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NOTE ON THE SUBTROPICAL JET STREAM IN JANUARY AND APRIL 1951

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Introduction.—A zone of strong westerly winds is known to occur in the upper troposphere just outside the tropics in many longitudes, as found, for example, by Namias and Clapp[1] in their study of mean temperature distribution in the upper air, showing the position of the mean strong streams or mean jet streams in the northern hemisphere in winter and summer. This subtropical jet stream is strongest in winter and spring. It has been studied over the United States where it is often combined with the strong upper current associated with the polar front[2,3]. Studies for other longitudes, for which sufficient high-level observations are available, have been made for the northern hemisphere over Iraq[3-7] (45°E.), India[8] (80°E.), China[9] (120°E.), and Japan[3,10] (140°E.). For the southern hemisphere studies have been made of the westerly flow over Australia[11,12] and New Zealand[13] (170°E.). For the most part analyses have been confined to an examination of the mean flow for periods of 1–3 months. Apart from that for longitude 170°E. in the southern hemisphere, these studies have related to land areas. Further it should be noted that, except in summer, there is a trough in the mean upper flow over North America and over the neighbourhood of east China and Japan[14]. The flow over southern Asia in winter and spring is influenced by the polar front which on the average is much nearer the equator over Asia than in other longitudes except over North America. Most information about the subtropical jet stream in the northern hemisphere is thus available from studies over land and in regions where the polar front is on the average further south than over the oceans. The paper by Namias and Clapp[1] extends the study over the oceans, but it is based on the few upper air temperatures observed before the year 1944.

It is clear that further information concerning the subtropical jet stream over the oceans is needed. More information about the structure of the stream is also required for all longitudes. The following note describes a study of wind observations in the upper troposphere over the region of the Hawaiian Islands and over the West Indies in January and April 1951, and over Dakar (14° 40′N. 17° 26′W.) in January 1951, which may throw some light on the nature of the subtropical jet stream over the eastern Pacific Ocean, on its structure over the West Indies and on its existence over west Africa.

Method of analysis.—Wind observations for levels of 300 mb. and above are less frequent than for lower levels, especially on occasions when winds are strong. The following analysis, using incomplete data, is therefore crude; it attempts merely to show that strong winds do exist in the upper troposphere and to describe their general character. The source of data is the tabulations in the *Daily series synoptic weather maps* of the United States Weather Bureau.

Several stations in the neighbourhood of the Hawaiian Islands report winds to high altitudes, namely Johnston Island, Midway Island, Lihue (or Mokuleia), Hilo and ocean weather station U (see Fig. 1). On some days perhaps none of these stations will have observed winds at 300 mb. or above; on others there will be several such observations. The criterion adopted here for the existence of the subtropical jet stream is the occurrence of a wind speed of 50 kt. or more at any of these stations at the level of 300 mb. or above; exceptions are those cases where the wind is between NW. and NNE. at 200 mb. which are (arbitrarily) not considered as examples of the subtropical jet stream. (The subtropical jet stream is usually thought of as a zonal current and for this reason cases of marked meridional flow are omitted from the analysis.) In the two months analysed, January and April 1951, the occurrence of strong winds in the upper troposphere over the Hawaiian area was not associated with the penetration of the main polar front to these latitudes as far as could be discovered from the charts published with the data.

Near the West Indies there are several stations reporting wind, namely Burrwood (28° 58′N. 89° 22′W.), Brownsville (25° 54′N. 97° 26′W.), Miami (25° 49′N. 80° 17′W.), Havana (23° 08′N. 82° 21′W.), San Juan (18° 28′N. 66° 06′W.), and Albrook Field (8° 58′N. 79° 33′W.). In January 1951, the wind exceeded 50 kt. in the upper troposphere over southern parts of the United States on every day for which there were sufficient observations to show whether this was so or not. In April 1951, a strong stream existed over the southern United States or the West Indies on all days except one when the polar-front jet stream was displaced northwards. In the analysis those occasions were picked out in which the wind observations showed a second wind maximum at about the 200-mb. level occurring over the West Indies and to the south of the main core of strongest winds over the southern United States. It is this secondary current which is called the subtropical jet stream, to which Gilchrist[3] has drawn attention. There were many occasions when, as far as could be determined from the available wind observations, the strong stream did not have this double structure. There were also many days, particularly when winds were strong, when observations were lacking for 200 mb. and it was impossible to say whether the subtropical jet stream existed separately or not.

The observations at Dakar were examined. Data were available for January 1951 but not for April 1951. From a study of unpublished charts in the Meteorological Office of the distribution of mean heights of constant-pressure surfaces in that area (admittedly vague over west Africa as temperature observations are few), the mean position of the axis of strongest winds would be expected to be 10° further north. For this reason the lower threshold of 45 kt. for the wind speed at 35,000 or 40,000 ft. above Dakar was taken as evidence for the existence of the subtropical jet stream in the neighbourhood of that station.

The next step was to list those days on which the subtropical jet stream, on the above definition, existed in the three regions. Table I gives a summary of

TABLE I—NUMBER OF DAYS WITH STRONG WINDS IN THE UPPER TROPOSPHERE

SS = Winds from SSW. to NW. 50 kt. or more (45 kt. or more at Dakar), occurring at or above the 300-mb. level and not associated with the polar front.

SN = Strong winds in the upper troposphere from between NW. and NNE.

IK = Insufficient observations to determine the wind structure in the upper troposphere.

CS = Strong winds in the upper troposphere but not having a definite maximum separate from the polar-front jet stream.

None = No strong stream in the upper troposphere.

	SS	SN	IK	CS	None
	number of days				
January 1951					
Hawaiian area ...	18	5	8	0	0
West Indies ...	21	0	7	3	0
Dakar	12	0	12	0	7
April 1951					
Hawaiian area ...	28	2	0	0	0
West Indies ...	13	0	0	16	1

details. When the subtropical strong stream was present the following data were extracted from the sounding judged to be nearest to the axis of the stream:

(i) maximum wind speed

(ii) height of axis

(iii) the base of strong vertical shear in the upper troposphere (i.e. shear greater than 2 kt./1,000 ft.).

The figures were necessarily crude estimates of these parameters as so few observations were available for analysis. The mean values of (i), (ii) and (iii) are given in Table II. Winds are tabulated in the *Daily series synoptic weather maps* for the standard levels 500, 300, 200 and 100 mb.; often, but not invariably, they are also given at the fixed heights 20,000, 25,000, 30,000, 35,000 ft., etc. The height of the maximum wind could thus often be determined to the nearest 5,000 ft. There were occasions, however, when the height of the maximum reported wind was also the limit of the ascent; the wind may have been stronger at greater heights. The mean height of the maximum wind given in Table II is therefore probably an underestimate. Similarly, the mean maximum wind speed is also likely to be too low.

TABLE II—MEAN CHARACTERISTICS OF THE STRONG STREAM IN THE UPPER TROPOSPHERE

	Mean maximum wind speed	Mean height of maximum wind	Mean height of base of strong shear*	No. of observations
	kt.	ft.†	ft.†	
January 1951				
Hawaiian area	75	42,000	25,000	16
West Indies	83	40,000	25,000	20
Dakar ...	66	40,000	22,500	12
April 1951				
Hawaiian area	83	41,000	28,000	26
West Indies	73	40,000	28,000‡	12

* Strong shear defined as 2 kt./1,000 ft. or more.

† In I.C.A.N. atmosphere.

‡ From 11 observations.

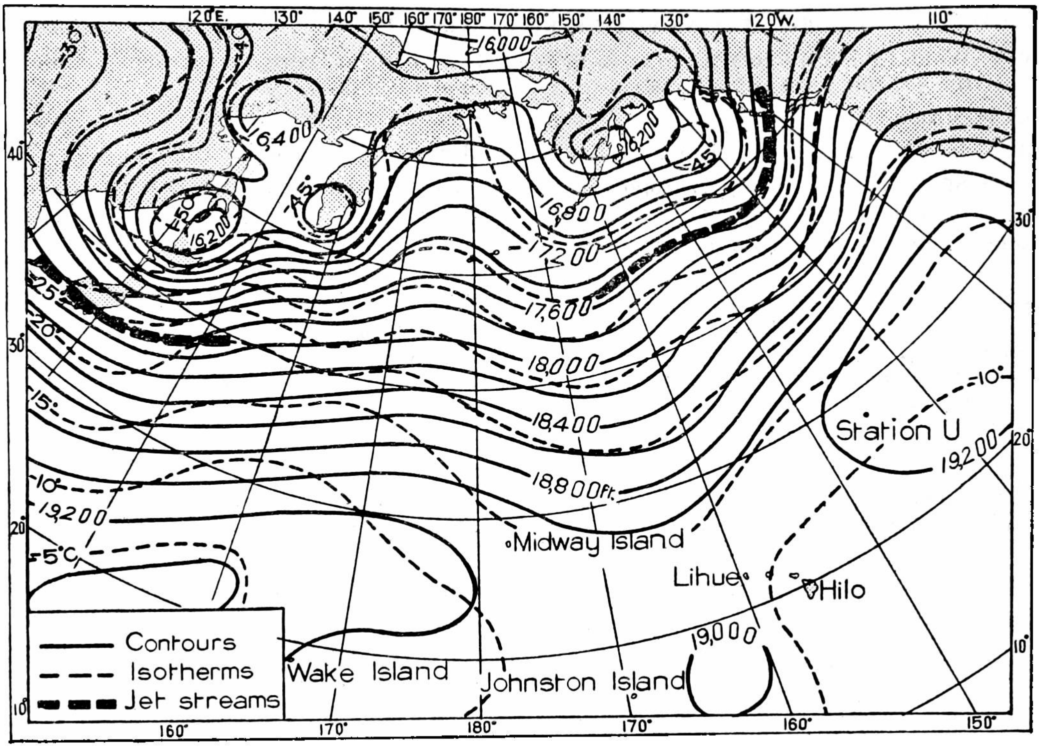


FIG. 1—500-MB. CONTOURS AND ISOTHERMS, 1500 G.M.T., JANUARY 13, 1951

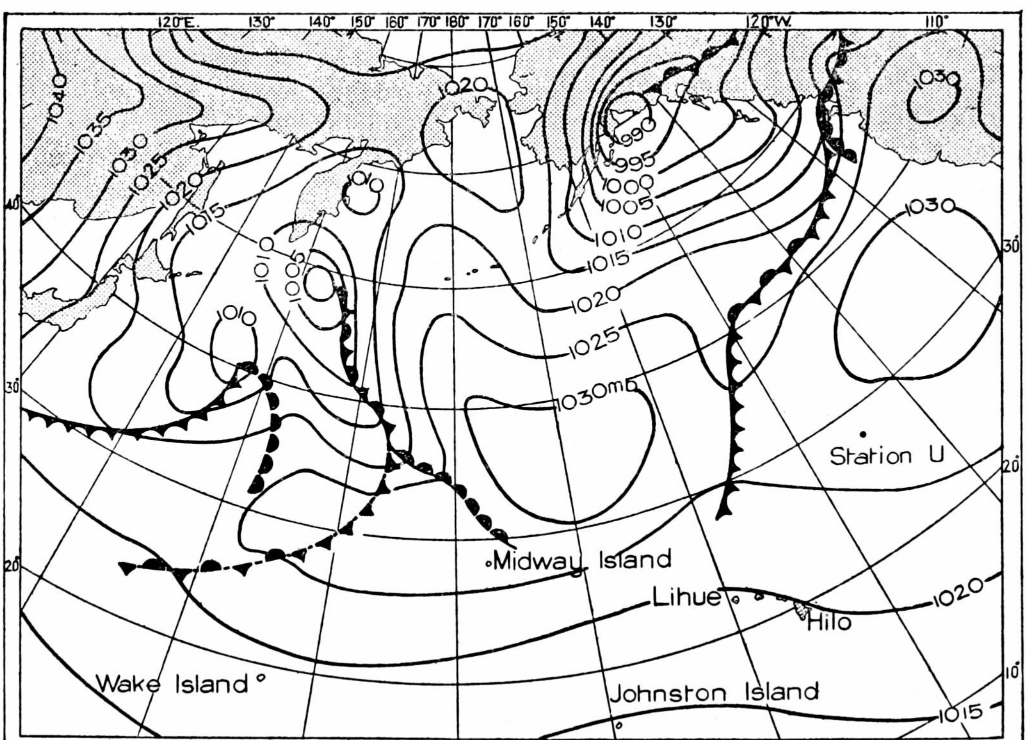


FIG. 2—SURFACE CHART, 1200 G.M.T., JANUARY 13, 1951

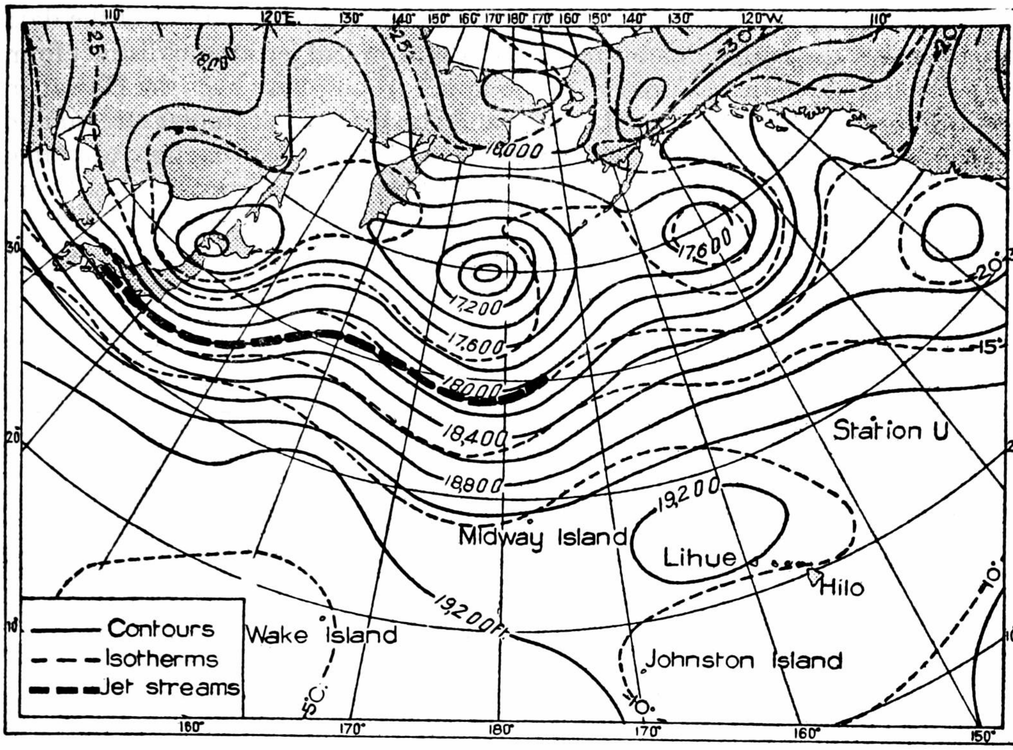


FIG. 3—500-MB. CONTOURS AND ISOTHERMS, 1500 G.M.T., APRIL 23, 1951

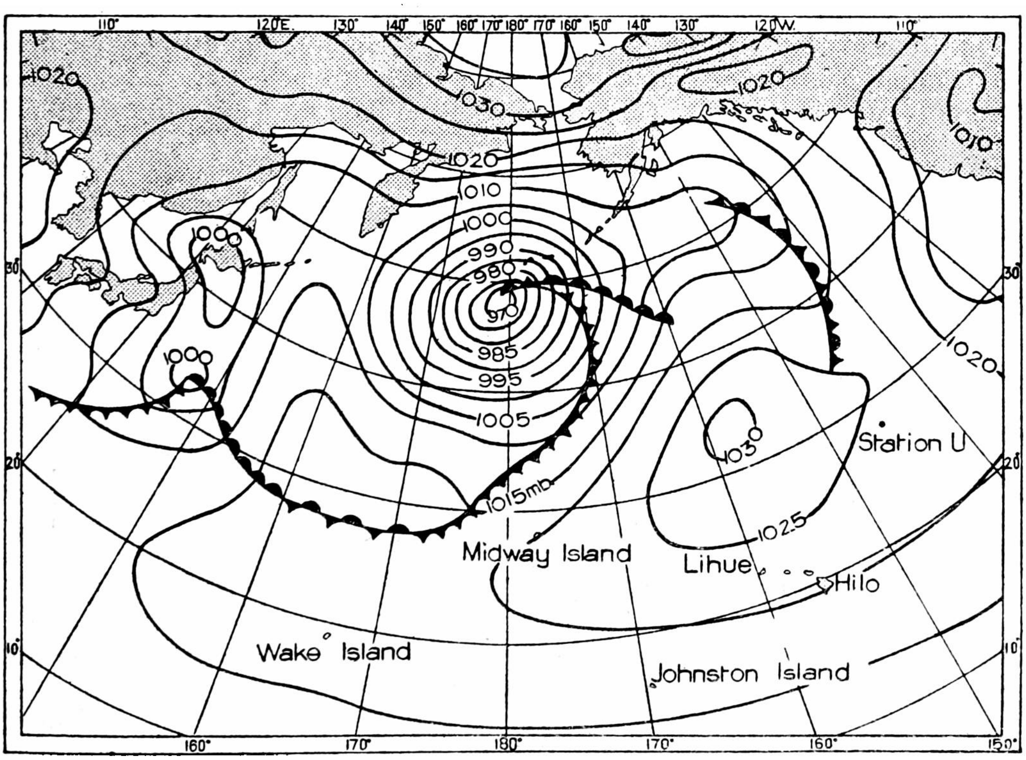


FIG. 4—SURFACE CHART, 1200 G.M.T., APRIL 23, 1951

Discussion.—The statistics in Table I, in spite of the limitations of the data on which they are based, demonstrate that a subtropical jet stream distinct from the polar-front system was present in the upper troposphere over the Hawaiian area on the majority of days of January and April 1951. A similar stream also occurred over the West Indies but, especially in April, the strong flow was often a part of the strong stream associated with the polar front, the axis of this stream being over the United States. It may also be deduced that on about half the days of January 1951 a strong stream existed in the upper troposphere near Dakar.

TABLE III—UPPER WINDS, 0300 G.M.T., JANUARY 13, 1951

Pressure level	Lihue Direction	Lihue Speed	Hilo Direction	Hilo Speed	Wake Island Direction	Wake Island Speed
mb.	°	kt.	°	kt.	°	kt.
100	240	61	...	...	...	...
150	260	88	...	...	...	...
200	250	86	270	110	330	58
240	260	58	270	96	...	...
300	250	28	280	65	320	49
375	220	23	280	10	...	...
500	230	6	170	2	30	9

To demonstrate that the Hawaiian stream was distinct from that of the polar front, Figs. 1–4 were prepared giving surface and 500-mb. charts for two typical cases, January 13, 1951 and April 23, 1951. These charts are tracings of the isopleths on the charts published in the *Daily series synoptic weather maps*. The axes of the polar-front jet streams have been added in Figs. 1 and 3. Table III gives details of the winds 12 hr. before the time of the chart in Fig. 2. Observations for Midway Island at the time of the chart gave a maximum wind of 56 kt. from 315° at 150 mb. (45,000 ft. approximately), and at the same time the wind at 250 mb. (34,000 ft.), the greatest height reached at ocean weather station U, was 270° 24 kt. Table IV gives wind data for 0300 G.M.T. April 23, 1951.

TABLE IV—UPPER WINDS, 0300 G.M.T., APRIL 23, 1951

Pressure level	Lihue Direction	Lihue Speed	Hilo Direction	Hilo Speed	Johnston Island Direction	Johnston Island Speed	Wake Island Direction	Wake Island Speed
mb.	°	kt.	°	kt.	°	kt.	°	kt.
100	...	...	290	33	...	...	330	30
116	260	62	270	43	...	...	...	...
150	270	68	270	71	...	...	...	...
200	270	39	270	66	270	82	270	60
240	250	14	280	35	...	...	...	...
300	180	18	240	15	...	...	270	15
375	90	14	170	8	...	...	...	...
500	60	19	110	9	...	...	160	16

Tables III and IV are examples of the type of data from which the values for the Hawaiian area in Table II were prepared, and show that the height of the axis of strongest winds was at or above 40,000 ft. (200 mb.) and also that the strong winds were a phenomenon of the upper troposphere only. Table II shows that a similar stream occurred over the West Indies also, as Gilchrist[3] and others have shown previously. When a strong stream occurred near Dakar in January 1951, it was also confined to the upper troposphere.

Table II shows that the subtropical jet stream near Hawaii was stronger in April than in January 1951. Mean winds over the Hawaiian Islands in 1950 and 1952 were also stronger in April than in January.

The strong northerly winds which occurred on a few days in the upper troposphere in the Hawaiian area are both interesting and surprising.

Conclusions.—This brief study has established that there was often a strong westerly wind stream in the upper troposphere in January and April 1951 at about 20°N. in the neighbourhood of the Hawaiian Islands and that this stream was quite distinct from the strong flow associated with the polar front which was 10° or more further north. The stream was confined to the upper troposphere. A similar stream was also found to exist over the West Indies (20–25°N.) on many occasions in the same months, confirming previous ideas[3]; the observations from Dakar suggest that a similar type of stream is often found over west Africa in winter.

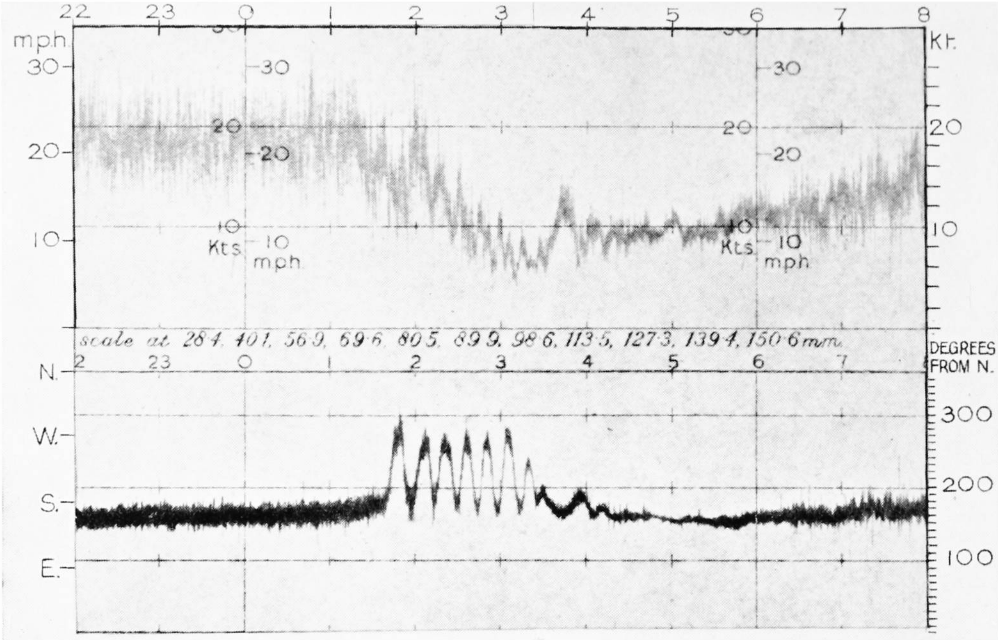
This strong flow in the upper troposphere in certain seasons in tropical or subtropical latitudes must be linked with the temperature field at these levels. It will be necessary to study wind and temperature observations together to find out more of the structure of the stream, and it would seem that the observations from the mid-Pacific Islands are probably best suited to such a study as the polar front is usually well to the north of this area. As stated in the introduction, other areas with good networks of upper air observing stations are in regions where the polar front is comparatively far south.

REFERENCES

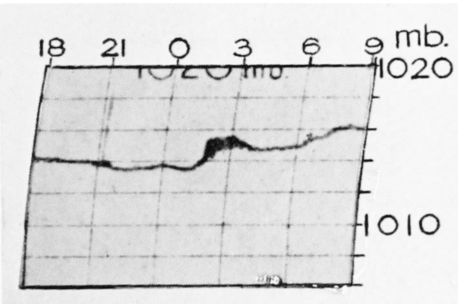
1. NAMIAS, J. and CLAPP, P. F.; Confluence theory of the high tropospheric jet stream. *J. Met., Lancaster Pa*, **6**, 1949, p. 330.
2. PHILLIPS, N. A.; The behaviour of jet streams over eastern North America during January and February 1948. *Tellus, Stockholm*, **2**, 1950, p. 116.
3. GILCHRIST, A.; Upper winds in the tropics and subtropics. *Met. Res. Pap., London*, No. 795, 1953.
4. FROST, R.; Upper air circulation in low latitudes in relation to certain climatological discontinuities. *Prof. Notes met. Off., London*, **7**, No. 107, 1953.
5. BANNON, J. K.; Note on the structure of the high-altitude strong-wind belt in the Middle East in winter. *Met. Res. Pap., London*, No. 821, 1953.
6. London, Meteorological Office. *Upper air data 1946–50*. Part 3. Habbaniya. London, 1953.
7. AUSTIN, E. E. and DEWAR, D.; Upper winds over the Mediterranean and Middle East. *Met. Res. Pap., London*, No. 811, 1953.
8. KOTESWARAM, P., RAMAN, C. R. V. and PARTHASARATHY, S.; The mean jet stream over India and Burma in winter. *Indian J. Met. Geophys., Delhi*, **4**, 1953, p. 111.
9. YEH, T.-C.; The circulation of the high troposphere over China in the winter of 1945–46. *Tellus, Stockholm*, **2**, 1950, p. 173.
10. OOI, S., MATSUMOTO, S., ITOO, H. and ARAKAWA, A.; A study of westerly troughs near Japan (II). *Pap. Met. Geophys., Tokyo*, **3**, 1952, p. 1.
11. LOEWE, F. and RADOK, U.; A meridional aerological cross section in the southwest Pacific. *J. Met., Lancaster Pa*, **7**, 1950, p. 58.
12. GIBBS, W. J.; Notes on the mean jet-stream over Australia. *J. Met., Lancaster Pa*, **9**, 1952, p. 279.
13. HUTCHINGS, J. W.; A meridional atmospheric cross section for an oceanic region. *J. Met., Lancaster Pa*, **7**, 1950, p. 94.
14. BROOKS, C. E. P., DURST, C. S., CARRUTHERS, N., DEWAR, D. and SAWYER, J. S.; Upper winds over the world. *Geophys. Mem., London*, **10**, No. 85, 1950.

WORLD METEOROLOGICAL ORGANIZATION

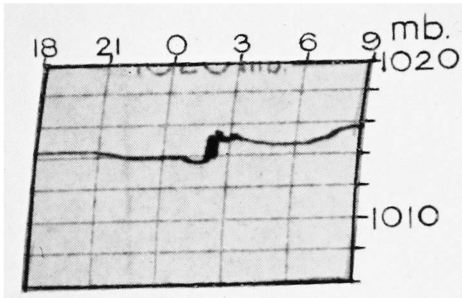
Three separate international meetings were held at the Central Meteorological Office, Zurich in May 1954 under arrangements made by the Director of the Swiss Meteorological Service, Prof. Dr. Lugeon.



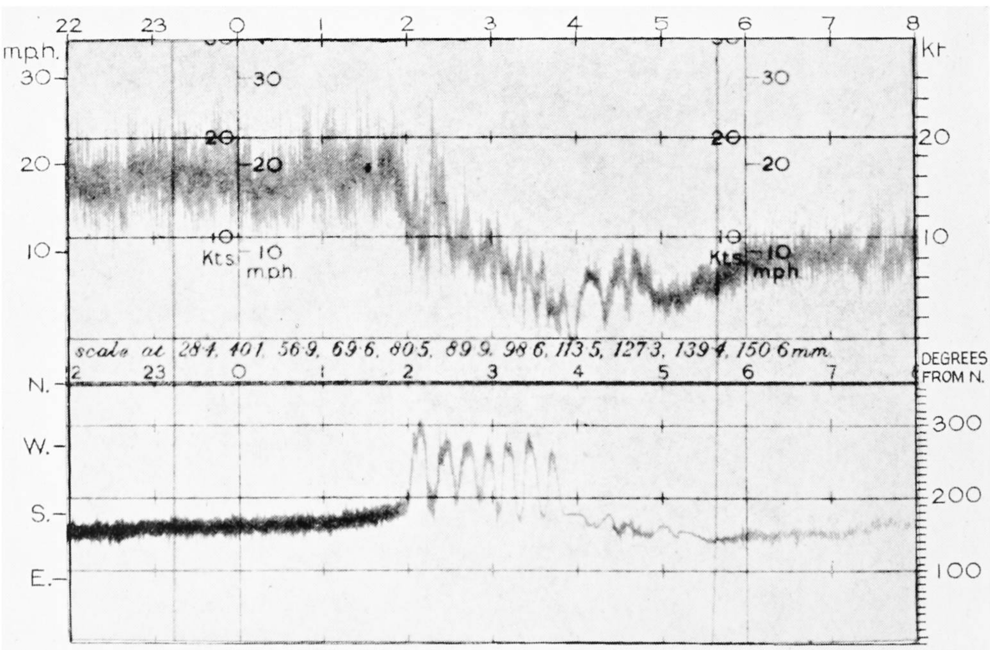
ANEMOGRAM, LUQA, MALTA, 2200 G.M.T., OCTOBER 15 to 0800 G.M.T., OCTOBER 16, 1953



BAROGRAM, LUQA, MALTA, 1800 G.M.T., OCTOBER 15 TO 0900 G.M.T., OCTOBER 16, 1953



BAROGRAM, QRENDI, MALTA, 1800 G.M.T., OCTOBER 15 to 0900 G.M.T., OCTOBER 16, 1953



ANEMOGRAM, HAL FAR, MALTA, 2200 G.M.T., OCTOBER 15 TO 0800 G.M.T., OCTOBER 16, 1953

Clock believed to be 9–10 min. fast

intervals of about 15 min. Two more swings of less amplitude but similar period occurred after 0315. Thereafter the wind settled down in about the same direction as before the occurrence. The wind fell from a mean speed of about 20 kt. before to about 10 kt. after the occurrence. There were no very strong squalls, the motion approximating more to a smooth oscillation. It is noticeable that the strongest gusts occurred in conjunction with the troughs in the direction trace, i.e. each time the wind reverted to its original southerly direction. The westerly puffs were less strong.

The barometer rose rather more than 2 mb. when the occurrence began, and the barogram (left-hand centre photograph) showed oscillations of about 1-mb. amplitude for as long as the wind continued swinging. Actually the amplitude of the pressure oscillations gradually decreased from nearly 2 mb. to perhaps 0·7 mb. The barograph record is not clear enough for precise measurement, particularly as regards separation and timing of the individual oscillations. It seems, however, that the westerly wind puffs brought a pressure maximum (or maxima) as there was a drop of nearly 1 mb. at the end of the oscillations, suggesting that waves on the pressure and wind-velocity traces were out of phase all the time.

None of the autographic records from the other instruments shows anything of interest. The sky was partly covered with altostratus, altocumulus, cirrus and cirrostratus, and there was a trace of rain about 0200 G.M.T. There was no low cloud.

Similar, and doubtless related, behaviour of the surface wind and pressure was briefly noted at Qrendi radio-sonde station, 3 miles south-west of Luqa, where however fewer swings of the surface wind were observed, and the Qrendi barogram (right-hand centre photograph) shows only two full oscillations, corresponding in time to about the first two of the eight swings at Luqa. The observer noted the surface wind at Qrendi as 170° 17 kt. at 0150, but when the radio-sonde balloon was released at about 0155 it was 270° 20 kt. By 0200 the surface wind was again southerly.

The winds obtained from the radio-sonde balloon are given in Table I. The rate of rise was plainly affected by vertical air currents. The figures in Table II are derived from the observations.

TABLE I—WINDS FROM RADIO-SONDE ASCENT, QRENDI, 0155, OCTOBER 16, 1953

	Height (ft.)					
	0	2,000	3,450	5,070	6,690	10,350
Direction	270°	221°	198°	202°	206°	202°
Speed (kt.)	20	17	45	40	39	28

TABLE II—VERTICAL AIR MOVEMENT OVER QRENDI, 0155, OCTOBER 16, 1953

	Time after release (min.)							
		1·65		2·75		5·00		10·00
Pressure level (mb.)		933		911		896		771
Height above station (ft.)		1,900		2,550		3,150		7,300
Mean actual rate of rise (ft./min.)...	1,150		590		266		830	
Mean deduced upward motion of air (ft./min.)	−180		−740		−1,070		−500	

The station height at Qrendi is 445 ft. above M.S.L. There was an inversion of temperature from 911 to 896 mb.—3,000 to 3,600 ft. above M.S.L. (see Fig. 1).

The balloon attained a steady rate of rise from about 7,500 ft. above sea level, averaging 1,333 ft./min. from the eleventh to the thirtieth minute. This figure has been used to get the figures in the bottom row of Table II. From these figures it can be deduced that the balloon became involved in air with a rapid downward motion (approximately 1,000 ft./min.) at a point not far behind the advancing front of the surface westerly breeze, especially near and underneath the inversion layer.

The Fleet Meteorological Officer Malta has kindly made available for examination the autographic records from the Royal Navy meteorological office at Hal Far, Malta, about 3 miles south-east by south (150°) from Luqa. Chief interest attaches to the anemogram (facing p. 265) which shows seven wind oscillations corresponding, with remarkable identity of form and period, to the first seven of the eight swings recorded at Luqa. The wind appears to have been 3 or 4 kt. lighter at Hal Far throughout, whereas the direction swings are in close agreement. Corresponding to the eighth (last) swing of the breeze at Luqa towards the westerly direction, Hal Far shows 5 min. of flat calm.

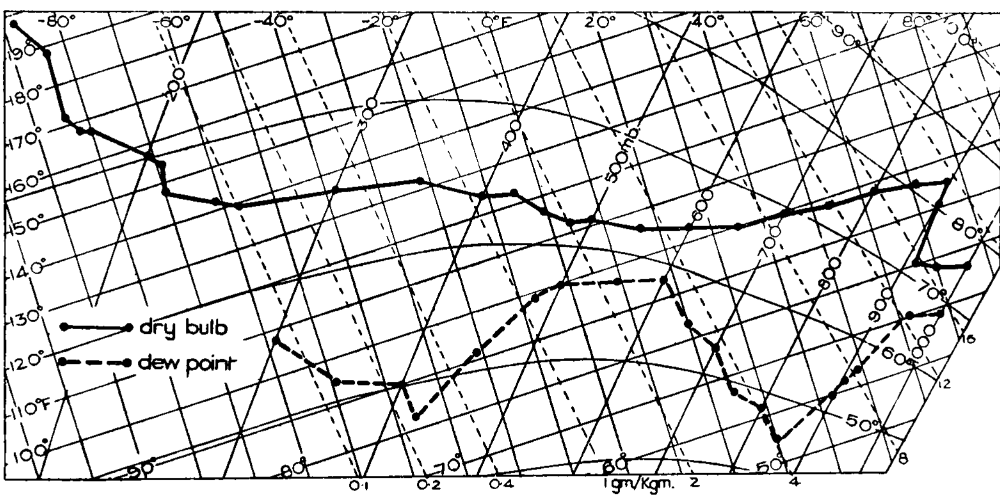


FIG. 1—TEPHIGRAM, QRENDI, MALTA, 0200 G.M.T., OCTOBER 16, 1953

Careful comparison of the Hal Far anemogram with the small-scale barogram for the same station and with the fixed-time observations in the register, suggests that the anemograph clock was 9–10 min. fast. Allowing for this, the westerly wind puffs registered by the anemometer at Hal Far must have come something like 7 min. after the corresponding features on the Luqa record. If this were a straight north–south frontal line of the westerly wind displacing the southerly stream, the time lag from Luqa to Hal Far would have been 15–20 min. From these figures it seems permissible to deduce that the front was of wavy form and that the tip of each wavelet (maximum eastward penetration of the surface westerly wind) was travelling northwards from abreast of Hal Far to abreast of Luqa in 8–13 min., a wave speed of the order of 12 kt. This is in the direction of the general southerly wind stream and of the same order of speed as this wind at the surface, but certainly slower than the southerly winds at 3,000–4,000 ft. (above the inversion). The wave-length would be of the order of 3–4 miles. Probably the amplitude was of the same order, because not all the waves recorded at Luqa reached Hal Far in the east or Qrendi in the west.

The weather map analysis showed a broad southerly air stream (the scirocco) between a ridge of high pressure from Russia and the Balkans to Cyrenaica and depressions centred in the western Mediterranean. The main cold front at the western boundary of the southerly wind stream lay along the coast of Tunisia and was accompanied by thunderstorms. There was also an old, degenerate cold front trailing north and south near (perhaps over) Malta. This front was marked chiefly by a discontinuity of wind speed and isobar spacing; west of the degenerate frontal line the winds, although still generally southerly, were much lighter and more erratic in direction.

The simplest and most plausible explanation is to suppose that the wind oscillations noted in Malta corresponded to ripplets on the degenerate front, the surface of which aloft is represented by the inversion in the Qrendi tephigrams. If so, this surface oscillated up and down with an amplitude of 3,000–4,000 ft. The Qrendi balloon encountered maximum downward air motion at about 3,000 ft.; there was some movement in the same sense up to twice this height.

The case may be held as an example of the general experience in the Mediterranean and north Africa, as elsewhere in suitable circumstances, that when a front is dying out the last characteristic of all to disappear is the discontinuity of wind, often still noticeable long after the main features of associated weather and cloud structure have gone (frontolysed).

Wind-direction oscillations of the kind here described are luckily infrequent; the situation was decidedly awkward for aircraft coming in and taking off from the busy Luqa airport.

The author's attention has since been drawn to published accounts of several similar occurrences observed in Great Britain together with some theoretical discussion of wide applicability[1–3]. Although no relevant upper air temperatures were available, it seemed reasonable in each instance to deduce the existence of a nearly horizontal discontinuity surface aloft. In one case—southern England August 14, 1914—this surface may have been as high as 13,000 ft.; in the other cases, e.g. Abbotsinch, Glasgow, November 16, 1936, it was probably much lower, say 4,000 ft. or below, though again associated air motions in the vertical plane were detected up to 12,000 ft. Goldie[1] also mentions having noticed one case where a steeply sloping frontal boundary was involved. The details of the present case in Malta indicate a frontal surface with a slope of roughly 1 in 7, say 8–10°, from the ground up to 3,000–4,000 ft.

The dimensions arrived at or suggested in these various cases are probably trustworthy as regards order of magnitude and are in fair agreement (see

TABLE III—COMPARISON OF OCCURRENCES OVER SOUTHERN ENGLAND, ABBOTSINCH AND MALTA

	Wave-length	Amplitude (horizontal)	Amplitude (vertical)	Period	Wave speed	Surface wind speed*	Maximum vertical air current
	miles	miles	ft.	min.	kt.	kt.	ft./min.
Southern England, 1914 ...	4½	...	1,500	10	25	10–20	...
Abbotsinch, 1936 ...	3	...	4,000	60 decreasing to 20	5	4–12	900 downwards
Malta, 1953	3–4	c. 4	3,000–4,000	15	12	6–16	1,070 downwards

* Approximate extremes of mean wind over several minutes.

Table III). In all cases the pressure fluctuations were of the same order, amplitude about 1 mb. or rather less. The waves travelled in the general direction of the upper wind at the height of the discontinuity surface but at differing speeds. Goldie examined several other cases for which less data were forthcoming; in these and the cases here discussed the associated discontinuity surface generally had a height of 3,000–6,000 ft. above the ground.

It seems probable that a fairly sharp temperature inversion is required, though there is nothing exceptional about the inversion of 11°F. observed at Qrendi on October 16, 1953. Such wave motion is theoretically likely at the boundary surface between two air streams marked by a discontinuity of velocity, and the problem of why the effects are so seldom observed in our instrumental records at the ground remains unsolved. The air motions must be in some respects not unlike those in rolls of stratocumulus cloud, for example. If these smooth oscillations are normally damped out near the ground by surface friction, perhaps the exceptional cases are attributable to some freak conformity of ground relief to the patterns of air circulation occurring. The phenomenon may well be commoner at sea and near windward coasts than elsewhere. Once set up, however, the English and Scottish cases show that the waves may continue for up to 12 hr. or more in the one area, and may travel 200 miles or more without notably changing their dimensions.

REFERENCES

1. GOLDIE, A. H. R.; Waves at an approximately horizontal surface of discontinuity in the atmosphere. *Quart. J. R. met. Soc., London,* **51**, 1925, p. 239.

2. ANDREWS, R. T.; Wave motion in the upper air. *Met. Mag., London,* **72**, 1937, p. 156.

3. BULL, G. A.; Wave motion in the upper air. *Met. Mag., London,* **73**, 1938, p. 231.

4. SHAW, SIR NAPIER, and AUSTIN, E. E.; Manual of meteorology. Vol. III. The physical processes of weather. London, 1930.

A SUCCESSFUL TRANSATLANTIC CROSSING IN A JET STREAM

By N. E. DAVIS, M.A.

British Overseas Airways Corporation stratocruiser G-ALSA, Captain L. V. Messenger, Navigating Officer M. H. Sutcliff, left New York at 2114 G.M.T. on August 2, 1953 and arrived at London Airport at 0828 G.M.T. on August 3 after a flight in which a tailwind approaching 100 kt. was experienced for over 3 hr. (over 1,000 nautical miles) at an altitude of 21,000 ft.

The general synoptic situation showed a deepening depression south-east of Greenland moving north-east and an anticyclone over the Azores with a ridge of high pressure over the United Kingdom. The cold air had advanced well round the southern side of the depression with the main cold front trailing back towards Bermuda. The warm air was advancing rather slowly towards Scotland and Iceland—the ridge over the United Kingdom being in cold air. The associated thermal pattern (1000–500-mb. thickness) was south-westerly over the greater part of the Atlantic becoming north-westerly ahead of the warm fronts. Hence the upper air contour charts showed a south-westerly air stream over most of the Atlantic becoming north-westerly over the British Isles. The 500-mb. and 300-mb. contour charts for 0300 G.M.T. on August 3, 1953 are shown in Figs. 1 and 2. They indicate a belt of strong south-westerly winds extending from south-east of Newfoundland to about 20°W. The centre of

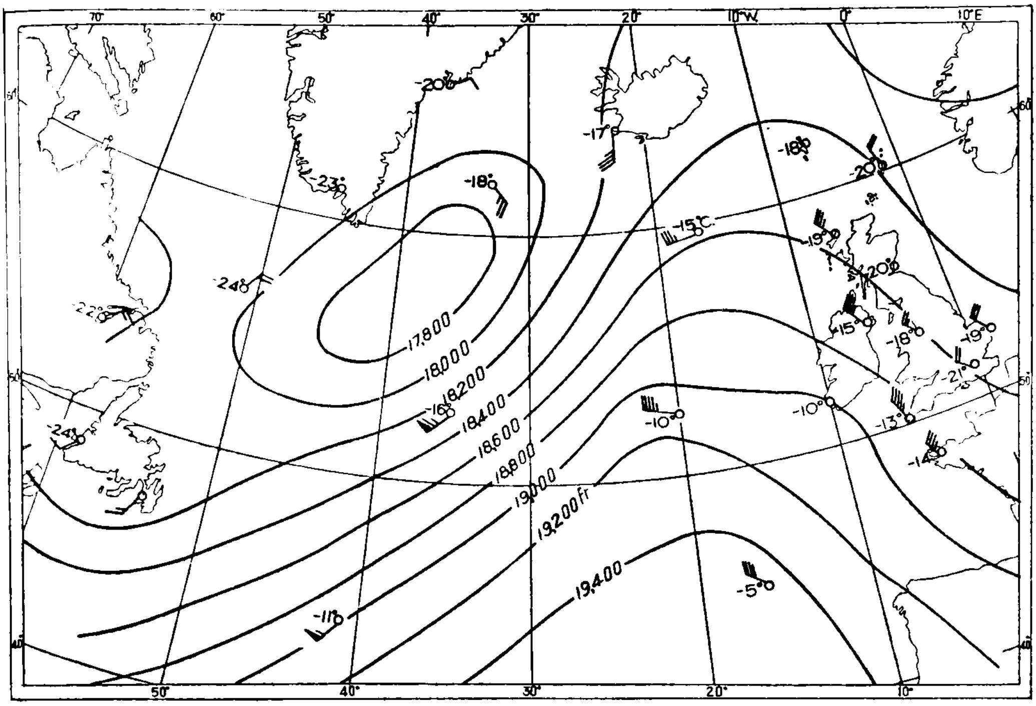


FIG. 1—500-MB. CONTOUR CHART, 0300 G.M.T., AUGUST 3, 1953
Wind speed—one full feather represents 10 kt., one half feather 5 kt. and one solid pennant 50 kt.

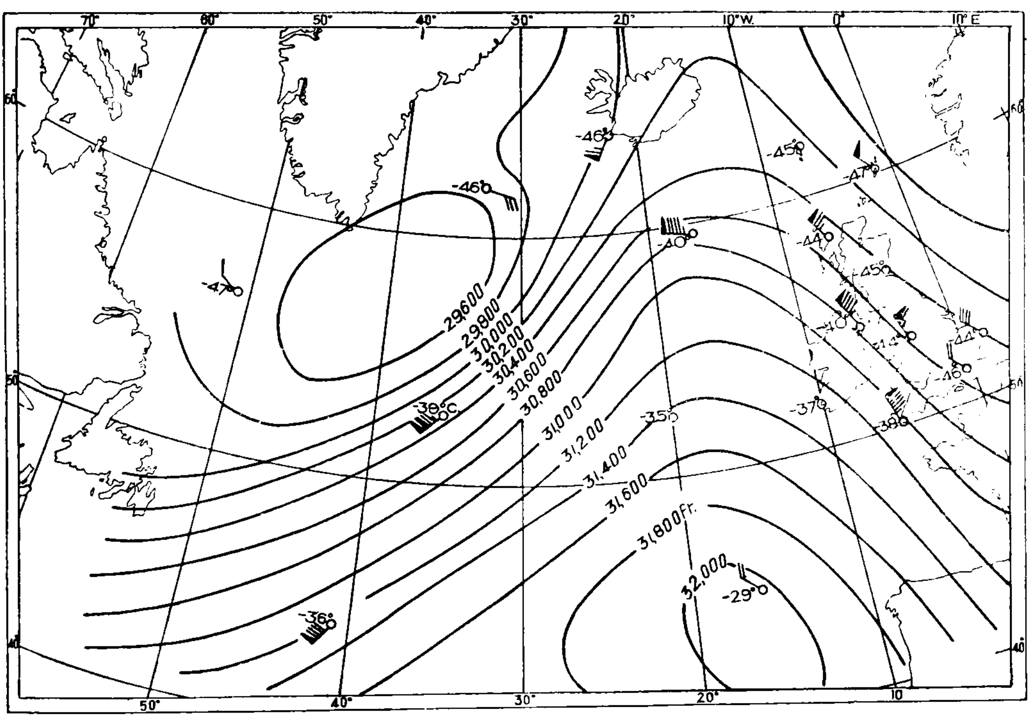


FIG. 2—300-MB. CONTOUR CHART, 0300 G.M.T., AUGUST 3, 1953
Wind speed—one full feather represents 10 kt., one half feather 5 kt. and one solid pennant 50 kt.

the belt at 500 mb. was along the line 45°N. 45°W. to 55°N. 25°W., and at 300 mb. somewhat farther north-west. The upper wind and temperature ascent made from the ocean weather ship at station C at 53°N. 35°W. was located on the north-west edge of the strong-wind belt though it gave the highest winds. The maximum speed of the belt at 500 mb. was about 80 kt. and at 300 mb. 140 kt. or more, so that at the level at which the aircraft flew (namely 21,000 ft.) the maximum speed was about 100 kt.

The aircraft left Idlewild, New York, on a rhumb-line track to 45°N. 50°W. and the flight plan was to fly thence on a great circle to Malin Head. The course of the flight may be best described by quoting the navigator's own words:

The 500-mb. forecast chart, provided by the meteorological office at Idlewild, indicated, as is usual with their charts, the forecast position of the upper front. Using this as a datum and noting that the forecast winds were to be strongest in the vicinity of this frontal surface, we altered our course to approach the jet somewhat sooner than planned, and, making use of the cross-section diagrams in the *Meteorological Magazine* for May 1953[1], made frequent observations of the outside air temperature, and, when this rose at an increasing rate, made more frequent observations of the wind velocity (by Loran fixes). When the wind speed approached 100 kt., we altered course to make this a tailwind and continued to take frequent fixes and temperature readings. The wind speed was maintained for over 3 hr. (over 1,000 nautical miles), the average component at the flight altitude of 21,000 ft. being +94 kt.—most of the time at this altitude was in the jet stream.

We also made some observations of the cloud forms (see *Meteorological Magazine* for October 1951[2]) but not too conclusively. The cloud to start with was small cumulus low down—the anticipated high stratus appeared to starboard (south-east) and crossed over our track at an oblique angle. There was light occasional turbulence, but no noticeable increase in wind speed.

When it eventually became necessary to alter course for Malin Head, the next fix after the alteration produced a wind velocity of 106 kt. The "quality" of fixes at that time was good, so it might be that we were not right in the centre of the stream.

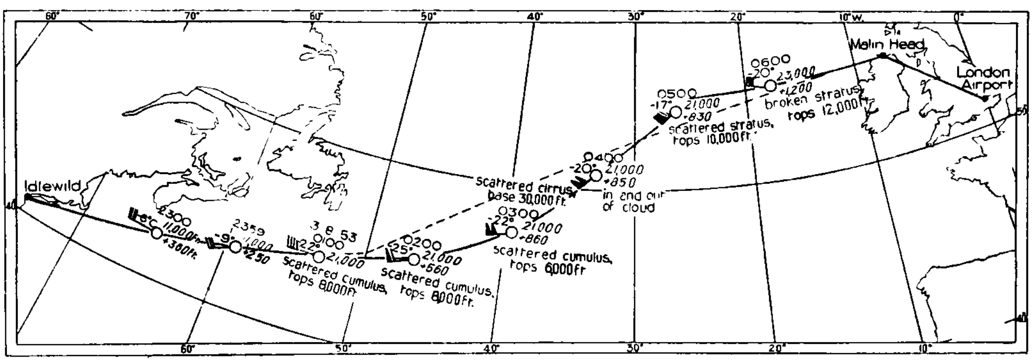


FIG. 3—TRACK OF AIRCRAFT AND HOURLY POSITION REPORTS

——————— Aircraft track   — — — — — — Planned route

Wind speed—one full feather represents 10 kt., one half feather 5 kt. and one solid pennant 50 kt.

Below the average height is given the D value, i.e. the difference between the radio altimeter and pressure altimeter readings

The track of the aircraft and its hourly position and weather reports are plotted in Fig. 3. The high cloud reported at 0300 and through which the aircraft flew at 0400 was evidently associated with a secondary cold front which crossed the track at 31°W. on the 0600 synoptic chart. No change of wind speed in the stream would be expected on passage through the cloud associated with such a secondary cold front. The D value (the difference between the radio altimeter and the pressure altimeter) showed a slight decrease along the jet stream between 0200 and 0500, and this, in conjunction with the reported wind speed of 106 kt. just after the change of course at about 25°W., would seem to indicate that the aircraft had edged towards the polar side while flying down the jet stream.

The navigator concluded his remarks on the flight by saying that the most helpful item in the forecast folder issued by New York, apart from the tabulated winds which could be seen to increase in mid ocean, was the indication of the upper air front on the 500-mb. chart. While this undoubtedly assisted the captain and navigator in deciding where to look for the jet stream, an indication on the 500-mb. chart of the probable position of the jet stream would have sufficed. The success of this flight depended to a very great extent on the frequent observations of outside air temperature—a rapid increase of which is generally associated with an approach to a jet from the polar side—coupled with the accurate and frequent determinations of wind speed and direction.

REFERENCES

1. MURRAY, R.; Jet stream over the British Isles during June 14–18, 1951. *Met. Mag., London*, **82**, 1953, p. 129.
2. SAWYER, J. S., and ILETT, B.; The distribution of medium and high cloud near the jet streams. *Met. Mag., London*, **80**, 1951, p. 277.

HUMIDITIES ASSOCIATED WITH MAXIMUM AND MINIMUM TEMPERATURES IN SOUTH-EAST ASIA

By G. A. TUNNELL, B.Sc.

Introduction.—During recent years British meteorological offices in south-east Asia have been examining and analysing their thermograms and hygrograms in order to collect data concerning maximum and minimum temperatures, the associated relative humidities, and their times of occurrence. This information is being analysed in the World Climatological Branch of the Meteorological Office, and, as the information is frequently requested by industrialists and scientists, a preliminary report has been made in which some 40 tables give the results of the analysis of the first two years of data. A summary of these tables for the five stations listed in Table I are given in Table II. Data for three years have now been collected and a more thorough analysis will be carried out on these at a later date.

TABLE I—STATIONS

	Latitude	Longitude	Height	Period of data
	N.	E.	ft.	
MALAYA				
Changi ...	1°22′	103°59′	34	January 1951–January 1953
Tengah ...	1°23′	103°42′	34	January 1951–January 1953
Butterworth ...	5°28′	100°23′	8	April 1951–February 1953
CEYLON				
Trincomalee ...	8°32′	81°11′	32	August 1950–November 1951
Negombo ...	7°10′	79°53′	28	August 1950–January 1953

The five stations examined (Changi and Tengah on Singapore Island, Butterworth near the west coast of Malaya, and Trincomalee on the east coast and Negombo on the west coast of Ceylon) are all in the paths of the NE. and SW. trade winds during the appropriate seasons. The data have been divided into three seasons: the NE. trade-wind season (NE. monsoon), the SW. trade-wind season (SW. monsoon) and the transitional months. Data are given for the last season, but only the seasons in which the trade-wind régime is definitely established are discussed here.

TABLE II—MAXIMUM AND MINIMUM TEMPERATURES AND ASSOCIATED RELATIVE HUMIDITIES IN SOUTH-EAST ASIA

U_1 = range of associated relative humidity U_2 = range of most frequent associated relative humidity U_3 = Mean associated relative humidity

	Highest					Lowest					Most frequent							Time of occurrence†		
	Value	Frequency*	U_1	U_2	Frequency* of U_2	Value	Frequency*	U_1	U_2	Frequency* of U_2	Value	Frequency*	U_1	U_2	Frequency* of U_2	Mean	U_3	Mean	Most frequent	Frequency*
	°F.	%	%	%	%	°F.	%	%	%	%	°F.	%	%	%	%	°F.	%			%
Maximum temperature																				
NE.-MONSOON SEASON (December–March)																				
Changi	92–93	7·1	55–69	55–59	3·3	76–77	0·5	95–99	95–99	0·5	90–91	26·0	45–74	60–64	8·0	87	66	13·8h.	13h.–14h.	26·9
Tengah	92–93	2·3	45–54	50–54	1·4	74–75	0·5	95–99	95–99	0·5	88–89	35·4	50–74	60–64	15·2	87	65	13·2h.	12h.–13h.	26·4
Butterworth	96–97	1·6	35–39	35–39	1·6	82–83	0·8	75–79	75–79	0·8	90–91	38·5	45–69	60–64	17·2	91	58	14·1h.	14h.–15h.	33·6
Trincomalee	92–93	0·8	55–59	55–59	0·8	76–77	0·8	90–94	90–94	0·8	82–83	39·8	60–94	75–79	13·2	84	75	12·8h.	13h.–14h.	28·1
Negombo	98–99	0·4	40–44	40–44	0·4	76–77	0·4	85–89	85–89	0·4	88–89	36·5	35–74	55–59	9·5	88	58	13·3h.	14h.–15h.	27·8
SW.-MONSOON SEASON (June–September)																				
Changi	94–95	3·3	55–64	60–64	2·2	78–79	0·5	90–94	90–94	0·5	90–91	32·7	45–84	60–64	14·2	89	64	13·6h.	14h.–15h.	27·9
Tengah	92–93	2·1	50–64	50–54	1·1	78–79	0·5	85–89	85–89	0·5	88–89	34·4	45–74	60–64	12·0	88	65	13·0h.	13h.–14h.	24·0
Butterworth	94–95	1·0	35–54	35–54	1·0	76–77	0·5	85–89	85–89	0·5	90–91	45·3	45–69	60–64	18·6	89	62	14·2h.	14h.–15h.	30·1
Trincomalee	100–101	1·1	35–39	35–39	1·1	82–83	0·6	70–74	70–74	0·6	96–97	25·6	30–54	40–44	14·4	95	45	13·3h.	13h.–14h.	36·9
Negombo	88–89	3·3	60–74	65–69	2·2	80–81	1·8	75–89	75–84	1·4	84–85	53·9	65–84	70–74	25·1	85	74	12·8h.	12h.–13h.	31·3
TRANSITIONAL MONTHS (April, May, October, November)																				
Changi	94–95	7·0	45–69	55–59	3·8	80–81	0·5	85–89	85–89	0·5	90–91	34·9	45–79	60–64	14·2	90	63	13·4h.	13h.–14h.	23·5
Tengah	92–93	3·8	50–59	55–59	2·2	80–81	1·0	75–89	75–89	1·0	88–89	40·9	50–74	65–69	16·4	89	64	12·7h.	12h.–13h.	27·3
Butterworth	94–95	0·5	35–39	35–39	0·5	80–81	0·5	80–84	80–84	0·5	88–89	42·6	55–79	65–69	20·8	89	65	13·7h.	13h.–14h.	29·0
Trincomalee	98–99	1·6	45–49	45–49	1·6	74–75	1·1	95–99	95–99	1·1	94–95	16·3	30–59	50–54	7·1	90	60	13·1h.	13h.–14h.	25·0
Negombo	90–91	4·9	35–74	65–69	2·5	78–79	0·8	75–84	75·84	0–8	88–89	35·3	40–79	70–74	14·8	87	71	13·0h.	12h.–13h.	26·8
Minimum temperature																				
NE.-MONSOON SEASON (December–March)																				
Changi	78–79	3·6	90–99	90–94	2·9	68–69	0·8	90–99	90–99	0·8	74–75	49·3	80–100	95–99	28·8	75	94	4·2h.	6h.–7h.	29·2
Tengah	76–77	3·3	90–99	95–99	2·2	68–69	1·1	95–99	95–99	1·1	72–73	53·4	90–100	95–99	44·2	73	97	4·9h.	6h.–7h.	31·8
Butterworth	76–77	4·7	85–99	95–99	4·2	68–69	5·7	85–99	90–99	4·8	72–73	37·3	85–100	95–99	25·5	73	95	6·7h.	7h.–8h.	60·4
Trincomalee	78–79	0·8	85–89	85–89	0·8	64–65	1·7	90–94	90–94	1·7	74–75	34·9	75–100	90–94	20·7	73	92	0·7h.	0h.–1h.	21·5
Negombo	76–77	4·6	85–99	95–99	2·3	62–63	0·3	95–99	95–99	0·3	72–73	35·1	80–100	95–99	16·1	72	93	5·6h.	6h.–7h.	67·2
SW.-MONSOON SEASON (June–September)																				
Changi	82–83	1·2	80–89	80–84	0·8	70–71	3·3	95–99	95–99	3·3	76–77	31·6	80–99	90–94	17·2	76	92	4·4h.	6h.–7h.	35·2
Tengah	78–79	0·4	95–99	95–99	0·4	68–69	0·8	95–99	95–99	0·8	74–75	48·7	75–100	95–99	38·1	74	96	4·7h.	6h.–7h.	30·3
Butterworth	78–79	0·8	90–99	90–99	0·8	70–71	1·6	95–100	95–100	1·6	74–75	56·1	85–99	95–99	53·7	74	97	6·4h.	6h.–7h.	50·0
Trincomalee	82–83	0·6	80–84	80–84	0·6	70–71	0·6	85–89	85–89	0·6	78–79	43·0	70–84	75–79	21·8	77	80	3·1h.	5h.–6h.	31·1
Negombo	80–81	8·2	70–94	80–84	3·9	72–73	1·9	90–100	95–100	1·6	78–79	47·2	75–99	85–89	25·6	77	90	4·0h.	6h.–7h.	32·9
TRANSITIONAL MONTHS (April, May, October, November)																				
Changi	80–81	2·4	85–99	85–89	1·2	70–71	1·2	95–99	95–99	1·2	76–77	43·0	80–99	90–94	20·1	76	94	4·4h.	6h.–7h.	36·9
Tengah	76–77	15·1	85–99	95–99	13·9	70–71	0·8	95–99	95–99	0·8	74–75	54·9	85–99	95–99	49·2	74	97	4·9h.	5h.–6h.	36·9
Butterworth	78–79	2·0	90–99	95–99	1·6	70–71	1·2	95–100	95–100	1·2	74–75	54·1	85–100	95–99	50·0	75	97	6·1h.	6h.–7h.	51·6
Trincomalee	78–79	8·6	75–94	85–89	6·0	68–69	0·5	90–94	90–94	0·5	74–75	35·0	75–94	90–94	23·0	75	89	2·6h.	5h.–6h.	23·7
Negombo	82–83	1·3	75–94	80–84	0·7	68–69	1·0	95–99	95–99	1·0	74–75	38·7	85–100	95–99	31·8	75	95	4·0h.	6h.–7h.	34·8

*Frequency expressed as a percentage of all observations † 82½° E. meridian time for stations in Ceylon; 112½° E. meridian time for stations in **Malaya**

Season of the NE. trade wind (NE. monsoon).—During the NE. monsoon, Singapore is exposed almost directly to the general air stream from the South China Sea, although both Changi and Tengah are to some extent sheltered. These two stations are on different sides of the island and this work shows that there are distinct climatic differences between them. The NE.-monsoon air reaches Butterworth after its passage across the Malay Peninsula but this does not seem to have a great influence upon the characteristics of the air.

The air of the NE. monsoon reaches Ceylon from the Bay of Bengal. Trincomalee is directly exposed while Negombo is sheltered. The effect of the passage across Ceylon is considerable.

Maximum temperature and associated relative humidity.—Malaya.—The main differences between the three Malayan stations are due to their varying degrees of shelter from air arriving directly off the sea. Tengah, which appears to be the most exposed of the three stations, has a number of occasions of lower maxima associated with higher humidities than any experienced at the other two stations. The flow round the southern end of Malaya is probably complicated and it may not be easy to trace the cause of this difference between Changi and Tengah. Butterworth, which is completely sheltered, has a compact frequency distribution. The frequency "tails" towards lower maxima and higher humidities experienced at Changi and Tengah are not evident. Maxima occur most frequently between 13h. and 14h. ($112\frac{1}{2}°$ E. meridian time) at Changi, 12h. and 13h. at Tengah, and 14h. and 15h. at Butterworth. Over 60 per cent. occur between 12h. and 15h. There is a distinct difference in the times of occurrence of maxima at Changi and Tengah. This is almost certainly due to differences of exposure.

Ceylon.—Air passing over Ceylon is considerably modified; maxima at Trincomalee are about 4°F. lower than those at Negombo and associated relative humidities are about 17 per cent. higher. Trincomalee experiences the NE. monsoon directly from the Bay of Bengal. This air is colder and wetter than that which reaches Singapore Island; this may be partly due to the influences of shelter although these cannot be very great. Even with this air direct from the sea there is a definite significant negative correlation between maximum temperature and associated relative humidity. Where there is considerable modification, as in this case, the range of temperature and humidity is likely to be greater after the air has passed across the island. The tables for Trincomalee and Negombo confirm this. At Trincomalee the sea-breeze is augmented by the trade winds. This influences the time of the maxima. In Ceylon there is a wide range of times of maxima from 11h. to 15h. ($82\frac{1}{2}°$ E. meridian time); 90 per cent. of maxima occur here during these hours. The sea-breeze usually gives an early maximum but it can delay it for an hour or so. There is a similar effect at Negombo but the trade wind is against the sea-breeze and the effect is not so large.

Minimum temperature and associated relative humidity.—Malaya.—Malayan night minima are very uniform. They are within 4°F. of 74°F. on more than 90 per cent. of occasions and the relative humidity is above 90 per cent. on over 90 per cent. of occasions. Changi has a high frequency of 90–95 per cent. relative humidity which is possibly associated with subsiding air. This is supported by slightly higher minima. The minimum may occur at any time of the day or night depending upon numerous causes. It most often occurs towards dawn. When it frequently occurs well before dawn, it points to the existence of some form of heating which is probably katabatic subsidence. This occurs at Changi and Tengah and to a lesser extent at Butterworth. There is not a high degree of negative correlation between minimum temperature and relative humidity.

Ceylon.—Minimum temperatures are not highly correlated with associated relative humidity in Ceylon during this season. The most striking feature is that the majority of minima at Trincomalee occur within about an hour after midnight; in addition the air is less frequently near saturation during the night than that at Negombo. The number of occasions of 95–100 per cent. relative humidity is less than half as many at Trincomalee as at Negombo. This clearly points to the existence of a flow of air off the higher land inland strong enough to reverse the trade wind at Trincomalee. Negombo is normal in having a high preponderance of night minima near sunrise. The range of minimum temperature is less than that of the maximum. This is also true for associated relative humidity but the humidity at Negombo is less variable than that at Trincomalee. Conditions at night in Ceylon are more variable than they are in Malaya although the general levels of temperature and associated relative humidity are very similar.

Season of the SW. trade wind (SW. monsoon).—During this season the SW. trade winds reach Malaya after they have passed across Sumatra and the Strait of Malacca.

Trincomalee and Negombo during this season have exactly opposite situations with regard to the SW. monsoon as they had to the NE. monsoon. Negombo is almost directly exposed to the air coming from the Indian Ocean while Trincomalee is sheltered by the island.

Maximum temperature and associated relative humidity.—Malaya.—The frequency distributions for the three places in Malaya are very similar. This is probably due to the air reaching them having very similar histories. The effect of Sumatra upon conditions at Malayan stations seems to be fairly uniform. The lower temperatures and higher humidities noted in the NE. monsoon are not experienced at the Singapore stations during this season. Butterworth does not differ greatly from the Singapore stations but it is slightly cooler and wetter than it was during the NE. monsoon. All the above facts are consistent with the change in wind direction and show that the NE. and SW. monsoons bring air to Malaya whose characteristics are very similar. The maxima occur at similar times to those in the NE. monsoon but there is a tendency for them to occur earlier.

Ceylon.—As in Malaya, there is clear negative correlation between maximum temperature and associated relative humidity at both stations in Ceylon during this season. Negombo, where the monsoon air arrives unmodified, has a very small variation of maxima and associated relative humidity. On almost 80 per cent. of occasions the associated relative humidity is between 70 and 80 per cent., and on over 90 per cent. of occasions the maxima are between 82° and 88°F. The monsoon air must be very homogeneous. Trincomalee, where the monsoon air is modified, experiences maxima about 10°F. higher than those at Negombo with associated relative humidities about 30 per cent. lower. There is in addition a greater variability. The maxima occur mainly between 13h. and 14h. at Trincomalee and between 12h. and 13h. at Negombo.

The difference is again probably due to an augmented sea-breeze at Negombo. At both places the maxima have a relatively high probability of occurrence over several hours about noon.

Minimum temperatures and associated relative humidity.—Malaya.—There is evidence that during this season Changi frequently experiences subsiding air. The frequencies of relative humidities of 95–100 per cent. are lower than those of 90–94 per cent. and the most frequent night minimum is higher than the corresponding temperature during the NE. monsoon. Tengah also is slightly drier and warmer. Butterworth is slightly more humid but its minimum temperatures are similar. Night minima occur mainly towards sunrise, but at Changi minima occur very frequently before dawn (on almost 50 per cent. of occasions). This is consistent with frequent subsidence.

Ceylon.—Night minima at Negombo are less variable during this season than during the NE. monsoon. They are higher and associated with lower relative humidities; again there is evidence here of subsidence. Trincomalee is also warmer and drier at night in this season; minimum temperature is more negatively correlated with associated relative humidity and conditions are less variable. All this confirms that the air during this season is more homogeneous than that of the NE. monsoon. Night minima in Ceylon occur mainly towards sunrise but they are also frequent before dawn, particularly within an hour after midnight at Trincomalee. Again subsidence or katabatic winds are indicated.

Conclusion.—This preliminary examination has brought to light features of climate in south-east Asia of which forecasters are probably aware. However statistical evidence is very useful to confirm ideas. The strong katabatic effects at Changi and Trincomalee, for example, must have a great influence on the prediction of night visibility. These stations should have good visibility at night.

The results obtained from the automatic records seem to carry a wealth of information and are quite reliable. It is not possible, however, to come to any striking conclusions until there are sufficient data to justify them.

LOWERING OF FREEZING LEVEL OVER A MOUNTAIN RANGE

By S. M. ROSS

A direct observation of freezing level during a mountain climb demonstrates the danger of slavishly taking the freezing level over mountain country from adjacent upper air ascents, and bears out, to some extent, one of the considerations discussed in a recent inquiry into the cause of an aircraft crash[1].

On Sunday, December 13, 1953, a moist homogeneous southerly air stream, conditionally unstable but with no marked fronts, covered the British Isles. The ascents for 0200 G.M.T. suggested that a freezing level in the region of 6,500–7,000 ft. would exist in the Cairngorm area of Inverness-shire.

A party set out with the intention of climbing Ben Macdhui by the north face of Cairn Gorm (Fig. 1), and about 3 miles south of Glenmore Lodge they climbed into patches of cloud at a height of 2,000 ft. The cloud became 8 oktas some 300 ft. higher and the visibility fell to 40 yd. remaining of that order throughout the climb. On the plateau, at a height of 3,700 ft., conditions became uncomfortably wet and cold as the party climbed up out of shelter into a strong southerly wind.

At midday, while sheltering behind some rocks near the summit of Cairn Gorm (4,084 ft.), it was noticed that small amounts of ice had been forming on woollen garments during the last 100 ft. or so of the climb, though not on smooth "wind-cheaters" which were quite wet. On examining the windward side of the rocks ice was found, in clear nodules, on every projection, while moisture was being blown back over the rock. The growth was very slow and difficult to observe owing to the moisture over the ice, but the average thickness was quarter of an inch with occasional half-inch projections. No actual precipitation was encountered and no ice was found on any but the windward faces of the rocks. The wind speed was estimated at 30 kt., blowing from 170°.

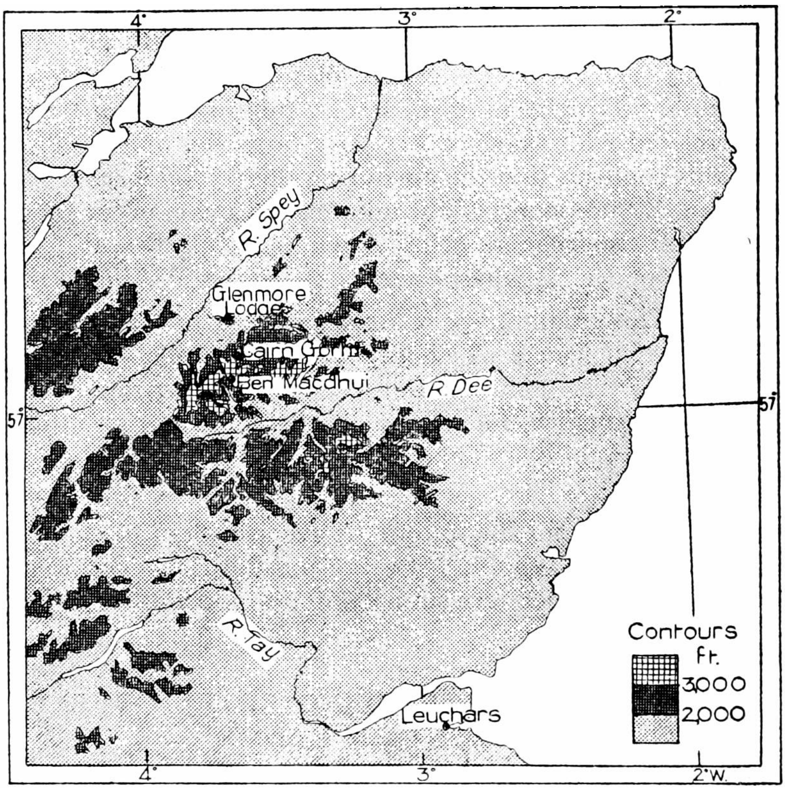


FIG. 1—THE GRAMPIANS, SHOWING THE POSITION OF CAIRN GORM, GLENMORE LODGE AND LEUCHARS

The Leuchars 1400 G.M.T. ascent (see Fig. 2) is taken as being representative of the air over the area during the period (Leuchars bears 150° 50 nautical miles from Cairn Gorm). This gave a freezing level of 6,400 ft. and 42°F. at 4,000 ft. The wind at 4,000 ft. from the ascent was 180° 20 kt. and increased by 10–15 kt. westwards, as shown by the Aldergrove and Stornoway ascents at that time. The freezing levels at 0200, as shown by the Liverpool, Aldergrove, and Leuchars ascents, were 6,800 ft., 7,000 ft., and 6,900 ft. respectively. The gradient wind measured on the 1200 surface chart was 170° 30 kt., while the surface wind at Glenmore Lodge was SE. force 1 and that found in the valley, 3 miles to the south, variable or N. force 1–2.

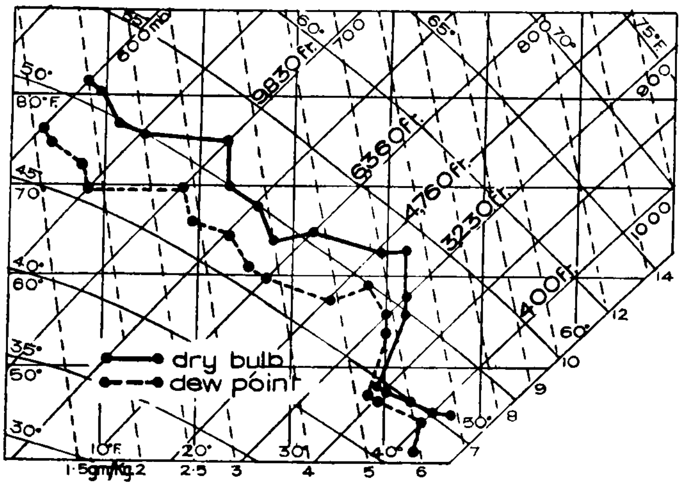


FIG. 2—TEPHIGRAM OF UPPER AIR ASCENT AT LEUCHARS, 1400 G.M.T., DECEMBER 13, 1953

From the above observations it would appear that the freezing level had fallen by some 2,500 ft., owing to the forced uplift of air over the Cairngorm Mountains which form a barrier at approximately right angles to the wind. Forced uplift between 1000 and 940 mb. of any air represented by the 1400 Leuchars ascent, would give condensation some 10 mb. higher and a freezing level between 873 and 865 mb. (4,000–4,250 ft.). The effects of forced uplift over the Highlands on cloud formation have already been discussed by Virgo[2].

The drying out by deposition of moisture in cloud on mountains is demonstrated by the 1200 observation at Glenmore Lodge, taken at a point 1,100 ft. above sea level (975 mb.) and 3 miles to the north, which gave a dry-bulb temperature of 43°F. and a dew point of 39°F. with 6 oktas cloud at 1,800 ft. This air, if forced to rise, would give condensation at 950 mb. (2,000 ft.) and a freezing level of 880 mb. (3,800 ft.).

REFERENCES

1. London, Ministry of Civil Aviation. Report of the court investigation on the accident to Dakota EI-AFL on 10th January, 1952. *M.C.A.P.*, No. 102, 1952, p. 17.
2. VIRGO, S. E.; Conditional instability over the Highlands of Scotland. *Met. Mag., London*, **80**, 1951, p. 88.

OFFICIAL PUBLICATIONS

The following publications have recently been issued:—

METEOROLOGICAL REPORTS

No. 14—Sea-breezes at North Front, Gibraltar. By A. Ward.

The southerly sea-breeze at Gibraltar is occasionally a considerable hazard to the safe landing of aircraft at the airfield at North Front since it blows at almost right angles to the only runway and, during the summer months, often reaches a mean speed of over 15 kt. with gusts to 30 kt.

This report is based on observations during 1947–49 and indicates a close relationship between the wind structure and temperature distribution from the surface to 3,000 ft. and the incidence of the sea-breeze. The sea-breeze occurs mainly when the air is stable and the wind at 2,000–3,000 ft. is westerly; it is comparatively rare when the upper wind is easterly.

No. 112—Classification of upper air temperature according to tropopause pressure. By J. K. Bannon, B.A.

Upper air temperatures in the neighbourhood of the tropopause are best classified for some purposes according to tropopause pressure. Resulting from such a classification for 20-mb. ranges of tropopause pressure, mean temperatures at Larkhill are presented for standard pressure levels from 500 to 100 mb. for four months for a period of three years. The use of these mean temperatures for obtaining statistics of lapse rates and for the study of year-to-year temperature variations is discussed.

ROYAL METEOROLOGICAL SOCIETY

At a meeting of the Society on May 19, 1954, with Prof. P. A. Sheppard, Vice-President, in the Chair, the following papers were read:—

*Mordy, W. A. and Eber, L. E.—Observations of rainfall from warm clouds**

This paper, which was presented by Mr. Mordy, gives detailed observations of rain from cloud in the trade-wind belt as it crossed the south-eastern corner of the island of Oahu in the Hawaiian group during 10 days of June–July 1952. In addition to special aircraft flights, pilot-balloon observations, etc., a continuous record of cloud conditions and movements were made by lapse-time cinematography supplemented by aerial photography; extracts from the film were shown.

The observations showed that appreciable rain, often of intensity 0·4 in./hr. and on one occasion totalling 2·10 in. within 24 hr., fell from comparatively shallow warm clouds of no more than 7,000 ft. vertical extent, the tops of which were never higher than 8,500 ft. The freezing level was about 14,000 ft. so that the Bergeron process of rain formation could not occur. The thicker the cloud the more the rain was likely to occur and it was noticed that an orographic lenticular-shaped cloud only a few hundred feet thick just above the cumuliform cloud was often associated with the rainfall. Droplets of diameter 300μ were occasionally observed falling from this cloud canopy but the precise mechanism was not understood. Seeding of the underlying cumulus clouds from the canopy was not observed on radar.

East, T. W. R., and Marshall, J. S.—Turbulence in clouds as a factor in precipitation†

It has been found difficult to explain the formation of raindrops in moderate-sized cumulus clouds that did not reach freezing levels because of the comparatively long time calculated as necessary for a cloud droplet of small initial size to grow to raindrop size by natural collision and coalescence with smaller droplets. This paper, which was presented for the authors by Prof. Sheppard, was a mathematical attempt to show how turbulence could increase the rate of collision—sufficient in all except small cumulus to cause rainfall without recourse to the Bergeron process.

If by some means, in this case turbulence, the gravitational field could be effectively doubled the range of diameters of the droplets collected by a drop of, say, 15μ diameter would be more than doubled, the efficiency of collection would be increased ten times to 30 per cent. at the most suitable size of droplet, and

* *Quart. J. R. met. Soc., London,* **80**, 1954, p. 48.
† *Quart. J. R. met. Soc., London,* **80**, 1954, p. 26.

the time required for growth would be reduced to a thirteenth. Attempts were then made to show that this order of acceleration could be effected by turbulence and to calculate the resulting growth rates. Discussion of the paper revolved mainly around the existence of such turbulent accelerations; Mr. Mason and Dr. Scorer pointed out that the suggested order of 1-dimensional turbulence, if it existed, would be audible at the frequencies claimed. Mr. Mordy said that in his experience turbulence did shorten the lifetime of a cloud droplet.

*Langleben, M. P.—The terminal velocity of snowflakes**

Mr. Langleben described some experiments by cinematography to measure the terminal velocity of snow-flakes. The size of the snow-flake was measured by subsequent melting on filter paper dusted with powdered dye and by measuring the melted diameter.

It was found that the terminal speed was approximately proportional to the one-tenth power of the mass of the snow-flake, provided the snow-flakes were all of the same type; dry dendrites were slower than plates and columns, but the speed of fall was increased by rime deposits or slight melting. The results were applied to observations of snow-fall by a zenith-pointing radar, and it was concluded, since the observed rate of fall near the generating region was two or three times higher than it would be for single crystals and no riming could be detected at ground level, that snow aggregates do exist at high levels, including those at extremely low temperatures.

Mr. Gold and Mr. Bonacina were both curious as to the difficulty of measurement of dancing or bouncing snow-flakes. Mr. Langleben said there had been no difficulty; stereoscopic photographs were taken but they were tedious to work out and it had been simpler to use the camera pointing cross-wind. The vertical speed was independent of wind strength.

LETTERS TO THE EDITOR

Distortion of condensation trail at a frontal surface

The photograph (facing p. 280) of an unusual distortion in a condensation trail was taken at Wick by Mr. W. Glander who has supplied the following details: Time of observation, 1030 G.M.T., March 2, 1954. Cloud—3 oktas altocumulus at 9,000 ft. with 3 oktas cirrus at 23,000 ft. (both heights estimated). Camera facing 170° true and elevated at 25°. The aircraft flew approximately from north to south, not quite overhead. When first formed the trail was quite straight, the distortion photographed occurring in some 6–8 min. as nearly as could be assessed afterwards.

At the time north-east Scotland was just coming under the influence of S.–SW. winds in cold air ahead of a warm front which, at 0600 G.M.T., was oriented north-north-west to south-south-east about 200 miles to the west-south-west of Stornoway. The winds were 290–300° in the warm air aloft.

It is thought that the aircraft may have climbed gently into the upper westerlies for a short time and descended again, or alternatively that there was a slight corrugation in the zone of separation between the lower southerlies and upper westerlies.

The Mintra height† at the time was about 17,000 ft. and the contrail would probably be quite near the cirrus, estimated at 23,000 ft. The length of the

* *Quart J. R. met. Soc., London,* **80,** 1954, p. 174.

† Theoretical minimum height at which condensation trails can form.

distortion on the photographic plate was about 0·4 in. so that the distance of displacement of the trail would be about

$$\frac{23000 \text{ cosec } 25 \times 2\cdot54 \times 12}{10\cdot5} \times \frac{0\cdot4}{12 \times 6080} \text{ nautical miles,}$$

that is about 1 nautical mile in 6–8 min. Thus the vector wind change was at least 8–10 kt. from some westerly direction.

A similar type of effect is shown by the Stornoway 0800 PILAR report which gives: at 14,000 ft. 204° 16 kt., at 16,000 ft. 240° 11 kt., at 18,000 ft. 265° 15 kt. That is a vector change between 14,000 and 18,000 ft. of 325° 16 kt. probably concentrated around 14,000 ft. Assuming an even slope in the frontal surface of about 7,000 ft. in 100 miles, the height of the frontal surface at Wick would be about 21,000 ft. at 0600, thus supporting, to some extent, the theory put forward above.

P. E. PHILLIPS

Pitreavie Castle, Dunfermline, April 28, 1954

Aircraft icing at very low temperatures

A rather interesting case of clear-air icing above the tropopause was experienced recently by Flt-Lt J. Gingell. It occurred during a flight on January 18, 1954 at an indicated height of 40,000 ft. (and a true height of 100–300 ft. below this in the area concerned). The flight had been from the Midlands to the Prestwick area and back, and the icing was first noticed just south of Stranraer at 1345 G.M.T. on the return flight. It was in the form of a thin layer of hoar frost on the leading edge which glistened in the sunshine and did not disperse until the aircraft descended into the lower levels over the Midlands. Flt-Lt Gingell observed that the top of all cirrus and cirrostratus on the ascent had been at 39,000 ft., and there was no cirrus as high as 40,000 ft. during the entire flight. He saw no condensation trails at the flight level, and at least over south Scotland any trails which his aircraft might have been making were non-persistent as none was visible when he turned to fly south; there were persistent trails at 2,000–3,000 ft. below flight level however.

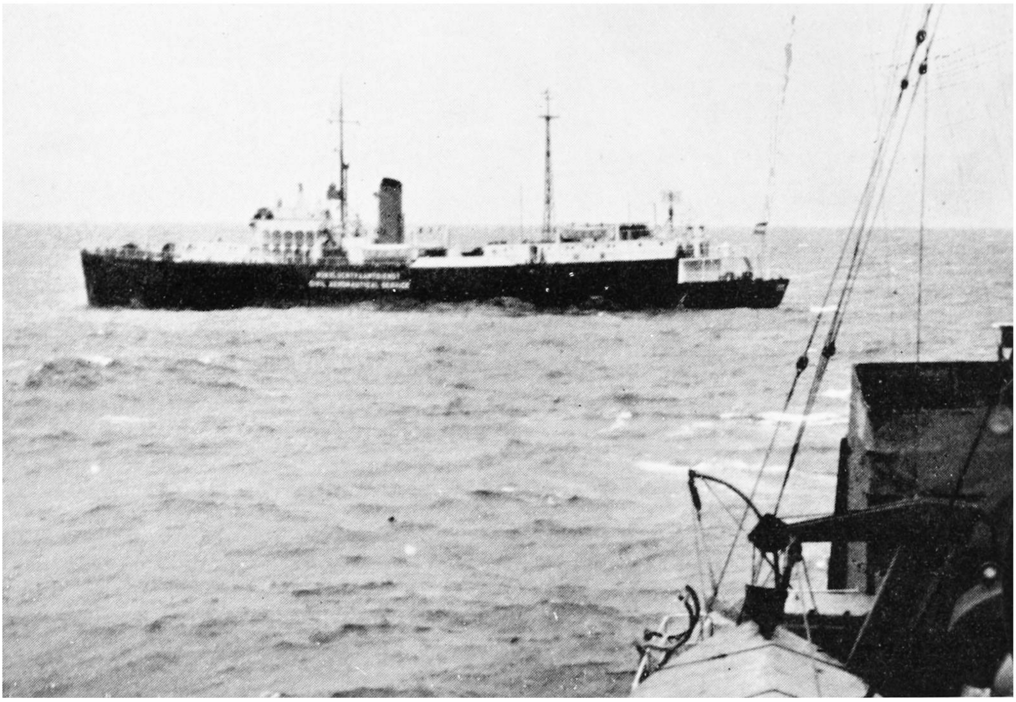
There was a deep depression south-west of Iceland at 1200 G.M.T. on January 18, and a warm front from Stornoway to Anglesey and Devon was moving east at 25 kt. in the north, slowly in the south. There were breaks in the cloud cover over the east Midlands, but from the Mersey northwards there was 8 oktas multilayered frontal cloud over the route. The tropopause height was 40,000 ft. in the vicinity of the Isle of Man, and 37,000 ft. near Prestwick. Winds were 280° 45–55 kt. at the level of flight. Considerable variation existed in the temperature at 200 mb. (38,200–38,500 ft.) and at 170 mb. (41,700–41,800 ft.) as the following data for 1500 G.M.T. show:–

	Liverpool	Aldergrove	Leuchars	Stornaway
		degrees Centigrade		
At 170 mb. ...	−67	−58	−54	−59
At 200 mb.	−68	−63	−53	−63

It is seen that at flight level appreciable differences of temperature existed in places not far separated in distance, and in the neighbourhood of the north Irish Sea and southern Scotland a difference of at least 6°C. could be expected

Reproduced by courtesy of Mr. W. Glander

DISTORTION IN A CONDENSATION TRAIL, WICK, 1030 G.M.T., MARCH 2, 1954
(see p. 279)



O.S.V. *Cumulus* AS SEEN FROM O.W.S. *Weather Watcher*
Photograph taken when relieving at station J

CAPT. FORD OF *Weather Recorder* AND CAPT. GROEN OF *Cumulus* WITH SOME OF THEIR STAFFS ABOARD *Cumulus* AT STATION J within the compass of about 50 miles, which could be covered easily in less than 10 min. As the aircraft would take longer than this to attain environmental temperature, part of the flight would be in conditions where the ambient temperature was distinctly warmer than the aircraft, with consequent hoar-ice formation if the frost point were sufficiently high.

G. W. HURST

Wyton, February 22, 1954

Two other instances of aircraft icing at very low temperatures have been reported. On the first occasion, the aircraft was flying from Lyneham to Doncaster at about 1500 G.M.T. on December 1, 1953. Icing, described as hoar or light rime forming at a low rate on the canopy and leading edge of the wings, was encountered for 30 min. at an indicated height of 40,000 ft. while in cirrus cloud. On leaving the cloud the ice formation ceased. The corrected temperature in the cirrus cloud during the encounter and the clear-air temperature on leaving cloud were reported as −61°C. and −65°C. respectively. Another aircraft from the same station reported icing in clear air in "similar circumstances" on the same day. Precise details of this encounter are not available.

On the second occasion, the aircraft was flying over Bristol between 1000 G.M.T. and 1100 G.M.T. on December 28, 1953. Icing, described as opaque rime forming at a low rate on the canopy, was encountered at an indicated height of 40,000 ft. while in clear air and continued in a climb to 45,000 ft. which was probably the maximum height reached. The corrected air temperatures at 40,000 ft. and 45,000 ft. were reported as −61° and −52°C. respectively.

These reports lead to the rather surprising conclusion that water exists in the liquid phase in the free atmosphere at temperatures as low as about −65°C. It has been stated by Ludlam[1] that the limit of supercooling, at which crystals grow spontaneously in liquid water without the aid of foreign nuclei, has been roughly estimated theoretically at about −70°C. or below, and that Rau appeared to have found this limit experimentally at −72°C. As far as is known to the writer, however, the lowest temperature at which aircraft icing in the free atmosphere has been reported previously[2] is −54°C. although aircraft-wing icing has been observed at an ambient air temperature of between −44°C. and −58°C. in a condensation trail formed at the airscrew[3].

J. B. SHAW

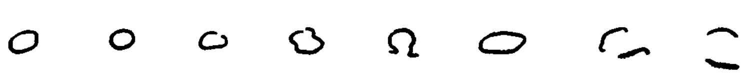
London, March 11, 1954

REFERENCES

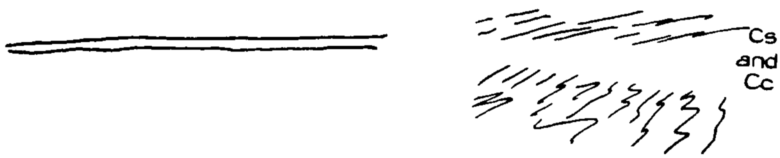
1. LUDLAM, F. H.; The physics of ice clouds and mixed clouds. Compendium of meteorology. Boston, Mass., 1951, p. 192.
2. BEST, A. C.; Ice accretion in cirrus cloud. *Met. Res. Pap., London,* No. 730, 1952.
3. AANENSEN, C. J. M.; Unusual condensation trails. *Met. Mag., London,* 77, 1948, p. 17.

Circular condensation trails

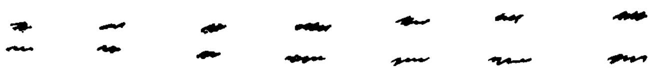
Around 1140 G.M.T. on Friday, April 11, 1954, a line of white rings, some incomplete, were seen high in the sky for a short time over Mildenhall and might have been very puzzling had the observer not seen the sequence of events which had led to their formation.



An aircraft, barely visible and estimated to be above 40,000 ft. and still climbing, had cut a wide swathe through a diffuse layer of cirrostratus and cirrocumulus and had then made a very dense double contrail against a background of blue sky:—



The double contrail soon began to expand and after about half a minute began to disperse except for regularly spaced patches:—



Several of the patches were then seen to form into circles, whilst others formed into rough ellipses and other shapes:—

At this stage it was seen that whilst the more diffuse shapes were dispersing the cloud constituting the better-formed circles was actually thickening and forming into hard and nearly annular shapes with clean-cut edges, each one writhing like a smoke ring. The size of each ring would be about a tenth that of the original contrail.

A possible explanation is that the double contrails were formed as counter-rotating vortices which were being broken down by the regular wave motion of the ambient air into dimensions best suited for forming annular vortices.

N. F. HORMBREY

Mildenhall, April 28, 1954

NOTES AND NEWS

"Half-century" of voyages by each of the British ocean weather ships

With the arrival at Greenock of o.w.s. *Weather Explorer* on March 30, 1954, each of the four British ocean weather ships has completed at least 50 voyages to either station I or station J.

During this period several members of the meteorological staff have rendered long service in ocean weather ships. The record is held by Mr. P. G. O. Felton who completed 38 voyages in o.w.s. *Weather Observer*; on leaving the ship he was presented with a suitably inscribed gold pencil. Two other meteorologists have completed 33 voyages and are still serving in the ships; others have completed 28, 27, 25 and 23 voyages, whilst no fewer than 14 of the remainder have completed two tours of duty (18 voyages). Thus a nucleus of seagoing meteorologists is being gradually built up. The Masters of all the ships have served in them continuously and so have 1 Engineer Officer, 3 Radio Overseers, 2 Chief Radio Technicians, 1 Chief Steward, 1 Radio Technician, 1 Radio Operator and 2 Boatswains.

Meteorological observations have been carried out in all weathers and only on rare occasions has a radio-sonde ascent been abandoned. Some of the meteorological teams have released a full-rig radio-sonde in a force 10 wind. Radio-sonde ascents very seldom fail to reach 100 mb. and wind measurements by radar are usually obtained to approximately 50,000 ft. The following meteorological statistics may be of interest:—

	Air temperature		Sea temperature		Average number of days of gales	Maximum mean wind speed
	Extreme maximum	Extreme minimum	Extreme maximum	Extreme minimum		
	°F.	°F.	°F.	°F.	days/yr.	kt.
Station I ...	61·3	28·0	59·6	45·3	89	68
Station J ...	65·5	35·0	64·0	46·0	89	68

Some of the meteorological staff have become very proficient as voluntary members of the ship's dinghy's crew.

Credit is due to the Chief Engineers and their staffs for their successful endeavours to economize in oil fuel. An average of 8·4 tons/day was used during the first voyage of each ship, whereas the average for each ship's 50th voyage is 6·9 tons/day. At over £7 a ton this means a considerable saving in cost.

A highlight of events during these 200 or more voyages was the attendance of o.w.s. *Weather Explorer* at the Review of the Fleet by Her Majesty the Queen at Spithead in June of Coronation Year.

The periodical air/sea rescue exercises, METHOP, carried out with aircraft of the Royal Air Force Coastal Command, during which mail and newspapers, in Lindholme containers, are dropped to the ship, and, more recently, the weekly MAILDROP by aircraft from the Royal Air Force station, Topcliffe, have not only provided valuable practice in air/sea rescue technique, but have also been a very welcome diversion to the ships' companies. In addition to the personal contacts which have been made at station J with individuals serving aboard Netherlands vessels during the last three summers, opportunity has occurred for an exchange of visits with officers of United States weather ships when, on two occasions, one of these vessels visited Glasgow. These personal exchanges of visits have been valuable both technically and socially.

o.w.s. *Weather Recorder* has been concerned in two search and rescue operations and *Weather Explorer* and *Weather Observer* in one each. On one occasion *Weather Recorder* navigated by radar through the islands off the west coast of Scotland and rescued the crew of a Norwegian ship. On the occasion of the loss of a United States Air Force aircraft over the North Atlantic, *Weather Recorder* was appointed to control the search vessels in the area, and herself recovered the body of the pilot which was subsequently transferred to a United States' ship. During this operation *Weather Recorder* and *Weather Observer*, who relieved her, between them steamed 806 miles. *Weather Explorer* steamed 1,700 miles on her search operation.

Passengers aboard the ships for complete voyages or parts of voyages have included the Deputy Director of the Naval Weather Service, the Marine Superintendent and other members of the Meteorological Office, as well as scientists from universities and other institutes, ornithologists and journalists.

Spare-time activities aboard the ships have included boat sailing and rowing in rubber dinghies, swimming, ornithology, darts, educational classes, model making and shark fishing. The weekly film show is very popular, also reading and card playing.

C. E. N. FRANKCOM

REVIEW

The climates of the continents. 4th edition. By W. G. Kendrew. 8½ in. × 5¼ in., pp. 607, *Illus.*, Geoffrey Cumberlege, Clarendon Press, Oxford, 1953. Price 50*s*. net.

This is a standard textbook, well established among both meteorologists and geographers, in which the principles, set out in Kendrew's equally well known "Climatology", are applied to the climates of the world on a regional basis. The book was first published in 1922 but was soon out of print. A second edition appeared in 1927 and this was reprinted in 1930. A considerably improved third edition was produced in 1937 and this was also reprinted—in 1941, 1944 and 1948. Now we have an even better and bigger fourth edition which, as the preface is dated 1950, might well have appeared earlier than 1953!

For this fourth edition there has been extensive revision to bring the various sections up to date. A discussion of air masses and fronts has been introduced, some specimen synoptic charts have been added, and there are indications of an approach to synoptic climatology. Many new diagrams are given and the climatic data have been improved and expanded, including the addition of new tables of wind direction, diurnal temperature, sunshine, visibility and other elements. However, the framework remains unaltered. This consists essentially of an introductory section giving some general remarks on temperature, precipitation and wind together with an outline of the main features of the distribution of atmospheric pressure and the prevailing winds. Then follow sections dealing with each of the continents. At the beginning of each section there is a chapter relating to the general features (now including the predominant air masses) of the continent or subcontinent, and at the end of each section, divorced from the text, are tables of climatic means. Finally, there are some useful conversion tables, a six-page bibliography and an index of place names and names of local winds.

Throughout the book the author brings out the effect of geographical features and oceanic conditions in conjunction with physical factors in determining local climate. As indicated above, there are now paragraphs describing the predominant air masses, their movement and boundaries and mention is made here and there of the effect of vertical air motion. No attempt is made, however, to depict three-dimensional air flow or to explain the variations of climatic régimes in terms of modern theories of the general circulation of the atmosphere. This is not surprising as, to do this, the climatologist needs the results of meteorological research and, as yet, the field of dynamic climatology has not been fully explored. Although the broad-scale patterns of atmospheric circulation are becoming fairly well established, their precise variation in time and place has still to be determined and explained.

The text is well written and the inclusion of apt quotations and anecdotes—some a bit dated—enables the reader to give local colour to his mental picture of the effect of climate on human activity. In this connexion it would be of current interest to know whether the white community in east Africa would agree with the paragraph discussing the suitability of the climate in that region for white settlement! To assess the accuracy of all the facts which are presented would require a detailed and world-wide knowledge of local climate, a knowledge which the reviewer does not claim to possess. One or two statements would doubtless be disputed by meteorologists in the light of current knowledge of the physics of precipitation and of upper air flow patterns, but, maybe, this points to the need for the geographer and the meteorologist to think in each other's terms.

There are now nearly 200 helpful illustrations but, without being unduly critical as the book is concerned with continental climates, one cannot help noting the lack of a diagram of the main ocean currents to which frequent reference is made. The collection of tables is one of the most useful available. Indeed, the whole book is a gold-mine of information; but it would have been useful, in view of secular changes, if the periods for which the data had been extracted were given. As the author says himself, "no mean, however long the period on which it is based, has absolute validity except for that actual period." The bibliography is quite comprehensive but one notices the omission of some important studies in the field of synoptic climatology. Now that the author has introduced his reader to the conception of air masses and fronts these omissions, it is suggested, ought to be made good in the next edition. The printing and reproduction of the diagrams are of the high standard which one has become accustomed to expect from the Clarendon Press. Students, teachers, travellers, economists and many others will find this a most valuable book to have in their library.

R. G. VERYARD

HONOUR

The following award was also announced in the Birthday Honours List, 1954, in addition to those mentioned in the July 1954 *Meteorological Magazine*:—

Queen's Commendation for Valuable Service in the Air

Flt-Sgt G. N. Franklin, Air Meteorological Observer Leader, Aldergrove.

OBITUARY

Mr. Osmond Bernard O'Sullivan.—It is with regret that we have to record the death of Mr. O. B. O'Sullivan, Senior Experimental Officer, last serving at Lyneham. This occurred on July 9, 1954, his 53rd birthday, as a result of a bicycle accident on July 3 from which he never recovered consciousness.

Mr. O'Sullivan joined the Office in 1921 and served at a number of outstations at home and overseas. His Irish temperament made him a noteworthy character at whichever outstation he served. "OBOS" was universally liked and his many friends will be saddened by the tragic manner of his passing.

METEOROLOGICAL OFFICE NEWS

University Degrees.—We offer our congratulations to Mr. A. C. Best, O.B.E., Assistant Director (Special Investigations), who has been admitted to the degree of D.Sc. in the University of Wales, and to Mr. R. G. Lloyd, Scientific Officer, who has been admitted to the degree of Ph.D. also in the University of Wales.

Horticultural Show.—The Air Ministry Horticultural Society held their Annual Show at Adastral House on July 16. The staff of the Office were represented in all three sections—flowers, fruit and vegetables. Prizes were won by Mr. B. G. Brame (flowers, fruit and vegetables), Miss H. G. Chivers (flowers and fruit) and Mr. H. A. Scotney, Miss D. J. Wordsworth and Miss A. F. Mickleburgh (flowers).

Sports activities.—*Netball.*—The Air Ministry Ladies' Netball Competition for 1954 was won by the Harrow Meteorological Office Ladies' team for the sixth consecutive year. This is a fine achievement particularly as the game is popular in the Air Ministry and competition is keen. The winning team is to be presented with spoons to mark the occasion.

Athletics.—The Air Ministry Annual Sports were held at the White City Stadium on July 14 and marked the end of the year for the competition for the Bishop Shield. The Meteorological Office retained the Shield by a considerable margin of points for the sixth consecutive year—an achievement due entirely to team work. The main contributions to the total number of points were successes in football, netball, athletics and swimming. On Sports Day, Miss K. Newman retained the Ladies' Sprint Championship for the fourth time, Miss M. Jones won the 70 yards and 100 yards Ladies' Handicap, Mr. R. Cohen was second in both the 100 yards and 220 yards Championships, Mr. B. J. Flatley was third in the 440 yards Championship and Mr. J. P. McDonald was third in the One Mile Championship. Mr. McDonald also won the Mile Sealed Handicap. The Office won the Men's Inter-Divisional Relay Championship for the third consecutive year, but the Ladies' Inter-Divisional Relay Championship was lost by a very narrow margin. The Office failed to retain the W. S. Jones Memorial Cup by two points only.

WEATHER OF JULY 1954

Mean pressure was below normal, generally between 1 and 6 mb., in the region extending from Iceland eastward to Scandinavia and south-eastward to central Europe. It was above normal in the Iberian peninsula and in the region of the Atlantic extending westward to the Azores and north-westward to Greenland. The mean pressure over most of the United States was below normal.

The mean temperature was generally 3–5°F. below normal over much of Europe; this is consistent with mean north-westerly winds associated with the mean pressure distribution over Europe.

In the British Isles the weather was notably cool and dull; it was wet in some southern and western areas but in large areas in north-east England and the Midlands and in parts of east and central Scotland rainfall was less than average. Throughout the month an anticyclone was situated near the Azores but at no time did it spread over the British Isles sufficiently to establish fine, warm weather; on almost every day some part of the country at least was under the influence of a low-pressure system. As far as can be estimated at present it was the coolest July since 1922; in particular the days were very cool, at Kew, for example, the mean daily maximum temperature was 6·1°F. below the average, while at Ross-on-Wye the absolute maximum, 70°F., was the lowest on record for July. The duration of bright sunshine was much below average but over the country generally the month was less dull than July 1944.

From the 1st to the 7th the whole country experienced a north-westerly to northerly type of weather beginning with frontal systems moving south-eastward and followed by a depression from Iceland, which became slow moving over the North Sea and Denmark. Cool weather was general throughout this period; the temperature was 10°F. below the average at times locally during the day while during the nights of the 5th and 6th temperature on the ground fell below freezing point in parts of Hampshire and south-west Scotland. Rain or showers occurred each day in many districts and thunderstorms were reported from the 4th to the 6th in widely scattered areas but chiefly in eastern England. There was, however, some sunshine on most days and daily totals rose to more than 12 hr. at a few places from the 4th to the 7th. From the 7th to the 24th pressure was low near Iceland and a number of small but often active depressions moved in some easterly direction across the British Isles. The intervening ridges of high pressure were weak and transitory but they gave some fine, rather warm days, particularly in the south and east; on the 20th temperature rose to 78°F. locally on the east coast. Throughout this period the weather was changeable with some rain or showers in many districts on most days; thunderstorms occurred locally in East Anglia on the 15th. The 16th and 17th were wet days; during the 24 hr. ending at 1700 on the 17th more than an inch of rain was recorded at a number of places in south and south-east England, while 2·14 in. fell at Llangurig, Montgomeryshire and 2·20 in. at Maesteg, Glamorgan in the 24 hr. ending at 0900 on the 17th. On the 23rd heavy rain fell in northern England and southern Scotland, for example, 3·10 in. at Ribblehead in the West Riding of Yorkshire, 2·24 in. at Stonyhurst, Lancashire and 2·22 in. at Blaenau Festiniog, Merionethshire. On the 25th and 26th a deepening depression moved south-east from the south of Iceland and after moving irregularly over Scotland on the 27th moved into the North Sea on the 28th. It was preceded on the 25th and 26th by small disturbances moving eastward across southern England, giving heavy rain in southern counties; more than 2 in. was registered locally in Devon, Dorset, the Isle of Wight and Sussex on the 25th (2·88 in. at Princetown, 2·47 in. at Creech Grange, Dorset and 2·07 in. at Heathfield, Sussex). From the 26th to the 28th there was widespread rain at times in northern England and parts of Scotland and showers in the south, but there were also sunny periods (2·85 in. of rain fell at Watendlath Farm, Cumberland on the 27th). Thunderstorms occurred in places on the 27th and 28th and strong winds, reaching gale force at times, occurred in many parts of England and Wales on the 27th and 28th, western and southern coastal districts being particularly affected. From the 29th onwards weather continued generally cool, with some rain, mainly slight, in Scotland, but also sunny periods especially in the east.

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

	AIR TEMPERATURE			RAINFALL		SUNSHINE
	Highest	Lowest	Difference from average daily mean	Percentage of average	No. of days difference from average	Percentage of average
	°F.	°F.	°F.	%		%
England and Wales ...	78	33	−3·5	126	+3	75
Scotland	76	29	−2·3	105	+2	80
Northern Ireland ...	69	41	−2·7	129	+6	66

RAINFALL OF JULY 1954

Great Britain and Northern Ireland

County	Station	In.	Per cent. of Av.	County	Station	In.	Per cent. of Av.
London	Camden Square ...	3·01	126	*Glam.*	Cardiff, Penylan ...	4·41	143
Kent	Dover	4·39	208	*Pemb.*	Tenby, The Priory ...	4·22	143
,,	Edenbridge, Falconhurst	2·85	124	*Radnor*	Tyrmynydd	4·74	115
Sussex	Compton, Compton Ho.	4·13	146	*Mont.*	Lake Vyrnwy	6·77	190
,,	Worthing, Beach Ho. Pk.	4·06	199	*Mer.*	Blaenau Festiniog ...	15·64	184
Hants.	Ventnor Cemetery ...	5·13	249	,,	Aberdovey	5·12	146
,,	Southampton, East Pk.	2·60	114	*Carn.*	Llandudno	2·54	113
,,	South Farnborough ...	2·32	114	*Angl.*	Llanerchymedd ...	3·95	138
Herts.	Royston, Therfield Rec.	3·10	123	*I. Man*	Douglas, Borough Cem.	3·51	115
Bucks.	Slough, Upton	2·69	140	*Wigtown*	Newton Stewart ...	4·94	157
Oxford	Oxford, Radcliffe ...	2·18	92	*Dumf.*	Dumfries, Crichton R.I.	2·95	90
N'hants.	Wellingboro' Swanspool	2·76	121	,,	Eskdalemuir Obsy. ...	5·30	129
Essex	Shoeburyness	2·34	128	*Roxb.*	Crailing	2·64	91
,,	Dovercourt	1·98	99	*Peebles*	Stobo Castle	3·91	135
Suffolk	Lowestoft Sec. School ...	1·75	77	*Berwick*	Marchmont House ...	2·36	77
,,	Bury St. Ed., Westley H.	3·32	133	*E. Loth.*	North Berwick Res. ...	2·22	86
Norfolk	Sandringham Ho. Gdns.	2·98	116	*Midl'n.*	Edinburgh, Blackf'd. H.	1·69	60
Wilts.	Aldbourne	2·28	96	*Lanark*	Hamilton W. W., T'nhill	2·90	101
Dorset	Creech Grange... ...	4·43	181	*Ayr*	Colmonell, Knockdolian	4·31	137
,,	Beaminster, East St. ...	2·61	100	,,	Glen Afton, Ayr San. ...	4·79	114
Devon	Teignmouth, Den Gdns.	2·13	91	*Renfrew*	Greenock, Prospect Hill	3·38	91
,,	Ilfracombe	4·77	188	*Bute*	Rothesay, Ardencraig ...	5·09	129
,,	Princetown	8·91	166	*Argyll*	Morven, Drimnin ...	3·90	88
Cornwall	Bude, School House ...	4·73	193	,,	Poltalloch	5·66	137
,,	Penzance, Morrab Gdns.	3·86	142	,,	Inveraray Castle ...	5·05	101
,,	St. Austell	4·40	131	,,	Islay, Eallabus	5·66	166
,,	Scilly, Tresco Abbey ...	3·35	151	,,	Tiree	3·02	83
Somerset	Taunton	2·01	95	*Kinross*	Loch Leven Sluice ...	2·92	101
Glos.	Cirencester	2·68	104	*Fife*	Leuchars Airfield ...	1·55	60
Salop	Church Stretton ...	2·98	113	*Perth*	Loch Dhu	3·61	75
,,	Shrewsbury, Monkmore	2·41	115	,,	Crieff, Strathearn Hyd.	2·48	84
Worcs.	Malvern, Free Library...	2·60	114	,,	Pitlochry, Fincastle ...	2·57	96
Warwick	Birmingham, Edgbaston	4·10	177	*Angus*	Montrose, Sunnyside ...	2·19	83
Leics.	Thornton Reservoir ...	2·21	89	*Aberd.*	Braemar	2·30	89
Lincs.	Boston, Skirbeck ...	1·99	90	,,	Dyce, Craibstone ...	2·74	90
,,	Skegness, Marine Gdns.	1·54	71	,,	New Deer School House	3·17	104
Notts.	Mansfield, Carr Bank ...	1·79	68	*Moray*	Gordon Castle	3·07	96
Derby	Buxton, Terrace Slopes	6·43	164	*Nairn*	Nairn, Achareidh ...	3·00	118
Ches.	Bidston Observatory ...	2·61	101	*Inverness*	Loch Ness, Garthbeg ...	3·01	95
,,	Manchester, Ringway...	3·79	136	,,	Glenquoich	5·45	86
Lancs.	Stonyhurst College ...	8·07	209	,,	Fort William, Teviot ...	3·51	72
,,	Squires Gate	4·41	159	,,	Skye, Broadford ...	4·18	76
Yorks.	Wakefield, Clarence Pk.	1·63	64	,,	Skye, Duntuilm ...	3·41	91
,,	Hull, Pearson Park ...	1·94	83	*R. & C.*	Tain, Mayfield ...	4·23	155
,,	Felixkirk, Mt. St. John...	2·78	102	,,	Inverbroom, Glackour...	5·76	155
,,	York Museum	2·05	81	,,	Achnashellach	5·21	107
,,	Scarborough	1·55	64	*Suth.*	Lochinver, Bank Ho. ...	5·45	180
,,	Middlesbrough... ...	1·65	64	*Caith.*	Wick Airfield	3·11	118
,,	Baldersdale, Hury Res.	2·32	79	*Shetland*	Lerwick Observatory ...	3·16	138
Norl'd.	Newcastle, Leazes Pk....	1·99	78	*Ferm.*	Crom Castle	4·27	123
,,	Bellingham, High Green	3·52	107	*Armagh*	Armagh Observatory ...	4·61	160
,,	Lilburn Tower Gdns. ...	2·17	88	*Down*	Seaforde	3·59	113
Cumb.	Geltsdale	5·09	148	*Antrim*	Aldergrove Airfield ...	3·60	129
,,	Keswick, High Hill ...	5·45	142	,,	Ballymena, Harryville...	3·99	116
,,	Ravenglass, The Grove	5·46	145	*L'derry*	Garvagh, Moneydig ...	3·42	106
Mon.	A'gavenny, Plâs Derwen	1·32	49	,,	Londonderry, Creggan	4·12	112
Glam.	Ystalyfera, Wern House	6·76	147	*Tyrone*	Omagh, Edenfel ...	5·93	174

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