

METEOROLOGICAL OFFICE

THE METEOROLOGICAL MAGAZINE

VOL. 81, No. 963, SEPTEMBER 1952

METEOROLOGICAL OBSERVATIONS IN CENTRAL ICELAND

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In August and September 1951 the British Schools Exploring Society's Thirteenth Expedition operated four meteorological stations in central Iceland. These were located around the margins of the Hofsjökull ice-cap at points A, B, C and D as shown in Fig. 1. The intention was to set up, for the first time, a synoptic reporting station in central Iceland and to investigate the effects of Hofsjökull on local weather conditions, with particular reference to surface winds. Certain aspects of the work are dealt with separately below.

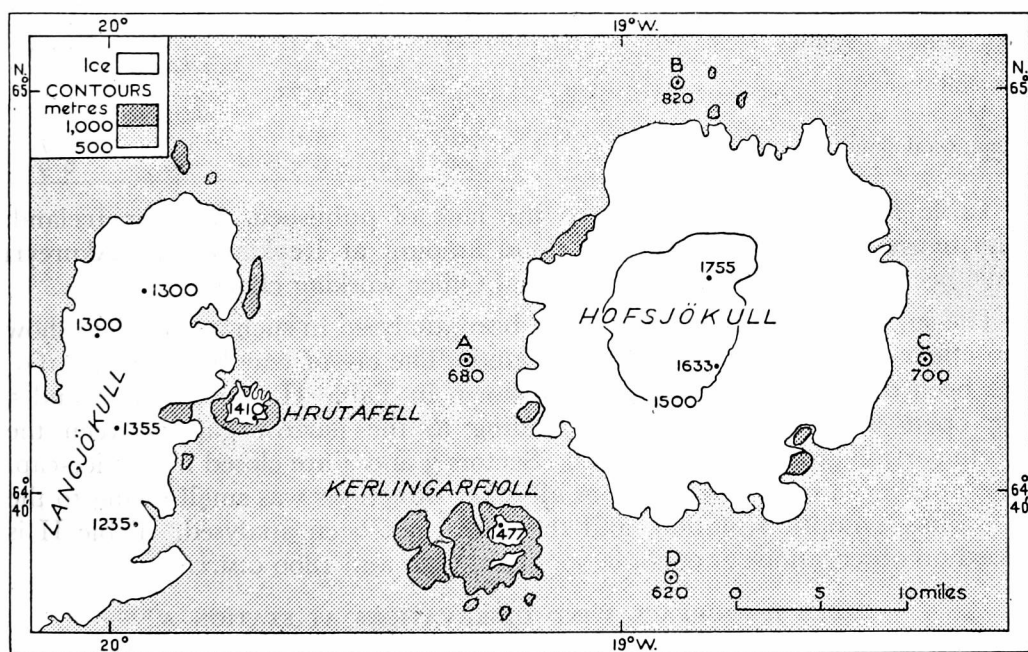


FIG. 1—POSITIONS OF THE METEOROLOGICAL STATIONS ROUND THE MARGINS OF HOFJSJÖKULL

All heights are given in metres

Observations at the main meteorological station.—The main station, station A, was located at the Expedition's Base Camp. Observations commenced on August 5 and were made at all daylight synoptic hours until September 11. These observations were passed to Reykjavik by W/T for transmission to Dunstable, using the identification "ice-cap" in place of a

station number. So far as is known, this was the first occasion on which observations from central Iceland have been immediately available to forecasters.

The station, at an altitude of 2,250 ft. (680 m.) above sea level, was situated on an undulating plain of fluvio-glacial debris and volcanic rock, almost bare of vegetation and about four miles west of the ice edge. Thermometers, screen and rain-gauge were of standard pattern and wind speeds were measured from ground level by means of a hand anemometer. Wind directions were obtained from an improvised wind-sock about 20 ft. above the ground.

Certain observations made at this station are compared in Table I with those reported from Reykjavik (64°08'N., 21°57'W.) and Akureyri (65°41'N., 18°05'W.) during the same period. Both these stations are less than 100 ft. above sea level.

TABLE I—COMPARISON OF OBSERVATIONS AT STATION A WITH THOSE REPORTED FROM OTHER ICELANDIC STATIONS

				Time of observation	Station A	Reykjavik	Akureyri
				G.M.T.	<i>degrees Fahrenheit</i>		
Mean temperature	...		{	0600	38·5	48·2	44·1
				0900	41·7	50·3	45·8
				1200	44·5	53·5	49·1
				1500	47·0	55·6	50·3
				1800	46·3	55·1	50·2
Mean night minimum temperature				1800–0600	35·8	...	...
Lowest night minimum temperature				1800–0600	25·4	...	...
					<i>inches</i>		
Rainfall	...	...	...	...	1·72	...	...
					<i>oktas</i>		
Mean total cloud	...	...	{	0600	6·6	5·7	6·7
				1500	6·3	5·8	6·9

Table I is incomplete owing to the lack of published data for Iceland. The figures for temperature and cloud amount at Reykjavik and Akureyri have been obtained from Meteorological Office working charts.

The surface wind observations have been analysed in such a way as to show the effect of the surrounding high ground. The arc of true bearing 340–160° has been divided into five sectors as shown in Table II. Sectors 1, 2 and 5 are open sectors, the last corresponding to the narrow gap between the Kerlingarfjoll group and Hofsjökull. Sectors 3 and 4 are closed by the ice-cap. The number of cases of wind from all other directions was small owing to the prevailing synoptic situation, and they have not been analysed. Table II is based on observations at 0600, 0900, 1200, 1500 and 1800 G.M.T.

TABLE II—SURFACE WIND OBSERVATIONS AT STATION A

Sector	Bearing	No. of Cases	Frequency	Mean Speed
	° true		%	kt.
1	340– 10	40	21·3	11·9
2	20– 50	57	30·4	15·0
3	60– 90	14	7·6	9·6
4	100–130	22	11·8	10·7
5	140–160	22	11·8	9·8
All other directions		26	13·9	8·5
Calm		6	3·2	...

Sector 5 has been restricted to 20° in order to show the effect of the narrow gap mentioned above. A possible explanation of the relatively high frequency in sector 4, a closed sector, is given later in this paper.

In view of the position of this area, on the air route across Iceland from Reykjavik to Akureyri (see Fig. 2), the following notes on visibility, cloud and precipitation are included.

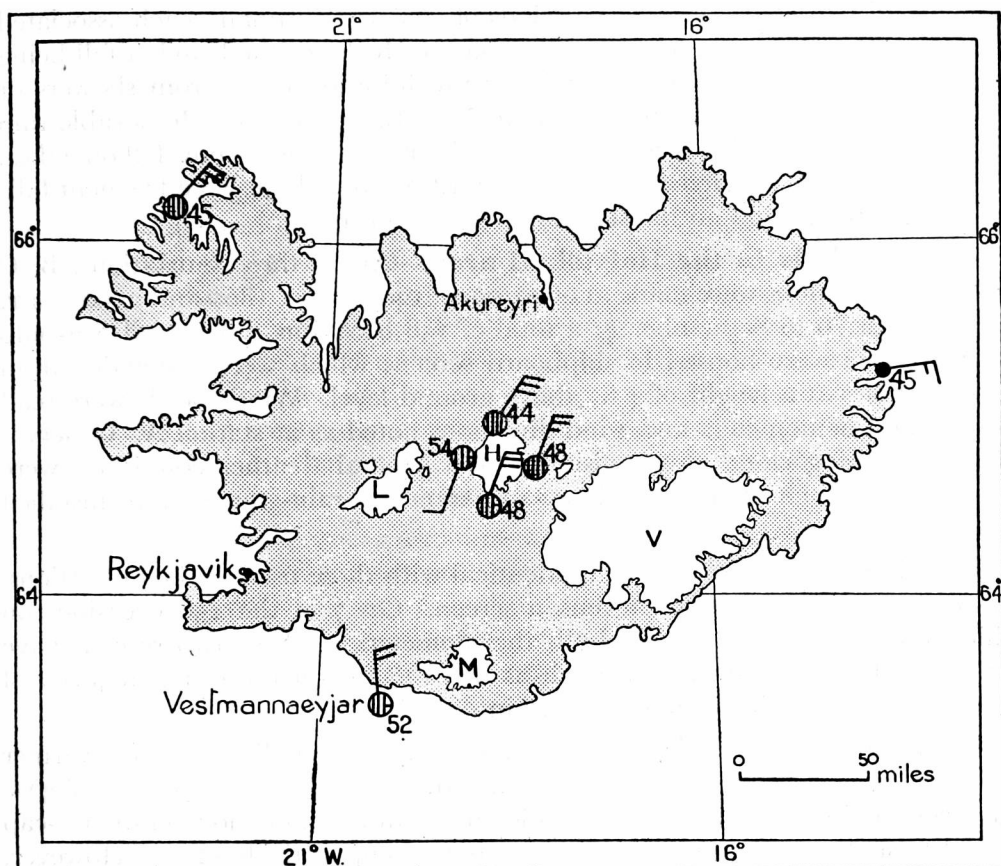


FIG. 2—SURFACE WIND AND SEA-LEVEL TEMPERATURE, 1200 G.M.T.,
SEPTEMBER 4, 1951

This map also shows the positions of the four main ice-caps of southern Iceland

L ... Langjökull V ... Vatnajökull
H ... Hofsjökull M ... Myrdalsjökull

Visibility.—This was normally excellent, varying between 20 and 60 miles. Deteriorations were due to:—

(i) Station in cloud. Fog occurred on five occasions, all of them at 0600 G.M.T.

(ii) Dust. Large areas of the land surface in this region are of volcanic dust and sand which is easily raised by the wind. Observed deteriorations in visibility due to this cause were very local, but given a prolonged dry spell and strong winds it seems probable that a general dust haze could be produced.

Cloud.—The height and amount of low cloud in the area depended mainly on orographic influences and therefore on wind direction. If low cloud was present at all it was rare for all the surrounding high ground to be clear of cloud. In particular, with the N.-NE. winds which prevailed during the period,

cloud caps were very common on Hrutafell and the east side of Langjökull and less common on the Kerlingarfjoll group and the west side of Hofsjökull. On many occasions it could be seen that the cloud broke to small amounts on the south-west horizon, and it was obvious that the southern coastal area was deriving considerable shelter from the ice-caps and other areas of high ground.

Precipitation.—There were four periods of prolonged rainfall, each associated with the passage of a depression to the south of Iceland, the heaviest fall being 0·34 in. on August 20. The remaining precipitation came from showers or troughs of low pressure in the prevailing N.–NE. air stream. Measurable rain fell on 29 days out of the 38 for which records are available. Snow fell on 2 days only at station A, the first as early as August 20, but there were frequent falls throughout the period on the surrounding high ground.

Surface winds in the Hofsjökull area.—At the three outstations, B, C and D, observations were made at 0600, 0900, 1200, 1500, 1800 and 2100 G.M.T. from August 10 to September 4; a total of 156 occasions. Dry- and wet-bulb thermometers were housed in shipboard screens which were suspended from bamboo poles at a height of 4 ft. above ground level. Wind speeds were read from hand anemometers and wind directions noted as at station A. Observations concerning cloud cover, visibility and general weather conditions were also made at each of these stations, and standard rain-gauges were installed at C and D.

At station A a shipboard screen, identical with those used at the outstations, was exposed alongside the Stevenson screen. On 7 of the 156 occasions on which they were read the dry-bulb thermometers in these two screens gave readings which differed by as much as 0·6°F., but on the great majority of occasions such readings agreed to within 0·2°F.

Whenever an unstable air mass moved over the Hofsjökull region, the warmer layers at ground level were cooled during their ascent of the ice-cap slopes. Such cooling invariably gave rise to thick mists and rain or snow on the ice-cap itself whilst the surrounding plains remained comparatively clear. However, on those occasions when the region came under the influence of an air mass which was stably stratified, it would seem that whilst stability was preserved and probably intensified over the ice-cap it was often destroyed over the surrounding plains of volcanic rock and fluvio-glacial debris.

This frequent development or preservation of air-mass stability over Hofsjökull was of considerable importance in connexion with the surface wind circulation, as is evident from the figures given in Table III.

TABLE III—FREQUENCY OF NORTHERLY, EASTERLY AND WESTERLY WINDS

Wind direction	Bearing	Station A (west)	Station B (north)	Station C (east)	Station D (south)
	° true		<i>number of occasions</i>		
Northerly ...	340–20	49	21	65	51
Easterly ...	70–110	13	33	2	38
Westerly ...	250–290	3	4	25	10

These show that the effectiveness of the barrier provided by the stable air mass over Hofsjökull was such that the station which experienced winds from a certain quarter on the fewest occasions was the one situated on the side of

the ice-cap facing that quarter. In this connexion it is also significant that northerly winds were weakest at station B. Here their mean speed was only 7 kt. as compared with 13, 14 and 11 kt. at stations A, C and D respectively. In the same way easterly winds were weakest at station C where their mean speed was only 7 kt. as compared with 9, 13 and 12 kt. at stations A, B and D respectively.

The figures given in Table III show that a station on the leeward side of the ice-cap experienced winds from a particular quarter very much more frequently than did the station on the windward side. The higher figure for the leeward station in each case would seem to suggest that on certain occasions air was drawn off the ice-cap on this side.

It has previously been reported that small ridges of high pressure occasionally appear to windward of the higher massifs in Iceland as a result of a banking up of air, and that troughs of low pressure or even shallow cyclonic centres appear on the leeward sides¹. It is now suggested that during the long summer days any such tendency for the development of a low-pressure centre on the leeward side of Hofsjökull is reinforced by the heating of those extensive areas of bare sand and rock which surround this ice-cap. As a result of this a stable stratified air mass frequently becomes unstable over these plains, and this is usually evidenced by the development of small cumulus clouds at very low levels (see Figs. 3 and 4 in the centre of this magazine).

Over a low-lying area near a mountain katabatic winds would normally be expected only between sunset and sunrise under conditions favourable to radiation. However, it is seen from Table IV that in the neighbourhood of Hofsjökull such winds off the ice-cap were experienced as frequently during the warmer afternoon hours as they were at the other times. Moreover, at each of the four stations the winds which blew off the ice-cap during these warmer hours were stronger than their evening and morning counterparts.

TABLE IV—WINDS OFF THE ICE-CAP

Station	At 1200, 1500 and 1800 G.M.T.		At 2100, 0600 and 0900 G.M.T.	
	No. of occasions	Mean velocity	No. of occasions	Mean velocity
		kt.		kt.
A	8	9.5	8	9.2
B	10	7.7	7	5.6
C	15	6.8	12	6.6
D	26	11.5	29	10.6

These figures suggest that on many occasions when winds off the ice-cap were experienced, these were the result of a drawing off of air to replace that which was rising over the stony plains. Support for this suggestion is provided by the figures given in Table V, for these show that on many occasions when a wind blew off the ice-cap during the afternoon this could not be regarded as a continuation of the wind on the opposite side.

On several occasions when conditions were most favourable to convection over the plains, winds which blew off the ice-cap at 1200 or 1500 G.M.T. had a cooling effect, which suggests that in spite of any adiabatic warming consequent upon their descent they were still cooler than the heated air which they replaced. On the other hand, winds which blew off the ice-cap at other times of day never showed this cooling effect. On the contrary they quite frequently demonstrated the föhn effect.

TABLE V

Station	No. of occasions when winds off the ice-cap were experienced at 1200, 1500 and 1800 G.M.T.	Bearing of such winds	No. of occasions when winds on the opposite side of the ice-cap were included within the same arc
		°true	
A	8	60-120	2
B	10	140-200	6
C	15	250-310	3
D	26	330-30	14

It is seen from Fig. 2 that the four main ice-caps of southern Iceland lie in the shape of a horseshoe which is open to the west. During the long summer days the stony surface in this horseshoe area is strongly heated, and it seems probable that as a result of this a low-pressure area frequently develops here, from which troughs extend up between the ice-caps like outstretched fingers from the palm of a hand. In addition to what has been reported above in connexion with winds off the ice-cap and the development of low-level cumulus cloud, the following facts further support this suggestion that areas of comparatively low pressure showed a tendency to develop to the west, south and east of stations A, D and C respectively.

(i) Station C experienced northerly winds more frequently than did any of the other stations (see Table III).

(ii) Northerly winds were strongest at station C, where their mean velocity was 14 kt. as compared with 13, 7 and 11 kt. at stations A, B and D respectively.

(iii) Stations A, B and D each experienced southerly winds on 16 occasions, whereas the corresponding figure for station C was only 5.

(iv) Whilst station A experienced easterly and south-easterly winds on 24 occasions, the corresponding figure for station C was only 5.

(v) Station C experienced westerly and north-westerly winds on 33 occasions, whereas the corresponding figure for station A was only 6.

(vi) Station D experienced easterly winds more frequently than did any of the other stations (see Table III).

Fig. 5, reproduced from the *Daily Weather Report*, shows conditions at 1200 G.M.T. on September 4, 1951. Winds and sea-level temperature at the Expedition's four meteorological stations at this time, together with readings reported from three of the coastal stations, are represented in Fig. 2. The marked differences between readings at Vestmannaeyjar, just off the south coast, and station A on the one hand, and between station A and stations B, C and D on the other, would seem to indicate that under the influence of a small depression, which had developed in the horseshoe area as postulated above, the occluded front had swung northwards, so that station A was located on its southern side. In fact, its passage across this station between 1000 and 1100 G.M.T. was clearly indicated by marked changes both in wind direction and temperature. The main depression shown in Fig. 5 moved north-eastwards fairly rapidly along a track which lay just off the east coast, but the occlusion, which showed signs of being anchored in the neighbourhood of station A, did not pass across the Hofsjökull area as a whole until the following morning, when south-westerly winds and rain were experienced at all four stations.

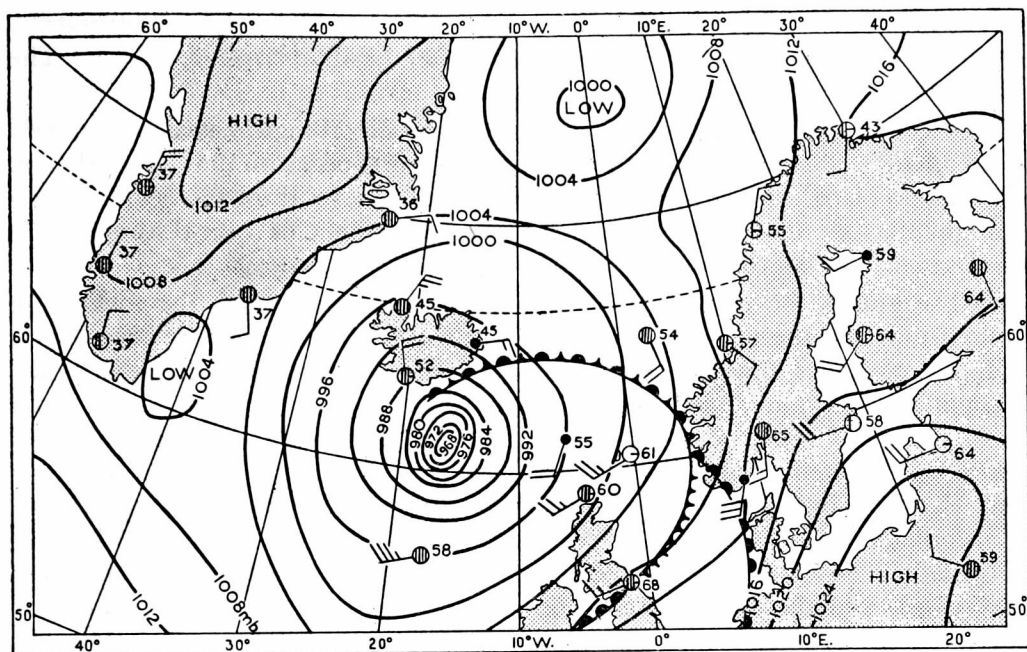


FIG. 5—SYNOPTIC CHART, 1200 G.M.T., SEPTEMBER 4, 1951

This chart has been copied from the *Daily Weather Report*

It is considered that observations in this area over a much longer period might well show that the development of low pressure by convection over these stony plains in summer is of considerable importance in the formation of small secondaries on the north side of those major depressions which move from west to east off the south coast of Iceland.

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RARE PARHELION SEEN AT OXFORD, AND A NOTE ON THE FREQUENCY OF SOLAR AND LUNAR HALOS AND ASSOCIATED OPTICAL PHENOMENA, 1882-1951

By J. G. BALK

On January 20, 1952, a parhelion to the solar halo of 8° radius was seen at the Radcliffe meteorological station, Oxford, similar to that observed from Northolt by Mr. J. G. Shipcott on August 5, 1951, and reported in the *Meteorological Magazine* for November 1951.

When the meteorological observations were taken at 0900 G.M.T. the sky was cloudless except for a small belt of cirrus cloud, about 30° in length and 3-5° in width, moving in a north-west-south-east direction. At 0920 this belt of cloud was passing across the sun, and in a small break a parhelion, brightly coloured with red towards the sun, appeared to the right of the sun at a distance of 8°. A small portion of the parhelic circle was also present, about 2° in length, which extended from the parhelion outwards, giving the appearance of a white "spur" to the parhelion. Similar "spurs" have frequently been observed in the past in connexion with parhelia to the 22° solar halo. The phenomenon lasted for about five minutes, disappearing as the break in the belt of cloud moved away to the south-east.

The surface meteorological conditions at the time were as follows:—

Wind NNW. force 2, air temperature 31°F., visibility 1,100–2,200 yd. The altitude of the sun was 9°.

A search through the records of the Radcliffe meteorological station (formerly the Radcliffe Observatory) shows that this is the first occasion that the parhelia to the halo of 16° diameter has been observed. As a result of this search it was thought that a note on the frequency of the occurrence of optical atmospheric phenomena at Oxford would be of interest.

Before giving the results it is necessary to comment upon the method of observation and the number of observers at the Observatory. The observation of halos, etc., was always a part of the ordinary meteorological routine at the Radcliffe Observatory. Before 1908 the staff consisted of the first, second and third assistants and the computer. The third assistant was responsible for taking the meteorological observations and reducing them. In June 1907 Mr. H. G. S. Barrett was appointed third assistant, having previously served in the meteorological section at the Royal Observatory, Greenwich, where he had made a special study of optical phenomena. He carried on with this work at Oxford, and the observation of optical phenomena became a speciality in which the remainder of the staff collaborated with enthusiasm and vigilance. In 1920 Mr. J. G. Balk was appointed third assistant. In 1935 when the Radcliffe Observatory was transferred to Pretoria the meteorological section was taken over by the University of Oxford, assumed the title “Radcliffe Meteorological Station”, and was placed under the supervision of the School of Geography. Since this date the observations have been made by Mr. Balk. Before 1935 the Radcliffe Observatory was favourably situated for the observation of halos, standing in spacious grounds with an almost uninterrupted view of the sky in all directions, and with the various staff rooms all facing due south. Being also an astronomical observatory the night sky was under observation for a considerable period during the hours of darkness. Most of the observations were made by direct vision, but a dark reflector, consisting of a piece of plate glass blackened at the back, which eliminated all glare was used to enable a more careful study to be made of parhelia, arcs of contact, etc. The halos observed were seldom complete, but rarely less than 60° in length. No observation was counted as a true halo unless the distinctive colours were seen. In doubtful cases the radius was measured and it was established that the arc did not move with the clouds. In all cases the solar and lunar halos are those of 22° diameter unless otherwise stated.

Table I gives the mean number of days per month with solar and lunar halos for the periods before and after the observation became more specialized, and also for the complete period, 1882–1951.

TABLE I—HALOS OBSERVED AT RADCLIFFE METEOROLOGICAL STATION

Period	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
Solar halos													
1882–1907	1·3	2·5	3·9	5·4	5·4	4·5	3·2	3·4	3·4	2·8	2·1	1·4	39·3
1908–51	9·6	8·6	11·1	12·1	12·0	11·0	10·9	11·1	10·5	10·1	9·2	8·9	125·1
1882–1951	6·5	6·3	8·5	9·6	9·6	8·6	8·0	8·2	7·9	7·4	6·6	6·1	93·3
Lunar halos													
1882–1907	2·2	1·3	1·7	1·3	1·3	0·3	0·0	0·7	1·3	1·4	2·2	1·8	15·5
1908–51	4·2	3·9	3·6	3·2	1·6	0·9	0·6	1·2	2·3	3·2	4·0	5·3	34·0
1882–1951	3·4	2·9	2·9	2·5	1·5	0·7	0·4	1·0	1·9	2·6	3·3	4·0	27·1

During the period 1908-51 the highest number of days with solar halos in a year was 177 in 1927 and the least, 67 in 1912. The highest monthly total was 21, in April 1923, and the lowest 1, in June 1908, February 1917, February 1932, February 1934, and January 1941. The longest periods of consecutive days with solar halos were 12 days, February 12-23, 1914, and 10 days, June 29-July 8, 1922, and March 24-April 2, 1932. The longest period with no solar halo was one of 31 days from August 28th to September 27, 1912.

The greatest number of lunar halos visible in a year was 55 in 1923 and the smallest 16 in 1918. The highest monthly totals were 11 in January 1928 and December 1947.

All the observers agree that in view of the fact that on several occasions the halo was only visible momentarily, many occurrences must have passed without being noted.

The total numbers of halos and associated phenomena observed at the Radcliffe meteorological station during various periods are given in Table II.

TABLE II—NUMBER OF OCCASIONS WITH HALOS AND ASSOCIATED PHENOMENA

	1882-1907 (26 yr.)	1908-51 (44 yr.)	1882-1951 (70 yr.)
	<i>number of days</i>		
SOLAR:			
22° halo	1,020	5,503	6,523
Upper arc of contact to 22° halo	1	305	306
Lower arc of contact to 22° halo	0	14	14
Parhelson to 22° halo	50	784	834
46° halo	2	81	83
Circumzenithal arc	0	34	34
90° halo	1	0	1
Parhelic circle	1	7	8
Anthelion	1	0	1
Sun pillar	1	152	153
LUNAR:			
22° halo	402	1,498	1,900
Upper arc of contact to 22° halo	0	16	16
Lower arc of contact to 22° halo	0	1	1
Lunar corona	92	739	831
Paraselenae to 22° halo	7	47	54
46° halo	0	21	21
Moon pillar	0	30	30
Zodiacal light	46	493	539
Zodiacal band	0	73	73
Counter glow (Gegenschein)	2	42	44
Aurora	22	27	49

During the period 1882-1951 there were several days with displays of solar halos and associated phenomena, the most outstanding being that of December 22, 1900, between 0900 and 1100 G.M.T. when the 22°, 46° and 90° halos, parhelia and upper arc of contact to the 22° halo, parhelic circle and anthelion were observed, together with a column of white light extending upwards from the horizon through the anthelion (altitude at 1000, 10°) to a height of 12°.

Since 1935, with the introduction of more powerful street lighting and to a lesser extent to the glare from the headlights of motor vehicles, the displays of zodiacal light, aurora, etc., have been more difficult to see from the confines of the city. The same trouble necessitated the removal of the Observatory

to Pretoria. During the past 19 years the zodiacal light has been observed on only 43 nights, 30 of these were during the period of the last war when the black-out was in operation.

Figures of halo frequency comparable with those at Oxford since 1908 are available from the Montsouris Observatory, Paris, and are published in the *Annales des services technique d'hygiene de la ville de Paris, Tome III, Météorologie*. On p. 24 of this publication the number of days of solar or lunar halos are given and on p. 25 the frequency of various types of halo, etc.

Table III gives the results for the two Observatories for the 10 years 1908–1914 and 1919–1921.

TABLE III

	Number of days with solar or lunar halos											
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Oxford	93	86	124	113	112	99	83	74	88	89	99	122
Montsouris	72	94	158	164	146	144	113	112	107	128	83	93

	Annual totals of days with solar or lunar halos											Total
	1908	1909	1910	1911	1912	1913	1914	1919	1920	1921		
Oxford	84	95	120	106	83	105	164	120	145	160	1,182	
Montsouris	134	146	158	132	126	135	138	138	159	148	1,414	

According to the frequency table for Montsouris given on p. 25 of the above publication the following are the totals for the 20 years 1898–1914 and 1919–21, which may be compared with the Oxford figures in Table II:—

22° solar halo...	...	...	...	2,577	46° solar halo...	...	...	...	167
Upper arc of contact to 22° solar halo	...	...	...	187	Parhelic circle	...	...	...	33
Parhelson to 22° solar halo	...	...	...	575	Sun pillar	...	...	...	50

SPEED OF WARM FRONTS

By A. G. MATTHEWMAN, B.A.

Summary.—An account is given of some statistical tests of certain empirical, kinematical, and dynamical formulae for the speed of warm fronts.

Formulae in use.—In practical forecasting the speed of a front may be estimated in various ways, one of which is the application of objective rules to the current data and the analysed chart. On the basis of recent charts prepared at the Central Forecasting Office some of these rules have been tested.

The most common practice in estimating the speed of a warm front is to take the speed u_f as some proper fraction of the geostrophic wind component measured at the front and at right angles to the front u_r . The fraction is variously taken as 60–80 per cent. by Petterssen¹, 50–70 per cent. by Byers², and as $\frac{2}{3}$ or as $\frac{3}{4}$ by various other practising forecasters; no doubt there are also other preferences, a state of affairs which is not surprising since no formula is accurate and the best regression equation must depend on many factors such as geographical locality and season of the year.

Another relationship which may be useful is the approximate equality between the speed of the warm front and the component of actual measured wind speed normal to the front above the friction layer (say at about 900 mb.) and on the cold side of the front. The equality would be exact, for kinematical

reasons, if the frontal surface were a substantial surface of discontinuity with the cold air moving horizontally¹.

Further, it is possible to derive dynamical expressions for the frontal speed, which depend on the equations of motion. Of these one form was given in an unpublished research paper by Matthewman³, and another by Miles⁴, but for use in practical work on synoptic charts perhaps the most satisfactory is that given by Økland⁵ which is practically identical with the following:

$$u = u_1 - \frac{1}{l} \frac{dv}{dt} + f,$$

where u and v are respectively the wind components normal to and parallel with the front, f is a frictional term, l is the Coriolis parameter, and d/dt indicates differentiation following the motion of the fluid.

Then

$$u = u_1 - \frac{1}{l} \left(\frac{\partial v}{\partial t} + u \frac{\partial v}{\partial x} + v \frac{\partial v}{\partial y} + w \frac{\partial v}{\partial z} \right) + f.$$

Accepting the kinematical approximation mentioned above that the speed of the front is given by the component u in the cold air, with w , the vertical velocity, and f , the frictional effect which is assumed negligible, we have

$$u_r = u_1 - \frac{1}{l} \frac{\delta v}{\delta t} + v \frac{\partial v}{\partial y} \quad \dots\dots\dots(1)$$

where $\frac{\delta v}{\delta t} = \frac{\partial v}{\partial t} + u \frac{\partial v}{\partial x}$,

and is the rate of change of v with time at a point moving with the front. Although the component u normal to the front is often significantly different from u_1 , the component v parallel with the front is more reasonably taken as given approximately by the geostrophic component v_1 . In any case, in common with Økland, we make the approximation $v = v_1$. The terms can then be estimated from the contours at 900 mb., which, in practical work, cannot be easily distinguished from the mean-sea-level isobars.

The present paper gives some new statistical tests of the formulae.

Data.—For the period 1949–51 all warm fronts near the British Isles were re-examined. As is well known many fronts which are justifiably so marked on working charts do not fit at all well with the classical model, and also in many cases there is no upper air observation at a time and place which permits the frontal structure to be known with any confidence. In order to obtain a reasonably homogeneous set of data only those warm fronts were included in which there was an observation of wind, temperature and humidity within the cold air ahead of the front showing a “frontal zone” of reduced lapse rate with the lower boundary of the zone between 910 and 840 mb. and with wet-bulb potential temperature increasing above the boundary. It was also required that the position of the front at the surface should be well defined and the run of the isobars tolerably certain. All the statistics, except some relating to the connexion between u_r and u_1 , were obtained from this set of 37 special cases.

The speed of the front u_r was taken as the average displacement per hour in the direction at right angles to the front for the 6-hr. period centred at the time of the chart (which was approximately synchronous with the upper air observations used). The wind component at right angles to the front

was taken from the radar wind observation referring to 900 mb. and below the frontal zone. Geostrophic components were estimated in the conventional way but special care was taken with the isobars. The value u_f refers to the component at the frontal position on the surface chart, the value u_f' refers to the component in the same direction but measured 75 miles ahead of the front. The quantity $\delta v/\delta t$ of equation (1) was not considered in the statistics as there were too few occasions where it was of significant magnitude.

The quantity $v \partial v/\partial y$ was estimated from its geostrophic approximation by a simple finite-difference approximation to the pressure gradient. A square scale similar to that suggested by Økland (although earlier and independently devised) was used.

When density and latitude variations are neglected (fully justifiable in this problem) it is clear that

$$v_f \frac{\partial v_f}{\partial y} = \frac{1}{2} \frac{\partial}{\partial y} (v_f^2) \\ \propto \frac{\partial}{\partial y} \left(\frac{\partial p}{\partial x} \right)^2.$$

If A, B, C, D is a square scale orientated with AB along the x -axis, and if p_a, p_b, p_c, p_d are the pressures at the points A, B, C, D, then with linear approximation

$$v_f \frac{\partial v_f}{\partial y} \propto \{(p_b - p_a)^2 - (p_c - p_d)^2\}.$$

The scale was taken with side 150 miles and was used by placing the side AB along or tangential to the front. With units of miles per hour and millibars we find sufficiently closely that, at latitude 50° approximately,

$$\frac{v_f}{l} \frac{\partial v_f}{\partial y} = \frac{3}{8} \{(p_b - p_a)^2 - (p_c - p_d)^2\}.$$

Statistical tests.—Various correlation coefficients, regression equations and variances were determined and are listed with brief comments in the next section. No attempt has been made to introduce sophisticated statistical tests and procedures, but it is worth while to comment on a special point which must frequently arise in synoptic meteorology. We are dealing with a turbulent fluid with fluctuations on a wide range of space and time scales, and the terms we use, such as wind velocity, geostrophic wind, pressure gradient, position of a front, etc., are taken with a common-sense interpretation according to the particular problem on hand. When numerical estimates are made, especially when they are to be handled statistically, it is, however, necessary to be a little more definite. In relating the quantities for our present problem we want "synoptic estimates" which we may take as implying values averaged or smoothed over distances of the order of 100 miles and periods of an hour or two. Nothing more precise can have much practical application in synoptic meteorology for the observations are themselves at wider intervals. For the best network in the world, upper air observations have a space grid of some 200 miles and a time interval of 6 hr. or more.

A geostrophic wind is obtained from a pressure gradient on a chart based on observations which are smoothed by eye in the drawing of isopleths. The standard deviation in estimating a synoptic pressure gradient from a good network of observations is about 4 m.p.h. A measured upper wind is averaged

over two or three minutes. It is liable to short-period fluctuations of standard deviation also about 4 m.p.h.

The position of a front on a chart is always uncertain, but to a varying degree depending on the data and the nature of the front. The well marked fronts with which we are concerned may be placed with a standard deviation of perhaps 20–30 miles (greater precision is often meaningless) and a “speed” estimated from a 6-hr. displacement cannot have a standard error less than some 5 m.p.h.

Thus the quantities with which we are concerned, having mean values of the order of 25 m.p.h. and standard deviations σ of about 10 m.p.h., may be regarded as estimated from quantities which include a “random” element ε of say 4 m.p.h. The maximum correlation which could be obtained between perfectly correlated quantities liable to such random errors is of course less than unity. If, for example, it were strictly true, according to physical theory, that

$$u_F = ku_J$$

or

$$u_F = u$$

the maximum correlation coefficient obtainable, apart from sampling errors, would be

$$r = \frac{(\sigma^2 - \varepsilon^2)}{\sigma^2}.$$

The best formula for estimating u_F from an observation of u (both in miles per hour) would, instead of the equality, be

$$u_F = 0.84 u + 4.$$

It will be found that correlations in this neighbourhood are actually obtained so that improvement by a general statistical formula will be difficult.

Results.*—*Linear relation between the speed of the warm front u_F and the component of geostrophic wind perpendicular to the warm front, measured at the front u_J or measured 75 miles ahead of the front in the cold air u_J' .*—Table I sets out the main statistics for this comparison. In the first column all cases in the vicinity of the British Isles are allowed excluding regions within 100 miles of the ends of the warm fronts and excluding the immediate vicinity of high ground. The working charts were not however revised. The correlation coefficient 0.72 is quite high. When, however, only the special set of cases (defined on p. 267) are accepted and the charts are carefully revised the correlation coefficient goes up to the high value of 0.82.

TABLE I—RELATION BETWEEN u_F AND u_J OR u_J'

	Warm fronts on routine unrevised charts 1949–51	Set of special warm fronts (defined on p. 267)	Set of special warm fronts taking u_J' instead of u_J
Number of cases ...	101	37	37
Correlation coefficient ...	0.72	0.82	0.85
Regression equation ...	$u_F = 0.55 u_J + 5.5$	$u_F = 0.60 u_J + 2.4$	$u_F = 0.70 u_J' + 3.0$
Root-mean-square residual	7.1	5.9	5.4
Mean value of u_F ...	22.9	18.9	18.9
Mean value of u_J ...	31.7	27.6	22.7 (u_J')
Standard deviation of u_F ...	10.2	10.3	10.3
Standard deviation of u_J ...	13.5	14.1	12.5 ($\sigma_{J'}$)

* All speeds are in miles per hour.

The formula

$$u_F = \frac{2}{3}u_J$$

is clearly very good as an average, and in the special cases is hardly distinguishable statistically from the regression

$$u_F = 0.6u_J + 2.4.$$

The third column in the table refers to the use of u_J' , the normal geostrophic wind component 75 miles ahead of the front. This arose in the use of the more complex formula. Not only is the correlation improved (and probably significantly so) from 0.82 to 0.85 but the mean value is nearer to u_F . The regression equation

$$u_F = 0.7u_J' + 3$$

must be very difficult to improve upon with the type of data.

Relation between the speed of the warm front u_F and the component u of the actual wind at 900 mb. perpendicular to the surface front.—The correlation is near the theoretical limit for the type of data, and the two quantities u_F and u have very nearly the same mean values and the same variances. The data are therefore consistent with the hypothesis that, with suitably smoothed values, $u_F = u$ is a physical relationship valid for well marked warm fronts.

TABLE II—RELATION BETWEEN u_F AND u

Number of cases	...	...	37	Mean value of u_F	...	...	18.9
Correlation coefficient	...	...	0.85	Mean value of u_J	...	...	18.5
Regression equation	$u_F = 0.80u + 4.1$			Standard deviation of u_F	...	...	10.3
Root-mean-square residual	...	...	5.5	Standard deviation of u	...	...	10.9

The rule $u_F = u$ gives root-mean-square residual 5.9

Although the regression equation is statistically the better formula for estimating u_F from a wind measurement the advantage over the theoretical formula is slight.

Relation between the speed of the front u_F and the dynamical estimate

$u_J' - (v_J/l) (\partial v_J / \partial y) \equiv u_J' - \Delta$.—The approximate theoretical equation

$$u_F = u_J' - \frac{v_J}{l} \frac{\partial v_J}{\partial y}$$

gives root-mean-square residual 5.8.

TABLE III—RELATION BETWEEN u_F AND $u_J' - \Delta$

Correlation coefficient	...	...	0.84	Mean value of $u_J' - \Delta$	...	...	19.3
Regression				Mean value of u_J'	...	...	22.7
equation	$u_F = 0.85(u_J' - \Delta) + 2.5$			Mean value of Δ	...	...	3.4
Root-mean-square residual	...	...	5.6	Standard deviation of u_F	...	...	10.3
Mean value of u_F	...	...	18.9	Standard deviation of $u_J' - \Delta$	...	...	10.3

It is clear from comparison with the third column of Table I that this complex formula is no improvement on the simpler regression on u_J' , although it seems to be a little better than using u_J at the front.

It is however significant that the additional term Δ brings the average values and variances almost exactly into line. It fails to improve on the correlation, probably because the value is near the maximum attainable, but the data are consistent with the assumption that the theoretical approximation

$$u_F = u_J' - \frac{v_J}{l} \frac{\partial v_J}{\partial y} = u_J' - \Delta$$

is close to the physical truth.

In the circumstances it was improbable that any further advantage could be gained by a double linear regression of u_r on u_j' and Δ , and this proved to be so. By least squares the best equation was found to be

$$u_r = 0.77u_j' - 0.33\Delta + 2.6,$$

but the root-mean-square residual is thereby only reduced from 5.6 to 5.4.

Conclusions.—The data are consistent with the physical assumption that the speed of a well defined warm front is equal to the component of the actual wind speed in the cold air below the frontal zone and above the friction layer, say at 900 mb. If such an observation is available it can be used as an estimate of frontal speed with an algebraic mean error less than 1 kt. and root-mean-square error less than 6 kt. A statistical regression equation is only a slight improvement.

The use of the geostrophic component is good. The best regression equation for the special warm fronts is

$$u_r = 0.6 u_j + 2.4,$$

which has a root-mean-square residual of 5.9, but

$$u_r = \frac{2}{3} u_j$$

with a root-mean-square residual of 6.0 is almost as good.

If u_j' is measured 75 miles ahead of the front (and so probably more representative of cold air above the friction layer) the correlation reaches the very high value of 0.85 for this type of data, and the best formula is

$$u_r = 0.7 u_j' + 3.0$$

with a root-mean-square residual of 5.4.

The introduction of the dynamical term does not, with these data, give any statistical advantage, but the results are consistent with the assumption that a very good physical approximation is given by the equation

$$u_r = u_j' - \frac{v_j}{l} \frac{\partial v_j}{\partial y}.$$

The straight use of this formula gives algebraic mean error less than 1 kt. and root-mean-square error less than 6 kt.

The question which arises of course is, to what use the results may be put and the answer must be related with the practical politics of forecasting. It must not of course be supposed that the forecaster is dependent on such formulae and such formulae alone, or that there are likely to be circumstances where the small statistical advantages of one formula over another will be of any significance either for the particular occasion or in the long run. Almost certainly the best procedure on any given occasion will be to use the relationship most suited to the available data. If an observed wind is available in the right place it should be taken. For all rough purposes the two-thirds rule is probably as good as any, but it may often be worth while to check with the dynamical estimate, especially when the quantity Δ is obviously significant, which can be judged by inspection.

It is hoped to collect a greater number of examples in which this term has large magnitude and investigate more fully the optimum size of the square-scale, and the best position to make the measurements. In one case, January 26–30, 1940, a warm front moved with a mean speed 12.5 m.p.h. less than that

given by the two-thirds rule but only 5·1 m.p.h. less than that given by the dynamical approximation as estimated above. Further improvement may yet be obtainable.

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FOG AT NORTH FRONT, GIBRALTAR

By A. WARD

Introduction.—The hourly observations made at the airfield at North Front since June 1943, on which the present investigation is based, provide the only reliable data giving the frequency of fog at Gibraltar; the earlier observations were made from badly exposed sites on the Rock, and prior to 1938 they were only made at infrequent intervals¹. The topography of the Rock and the surrounding country is shown in Figs. 1 and 2.

In order to illustrate the variability of the fog observations, a comparison is made between the frequencies of fog at North Front, Windmill Hill, and in the Straits, but the main purpose of the paper is to set out the facts about fog formation at North Front and to discuss the associated forecasting problems.

Types of fog in the vicinity of Gibraltar.—Experience based on 14 years of continuous observation by Meteorological Office staff at Gibraltar shows that the most important type of fog there is sea fog, formed in the Straits and over the sea east of Gibraltar, and advected over North Front by light on-shore winds. Sea fog may occur with both easterly and westerly winds¹, but extensive fog is almost always associated with easterly winds, to which North Front is completely exposed.

Occasionally during the wet season, the visibility may be reduced to fog limits by heavy rain (either associated with upper-level thunderstorms arriving from north Africa or with vigorous cold fronts moving south-eastwards across Spain and Portugal) or by the low cloud and rain associated with slow-moving or quasi-stationary fronts in the Straits of Gibraltar.

During recent years there have been two occasions when visibility at North Front was reduced to less than 1,100 yd. by dust and sand carried from French Morocco by a strong south-south-westerly wind. A full description of the duststorm which occurred on December 5, 1950 was given in the July 1951 *Meteorological Magazine*².

Radiation fog does not occur at North Front, but small patches are occasionally observed at the mouth of the Guadarranque river at the northern end of Gibraltar Bay.

Seasonal variation of fog.—*Monthly distribution.*—Table I shows the average monthly number of days of fog, i.e. days when the visibility fell below 1,100 yd. at any time, at North Front, Windmill Hill and in the Straits. Fog is most frequent during the summer months, and occurs more often in the Straits than at North Front or Windmill Hill.

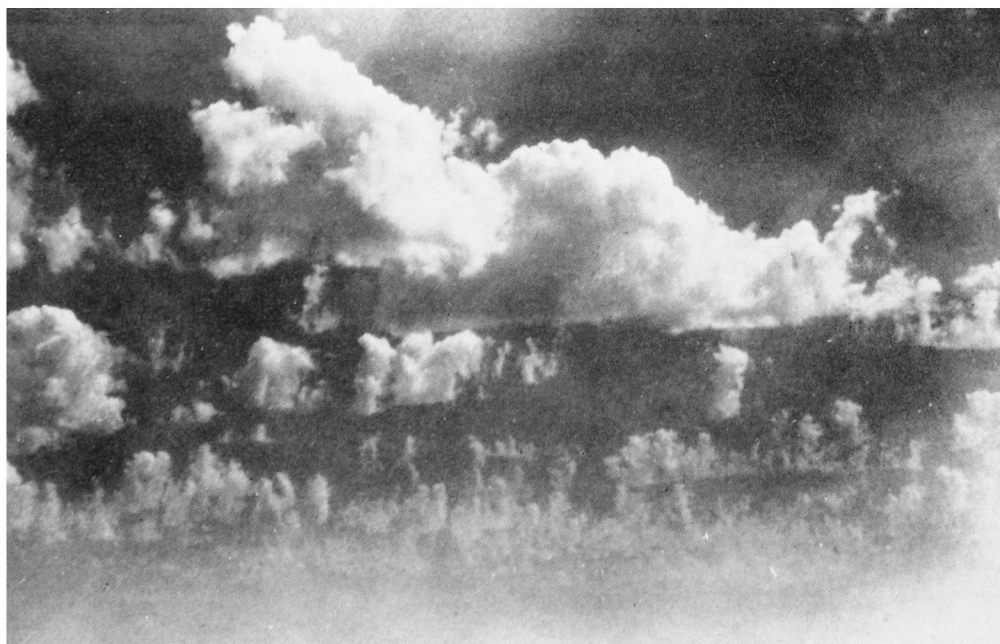


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CAPT. N. F. ISRAEL, D.S.C., WITH THE SHIELD PRESENTED BY O.W.S. *Weather Observer*
TO HILLHEAD HIGH SCHOOL, GLASGOW, FOR THE INTER-HOUSE RELAY RACE

Left to right:—Mr. I. P. McIntosh (Meteorological Officer-in-Charge), Mr. Stewart, W. S. Marson (School Captain), Capt. Israel, Mr. L. Lambert (Radio Overseer), Mr. Paterson (Headmaster), J. F. MacLeod (School Captain).

(see p. 254)



ALTOCUMULUS FLOCCUS AT STRADISHALL, JULY 1, 1952, ABOUT 1430, BASE
ABOUT 10,000 FT.

(see p. 284)



FIG. 3—DEVELOPMENT OF LOW-LEVEL CUMULUS CLOUDS AT 0920 G.M.T.
View taken from the summit plain of Hofsjökull looking towards the stony plain near station A
(see p. 261)

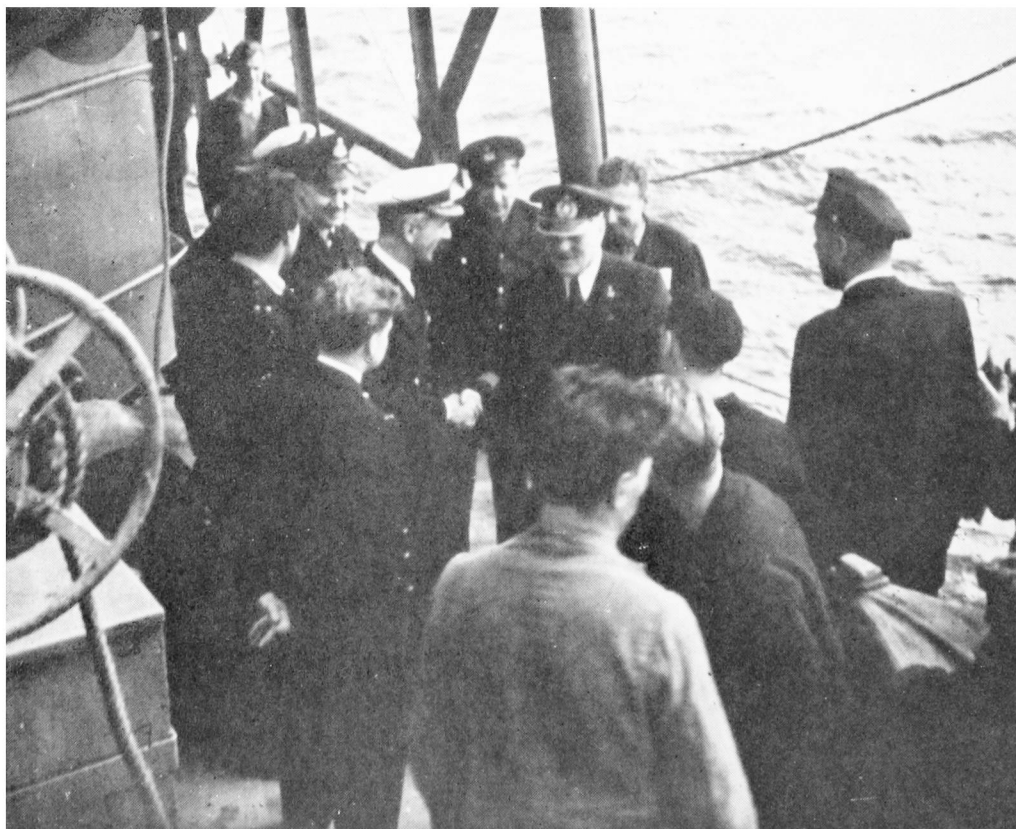


FIG. 4—DEVELOPMENT OF LOW-LEVEL CUMULUS CLOUDS AT 0940 G.M.T.
View taken from the summit plain of Hofsjökull looking towards the stony plain near station A
(see p. 261)



Reproduced by courtesy of J. K. McNair

Capt. J. P. Groen of the o.s.v. *Cumulus* being welcomed aboard the o.w.s. *Weather Observer* by Capt. N. F. Israel



Reproduced by courtesy of J. K. McNair

Netherlands and British staff aboard o.w.s. *Weather Observer*
VISIT OF CAPTAIN AND OFFICERS OF O.S.V. *Cumulus* TO O.W.S. *Weather Observer*
ON STATION JULIETT MAY 10, 1952
(see p. 284)

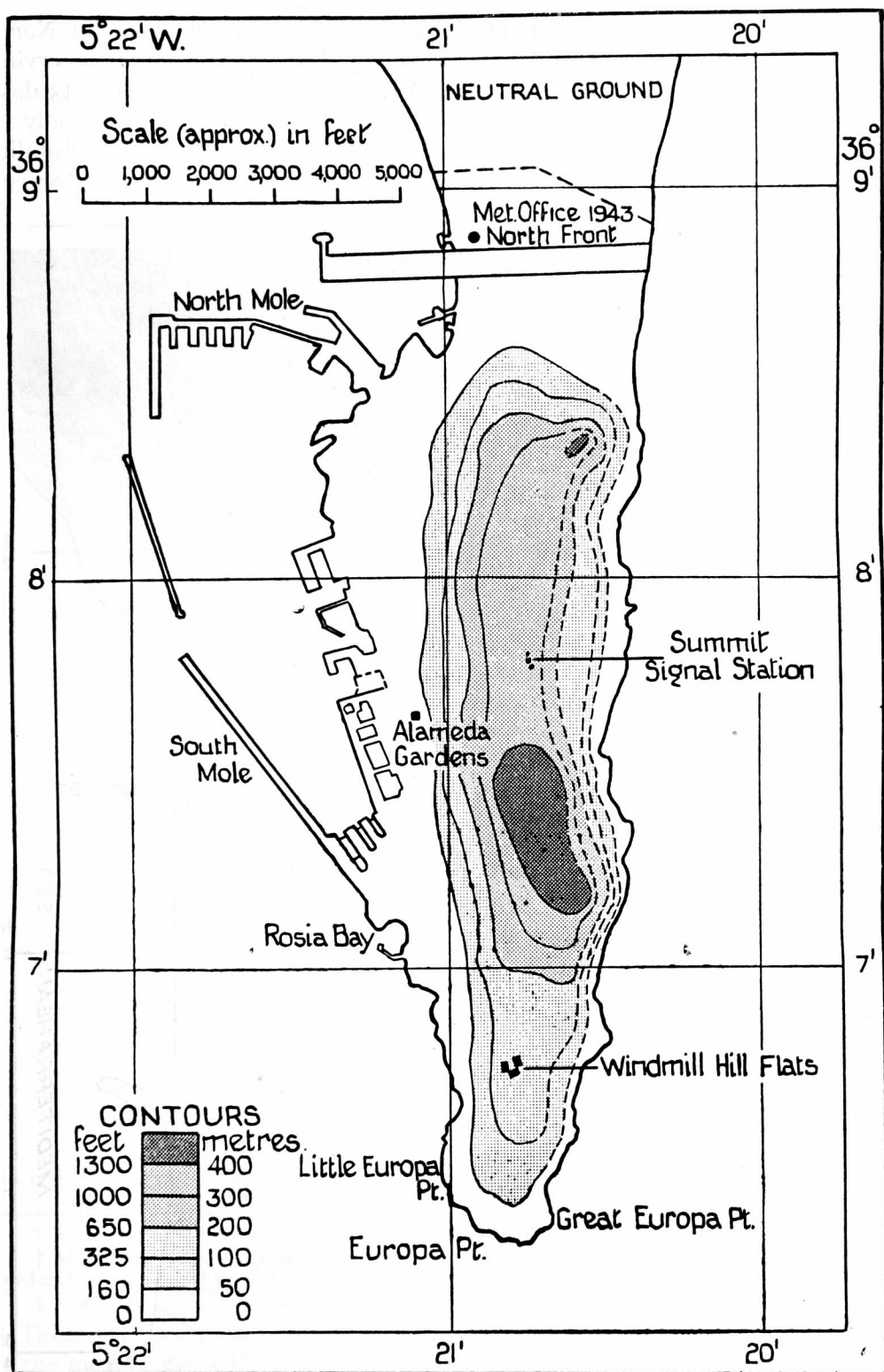


FIG. 1—PLAN OF THE ROCK OF GIBRALTAR SHOWING THE SITES OF THE METEOROLOGICAL STATIONS

Approximate contours are drawn for 10, 100, 200, 300 and 400 m.

The frequency of fog at Windmill Hill is appreciably less than at North Front, largely because of the difference in height above sea level of the observing stations. During the period June 1943 to December 1947 there were 43 days on which fog occurred at both stations. On 32 days, fog occurred only at North Front; Windmill Hill was above the fog and reported good visibility on 24 of these days, while on the remaining 8 days low stratus was observed

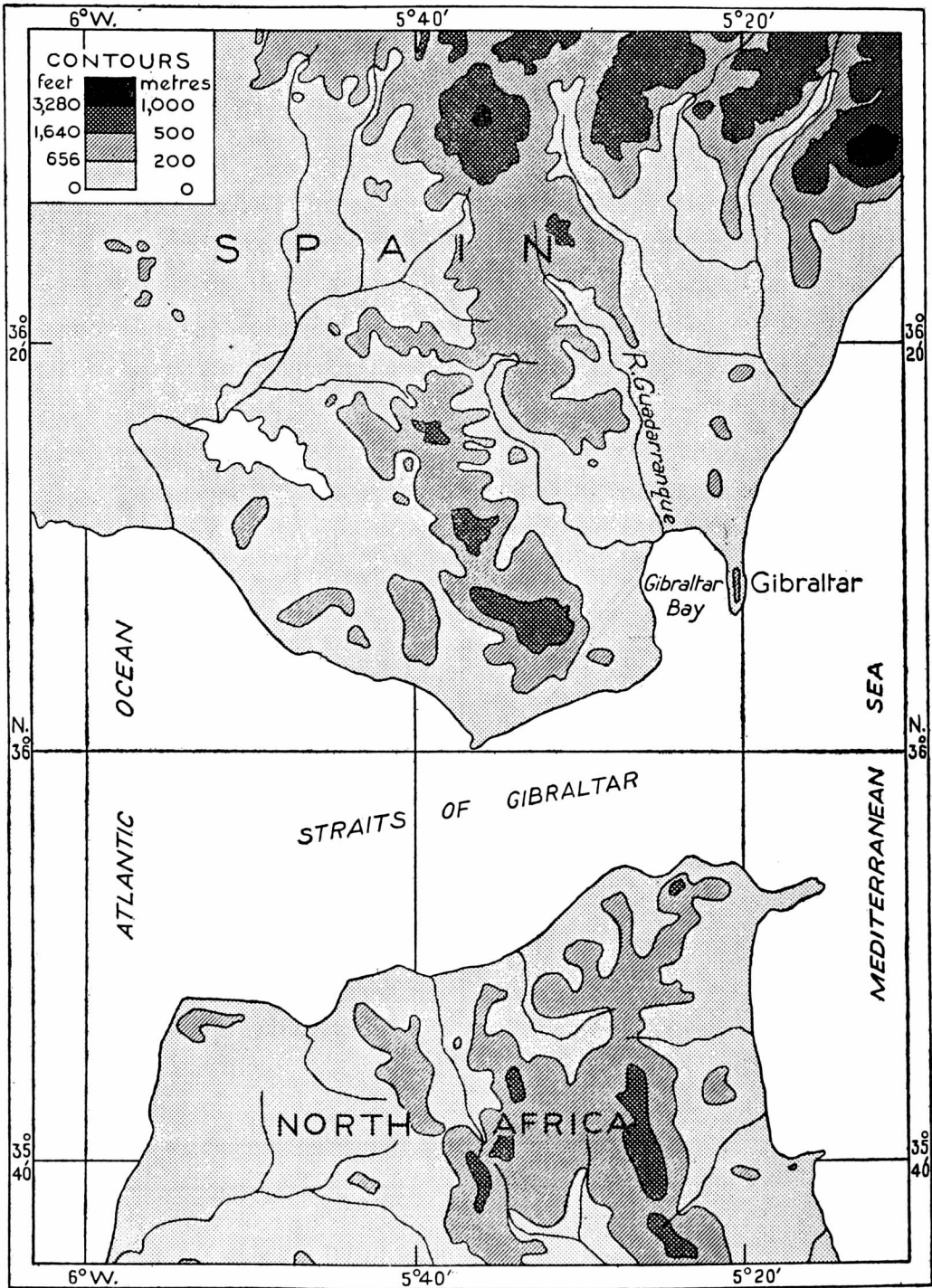


FIG. 2—THE STRAITS OF GIBRALTAR

TABLE I—MONTHLY FREQUENCY OF FOG AT GIBRALTAR

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
	<i>number of days</i>												
North Front *	0.1	0.6	0.4	0.7	0.7	2	4	4	3	0.9	0.9	0.4	18
Windmill Hill†	0.1	0.5	0.5	0.4	0.7	1	3	1	2	1	0.4	0.1	11
Straits‡	0.7	1	0	0.5	2	5	11	8	4	3.5	2.5	0	38

* Based on hourly observations during the period June 1943 to August 1951 inclusive.

† 10-year mean, period 1938 to 1947 inclusive.

‡ Based on observations, from the last quarter of 1935 until 1939, from the Meteorological Office at Windmill Hill³. The exact criterion used to define "fog over the Straits" is not known, so that the frequencies may not be strictly comparable with those for North Front and Windmill Hill.

with base at between 50 and 300 ft. above station level, a lifting of the fog which was probably due to the additional turbulence over the southern end of the Rock. On 12 days fog occurred only at Windmill Hill; extensive low stratus with base below 600 ft. was observed at North Front on 9 of these days, while on the remaining 3 days the fog appears to have been very local.

Relation to sea temperature.—The major cause of reduction of visibility to fog limits at North Front is sea fog. Pure sea fog is formed in warm damp air which passes over a cold sea surface; the air is cooled below its dew point, and condensation results⁴. It is to be expected, therefore, that the frequency of fog at North Front will be a maximum when the difference between the mean air temperature and the mean sea temperature is greatest, and the difference between the mean dew point and the mean sea temperature least. Table II shows that from June to September inclusive, when fog is most frequent, the mean air temperature is 5–8°F. above the mean sea temperature, and the mean dew point only 1–3°F. below the mean sea temperature.

TABLE II

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
	<i>degrees Fahrenheit</i>											
Mean air temperature*	56	58	60	63	65	72	76	78	74	69	63	57
Mean dew point†	49	51	53	55	57	64	67	67	67	63	58	51
Mean sea temperature‡	59	58	57	60	62	65	68	70	69	66	63	59
Mean air temperature minus mean sea tem- perature	–3	0	+3	+3	+3	+7	+8	+8	+5	+3	0	–2
Mean sea temperature minus mean dew point	10	7	4	5	5	1	1	3	2	3	5	8
	<i>number of days</i>											
No. of days of fog	0.1	0.6	0.4	0.7	0.7	2	4	4	3	0.9	0.9	0.4

* Mean air temperature = $\frac{1}{2}$ (mean max. + mean min.), May 1946 to March 1951.

† Mean dew point = $\frac{1}{2}$ (mean 0300 dew point + mean 1500 dew point), January 1945 to March 1951.

‡ Values for northern Straits¹.

Table III shows that the difference between the mean sea-fog point (defined as the mean dew point 3–6 hr. before the onset of fog at North Front) and the mean sea temperature is positive during the months June to September inclusive, when fog is most frequent, and negative during the remaining months. Although there are too few observations to permit of any firm conclusions, nevertheless there does seem to be some relationship between the change of sign of this difference and the seasonal and local variations of sea temperature.

TABLE III

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
	<i>degrees Fahrenheit</i>											
Mean sea-fog point	...	57	56	59	60	66	70	71	70	64	61	...
Mean sea-fog point minus mean sea temperature	...	-1	-1	-1	-2	+1	+2	+1	+1	-2	-2	...
	<i>number of observations</i>											
No. of observations	...	3	3	6	6	12	23	23	20	6	6	...

From June to September, the normal distribution of sea temperature over the area east and west of Gibraltar is a decrease from east to west⁵ so that air moving westwards undergoes a steady cooling, a well marked temperature inversion is established, and the lower layers of air acquire a large moisture content. If the dew point of the easterly air stream is initially high, the progressive cooling effect of the sea surface will result in the development of fog in the vicinity of Gibraltar. Conditions are particularly favourable for fog development after a wind change from west to east, when a spell of westerly winds has brought cool Atlantic water into the Straits¹.

From October to May, however, the normal distribution of sea temperature is fairly uniform over the area east and west of Gibraltar⁵, and is not so favourable for fog development in the vicinity of Gibraltar. During these months the mean sea temperature exceeds the mean sea-fog point, indicating that a necessary condition for fog development is a sea-surface temperature below average. This condition is most probable after a prolonged spell of westerly winds has brought water of Atlantic origin much colder than normal into the Straits. The distribution of sea temperature from west to east will then follow the summer pattern, and a wind change from west to east will favour the development of fog.

Diurnal variation of fog.—Tables IV and V show that, although fog may occur at any time of day, it is most frequent during the period midnight to 0800 G.M.T. The fog is often very patchy, and even at night frequently clears within two hours of the time of onset. During the day, the surface heating and increased turbulence over the Rock and the isthmus normally result in a rapid lifting and dispersal of the fog, and a complete clearance by midday. On a large number of occasions the fog also disperses for a considerable distance out to sea, but sometimes fog patches may persist for long periods only a short distance off the eastern end of the airfield.

TABLE IV—TIME OF ONSET AND DURATION OF FOG

Time of onset of fog	Duration of fog						Total
	< 1 hr.	1-2 hr.	2-4 hr.	4-6 hr.	6-8 hr.	8-12 hr.	
G.M.T.	<i>percentage frequency</i>						
0000-0300	4.9	7.7	7.0	2.8	1.4	0.7	24.5
0300-0600	8.4	6.3	7.7	3.5	0.7	0.7	27.3
0600-0900	3.5	5.6	3.5	1.4	...	...	14.0
0900-1200	2.1	4.2	2.8	...	...	...	9.1
1200-1500	1.4	0.7	0.7	...	...	...	2.8
1500-1800	1.4	0.7	...	...	...	...	2.1
1800-2100	...	2.1	0.7	1.4	1.4	0.7	6.3
2100-2400	3.5	3.5	2.8	0.7	1.4	2.1	14.0
Total	25.2	30.8	25.2	9.8	4.9	4.2	

The onset of fog is at times sudden, and it may sweep round both ends of the Rock to envelop North Front, Windmill Hill and most of the Bay within a few minutes.

TABLE V—HOURLY DISTRIBUTION OF FOG

Hour (G.M.T.) centred at											
0030	0130	0230	0330	0430	0530	0630	0730	0830	0930	1030	1130
<i>percentage frequency of total number of occasions</i>											
6.6	7.3	7.8	8.0	8.6	8.3	8.4	6.6	4.7	4.7	4.9	3.1

Hour (G.M.T.) centred at											
1230	1330	1430	1530	1630	1730	1830	1930	2030	2130	2230	2330
<i>percentage frequency of total number of occasions</i>											
1.6	1.0	1.0	0.5	0.5	0.7	0.7	1.0	2.1	3.3	4.2	4.4

Fog in relation to wind.—Observations of fog during the period investigated show that 42 per cent. occurred with easterly winds of less than 5 kt., 40 per cent. with easterly winds of 5 to 10 kt., 10 per cent. with easterly winds of 10 to 15 kt., and 8 per cent. with westerly winds of less than 5 kt.

The sea fogs affecting North Front may be classified as follows:—

Fog occurring after a wind change from west to east (48 per cent. of total occasions).—Fog of this nature may develop at any time of day after a wind change from west to east, provided that the dew point exceeds the sea temperature. The time lapse between the change of wind and the onset of the fog is usually less than 18 hr. The fog may be extensive when the wind change to east occurs after a long spell of westerlies. With continuing light easterly winds, the fog may recur on the second and third nights after the wind change, but after the easterly winds have been established for some time the drift of warmer Mediterranean water produces a rise in sea temperature and the fog formation ceases. The following example is a case of this type.

September 7, 1950. Fog from 2040 to 2230 G.M.T.

A deep depression moved north-eastwards over the British Isles on September 5, 6, and 7, 1950, while the associated cold front moved south-eastwards at decreasing speed into the Bay of Biscay. A ridge of high pressure from the Azores anticyclone developed north-eastwards over Spain ahead of the weakening cold front on the 6th and 7th, resulting in a change of wind at Gibraltar from west to east at 1200 G.M.T. on the 7th. The fog developed at 2040 on the 7th, cleared at 2230, re-formed at 0640 on the 8th, and finally cleared at 0950 G.M.T. The dew points were 64–65°F. during the spell of westerly winds, rising to 69–72°F. with the onset of the easterly winds. The mean sea temperature in September is 69°F.

Fog occurring during a spell of easterly winds (30 per cent. of total occasions).—Fog may develop during a spell of easterly winds, even though it may not have occurred after the initial wind change to east. It is invariably associated with the influx of moister air from the east, and a steadily rising dew point at Gibraltar, as in the following example.

August 14, 1950. Fog from 0100 to 0140 G.M.T.

A pronounced ridge of high pressure from the Azores anticyclone to north Spain and the western Mediterranean resulted in a spell of easterly winds at Gibraltar. The wind change to east occurred on the 10th, and light easterly winds continued until the 16th. The dew points were 65–70°F. on the 10th and 11th, rising to 72–74°F. by the 13th. The fog developed at 0100 on the 14th, and cleared at 0140 G.M.T., and shortly afterwards the dew point dropped to 68–70°F. The mean sea temperature in August is 70°F.

Fog occurring at the end of a spell of easterly winds (20 per cent. of total occasions).—The general change of wind from east to west, after a spell of easterly winds, is often preceded by a short period of light and variable winds, and during this period the reduced turbulence and consequent accumulation of moisture

in the lower layers favours the formation of fog. With initially high dew points the fog may be very extensive, and at times the Straits are completely filled. On these occasions, fog banks may drift into the northern half of the Bay, and approach North Front from the west. All fogs which occurred with westerly winds were of this nature. This type of fog usually develops late in the night, as in the following example.

July 6, 1948. Fog from 0400 to 0600 G.M.T.

A well developed ridge of high pressure over north Spain and the western Mediterranean, from an anticyclone centred in mid Atlantic, resulted in a spell of moderate to fresh easterly winds at Gibraltar. The southward movement of a cold front over the Bay of Biscay and north Spain on the 4th and 5th produced a fall in pressure over the western Mediterranean, and the easterly wind at Gibraltar slowly moderated, becoming light and variable during the evening of the 5th. Fog developed at 0400 on the 6th, and cleared at 0600 G.M.T. The dew points throughout were 65–66°F. The mean sea temperature in July is 68°F.

Precipitation fog at North Front (2 per cent. of total occasions) occurs only in the heavy rain associated with upper-level thunderstorms moving northwards from north Africa, or with vigorous cold fronts moving south-eastwards across Spain and Portugal.

The low stratus and rain associated with quasi-stationary fronts in the Straits of Gibraltar occasionally produce fog in the vicinity of Gibraltar¹, but not, during the period investigated, at North Front. However, since these fronts result in very poor conditions at North Front, during which there is a considerable risk of fog, the synoptic situation is considered worthy of note. The following three examples are of interest.

September 9, 1949

The upper air charts for 0300 G.M.T. on the 9th showed a cold pool centred to the west of Gibraltar. Thundery medium-level cloud developed over north Africa during the morning of the 9th and spread towards Gibraltar. During the early afternoon, a thunderstorm moved towards Gibraltar from the south-west. Very heavy thundery rain commenced at 1255 and continued until 1415 G.M.T., the total rainfall during this period⁶ being 97·2 mm. The visibility in rain was at times reduced to 200 yd.

March 7, 1951

A deep depression moved north-north-eastwards over south-west England and west Wales on the 7th, while the associated cold front moved quickly south-eastwards over Spain and Portugal, and cleared Gibraltar by 2200 G.M.T. The pre-frontal rain commenced at Gibraltar at 1200 G.M.T., and the surface wind gradually freshened to south-westerly 22–25 kt. The visibility was reduced to 400–800 yd. in moderate to heavy rain between 1600 and 1700 and between 1930 and 2030 G.M.T.

March 14, 1951

A deep depression moved north-north-eastwards over the Bay of Biscay and the British Isles on the 13th and 14th, while the associated cold front moved south-east, and cleared Gibraltar by 2000 G.M.T. on the 13th. The cold front became retrograde on the 14th, as a wave depression moved quickly east-north-eastwards from the Azores. As the front moved slowly northwards towards Gibraltar, the surface wind backed to easterly, and increased to 8–12 kt. Frontal drizzle commenced about 1000 G.M.T., and continued until the passage of the front at 0600 G.M.T. on the 15th, when the surface wind veered to south-westerly. For long periods, the visibility was reduced to 1,200 yd. in drizzle, with a cloud base of 300–400 ft.

Forecasting fog.—Fog at North Front is almost always associated with easterly winds. At all times of the year, and in particular during the summer months when the surface wind is easterly or when a change from west to east seems likely, a close watch must be kept on the observations of dew point in relation to sea temperature in the area to the east of Gibraltar. In this connexion, however, it must be emphasized that the dew points reported by coastal stations east of Gibraltar, because of the many local peculiarities and the effect of off-shore winds, are frequently not representative of the air mass over the sea. Forecasting difficulties are further increased by the lack of regular observations of sea temperature from the area east of Gibraltar, and

by the considerable variations which follow a general change of wind direction. Fog is more probable when a wind change from west to east follows a prolonged spell of westerly winds. The sea temperature may then be expected to be well below average. The effect of a change of wind on the sea temperature is of paramount importance in forecasting fog, and the reader is referred to a more detailed discussion of this subject elsewhere³.

If observations of sea temperature and dew point to the east of Gibraltar are lacking, the average and extreme values of sea-fog point during the period investigated, given in Table VI, may be of value in assessing the possibility of fog formation.

TABLE VI—SEA-FOG POINTS

	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.
	<i>degrees Fahrenheit</i>									
Mean sea-fog point	57	56	59	60	66	70	71	70	64	61
Lowest sea-fog point	56	55	55	57	58	61	65	63	63	58

Owing to the lack of homogeneity in the easterly air stream the fog frequently forms in isolated patches, and on over 50 per cent. of occasions of fog the period during which North Front is affected is less than two hours. If the horizontal extent of the fog is known from aircraft observations, it is possible, by estimating the rate of drift of the fog bank, to forecast the time of onset or clearance with a high degree of accuracy.

Fog at North Front is subject to a very marked diurnal variation, with a maximum frequency about dawn and a minimum frequency during the afternoon. In midsummer, the surface heating over the Rock and the isthmus results in a complete clearance during the forenoon. At other times of the year, particularly if there is a layer of cloud above the fog, the clearance may be delayed until the early afternoon, and on very isolated occasions fog may persist all day.

Apart from the general changes of surface wind from west to east or from east to west due to a changing pressure distribution, the forecaster must also be alert for any local or temporary variations in wind, since these may significantly affect the onset or clearance of fog, e.g. a temporary backing of an easterly surface wind to NE. or NNE. may result in a bank of fog being carried to the south of the Rock without affecting North Front. With very light easterly winds the katabatic effect assumes considerable importance, and often causes a complete reversal of wind from a light easterly to a light westerly during the night, the wind reverting to a light easterly after dawn. Under these conditions, fog which may be over North Front at dusk is gradually cleared by the katabatic flow during the night, only to return again with the onset of the easterly wind after dawn.

REFERENCES

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2. WARD, A.; Duststorm at North Front, Gibraltar. *Met. Mag., London*, **80**, 1951, p. 196.
3. GORDON, A. H.; Topographical factors affecting the forecasting of weather at Gibraltar. Meteorological Office, London, 1940.
4. London, Admiralty, Hydrographic Department. Admiralty weather manual. London, 1941, p. 222.
5. London, Meteorological Office. Monthly meteorological charts of the Atlantic Ocean. London, 1948.
6. PEPPER, J.; Very rare rainfall at Gibraltar on September 9, 1949. Typescript, Meteorological Office, London, 1949.

ROYAL METEOROLOGICAL SOCIETY

At the meeting of the Society held on June 18, 1952, Dr. R. C. Sutcliffe Vice-President in the Chair, the following papers were read:—

*Taylor, R. J.—Dissipation of kinetic energy in the lowest layers of the atmosphere.**

Mr. Taylor's paper was read by Dr. Pasquill. Taylor calculated the vertical flux of kinetic energy and the rate of dissipation of kinetic energy in the lowest layers from observations of mean wind and the eddy components, assuming that the mean vertical mass flux is zero and that the wind profile is logarithmic. The observations were made at heights of 2 m. or 29 m. near Melbourne on occasions of small lapse rate and moderate wind. It was found that the dissipation of kinetic energy within a layer near the ground could account for about a quarter of the rise of temperature observed in the layer; this is an observation of much importance as the dissipation of kinetic energy is normally neglected in a study of the vertical heat transfer in the lowest layers. Dr. R. C. Sutcliffe, Prof. P. A. Sheppard, Dr. G. D. Robinson and Dr. Pasquill took part in the discussion in which the chief point raised was the validity of the supposition that the mean vertical flux of mass is zero. This assumption is particularly important because in the formula for flux of kinetic energy the vertical mass flux is multiplied by half the square of the mean wind. Dr. Robinson said his measurements showed that at any one point this quantity was not zero when measured over periods of minutes; some values of energy flux measured at Kew, after subtracting the part proportional to the vertical mass flux, agreed with Taylor's values.

Murray, R. and Johnson, D. H.—Structure of the upper westerlies; a study of the wind field of the eastern Atlantic and western Europe in September 1950.†

Mr. Murray's and Mr. Johnson's paper, read by Mr. Murray, described cross-sections of the atmosphere made twice a day during September 1950 from the surface to 150 mb. along the lines Greenland–Malta and Azores–Sweden, crossing near Larkhill. September 1950 was unusually stormy and the depressions followed one another across the British Isles. It was found that one or more wind maxima occurred on every occasion on these sections and with the centre of maximum wind near the tropopause. The general structure of these jet streams was similar to that described by previous writers but with variations in detail. The wind shear on the warm side of the maxima was only about two-thirds of the shear on the cold side where the shear averages 20 kt./100 miles and may exceed 100 kt./100 miles. Mr. Murray showed sample cross-sections and also charts showing the situation of the jet streams relative to the surface isobars and fronts. Their situation relative to fronts was usually as previously described, but such complexities as divided jet streams and double jet streams were found. On September 26 jet streams in the nearly opposite directions of north to south and south-west to north-east were observed over western Europe.

During the discussion, in which the paper was welcomed as a fundamental contribution to synoptic climatology, Mr. Gold said he was interested to see jet streams could blow from north or south as well as from a westerly point; Prof. Sheppard inquired if changes in the thermal field produced characteristic

* *Quart. J. R. met. Soc., London*, **78**, 1952, p. 179.

† *Quart. J. R. met. Soc., London*, **78**, 1952, p. 186.

changes in wind structure; Mr. Galloway thought there should be a velocity discontinuity across the tropopause; and Mr. Bannon inquired if there were differences in structure of jet streams in winter and summer, and between those over the British Isles and the southern United States. Mr. Murray thought that the only difference between summer and winter was that intense jet streams were more frequent in winter, and as regards the southern United States jet streams that they appeared to have the stronger shear on the warm side. Dr. Sutcliffe discussed the possibility of a jet stream completely encircling the globe as the polar front had once been thought to do. The low-latitude jet stream over the subtropics was always present where observations were available, but it was uncertain if it was broken over the oceans.

OFFICIAL PUBLICATION

The following publication has recently been issued:—

Observer's handbook

The "Observer's handbook" is the authoritative manual of surface meteorological observing. It covers all standard observations at all types of meteorological stations, whether synoptic stations where the major interest is in forecasting, ordinary climatological stations maintained for more varied and general interests in weather records, or those climatological stations having behind them other special interests as in the case of crop weather and health resort stations. Various types of highly specialized observations, including upper air observations, do not come within the scope of the Handbook.

The new Handbook differs from its predecessors (the successive editions of the "Meteorological observer's handbook") in two important respects. It has been written with the needs of modern meteorology in mind, and due prominence is therefore given, in the relevant sections, to the international codes which have been in use since January 1, 1949. Secondly, the body of the book is concerned with observing proper, and it is therefore assumed that the station has been properly sited and equipped on the scale appropriate to its class and is in full working order. The first chapter contains a summary of the observing procedure at each type of station with some general notes on observing, and the following chapters are devoted in turn to the details of observing the separate elements.

The selection of the site and other matters which must receive attention when the station is first set up are, however, discussed in an appendix. Other appendices cover such matters as, for example, the recording of observations and the preparation of barometer correction cards, which are relevant to the techniques of observing but do not strictly belong to them.

Where instruments are concerned sufficient information is given for the purposes of day-to-day use and maintenance, but for more complete details of design and construction the reader is referred to the separate "Handbook of meteorological instruments", which is to be published later.

ERRATUM

JULY 1952, PAGE 213; Owing to an error in conversion of velocity units the estimates of vertical motion in the stratosphere are in error by a factor of ten. Therefore

line 21, for "5 cm./sec." read "0.5 cm./sec."

line 40, for "10 cm./sec." read "1 cm./sec."

LETTER TO THE EDITOR

South Polar atmospheric circulation

A recent article on the "South Polar atmospheric circulation and the nourishment of the antarctic ice-cap" by H. H. Lamb has just been called to our attention. Impressions received from analysing a two-year series of southern hemisphere weather charts for the period July 1948–June 1950 are somewhat at variance with Lamb's ideas of antarctic cyclones and anticyclones.

First, it appears futile to refer to sea-level pressure systems over Antarctica. Doubtless a shallow anticyclone exists over the ice-cap, with an indeterminate circulation aloft. But to extend a surface analysis so as to cover the continent requires much imagination, the results of which may not reliably fulfil our expectations. Our Weather Bureau—Massachusetts Institute of Technology Southern Hemisphere Project—has had considerable data from whaling vessels for several summer seasons, but our analysts do not consider that such data are sufficient to allow a detailed analysis over the continent. It is our considered opinion, however, that there is not much likelihood that well developed cyclonic vortices exist there as surface systems. If there are weak cyclonic systems emerging from Antarctica, as stated by Lamb, such systems should certainly increase in intensity, inasmuch as they would be passing out over a warm surface.

The fact that the *Balaena* was as much as 200 miles from the coast is significant. In summer-time there seems to be evidence in favour of the existence of a storm track that approximates the ice-edge. Observations made from ships that far from the coast may not, therefore, faithfully represent conditions on the continent. Observations from the combined expedition at Maudheim and the French expedition at Adélie Land have not, in our opinion, ever shown any evidence of cyclones having passed over Antarctica. They rather give the impression of high pressure over the continent, with cold air seeping out constantly behind the eastward-moving cyclones along the coast. Winter-time pressures of as high as 1023 mb. have been observed at Adélie Land in our recent series, although the mean is considerably lower. At Maudheim there have been observed pressures of 1019 mb., while the stations on Palmer Peninsula have had pressures as high as 1030 mb. with definite evidence of occasional winter-time outbreaks of polar anticyclones that have reached as far north as South Africa.

It is also our opinion that the Ross and Weddell Seas, because of the surface temperature contrast they offer to the cold continent, are likely to have lower pressure than the other ice-covered areas at the same latitude. The low pressures are not *a priori* evidence that cyclonic situations occur from time to time over the South Polar regions, as stated by Mr. Lamb. The occurrence of cloud sheets and clouds with vertical growth can be explained by the relatively warm and moist air from the north passing over a high and cold continent. The stability conditions of such air will determine the type of cloud forms to be observed. Such overrunning may contribute considerable amounts of precipitation to the ice-cap. As regards cloud banks emerging from the interior, there is every reason to believe that cold air does move out from the continent and should be associated with clouds and precipitation just off shore due to its passing over a warm undersurface.

Mr. Lamb's effort to explain, in part, the South Polar circulation is commendable, but perhaps based upon insufficient data. Our own feeling is that much more in the way of continuing observations are required before the meteorologist can hope to portray successfully such a circulation on a surface weather chart.

MORTON J. RUBIN

185 Ash Street, Waltham 54, Mass., June 10, 1952,

[Mr. Rubin's comment seems to imply a hasty reading of the evidence presented in my article on the South Polar atmospheric circulation. The article admittedly suffered from excessive abbreviation, especially in that there was no space to elaborate the justification for the analysis of each day's chart in the illustrative synoptic sequence. Every possible check and countercheck was used. Indeed the sequence was chosen not solely for the interesting developments portrayed, but still more because the checks and counterchecks were particularly convincing over this period.

Sea-level isobars may be drawn over Antarctica with about the same reservations as over Greenland. Depressions, including even some well developed cyclonic vortices, are now known to pass across all parts of Greenland on occasion. He would be a bold man who would assert that the same cannot happen in Antarctica. To say that pressures as low as 932 mb. at Little America (77°S.) in the Ross Sea (observed by Court in 1941) do not imply cyclonic situations over the South Polar regions requires a pressure gradient of at least 60–70 mb. in the 800 miles between there and the South Pole, even if Mr. Rubin will allow the strong cyclonic circulation to extend as far as the pole itself.

Cyclonic circulations centred over the continental ice are certainly necessary to explain the westerly winds sometimes reported at coastal observation points, still more so the north-westerly winds noted on the ice-cap near the magnetic pole in the Adélie Land sector by Shackleton's expedition. No doubt these cyclonic circulations are often rather weak, but they tend to be rejuvenated if and when they emerge once more over the ocean. Nor can the evidence presented of occasional warm anticyclones with deep-reaching circulation, probably up to the observed high tropopause, be brushed aside without discussion. The main point, which concerns future expeditions to the interior of Antarctica even more than it concerns meteorologists, is that it now seems prudent to admit much more variability in the atmospheric circulation patterns and weather types occurring over Antarctica than was formerly realized or than seems to be so far accepted by Mr. Rubin.

It seems necessary to make clear that it is not a fact that the *Balaena* was as much as 200 miles from the antarctic coast during the period analysed. This figure was quoted in connexion with an occurrence nearly two weeks later, when she was on her way home. In March the ship was generally within 100 miles of the coast and occasionally within sight of it. Our aircraft flew over the coastal mountains, and the smaller sea-going craft gave reports close to the coast and along the edge of the at-that-time narrow ice belt within 150–200 miles of the *Balaena*. Normal frontal medium-cloud systems, occasionally with embedded cumulonimbus, as on March 17, 1947, were rather frequently seen over the continent itself (i.e. direct observation), and, in this case, emerging from the interior in a wind stream with general southerly components.

Mr. G. de Q. Robin, of the recently returned Norwegian-British-Swedish expedition based at Maudheim in the Norwegian sector, has commented that he believes their observations will be found to bear out all the conclusions I stated except perhaps the suggestion of any net up-slope drift of the accumulated snow in Antarctica. It is greatly to be hoped that this expedition's material will be used together with the data now available from Prince Edward Island and Heard Island and from the Falkland Islands Dependencies in Antarctica for other specialized synoptic studies to broaden our knowledge of the day-to-day weather processes over Antarctica.—H. H. LAMB.]

NOTES AND NEWS

Alto cumulus floccus at Stradishall, West Suffolk

The lower photograph facing p. 272 was taken at Stradishall, West Suffolk, on July 1, 1952, looking south-south-east at about 1430. It shows alto cumulus floccus, base about 10,000 ft., which gave a moderate shower beginning at 1426 and lasting two minutes only. A number of similar showers from only 2–4 oktas of cloud were reported over East Anglia during the day and rain from a seemingly clear sky was reported in the London area. Alto cumulus castellatus was observed at Harrow.

The clouds were associated with upper air instability. A shallow depression moved northwards from the Bay of Biscay on July 1 and thunderstorms occurred over south-west England. July 1 was the last and hottest day (92°F. was recorded at Camden Square and London Airport) of a warm spell that had occurred in the southern part of England during the last week in June.

Ocean weather stations

The International Civil Aviation Organization introduced on November 1, 1951, a new phonetic alphabet. This has meant the renaming of the ocean weather stations from JIG and ITEM to JULIETT and INDIA. The positions are unchanged and the renaming took effect from May 1, 1952.

At this time o.w.s. *Weather Observer* was on station JULIETT. On May 10, *Weather Observer* was relieved by the Netherlands o.s.v. *Cumulus*. During the take-over of station duties on this day, Capt. J. P. Groen of the *Cumulus*, accompanied by his Chief Meteorological Officer, Oceanographical Officer and Radio Supervisor, visited *Weather Observer*, staying for an hour and a half. Three of *Weather Observer*'s Officers returned the visit. Photographs illustrating the visit are reproduced facing p. 273.

During their visit mutual difficulties were discussed.

WMO Bulletin

We welcome the publication of the first number of the *WMO Bulletin* published by the World Meteorological Organization. The purpose of the *Bulletin* is to provide periodically a summary of the activities of the World Meteorological Organization and of developments in international meteorology of interest to members of the Organization and others concerned with the application of meteorology to human activities. To begin with the *Bulletin* will be published quarterly in separate French and English editions.

The contents of the first number include:—

A general account of the functions of the World Meteorological Organization with list of member states and of the officers.

A description of the new Headquarters building and a map of Geneva showing its location.

Notes on collaboration with other international organizations, on the activities of Regional Commissions and on the Technical Assistance Programme for under-developed countries.

A list of publications by the World Meteorological Organization.

Calendar of coming events.

Details of the sale and free distribution arrangements will be settled by the Executive Committee at its meeting in September 1952.

OBITUARIES

Dr. A. Crichton Mitchell.—The following facts relating to the late Dr. Crichton Mitchell's services to the Royal Meteorological Society should be added to my note published in the June 1952 number.

Dr. Crichton Mitchell was a life Fellow of the Scottish Meteorological Society, elected into Fellowship in 1891, and became a life Fellow of the Royal Meteorological Society when the two Societies were amalgamated in 1921. He was at one time a Secretary and later a Vice-President of the Royal Meteorological Society. He represented the Society on the Committee of the Meteorological Office, Edinburgh, from 1928 to 1937.

R. A. WATSON

Frederick William George Ruddle.—It was with great regret that we heard of the sudden death of Mr. F. W. G. Ruddle, Experimental Officer, on June 8. Mr. Ruddle joined the Office as an Observer early in 1935, transferring to the Carpenter scientific grades when the grade of Observer was abolished in 1940. In the 17 years he was with the Office Mr. Ruddle set a fine example of devoted and conscientious service and was held in high esteem both by his colleagues and his R.A.F. associates.

BOOKS RECEIVED

Zur Meteorologie und Meteorobiologie des Alpenföhns. By W. Mörikofer. *Verh. schweiz. naturf. Ges., Davos*, pp. 11–32. Illus. 1950.

Erweiterung des Frigorimetermessbereiches zur Miterfassung der Aufwärmungsgrosse. By H. Wierzejewski. *Verh. schweiz. naturf. Ges., Davos*, pp. 153–4, 1950.

METEOROLOGICAL OFFICE NEWS

Ocean weather ships.—Ocean weather ships have been co-operating with Dr. G. V. T. Matthews of the Department of Zoology, University of Cambridge, in his experiments on the homing of gulls.

Twenty ringed manx Shearwaters were despatched from the island of Skokholm, off the coast of Pembrokeshire, to Glasgow railway station where they were collected by Captain A. W. Ford for conveyance to the o.w.s. *Weather Recorder* to take to sea on June 18 for release at least 100 miles from land. Instructions were that the birds should not be fed at all and that a sunny day should be chosen for their release in case they should use the sun as an aid to navigation.

The birds were released between 1033 and 1125 on Friday, June 20, in position $56^{\circ} 40' \text{N.}$, $10^{\circ} 42' \text{W.}$ (345 miles north-north-west of Skokholm). The sun was visible throughout, though the sky was covered with 7 oktas thin stratocumulus at 3,500 ft. and with 7 oktas cumulus at 1,800 ft. The wind was 17 kt. from 290° .

Most of the birds circled, or partly circled, the ship before heading off, and, of the 20 birds, 6 went off in the north-east quadrant, 8 in the south-east quadrant, 3 in the south-west quadrant, and 2 in the north-west quadrant. One bird settled on the sea not far from the ship.

A letter received subsequently from Dr. Matthews reported that when he stopped checking, 18 of the 20 birds had returned to Skokholm; the first arrival came in on the night of Saturday, June 21, 5 more arrived on the Sunday, and 2 on the Monday, the others coming in at intervals.

Dr. Matthews expressed great satisfaction with the result which gave him most valuable data. He hopes to be able to arrange for another release next year.

Examination successes.—We congratulate the following on their achievements in passing their examinations while working in the office:—

J. E. Burns—Part I, B.Sc. London, special physics.

J. L. Burn—Intermediate B.Sc. London, physics, pure mathematics and geography.

D. F. Winter—Higher National Certificate in electrical engineering.

Horticultural Show.—The staff of the Office were represented in all three sections—flowers, fruit, and vegetables—of the annual show of the Air Ministry and Ministry of Civil Aviation Horticultural Society held on July 8. The exhibitors were Misses H. G. Chivers and D. J. Wordsworth, and Messrs. B. G. Brame, N. E. Davis and H. A. Scotney, and all gained prizes.

WEATHER OF JULY 1952

Mean pressure was generally above normal over the North Atlantic and western Europe, and below normal in north Scandinavia and the Mediterranean region. The highest mean pressure, 1027 mb., which was 7 mb. above normal, occurred in the area north-east of the Azores as far as latitude 45°N. In west Europe mean pressure was uniform, between 1017 and 1020 mb., generally 3 mb. above normal, but in the Mediterranean, mean pressure was 1 or 2 mb. below normal in places. The lowest mean pressure, 1009 mb., occurred between Scandinavia and Greenland; this was 2 mb. below normal.

Mean temperature was above normal in most of Europe; in most places it was between 65° and 75°F. , generally 5°F. above normal, but nearly 10°F. above normal locally in south-east France. In Scandinavia, however, where mean temperature was in the region of 60°F. , it was about 2°F. below normal.

In the British Isles the weather was drier than usual except at a few scattered places chiefly in the north-west. It was warm on the whole except in the north of Scotland. Sunshine was mostly somewhat below the average but in south and east Scotland and extreme north-east England there was a considerable excess. An absolute drought prevailed at many places in the south of England towards the end of the month.

On the 1st a depression over the Bay of Biscay moved north-north-east across England, while another off west Scotland moved north-east; heavy thunderstorms occurred widely in western, central and northern England, and local thunderstorms in south-west Scotland and Northern Ireland (1·73 in. of rain fell at Bredbury, Cheshire, in 25 min., 1·72 in. at Ilkeston, Derbyshire, in 30 min., and 1·23 in. at Nottingham in 15 min.). It was very warm on the 1st, particularly in the south-east where temperature approached 90°F. at a number of places and reached 92°F. at Camden Square, London Airport and Southampton. A cold front moved across south-eastern districts on the 2nd with little rainfall, but a rain area developed behind the front and it was persistently wet on the 3rd, though amounts were small except in the extreme south-east. Temperature fell rapidly, the maximum at London Airport on the 3rd being 60°F. as compared with 92°F. on the 1st. On the 4th an anticyclone moved north-east across the British Isles being centred over southern Scandinavia by the 6th, and temperature rose again reaching 80°F. in some places on the 5th and 88°F. at Mildenhall on the 6th. The 4th was an unusually sunny day in northern districts; 16·2 hr. was registered at Leuchars. Between the 6th and the 8th a complex depression off our south-west coasts moved north over Ireland and western Scotland. In the early hours of the 6th there was a widespread outbreak of thunderstorms in the south-western half of England and much of Wales; the storms were severe in places and 1·32 in. of rain fell in 72 min. at Minehead. Later that day thunderstorms occurred fairly widely but rainfall was variable. Subsequently pressure was high to the south and low to the north of the British Isles and a westerly type of weather developed which lasted until the 19th. In the southern half of the country there was little or no rainfall during this spell except at some places, chiefly in the south-east, on the 11th. The period 12th–18th was mainly cool. By the 20th a ridge of high pressure extended north-east over the British Isles from the Azores anticyclone and a spell of warm, close, dry weather ensued, though slight rain fell at times, mainly in the west and north of Scotland. From the 26th to the 28th a depression over Iceland moved to a position off Denmark; temperature fell considerably and scattered rain occurred, mostly in the north and east. Drought conditions ended at some places in the south on the 29th when minor troughs of low pressure moving in from the Atlantic brought westerly winds and local rain accompanied by some rise in temperature. At a number of places in the south of England, however, the drought persisted until the end of the month.

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

	AIR TEMPERATURE			RAINFALL		SUNSHINE
	Highest	Lowest	Difference from average daily mean	Per-centage of average	No. of days difference from average	Per-centage of average
	°F.	°F.	°F.	%		%
England and Wales ...	92	32	+1·6	47	—5	97
Scotland ...	82	33	+0·6	79	0	114
Northern Ireland ...	75	40	+1·4	55	—3	78

RAINFALL OF JULY 1952

Great Britain and Northern Ireland

County	Station	In.	Per cent. of Av.	County	Station	In.	Per cent. of Av.
<i>London</i>	Camden Square ...	0·70	29	<i>Glam.</i>	Cardiff, Penylan ...	2·87	93
<i>Kent</i>	Folkestone, Cherry Gdn. ...	1·12	53	<i>Pemb.</i>	Tenby, The Priory ...	1·52	52
<i>„</i>	Edenbridge, Falconhurst ...	0·82	36	<i>Radnor</i>	Tyrmynydd ...	1·93	47
<i>Sussex</i>	Compton, Compton Ho. ...	0·64	23	<i>Mont.</i>	Lake Vyrnwy ...	2·78	78
<i>„</i>	Worthing, Beach Ho. Pk. ...	0·79	39	<i>Mer.</i>	Blaenau Festiniog ...	3·35	39
<i>Hants.</i>	Ventnor Cemetery ...	0·41	20	<i>„</i>	Aberdovey ...	1·88	54
<i>„</i>	Southampton, (East Pk.) ...	0·31	14	<i>Carn.</i>	Llandudno ...	1·62	72
<i>„</i>	Sherborne St. John ...	0·68	30	<i>Angl.</i>	Llanerchymedd ...	1·29	45
<i>Herts.</i>	Royston, Therfield Rec. ...	0·66	26	<i>I. Man</i>	Douglas, Borough Cem. ...	1·41	46
<i>Bucks.</i>	Slough, Upton ...	0·44	23	<i>Wigtown</i>	Newton Stewart ...	2·21	70
<i>Oxford</i>	Oxford, Radcliffe ...	0·29	12	<i>Dumf.</i>	Dumfries, Crichton R.I. ...	2·65	81
<i>N^ohants.</i>	Wellingboro' Swanspool ...	0·45	20	<i>„</i>	Eskdalemuir Obsy. ...	3·63	89
<i>Essex</i>	Shoeburyness ...	0·57	31	<i>Roxb.</i>	Kelso, Floors ...	1·53	58
<i>„</i>	Dovercourt ...	0·83	41	<i>Peebles</i>	Stobo Castle ...	2·36	81
<i>Suffolk</i>	Lowestoft Sec. School ...	1·61	71	<i>Berwick</i>	Marchmont House ...	1·42	47
<i>„</i>	Bury St. Ed., Westley H. ...	0·95	38	<i>E. Loth.</i>	North Berwick Res. ...	1·96	76
<i>Norfolk</i>	Sandringham Ho. Gdns. ...	0·92	36	<i>Midl'n.</i>	Edinburgh, Blackf'd. H. ...	2·23	79
<i>Wilts.</i>	Aldbourn ...	0·34	14	<i>Lanark</i>	Hamilton W. W., T'nhill ...	2·46	86
<i>Dorset</i>	Creech Grange ...	0·96	39	<i>Ayr *</i>	Colmonell, Knockdolian ...	2·76	88
<i>„</i>	Beaminster, East St. ...	0·98	38	<i>„</i>	Glen Afton, Ayr San. ...	4·84	115
<i>Devon</i>	Teignmouth, Den Gdns. ...	0·88	38	<i>Renfrew</i>	Greenock, Prospect Hill ...	2·87	78
<i>„</i>	Cullompton ...	1·05	39	<i>Bute</i>	Rothsay, Ardenraig ...	3·76	95
<i>„</i>	Ilfracombe ...	1·56	61	<i>Argyll</i>	Morven (Drimnin) ...	...	...
<i>„</i>	Okehampton Uplands ...	1·46	45	<i>„</i>	Poltalloch ...	4·67	113
<i>Cornwall</i>	Bude, School House ...	0·89	36	<i>„</i>	Inveraray Castle ...	4·25	85
<i>„</i>	Penzance, Morrab Gdns. ...	1·35	50	<i>„</i>	Islay, Eallabus ...	3·35	98
<i>„</i>	St. Austell ...	1·36	41	<i>„</i>	Tiree ...	2·81	78
<i>„</i>	Scilly, Tresco Abbey ...	2·07	93	<i>Kinross</i>	Loch Leven Sluice ...	2·12	74
<i>Glos.</i>	Cirencester ...	0·19	7	<i>Fife</i>	Leuchars Airfield ...	1·62	62
<i>Salop</i>	Church Stretton ...	1·06	40	<i>Perth</i>	Loch Dhu ...	2·95	61
<i>„</i>	Shrewsbury, Monksmore ...	0·67	32	<i>„</i>	Crieff, Strathearn Hyd. ...	2·24	75
<i>Worcs.</i>	Malvern, Free Library ...	1·08	47	<i>„</i>	Pitlochry, Fincastle ...	1·97	73
<i>Warwick</i>	Birmingham, Edgbaston ...	1·73	75	<i>Angus</i>	Montrose, Sunnyside ...	2·22	84
<i>Leics.</i>	Thornton Reservoir ...	0·55	22	<i>Aberd.</i>	Braemar ...	0·96	37
<i>Lincs.</i>	Boston, Skirbeck ...	0·36	16	<i>„</i>	Dyce, Craibstone ...	2·20	73
<i>„</i>	Skegness, Marine Gdns. ...	0·41	19	<i>„</i>	New Deer School House ...	1·91	62
<i>Notts.</i>	Mansfield, Carr Bank ...	0·64	24	<i>Moray</i>	Gordon Castle ...	2·37	74
<i>Derby</i>	Buxton, Terrace Slopes ...	2·97	76	<i>Nairn</i>	Nairn, Achareidh ...	1·74	68
<i>Ches.</i>	Bidston Observatory ...	1·13	44	<i>Inverness</i>	Loch Ness, Garthbeg ...	2·38	75
<i>„</i>	Manchester, Ringway ...	3·30	119	<i>„</i>	Glenquoich ...	6·32	98
<i>Lancs.</i>	Stonyhurst College ...	3·46	89	<i>„</i>	Fort William, Teviot ...	3·52	72
<i>„</i>	Squires Gate ...	1·17	42	<i>„</i>	Skye, Duntuilum ...	3·00	80
<i>Yorks.</i>	Wakefield, Clarence Pk. ...	1·15	45	<i>„</i>	Skye, Broadford ...	2·86	52
<i>„</i>	Hull, Pearson Park ...	2·53	108	<i>R. & C.</i>	Tain, Tarlogie House ...	1·89	69
<i>„</i>	Felixkirk, Mt. St. John ...	1·71	63	<i>„</i>	Inverbroom, Glackour ...	3·68	99
<i>„</i>	York Museum ...	1·67	66	<i>„</i>	Achnashellach ...	5·71	117
<i>„</i>	Scarborough ...	2·24	92	<i>Suth.</i>	Lochinver, Bank Ho. ...	3·70	122
<i>„</i>	Middlesbrough ...	1·29	50	<i>Caith.</i>	Wick Airfield ...	1·60	61
<i>„</i>	Baldersdale, Hury Res. ...	1·33	46	<i>Shetland</i>	Lerwick Observatory ...	1·82	79
<i>Norl'd.</i>	Newcastle, Leazes Pk. ...	0·92	36	<i>Ferm.</i>	Crom Castle ...	1·92	55
<i>„</i>	Bellingham, High Green ...	1·57	48	<i>Armagh</i>	Armagh Observatory ...	1·70	59
<i>„</i>	Lilburn Tower Gdns. ...	1·24	50	<i>Down</i>	Seaforde ...	1·51	47
<i>Cumb.</i>	Geltsdale ...	3·38	98	<i>Antrim</i>	Aldergrove Airfield ...	1·73	62
<i>„</i>	Keswick, High Hill ...	3·99	104	<i>„</i>	Ballymena, Harryville ...	2·04	59
<i>„</i>	Ravenglass, The Grove ...	2·63	70	<i>L'derry</i>	Garvagh, Moneydig ...	1·87	58
<i>Mon.</i>	Abergavenny, Larchfield ...	1·36	55	<i>„</i>	Londonderry, Creggan ...	2·24	61
<i>Glam.</i>	Ystalyfera, Wern House ...	2·50	54	<i>Tyrone</i>	Omagh, Edenfel ...	1·40	41