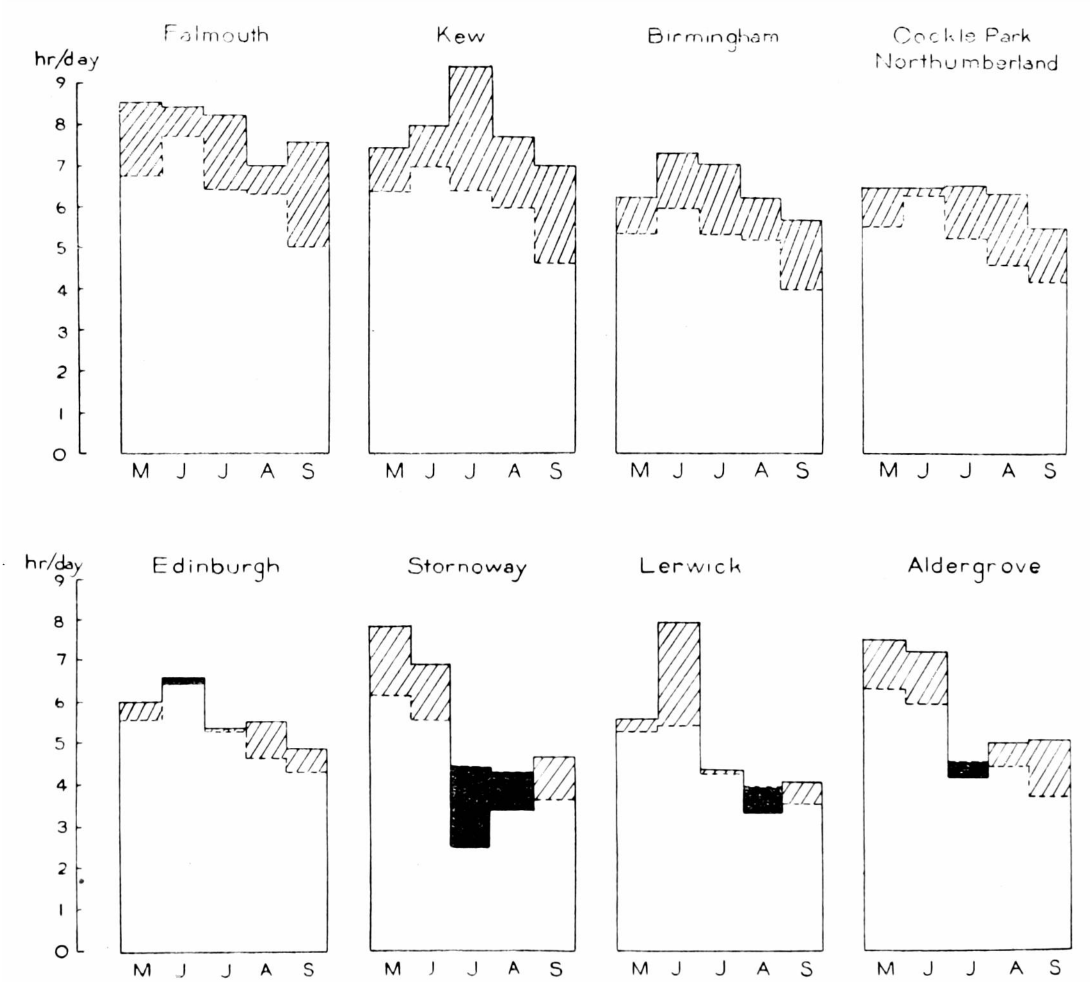

FIGURE 3—MONTHLY VARIATION OF SUNSHINE, MAY–SEPTEMBER, 1959

In Figure 2 the hatched areas show the rainfall deficiency, and the black areas the rainfall excess, with respect to the 1916–50 average for each month. The number of days without measurable rain in each month is given at the head of each column. In Figure 3 the hatched area gives the number of hours by which the mean daily duration of sunshine exceeded the 1921–50 average each month, and the black area shows the deficit where appropriate.

Table II gives for England and Wales for the three summer months, June, July and August taken together, lists in ranking order, showing the ten warmest and driest summers since 1900 and the ten sunniest summers since comparable records became available in 1909.

TABLE II—RANKING ORDER OF THE WARMEST, DRIEST AND SUNNIEST SUMMERS IN ENGLAND AND WALES

Temperature *°F*	Year	Rainfall *inches*	Year	Sunshine *hours per day*	Year
63·0	1947	4·7	1949	7·96	1911
62·9	1911	4·8	1913	7·35	1959
62·5	1933	5·5	1921	7·27	1949
62·4	1959	5·6	1933	7·14	1933
62·1	1949	5·7	1940	6·87	1940
62·0	1935		1955	6·50	1918
61·8	1934	5·8	1911	6·79	1935
	1955		1937	6·78	1934
61·6	1921	5·9	1947	6·76	1955
61·5	1901	6·1	1959	6·72	1921
	1950				

In spite of the fact that this century there were nine drier summers than 1959 (severe local thunderstorms occurred in 1959), there are only three warmer summers, 1947, 1911 and 1933, and one sunnier summer, 1911, in these lists.

Five summers are common to each section of Table II, namely 1959, 1949, 1933, 1921 and 1911, but the selection of the "best" summer will depend on how much weight is given to a particular element: whether, for example, abundant sunshine is considered more important than lack of rain. Similar ranking lists for Scotland show that the summer, June to August 1959, was the 4th warmest but only the 23rd driest since 1900 and the 20th sunniest since 1909.

The outstanding feature of 1959, however, was the unusual sequence of warm and sunny months from May to September. Tables III and IV give ranking orders for this period, similar to those for the summer months, of the five warmest, driest and sunniest such five-month periods in England and Wales and in Scotland respectively.

TABLE III—RANKING ORDER OF THE WARMEST, DRIEST AND SUNNIEST MAY TO SEPTEMBER PERIOD IN ENGLAND AND WALES

Temperature *°F*	Year	Rainfall *inches*	Year	Sunshine *hours per day*	Year
61·1	1947	7·5	1959	7·42	1911
60·6	1911	8·9	1921	7·14	1959
60·4	1949	9·2	1940	6·74	1949
	1959	9·3	1949	6·65	1940
60·2	1933	9·7	1911	6·64	1921

Over England and Wales 1959 leads the ranking list for dryness and, as in the summer list, is second only to 1911 for sunshine; only 1947 and 1911 were warmer. Table III also shows that the driest and sunniest May to September periods occurred during the same five years although the ranking order was different, and that three of these years, 1911, 1949 and 1959, were also among the warmest for the period.

Table IV shows that for Scotland for the five-month period there was only one warmer year and four drier years than 1959; there were seven sunnier years.

TABLE IV—RANKING ORDER OF THE WARMEST, DRIEST AND SUNNIEST MAY TO SEPTEMBER PERIOD IN SCOTLAND

Temperature °F	Year	Rainfall *inches*	Year	Sunshine *hours per day*	Year
56·9	1933	13·2	1955	6·07	1955
56·7	1959	13·7	1913	5·71	1911
	1947	14·0	1933	5·60	1919
56·3	1901	14·1	1915		1940
56·2	1911	14·2	1959	5·47	1949

The ranking lists in Tables II, III and IV are based on observations taken from the beginning of the century for temperature and rainfall and from 1909 for sunshine. Estimates by various authorities, however, make it possible to construct similar lists covering more than 200 years for rainfall and temperature. General monthly rainfall values based on Meteorological Office station readings during the last hundred years have been extended back to 1727 by Nicholas and Glasspoole.[1] The nearest approach to the 7·5 inches of rainfall recorded in England and Wales during the five-month period May to September occurred in 1750 when the estimated fall was 8·1 inches. A table of average monthly temperature values has been compiled by Professor Gordon Manley[2] from various sources representative of Lancashire and the Midlands for as far back as 1723. Extending this table the average temperature for the period May to September was higher in 1959 than in any of the other 236 years except 1947.

The period May to September 1959 has therefore certainly been the driest such period in England and Wales since the beginning of the century and probably since before 1727. It has also been the third warmest this century (see Table III) and probably for much of central England the second warmest since before 1723.

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SIMILARITIES OF THE METEOROLOGICAL SITUATIONS IN WHICH AIRCRAFT WERE DAMAGED BY HEAVY HAIL

By T. N. S. HARROWER, M.A., B.Sc., and D. C. EVANS

Introduction.—In August 1954 an aircraft was damaged by hail while flying near Lyon and in August 1958 similar damage was sustained by another aircraft near Limoges. The similarity of the meteorological situations in which these incidents occurred is considered to be worth noting.

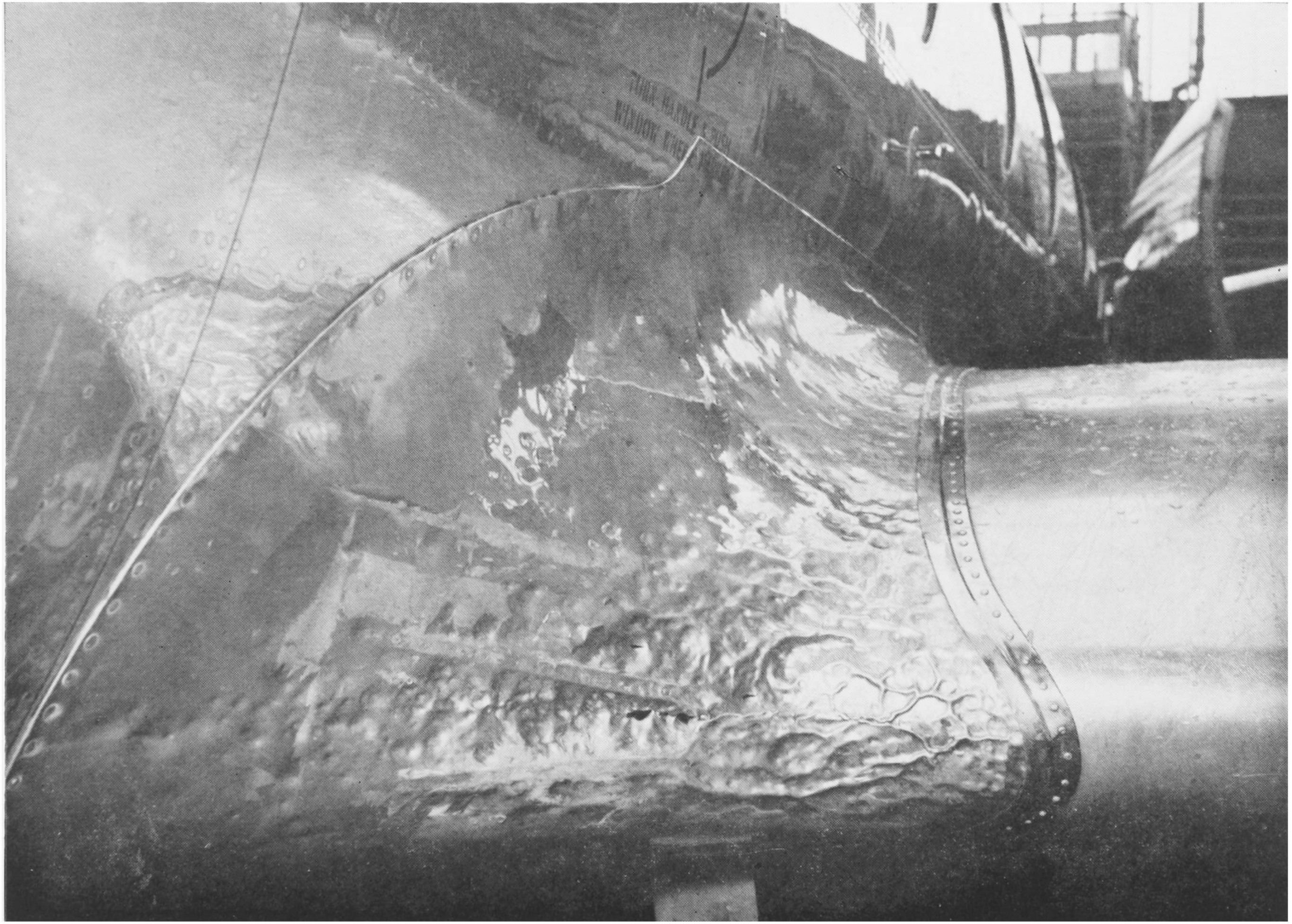
Narrative of the incidents.—The first incident was fully reported in a previous issue.[1] The second occurred on 18 August 1958, when Captain R. J. B. Cann was the pilot of a British European Airways Viscount aircraft which left Palma on a scheduled flight to London. At 1635 G.M.T. near Limoges the aircraft entered a cumulus cloud at an indicated altitude of 19,000 feet when the air temperature was −10°C. The true airspeed was reduced to about 220 knots but turbulence very soon became severe, with vertical speeds, at times, of up to 4,000 feet per minute. Moderate rime icing and hail were encountered, the hail becoming very severe. Difficulty was experienced in controlling the aircraft

By Courtesy of British European Airways

Upper side of nose

HAIL DAMAGE TO A BRITISH EUROPEAN AIRWAYS VISCOUNT

(see p. 80)

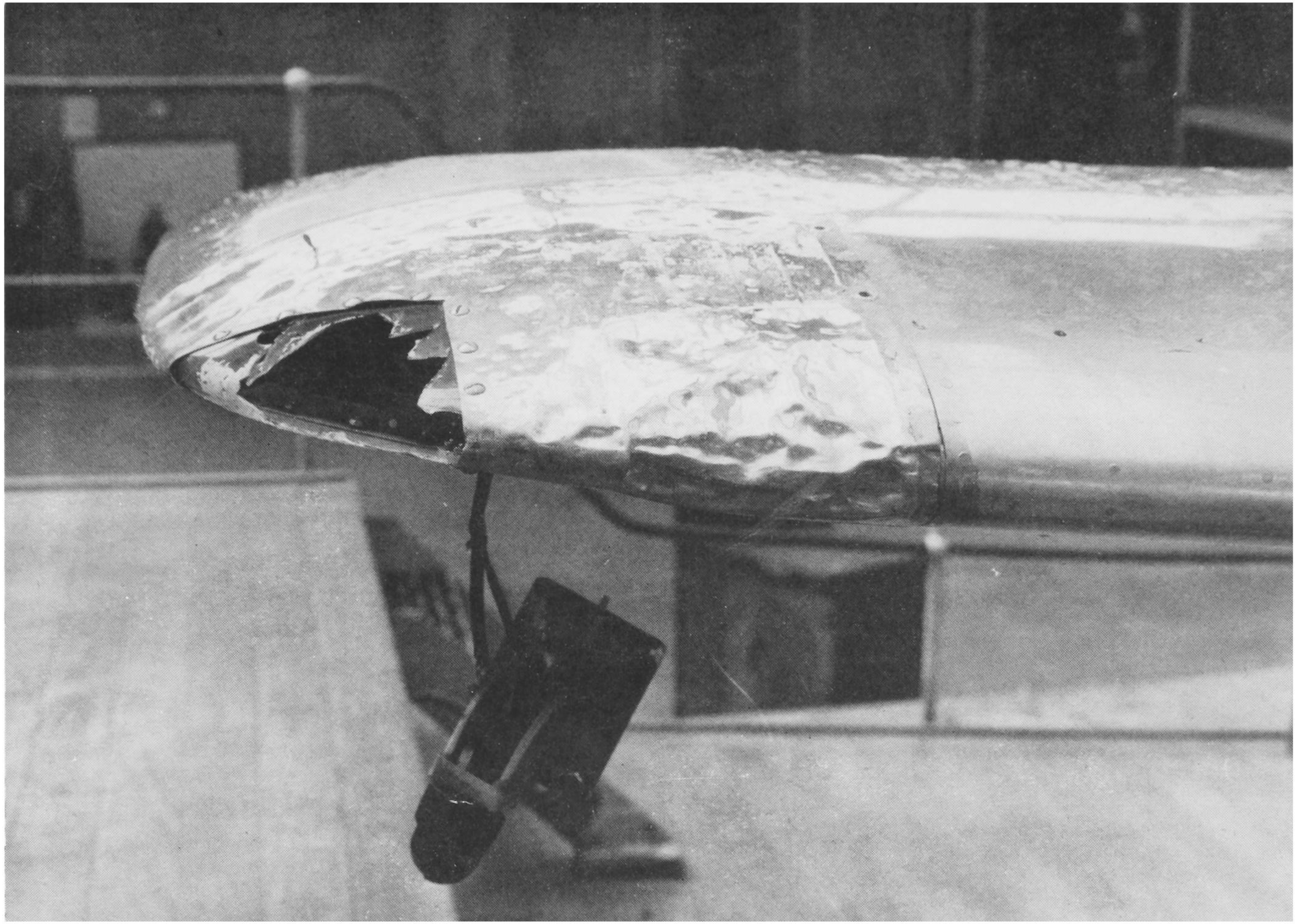


By Courtesy of British European Airways

Port wing leading edge fillet

HAIL DAMAGE TO A BRITISH EUROPEAN AIRWAYS VISCOUNT

(see p. 80)

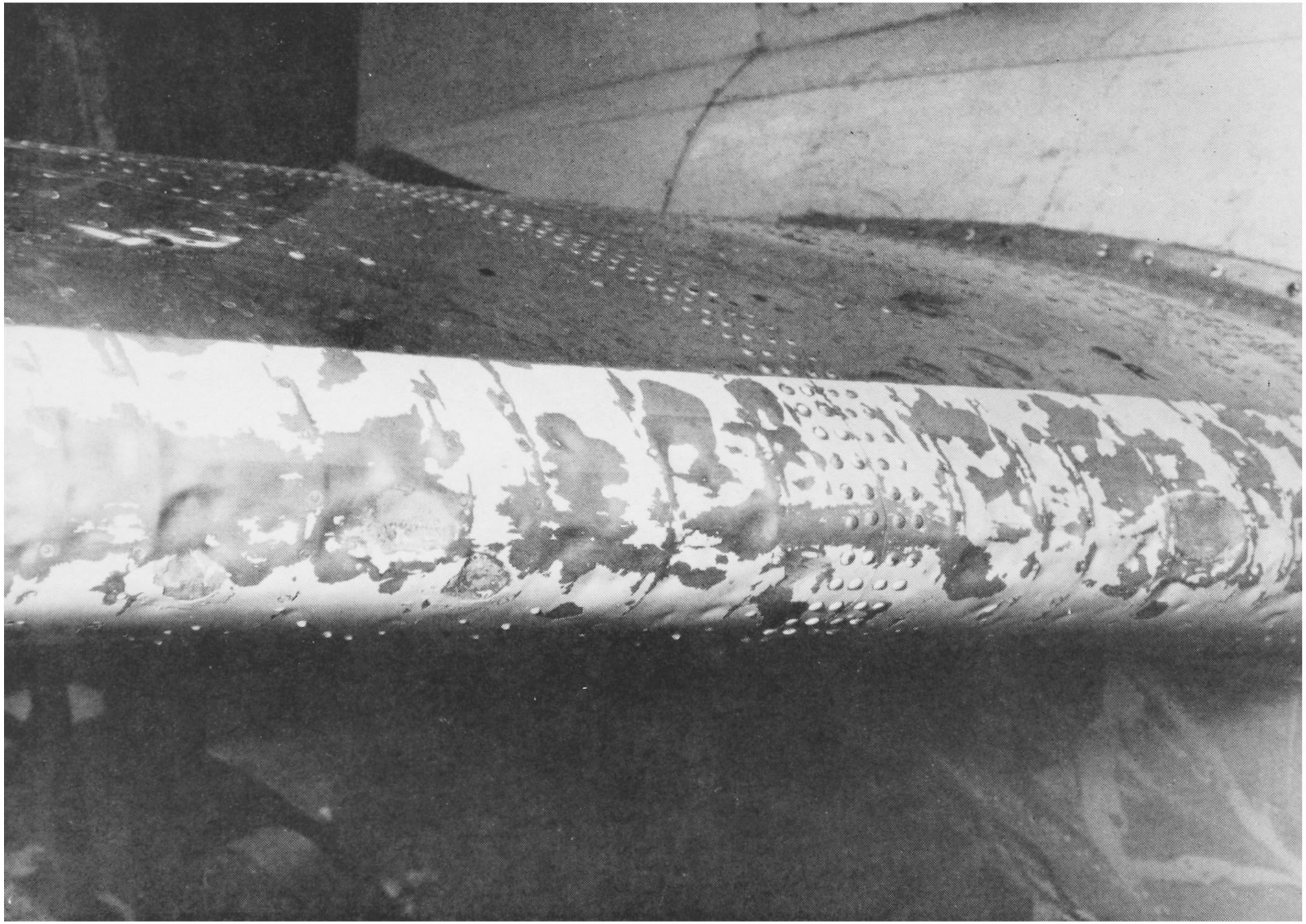


By Courtesy of British European Airways

Starboard wing tip

HAIL DAMAGE TO A BRITISH EUROPEAN AIRWAYS VISCOUNT

(see p. 80)



By Courtesy of British European Airways

Close-up of leading edge of starboard tailplane

HAIL DAMAGE TO A BRITISH EUROPEAN AIRWAYS VISCOUNT

(see p. 80)

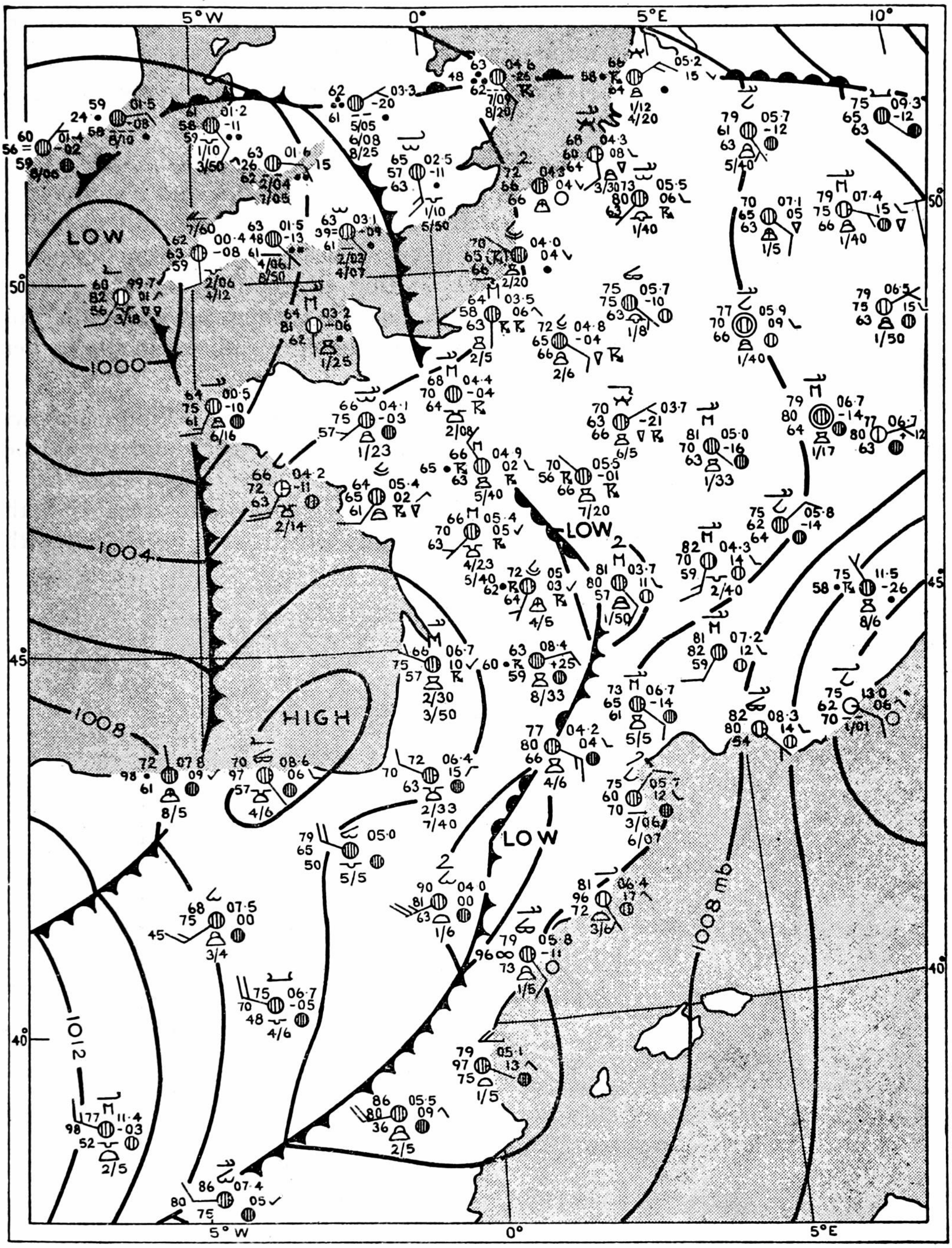


FIGURE 1—SYNOPTIC CHART FOR 1800 G.M.T., 18 AUGUST 1958

which was twice struck by lightning. These conditions continued in varying intensity until about 1648 G.M.T. when the aircraft came out into clear air. After passing through the hail there was continuous vibration in the elevator and aileron controls, but the pressurization functioned normally throughout. The Captain decided to descend in clear air and landed at Cognac at 1734 G.M.T.

Damage to the aircraft.—The Viscount aircraft was extensively damaged by hail as follows:

The outer layer of the windscreen centre panel was cracked from top to bottom; the fuselage nose-cone, wing root fairings, wing tips and a number of protrusions, such as pitot head and generator vent fairings, were badly distorted and, in some cases, pierced. The wing tip navigation-light covers were destroyed and there was excessive denting in the leading edges of all surfaces. Some photographs of the damage (between pp. 80–81) are reproduced with this report. Similar details and photographs of the damage sustained in the earlier incident have already been published.[1]

The points of similarity of meteorological situations.—Figure 1 shows the surface synoptic chart for 1800 G.M.T. on 18 August 1958 and should be compared with the 1500 G.M.T. chart for 14 August 1954.[1] Both show slow-moving cold-frontal systems associated with shallow low-pressure areas. In both cases the incidents occurred near the cold fronts which were associated with widespread thundery activity over France.

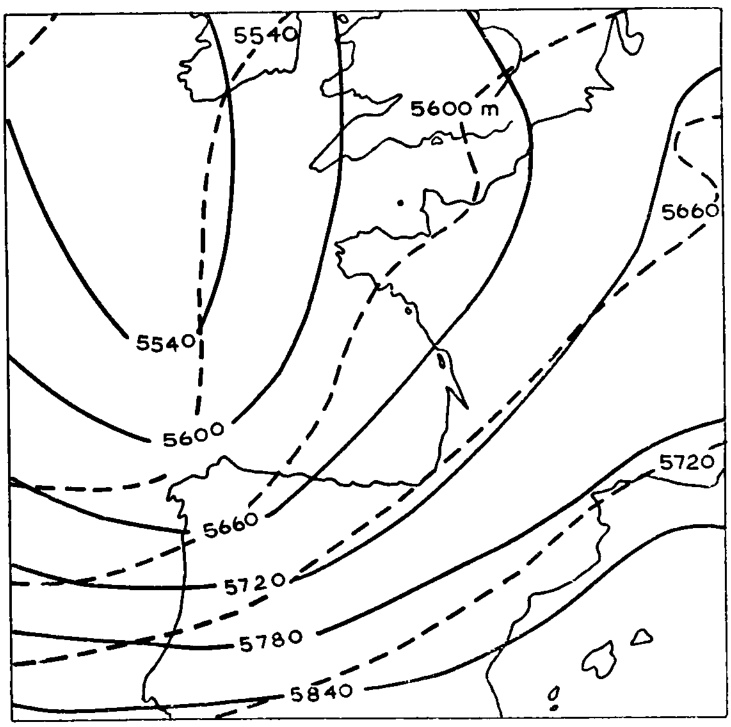
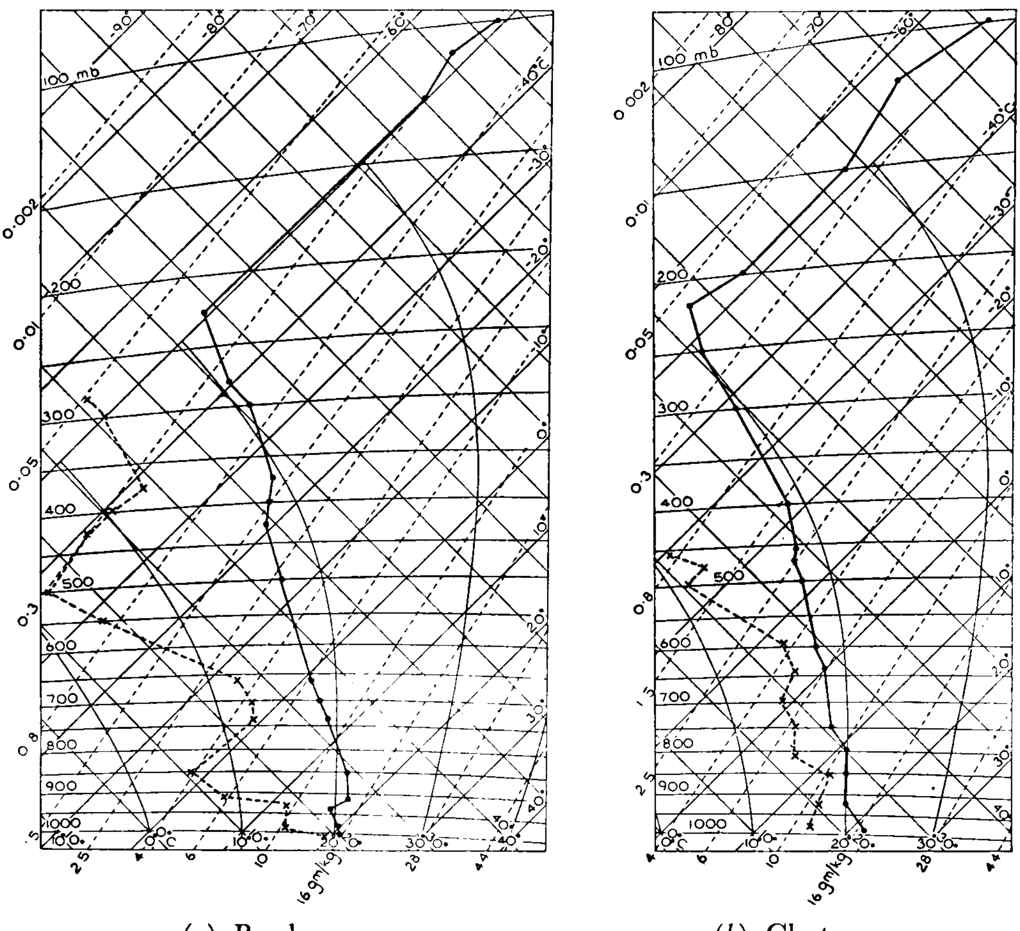


FIGURE 2—500-MILLIBAR CHART FOR 1200 G.M.T., 18 AUGUST 1958
Continuous and broken lines are contours and thickness lines respectively.

Figure 2 shows the 500-millibar upper air chart for 1200 G.M.T. on 18 August 1958 which should be compared with the 1500 G.M.T. chart of 14 August 1954.[1] There is a similarity in the shape of the pattern of the contour lines relative to the points where the incidents occurred, although the strong wind belt and jet stream of 14 August 1954 does not appear on the later chart. In both cases there is a south-westerly flow over the area concerned, with a marked cold trough about 400–500 miles to the west.



(*a*) Bordeaux (*b*) Chateauroux

FIGURE 3—UPPER AIR ASCENTS FOR 1200 G.M.T., 18 AUGUST 1958

Figures 3(*a*) and (*b*) show the upper air ascents for Bordeaux and Chateauroux respectively for 1200 G.M.T. on 18 August 1958 which should be compared with the ascents for Nîmes and Payerne for 1500 G.M.T. on 14 August 1954 which are shown as Figure 4 in the previous note.[1] The Chateauroux ascent, like Payerne, was moist and unstable and consistent with the extensive areas of thundery activity reported. Bordeaux ascent, like Nîmes, was made just to the west of the cold front and was dry aloft, but the thermal contrast between Chateauroux and Bordeaux was much less than existed between Payerne and Nîmes on the first occasion. This is also shown by the lack of thermal gradient on the 500-millibar chart on the second occasion compared with the earlier one and it is therefore suggested that although severe hail is frequently associated with cold fronts, the degree of thermal contrast across the front does not control the size of the hailstones.

Some American meteorologists have devised methods for relating the size of hailstones to the representative upper air ascents at the time of the hailstorm. From these four European ascents, hail sizes at the earth's surface should all be less than a quarter of an inch in diameter as computed by either of the methods, the first devised by Fawbush and Miller,[2] the second by Foster and Bates.[3] The fact that in some of these cases where the wet-bulb freezing level is about 10,500 feet, the authors would not have predicted hail at the surface does not alter the size which might be encountered at flying levels. These sizes are obviously much smaller than were actually experienced and it appears that similar assessments of the upper air ascents in most hail-producing situations in Europe do not give large enough values for hail size.

A vertical cross-section across France of the wind structure was constructed for the second incident but, unlike the cross-section shown as Figure 3 in the previous report,[1] showed no interesting features. Winds over France were all between 180 and 230 degrees and between 24 and 46 knots up to 400 millibars and there was no marked wind shear either horizontally or vertically. It is possible that this uniformity of the wind might have contributed to the development of large hail. Hailstones would tend to remain and therefore grow within the core of a cumulonimbus cloud which was not distorted in shape by wind shears and conversely a hailstone falling from high up in a cumulonimbus cloud which is leaning to one side is likely to fall out of the cloud early in its life. It is understood, however, that at a Monday discussion[4] Ludlam stated that wind shear does not discourage the formation of large hail and this is confirmed by the changes of wind speed with height which were reported at Lyon on the occasion of the first incident, namely: 47 knots at 750 millibars to 88 knots at 650 millibars.

Notes on other recent encounters with hail by British European Airways aircraft.—There have only been five other incidents of hail damage to B.E.A. aircraft during the years 1955–58 and nearly all these have been much less serious than the incidents already discussed. The following is a brief summary of these incidents:

1. 26 June 1955 at 18,500 feet over Basle in very severe thunderstorms. There was a quasi-stationary front over Basle, extending from just north of Frankfurt to just north of Bordeaux. It is possible that a shallow wave on the front could have been in the vicinity of Basle.
2. 10 May 1956 at 5,500 feet just east of Hamburg in medium hail. There was a cold front in the vicinity which extended from Oslo to Berlin and Zurich and which was moving east at 30 knots.
3. 27 August 1956 on climb from Zurich in a violent thunderstorm. There was a wave on a cold front centred over Zurich.
4. 5 May 1957 on climb about 50 miles north of Barcelona, in heavy hail, for approximately 30 to 45 seconds, which resulted in damage similar in extent to the two main incidents already described. There was a depression centred over northern Italy with a trough over the western Mediterranean but no fronts could be found to the west of the centre.
5. 1 July 1957 at 20,500 feet over Frankfurt and again about 50 to 100 miles further west at 24,000 feet in heavy hail. The second location coincided with a cold front extending from Denmark to Paris but there was a marked

trough within the warm sector over Frankfurt which suggests that another cold front could be inserted ahead of the main front. It is interesting to note that this same frontal system was still producing hail about 42 hours later over the English Channel.[5]

Thus in Europe, the association of hail damage with slow-moving fronts and shallow troughs of low pressure appears to be more frequent than with steadily moving cold fronts. It is regretted that the American study[6] which associated 59 per cent of the thunderstorms which produced hail with cold fronts as opposed to warm fronts and air masses did not consider the speed of movement of the fronts. However, one situation in North America was published[7] as typical of situations which produce widespread hail damage and this was dominated by slow-moving fronts and shallow low-pressure areas, in fact the similarity of the surface chart and the 500-millibar chart to Figures 1 to 3 is quite remarkable.

Conclusion.—Attention has been drawn to the points of similarity in the situations in which severe damage from hail has been sustained by aircraft, and this may help forecasters to recognize the existence of, or predict the development of such a situation in summer, and to include heavy hail in their forecasts for individual flights and in SIGMET warnings, and at briefings to remind pilots of damage experienced in similar situations. If as a result of these reminders pilots are able to change their intended tracks and avoid severe hail damage, it is felt that this would constitute an advance in an extremely difficult and important field.

Acknowledgement.—We wish to thank British European Airways for permission to include in this report details of this incident and for supplying and giving permission for the publication of the photographs.

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METEOROLOGICAL OFFICE DISCUSSION

Mediterranean meteorology

The subject for the Meteorological Office discussion at the Royal Society of Arts on Monday, 16 November 1959 was "Mediterranean meteorology". The openers were Messrs. H. B. Rowles, J. C. Gordon and S. G. Abbott.

Mr. Rowles first remarked that the winter weather of the Mediterranean is characterized by abrupt variations both in space and time, many of which result from the topographic complexity of the area. At this season the region is one of relatively low pressure, the frequent occurrences of cyclogenesis and disturbed weather being associated with the penetration of cold air from northerly sources. In summer circulation in the western Mediterranean is weak, while the eastern basin comes under the influence of warm subsided air flowing round the large thermal low of south-west Asia. The important influence of sea surface temperature on Mediterranean weather was illustrated by showing the close correlation between the essentially convectional rainfall of Malta and the difference between air and sea temperature for each month.

In the Mediterranean broad-scale weather patterns are greatly modified by the influence of high ground, local differences in surface heating and cooling, rates of evaporation, convergence and vertical motion. Thus to account for and forecast the weather, close attention must be paid not only to the mid-latitude circulation, but also to meso- and small-scale features. It was shown how greatly the mountain ranges of southern Europe and north Africa influence air flow to give rise to an ageostrophic wind field in the Mediterranean, with strong local winds, such as the mistral and bora, developing under suitable conditions in gaps between high ground. Reported surface winds cannot therefore be regarded as representative other than over very restricted areas.

Upper winds.—At 850 millibars orographic effects are less marked than at sea level and contours for this surface provide a guide for estimating winds. Moreover, the superimposition of 850-millibar isotherms enables areas of cold or warm air advection in the lower layers to be detected and lapse rate variations deduced at least qualitatively. At higher levels flow patterns are dominated in winter by the subtropical jet stream normally found over northern Africa with a core at about 200 millibars and a tropopause discontinuity; winds associated with the jet tend to increase eastwards. In summer upper wind strengths are much reduced. The jet occurs in tropical air and may on occasions be associated with a frontal surface over the Sahara separating much modified polar air from air of equatorial origin. Harding[1] has shown that the strong winds are often present in broad belts in which shear may be negligible over distances up to 200 nautical miles, though quite large near the edges.

When very cold air invades the Mediterranean and at the same time there is some northward advection over North Africa, the jet can become intense and remain very strong over prolonged periods. Lamb[2] and others have discussed such situations when the upper winds in the Mediterranean may rise to between 180 and 220 knots.

Though the jet axis is normally rather to the south of the Mediterranean, it is significant that it lies nearly parallel to a number of tracks followed by aircraft. Thus a relatively small shift of the jet northwards may increase winds by as much as 90 knots in 12 hours over a considerable portion of an air route.

Air masses.—In winter the Mediterranean is invaded by a succession of cold air masses which may initially be very unstable but become transformed by subsidence and surface heating into a virtually new air mass: Mediterranean cold air; this is convectively unstable. Though maritime arctic and continental arctic air occasionally reach the area, the commoner air masses are maritime polar, which frequently enters the western Mediterranean, and continental polar, which reaches the eastern basin when high pressure extends westward from Russia. Maritime tropical air is rare and confined to western districts.

The Sahara is a source region for continental tropical air and particularly between March and May that air mass may be carried northwards by strong southerly or south-easterly winds in advance of depressions or troughs. Initially this air is remarkable for its dryness, high surface temperatures and a lapse rate approaching the dry adiabatic value up to 600 millibars. On passing northwards over the sea, however, it absorbs moisture rapidly and, as the air is convectively unstable, subsequent lifting can give rise to heavy rain.

In summer the Mediterranean is generally a source region for tropical air, though occasionally polar air may reach northern Italy and cause severe thunderstorms.

Fronts.—Although the various air masses affecting the Mediterranean may be fairly easily identified, it is often difficult to decide precisely where fronts should be placed. Frontal discontinuities tend to be weak and the air masses themselves are subject to considerable modification through subsidence, surface heating and orographic uplift. Warm fronts can be associated with incursions of maritime tropical and continental tropical air, but in general they are of little consequence compared with the effects of cold fronts and occlusions. For forecasting, these features must be followed meticulously as they advance towards the Mediterranean. On reaching the mountain barriers surface fronts are subject to much distortion, for at low levels the new air mass tends to enter the region largely through certain gaps. The upper portion of a front may however advance over a range and analysis then becomes a very complex problem. Two features which merit careful consideration when placing fronts are the 1000–500-millibar thickness pattern and the 850-millibar isotherms. It must be admitted however that the drawing of accurate thermal charts from the data available is difficult.

Cyclogenesis and depressions.—In winter the frequency of depressions and cyclogenesis in the Mediterranean is high. A certain number of depressions move into the area from the Atlantic or Sahara, but the great majority develop within the region itself. Many low-pressure features may be associated with the influence of mountain barriers on air flow, lee troughs and depressions being characteristic of the area. Alpine depressions develop when a cold front or occlusion passes south-eastwards across France and Germany and there is a component of wind directed across the mountains. A circulation normally develops over the Gulf of Genoa and cold air extends across the western Mediterranean. Lee depressions may also develop near the Balearic Islands and to the south of the Atlas mountains. Though initially lee depressions may have no frontal structure, a baroclinic zone is normally in evidence during later development.

There is a close correlation between the advance of 500-millibar troughs or cold pools into the Mediterranean and surface cyclogenesis. George and Wolff[3] have shown that in winter the establishment of a long-wave ridge in the eastern Atlantic leads to repeated cyclogenesis in the Mediterranean, surface lows developing near or below an upper trough. There is a considerable lag between the translation of a westerly 500-millibar pattern on the Atlantic to a north-westerly one, with the production of an inflexion point, and the subsequent cyclogenesis in the Mediterranean. The location and development of such an inflexion point may thus be used for predicting cyclogenesis. An objective method has been tested for locating the position of cyclogenesis for up to 24 to 48 hours in advance based on the position of the inflexion point. This procedure was illustrated by several slides.

Mediterranean depressions tend to move along certain preferred tracks which in winter are largely over the sea. Other useful guides to motion are the 24-hour surface tendency field and the 1,000–500-millibar thickness pattern. The best objective indicator of a stationary-wave cyclone is the superimposition of a closed non-moving low at 500 millibars over a surface low.

Differential heating effects.—Bleeker[4] has laid stress on the influence of differential heating as between land and sea on the pressure field and has made a study of these effects in the Mediterranean area. The model which he has postulated for the variations in pressure and circulation when a coastal area is alternately heated and cooled over land by day and night was illustrated. The differential heating was shown to give rise to areas of divergence and convergence resulting in the development by day of a surface coastal trough over the land and a ridge over the sea; by night the areas of relatively low and high pressure become reversed. When isobars are initially orientated at an angle to the coast, the differential heating results in refraction of pattern. Over narrow land masses such as Italy the day and night troughs and ridges over land associated with each coast tend to merge and the diurnal variations in the surface pressure pattern become pronounced. It was also shown that pressure changes between day and night were likely to be particularly marked over land near a coast with convex curvature towards the sea, whereas if curvature is in the opposite direction the effect will be more significant over the sea. Neumann[5] has shown that in coastal Mediterranean areas thunderstorms occur mainly at night when the coast is concave to the sea and by day when curvature is in the opposite sense. This is to be expected from the surface convergence associated with the land- and sea-breezes.

Conclusion.—Mr. Rowles concluded by remarking that improvements in forecasting over the region were dependent not only on better representation of large-scale features by more accurate and consistent synoptic charts; a fuller appreciation was needed of the many local surface effects which played so large a part in Mediterranean weather.

Malta rainfall.—Mr. Gordon said that Malta normally experienced a dry season from May or June to September or October and a wet season. Rainfall is important to this small but densely populated island for a significant deficiency can lead to water rationing. Intense rainfall is of little value, however, owing to rapid run-off. Rainfall records are therefore of considerable interest; these are available from the middle of last century. Diagrams of mean monthly rainfall show that the months of April to September have very little rainfall. There is a rapid increase in rainfall amount from September to October which can be a very wet month. In October 1951 almost 20 inches of rain fell at Luqa and larger amounts elsewhere on the island. There were also very heavy falls in October 1957.

Heavy rainfall over Malta is frequently associated with thunderstorm activity in moist south-easterly currents ahead of wave depressions which move from central Algeria to the central Mediterranean after cold air has penetrated south of the Atlas mountains. If the thermal trough persists to the west of Malta, a succession of such systems is likely to affect the island and rainy weather will continue till the trough passes away eastwards. The strong winds which may be associated with these depressions can affect Malta in two ways. If they blow from the north-east a gregale warning has to be issued to ships in the Grand Harbour which does not give protection from this quarter. Dust- and sandstorms may develop over North Africa, and even at Malta the visibility can fall to 400 yards because of dust. Forecasting the formation and movement of these depressions is difficult on account of the sparseness of low-level surface observations and upper air data from North Africa. Useful reports on strong winds have recently been obtained from aircraft using Doppler methods for computing.

Diagrams were shown of the diurnal variation of rainfall for the period 1947–1956. These indicate a marked maximum at about 0600 G.M.T. and a secondary maximum about 1200 or 1300 G.M.T. The first maximum occurs at about the time of greatest radiational cooling which might also be expected to be the time of greatest cloud growth over the sea.

Weather forecasting in the eastern Mediterranean.—Mr. S. G. Abbott spoke of the work of the forecaster in the eastern Mediterranean, with particular reference to Cyprus. Most of the rainfall of this area occurs in winter in association with cold troughs over the eastern Mediterranean. Sea surface temperatures above 60°F then give rise to abundant instability rain, often with thunderstorms. In Cyprus snow falls on the mountains when the 0°C isotherm drops to 6,000 feet and snow may occur at sea level if the 1000–500-millibar thickness is less than 5280 metres. If a cold outbreak occurs further west, a warm ridge may cover the eastern Mediterranean giving a fine hot spell. This may be serious for farmers in spring for apart from the absence of rain the intense heat associated with easterly winds may scorch young corn.

Sea-breezes are an important local weather feature in Cyprus, for in six to seven months day maxima inland may be up to 20°F above sea surface temperature. At Nicosia the sea-breeze normally blows from the west-north-west, but occasionally from the east. If in summer the axis of the seasonal surface trough, normally found south of Turkey, is north of Cyprus the sea-breeze will reinforce the general flow and day temperatures will be relatively low; if the axis is located south of the island, however, the sea-breeze may be inhibited, resulting in very trying hot weather.

The sea-breeze brings moist air inland during the afternoon and evening, and stratus cloud, which may be low enough to cover Nicosia airfield (about 700 feet above sea level), can form inland after dark. On nights with light winds radiation fog patches may develop over lower ground and be advected by a light easterly wind to Nicosia airfield. Katabatic winds from the mountains however often keep the airfield clear. It is rare for Akrotiri, on the coast, and Nicosia airfields to be affected simultaneously by fog, but this is possible if the air to the west of Cyprus is exceptionally damp and the pressure pattern indicates light advection eastwards. In order to place the forecasting of fog at Nicosia on a more objective basis, the relationship between fog formation and certain temperature parameters obtained from Morphou Bay, a coastal station west-north-west of Nicosia, combined with the 3000-foot wind, have been investigated.

Pedlow has made a tentative adoption for Nicosia of the Gold[6] method for estimating the maximum day temperature. Monthly values for the depth of the surface layer which can be changed from an isothermal to a dry adiabatic lapse rate by insolation have been calculated and found to range from 85 to 135 millibars.

Mr. Abbott concluded his remarks by discussing some of the communication problems involved in collecting meteorological data at forecasting centres in the Mediterranean.

In opening the subject for general discussion the *Director-General* asked what use could be made by meteorologists of weather-warning radar. Since thunderstorms are a typical feature of Mediterranean weather is it possible to see airfield radars? Several speakers indicated that such installations would be an aid to forecasting.

Mr. Hurst, commenting on weather at Gibraltar, said that surface winds tended to be either westerly or easterly. Westerly winds normally brought good conditions though with directions between west and south-south-west turbulence could render landings dangerous on the airstrip. Easterly airstreams were liable to be damp, bringing low stratus and fog to the Straits. The rainfall pattern at Gibraltar is similar to that at Malta and a satisfactory amount of rain is equally important there for the local population. The quantity of rain which falls is however very variable; up to 20 inches of rain can however fall in one week and static rainfall areas develop.

Mr. Wallington asked whether, in view of the considerable thunderstorm activity in the Mediterranean, any remarkable downdraughts had been observed.

Mr. Thornton-Smith instanced a clear-weather squall at Malta being traced back to heavy thunderstorm activity over north-east Tunisia. He also mentioned that while incursions of tropical maritime air through the Straits of Gibraltar are uncommon, conditional instability is achieved when it reaches the central Mediterranean. Provoked by the orographic uplift of Italy and Sicily coupled with lifting over cooler air masses widespread dangerous weather results, with dense cloud from 600 to 40,000 feet, and embedded cumulonimbus. An example was the flooding in central Italy in October 1944.

Mr. Lamb believed that Malta's second diurnal rainfall maximum at around 1200 G.M.T. corresponded to convection over the island. It might be expected rather later in central parts of the island, where the sea-breezes from opposite coasts meet, since strongest development of these convection breezes is around 1300 G.M.T. (1400 hours local time). 1100–1200 G.M.T. is when the sea-breeze convergence is commonly close to Luqa airport. Aircraft have on occasions reported inconveniently strong upcurrents at this convergence. Similar phenomena doubtless occur over other Mediterranean islands. Mr. Lamb also considered that a Sferics network for tracking thundery disturbances before they emerged from the African desert would be very helpful in synoptic analysis over the Mediterranean.

Mr. Jenkinson regarded true maritime tropical air in the Mediterranean as essentially a stable air mass. After a long track over desert regions, however, it assumed the characteristics of continental tropical air which is convectively unstable.

Mr. Harding referred to the significance of sea-breezes in Cyprus meeting over Nicosia. This could give rise to thunderstorms outside the normal period for them. Referring to Mr. Wallington's query, he had not found anything very unusual about thunderstorms in Egypt probably because they occurred in the winter season. Referring to chart analysis, he urged that very great caution should be exercised before discarding any front in the Mediterranean region.

Mr. Miles was interested to note the use of north-westerly inflexion points to give a 24-hour warning of cyclogenesis and inquired whether the wind needs to have a minimum veer from a westerly direction. He thought that the use of south to south-westerly inflexion points some 40 degrees longitude upwind of Ireland would give about a 24-hour warning of the occurrence of over 70 per cent of these north-westerly inflexion points. He believed it to be the case that cyclogenesis in the west Mediterranean begins about two months earlier than it does in the east Mediterranean and wished to put forward the suggestion that this is due to the longitude of most frequent cold outbreaks moving east as the westerly circulation grows to its maximum about mid-January. Replying, Mr. Rowles said that a minimum veer of wind was not specified for the identification of an inflexion point. He agreed that the later onset of cyclogenesis in the eastern Mediterranean as compared with the west was likely to be associated with seasonal variations in the most likely longitude for cold outbreaks.

Mr. Hunt was surprised that no mention had been made of lee waves in the Mediterranean. He had recently observed such effects and aircrew had mentioned to him downcurrents and sometimes turbulence which have had marked effects on the operation of their aircraft; aircrew had also reported that winter weather in the Mediterranean can give rise to conditions as severe as in an active section of the Inter-Tropical Convergence Zone. Referring to the reporting of cumulonimbus cloud, he thought it was possible on occasions for several stations all to report one isolated cloud from which an exaggerated impression might be formed of the threat to aviation. Weather radar he felt would be of great value in places such as Nicosia, but owing to high ground the positioning of any set would provide problems.

Mr. Wilson, referring to conditions created by depressions likely to be dangerous to aircraft operations, recalled an occasion in 1944 which caused very severe sandstorms in the eastern Mediterranean. A depression of some 980 millibars moved steadily eastwards from the Gulf of Sirte towards Egypt, turned north-eastwards into Palestine and thence into Iraq. The vertical extent of the associated sandstorms reached a minimum height of 20,000 feet and pilots reported almost nil visibility at a height of 10,000 feet.

Mr. Jenkinson also spoke of this storm, saying that it gave rise to sandstorms over some 1,200 miles. It was difficult to follow the development of such features though a study of the 24-hour isallobaric field was informative. Speaking of fronts in the Mediterranean and over North Africa, he emphasized the necessity of tracking their movement by means of changes in maximum day temperatures and upper air data.

Mr. Bulmer, commenting on the secondary maximum in October shown for Malta rainfall in Mr. Gordon's slides, pointed out that the secondary maximum in October was due to the exceptional fall in 1951. An analysis of rainfall for the period 1921 to 1950 produced a smooth curve from the July minimum to the December maximum. Further, a sufficiently long period including the abnormal year 1951 produced a similar smooth curve with no October peak as was found for the analysis of the 100 years 1854 to 1953.

The *Director-General*, in closing the discussion, thanked the openers as well as the speakers from the floor and remarked that the meteorology of the Mediterranean could be regarded as that of a very large lake though with some of the properties of an ocean.

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REVIEWS

International journal of air pollution, Vol. 1, Nos. 1/2, October 1958. Editors: Dr. R. S. Scorer, Mr. G. Nonhebel, Dr. J. Pemberton, Prof. A. J. Haagen-Smit. 10 in. × 6½ in., pp. 154, *illus.* Pergamon Press Ltd., 4 and 5 Fitzroy Square, London W.1, 1958. Price: £6 per volume.

We welcome the publication of this new journal which will provide a forum for technical papers in all the subjects (meteorology, medicine, engineering, chemistry) concerned in the study of atmospheric pollution. Hitherto there has been no specific journal for technical as distinct from semi-popular articles on this extremely important subject. Review articles to acquaint specialists in the individual studies concerned with progress in others are to be a special feature. The first number includes papers on a wide variety of topics from the relation between atmospheric pollution and cancer mortality to the diffusion of nuclear reactor gases. There are two review articles and reviews of seven books. The journal is published quarterly by the Pergamon Press.

G. A. BULL

Klima und Bioklima von Wien, III Teil. By Prof. Dr. F. Steinhauser, Dr. O. Eckel and Dr. F. Sauberer. 9½ in. × 6½ in., pp. 136, *illus.* Verlag: Ö. Sterr. Gesellschaft für Meteorologie, Wien, Hohe Warte 38, 1959.

This third volume completes the monumental work on the climatology of Vienna and the surrounding district prepared by Dr. Steinhauser, Dr. Eckel and Dr. Sauberer for use in town planning and building. It deals with the variation of precipitation over the area, wind, atmospheric pollution, and the climate of the streets. It is full of interesting details. The last part, for example, deals with daylight illumination of streets of varying width and type of building, wind variations and temperature differences in streets and squares.

This publication is a model of its kind as well as a major contribution to the climatology of Vienna.

G. A. BULL

METEOROLOGICAL OFFICE NEWS

Royal Air Force Volunteer Reserve (Meteorological Section).—*Award*—It was announced in Air Ministry Orders dated 9 December 1959 that Flight Lieutenant S. G. Silverman had been granted the Air Efficiency Award.

NOTES AND NEWS

Observation of lightning out of the top of a cumulonimbus

The following unusual observation of tropical lightning was reported by Flt.-Lt. R. Trigg, the pilot of a Vulcan flying from Karachi to Butterworth, via Ceylon.

At 2130 G.M.T. on 19 October 1959 when at the position 14°32′N and 73°13′E, flying towards the south-south-east at a height of 47,000 feet (ICAN), a flash of lightning was observed extending upwards from the top of a cumulonimbus ahead.

Flt.-Lt. Trigg stated that he was flying in clear air, and had been watching the line of cumulonimbi ahead for some time. The line of cloud was illuminated internally by frequent flashes of sheet lightning. The cloud top was clearly visible (it was three days after full moon). While still at a distance of about sixty miles a single upward flash of lightning was seen from the top of one of the cumulonimbi, reaching several thousand feet higher. Flt.-Lt. Trigg made special note of this because he had never observed such an occurrence before, nor heard any reports of such an occurrence. The flash was straight, with no forking. Flt.-Lt. Trigg does not think it was an optical illusion, nor had he been flying for long enough to become fatigued.

On reaching the bank of cloud he altered course to avoid the higher tops, which were estimated to reach 50,000 feet. This cloud belt was about thirty miles wide and lay across the flight track which was just west of the coast of India. No cirrus was observed around or above the bank of cumulonimbus.

T. A. M. BRADBURY

Exceptional rainfall at Singapore in December 1954 and Mahe, Seychelles, in January 1955

We are indebted to Mr. B. W. Thompson, Ag. Deputy Director, East African Meteorological Department, for transmitting a letter to himself, from the Senior Observer, Seychelles, commenting on the article "Comparison of months giving extremes of rainfall during north-east monsoon at Changi, Singapore Island" published in the October 1958 number of the *Meteorological Magazine*. The following text is an extract from the letter:

Date: 2nd March, 1959.

I have read with interest an article appearing in the *Meteorological Magazine* of October 1958 entitled "Comparison of months giving extremes of rainfall during north-east monsoon at Changi, Singapore Island". Is is mentioned in the article that at Changi, Singapore, a total of 35·91 inches of rain was recorded in December 1954. This is 3½ times the 54-year mean for December (10·22 inches).

It is significant that in January 1955 an exceptional total of 37·10 inches of rain was recorded at Mahe, Seychelles, this being 2½ times the 54-year mean for January (14·64 inches). Perhaps an analysis of the synoptic situation between Seychelles and Singapore for January 1955 will show that the exceptional rainfall of January 1955 at Mahe was closely associated with the exceptional rainfall of December 1954 at Changi, Singapore Island.

(signed) F. J. McGaw,
Observer-in-Charge.

In sending the letter Mr. Thompson states that there may be some truth in the suggested connexion but lack of information is likely to preclude any examination of the subject for many years. Mr. K. Bryant, the author of the original article, agrees that no detailed investigation of a connexion between weather in the Singapore and Seychelles areas is possible at present but that it is most likely to be found in the effect of the major extratropical pressure systems on the position of the northern and southern shearlines over the Indian Ocean.

WEATHER OF NOVEMBER 1959

Northern Hemisphere

Intense anticyclones were present for much of the month over western Russia and mean pressures were above average over a large area including Scandinavia, central and southern Europe east of 10°E and almost all of Russia. Anomalies reached the exceptionally large value of +18 millibars around Archangel and over the White Sea. The Iceland low was deeper than usual and had an extension south-eastwards towards France which gave negative anomalies of pressure over the British Isles and western Europe. In association with anomalies of up to −8 millibars over the north-east Atlantic and +18 millibars over north-west Russia there was an exceptionally strong mean southerly flow across the North Sea, Scandinavia and the Baltic. Both the polar anticyclone and the Azores anticyclone were more intense than usual. The latter was situated north-west of its normal position and an anomalous north-west to south-east orientation of the ridge across the Atlantic gave an area of positive pressure anomaly south-east of Newfoundland. A strong ridge over the Rockies gave anomalies of up to +8 millibars in the western United States of America. Cyclonic activity over the North Pacific was more vigorous than usual and the Aleutian low was 8 millibars deeper than average.

Over the British Isles and western Europe mean temperatures were a little above normal but in the Barents Sea area they were up to 5°C above average. Asia, north of 60°N, was also warmer than usual due to the strong advection of relatively warm air around the anticyclones over western Russia. Further south in Asia and in most areas of North America it was a colder month than usual, probably because of the predominance of anticyclonic conditions over a snow-covered surface.

The rainfall distribution over Europe was rather irregular and not easily described. Along the eastern seaboard of North America and at many places in the interior of the continent it was a wetter month than usual, but totals were below normal along the entire west coast from Alaska to Central America and also over much of northern Canada.

WEATHER OF DECEMBER 1959

Northern Hemisphere

One of the outstanding features of the month was the vigour of the circulation over the whole hemisphere. In particular, cyclonic activity over the Atlantic was very intense and the Iceland low on the mean pressure chart was about 12 millibars deeper than usual. As it was centred south-east of its usual position there were pressure anomalies of as much as −15 millibars over the north-east Atlantic. The Siberian high was 6 millibars more intense than usual but over north-west Russia mean pressures were up to 12 millibars above average. As in November, there was an exceptionally strong mean southerly flow across Scandinavia and the Baltic. The Aleutian low had two centres; one, over the Kamchatka peninsula, was about the usual depth while the other, in the north of the Gulf of Alaska, was 5 millibars deeper than usual. Over North America, apart from Alaska and the extreme north-west of Canada, mean pressures were above normal. The largest anomalies, +7 milibars, occurred east of Hudson Bay where an anticyclone had remained almost stationary throughout the second half of the month. A few deep depressions were present in unusually high latitudes north of Siberia and on the mean pressure chart a low was centred close to the pole where anomalies were −15 millibars.

With vigorous cyclonic activity and a strong southerly flow over much of Europe mean temperatures were above normal in most places. Anomalies were +1° or +2°C over wide areas and reached +4°C in the Balkans where a predominantly south-westerly flow replaced the usual south-easterly one. The cold régime which was established in the late autumn continued across Siberia and Europe east of the Baltic. In Finland mean temperatures were 3°C below average, while farther south near the Caspian Sea it was as much as 5°C colder than usual. Over North America it was unusually warm almost everywhere; anomalies in many places were large and reached +8°C in central Canada. This pattern was completely different from that in November when negative anomalies predominated. The change was apparently a consequence of warm air advection over the Rockies in association with vigorous cyclonic activity over the North Pacific, southerly advection over much of the continent when pressure was high over eastern Canada, and continued subsidence.

At the beginning of the month extremely stormy weather was experienced in southern Europe. Strong winds and prolonged heavy rain were reported from Spain, France and Italy and there were heavy falls of snow and landslides in parts of the Alps. On the night of 2 December, after three days of almost continuous rain on the French Riviera, the Frejus dam collapsed following the rise of water in the reservoir to an abnormal height. Much property and many lives were lost in the ensuing floods.

WEATHER OF DECEMBER 1959

Great Britain and Northern Ireland

For most of the first week winds over the British Isles were westerly and mainly light, but fresh to strong easterly winds, associated with a low pressure area near the Bay of Biscay, persisted over much of the country from the 6th until the 11th. A succession of Atlantic depressions, moving eastwards to the north of Scotland, maintained very unsettled weather during the second half of the month with periods of heavy rain and strong to gale force winds.

Fog over much of England on the 1st was dispersed the following morning by increasing winds ahead of a fast-moving depression, and weather became generally unsettled during the next few days with rain in most districts, although fog returned to the Forth–Clyde Valley later on the 3rd and persisted for about 36 hours. A deep depression approached from the south-west on the 6th bringing heavy rain and gales to many parts of southern England; falls of more than two inches in 24 hours occurred locally in South Wales, Somerset and Devon.

Widespread rain and gales continued in many districts during the next two days as the depression moved northwards to the Irish Sea. The depression filled on the 9th but another formed in the Bay of Biscay. Winds over the British Isles backed from south-east to east and there was a marked fall of temperature with some sleet or snow over high ground in the north.

On the 12th a ridge of high pressure extended north-eastwards across the country from the Azores to Scandinavia and the following morning there was frost and fog over much of central and southern England. The fog was short-lived, however, as on the 13th an intense depression off the north-west of the British Isles deepened still further as it moved north-east and weather became milder with widespread rain and gales. In north-west Scotland the gales were severe with gusts of 70–80 knots. A temporary lull brought a return of the foggy conditions to many districts on the 15th, but late the next day an active depression deepened as it approached north-west Scotland and this proved to be the beginning of a very unsettled period, which lasted for most of the remainder of the month, with strong winds accompanied by frequent rain or squally showers and above average temperature; on the 19th and 20th the temperature reached the middle fifties at a number of places.

During the last ten days of the month deep depressions moved towards Scotland from the west and associated fronts brought rain or showers to most districts accompanied by strong to gale force winds. The showers were heavy and squally at times with local hail and thunderstorms. Rainfall was unusually heavy in southern England and the Lake District during the Christmas period and in Scotland at the end of the month.

December was a mild month generally with mean day temperature 1–2°F above average in the north and about 3°F above average in the south. Sunshine was very variable, being above average in parts of the Midlands but less than half the average in some south-eastern coastal districts. Over England and Wales it was the wettest December since 1934 with rainfall 181 per cent of the 1916–50 average. Over Scotland and Northern Ireland rainfall was 141 and 132 per cent of the average respectively.

The gales and rain badly delayed outdoor work and upset many winter planting programmes; in some districts work had to be left over until the spring. Ploughing and pruning operations, however, were not badly affected. Sprouts were generally poor owing to aphis damage but rain cleaned the later crops to a certain extent. Christmas trees were good and plentiful but the holly was almost devoid of berries.