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MR. R. H. MATHEWS, O.B.E., B.A.

After nearly 40 years of Government service, Mr. R. H. Mathews, Assistant Director for Climatology, retired from the Meteorological Office on January 31, 1953. Having graduated with honours in mathematics at East London College, University of London, Mr. Mathews started his career in September 1913 in the Customs and Excise Department. Came World War I, and in August 1917 he was released for active service in the Gunners. On demobilization in January 1919 Mr. Mathews returned to Excise duties, but on April 1, 1920, he transferred to an appointment as Junior Professional Assistant in the Meteorological Office.

After a period of training in outstation work at the R.A.F. School of Navigation at Calshot, Mr. Mathews was posted to the Forecast Division, where he was concerned with meeting the meteorological requirements for the civil air routes to the Continent. With the increasing demands for forecasting facilities from the R.A.F., it became necessary early in 1922 to provide a 24-hr. roster for Service and civil aviation, and M.O.6, which was then the Aviation Branch, was expanded to meet this requirement. As a Senior Professional Assistant Mr. Mathews served on the M.O.6 roster until November 1928. It was during this period that, in collaboration with Mr. H. L. B. Tarrant, Mr. Mathews organized the Meteorological Office Social and Sports Club, and himself played in the Meteorological Office football team which won the Air Ministry Championship year after year.

At the end of 1928 Mr. Mathews was posted to Leuchars, another R.A.F. station, where, to gain yet more experience in meeting the ever increasing demands of military aviation, he took full advantage of the opportunity to make familiarization flights. It is of interest to note that it was at Leuchars that "sferic" observations were first made by the Meteorological Office. Using radio direction-finding equipment designed by the now famous Sir Robert Watson Watt with teams at Leuchars and Datchet, the pioneer work on thunderstorm location was started. By contributing to the success of this work, Mr. Mathews assisted in no small degree in laying the foundations of the elaborate programme of "sferic" observations which we maintain today.

At the end of 1933 Mr. Mathews volunteered for duty in Iraq, and, as Assistant Superintendent, went to Hinaidi to take charge of the meteorological office there which served civil airlines as well as the R.A.F. This post enabled Mr. Mathews to acquire a knowledge of staff work which was to stand him in good stead in the exacting years of World War II. During this period plans were made by the Iraq Government for the establishment of an Iraq Meteorological Service, and in May 1936 Mr. Mathews accepted an invitation to inaugurate the Service as its first Director. He remained in Iraq for a three-year tour. Here he was nick-named "the Gremlin" by the R.A.F.—a name which stuck to him to the end of his service with the R.A.F.

In January 1937 Mr. Mathews was posted as officer-in-charge of the meteorological office at the R.A.F. Cadet College, Cranwell, where for over a year he maintained the high standard which had already been set by his predecessors for inculcating in the minds of the cadets, destined to be the R.A.F. Commanding Officers of the future, the necessity of being "weather conscious". With the increasing menace of Hitlerism in the troubled days before World War II, a considerable expansion of the R.A.F. was planned. Part of this expansion included the creation of a number of new Groups in Bomber Command. One of these was No. 5 Group, a Group which was to become famous during the war for its precision bombing. Mr Mathews was posted to Grantham as Senior Meteorological Officer of No. 5 Group in March 1938. It was in this capacity, in which he served until shortly after VE Day, that he was able to put to such good use the long experience which he had acquired over the years of providing meteorological information and guidance to the R.A.F. All will have heard of the "dam-busting" and other valiant achievements of the squadrons in No. 5 Group, but many may not have realized how much the success of these efforts depended on the harmonious team work and mutual understanding of meteorological and operations staff which Mr. Mathews excelled in developing. It was in No. 5 Group that, under the direction of such brilliant Commanders as "Bomber" Harris, Slessor and Cochrane, the tactical use of weather, good and bad, was again and again employed in bomber operations with such gratifying results, and it was for his contribution to the planning of such operations that Mr. Mathews was appointed an O.B.E. in 1943. With promotion to Principal Technical Officer and Acting Group Captain in May 1945, Mr. Mathews was assigned for meteorological duties in connexion with the planning of a special operation overseas in which No. 5 Group was to take part, but the ending of World War II rendered this operation unnecessary.

In November 1945 Mr. Mathews became Chief Meteorological Officer, Transport Command, under his old chief, Sir Ralph Cochrane. Four years at H.Q. Transport Command, which included several flights overseas, saw the end of his long association with the R.A.F., and in January 1949 Mr. Mathews took up office at Harrow on promotion to Assistant Director in charge of climatology.

In this new capacity he piloted the publication of the "Climatological atlas of the British Isles" which, owing to the war, had been so long delayed. During his four years at Harrow, Mr. Mathews took a very special interest in the welfare of his staff, and fathered, with much success, the social and sports activities of all the staff at Harrow.

At a ceremony in Victory House on January 30 the Director expressed the good wishes of the staff of the Office to Mr. Mathews, and presented him on their behalf with a cheque for buying a greenhouse, an inscribed copy of the

"Climatological atlas of the British Isles" and an album of signatures. The Director referred to the high opinion of Mr. Mathews's work expressed by high R.A.F. officers, and to his genial personality and ability to get the best out of his staff. Mr. Mathews, in reply, paid tribute to the zeal, friendliness, and cordial collaboration between all ranks which prevailed in the Meteorological Office, and referred to the need for constant encouragement of the junior staff on the quality of whose work the success of the Office as a whole was dependent.

LONDON FOG OF DECEMBER 5–8, 1952

By C. K. M. DOUGLAS, B.A. and K. H. STEWART, Ph.D.

Fog was fairly widespread over eastern England during the period December 5–8, 1952. The fog was thickest in the London Basin in which visibility over large areas was below 20 yd. for many hours on end and was often below 10 yd.

The primary cause of the persistent dense fog was the complete absence of any pressure gradient for an exceptionally long period. All the observations in the London area on December 5–7 reported almost nothing but calm, and the absence of wind was not confined to the Thames Valley but was also very noticeable on adjacent high ground. Very sluggish air movement due to drainage may have affected the details of fog density, but even the most detailed synoptic charts throw no light on this problem. Precisely how rare the prolonged calm was could only be found from wind statistics. At first sight it may seem surprising that it should be rare, in view of the frequency of quasi-stationary anticyclones and belts of high pressure, but a closer examination of such cases shows that the region of complete calm rarely remains stationary for long. Small irregular movements of the centre or ridge are frequent, with small pressure changes close to the centre of the same sign as larger changes in the periphery zone. A geostrophic wind of only 10 kt. may be important in relation to the persistence of very dense fog, as distinct from fog of a more normal type, and a very light wind did in fact give rise to a temporary improvement on December 8.

The anticyclone reached the London area from the north-west in the early hours of December 5 and then became stationary. The situation at 1800 on the 6th is shown in Fig. 1. The western end of the belt of high pressure can be regarded as the original anticyclone, and the eastern end as another and more mobile system. Though pressure remained high in that area for some days, there was no region of prolonged calm. The pressure on the Continent did not rise high enough to produce a southerly gradient in the London area, and at Manston and Felixstowe the pressure on December 6–8 was on the whole identical with that over London Airport. The thickness pattern on the chart showed a pronounced thermal wedge to the west of Ireland, which was unfavourable for any development of the sea-level trough off our north-west coasts. The thermal gradient over south-east England was weak, and the axis of the ridge remained stationary over the London area till December 8, and on that day it was somewhere near the North Downs.

The air mass originated in high latitudes, but it was over open water between December 1 and 4, and though it was cold and dry these features were less pronounced than on some days with N. or NW. winds in December 1950, and again on December 15, 1952. The air which was over London on the 5th had

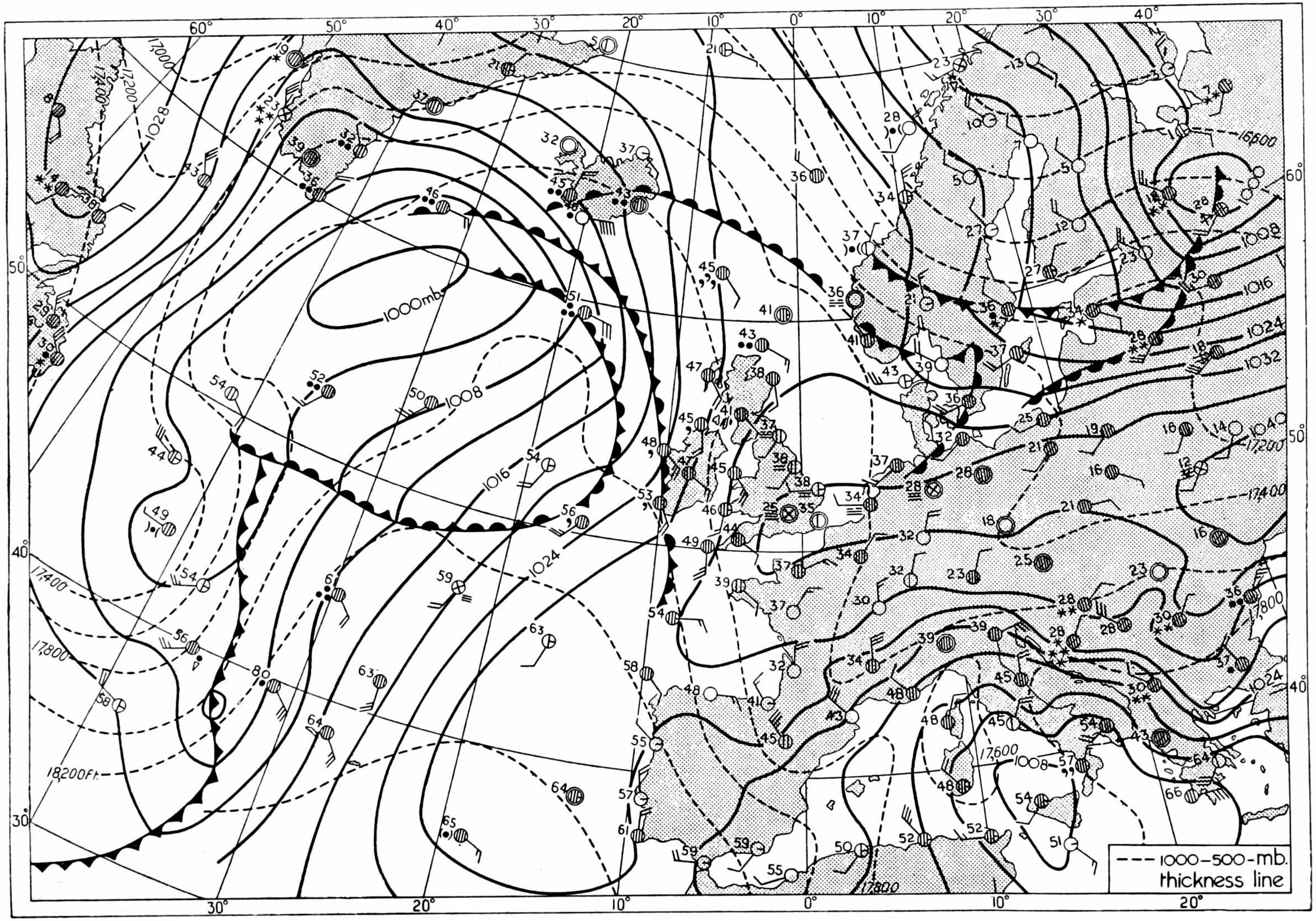
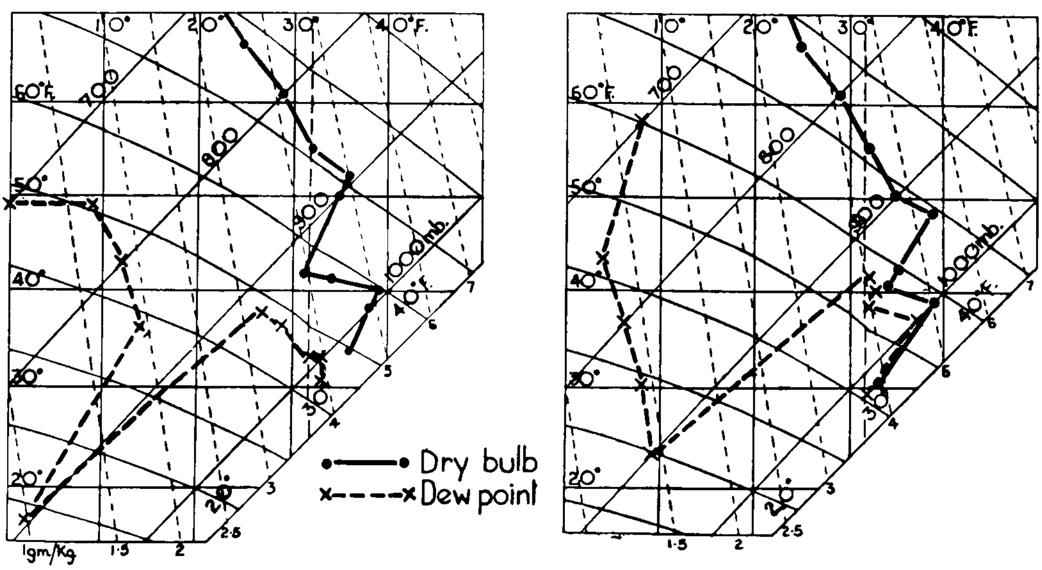


FIG. 1—SYNOPTIC CHART, 1800 G.M.T., DECEMBER 6, 1952

given inland maxima of about 40°F. on the 4th with dew points about or a little below freezing point. There were some stratocumulus clouds on the 4th, but the clear skies on the axis of the ridge on the 5th–8th were almost inevitable in the absence of thicker and more general previously existing clouds. The fog on the 5th was mainly an urban fog, but on the next three days there was dense rime-producing water fog extending to rural areas. The photograph facing p. 81, reproduced from *The Times*, shows the shallow nature of the fog in the region of Box Hill; Ranmore Common (616 ft. above M.S.L.) was clear of the fog. The 400-ft. hills to the north of London were well covered with fog to beyond St. Albans. By about 11 a.m. the fog in the higher rural areas cleared to mist with weak sunshine, but this does not necessarily imply that a comparable clearance would have occurred in the Thames Valley in the absence of smoke, taking into account the shortness of the days and the low elevation of the sun. A light wind brought an improvement to much of London on the 8th, but the fog was again very dense in the evening and night. On the 9th there was a general SW. wind of force 2–3, but in the north-east districts of London the fog was slow to clear.

The coldest days were December 6 and 7 when London Airport had minima of 23° and 22°F. and maxima of 29° and 31°F. In central London the temperature, as would be expected, was not so low with minima some 6°F. and maxima 2 – 3°F. higher.



0300 G.M.T., December 6, 1952   0300 G.M.T., December 7, 1952

FIG. 2—TEPHIGRAMS OF RADIO-SONDE ASCENTS AT LARKHILL

On December 5 and 6 the subsidence inversion at Larkhill and Hemsby was distinct from the surface radiation inversion, but by the 7th the two inversions were closer together, and in the London area this process may well have been more complete. The 0300 soundings at Larkhill on December 6 and 7 are reproduced in Fig. 2; the dew points below the main inversion were affected by advection from the English Channel, especially on the 7th, and cannot be regarded as representative of the air over London.

A low subsidence inversion increases stability, and the dryness aloft favours radiation from the top of the fog, but if the dry air comes exceptionally low a light wind may dissipate the fog. It is possible that this happened on December 8 when the improvement began remarkably early in parts of London. There was better evidence for it on December 26, 1944, when the fog cleared over a large area and the air was very transparent above 400 ft. More recently, a similar development occurred in parts of southern England on January 20, 1953.

Taking into account both density and duration, the only closely comparable fog in the London area in recent decades was that of November 27–December 1, 1948. The foggy spell of November 22–27, 1936, was more prolonged but the fog was for the most part not of comparable density on low ground, mainly owing to its greater thickness in the vertical. The 1948 fog was associated with an anticyclone which spread from the Continent, and on November 28–30 the pressure distribution over much of England resembled that in the recent foggy period, though it developed quite differently. In the earlier period the fog was far more extensive, the temperature and water content were higher, and the inversion (the amalgamated ground radiation and subsidence inversions) was much larger. When a southerly geostrophic wind of 17 kt. developed on December 1 the fog cleared quickly in London, except locally in the north, but much more slowly in parts of northern England where the air had traversed a large area of comparatively level country, though the gradient there was stronger.

There was an even longer spell of dense and persistent fog in the Glasgow area on November 16–21, 1925. The geostrophic wind was not so persistently low as in the case of the two prolonged London fogs, but the local topography in the Clyde Valley favours a dense fog with almost no surface wind even with an appreciable geostrophic wind from certain directions. In the London area the Downs are a barrier against S. winds, but its effectiveness is limited, though of course it varies according to the strength of the temperature inversion.

The prolonged calm inversion conditions which brought fog also led, of course, to high concentrations of smoke and other atmospheric pollution in and around the built-up area of London. The average smoke content (as measured by filter-paper gauges) for the 6th and 7th at stations in central London ranged from 2 to 4 mgm./m.^{3}, and the concentration of sulphur dioxide was about one part per million of air. These values are some 10–15 times the normal (non-foggy) December ones. The smoke content at Kew Observatory, where it is measured every hour, rose to a maximum of over 2·3 mgm./m.^{3} in the late evening of the 5th, but fell to somewhat lower values on the succeeding days.

These amounts of pollution are not exceptional for foggy weather although they are large by comparison with average winter conditions, and are quite high enough to account for the obvious dirtiness and general unpleasantness of the fog. The direct effect of the pollution on visibility must have been small; in order to get visibilities as low as 5 yd. there must be at least 200 mgm./m.^{3} of suspended matter in the air, and since "smoke" contributed at most only 4 mgm./m.^{3} it is clear that at least 98 per cent. of the suspended matter was made up of the water droplets of the fog. It is likely, however, that the atmospheric pollution had important indirect effects in reducing the visibility. By providing an abundance of nuclei for the formation of water droplets, the pollution probably caused the droplets of the London fog to be smaller, more numerous and more stable than those of the fog in the surrounding country, and so produced a denser and less easily cleared fog. That some such mechanism must operate is clear from climatological maps, which show maximum frequencies of fog and dense fog in industrial areas. The present case, however, is not an ideal one in which to study the mechanism, because the area in which pollution favoured fog coincided very closely with that where synoptic conditions favoured it too.

A detailed investigation of the fog is being made by the Meteorological Office.

GALE OF DECEMBER 17, 1952

By C. K. M. DOUGLAS, B.A.

A very severe gale was experienced over Scotland and northern England on December 17, 1952. A number of walls and chimneys were blown down and roofs damaged over a wide area. The damage seems to have been particularly heavy in Lancashire and the Isle of Man.

The chart for 0600 on December 17 is reproduced in Fig. 1, and includes the track of the centre, which split into two portions after 1800 on the 16th, one centre moving eastward between Orkney and Shetland, and the other moving south-east over Scotland. This is shown as a separate centre on some of the hourly charts, but not on all, owing to topographical complications. The depression was complex in its early stages, and seems to have been composed of two systems which both formed near south Greenland. For this reason the movement of the centre of gravity of the system was rather slow in its warm-sector stage, although there was a fairly strong thermal wind over a wide belt. By 0600 on the 16th its central pressure had fallen to 974 mb. and it was just becoming occluded. Pressure fell to 960·9 mb. at Sule Skerry at 0300 on the 17th, but by 0600 the northern centre was beginning to lose depth. Subsequently the northern centre filled quickly and the southern one moved south-east and filled less rapidly, but by 0600 on the 18th it had a central pressure of 990 mb. Between this depression and an advancing ridge of high pressure to westward, with its crest at 26°W. at 0600 on the 17th, there was a steep NW.–N. gradient wind with an exceptional concentration of isobars in the neighbourhood of the Hebrides. The gale spread south-eastwards, but owing to the filling of the depression it had lost its severity by the time it reached southern England.

The anemogram for Bidston, Liverpool, shows an hourly mean wind of 45 kt. (52 m.p.h.) between 0800 and 0900 and the mean was not often below 43 kt. (50 m.p.h.) between 0700 and 1400. Gusts exceeding 70 kt. (80 m.p.h.) occurred in all hours between 0650 and 1530; the highest was 75 kt. (86 m.p.h.) at 1320. At Stornoway the mean speed was 55 kt. from 0400 to 0500 and about 52 kt. between 0330 and 0700. There were many gusts exceeding 70 kt., and the highest was 80 kt. at 0450.

In addition to the general gale, there was a most extraordinary gust of 96 kt. (111 m.p.h.) during a brief squall at Cranwell at 0640 in the morning, shown in Fig. 2. During this unique gust the anemometer pen was being watched by two observers, Mr. R. Needham and Mr. K. Hodgson. There were four gusts of 57 kt. just before it, and several of 53–63 kt. just after it. During the

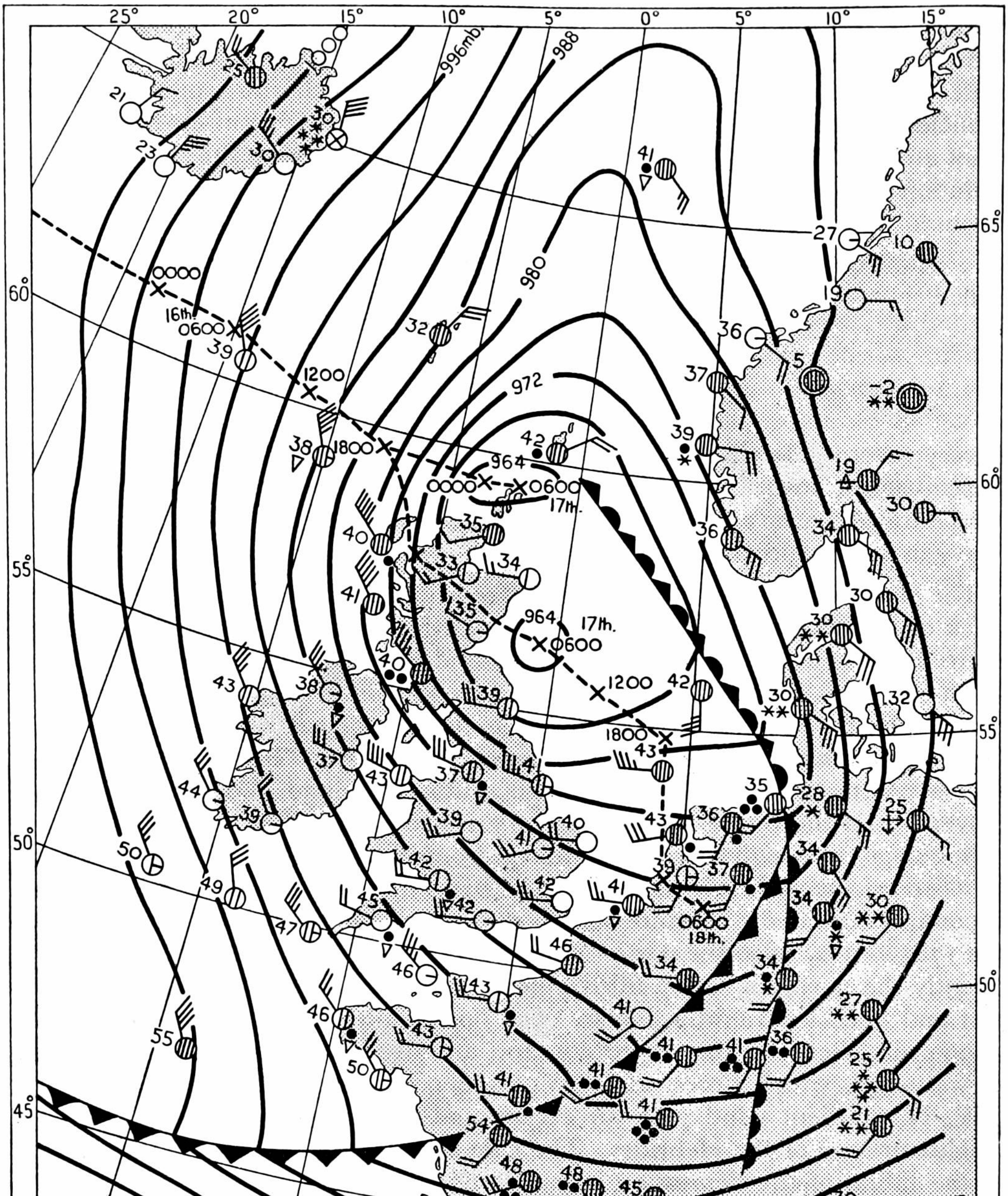


FIG. 1—SYNOPTIC CHART, 0600 G.M.T., DECEMBER 17, 1952

squall pressure rose 1·5 mb. in 5 min. and 0·8 mm. of rain fell in just over 5 min. at a rate of 10 mm./hr. The rainfall trace is given in Fig. 3. Mr. J. Newton, the Meteorological Officer at Cranwell, was approaching the office in his car at the time and it was almost blown off the road. He describes the shower as a "wall of water" which suggests that a descending squall was somehow concentrated into an exceptionally narrow zone. The writer has no

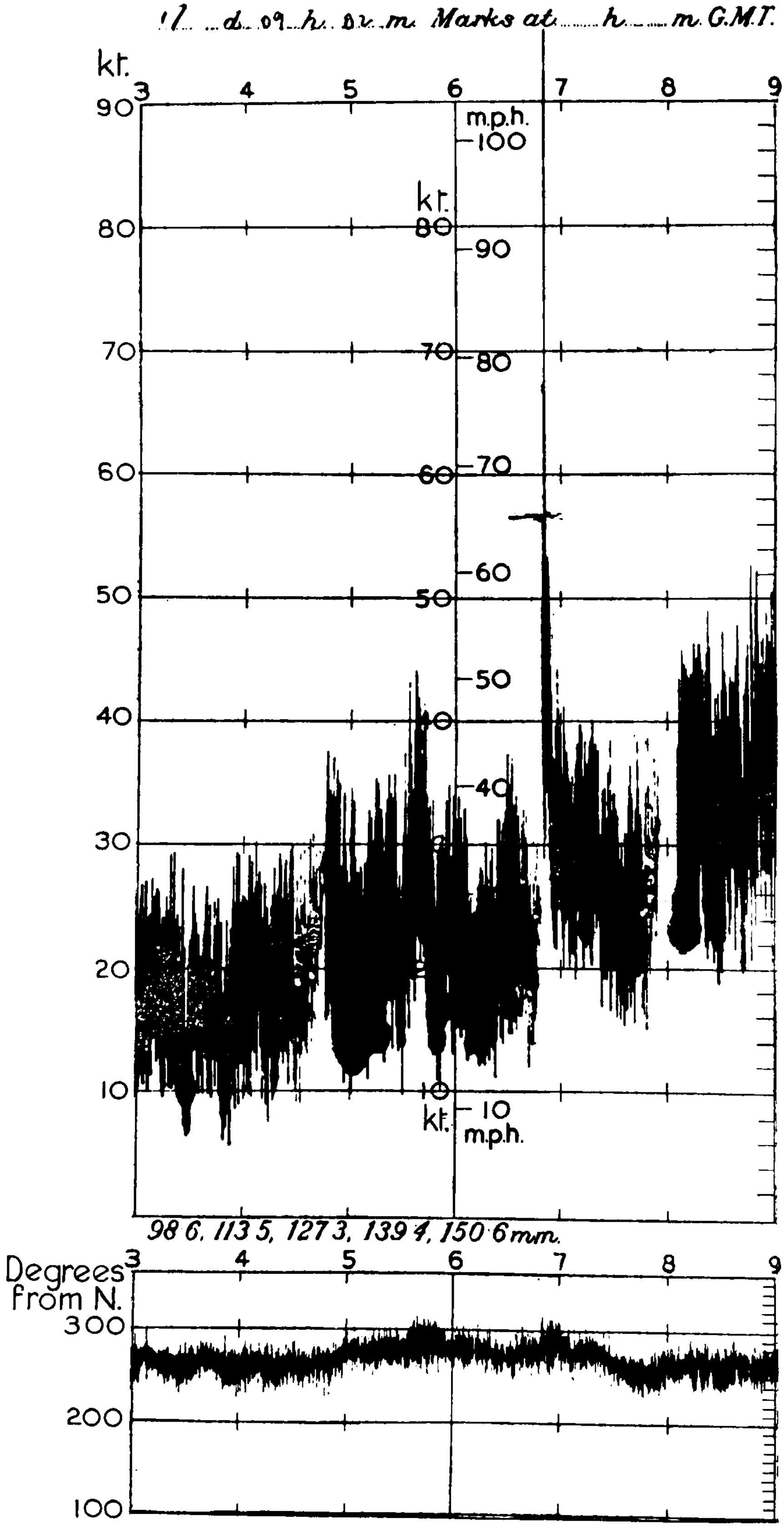


FIG. 2—ANEMOGRAM FROM CRANWELL, DECEMBER 17, 1952

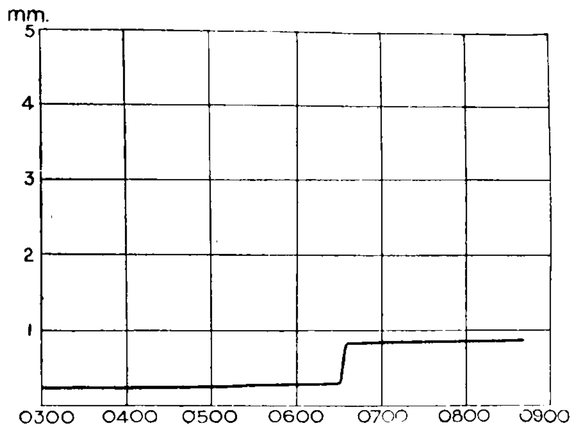


FIG. 3—HYETOGRAM FROM CRANWELL, DECEMBER 17, 1952

knowledge of anything closely similar having been recorded in this country. The squall occurred well ahead of the main gale, but the geostrophic wind was up to about 70 kt. There was a small trough of low pressure, but such troughs are very characteristic of unstable currents. The Hemsby wind sounding at 0900 showed a speed of only 46 kt. at 2,000 ft. increasing to 57 kt. at 5,000 ft., but decreasing to 31 kt. at 14,000 ft., then increasing to 69 kt. at 27,000 ft.

FÖHN TEMPERATURE IN SCOTLAND

By E. N. LAWRENCE, B.Sc.

In the May 1952 *Meteorological Magazine*[1], there was a description of an example of the föhn effect over Scotland. That the gain in air temperature in the case described was only 5°F. was probably due mainly to the fact that the air before the uplift was far from saturation point (precipitation is presumed to occur on windward slopes) and partially to the gradient wind being south-easterly rather than south-westerly with the lesser likelihood of a great proportion of the air being lifted to a height about that of the Cairngorms.

The following example, which occurred on February 18, 1945, shows a temperature of at least 60°F. in north-east Scotland at 0300, a time which precludes any insolation. The moist south-westerly air stream had almost a maximum length of mountainous track over the Grampians, and precipitation was widespread on western slopes.

From the morning of February 15, 1945, (or earlier) until the morning of the 18th, a south-westerly air stream from the Azores to Scotland persisted. The average pressure gradient for this period was sufficiently high to bring air from the vicinity of the Azores to Scotland. Throughout this period the North Atlantic was covered by a complex low-pressure area between the winter anticyclones of Eurasia and North America. On the morning of the 18th, the main depression was centred just south of Iceland with its warm sector extending south-east from the centre and covering the whole of the British Isles. There was a double cold front, but neither front was associated with any significant wind veer (or marked change in surface air) and the south-westerly air stream extended from the Azores to the British Isles. Between the Azores and Newfoundland, a further young depression was moving eastwards. Fig. 1 shows the situation at 0300 on February 18, 1945.

Theoretical estimates of the dry-bulb temperature and dew point at Dallachy, Morayshire (57°39′25″N., 3°04′00″W., 37 ft.), have been calculated from the Aldergrove radio-sonde ascent (see Fig. 2) on the assumption that air represented by the Aldergrove radio-sonde ascent at 1700 on February 17 reached the area of Dallachy at about 0300 on the 18th, and that the average mechanical uplift of air due to the mountains was 3,000 ft. The latter is a reasonable assumption as much of the land in the vicinity of the track is over

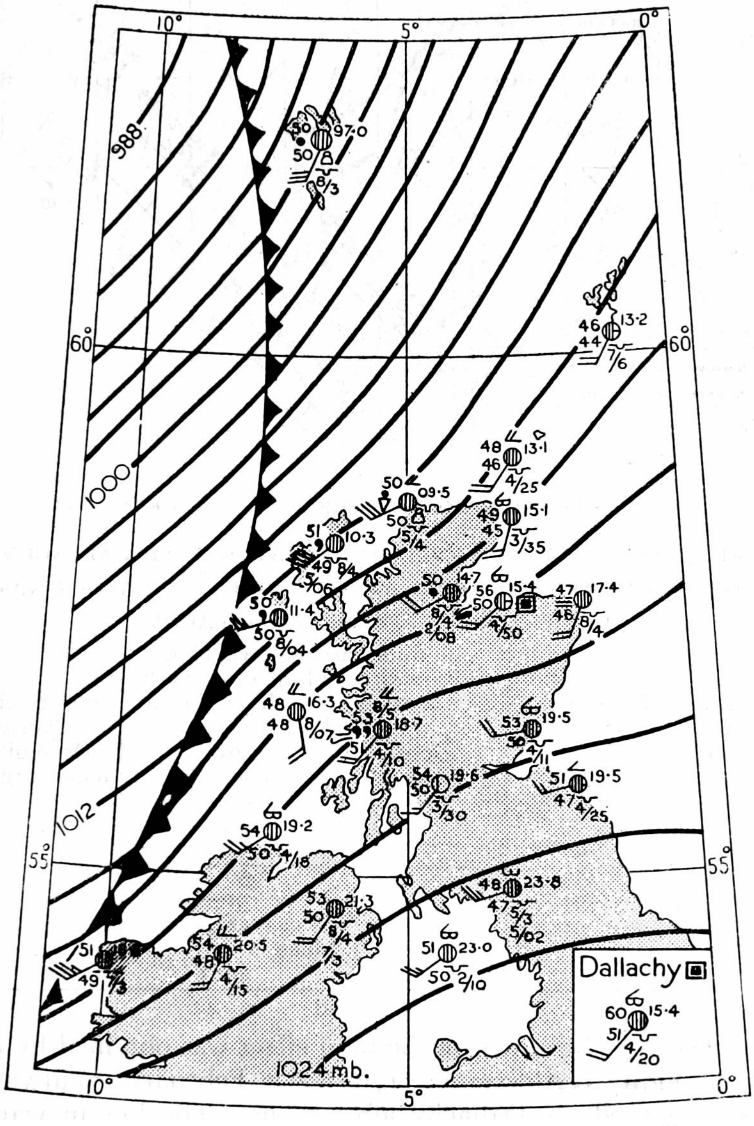


FIG. 1—SYNOPTIC CHART, 0300 G.M.T., FEBRUARY 18, 1945

2,000 ft. and the highest points just over 4,000 ft. (see Figs. 3 and 4). Furthermore, the Aldergrove ascent shows that the air above 3,000 ft. was very stable, thus reducing turbulent mixing with layers of air above the mountain-top level. It was assumed that air at various levels was lifted mechanically to an average height of 3,000 ft., and that after saturation was reached further lifting resulted in precipitation. The air then descended at the dry adiabatic lapse rate. The results are given in Table I.

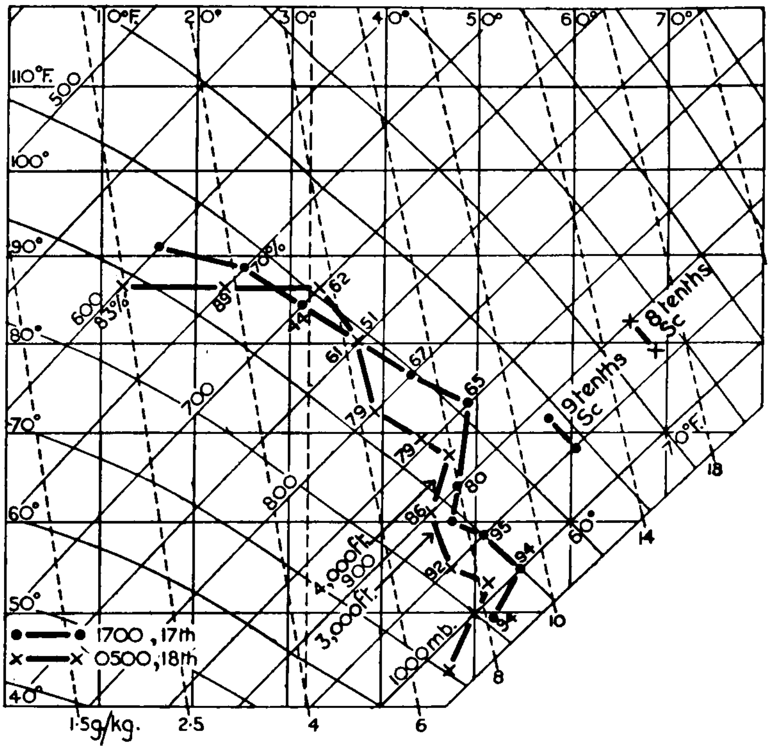


FIG. 2—TEPHIGRAMS OF ASCENTS AT ALDERGROVE

TABLE I—CALCULATED AND OBSERVED TEMPERATURES AT DALLACHY ASSUMING ASCENT OF AIR FROM VARIOUS LEVELS AT ALDERGROVE TO ABOUT 3,000 FT. AND DESCENT TO SURFACE AT DALLACHY

Conditions at Aldergrove 1700 G.M.T., February 17, 1945			Air from various levels above Aldergrove after lifting to 3,000 ft. and descending to the surface at Dallachy		Surface observation at Dallachy at 0300	
Pressure level	Temperature	Relative humidity	Dry-bulb temperature	Dew point	Dry-bulb temperature	Dew point
mb.	°F.	%	°F.	°F.	°F.	°F.
915	47	90*	62	50		
950	51	95	62	50		
1000	55	94	62	51		
1018	52	94	58	46		
			Mean			
			61	49·3	60	50·5

* Estimated

A further check on the extent of the föhn effect was obtained by comparing the absolute humidity at Aldergrove (1700 G.M.T. February 17) at various levels with values computed for Dallachy after lifting. The loss in water content produced by mechanical uplift was calculated and compared with the observed rainfall. For this calculation, it was assumed that the surface layer was lifted to a height of 2,500 ft., that at 8,000 ft. the air was undisturbed (vertically) by the orographic uplift, and that intermediate layers were lifted in inverse proportion to their height. The computation was carried out for the levels, 1000, 950, . . . 750 mb. and the values of the absolute humidity so obtained were subtracted from the corresponding values for Aldergrove, giving a difference in water content of approximately 0·95 gm./Kg. for the lowest 2,000 ft. and 0·45 gm./Kg. for the next 1,700 ft. and thereafter zero. Hence for a column

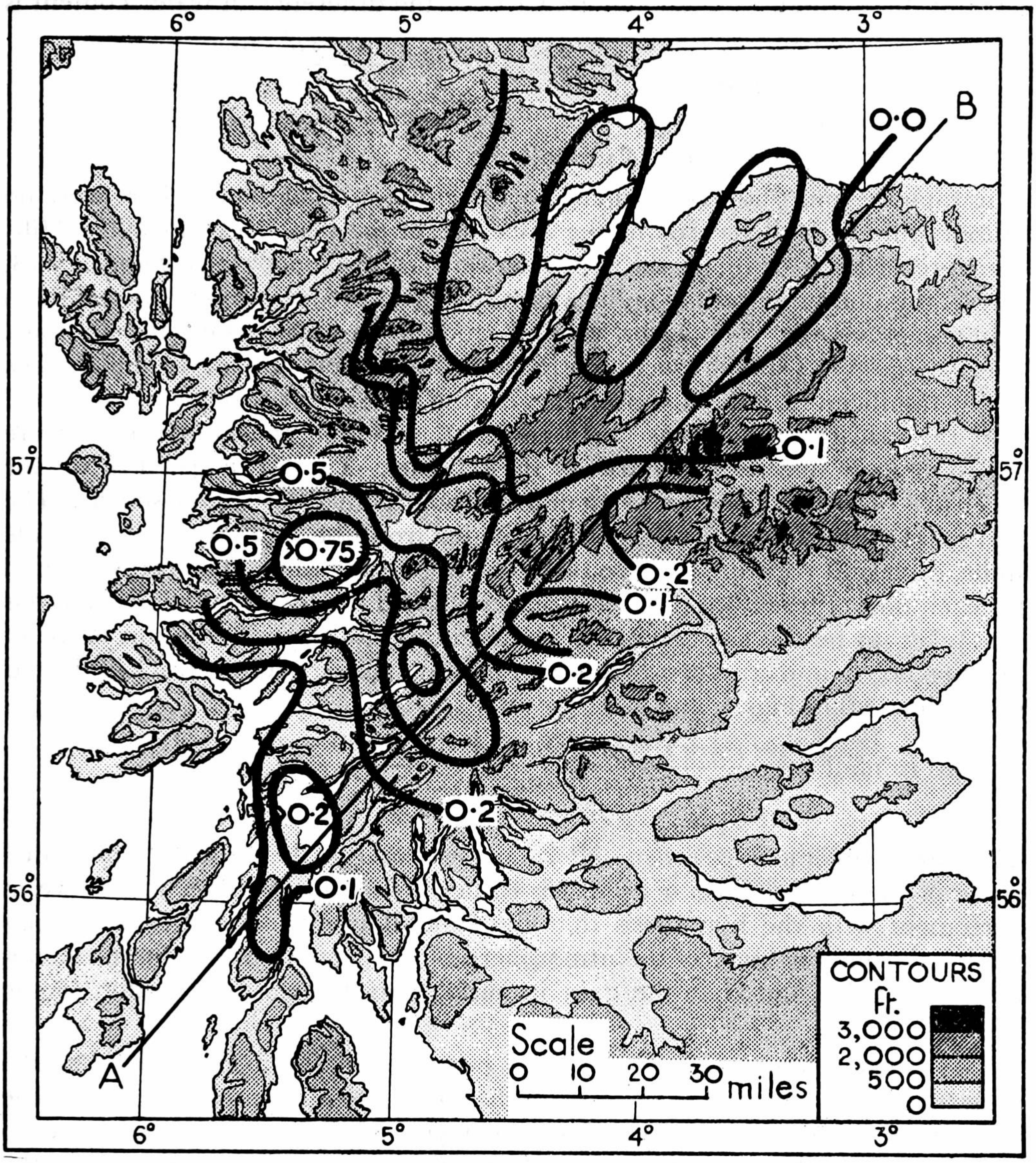


FIG. 3—RAINFALL OF FEBRUARY 17–18, 1945, OVER PART OF SCOTLAND

The rainfall measurements are given in inches

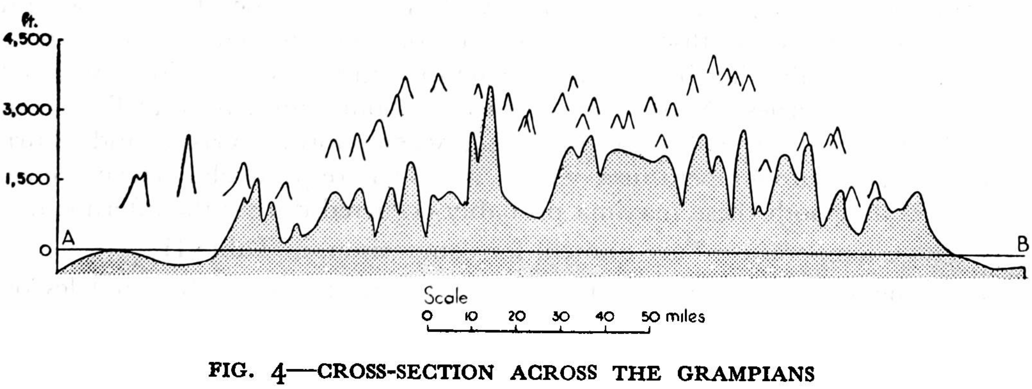


FIG. 4—CROSS-SECTION ACROSS THE GRAMPIANS

Mountain peaks within ten miles of the line AB are also indicated

8,000 ft. high and cross-sectional area 1 cm.[2] the difference in water content is

$$\frac{2000 \times 0\cdot95 + 1700 \times 0\cdot45}{1000} \times 30\cdot48 \times \frac{1\cdot2928 \text{ gm.}}{1000}$$

$= 0\cdot112$ gm.

$= 0\cdot04$ in. ($1\cdot12$ mm.) of rainfall.

This quantity must now be compared with actual rainfall data. There were no autographic rainfall records in the area except for Greenock (Prospect Hill) which recorded 0·01 in. for the 24-hr. period ending at 0900 G.M.T. February 18, but at this point orographic uplift was only slight. Hence recourse was made to rain-gauge records. The 24-hr. rainfall amounts in inches along the air track over Scotland to Dallachy were plotted and the isohyets drawn. In the absence of any significant frontal discontinuities during the 24-hr. period, it was assumed that the rate of rainfall was fairly constant, and that the hourly rates were approximately one twenty-fourth of these values. The mean speed of the air layer to 8,000 ft. was assessed as 30 m.p.h. (roughly the geostrophic speed). The 170 miles of track over Scotland were divided from the south-west into 30-mile units, each unit corresponding to one hour in journey time. The mean rainfall for each unit of track was assessed from Fig. 3 and the total for the six divisions was taken to be the assessment of the actual rainfall from a column of air of height 8,000 ft. and cross-sectional area 1 cm.[2] in passing over the track indicated by the line AB in Figs. 3 and 4.

$$\text{Thus rainfall} = \frac{0\cdot15 + 0\cdot39 + 0\cdot19 + 0\cdot13 + 0 + 0}{24} \text{ in.}$$

$= 0\cdot04$ in.

The close agreement between this quantity and the theoretically calculated value of the rainfall (also 0·04 in.) is rather fortuitous, but the figures are in agreement with the hypothesis that the rainfall was produced from a comparatively shallow layer of the atmosphere by orographic uplift due to mountainous terrain, and that the gain in surface air temperature is due to the föhn effect.

The above computation was carried out also on the assumption that the undisturbed level was at 4,000 ft., and that owing to air compression above the mountains the mean wind speed of the layer to 4,000 ft. was increased to 35 m.p.h. over the Scottish section of the track. Under these conditions the corresponding values for the calculated and observed amounts of rainfall were 0·03 in.

February 18, 1945, was associated with record temperature at several places in this area of north-east Scotland. Throughout the century (since 1901) for any time of the day in February, a temperature record of 60°F. was not exceeded at Inverness, Nairn, Gordon Castle (about 2 miles from Dallachy) or Aberdeen except on February 18, 1945, when Gordon Castle and Nairn reported maximum temperatures of 61°F. and 62°F. respectively. The evidence suggested that both these maxima probably occurred during the afternoon.

Average temperatures[2] are quoted, for comparison, in Table II.

That the south-westerly air stream over the north of the British Isles on February 18, 1945, was both unusually warm and moist may be seen from the following comparison between the air and sea temperatures[3] over the sea area to the west of Ireland and over the North-West Approaches for February and

TABLE II—AVERAGE MAXIMUM AND MINIMUM TEMPERATURE

	Temperature in February		Temperature in July	
	Average minimum	Average maximum	Average minimum	Average maximum
	°F.	°F.	°F.	°F.
Aberdeen	35·2	43·3	51·2	62·2
Wick	36·1	43·1	49·8	58·9
Gordon Castle ...	33·8	44·9	50·0	65·1

the observations of dry-bulb temperature and dew point respectively on the synoptic chart for 0000 on February 18, 1945.

Absolute maximum temperature observed at sea[3]:—

	Air temperature °F.	Sea temperature °F.
West of Ireland	52	51
North-West Approaches	52	49

Temperature observed at 0000 on February 18, 1945:—

	Air temperature °F.	Dew point °F.
Aldergrove	55	52
Oban	54	51

It might be expected that the frequency in winter of high temperature produced by föhn-effect situations would be quite high, because warm damp SW. winds are so frequent over north Scotland, particularly during the winter. On the occasion described the record temperatures were probably produced by the coincidence of an unusual vertical temperature distribution (inversion from 3,000–5,000 ft.) with extremely high temperature and dew point in the air over the Atlantic. The inversion is believed to have reduced mixing with drier air above, thereby increasing the amount of water condensed and the latent heat liberated in the uplifted air.

REFERENCES

1. MCCAFFERY, W. D. S.; Föhn effect over Scotland. *Met. Mag., London*, **81**, 1952, p. 151.
2. London, Meteorological Office. Averages of temperature for the British Isles for periods ending 1935. London, 1936.
3. London, Meteorological Office. Monthly meteorological charts, Home Waters. London, 1939.

HIGH-LEVEL CLOUD IN THE TROPICS

By C. S. DURST, B.A.

During a flight on March 18–19, 1952, in a Comet aircraft from Wadi Seidna airfield (Khartoum) to Entebbe and thence to Livingstone, it was observed that there appeared to be a continuous sheet of cirrus or cirrostratus at about 45,000–50,000 ft. extending from 10°40′N., 32°40′E. to 16°10′S., 27°30′E., a distance of over 1,600 nautical miles. Seen from between 30,000 and 35,000 ft. it looked very thin when observed at a small angle with the vertical, indeed it often could not be recognized above the aircraft, but when observed at a small angle of elevation it appeared quite definitely as a comparatively thick sheet all round the horizon with a layer of clearer air below.

On the return trip the first appearance of high cirrus, though not dense, was at 1220 G.M.T. on March 21 at about 15°S. The veil did not seem to be so continuous as on the outward trip but it was present at about 45,000 ft. At about 7°S. there was the appearance of a definite thin veil of cirrostratus far above the cirrus thrown off by large cumulonimbus with all the appearance of a clear layer in between. This persisted to about 3°S. On March 22 cirrus was seen above the aircraft soon after leaving Entebbe and appeared to be rather patchy until 6°N. However, at 7°N. there was no cirrus veil. The veil was renewed again between 9° and 10°N. but was again very patchy.

Some photographs of the cloud are reproduced in the centre of this magazine. I am informed by officers of the British Overseas Airways Corporation and others who have travelled by Comet in the tropics that this cirrus layer is the rule rather than the exception.

It has been the custom to think that cirrus cloud seen in the tropics was either directly associated with the cumulonimbus of the tropical thunderstorms, or was the residual cloud from these storms which persisted after the violent convection had ceased. But the great extent of the cirrus or cirrostratus, which in the case reported above extended for 1,600 nautical miles (and even beyond the limits of normal rainfall in March), makes it most improbable that it is to be attributed to the residual cloud of convectional storms.

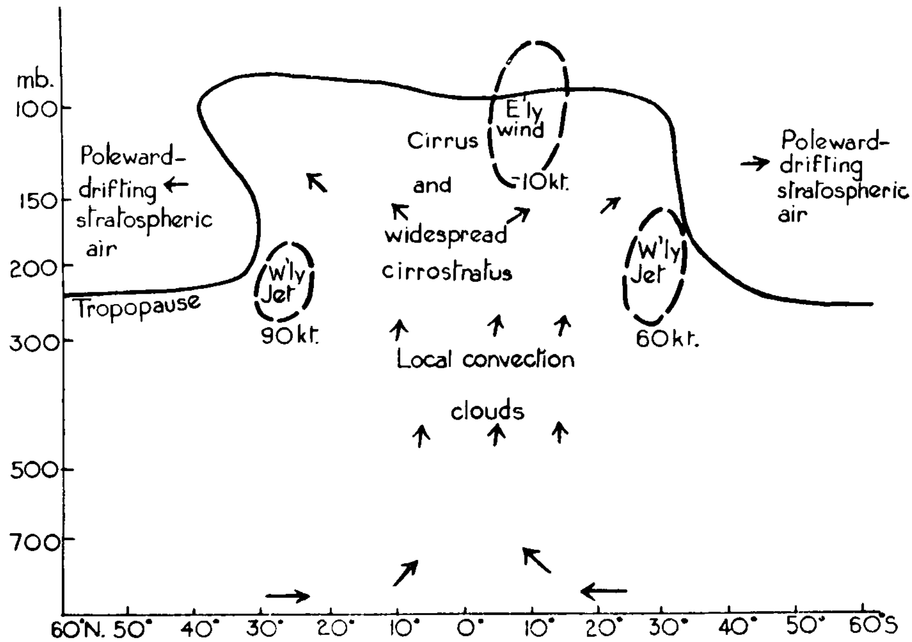


FIG. 1—SCHEMATIC DIAGRAM OF THE GENERAL VERTICAL CIRCULATION

The section of the atmosphere postulated by Frost[1] shows an abrupt rise in the normal level of the tropopause at about 30°N. and 30°S. at the equinoxes, the equatorial tropopause being above the 100-mb. level (say 55,000 ft.) the extratropical tropopause being below the 250-mb. level (say 35,000 ft.). At the positions where the tropopause starts to rise abruptly there are the two semi-permanent jet streams with maximum speeds at about 40,000 ft. (200 mb.). Moreover, it has been supposed that the general circulation of the atmosphere is such that air flows towards the equator near the surface, rises between the tropics and flows outwards high up in the atmosphere.

It is therefore suggested that the cirrus seen at high levels is the result of condensation as the intertropical air rises. When this suggestion was put

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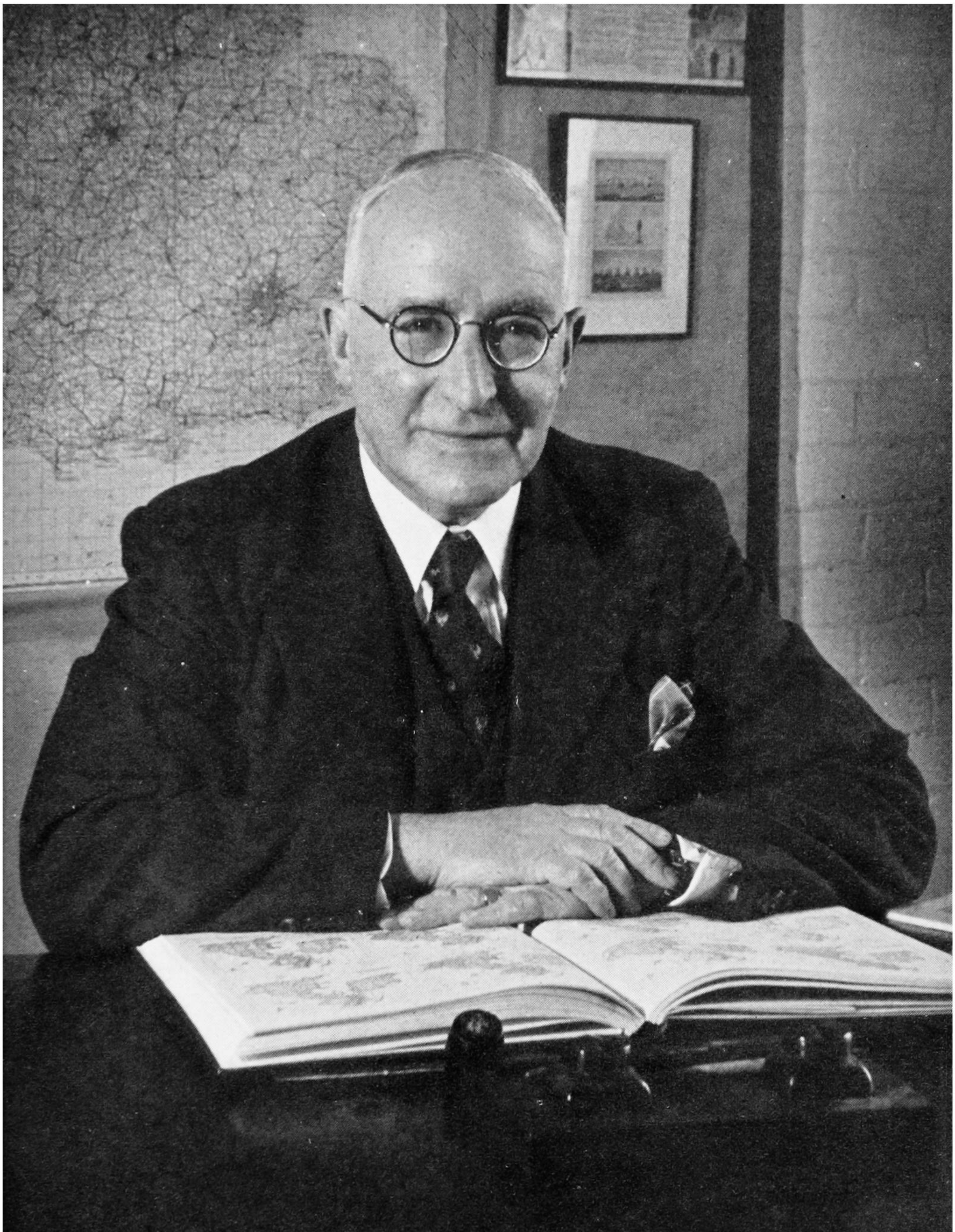

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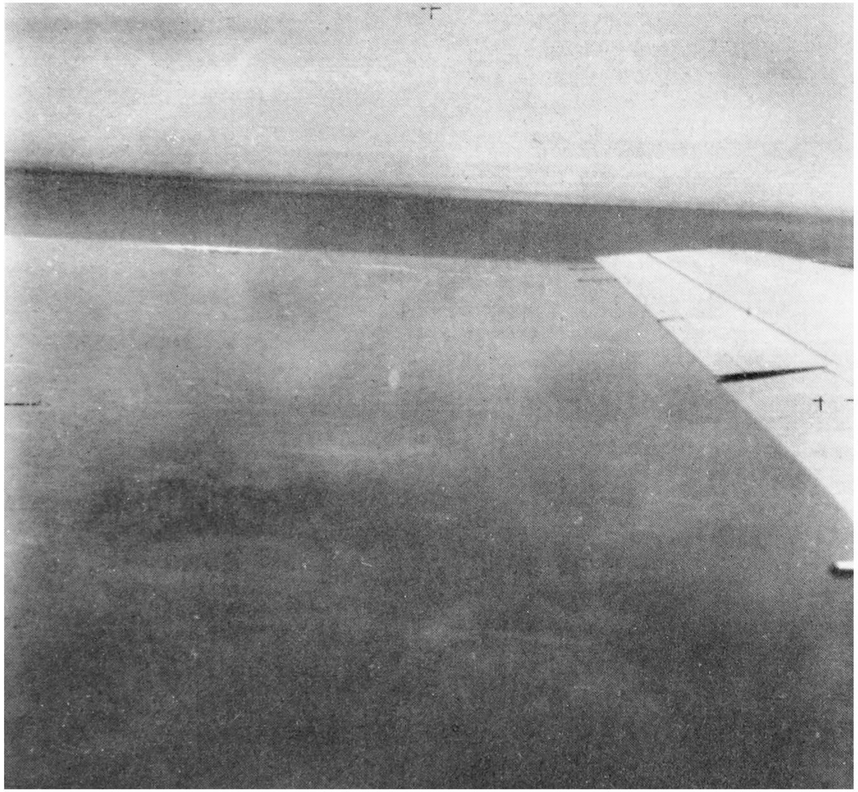
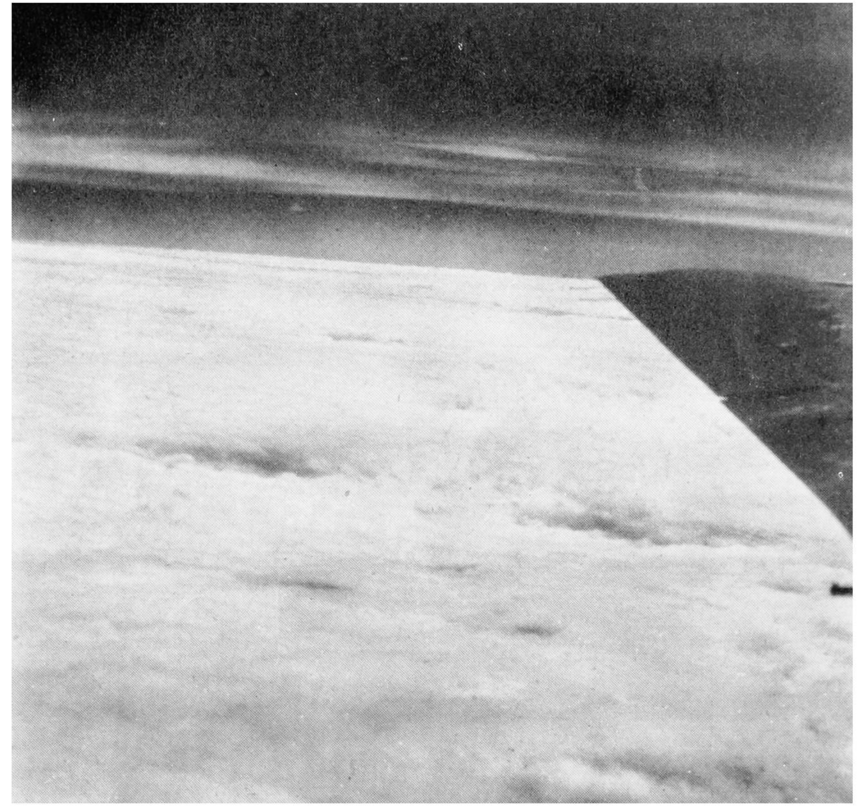
R. H. MATHEWS, O.B.E., B.A.



10°40′N. 32°40′E. from 32,500 ft. 0635 G.M.T., March 18, 1952

This photograph, taken over the Sudan, shows a dust haze stretching up to about 18,000 ft. with the top of a rising column revealed by a cloud at the top of the dust. Some 20,000 ft. above the top of the dust is the sheet of cirrostratus.

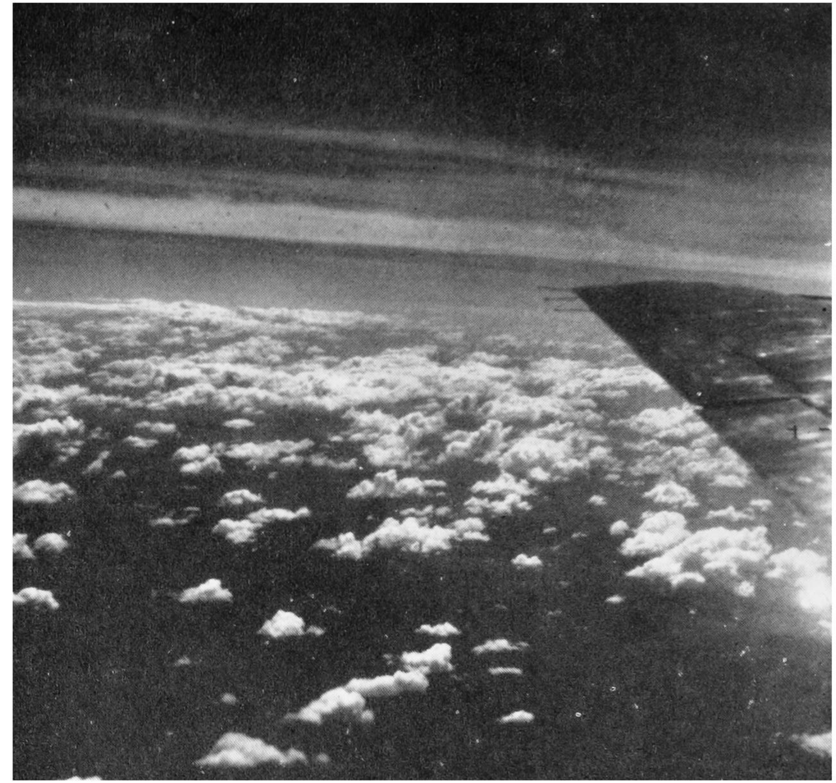


08°18′N. 32°45′E. from 33,000 ft. 0657 G.M.T., March 18, 1952

This photograph, taken over the Sudan, shows a sheet of altostratus or altocumulus cloud, one of a number of patches, an individual patch extending over some thousand square miles. The altocumulus layer has been measured at a height of about 16,500 ft. above M.S.L. Above can be seen the cirrus or cirrostratus layer, the height of which was estimated by eye to be 45,000 ft. or more.

04°20′S. 30°53′E. from 30,000 ft. 0736 G.M.T., March 19, 1952

This photograph shows a mass of cumulus and cumulonimbus cloud beneath. The aircraft had climbed through and past cumulus and cumulonimbus cloud over Lake Victoria and during the ten minutes preceding this photograph had passed by a big cumulonimbus head on the starboard side towering above the aircraft. Cirrus and cirrostratus had been passed through at 30,000 ft. Above these convectional clouds can be seen in the photograph the cirrus or cirrostratus far above the aircraft.



03°00′N. 33°00′E. from 34,600 ft. 0745 G.M.T., March 18, 1952

This photograph, taken over Uganda, shows typical cumulus cloud with base 6,000 ft. above M.S.L. (3,000 ft. above ground level) and tops to 11,000 ft. but mainly 7,000 or 8,000 ft. It was notable how the cumulus could be seen to hang over the hill tops of the broken country beneath. Above is the cirrus or cirrostratus veil the height of which was estimated at 45,000 ft. or more. The measurements from the photographs gave an approximate value of 43,000 ft. for the height of the cirrostratus cloud.

CIRRUS AND CIRROSTRATUS CLOUD IN THE TROPICS

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Reproduced by courtesy of A. F. Kersting

TOP OF THE FOG FROM BOX HILL, LOOKING TOWARDS RANMORE COMMON, DECEMBER 8, 1952 forward objection was raised that the condensation would happen not only in the layers between 45,000 and 50,000 ft. but throughout the whole of the atmosphere up to the tropopause. It has, however, been observed by Frith on a number of occasions, from aircraft of the Meteorological Research Flight, that when cirrus was visible from the ground it was invisible when the aircraft was amongst it, the reason being that the ice needles of which it was composed were too sparse to be noticeable at a close view. Therefore it is possible that the Comet was, in fact, among ice needles during the flight from 10°N. to 16°S. This supposition is supported to some extent by the observation that the cloud was not easily visible except when one was looking through a great quantity of it, i.e. when the line of vision was nearly horizontal. Fig. 1 is intended to show in a very schematic manner how the general vertical circulation would take place if the speculation I have put forward above is true.

It is to be noted that in many of the photographs[2] taken from a Comet when flying from Calcutta to Karachi in September 1951 high cirrus cloud far above the aircraft (flying at 40,000 ft. or so) was visible to the southward. It is probable that this cloud, too, is the expression of the general rising of the air in the intertropical region.

REFERENCES

1. FROST, R.; The upper air circulation in low latitudes in relation to certain climatological discontinuities. *Prof. Notes Met. Off., London*, **7**, No. 107 (in the press).
2. HURST, G. W.; Cloud photographs taken from Comet aircraft. *Met. Mag., London*, **81**, 1952, p. 173.

METEOROLOGICAL OFFICE DISCUSSION

Cold pools

The discussion on December 15, 1952, was opened by Mr. S. E. Virgo, who based his statement on the following papers:—

BUSCHNER, W.; Untersuchungen über Verlagerung, Aufbau und Dynamik zweier winterlicher Kaltlufttropfen. *Ber. dtsch. Wetterdienstes, U.S. Zone, Bad Kissingen*, **4**, No. 23, 1951.

FONTAINE, P.; Les "gouttes d'air froid" sur l'Europe, la Méditerannée et l'Atlantique Est. *Météorologie, Paris*, Serie 4, No. 22, 1951, p. 98.

In his introduction the Director remarked that it was fitting that a German paper was being considered on this occasion, the first discussion since the formation of a unified Meteorological Service for the Western Zones of Germany.

Mr. S. E. Virgo first summarized Buschner's paper. Buschner asserts that, in general, a moving cold pool is steered in the direction of the gradient wind at the surface. He considers that cold pools in winter move at about 60 per cent. of the speed of the gradient wind, and he attributes the difference to losses of energy caused by changes of temperature and pressure within the cold pool, by radiation, and also by vertical motions.

Buschner analyses the vertical structure of cold pools by means of vertical cross-sections of temperature, pressure and relative humidity constructed from radio-sonde reports. In his temperature cross-sections he plots the difference between temperatures within the cold pool and those in the undisturbed air outside. In the examples of cold pools in motion which he examines the maximum cooling, about 15°C., occurs at about 650 mb. The upper limit of the negative temperature anomaly occurs at about 400 mb.; above that level the air above the cold pool is warmer than its surroundings, though this heating is not of such a magnitude as to compensate for the cooling at lower levels.

Although there are no marked pressure tendencies at the surface, the pressure cross-sections show increasing anomalies up to the base of the stratosphere, and indeed the sag in the 400-mb. surface within the cold pool on December 15, 1946, amounts to about 800 ft. Moreover there is no change in sign of the pressure anomaly right up to the greatest heights attained by the radio-sondes. In other words, the pressure at any level within the cold pool is lower than in the surrounding air at the same horizontal level, but there is nevertheless complete compensation at the surface.

The cross-sections of anomalies of temperature and pressure are symmetrical, but the cross-section of relative humidity is not symmetrical. There is a tongue of drier air ahead of the axis of the cold pool, suggestive of descending air, and a tongue of moister air behind, suggestive of rising air. This pattern is confirmed by the distribution of cloud and precipitation. There is a cloudless area ahead of the cold pool, and an area of much cloud and snowfall behind.

Buschner asserts that the observed temperatures can only be maintained if the losses due to radiation from the cloudless area ahead of the cold pool are offset by heating caused by downward motion, and with the aid of a radiation diagram he calculates this rate of descent. He then refers to a theorem by Lettau which attributes large-scale downward motions of air to outflow across the isobars in the frictional layer near the earth's surface, and he applies Lettau's formula to obtain an estimate of the downward motion in advance of the cold pool. The rate of descent obtained by this method is significantly higher than that obtained from the radiation calculation. Buschner explains the difference by supposing that the cold pool moves against the air stream, and he is able to calculate from the temperature distribution the up-wind component which would resolve the discrepancy; he finds that it is of the order of 30 per cent. of the speed of the gradient wind. This is in fair agreement with his earlier observation that the cold pool moves at a rate equal to 60 per cent. of the speed of the gradient wind.

The cause of the stagnation of a cold pool is the development of an area of falling tendencies ahead of it; this destroys the strong gradient which is steering the system, and also causes an area of low pressure to appear at the surface under the cold pool. The cold pool then becomes symmetrical, with ascending air, cloud and precipitation occurring vertically above the centre of low pressure.

Fontaine's paper is mainly statistical. He classifies the cold pools which affected the eastern Atlantic and the continent of Europe during the years 1946–49 into three categories according to their origin and trajectory: 51 per cent. fall into the Atlantic category, 33 per cent. into the Mediterranean category, and only 16 per cent. into the continental category. This analysis gave point to a suggestion made by speakers later in the discussion, that Buschner's cold pools were of a rather special kind.

Fontaine also recognizes a correlation between frequency of occurrence of cold pools, and storminess and hail. He draws attention to the number of cold pools which become retarded on the Atlantic between the Azores and Portugal. In the second part of his paper, Fontaine endeavours to find a correlation between the behaviour of cold pools and solar activity.

Mr. Douglas remarked that the Germans introduced "cold drops" in the 1930's, and they were associated with comparatively straight currents at sea level, while "cold pool" is a wider generic term which came into existence at the Central Forecasting Office during the 1939–45 war. Recent extensive research by Mr. Sumner has shown that the "cold drops" are one class in a very large and complex set of entities. Great caution is needed in making generalizations about their relation to weather, and there is sometimes precipitation ahead of cold pools from the east. (Communicated later) Examples of such precipitation occurred in southern England on October 31, 1946, January 28, 1947, and February 20, 1948, the last two with important snowfalls. All three cases were associated with small but increasing troughs of low pressure at sea level, and in 1947 the snow started in Germany. If the absence of any falling tendency of sea-level pressure is made a condition, one is left with a rather small sub-class, and notably so when a cold pool reaches France or southern England from the east. When there is subsidence ahead of a "cold drop", it is a similar phenomenon to the subsidence commonly found behind a cold front but ahead of the related cold tongue in the 1000–500-mb. thickness field. Sea-level pressure is usually rising, but if there is a fall over a large area the belt of subsidence may only be represented by a weakness in the general fall.

Mr. Jacobs pointed out that the slow-moving surface depressions in the Azores region, which he and Mr. Murray had described in "Aviation meteorology of the Azores", were associated with upper cold pools. He had looked through the *Daily Weather Reports* and *Daily Aerological Records* for 1952 and had found that the frequency of these stagnant lows, which could occur anywhere within the region southern Ireland–Bermuda–Azores and southward to Madeira–Portugal was roughly similar to that for the two years previously studied, 1943–45. The lows form as the last wave on a north-east–south-west polar front, which becomes blocked by the build-up of the North American and European highs to the north and then drifts east to south-east, deepens and quickly occludes. The longest periods of bad weather in the Azores region occur with these lows, and the frequent showers or thunderstorms and often strong to gale force winds can be accompanied by drizzle and very low stratus cloud once the centre of the low gets to the south of the Azores. The lows usually persist for one or two weeks, about 4–6 times a year in autumn, winter and spring (when the highs are well developed), but may dominate a whole season as in the autumn of 1945. The upper cold air is often renewed by the arrival of polar lows or of old occluded lows from Florida. The type ends either by the low filling or moving away north-eastwards as the northern highs weaken. Mr. Virgo said that Fontaine had given no reason why he obtained a correlation between strong winds and cold pools, but this might have been analogous to the frequent occurrence of strong winds with the Azores lows.

Mr. Wallington mentioned the large number of cold pools which Fontaine recorded near the east coast of Spain. He pointed out that upper air data from Spain are sparse, and wondered whether the east coast of Spain was in fact a favourable place for cold pools, or whether the number had been artificially increased by the way in which the charts had been drawn.

Mr. Hawson said that at the Central Forecasting Office each cold pool was treated on its merits. The movement of a thickness line might be affected by advection, insolation and vertical motion, and each of these processes was considered separately. He thought that the ratio of the speed of movement of the cold pool to the speed of the gradient wind could vary between very wide limits.

Dr. Sutcliffe referred to the possible confusion in terminology. In the paper discussed, and generally in German literature, the Kaltlufttropfen was defined as a cold pool having little or no associated pressure irregularity at the surface. It occurred over the continent with easterly surface winds and was rather a rare phenomenon. The cold pool, as understood in English literature, was defined as a cut-off region with closed isotherms or thickness lines and could be associated with any surface pressure pattern (as far as the definition was concerned) and was a very common phenomenon. The distribution of convergence, divergence and vertical motion in the neighbourhood of a cold pool or cold drop presented a complex dynamical problem for which there could be no universally valid solution, but on the whole Dr. Sutcliffe's experience confirmed the tendency for the rainfall to lie to the east and so to be behind the westward-moving system. If there were little variation in the surface pressure gradient over the region, the dynamical problem would be little affected by eliminating this gradient (by adding an equal and opposite geostrophic wind at all heights). We should then have a purely thermal wind field, and, in accord with development theory, cyclogenesis and upward motion would normally be found to the east of the thermal trough. Over the sea cold pools were most commonly associated with marked cyclonic circulations, and the German type of "cold drop" was very important because, if it should drift over the sea, it was liable to give rise to important cyclonic activity.

Mr. C. V. Smith spoke of Sumner's recent statistical and synoptic study of cold pools, not yet published. In effect, Sumner has defined a cold pool as the area lying within a closed line in the 1000–500-mb. thickness pattern. He was concerned with only the more intense features, those which were associated with two or more closed thickness lines, and which appeared on at least two successive 0300 G.M.T. charts. His data were for a five-year period, and for a sector which covered the Atlantic and Europe as far as 30°E.

Charts have been produced showing where the pools were located. The greatest concentration is over Europe at all seasons; over the Atlantic there are areas in which pools of the intensity specified by Sumner never occur. Cold pools occur mostly in spring and early summer. Rex and Brezowsky have discerned a maximum blocking of the upper westerlies about this time. A cold pool (especially if it is formed by the cut-off process) is frequently associated with the low vortex (at the 500-mb. level) of the typical blocking pattern formed by the concomitant high and low vortices. Persistence of the pool may then be in part linked with the persistence of this pattern.

The greater number of the cold pools studied by Sumner were formed by the cutting-off of the cold air at the southernmost extremity of an upper cold trough. This was usually of large amplitude and slow moving, though with some relative motion between the northern and southern parts of the trough which resulted in the northern portion shearing forward leaving a closed vortex to the south-west. On the surface this process was associated with a marked anticyclonic development across the area directly below the middle of the upper trough and with the maintenance of a cyclone to the south in association with the developing cold pool. Warm advection from the west across the top of the anticyclone completed the cutting off. There were, however, many variants of this basic model, depending mainly on the degree of development of the surface systems. The predominant agency in removing cold pools was warming *in situ*. The average persistence was three days.

Any configuration of surface isobars could be associated with an upper cold pool. Sumner's data gave about 200 cases for the five-year period of which one fifth to one sixth were of the cold-drop type described by Buschner. The most commonly occurring surface feature was the cyclone.

Statistics have been produced concerning the weather within the area of the cold pools. There were occasions when it was completely fine or completely overcast, but these extremes were rare. Generally, partly cloudy conditions obtained. Precipitation could occur with any associated surface features.

The central thickness (1000–500 mb.) of the pools studied was invariably below—usually 400–500 ft. below—the normal for the time and place, with some tendency to "relax" to an anomaly of about −450 ft. if greater or less than this value.

Mr. Bannon recalled some points made by Scherhag in a lecture. He said that cold pools of the kind described by Buschner are a special type. They die out quickly as soon as they move out over the sea. Mr. Bannon placed little reliance on the 60-per-cent. rule.

Mr. Sawyer said that the disappearance of continental cold pools is often associated with strong cyclogenesis over the sea, a fact which might be important to forecasters.

Mr. Gold was sceptical about Buschner's radiation calculations.

Mr. Boyden said that Lettau's formula for vertical velocity depends upon the curvature of the isobaric surfaces in the frictional layer. The curvature is derived from the configuration of the surface pressure chart. Mr. Boyden failed to see how this could be used to compute vertical motion in a cold pool which makes no impression on the surface pressure chart.

Dr. Sutcliffe agreed that surface frictional convergence and divergence were unlikely to be the main cause of the observed fields of motion in this type of system, any more than in others. The absence of associated surface pressure features over the cold land in winter was probably due to the damping of development by vertical stability over the relatively warm sea—cyclogenesis could take place more freely.

Mr. Kirk referred to the statement that anticyclonic conditions may occur ahead of the cold pool and cyclonic conditions behind it. In the following mathematical argument, he shows that an explanation may be based on the relationship between the winds and the temperature field. It is convenient to examine temperature change along the path of the air in terms of changes related to the constant-pressure surface. Thus

$$\frac{dT}{dt} = \left(\frac{\partial T}{\partial t}\right)_p + \mathbf{V}_{\mathrm{H}} \cdot \nabla_p T + \frac{\partial T}{\partial p}\frac{dp}{dt} \qquad \ldots (1)$$

where T denotes temperature, p denotes pressure, a suffix H denotes the horizontal component, and a suffix p denotes differentiation along the constant-pressure surface.

If Q is the heat received by unit volume then from the principle of the conservation of energy

$$\frac{dQ}{dt} = c_v \frac{dT}{dt} + p \frac{d}{dt}\left(\frac{1}{\rho}\right),$$

where c_v is the specific heat at constant volume and ρ the density, or

$$\frac{dQ}{dt} = c_p \frac{dT}{dt} - \frac{1}{\rho}\frac{dp}{dt}, \qquad \ldots (2)$$

c_p being the specific heat at constant pressure. Substituting from (1) in (2) and rearranging terms, we derive

$$\left(\frac{\partial T}{\partial t}\right)_p = \frac{1}{c_p}\frac{dQ}{dt} - \mathbf{V}_H \,.\, \nabla_p T + \frac{1}{g\rho}\left\{\frac{\partial T}{\partial z} + \Gamma\right\}\frac{dp}{dt} \qquad \ldots (3)$$

where Γ is the dry adiabatic lapse rate. If the velocity of the isotherms is $\mathbf{c}$ and the temperature field moves without intensification or weakening, then

$$\left(\frac{\partial T}{\partial t}\right)_p + \mathbf{c} \,.\, \nabla_p T = 0\,.$$

Hence, substituting in (3),

$$(\mathbf{V}_H - \mathbf{c}) .\, \nabla_p T = \frac{1}{c_p}\frac{dQ}{dt} + \frac{1}{g\rho}\left\{\frac{\partial T}{\partial z} + \Gamma\right\}\frac{dp}{dt}$$

If colder air approaches and the wind is moving faster than the isotherms, then ahead of the cold air $(\mathbf{V}_H - \mathbf{c}) \,.\, \nabla_p T$ is positive. If the non-adiabatic term can be regarded as of secondary importance then dp/dt must be positive since $\partial T/\partial z + \Gamma$ is essentially positive. Hence, since dp/dt may be used as a criterion for development, we should expect anticyclonic conditions ahead of the cold air. A similar argument suggests the necessity for cyclonic activity in the rear of the cold pool.

These results therefore follow from

(i) the assumption that the motion is essentially adiabatic

(ii) the assumption that the cold pool moves as an entity slower than the wind.

Mr. Boyden remarked that the drawing of contours was to some extent subjective, especially over those areas where radio-sonde data were few. He thought forecasters ought to be sure that they had good evidence before they cut off the end of a long cold tongue and made it into a cold pool. He hoped that this discussion would not lead to the appearance of large numbers of cold pools on charts.

Dr. Stagg stressed the need for exact definitions of the terms "gouttes d'air froid", "Kaltlufttropfen" and "cold pools". The precise meanings of all these terms were by no means evident from the discussion; and unless they were clearly defined, confusion was bound to follow.

Mr. Virgo gave his reason for translating the "Kaltlufttropfen" of Buschner's paper as "cold pool". He said that Douglas had defined a cold pool in terms of at least one closed thickness line, and by this definition the "Kaltlufttropfen" of Buschner's paper were "cold pools".

Mr. Veryard said that, in the Mediterranean, rain was associated with cold pools all the time they lasted.

The Director, in closing the Discussion, commented that it was clear that the definition of the term "cold pool" had not yet become standardized.

METEOROLOGICAL RESEARCH COMMITTEE

Joint Meteorological Radio Propagation Sub-Committee

The Joint Meteorological Radio Propagation Sub-Committee—a joint sub-committee of the Meteorological Reseach Committee and of the Tropospheric Wave Propagation Committee of the Radio Research Branch—has been dissolved. Matters primarily of meteorological interest which were formerly dealt with by the Sub-Committee will in future be considered by the Physical Sub-Committee of the Meteorological Research Committee. Matters having primarily a radio interest will be considered by the Tropospheric Wave Propagation Committee.

OFFICIAL PUBLICATIONS

The following publications have recently been issued:—

A century of London weather.

Many inquiries are received in the Meteorological Office from the Press, the general public, gardeners and students requiring comparisons of current weather with the weather experienced in the past. Printed and manuscript weather observations made in London since 1841 have now been assembled in one cover for the first time in a form designed to give quick and reliable answers to the questions experience has shown to be most frequently asked.

Averages and extremes of temperature, rainfall and sunshine are supplemented by weather details of perennial interest. Coloured diagrams enable the reader to see at a glance how each individual month, season and year compares with the average and with each other, and thus to obtain a broad picture of weather trends in London over the past century.

London fogs are compared with those of 50 years ago, while temperature readings each day for a hundred years have been examined to see whether any periods of the year have in fact been subject to warm or cold spells with any significant regularity.

The more orthodox tabular summaries will be of value to students and to the investigator who wishes to relate weather conditions to his own particular problem.

GEOPHYSICAL MEMOIRS

No. 88—*Humidity of the upper troposphere and lower stratosphere over southern England.* By J. K. Bannon, B.A., R. Frith, Ph.D. and H. C. Shellard, B.Sc.

This Memoir gives details of the first series, made anywhere in the world, of observations of humidity in the upper troposphere and lower stratosphere. The observations were made on 130 flights, mainly in Mosquito aircraft, over southern England, usually to heights of 38,500 ft. or above. The observations are analysed with respect to their height above or below the tropopause thus emphasizing any humidity differences between troposphere and stratosphere. Correlation coefficients are given between humidity (frost-point temperature) and other parameters at various levels. The humidity is also analysed at fixed levels to show the variation between different synoptic types, between different seasons and between different air masses. Changes in humidity in passing through frontal surfaces are discussed and attention is drawn to some observations made near jet streams. Because of the height limitation of the aircraft, observations penetrating well into the lower stratosphere were only possible when the tropopause was at its normal height or lower.

No. 89—*Temperature and humidity gradients in the first 100 m. over south-east England.* By A. C. Best, M.Sc., E. Knighting, B.Sc., R. H. Pedlow, B.Sc. and K. Stormonth, B.Sc.

Using temperature and humidity elements at four different heights on a lattice tower the vertical gradients of temperature and of absolute humidity in the lowest 100 m. of the atmosphere have been recorded over a period of three years at a site near the coast of south-east England.

From these records meân hourly values of temperature and humidity at each height, and of the vertical gradients, have been extracted for each month. The diurnal variation of these atmospheric parameters is examined. Tables are also given showing the effect of cloud cover upon the gradient of temperature and humidity and also the frequency of gradients of specified magnitudes.

The effect of snow cover is briefly considered. The vertical gradient of temperature and humidity in a radiation fog is discussed and one such occasion is examined in detail.

ROYAL METEOROLOGICAL SOCIETY

At the meeting of the Society held on December 17, 1952, the President, Sir Charles Normand, in the chair, the following papers were read:—

*Roper, R. D.—Evening waves**

An explanation was given of lifts encountered by gliders flying in the evening from Camphill, Derbyshire, which carried them to heights greater than those which they had been able to attain all day. This phenomenon was previously described as an "evening thermal", and was observed at Camphill with a moderate or fresh W. or NW. wind following a sunny day. Haze was common up to about 2,000 ft., and often a lenticular or roll cloud was stationary over or on the hills to the west. Some good examples of these clouds were shown on slides in colour. The author considered the explanation to lie in the rapid change of lapse rate in the lowest layers in the evening which makes conditions suitable for standing waves to occur. An appendix by Scorer showed that an evening inversion at 2 Km. would be associated with a standing wave of wave-length 5 Km. in these meteorological conditions in the evening when most of the shallow convective layer had had time to disappear.

In the subsequent discussion, to which Mr. Gold, Dr. Scorer and others contributed, it was shown that standing waves were quite frequent near many gliding centres and lifts up to 20,000 ft. were known. Probably more cases of such lifts to great heights would have been recorded if the ascent had not been terminated due to the onset of darkness or the pilot's shortage of food or oxygen. An essential condition for the formation of standing waves was the existence of strong vertical wind shear and stability in the lowest layers. Since the amplitude of these standing waves often amounted to several thousands of feet, down-draughts from them constituted a serious menace to aircraft flying near mountains. It was significant that on the occasion of the aircraft crash near Snowdon on January 10, 1951, the wind speed at 30,000 ft. was 155 kt. Mr. Gold

* *Quart. J. R. met. Soc., London,* **78**, 1952, p. 415.

asked whether it was possible to define the magnitude of wind and temperature gradients in the vertical which would be favourable or would prevent the formation of standing waves, and Dr. Scorer believed this would be possible. "Evening thermals" were defined as standing waves which were able to develop in the evening when convection had weakened. As a result of this work stratocumulus hitherto believed to be formed by the spreading out of cumulus at the end of the day can now be ascribed to the development of standing waves. On many occasions standing waves develop without associated cloud.

*Sheppard, P A. Charnock, H. and Francis, J. R. D.—Observations of the westerlies over the sea**

Sheppard, P. A. and Omar, M. H.—The wind stress over the ocean from observations in the trades†

In the past, investigations of wind structure in the first few hundred metres have assumed the existence of a boundary layer at the top of which the wind merges smoothly with the general air flow above, assumed to be geostrophic. No turbulent transfer of momentum in the vertical takes place therefore at this level. Hence the frictional drag exerted by the earth's surface on the moving air may be calculated by balancing the momentum thus extracted with that acquired by virtue of the cross-isobaric flow. This principle has been successfully applied for many years to the wind structure over land surfaces but seems to have had little application to winds over the sea.

These two papers, presented by Prof. Sheppard, describe a practical investigation undertaken at the Scilly Isles for the temperate-latitude westerlies, and, for reasons which emerged later, a theoretical investigation on similar lines for the trade winds. At Scilly a series of accurate pilot-balloon observations were made at half-hourly intervals during a winter spell of westerlies. Some valuable results concerning the finer structure of the westerlies near the surface were obtained, but the main outcome of this work was to show that the principle of momentum balance referred to above could not be applied to these winds; there was no boundary layer, for the baroclinic structure of the atmosphere led to a continued velocity gradient, probably up to the tropopause in many cases. This requires little or no cross-isobaric flow at the surface—which was confirmed by the observations. It is interesting to note that the climatological charts for the North Atlantic Ocean also show no cross-isobaric flow in the westerlies.

The trade winds, however, normally show a reversal of velocity gradient at a height of a few hundred feet, whence it may be inferred that there is a boundary layer into which momentum is transported from above. Cross-isobaric flow is a characteristic of the trade winds, both for individual observations and in the mean. The investigation described in the second of these papers used reported pilot-balloon ascents for certain tropical islands and led in the main to reasonable and consistent values for the surface drag.

A lively and interesting discussion followed. Mr. F. H. Ludlam and Mr. J. S. Sawyer raised the question as to how far the turbulence measured by the half-hourly observations of horizontal wind was applicable to the scale of

* *Quart. J.R. met. Soc., London*, **78**, 1952, p. 563.
† *Quart. J.R. met. Soc., London*, **78**, 1952, p. 583.

turbulence involved in vertical momentum transport. Dr. R. C. Sutcliffe welcomed the employment of an observational method specifically for the determination of the drag coefficient over the sea. He pointed out the possibility of interaction between the upper and surface levels in the trade winds, and suggested that some downward transport of momentum might be effected by general subsidence arising from a large-scale meridional circulation. Dr. E. T. Eady also suggested that the large-scale circulations were important in this problem and saw no reason why they should be inconsistent with cross-isobaric flow against the pressure gradient.

Prof. Sheppard in reply said that we had as yet no definite knowledge on these points. It was planned to extend the work by using the Scilly observational technique at a tropical location in the not too distant future.

The President, Sir Charles Normand, in closing the discussion, congratulated Prof. Sheppard on his recent appointment to the only Chair of Meteorology in a British University, and expressed his confidence that we could look forward to many papers describing work of the same high quality from Prof. Sheppard's Department in the coming years.

INSTITUTION OF WATER ENGINEERS

Symposium on hydrology

In 1951 the Hydrological Research Group of the Institution of Water Engineers was reformed with revised terms of reference—"The study of hydrology, especially those branches relating to rainfall, run-off, percolation and evaporation, the scope of the studies to include methods of measurement of the phenomena and interpretation of the records, including the appropriate use of statistical methods". After several meetings the Group decided, as a first step, to hold a discussion so that all those interested in hydrology from any of the various aspects could make their contribution. In order to stimulate a discussion the Group prepared a symposium setting out briefly present-day knowledge, the problems involved and the uncertainties. The Discussion was held on November 12, 1952, the meeting being arranged under the auspices of the South-Eastern and Land-Drainage Sections of the Institution of Water Engineers.

The Symposium consisted of four papers: "Hydrological measurements" (divided into four sections: precipitation, evaporation and percolation, run-off, and ground-water levels and storage); "Estimation of yield (overground)"; "Estimation of yield (underground)"; and "Some observations on pumping tests carried out on chalk wells".

Reference can be made only to some of the points raised in the Discussion by the 34 contributors. Mr. N. E. Rider (Meteorological Office) referred to the work now being carried out at Cambridge in measuring dry-bulb and wet-bulb temperatures and wind changes near the surface of the ground. One of the objects is to evolve a simple method of determining evaporation applicable to specific cropped areas for periods of a day or longer. Dr. F. Pasquill (Meteorological Office) paid tribute to the neat way in which Dr. Penman had avoided using surface temperature, which is difficult to measure, but had used quantities normally specified in climatological records: duration of bright sunshine, air temperature, vapour pressure and wind speed. Dr. Pasquill emphasized the importance of continuing the fundamental research work at Cambridge and also of considering incoming radiation as a measure of the heat loss due to evaporation over long periods. Mr. D. J. Schove referred to long-term climatic variations by quoting from his paper "The climatic fluctuations since A.D. 1850 in Europe and the Atlantic"*, but hesitated to apply past fluctuations to forecast future rainfall trends. Capt. W. N. McClean advocated the use of the 33 years, 1913–46, for future averages, because it covered three sun-spot periods. Mr. A. Bleasdale (Meteorological Office) pointed out that the run-off characteristics of a drainage area might change with time. Thus following the heavy rain of August 15 in the Lynmouth area the beds of upland streams were found to have been scoured out. As a result there was some evidence of better drainage of bogs and of streams flooding and falling more quickly. Similar changes in land use or of field drainage might affect relationships between rainfall and run-off over a period of years. Mr. G. Santing referred to experiments carried out in Holland with four large percolation gauges with bare soil, dune vegetation, leafed trees and conifers. The percolation was least with conifers. Many speakers stressed the importance of securing more run-off records, deploring the recent suspension as a measure of economy of the Inland Water Survey Committee.

The afternoon session was devoted to underground hydrology, but it was apparent that this was closely related to surface hydrology. The fullest use of underground water would benefit the supply engineer, and in some cases provide storage in the ground for winter rains to the advantage of the drainage engineer.

The papers and the discussions are being published in the May 1953 number of the *Journal of the Institution of Water Engineers.* The discussion is being considered in detail by the Hydrological Research Group in order to prepare a comprehensive report for submission to the Institution of Water Engineers with a view to publication.

J. GLASSPOOLE

LETTER TO THE EDITOR

Forecasting ground frost

From investigations made at Munster, a low-lying station in Germany, R. Faust† proposed the formula

$$T + \frac{D}{2} < 79$$

for the forecasting of ground frost on radiation nights, where T and D are screen temperature and dew point respectively in degrees Fahrenheit at 1400 local time. G. J. Jefferson‡ examined the applicability of the formula to Hullavington, Wiltshire.

A test has now been made for St. Athans, Glamorgan, a low-lying station, 150 ft. above M.S.L., in fairly level country two miles from the coast. The observations used were for the whole of 1945 and the period November 1949 to May 1951.

* *Quart. J.R. met. Soc., London,* **76,** 1950, p. 147.
† FAUST, R.; Ein Hilfsmittel zur Nachtfrostvorhersage. *Ann. Met., Hamburg,* **2,** 1949, p. 105.
‡ JEFFERSON, G. J.; Forecasting ground frost. *Met. Mag., London,* **80,** 1951, p. 295.

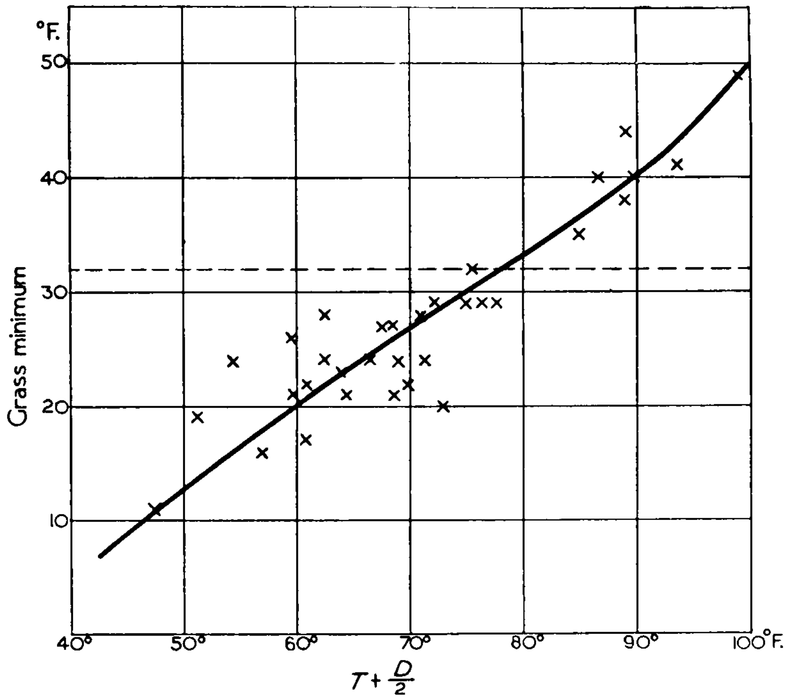

FIG. 1—RELATION OF MINIMUM GRASS TEMPERATURE TO SCREEN TEMPERATURE AND DEW POINT

A similar curve, Fig. 1, was obtained to that given by Jefferson with a constant 78 almost the same as the value 79 given by Faust. A curve, not reproduced, was also drawn for screen minimum temperature. This curve was almost the same with a constant of 66 in place of 78.

W. E. JAMES

Llandow, Glamorgan, August 18, 1952

REVIEW

The Climate of the Gold Coast. By H. O. Walker and A. D. Swan. *Notes Gold Coast met. Serv., Accra,* No. 1, 1952, British West African Meteorological Services, Lagos, 1952.

The author's intention is to describe the climate of the Gold Coast for any person interested in this region but it is not intended for the professional meteorologist.

Only five years' observations (1947–51) for 13 stations have been used as a basis for this study but mainly over 20 years' observations for the discussion of rainfall. Owing to the small and regular changes of temperature and humidity, the short period gives a sufficiently accurate picture of these important elements of climate; the tables based on the longer periods show the large monthly and yearly variations of rainfall as well as illustrating the seasonal variations described in the section on rainfall. Plans for the future will provide data on short-period rainfall intensities and evaporation.

An elementary discussion is given of the air masses affecting the Gold Coast, and of the intertropical convergence zone—it is a pity that maps are not provided for illustrating the seasonal pressure and wind distributions and the associated movements of the zone; they would also have clarified the description of the rainfall seasons over the region.

Brief but useful descriptions are given of cloud, sunshine, thunderstorms and visibility with tables of mean values for the first three; it does not seem worth while giving two tables (for 0900 and 1500) showing mean amount of low cloud as well as the four tables (for 0300, 0900, 1500 and 2100) of means of total cloud amount.

In the section on relative humidity and the specification of water vapour in the atmosphere, it is stated that the wet-bulb thermometer measures the temperature to which the liquid water cools; is not the theory that heat is supplied to the water in order to evaporate it, the heat being drawn from the air passing over the wet bulb and from the thermometer itself? It is suggested that for a future edition, data on wet-bulb temperatures (in addition to relative humidity) would be very useful.

For the person visiting the Gold Coast for the first time a study of this short note, and the appropriate tables, would give him an adequate idea of what weather to expect—this would even apply to the professional meteorologist!

J. PEPPER

ERRATA

November 1952, PAGE 330, FIG. 4; Insert an additional 20 per cent. line over south-eastern Australia joining the points: 35°S., 136°E.; 36°S., 141°E.; 37½°S., 145°E.; and 38½°S., 147°E.

January 1953, PAGE 22, line 47; *for* "inside" *read* "beside".

February 1953, PAGE 46, line 9; *for* "$\frac{\varepsilon_1}{2} + \frac{\varepsilon_2}{2} + \eta$" *read* "$\frac{\varepsilon_1}{2} + \frac{\varepsilon_3}{2} + \eta$."

OBITUARIES

Mrs. Lempfert.—We regret to announce the death on January 10, 1953, of Mrs. Lempfert (Marjorie Hayward, F.R.A.M., Professor of the Royal Academy of Music) wife of Mr. R. G. K. Lempfert, C.B.E., formerly Assistant Director of the Meteorological Office.

Mrs. Lempfert will be remembered by many of the older staff of the Meteorological Office for her contributions, musical and other, to the success of many Annual Soirées.

Francesco Vercelli.—We regret to report that the distinguished Italian geophysicist Professor F. Vercelli, Director of the Geophysical Observatory and of the Thalassographical Institute of Trieste, died, aged 69, on November 24, 1952.

Professor Vercelli contributed to research in several branches of geophysics. In oceanography he investigated the transmission of solar radiation through sea and lake water and the effects of wind and pressure variations on the tides, and led oceanographic expeditions in Italian naval vessels to various parts of the Mediterranean and Red Sea. He devised a method of harmonic analysis and applied it to the prediction of pressure changes. He sought for the sun-spot cycle in tree-ring records. His earliest geophysical work was concerned with the temperature in tunnels in connexion with the construction of the Simplon tunnel; later he founded a seismological station at Trieste and took part in seismic and electromagnetic prospecting for oil in the Po Valley.

He was appointed Director of the Geophysical Institute of Trieste in 1920. When the Institute was divided in 1949 he became Director of both the Geophysical Observatory and the Thalassographical Institute. His last years were devoted to preparing a second edition of his book on meteorology "L'Aria" and to writing a large work on oceanography, "Il Mare".

NEWS IN BRIEF

Dr. P. R. Crowe, Reader in Geography in the University of London, has been appointed Professor of Geography in the University of Manchester with effect from April 1953. Dr. Crowe worked in the Climatology Branch of the Meteorological Office during the war. His meteorological researches have dealt with the trade winds and with the analysis of rainfall data in Great Britain and the United States of America.

METEOROLOGICAL OFFICE NEWS

Social and sports activities.—In appreciation of the local forecasts issued to them during 1952 the Union Castle Line and the Cunard White Star Company invited the staff of Eastleigh Meteorological Office to lunches on the *Edinburgh Castle* and the *Queen Mary* followed by conducted tours of the ships.

The Meteorological Office Social and Sports Committee announce that the Evening Party will be held in the Air Ministry Restaurant, Whitehall Gardens, on Tuesday, March 24.

Miss B. Edwards, Miss N. Edwards and Mrs. J. Sugden were selected for the Civil Service ladies netball team in a representative match against Oxford University at Oxford on January 24. The Civil Service won the match with 21 goals to 11.

WEATHER OF JANUARY 1953

Mean pressure over most of the North Atlantic, north of 40°N., and west Europe was above normal, the greatest excess being 11 mb. just to the west of Ireland (1017 mb.). Mean pressure over Sweden, Finland, southern Europe, the Mediterranean and the Azores was below normal, the greatest deficit being 9 mb. in Finland (1001 mb.) and 9 mb. in the Azores (1015 mb.). The lowest mean pressure, 996 mb., occurred off the north coast of Norway, and the highest, 1023 mb., in France.

Mean temperature over most of Europe and Scandinavia was below normal. It varied from 9°F. in the north of Sweden to 30–40°F. in Europe and 45–55°F. in the Mediterranean region. The greatest deficit of temperature occurred in the south of France where mean temperature was 7°F. below normal. Mean temperature was above normal over the United States generally, the largest excess being 10°F. in the west.

In the British Isles the weather was dry; it was somewhat milder than usual in Scotland but rather cold in England and Wales, particularly in the south. Sunshine was below the average in most parts of England and Wales but exceeded the average in Scotland, particularly on the coast of Fifeshire; it also exceeded the average in extreme south-west England. An unusually severe north-westerly to northerly gale occurred on the 31st.

A depression over north-east France moved away south-east on the 1st and a ridge of high pressure moved over the British Isles from the west. Thereafter a belt of high pressure became established from Scandinavia across the British

Isles to east of the Azores and maintained cold, mainly dry weather, though some scattered precipitation occurred at times. Fog occurred locally at times, particularly in the Clyde area from the 2nd to the 4th; at Renfrew the fog was persistent and day temperature only reached 27°F. on the 2nd and 25°F. on the 3rd. Good sunshine records were obtained locally in the west and north during the first four days. On the 5th and 6th a trough of low pressure moved south-east across the country giving rain in the west but snow in the east and parts of the Midlands. Cold northerly winds prevailed behind the trough, with wintry showers. Subsequently a ridge of high pressure moved slowly south-east and was followed by another trough which gave further slight precipitation except in the south-east. On the 9th an anticyclone off our south-west coasts spread north-east and later moved to Germany. Troughs of low pressure caused slight rain in the west and north and temperature rose, but the rise was only temporary in the south-east. Cold weather with widespread fog prevailed over much of south-east and east England and the Midlands from the 13th to the 15th. Subsequently pressure was high from south Russia to France, while troughs associated with a depression south of Iceland approached our west coasts; milder weather spread to all districts and there was slight rain locally in the west and north. Between the 17th and 23rd another anticyclone moved from the Atlantic to Germany and a spell of dry, cold weather, with a good deal of fog ensued in the south but rather mild conditions persisted in the north with rain at times, particularly from the 21st to the 23rd. Good sunshine records were obtained on the 18th and locally on the 19th and 20th, but sunshine was variable due to the incidence of fog. On the 24th, 26th and 27th troughs of low pressure gave slight rain in places in the south and east and heavier rain locally in the north. Pressure continued high to the south of the British Isles and on the 28th a small disturbance moved rapidly from the south-west of Iceland across the north of Scotland giving rain there. On the 30th a depression south of Iceland moved east-north-east and later turned south-east to Denmark, becoming very deep; rain fell generally on the 30th and wintry showers on the 31st. A widespread severe north-westerly to northerly gale prevailed. The *Princess Victoria* foundered in the North Channel with heavy loss of life during the afternoon of the 31st. During the evening and night there were strong north-westerly gales in the North Sea and a high spring tide; exceptional floods and coastal damage occurred with consequent heavy loss of life from Yorkshire to the Thames Estuary and in Holland. During the gale, on Costa Hill, Orkney, several gusts exceeded 105 kt. and the highest reached 109 kt.; and at Milltown, near Lossiemouth, several gusts exceeded 93 kt.

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 ...	58	11	−1·0	46	−5	85
Scotland	58	9	+1·8	63	−2	107
Northern Ireland ...	54	16	+0·1	44	−3	93

RAINFALL OF JANUARY 1953

Great Britain and Northern Ireland

County	Station	In.	Per cent. of Av.	County	Station	In.	Per cent. of Av.
London	Camden Square ...	0·92	49	*Glam.*	Cardiff, Penylan ...	1·11	30
Kent	Dover	1·06	50	*Pemb.*	Tenby, The Priory ...	1·76	47
,,	Edenbridge, Falconhurst	1·27	52	*Radnor*	Tyrmynydd	2·14	34
Sussex	Compton, Compton Ho.	1·43	45	*Mont.*	Lake Vyrnwy	2·17	38
,,	Worthing, Beach Ho. Pk.	1·18	51	*Mer.*	Blaenau Festiniog ...	6·67	65
Hants.	Ventnor Cemetery ...	1·33	51	,,	Aberdovey	2·07	53
,,	Southampton, East Pk.	0·92	34	*Carn.*	Llandudno	0·96	40
,,	Sherborne St. John ...	0·81	35	*Angl.*	Llanerchymedd ...	2·34	74
Herts.	Royston, Therfield Rec.	1·28	74	*I. Man*	Douglas, Borough Cem.	2·25	67
Bucks.	Slough, Upton... ...	0·81	44	*Wigtown*	Newton Stewart ...	1·96	48
Oxford	Oxford, Radcliffe ...	0·85	47	*Dumf.*	Dumfries, Crichton R.I.	1·23	38
N'hants.	Wellingboro' Swanspool	0·98	53	,,	Eskdalemuir Obsy. ...	2·52	47
Essex	Shoeburyness	0·85	63	*Roxb.*	Crailing	0·72	37
,,	Dovercourt	0·68	43	*Peebles*	Stobo Castle	1·14	38
Suffolk	Lowestoft Sec. School...	0·96	57	*Berwick*	Marchmont House ...	0·99	44
,,	Bury St. Ed., Westley H.	1·10	61	*E. Loth.*	North Berwick Res. ...	0·57	33
Norfolk	Sandringham Ho. Gdns.	1·23	63	*Midl'n.*	Edinburgh, Blackf'd. H.	0·32	18
Wilts.	Aldbourne	1·45	63	*Lanark*	Hamilton W. W., T'nhill	1·32	40
Dorset	Creech Grange... ...	1·10	34	*Ayr*	Colmonell, Knockdolian	1·52	35
,,	Beaminster, East St. ...	1·15	33	,,	Glen Afton, Ayr San. ...	2·55	50
Devon	Teignmouth, Den Gdns.	0·53	18	*Renfrew*	Greenock, Prospect Hill	3·64	56
,,	Cullompton	0·60	19	*Bute*	Rothesay, Ardencraig...	3·42	76
,,	Ilfracombe	1·01	31	*Argyll*	Morven (Drimnin) ...	5·12	81
,,	Okehampton	1·27	25	,,	Poltalloch	4·16	82
Cornwall	Bude, School House ...	1·22	40	,,	Inveraray Castle ...	7·06	86
,,	Penzance, Morrab Gdns.	1·42	37	,,	Islay, Eallabus... ...	3·14	67
,,	St. Austell	1·43	33	,,	Tiree	3·03	71
,,	Scilly, Tresco Abbey ...	1·65	53	*Kinross*	Loch Leven Sluice ...	0·77	24
Glos.	Cirencester	0·77	31	*Fife*	Leuchars Airfield ...	0·49	27
Salop	Church Stretton ...	0·79	30	*Perth*	Loch Dhu	4·90	54
,,	Shrewsbury, Monksmore	0·60	31	,,	Crieff, Strathearn Hyd.	0·70	17
Worcs.	Malvern, Free Library...	0·46	21	,,	Pitlochry, Fincastle ...	0·87	25
Warwick	Birmingham, Edgbaston	0·97	48	*Angus*	Montrose, Sunnyside ...	0·81	41
Leics.	Thornton Reservoir ...	1·15	58	*Aberd.*	Braemar	1·01	32
Lincs.	Boston, Skirbeck ...	0·86	53	,,	Dyce, Craibstone ...	1·20	51
,,	Skegness, Marine Gdns.	0·64	37	,,	New Deer School House	1·63	70
Notts.	Mansfield, Carr Bank...	0·39	18	*Moray*	Gordon Castle	1·74	86
Derby	Buxton, Terrace Slopes	2·60	58	*Nairn*	Nairn, Achareidh ...	1·05	58
Ches.	Bidston Observatory ...	0·81	38	*Inverness*	Loch Ness, Garthbeg ...	2·44	55
,,	Manchester, Ringway...	1·28	54	,,	Glenquoich	14·18	103
Lancs.	Stonyhurst College ...	2·34	55	,,	Fort William, Teviot ...	6·24	64
,,	Squires Gate	1·48	57	,,	Skye, Duntuilm ...	3·85	73
Yorks.	Wakefield, Clarence Pk.	0·46	24	,,	Skye, Broadford ...	7·56	100
,,	Hull, Pearson Park ...	1·15	64	*R. & C.*	Tain (Mayfield) ...	1·70	70
,,	Felixkirk, Mt. St. John...	0·88	44	,,	Inverbroom, Glackour...	6·47	120
,,	York Museum	0·47	27	,,	Achnashellach	8·64	95
,,	Scarborough	1·10	55	*Suth.*	Lochinver, Bank Ho. ...	3·66	86
,,	Middlesbrough... ...	0·78	49	*Caith.*	Wick Airfield	2·80	114
,,	Baldersdale, Hury Res.	0·99	30	*Shetland*	Lerwick Observatory ...	4·20	99
Norl'd.	Newcastle, Leazes Pk....	0·78	39	*Ferm.*	Crom Castle	1·25	88
,,	Bellingham, High Green	1·38	48	*Armagh*	Armagh Observatory ...	0·94	37
,,	Lilburn Tower Gdns. ...	1·43	69	*Down*	Seaforde	1·33	42
Cumb.	Geltsdale	2·08	74	*Antrim*	Aldergrove Airfield ...	1·48	54
,,	Keswick, High Hill ...	2·32	46	,,	Ballymena, Harryville...	1·63	44
,,	Ravenglass, The Grove	2·74	82	*L'derry*	Garvagh, Moneydig ...	1·47	43
Mon.	Abergavenny, Larchfield	0·64	19	,,	Londonderry, Creggan	1·46	41
Glam.	Ystalyfera, Wern House	2·31	37	*Tyrone*	Omagh, Edenfel ...	1·79	51

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