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Dr. C. E. P. Brooks, an Editor of the *Meteorological Magazine* for some 22 years, died on December 14, 1957, at the age of 69, after being confined to his home at Ferring, Sussex, for a few months with heart trouble.

For 41 years Dr. Brooks worked full time in the Meteorological Office, retiring as Assistant Director in charge of the Climatological Division. Initially he was allocated to the Library, where his wide reading and remarkable memory made him of particular service to his colleagues and also enabled him to develop his main interest in World Climatology. Author of numerous papers he was awarded the Buchan Prize of the Royal Meteorological Society in 1931. His published books include: *The evolution of climate* (1925); *Climate through the ages* (1926, second edition 1948); *British floods and droughts* (1928) with Dr. J. Glasspoole; *Climate* (1929); *Climate in every-day life* (1950); *Handbook of statistical methods in meteorology* (1953) with Miss N. Carruthers; and *The English climate* (1954). He gained an international reputation, notably in the field of climatic change, and has left the results of his life work for the benefit of present and future generations.

Dr. Brooks put forward the theory that the dominant factors in producing climatic changes were geographical, including variations in the distribution of land and sea, systems of ocean currents, the vertical circulation of the sea, the elevation of the land and the amount of explosive volcanic activity. Along these lines he gave an explanation of the Permo-Carboniferous glaciation over low-lying areas in equatorial regions.

Dr. Brooks had the responsibility of moving the Library and the Climatological Records to Stonehouse, near Stroud, at the beginning of the war, and afterwards to Harrow. He had a reputation for swift action, but the sudden arrival of a large consignment of packing cases at the Office at South Kensington at the beginning of hostilities surprised even those familiar with his way of cutting through any red tape. He also did much to keep the staff happy, while in billets, and during the enforced long hours of work during the war. Then he had the responsibility of preparing climatological reports on various parts of the world, coping with many war-time climatological problems and also keeping together the corps of voluntary climatological and rainfall observers. Towards the end of the war he was directed to devote his full time to long-range forecasting, a problem in which he was especially interested. He did not spare himself, although this investigation did not produce the hoped-for results. Some indication of the scope of the work for which he was responsible is reflected by the various separate Branches which emerged under post-war conditions:—British Climatology, Rainfall of the British Isles and Hydrology, Agricultural Meteorology, Overseas Climatology, Upper Air Climatology, Library and Editing, and the Machine Pool using Hollerith cards for climatological data.

Dr. Brooks always had time to help and encourage his colleagues, and with his ready wit and understanding made even the most laborious extractions or computations of live interest to his staff. He set an example of energetic application to his work. He lived a full life, often claiming that he produced more useful work in his train journeys to and from Ferring than in the routine of Office administration. Following a short period of part-time employment at the Meteorological Office he found congenial work at home in abstracting meteorological literature for the American Meteorological Society, which later resulted in a visit to Washington.

Dr. Brooks' energies were not entirely confined to work. He started the Air Ministry Chess Club after the First World War and under his guidance the team moved steadily to the first division of the Civil Service Tournament. He was keen on swimming, lawn tennis, and on contract bridge.

Dr. Brooks was Secretary of the Royal Meteorological Society from 1928 to 1932 and later Vice-President. He served as the Meteorological Office representative of the International Meteorology Organization Commissions for Climatology, Hydrology, Agricultural Meteorology and Bibliography and Publications at Toronto in 1947.

Dr. Brooks married Miss Dora Buckeridge, whom he met at the Meteorological Office, and whose constant help he acknowledged in his books and papers. She survives him, as does also their son, and they have the sympathy of his wide circle of friends.

J. GLASSPOOLE

THE FORECASTING OF DAILY MEAN SURFACE TEMPERATURE FROM 1000–500 MILLIBAR THICKNESS LINES

By C. J. BOYDEN, B.A.

A broad relationship between upper air temperature and the temperature at screen level has long been recognized. Nevertheless, for any given level of temperature in the upper air there can be wide fluctuations of temperature near the ground, depending on the surface transfer of heat as determined by such factors as wind speed, cloud cover and time of day. The present investigation was undertaken in the belief that a fairly high correlation would be found between the general level of upper air temperatures and the mean surface temperatures over 24 hours. The supposition was that to some extent the factors resulting in a high day temperature would also favour a low night temperature: thus in a dry air mass, with small amounts of cloud, a high lapse rate by day is often accompanied by a marked inversion at night, and one might therefore expect the mean temperature to be much the same as during 24 hours of moist air and persistent cloud, when the diurnal range of temperature and lapse rate is much smaller.

No account was taken of the vertical distribution of upper air temperature but only of the mean temperature of the layer between 1000 and 500 millibars, which is directly proportional to the thickness of the layer between these two isobaric surfaces. The 1000–500-millibar thickness rather than that for, say, 1000–700-millibars was chosen simply because it has become a standard isopleth on upper air charts. The mean daily screen temperature to which the thickness has been related was the mean of maximum read at 2100 G.M.T. and the minimum read at 0900 G.M.T.

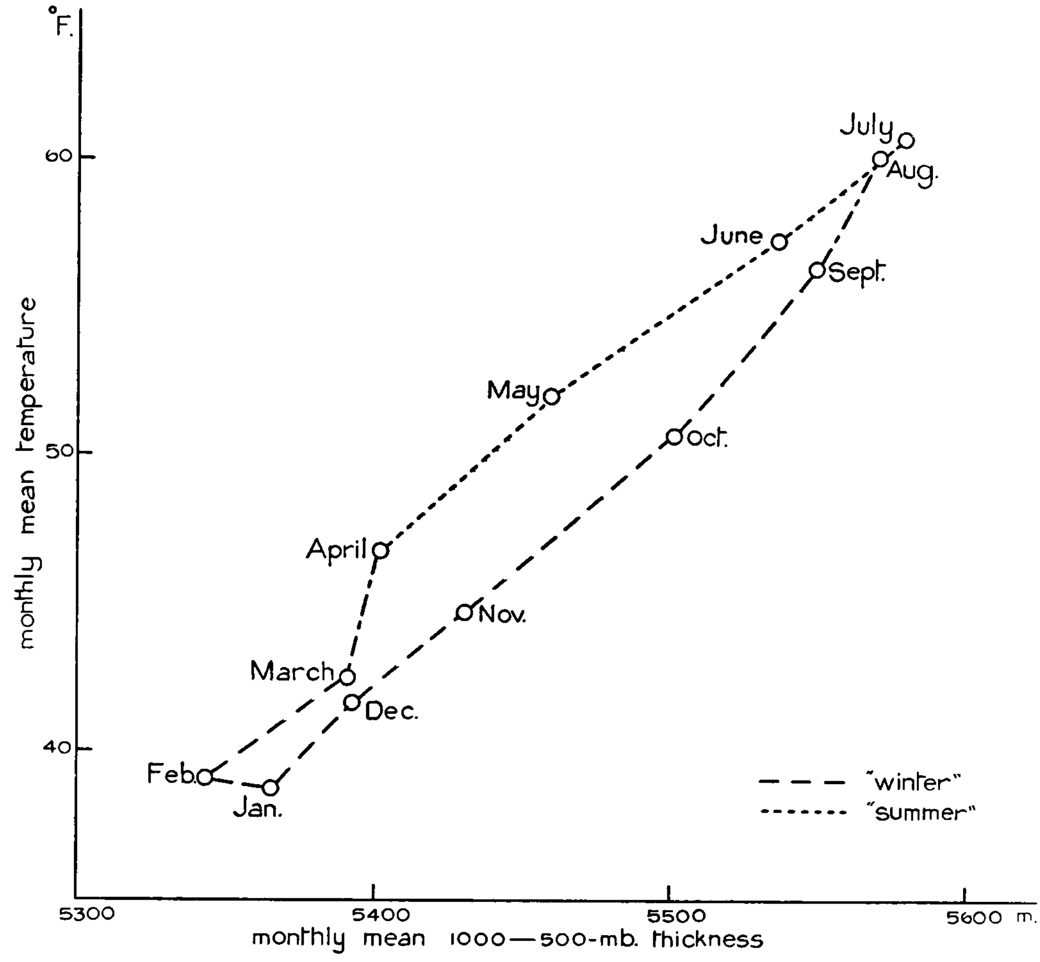


FIG. 1—RELATIONSHIP BETWEEN MONTHLY MEAN SURFACE TEMPERATURE AND MONTHLY MEAN 1000–500-MILLIBAR THICKNESS AT CRAWLEY/LARKHILL, 1948–55

The first step was to plot the monthly mean temperatures for Crawley (Larkhill in earlier years) against the monthly mean 1000–500-millibar thickness for the longest available period, 1948–55. The result, shown in Figure 1, is of considerable interest. Taken collectively the years show two distinct seasons, a "summer" from April to August, when the mean temperature was high for the thickness, and a "winter" lasting for the remaining seven months, though January is not a good fit. In order to make certain that these features did not arise from one or two exceptional years, the month-to-month variation of thickness throughout each of the eight years was examined. In five of these years a decrease of mean thickness from March to April was confirmed, in one the rise between

January and March was slightly checked in April, and in the other two years, following a cold February, there was a sustained rise in thickness which was maintained into April. The discontinuity in the autumn, on the other hand, was less consistent and was somewhat more variable in the month of occurrence. Another feature of the months from April to August is that over the waters around the British Isles the air is normally warmer than the sea. There is thus reasonable support for the two seasons chosen, but the abrupt change between March and April presents its problems. Outbreaks of cold air from the north and north-west are common in April, but it is not clear how the surface temperature is accommodated to the reduced 1000–500-millibar thickness so as to retain the smooth upward trend of monthly mean temperature, particularly as there is no corresponding discontinuity in average monthly totals of sunshine.

Table I shows the variation throughout the year of the maximum and minimum lapse rate as given by the Kew normal monthly mean of daily maximum and minimum temperature minus the Crawley/Larkhill mean 700-millibar temperature over the years 1948–55.

TABLE I—MAXIMUM AND MINIMUM LAPSE RATES BETWEEN THE SURFACE AND 700 MILLIBARS IN °F.

	Jan.	Feb.	March	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Maximum	27·2	30·3	31·0	35·7	38·2	38·1	37·6	37·4	33·7	29·4	26·6	25·7
Minimum	18·4	20·5	18·0	21·4	21·8	21·8	21·8	21·8	19·4	16·8	17·0	17·3

From these figures it is seen in what manner the lapse rates segregate the months April to August from the rest of the year. April to August, and to some extent September, show rather higher lapse rates at night than do the remaining months, but relative to the air mass temperature the rise in mean temperature in the summer was due primarily to the maximum temperatures.

A nearly linear relationship (Fig. 1) between thickness and surface temperatures during the months of each season does not postulate a linear relationship between daily values. The next step taken was therefore to plot daily mean temperatures for London Airport throughout 1956 against the mean of the thicknesses measured twice daily (at 0300 and 1500 G.M.T.) over Crawley. The relationship for summer, defined as April to August, and winter, the seven months September to March, is shown by the two curves of Fig. 2 (the coordinates are given in an appendix). The scatter was analysed, but for the purpose of verifying the relationship the Crawley thicknesses were used to forecast the temperature for each day in 1955, the preceding year, using the curves established from the 1956 data.

Table II gives the root mean square errors for each month together with the root mean square of the 2-day change, in other words the corresponding errors of 2-day forecasts if no change of temperature had been predicted.

A study of the daily forecasts showed no systematic error apart from unreliability in the forecasting of low temperatures in stagnant air in January. Even this was not a consistent error, for in such conditions the surface temperature was determined largely by the cumulative effect of cloud, prolonged radiation and the state of the ground, and with the extreme stability the surface air became virtually divorced from the air mass as defined by the 1000–500-millibar thickness. When forecasting surface temperature during persistently still weather in winter (normally in January) one must therefore be prepared for lower temperatures than the thickness suggests, and an accurate forecast of other elements is necessary for a closer approximation. Some caution is also required in April, where more positive than negative errors occurred because the change from the winter to the summer curve is not necessarily applicable as soon as the month opens. It may be found that the summer curve becomes the appropriate one when thicknesses are below normal.

TABLE II—ROOT MEAN SQUARE ERRORS OF DAILY FORECASTS OF MEAN TEMPERATURE TOGETHER WITH ROOT MEAN SQUARE OF 2-DAY CHANGE

	Jan.	Feb.	March	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Root mean square forecast error	7·76	3·54	4·23	3·37	3·09	3·50	3·25	3·29	4·70	5·60	5·92	4·74
Root mean square variance	5·50	4·83	5·94	5·18	5·08	5·54	3·59	4·85	4·25	5·89	5·88	8·14

It was found that this method of forecasting the mean temperature for London gave for 1955 a probable error of 2·8°F. in winter and 1·8°F. in summer. These may be regarded as satisfactorily small errors for forecasting purposes, particularly when one takes into account that no allowance is made for cloud, precipitation or fog. Another point to be noted is that whereas the mean temperature is based on the highest and lowest points of a continuous record, the mean thickness is the mean of values at two fixed times: there were, for example, occasions on which the passage of a tongue of warm air raised the mean temperature but escaped detection in the 12-hour gap between successive upper air temperature soundings.

This investigation was begun primarily to improve forecasts of mean temperature, or at least to make them more objective. Whether this can be done depends partly on the criteria one adopts in assessing the success of a forecast. Taking first the question of objectivity, one must bear in mind that with the aid of the numerical computer an eventual increase in the accuracy of forecasts of thickness is to be expected. But objectivity is intended also to include the advantages to be gained by forecasting without reference to the present or past values of the element involved. In present practice the accuracy of mean temperature forecasts for one or even two days ahead is dependent to no small degree on the temperature distribution when the forecast is made, and may be biassed by such factors as the climatological mean. The forecasting of any element by an assessment of the change from the present value is not the most desirable method, though over short periods it is probably the most successful so far. For longer periods some general parameter which can be advected from chart to chart is an essential basis for temperature forecasting, and the thickness between isobaric surfaces, in view of the close relationship with mean surface temperature, must be regarded as the only suitable parameter available. In other words, the problem of forecasting the mean temperature is substantially the problem of forecasting the thickness.

It is as well to consider at this stage how a temperature forecast should be verified. No forecast verification has absolute significance unless it is considered in relation to the purpose of the forecast. The verification of forecasts which can be expressed numerically, as can temperature, is often based on root mean square errors, and comparison is sometimes made with the root mean square error which would have occurred if no change in the element had been forecast.

Table II showed that temperature forecasting by thickness gave a substantial improvement over persistence forecasting in seven months of the year, was of comparable standard in four and was worse in one. If the error in forecasting the thickness were added, persistence forecasting would stand in a better light. This is not so much a criticism of the accuracy of forecasting, as an illustration of the limitations of the root mean square error as an index of success. The average user of a temperature forecast is most concerned with the amount and the sign of the change from the present level. Forecasting by persistence may produce a quite respectable root mean square error, but since it never predicts a rise or fall of temperature it is a method that is clearly worthless. A measure of persistence of temperature should therefore be regarded as a measure of variability, not as a yardstick for assessing a method of forecasting. That can be judged only by studying the nature of the errors.

The daily routine at the Central Forecasting Office includes the construction of forecast 1000–500-millibar thickness charts over an area which includes North America, the Atlantic and Europe. Once daily, on most days of the week, these are constructed for one, two and three days ahead. The main purpose is to help in the forecasting of pressure systems on a broad scale, and no particular attention is given to the forecast of thickness over any one place. Nevertheless the charts give some indication of the accuracy at present attainable in a forecast of thickness. From these charts the thickness at Crawley forecast one, two and three days beforehand was read for the 192 days on which it was available in 1956. The root mean square errors (in metres) for each season are shown in Table III together with the root mean square errors that would have occurred if no change from the latest actual thickness had been forecast on each occasion. F_r is the root mean square error of the forecast made r days ahead, and P_r the corresponding error of a persistence forecast. The temperatures shown beneath each thickness are the corresponding errors in mean surface temperature based on the approximate equivalence of 100 metres to 8°F., as given by Fig. 2.

TABLE III—ROOT MEAN SQUARE ERRORS OF FORECAST THICKNESSES AND EQUIVALENT MEAN TEMPERATURES

	Winter (Jan.–March, Sept.–Dec.)		Summer (Apr.–Aug.)	
	metres	°F.	metres	°F.
F_1	54	4·3	44	3·5
F_2	85	6·8	65	5·2
F_3	108	8·6	72	5·8
P_1	71	5·7	63	5·0
P_2	99	8·0	77	6·2
P_3	112	9·0	91	7·3

Combining the error in the forecast thickness with the error in the mean temperature as forecast from that thickness, one obtains root mean square

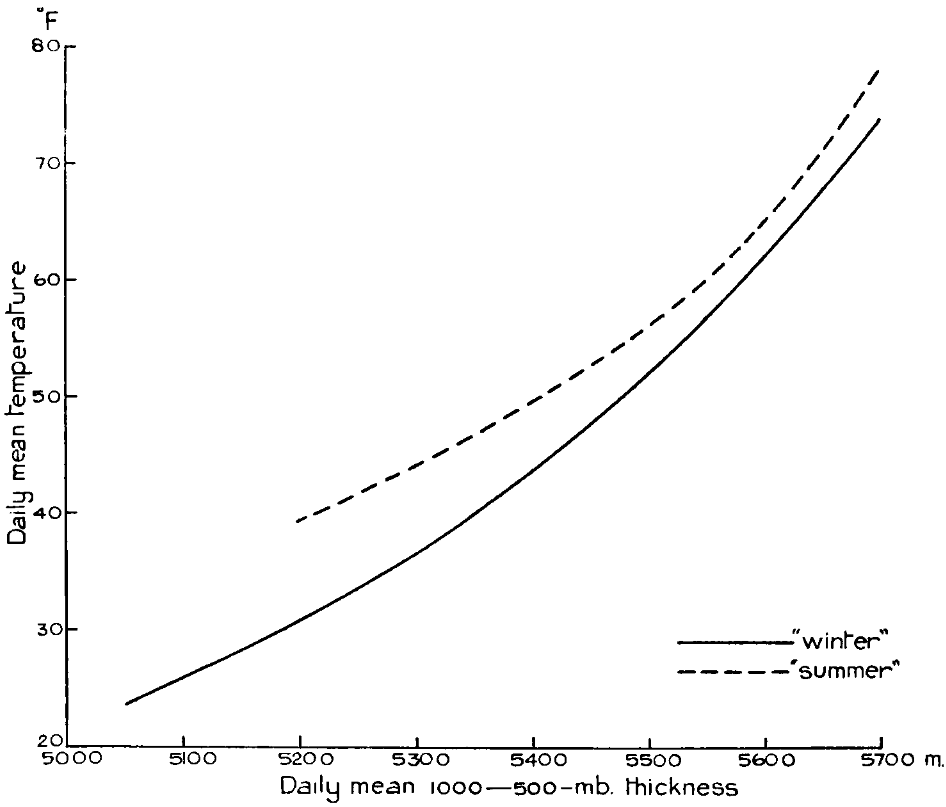


FIG. 2—RELATIONSHIP BETWEEN DAILY MEAN SURFACE TEMPERATURE AT LONDON AIRPORT AND DAILY MEAN 1000–500-MILLIBAR THICKNESS AT CRAWLEY, 1956

errors in the forecast temperature about 2°F. larger than those obtained by assuming the surface temperature is unchanged from its value two days before.

The limited significance of these figures is illustrated by an analysis of the forecasts of temperature changes of varying magnitude, given as a contingency table in Table IV. The temperature-change equivalents of forecast thickness

TABLE IV—DISTRIBUTION OF MEAN TEMPERATURE ERRORS RESULTING FROM FORECASTS OF THICKNESS

	Actual change (°F.)													
	Winter							Summer						
	R_L	R_M	R_S	S	F_S	F_M	F_L	R_L	R_M	R_S	S	F_S	F_M	F_L
Forecast change (°F.)	number of occasions													
R_L	2	3	1	0	1	0	0	2	1	0	1	1	0	0
R_M	2	10	5	0	2	1	0	0	6	3	1	0	0	0
R_S	1	6	14	1	7	1	1	0	4	12	3	6	2	1
S	0	0	4	0	2	0	0	1	1	3	1	3	0	0
F_S	1	0	3	0	12	4	4	0	0	3	2	6	4	2
F_M	0	0	5	0	4	3	1	0	0	2	0	6	0	2
F_L	0	0	1	0	1	4	3	0	0	0	0	1	2	1

changes over a 2-day period were classified as follows:—

Large rise (R_L) or fall (F_L) ... more than 10°F.
Medium rise (R_M) or fall (F_M) ... 6–10°F.
Small rise (R_S) or fall (F_S) ... 1–5°F.
Steady (S)... ... ... 0°F.

It will be seen that the forecast change was correct on 44 of the 110 winter occasions and on 28 of the 82 summer ones. Taking the medium and large changes together, these were forecast to occur the right number of times in each season so the general variability of temperature was not underestimated. Nevertheless, about one third of the forecast rises and one half of the forecast falls of this magnitude did not fully materialize or were wholly in error. The forecasts which might be regarded as worthless are those outside the zigzag lines; these totalled 20 out of 110 in winter and 13 out of 82 in summer. It should be noted that these figures are based on the success with which thickness lines were forecast. Contingency tables for the corresponding temperatures should not be significantly different apart from some modification due to the over-estimation of some of the low January temperatures. It is therefore reasonable to conclude that forecasts of mean temperature based on forecasts of the 1000–500-millibar thickness are much more successful than Table III might suggest.

Forecasting the mean temperature has been considered primarily for the purpose of issuing forecasts for 2 days ahead, for in that period substantial changes of air mass often have to be considered. The accuracy of the method over a longer period is limited only by the accuracy with which the thickness can be predicted. It could be applied equally well to monthly anomalies of thickness should they ever become available. The possibility of using the forecast mean temperature as a basis for a forecast of the maximum or minimum temperature is not promising, for the reason that an accuracy in cloud forecasting is required which in many synoptic situations is unlikely to be attained.

Appendix

MEAN SURFACE TEMPERATURE AT LONDON CORRESPONDING TO THE 1000–500-MILLIBAR THICKNESS AT CRAWLEY

Thickness	Winter*	Summer†	Thickness	Winter*	Summer†
m.	°F.	°F.	m.	°F.	°F.
5050	24	...	5210	31	40
5060	24	...	5220	32	40
5070	25	...	5230	32	41
5080	25	...	5240	33	41
5090	25	...	5250	34	42
5100	26	...	5260	34	42
5110	26	...	5270	35	43
5120	27	...	5280	35	43
5130	27	...	5290	36	44
5140	28	...	5300	37	44
5150	28	...	5310	37	45
5160	29	...	5320	38	45
5170	29	...	5330	39	46
5180	30	...	5340	39	46
5190	30	...	5350	40	47
5200	31	40	5360	41	47

(*Continued on next page*)

Thickness	Winter*	Summer†	Thickness	Winter*	Summer†
m.	°F.	°F.	m.	°F.	°F.
(Continued from previous page)					
5370	41	48	5540	56	59
5380	42	48	5550	57	60
5390	43	49	5560	58	61
5400	44	50	5570	59	62
5410	44	50	5580	60	63
5420	45	51	5590	61	64
5430	46	51	5600	62	65
5440	47	52	5610	63	66
5450	48	53	5620	64	67
5460	48	54	5630	65	68
5470	49	54	5640	67	70
5480	50	55	5650	68	71
5490	51	55	5660	69	73
5500	52	56	5670	70	74
5510	53	57	5680	71	75
5520	54	58	5690	72	76
5530	55	59	5700	74	78

*Winter = Jan.–March, Sept.–Dec.
†Summer = Apr.–Aug.

A CROSS-SECTION OF EQUATORIAL UPPER WINDS AT 103°E.

By L. S. CLARKSON, M.Sc. and L. W. LITTLEJOHNS

Introduction.—Daily radar wind ascents at 0400 G.M.T. undertaken by the Royal Naval Weather Service at Christmas Island (105° 36′E., 10° 31′S.) from April 22 to June 21, 1956 have been utilized in conjunction with routine 0300 G.M.T. radar wind reports over the same period from Singapore (103° 54′E., 01° 21′N.), Songkhla (100° 36′E., 07° 13′N.) and Bangkok (100° 30′E., 13° 44′N.) to construct a cross-section of mean zonal flow at 103°E.

Although necessarily representative of one specific and rather limited period, the cross-section is based on sufficient observations above the equatorial tropopause (believed to be around 60,000 feet) to show interesting features of the extent of the easterlies in the upper troposphere, and of the overlying westerlies in the lower equatorial stratosphere.

Observations and analysis.—Results of the evaluation at 5,000-foot height intervals of the mean westerly component of the 0300–0400 G.M.T. observed winds over the period April 22 to June 21, 1956 are shown in Table I, and in the form of a cross-section along the 103°E. meridian at Fig. 1. The numbers of available observations from which the means have been derived are included in brackets within the Table.

The mean zonal flow.—In the lower troposphere over Bangkok the deep westerly flow of the south-west monsoon extended to over 20,000 feet; prevailing light equatorial westerlies to which Watts[1] has drawn attention were evident up to 15,000 feet at Singapore, but south of the equator towards Christmas Island there was little mean zonal flow in the lower troposphere except for signs of the south-easterly trade below 5,000 feet.

In the upper troposphere a broad belt of equatorial easterlies overrides the westerlies in the northern hemisphere, increasing with height to a maximum around 50,000 feet. For the particular period of the cross-section, the core of the high-level easterlies appeared to be located over or to the north of Bangkok, where the mean east to west component reached 46 knots at 54,000 feet, no observations being available at higher levels. The easterlies decreased in

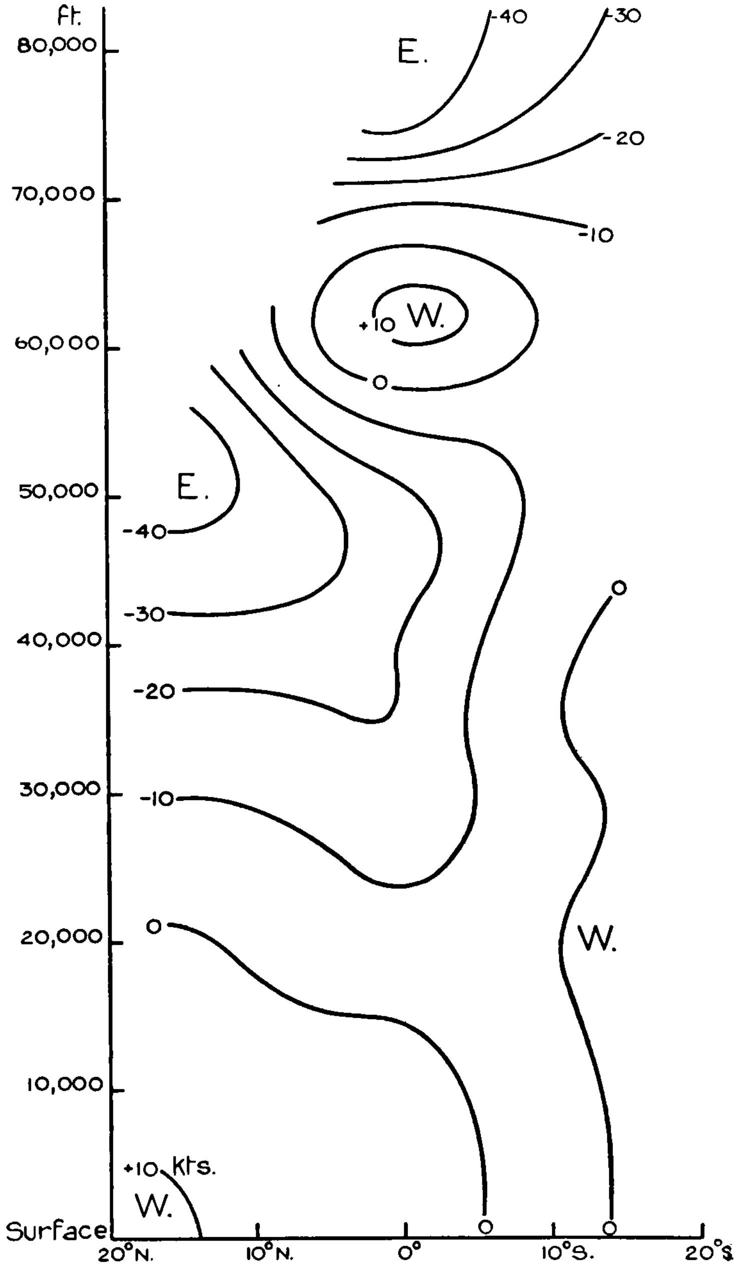


FIG. 1.—MEAN CROSS-SECTION FOR 103°E. FOR APRIL–JUNE, 1956

strength southwards, but were still evident at 50,000–55,000 feet over Christmas Island.

Although data in the stratosphere are restricted to Christmas Island and Singapore, there are enough observations available to indicate the existence over or just to the south of the equator of a layer of lower stratospheric westerlies which, during this particular period, lay between 58,000 feet and 68,000 feet. Above them, and increasing with height, the well-known Krakatoa easterlies were in evidence.

The westerlies were no doubt the Von Berson westerlies discussed by Palmer[2] but considered to be too light and of insufficient extent to be shown in world-wide charts of the average wind at 60 millibars[3].

TABLE I—MEAN WESTERLY COMPONENT ALONG 103°E., APRIL 22 TO JUNE 21, 1956

Height	Bangkok		Songkhla		Singapore		Christmas Island	
feet				*knots*				
85,000	...		...		...		−36	(10)
80,000	...		...		...		−34	(29)
75,000	...		...		−43	(5)	−25	(36)
70,000	...		...		−13	(18)	−12	(43)
65,000	...		...		+ 8	(40)	− 2	(51)
60,000	...		...		+ 9	(52)	0	(59)
55,000*... ...	−46	(40)	...		− 9	(58)	− 5	(60)
50,000	−43	(48)	...		−24	(59)	− 5	(60)
45,000	−37	(50)	...		−27	(59)	− 2	(60)
40,000	−26	(51)	...		−23	(60)	− 1	(60)
35,000	...		...		−20	(60)	0	(60)
30,000	−11	(53)	−11	(14)	−16	(60)	− 2	(60)
25,000	− 3	(53)	− 8	(17)	−11	(60)	− 1	(60)
20,000	+ 1	(53)	− 2	(19)	− 5	(60)	0	(61)
15,000	+ 4	(55)	0	(19)	− 1	(60)	− 1	(61)
10,000	+ 6	(56)	+ 4	(20)	+ 6	(60)	− 1	(61)
5,000	+ 7	(56)	+ 5	(22)	+ 7	(60)	− 5	(61)

*54,000 ft. at Bangkok

Number of observations from which the means have been derived are shown in brackets.

Comparison with other equatorial cross-sections.—The cross-section for April–June 1956 at Fig. 1 is very similar to that given by Ramsey[4] for the 110°E. meridian for July 1953; unfortunately this latter includes no data above 50,000 feet and hence gives no indication of the existence of the Von Berson westerlies. A cross-section at 45°E. in July given by Gilchrist[5] is also broadly similar, although with a weaker westerly monsoon flow in the lower troposphere north of the equator, and stronger overriding easterlies. Gilchrist's July cross-section shows westerlies in the lower stratosphere above 57,000 feet with their centre just south of the equator.

Summary and conclusions.—During the period April 22 to June 21, 1956 the mean zonal wind structure across the 103°E. meridian near the equator was as depicted in Fig. 1, interesting features of which are the broad belt of easterlies just below the tropopause, the band of stratospheric westerlies near the equator, and the overlying Krakatoa easterlies.

REFERENCES

1. WATTS, I. E. M.; Equatorial Weather. London, 1955.

2. PALMER, C. E.; The general circulation between 200 mb. and 10 mb. over the equatorial Pacific. *Weather London*, **9**, 1954, p. 341.

3. BANNON, J. K., and JONES, R. A.; Average wind at 60 mb. *Met. Mag., London*, **85**, 1956, p. 194.

4. RAMSEY, B.; Upper winds in the South-East Asia – West Australia region. *Met. Mag., London*, **84**, 1955, p. 372.

5. GILCHRIST, A.; Wind between 300 and 100 mb. in the tropics and subtropics. *Met. Rep., London*, **2**, No. 16. 1955.

METEOROLOGICAL OFFICE DISCUSSION

Atmospheric chemistry

The discussion held on Monday, December 16, 1957, at the Royal Society of Arts was opened by Mr. B. C. V. Oddie.

Although atmospheric chemistry comprises a very wide variety of subjects, the greatest and most systematic effort made hitherto has been devoted to the study of a group of simple inorganic salts which together rarely amount to one millionth part by weight of the atmosphere. Two methods of study are employed. In the older and more widely used, rain-water is collected for analysis using a glass funnel and collecting bottle; in the other method, air is drawn through a solvent solution. In either case the sample is collected over a period of one calendar month. The rain-water is analysed for chloride, sulphur (SO_4 and SO_3), nitrate (including nitrite), bicarbonate, sodium, potassium, calcium, magnesium and ammonium. The results are usually expressed in milligrams deposited per square metre of surface. Acidity (pH) and conductivity are also measured. The air sample is analysed for all the same constituents except bicarbonate and nitrate, and the results are expressed in microgrammes per cubic metre.

The nitrogen compounds in rain-water are valuable as plant foods, and have have been studied by agriculturists for over a century. The present network for atmospheric chemistry is indeed merely a considerable extension of a nation-wide system set up in Sweden just after the last war, which was originally intended for purely agricultural purposes.

At present it consists of about eighty stations distributed over Finland, Sweden, Norway, Denmark, Holland, Belgium, north-west Germany, and Great Britain. The existing British stations are Aberdeen, Edinburgh, Leeds, Rothamsted and Newton Abbot (all set up in 1954–55 by the Meteorological Department of Imperial College) and four Meteorological Office stations—Lerwick, Eskdalemuir, Stornoway and Camborne—set up in the last few weeks. One additional station will be opened at Aldergrove very soon.

Slides of the sampling equipment were shown. The rain-water is collected by a funnel and bottle, while the essential parts of the air sampler are a continuously acting air pump, a gas-meter to measure the quantity of air sampled (normally about 40 cubic metres per month) and the absorbing column in which the air bubbles through 125 millilitres of a dilute solution of nitric acid and hydrogen peroxide. The whole apparatus is contained in a cabinet which is automatically warmed in cold weather to prevent freezing. The main precautions aim at avoiding contamination of the samples, a point of especial importance since the quantities of solute are extremely small. In particular the apparatus must be of materials which are very insoluble: ordinary glass is unsuitable and the materials used in the British equipment are polythene for the collecting funnel and tubes, and Pyrex glass for storage bottles and blown-glass parts.

The present international network is barely three years old, and no detailed study of its results has yet been published. There have been several papers concerned with results obtained from the smaller, mainly Swedish network which operated before 1954, but these are based almost entirely on rain-water samples. The most obvious point revealed by these studies is that in Scandinavia the sea is the principal source of the inorganic matter in the air. Except for calcium and ammonium, all the ions are deposited in quantities which are greatest on the south-west, or windward, coasts, and decrease rapidly towards the north-east. Thus in one year (August 1955 to July 1956) the total amount deposited at Askov near the west Danish coast was about 17 grammes per square metre, whereas at Flathult, 130 miles inland in Sweden, it was about 3 grammes. The difference here is not due to a difference in the amount of rain, which was almost exactly the same at the two places. Presumably the material enters the atmosphere in the form of spray: and as a rule it will remain in the form of small droplets, since the air is generally too moist to allow crystallization to occur, at any rate in the lowest few thousand feet. Later, these droplets must be washed out by rain, the constitution of which may therefore be expected to resemble that of very much diluted sea-water.

In fact, near windward coasts, this is nearly true—the ratios between the amounts of sodium, potassium, magnesium and chlorine are much the same in rain-water as in sea-water. As however one goes inland, one finds that the proportions change. In particular the ratio, weight of chlorine:weight of sodium, which is about 1·8 on the windward coasts and in sea-water, decreases inland and is as low as 0·6 at some eastern stations. There are thus two parts to the problem:

(i) Why does the total amount of inorganic matter brought down by rain decrease so rapidly with increasing distance inland?

(ii) Why does the Cl:Na ratio in rain-water decrease with increasing distance inland?

The second part is at first sight the more difficult, because salt, (NaCl) is a very stable compound, which must be decomposed somehow before its elements can be physically separated.

One solution, proposed originally by Cauer[1] and developed by Rossby and Egner[2], assumes that the general decrease in the amount of matter deposited is due to simple washing-out by rain. The change in constitution is explained by supposing that some other constituent of the atmosphere (either ozone or sulphuric acid, both of which are present) reacts with the droplets of salt solution so as to release hydrochloric acid (HCl) into the air. Thus when these droplets are brought down as rain they will be deficient in chlorine, which is in accordance with the observations.

This view of the matter is no longer tenable now that the results of air analysis are available. For clearly, if the chlorine remains in the air while the sodium is washed out, the ratio of Cl:Na *in the air* must increase steadily as one goes inland, and of this increase there is no sign whatever. Moreover, it is impossible to explain the observed decrease in the total amount of material in the air as due to washing by rain, because rain falls for only a fraction of the time and could not greatly affect the *average* concentration.

An argument essentially similar to this last has recently been developed by Junge and Gustafson[3], who were led to the same conclusion that wash-out could not greatly affect the constitution of the air. Their suggested explanation of the observed changes, based on measurements in the trade-wind belt, is that salt particles while over the sea are confined to the lowest two or three thousand feet by the inversion which is normally present: and are therefore in high concentration. Over the land, the inversion breaks down, and the salt particles are free to spread upward. They ascribe the change in the Cl:Na ratio to particles picked up from the ground by the wind, and consisting mainly of sodium salts other than the chloride. It is thus unnecessary to invoke the kind of physical-chemical separation imagined by Cauer.

It seems unlikely that this mechanism is really the principal one in Scandinavia. In the first place, the inversion does not normally break down soon enough after passing the coastline to explain the observed decrease in total concentration. Moreover the amounts of sodium which would have to be transferred from the ground to the air to explain the observed change in the Cl:Na ratio are quite implausible. It is clear too that some kind of chemical decomposition of the salt must occur, because even on windward coasts the Cl:Na ratio in rain-water often departs appreciably from the normal value, and the differences are too large to be accounted for by material transferred from the ground.

The speaker suggested that the principal, or at least a very important, means by which inorganic salts are removed from the air is by direct deposition, particularly on plants. It is a matter of common observation that plants near the coast collect considerable amounts of salt; moreover Eriksson has shown that the Scandinavian rivers carry down to the sea an amount of chloride considerably greater than that brought down by rainfall, and attributes the difference to direct dry-deposition of salt on trees etc. The change in the Cl:Na ratio may similarly be explained by assuming that chlorine or hydrochloric acid released by oxidation of sea-salt is removed from the air by reaction at the surface. We know that plants remove from the air every day, on average, an amount of carbon dioxide equal to all that contained in the lowest 500 metres of the atmosphere, so that it is evident that this kind of scavenging can be very rapid and effective.

In conclusion, a brief account was given of one or two of the many other subjects in the field of atmospheric chemistry which have recently been studied. A small network of fifteen stations was set up in Scandinavia in 1954 to study the distribution and seasonal changes in the amount of carbon dioxide in the air, but the data so far obtained have not revealed any very clear-cut or systematic variations. Another subject of great importance concerns the exchange of carbon dioxide between the atmosphere and ocean. If carbon dioxide continued to be generated by human activities at the present rate, and if it all remained in the air, there would be a change in the world's climate which within a few centuries might be disastrous: however carbon dioxide is soluble in water, and in equilibrium the amount in solution in the sea is nearly fifty times the amount in the air. The important thing is to know how rapidly any excess in the air will be taken up by the sea. A number of studies have been made of this subject, the more recent ones relying on the use of radioactive carbon, which is always present in natural carbon dioxide. The results which have been obtained have however been very discordant, the estimates of the exchange time varying from a few days to many years.

These are problems of great interest and importance. The behaviour of the simple inorganic salts in the air is still, however, the central problem of atmospheric chemistry. Whether it justifies the permanent maintenance of the present considerable network of stations is somewhat doubtful. The immediate intention is to continue the work until the results gathered during the International Geophysical Year have been examined, and then to take stock.

Mr. Durbin described work currently being carried out at the Meteorological Research Flight on the sampling of atmospheric chloride particles. This work is being done principally for cloud physics studies but results obtained from it are clearly of great value to the study of atmospheric chemistry.

The method of sampling is based on the discovery due to Liesegang that when a chloride particle impinges on a surface coated with a layer of gelatine impregnated with silver nitrate a ring forms. If the surface be then exposed to a bright light for a few hours the area within the ring goes brown and is clearly seen. The chemical reaction is not fully understood but probably involves the formation of silver chloride and subsequent reduction of the silver chloride to metallic silver.

Sampling in flight is carried out using an impactor, which is simply a metal pole with a shutter arrangement on one end, and small perspex slides which are coated and kept in a light-tight box before the aircraft takes off.

Three pictorial slides were shown and these illustrated:

(*a*) the stages of the reaction between the gelatin-silver-nitrate solution and droplets of sodium chloride solution, obtained during a laboratory calibration of the technique.

(*b*) a typical sample obtained in flight and having a mean particle mass of about 5×10^{-11} grammes.

(*c*) a series of samples obtained on a flight from Farnborough to Northern Ireland, the outward leg being at 1,000 feet and the return leg at 2,000 feet. The track lay through a weak cold front and the slide clearly showed how the sizes and concentrations of the particles increased in the vicinity of the front.

Three other slides shown gave results obtained from twelve flights made to sample chloride particles at heights between 100 and 10,000 feet over the sea and to obtain comparative samples at selected heights over the land.

The evidence was that particles having masses greater than the smallest that the impactor could collect, about 10^{-13} grammes, occurred in concentrations up to about 2000 per litre, the highest concentrations usually being at the sea surface indicating that this is their source. The mean value at the surface for seven flights was about 500 per litre while the corresponding concentrations for particles having masses greater than about 10^{-11}, 10^{-10} and 10^{-9} grammes were up to about 60, 12 and 1 per litre respectively. For these three sizes there was no significant difference between concentrations over the land and over the sea but for particles of all sizes the land concentrations were higher. This suggests that the land itself produces particles having masses of 10^{-11} grammes or less.

Examination of the trajectories of the air during the three days preceding the flights indicated that in general the land acts as a sink while the sea acts as a source. This was not always so however but attempts to correlate particle concentrations with wind speed, lapse rate and state of sea did not provide a simple explanation of the observed particle concentrations.

Usually, particle concentrations became quite low above haze layers and cloud tops and there were usually strong resemblances between the vertical profiles for concentrations of particles having masses greater than certain specified values. There was also a strong resemblance of these profiles with the vertical frost-point profile indicating that the chloride particles, having been produced by whatever method, are distributed throughout the atmosphere by diffusion.

Mr. Durbin concluded by remarking that this kind of technique can be used to sample particles other than chlorides and that Vittori[4] had recently given details of several such reactions. Particle sampling of this kind could be carried out on a routine basis from the ground at relatively little expense.

Dr. Harrison noted that polythene was used for the rain funnel of the sampling equipment because glass was insufficiently inert. Why was glass used for the collecting bottle and for the air-sampling equipment? In reply, Mr. Oddie said that Pyrex glass was quite satisfactory, and was used in the equipment. The polythene funnel was used mainly because a suitable Pyrex one was unobtainable.

Mr. Craddock asked whether there was any information on the Cl:Na ratio in the air at greater distances from the sea; and what happened to the considerable amounts of carbon monoxide now being pumped into the air by petrol and Diesel engines? Mr. Oddie replied that very little information on the Cl:Na ratio in the air was available except from the Scandinavian network. Carbon monoxide cannot be detected except in cities and is probably very quickly oxidized.

Mr. D. D. Clark asked whether any significant part of the matter brought down by rain consisted of meteoritic dust; and whether there was a reasonably close balance between measured amounts of anions and cations in rain-water? Mr. Oddie said the amount of meteoritic dust was insignificant; the ionic balance in rain-water was as a rule quite good, indicating that the analyses were reliable. It could not be determined for the air samples because of the nitric acid used as a solvent.

Dr. Stagg found some difficulty in visualizing the nature of the reactions, and the relationship between the air samples and the rainfall samples. It seemed from Mr. Durbin's remarks that most of the material was present in the form of crystalline particles and therefore would be relatively inert. Mr. Durbin replied that laboratory calibration experiments showed that Liesegang rings were produced by sodium chloride crystals as well as by drops of solution. It had been assumed in the calibration that at relative humidities below about 75 per cent the particles were in the form of crystals while above this value they were in the form of droplets. This involves the supposition that atmospheric chloride particles are essentially compounds of sodium and that Dessen's observations that such particles had been observed in the laboratory to occur as drops of supersaturated solution at relative humidities as low as 40 per cent would not apply in a turbulent atmosphere.

Mr. Sawyer pointed out that the maps of distribution of Na and Cl which had been shown have a marked resemblance to the rainfall maps of the same area. To what extent was the decrease in the amount of material brought down inland merely a consequence of the decrease in rainfall? Mr. Oddie replied that the amount deposited was of course dependent on rainfall, but that if maps were drawn of the mean concentration of ions in the air, there was still a very striking decrease from west to east.

Photograph by C. B. Gavin-Robinson.

DUSTSTORM OVER THE QATAR PENINSULA, PERSIAN GULF, SEPTEMBER 4, 1957

(see p. 116)

Photograph by W. G. Pendleton

Photograph by W. G. Pendleton

CLOUD AT TERNHILL, OCTOBER 18, 1957

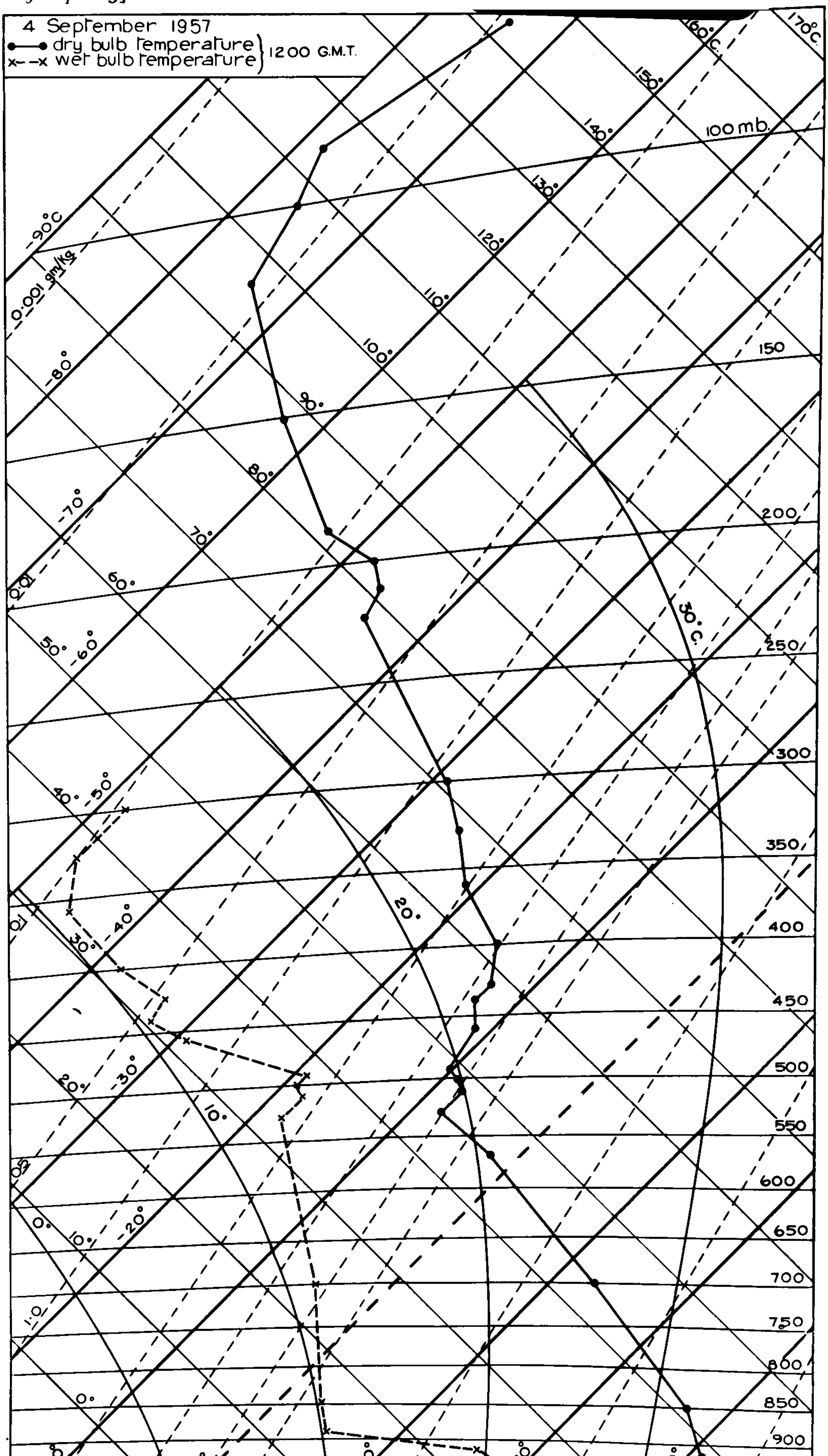
(see p. 116)

Photograph by W. G. Pendleton

CLOUD AT TERNHILL, OCTOBER 18, 1957

(see p. 116)

To face p. 113]



TEPHIGRAM FOR BAHRAIN, SEPTEMBER 4, 1957

(see p. 118)

Dr. Stagg asked whether any analyses had been made of different kinds of rain; for example, was there any difference in constitution between thunderstorm rain and warm-front rain? Was there any possibility that the electric field of a thunderstorm might have some effect on the separation of ions? He asked the opinion of Dr. Robinson who replied that as the ions were in solution in droplets it must be possible for them to react with gases in the atmosphere, but that they could not be physically separated by an electric field.

A speaker remarked that a dry crystal would not readily enter into reactions: presumably however since salt is hygroscopic each crystal would be covered with a film of solution and reactions would take place in this film. He wondered whether the release of chlorine might be due to its displacement by carbon dioxide from the air. Mr. Oddie replied that the salt was normally in the form of droplets of solution, crystallization only occurring in very dry air. The bicarbonate ion could not directly displace chlorine from sodium chloride, although when hydrochloric acid had been displaced by oxidation, carbon dioxide was absorbed by the droplets.

Dr. Stagg wondered how it came about that the Cl:Na ratio in rain-water according to the slides which had been shown, was only 1·2 even on the windward coasts. In reply Mr. Oddie said that probably later and more reliable measurements would show rather higher values, but that in any case, if the ratio was modified by a process of chemical dissociation, there was no reason why some of the change should not occur over the sea.

Mr. Shellard thought it would be interesting to collect rainfall on an Ocean Weather Ship. Experiments with rain-gauges had shown that provided they were set high on the mast they did not collect sea-spray. Mr. Oddie agreed that it would be an interesting experiment, but thought that too much spray would enter the collector, as it evidently did on many occasions at coastal stations such as Lista.

Mr. H. L. Wright asked whether there was any evidence of the presence of significant amounts of nitrous acid in the air: some early experiments which he had performed had shown that it is always formed when combustion takes place.

In reply Mr. Oddie said that Junge had recently made some careful analyses of airborne particles. Following up Mr. Wright's well-known work, Junge had paid particular attention to nitrite, and had concluded that there was no detectable quantity in aerosols. This might be because it was all oxidized to nitrate: however Junge does not consider that combustion is an important source of nitrate, most of which he believes originates on the coasts. But his evidence is not conclusive.

Mr. Craddock, referring to the exchange of carbon dioxide between the sea and atmosphere, suggested that only a shallow surface layer of the sea, that is, that which is disturbed by the action of waves and tides, took an active part in the process, and that therefore the ability of the sea to absorb excess carbon dioxide generated by human activity was much less than had been suggested. In reply, Mr. Oddie agreed that only the top 70–100 metres of the ocean took a part in the direct absorption of carbon dioxide: but there was some transfer to the deep ocean, and a principal object of some of the current research was to discover how this occurred. It is a curious fact that the concentration of carbon dioxide in the ocean increases downward, so that any mixing process would transfer carbon dioxide upwards. There must therefore be some compensating downward transfer, but it was not yet understood.

Mr. Hamilton asked whether there had been any attempts made to compare the concentrations of inorganic salts in rain with those in snow. Mr. Oddie replied that he did not know of any. A comparison of the summer and winter maps of amounts deposited in Scandinavia did not reveal any immediately obvious effects.

A speaker asked whether it was not possible to take air samples in exclusively anticyclonic conditions and compare them with samples taken in exclusively cyclonic conditions. Mr. Oddie replied that the existing organization was based on monthly samples, and would be difficult to modify in the way suggested.

Mr. Hay (referring to Mr. Oddie's earlier reply to Mr. H. L. Wright) said that Porton had recently developed a method of estimating nitrous fumes in the air. Their measurements had shown amounts of about 6 microgrammes per cubic metre: and it was clear that these were not generated locally. Mr. Oddie replied that this seemed a very large amount, in view of Junge's findings.

A speaker referred to some work in India suggesting that nitric or nitrous acid was formed directly by lightning flashes, in quantities sufficient to be measurable and significant in agriculture. Mr. Oddie replied that lightning flashes and, probably, continuous discharges in the high atmosphere, did cause some combination of atmospheric oxygen and nitrogen, and it had even been suggested that the Chile nitrate beds originated in this way.

A speaker pointed out that rainfall was not the only natural way by which nitrogen was transferred from the atmosphere to the soil: nitrogen-fixing bacteria also played an important part.

Mr. Hamilton thought it would be interesting to analyse the ice which frequently collects on high radio masts in winter, since this would presumably represent the material actually present in cloud particles.

A speaker asked when the results of the United Kingdom analyses would be published. Mr. Oddie replied that the present intention was to publish them in *Tellus* along with those from the rest of the European network; but arrangements could no doubt be made for a separate circulation to interested parties in this country if it were thought worth while.

Mr. Gold felt that the discussion had brought out the great need for more frequent analyses, so that differences between, for example, thunderstorm rain and other rain, or between rain from the sea and rain from inland could be studied. He complimented Mr. Durbin on the slide showing the distribution of salt particles along a flight track. This was a new and promising study, and a most effective presentation of the results. He wondered however how effective these gelatin covered slides were in collecting salt particles: and what effects temperature and humidity had on the records. In particular, what differences are there between the stains produced by a crystal and by the same amount of salt in solution as a droplet?

Mr. Durbin replied that particles having chloride masses of down to 10^{-13} grammes could be detected using this gelatin technique. No accumulation of the smallest particles near the edges of the slides had been noticed and it had therefore been assumed that the efficiency of catch for all identifiable particles was unity. He did not know what effect temperature would have on the reaction between the chloride particles and the gelatin-silver-nitrate coating and thought that this aspect was worth investigating. Regarding the effect of humidity, the calibration showed that above a relative humidity of about 75 per cent the stain diameter due to a given mass of sodium chloride depends on the relative humidity at which the impaction was made.

REFERENCES

1. CAUER, H.; Ergebnisse Chemisch—Meteorologischer Forschung. *Arch Met., Wien,* Serie B, Band I, 1949, p. 221.
2. ROSSBY, C. G. and EGNER, H.; On the chemical climate and its variations with the atmosphere circulation pattern. *Tellus, Stockholm,* 7, 1955, p. 127.
3. JUNGE, C. and GUSTAFSON, P. E.; On the distribution of sea salt over the U.S.A. and its removal by precipitation. *Tellus, Stockholm,* 9, 1957, p. 164.
4. VITTORI, O.; 1956, Research in Chemical Composition of some forms of Atmospheric Particles. Tech. Note No. 5, University of Chicago, Dept. of Met., 1956.

WORLD METEOROLOGICAL ORGANIZATION

Commission for Bibliography and Publications

The second session of the Commission for Bibliography and Publications of the World Meteorological Organization was held in Paris from November 5 to 22, 1957. Representatives of Belgium, the United States, France, West Germany, Holland, Great Britain, the Soviet Union, Spain and Venezuela were present.

The President of the Commission, M. M.Mézin, was in the chair.

The major subjects considered were the revision of the meteorological section (551.5) of the Universal Decimal Classification and the publication of a World Meteorological Bibliography and an International Meteorological Vocabulary and Nomenclature.

551.5 was brought right up to date by adding a number for observations by artificial satellites. Numerous improvements in detail were made notably in atmospheric radioactivity, radiation and atmospheric electricity. Suggestions from the Scott Polar Research Institute for changes in the classification of snow cover to agree with general proposals made by the Institute for revision of the classification of the properties of snow and ice were considered and mostly adopted. These U.D.C. proposals have to be accepted by the Executive Committee of W.M.O. and by the International Federation of Documentation before they come into force.

It was agreed to recommend that the monthly accessions list of the Library of the Meteorological Office, London, should be used as the basis of a provisional World Meteorological Bibliography. Members of W.M.O. would be asked to supply monthly lists of books and articles published in their respective countries which are not in the monthly accession lists with a view to the publication of six-monthly amendment lists. Later, using experience gained with the provisional Bibliography, it was considered it should be possible for W.M.O. to publish a bibliography compiled from national lists of published books and articles.

A working group on the International Meteorological Vocabulary completed its work with the preparation of a draft Vocabulary with terms in French, English, Spanish and Russian and definitions of the terms in French and English.

The draft is to be submitted to Members and Presidents of Technical Commissions of W.M.O. for criticism. It is hoped, after co-ordination of the comments by the Working Group, that the Vocabulary will be published late in 1958. Later a polyglot nomenclature giving equivalents in the four official languages of W.M.O., English, French, Russian, Spanish, will be published. It should be noted that the terms "Vocabulary" and "Nomenclature" are terms agreed by the International Standardization Organization (I.S.O.) for the kinds of publication described.

Another decision of general interest is the one to recommend Members to use the I.S.O. system of Cyrillic transliteration in all documents intended for international use.

M. Mézin retired as President at the end of the meeting and was succeeded by Dr. A. Vandenplas of Belgium.

Visits were paid to the Bibliothèque Nationale, the International Business Machine Computing Centre in Paris, and the Documentation Centre of the National Centre for Scientific Research. At the Computing Centre was seen the latest I.B.M. electronic computor—the 704, and at the Documentation Centre the Filmorex document selector which using a photo-electric device can scan, by subject or combination of subjects, 600 microfiches a minute, separating those desired from the others. G. A. BULL

LETTER TO THE EDITOR

Cloud photographs taken at Ternhill

The photographs between pp. 112–113 were taken about 1645 G.M.T. on Friday, October 18, 1957, looking south-west from Ternhill. The tip of a warm sector, or the occlusion, had passed through Ternhill about an hour before the photograph was taken. I think it is probable that the cloud was formed originally over the Welsh hills in the warm air, and then streamed away in the wind direction, developing and producing the trails of falling crystals.

The main cloud sheet on the left of the photograph was altocumulus–altostratus with a more or less uniform base of about 12,000–13,000 feet. To the west was some high, thin, filmy cirrus.

Ternhill, Salop, November 27, 1957. W. L. LINEHAM

NOTES AND NEWS

Duststorm, Qatar Peninsula, Persian Gulf

We are indebted to Captain C. B. Gavin-Robinson of Gulf Aviation Ltd. for the photograph (facing p. 112) of a duststorm around the base of a cumulonimbus cloud observed by him when flying over the Qatar Peninsula, which extends northwards into the Persian Gulf east of Bahrain, on the afternoon of September 4, 1957.

Captain Gavin-Robinson first saw the storm, a well developed cumulonimbus with the base obscured by rising dust, while en route from Dukhan to Umm Said at 1600 local time, see Fig. 1; he then writes:—

"I took off from Umm Said for Dukhan (Fig. 2) at about 1650 local time and climbed to 3,000 feet. The cumulonimbus was in the same position, but surrounding it in an arc, convex to the north and terminating 5 miles west of Umm Said at one end and just east of Dukhan at the other, was a solid wall of dust, rising from the surface of the desert to 5,000 feet. I altered course to the northward to avoid the dust, and kept close to the wall. At one point I came within about ½-mile of it. Here I was carried from 3,000 feet up to 5,000 feet quite smoothly at about 1,000 feet per minute, see Fig. 3; I then headed away from the wall, reduced power, and decended to my cruising altitude of 3,000 feet.

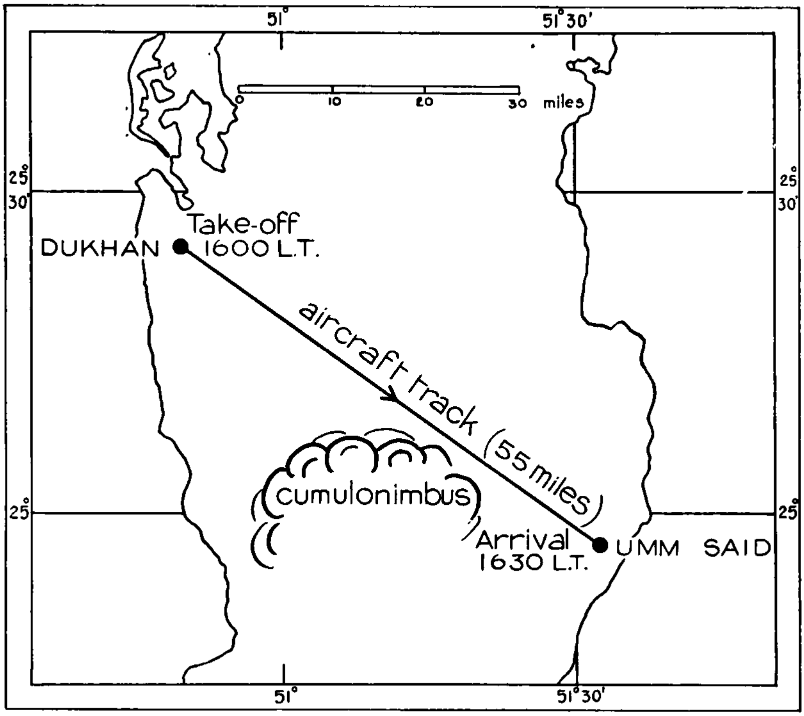


FIG. 1—FIRST FLIGHT OF AIRCRAFT OVER THE QATAR PENINSULA FROM DUKHAN TO UMM SAID, 1600–1630 LOCAL TIME

Sky clear; visibility 30 miles

At the half-way mark to Dukhan, that station reported that the dust had reached the airfield, that the visibility had fallen to 10 yards, and that the wind had changed from northerly at 18 knots to southerly at 25 knots. I therefore decided to divert either to Bahrain or Doha. I could see the latter place quite clearly at 20 miles range, the visibility north of the dust being excellent and the sky clear. At the request of the passengers I chose Bahrain for my diversion and set course for that place. Ten minutes later I received a message from Dukhan to say that the visibility there had improved to 2–3,000 yards "in bands". In view of the probable turbulence associated with the "dust front" I decided to continue to Bahrain.

On the way I passed 10 miles north of Dukhan, which was invisible behind the dust wall, and saw the dust solid down to the surface of the sea on which it appeared to float like an immense brown pillow.

I landed at Bahrain at about 1730 local time, and was then informed that the dust had reached Doha where the visibility had dropped to 100 yards."

Mr. F. E. Dinsdale, Meteorological Officer at Bahrain, writes:—

"This cumulonimbus was observed at Bahrain and the suggested height of 20,000 feet is almost certainly an under-estimate. Probably 35,000–40,000 feet is nearer the mark. There was some indication on the 1200 G.M.T. chart of a shallow surface depression over the desert south of Qatar, and as the radar wind at Bahrain for 1200 G.M.T. gave speeds of less than 22 knots to 60,000 feet there was little tendency for the upper part of the cloud to sheer off. The tephigram (dry- and wet-bulb temperatures) for 1200 G.M.T. is shown facing p. 113. The surface temperature over southern Qatar during the early afternoon was probably around 110°F.

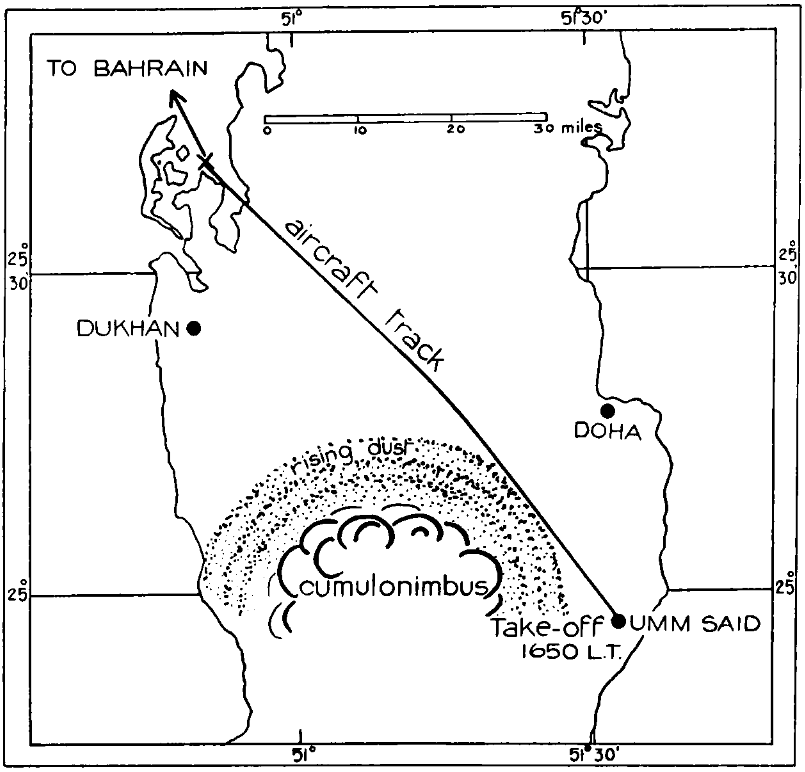


FIG. 2—SECOND FLIGHT SHOWING POSITION OF DUST AT 1700 LOCAL TIME

Sky clear; visibility 30 miles

The photograph was taken from the aeroplane at the position marked with a cross in Fig. 2, facing south, and shows the wall of dust billowing out over the shallow waters of El Hasam Bay with Ras Abaruk just visible in the right foreground.

Isolated cumulonimbus clouds are observed from time to time in this locality, but never before has one of this size and intensity been reported."

Mr. R. Murray, Senior Meteorological Officer, Aden, notes that the upper air soundings at Bahrain generally indicate very dry air away from the surface layer, tending to inhibit the growth of cumulus cloud. The reason for development of a large cumulus near Bahrain on September 4 is not clear as the sounding shows very dry air aloft.

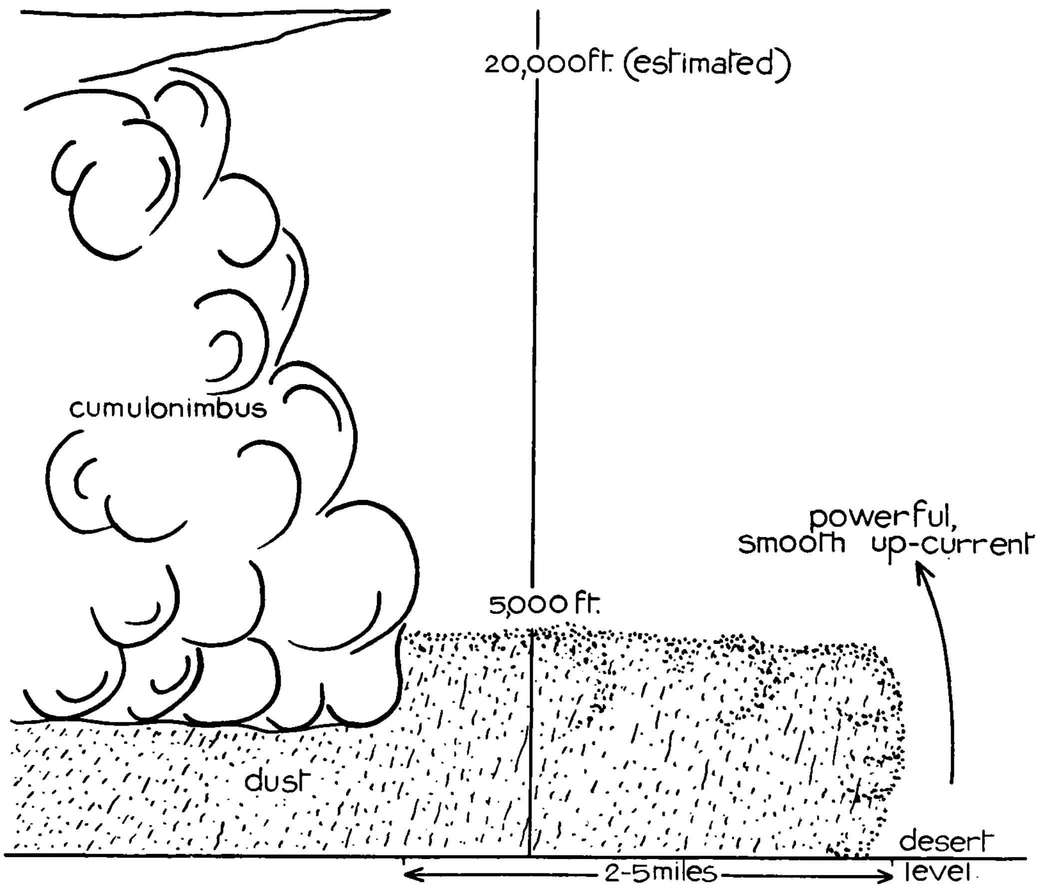


FIG. 3—VERTICAL SECTION OF DUST LOOKING WEST, 1700 LOCAL TIME

OBITUARY

James Strachan Farquharson, M.A., D.Sc.

The tragic death of Dr. Farquharson in a road accident on January 31, 1958 brought to a sudden and untimely end a career in the Meteorological Office covering more than 32 years.

James Farquharson was born on June 30, 1904 and educated at Robert Gordon's College and Aberdeen University, from which he received the degree of D.Sc. in 1944. He joined the Meteorological Office in July 1925, and the first ten years of his service were spent partly at Headquarters in London and partly at various outstations, including Lerwick and Croydon Airport. In 1935 he was posted for duty at Khartoum for a year to advise on the organization of the Sudan Meteorological Service which was being established in connexion with the development of Empire Air Routes, and he subsequently contributed to the Quarterly Journal of the Royal Meteorological Society two studies of the meteorology of that region, namely: *Haboobs and instability in the Sudan*, and *The diurnal variation of wind over tropical Africa.* On returning from Khartoum he worked again at Headquarters until on the outbreak of war he went to Paris as Meteorological Liaison Officer. In 1940 he was seconded to the Iraq Government as Director of the Iraq Meteorological Service and this was followed by a period as Meteorological Adviser at Air Headquarters India. In 1943 he was posted to Supreme Headquarters Allied Forces in Europe with the rank of

Wing Commander. At the end of the war he held, successively, the posts of Chief Meteorological Officer Royal Air Force Coastal Command, and of Royal Air Force Bomber Command, until in 1948 he was transferred to the Central Forecasting Office, Dunstable, with promotion to the rank of Senior Principal Scientific Officer. This was followed in 1954 by his appointment to the newly created Headquarters post of Assistant Director (Public Services), in which capacity he was responsible for the development of television weather forecasting, and the automatic telephone weather service. In December 1957 he returned to Dunstable as Assistant Director (Observations and Communications).

Throughout his career he was a vigorous thinker, often inclined to be impatient with the existing order, but nevertheless imbued with a keen urge to make constructive and, if necessary, unorthodox contributions towards greater efficiency within his sphere of responsibility as he felt the need. Although this inevitably brought him, on occasions, into disagreement with the more cautious of his colleagues, his genial personality and ready and infectious humour commonly won for him a tolerance, and indeed an affection, even from those who did not share his views, as well as a host of friends.

In a period of tendency towards a decay of standards in many spheres of human activity the loss can be ill-afforded of such a one as Dr. Farquharson, in whom was displayed a youthful zest and energy, combined with a deep-seated concern, of which only his really intimate associates probably knew, for the preservation of certain fundamental principles of conduct in everyday life.

Our deepest sympathy is extended to his widow, and to his family of two sons and three daughters. S. P. PETERS

RETIREMENT

John Glasspoole I.S.O., Ph.D.

Dr. J. Glasspoole retired on December 31, 1957 after nearly 38 years service in the Meteorological Office during which period he had the unique good fortune to be able to study continuously the distribution in the British Isles of one particular element, rainfall.

Dr. Glasspoole started his career in the British Rainfall Organization which he joined in 1916. At that time the British Rainfall Organization, under the control of Dr. H. R. Mill, was still a private concern. During 1919, however, the organization was taken over by the Meteorological Office (which had just been transferred to the Air Ministry) and Dr. Glasspoole was appointed Junior Professional Assistant on August 18, 1919. Prior to this Dr. Glasspoole served for a period, during the first World War, in the Chemical Inspection Department of the War Office at Woolwich, where he carried out analytical and research work. In April 1920 Dr. Glasspoole was promoted to a Senior Professional Assistant.

For several years, the British Rainfall Organization remained a separate unit of the Office, firstly under Mr. Carle Salter and later under Dr. F. J. W. Whipple. The organization, which had suffered a setback during the war years, was firmly re-established under the guidance of Dr. Glasspoole. He initiated and published a series of studies of the rainfall distribution in the British Isles and for this original work he was awarded the degrees of M.Sc. and Ph.D. in the University of London in 1922 and 1925 respectively.

In May 1925 the British Rainfall Organization was absorbed in the British Climatology Division, known in those days as M.O.7, and Dr. Glasspoole whilst continuing his special work on rainfall became associated with the more general climatological work in respect of the British Isles. Dr. Glasspoole remained in M.O.7. until 1939 when M.O.7 was absorbed by M.O.3 then called the Climatological Division with Dr. C. E. P. Brooks in charge. During an earlier reorganization, Dr. Glasspoole had been assimilated as a Technical Officer and in January 1939 he was promoted to Senior Technical Officer. In November of that year he went with M.O.3 and the other Divisions located at South Kensington, to the evacuation headquarters at Stonehouse near Stroud. There, during the Second World War, he was busily engaged not only in keeping the British Rainfall Organization a going concern, but in assisting with the many climatological investigations required by the Fighting Services.

After the War, in September 1945, M.O.3 was moved to its present location at Harrow and in 1946 Dr. Glasspoole was appointed a Principal Scientific Officer. He became Head of M.O.3 in 1948 and remained so until the last re-organization of the Office in July 1957 when Branch structure was abandoned.

Although Dr. Glasspoole, especially in co-operation with Dr. C. E. P. Brooks, carried out many studies concerning the climatology of the British Isles and made an important contribution to the production of the *Climatological atlas of the British Isles*, his main interest was always in the rainfall of the British Isles. He wrote very many papers on the subject and became the recognized authority on the incidence and distribution of rainfall in this country. He became particularly well known to Water Engineers, River Boards and all those who require rainfall data and advice thereon. In October 1957, in recognition of his services, the Institution of Water Engineers made him an Honorary Member of the Institution. A little earlier he was appointed a Companion of the Imperial Service Order for long and meritorious service in the Meteorological Office. These honours may well be said to set the seal of achievement on his work.

At a crowded gathering on December, 31 at Harrow, Dr. Glasspoole was presented with a cheque by Mr. R. G. Veryard, Assistant Director, on behalf of the many colleagues who wished to express their esteem and appreciation of Dr. Glasspoole and his work in the Meteorological Office. In expressing his thanks, Dr. Glasspoole recalled some of his interesting experiences in the Office and emphasized his gratitude to the staff who had worked with him during his career.

REVIEWS

Atlas Middellandse Zee (The Mediterranean). 11½ in. × 11½ in., pp. xix + 91, *illus.*, Koninklijk Nederlands Meteorologisch Instituut, De Bilt, 1957. Price: *F*20.

There is inevitably some duplication by maritime nations of atlases of marine climatological charts but no other recent one has been produced specifically for the Mediterranean. These monthly charts therefore meet the need of anyone making a detailed study of the climate or surface ocean currents of this area. The only recent comprehensive atlases which included the area did so with the representation of this sea as a small adjunct to the North Atlantic or even the whole Atlantic; most of the charts of this area were on so small a scale that they could not be used for an exhaustive study in an area where local variations necessitate more detailed charts than for the open ocean.

Some of the data in this atlas have been computed for one-degree squares and some for 47 larger areas into which the Mediterranean has been divided, partly on a geographical and partly on an arbitrary basis. The information computed for one-degree squares is vector means of sea-surface currents and winds, mean pressure, mean air and sea-surface temperature, the percentage duration of fog and the percentage duration of precipitation. The information given for the 47 areas is sea-surface current roses, wind roses and tabulated data for mean air and sea temperature and pressure and their standard deviations, duration percentage of fog and precipitation, the percentage frequency of gales, mean cloud amount and mean cloud amounts worked separately for day and night.

The advantage of using such a small basic area as a one-degree square instead of a larger area is that the statistics so obtained are more akin to those for a land station or fixed ship, particularly for those areas where there are strong horizontal gradients of the elements being considered: the use of a one-degree square also has the advantage that if data are required for a large area they can generally be obtained by combining those given for the one-degree squares which the area incorporates. Observations available however in each one-degree square are often very few, particularly in the less frequented ocean areas and in this atlas there are many for which no data are available.

A gale is defined in this atlas as Beaufort force 8 or more and this definition is now in fairly general use in marine climatology. The United Kingdom hitherto used force 7 or more as the definition of gales for the preparation of marine climatological charts.

The standard deviations of air and sea-surface temperature as given in this atlas are generally more convenient for scientific use than the 5-percentile maximum and minimum, but the latter (which are used in the United Kingdom marine atlases) doubtless mean more to the average mariner.

Even where isopleths are drawn, it is advantageous to print in the actual data on which they are based as is done in this atlas. Not only can this procedure be useful when one has to carry out a study requiring exact values but it also gives some idea of the confidence that can be placed in the isopleths by showing the number of observations in each square.

The printing and whole production of this publication is first-class as is always so with Dutch marine atlases. The inclusion of 12 pages of blank overlay maps at the back of the atlas is a new and useful idea. It should be noted when using the charts on fog that the word "mist" is the Dutch for fog and has no connexion with the English definition. P. R. BROWN

Cloud study. By F. H. Ludlam and R. S. Scorer, (foreword by R. C. Sutcliffe). $9\frac{1}{2}$ in. × 6 in., pp. 80, *illus.* John Murray, London, 1957. Price: 12*s.* 6*d.*

It was a happy thought for the Royal Meteorological Society to have arranged for the publication of a selection of its large collection of cloud photographs, and Ludlam and Scorer were the only possible choice as authors and selectors. The resulting book is remarkably good value for 12*s.* 6*d.* in these days. There are 74 excellent reproductions, of which five are coloured, in addition to the frontispiece and the beautiful picture on the jacket, which illustrates the high standard of modern techniques.

In the Introduction much useful information has been included in twelve pages. It is written very simply, but only experts could have provided the quality. The book deals mainly with the processes of cloud formation, and only indirectly with their appearance from the ground, on which their classification is based. A list of the names appropriate to each photograph is given in pp. 19–20. There are a few photographs from the air, but most are from the ground, and the Arctic and Antarctic are represented. All are of interest, and many are of striking beauty.

The copious descriptive notes provide a mine of information, some of it not readily available elsewhere. There is little to disagree with, but on a few points there is inevitably some room for difference of opinion. I should have called the very tall left hand tower of No. 10 cumulonimbus calvus. The detail is less clear than that of the right hand tower, and this blurring is usually soon followed by a change to a fibrous structure, and therefore presumably indicates the first stage of glaciation. In the case of No. 23, there is no evidence in the photograph that the base consists of evening stratocumulus; similar clouds can develop without having been reached by any recent convection from the ground, at any time of day or night. For the sake of completeness, a sheet of simple stratocumulus of the type which gives us so much dull weather in the winter might have been included. These are minor points, and there can be no two opinions about the high quality of the book, which should do much to stimulate interest in cloud study. C. K. M. DOUGLAS

Klima und Bioklima von Wien. II Teil. By Prof. Dr. F. Steinhauser, Dr. O. Eckel and Dr. F. Sauberer. 9½ in. × 6½ in., pp. 136, *illus.*, Verlag, Österr. Gesellschaft für Meteorologie, Wien, 1957.

Part I of this publication, the tabulations of the observations made in Vienna since 1775, was reviewed in the *Meteorological Magazine* of December 1955.

This second part deals with secular changes in the meteorological elements, with special investigations of importance in building and in hygiene, and with the temperature distribution in the city and its surroundings.

It is a work of the highest importance in the study of the climatic changes of the past 200 years and in the climatology of great cities. It describes probably the most intensive investigations of the kinds concerned which have ever been performed.

The first section deals with secular changes of temperature, precipitation, number of rain-days, snow cover, sunshine and wind. For temperature, annual means and both 5 year and 30 year overlapping means are provided with much information on warmest years, warmest lustrum (5 years), length of winter, and so on. It is instructive to be able to compare directly three types of smoothing. An interesting fact revealed is that all but one of the warmest years, defined as a mean temperature greater than over-all mean plus twice the standard deviation, occurred before 1863. The exception was 1934.

All the coldest years, defined similarly, occurred before 1872 except for 1940. The 30 year overlapping means, which are given for every month, season and year, show the period 1811–1840 to have been warmest followed by a fall and then a rise after about 1891–1920 in all seasons except winter which was intermediate at first, then fell and rose to a maximum between 1891 and 1940.

Data on periodicities show the sudden appearance and similar end of individual frequencies and show, as the authors say, how little a period can be relied on.

The observations of temperature on which these statements are based were not all made at the same site. Full details of the three sites concerned are given in Part I. The values, except for the absolute extremes, have been reduced to those of the site in use since 1872 at Hohe Warte. The two sites used between 1775 and 1872 were in the city itself. Hohe Warte is in a less densely built over park quarter. One might expect therefore the absolute maxima and minima to be rather high in the earlier years by comparison with those of the later period.

Similar information is given for the secular variations of other elements.

The second part deals mainly with frequencies of combinations of elements such as the precipitation with different wind directions, with the distribution of fog, smoke, and dust according to wind and weather type, with accumulated temperatures, with amount of solar radiation on walls etc.

The third part gives a detailed account of the distribution of temperature over the city and its suburbs. There are tables of mean daily and hourly temperatures at different stations and the records of thermometers in motor cars giving cross-sections in different weather types; frosty night, warm winter's day, hot summer day, etc. The greatest temperature differences between the city centre and the suburbs occur in the evenings in clear quiet weather and reach 6° to 8°C.

The work is written from a very practical angle. Thus very cold days in winter are discussed in the greatest detail because it is then that small temperature differences are of the greatest importance.

A third part is promised to appear later which will deal with the distribution over the city of meteorological elements other than temperature, with the effect of different weather types on the city climate, with illumination and street climate.

G. A. BULL

Physical Meteorology. By John C. Johnson. 9 in. × 6 in., pp. xii + 393, *illus.* The Technology Press of the Massachusetts Institute of Technology and John Wiley & Sons, Inc. New York. Chapman and Hall, Ltd., London. 1954. Price: $8.50, 60*s.*

This book is a valuable addition to meteorological text books with much in it of value to both the degree student and research worker. It brings together in one volume topics which are only sketchily treated, if at all, in the usual meteorological text book and is confined to "phenomena not directly linked with the circulation of the atmosphere".

The first two chapters deal with the refraction and scattering of electromagnetic waves in the atmosphere. A useful feature is that the discussion is not confined to wave-lengths in the visible part of the spectrum but deals with the whole range of wave-lengths from the ultra-violet to the broadcast radio wave-lengths. This makes a useful preliminary to the discussion of radar meteorology in Chapter 8. It would seem to have been more logical to follow these chapters immediately with the sixth chapter which deals with refraction and diffraction by atmospheric suspensoids including the theories of rainbows, haloes and coronae.

The third chapter is a very useful discussion of visibility theory including the difficult problems of slant and horizontal visual range. Radiation and the heat budget of the earth are dealt with adequately in the fourth and fifth chapters.

Chapters 7 and 8 deal with the subject of cloud physics and the author is commendably cautious in distinguishing between experimental facts and the theories which have been devised to account for these facts. The two and a half pages devoted to the stimulation of precipitation by artificial means are in striking contrast to the vast amount of literature which has been published on the subject, but are certainly none the worse for that. Those pages do in fact summarize very fairly the present position in this much publicized field of operation. The section on radar meteorology is rather sketchy and deals mainly with the possibility of quantitative measurements of rain-water content of clouds without, however, dealing thoroughly with the many difficulties encountered in making and interpreting such measurements. The uses of radar in delineating precipitation patterns, in storm detection and in forecasting are presumably regarded as being outside the scope of the book. One statement should not however be allowed to go uncorrected (pages 250, 251); it is stated that half the power radiated by the antenna flows through the cross-section of the beam as usually defined. In fact virtually all the transmitted power is confined within the beam width.

Remaining chapters deal with atmospheric electricity, the ionosphere and ozonosphere and the upper atmosphere (that is, above about 25 kilometres).

The information is clearly presented, although occasionally an attempt at over-simplification makes the text rather discursive, and the numerous figures and diagrams are an asset. In all chapters use is made of papers published almost up to the date of publication of the book and the references and source books given are comprehensive and a useful guide to further study. The printing is excellent and almost entirely free from errors and the figures are particularly well reproduced. The problems set at the end of each chapter will no doubt be welcomed by examiners and are based on experimental results rather than artificially contrived. R. F. JONES

OXFORD UNIVERSITY

Jesus College.—The following election has been made:

Honorary Fellow.—Sir Graham Sutton, F.R.S.

THE WEATHER OF DECEMBER 1957

Northern Hemisphere

The Icelandic and Aleutian depressions were deeper than usual. The centre of the former was situated over the extreme north of Scandinavia and that of the latter over the Gulf of Alaska. Both the Azores anticyclone and the North Pacific anticyclone were more intense than usual and were displaced to the west. The centre of the Siberian high appeared to be near normal both in position and intensity but a marked ridge extended north-east from the centre.

Negative pressure anomalies were well-marked over northern Scandinavia and northern Russia and reached 16 millibars at a position 65°N. 60°E. A pressure anomaly of −13 millibars occurred over the Gulf of Alaska and associated negative anomalies extended across Western Canada into the centre of the United States. Pressure was higher than normal over a large part of the North Pacific Ocean; the greatest anomaly was + 13 millibars at approximately 40°N. 180°W.

Flow around the Canadian cold trough was weaker and of smaller amplitude than that usual for December. It is also to be noted that the north-westerly flow in the vicinity of the Davis Strait was rather weaker than usual.

The Arctic region was unusually cold and anomalies of −7°C. were reported in both Novaya Zemlya and Alaska. The main regions of positive temperature anomaly were across central Asia and across North America. The largest positive temperature anomalies in America occurred in the northern part of the United States; temperatures were 7°C. above normal just to the east of the Rocky Mountains. Similar anomalies were reported by a number of stations in Russia near the Urals at about 55°N. and also further east near Irkutsk. Other regions in which temperatures were 3°C. or more above normal were in eastern Europe, parts of India, parts of Japan and in Panama. Temperature anomalies over Europe and in the Mediterranean area were generally of the order of 1°C. either positive or negative.

The rainfall distribution over Europe was rather irregular but the amounts were near or greater than normal. Precipitation was appreciably greater than normal in Russia north of latitude 60°N. and also on the east of Asia as far south as 40°N. Over most of India, Burma and Indo-China rainfall amounts were negligibly small. The extreme northern regions of Canada and Alaska were drier than normal. Elsewhere in the North American Continent precipitation was rather above the average for the month.

WEATHER OF JANUARY 1958

Great Britain and Northern Ireland

For the first 11 days of the month frontal troughs and vigorous depressions moved eastwards across the British Isles but anticyclonic conditions prevailed from the 12th to the 16th. Northerly winds on the 18th initiated a week of freezingly cold weather with severe night frosts until, around the 25th, a southerly airstream brought a spectacular rise in temperature. Cold anticyclonic weather returned during the last two days of the month.

The fine, rather cold weather with which the year began in Scotland spread southwards across the whole country on the 2nd, but an unsettled milder type set in on the 4th as a large and deep depression from the Davis Straits reached the Iceland area, and associated troughs brought widespread rain and drizzle to most districts and snow to parts of northern England and Scotland. Changeable, rather stormy conditions were maintained for about another week by depressions which moved eastwards across the northern part of the British Isles on the 6th, 9th and 10th. Rain was widespread and locally heavy and wind frequently reached gale force, especially on the north and west coasts, during the passage of these depressions, but showery spells, with local hail and thunder, occurred between. The depression of the 6th brought an influx of very mild air with temperatures reaching the middle fifties over much of southern England, and on the 9th wind reached 81 knots in gusts at Tiree. An anticyclone moved towards the British Isles from the Azores on the 12th and weather was quieter for the next few days with fog in many areas. A vigorous depression near northern Scandinavia deepened further on the 16th and 17th, while an unusually intense anticyclone formed over Greenland. Northerly winds between these two features brought exceptionally cold air and snow showers to all parts of the British Isles while shallow polar depressions, embedded in the airstream, gave areas of more general snow. Temperatures in many northern districts remained below freezing day and night for nearly a week and there were severe night frosts generally. Negative air temperatures are rarely recorded in the British Isles, but on the 20th temperature fell to −2°F. at Driffield and on the 23rd, the coldest night of the spell, to −3°F. at Shawbury; −2°F. was also recorded the following night at Dyce near Aberdeen. Southerly winds soon afterwards brought a dramatic rise in temperature and a rapid thaw which, coupled with heavy rainfall, led to floods in many parts of the country; on the 25th, afternoon temperatures rose above 50°F. over the whole of the south-western part of the country and were maintained at that value throughout the night at some places and on the following day 60°F. was reached in North Wales. The mild weather, with rain, drizzle and hill and coast fog continued for three or four days but an anticyclone from the south-west became centred over England and Wales on the 30th and 31st and the month ended with a return to colder weather with widespread fog which was dense and persisted in some areas.

Temperature for the month was between one and three degrees below normal, both by day and night, over much of the country; in parts of Yorkshire it was nearly 5°F. colder than normal at night. The warmest day was the 6th in southern England but the 27th in the Midlands and North, when Llandudno, with 61°F. had the highest January temperature recorded in England and Wales since 1940. Rainfall was slightly below the 1916–50 average in England and Wales and also in Northern Ireland, but a little below in Scotland. Less than half the average occurred in East Lothian. Amounts elsewhere were mainly less than the average, but the average was exceeded over Cornwall, and over much of other southern counties and some eastern counties of England, and locally on the west and east coasts of northern England and Scotland. More than 150 per cent of the average was recorded in Oxfordshire and over the north-eastern part of Aberdeenshire.

Normal cultivation for all outdoor crops was held up to some extent during the first two weeks of the month by wind and rain, and it came to a standstill during the snow of the third week. The soil was well saturated throughout the month and flooded locally, following the rapid thaw around the 25th, but on the whole, work at the end of the month was fairly well up to date for the time of year. In the fruit orchards pruning and spraying was well in hand and prospects for spring vegetables appeared generally good.

WEATHER OF FEBRUARY 1958

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 ...	60	13	+1·2	179	+5	86
Scotland	56	−2	−1·7	115	+3	86
Northern Ireland ...	57	12	0·0	145	+2	85

RAINFALL OF FEBRUARY 1958

Great Britain and Northern Ireland

County	Station	In.	*Per cent of Av.	County	Station	In.	*Per cent of Av.
London	Camden Square Gdns.	2·55	153	*Carm.*	Pontcrynfe	8·02	174
Kent	Dover	3·60	175	*Pemb.*	Maenclochog, Ddolwen B.	5·23	112
"	Edenbridge, Falconhurst	2·85	116	*Radnor*	Llandrindod Wells ...	7·52	234
Sussex	Compton, Compton Ho.	3·25	113	*Mont.*	Lake Vyrnwy	9·03	151
"	Worthing, Beach Ho. Pk.	2·60	130	*Mer.*	Blaenau Festiniog ...	15·20	158
Hants.	St. Catherine's L'thouse	3·02	140	"	Aberdovey	7·77	236
"	Southampton, East Pk.	2·85	123	*Carn.*	Llandudno	5·04	232
"	South Farnborough ...	2·36	123	*Angl.*	Llanerchymedd ...	5·91	210
Herts.	Harpenden, Rothamsted	3·06	163	*I. Man*	Douglas, Borough Cem.	6·37	204
Bucks.	Slough, Upton ...	2·77	161	*Wigtown*	Newton Stewart ...	4·32	123
Oxford	Oxford, Radcliffe ...	2·57	144	*Dumf.*	Dumfries, Crichton R.I.	3·95	138
N'hants.	Wellingboro' Swanspool	3·10	183	"	Eskdalemuir Obsy. ...	5·03	109
Essex	Southend W.W. ...	1·89	136	*Roxb.*	Crailing...	2·18	125
Suffolk	Ipswich, Belstead Hall	2·59	164	*Peebles*	Stobo Castle	3·35	121
"	Lowestoft Sec. School	3·11	202	*Berwick*	Marchmont House ...	2·09	96
"	Bury St. Ed., Westley H.	3·32	195	*E. Loth.*	N. Berwick	2·55	174
Norfolk	Sandringham Ho. Gdns.	4·08	214	*Midl'n.*	Edinburgh, Blackf'd H.	1·65	98
Dorset	Creech Grange... ...	3·47	126	*Lanark*	Hamilton W.W., T'nhill	2·23	79
"	Beaminster, East St. ...	4·17	138	*Ayr*	Prestwick	3·32	140
Devon	Teignmouth, Den Gdns.	3·28	122	"	Glen Afton, Ayr San. ...	5·65	129
"	Ilfracombe	6·16	220	*Renfrew*	Greenock, Prospect Hill	3·46	68
"	Princetown	10·18	149	*Bute*	Rothesay, Ardencraig...	3·73	91
Cornwall	Bude	4·10	163	*Argyll*	Morven, Drimnin ...	3·88	86
"	Penzance	5·84	167	"	Poltalloch	4·10	92
"	St. Austell	6·59	162	"	Inveraray Castle ...	4·19	58
"	Scilly, St. Mary ...	4·13	152	"	Islay, Eallabus ...	4·92	129
Somerset	Bath	3·69	162	"	Tiree	3·48	112
"	Taunton	3·05	145	*Kinross*	Lock Leven Sluice ...	3·30	123
Glos.	Cirencester	4·00	163	*Fife*	Leuchars Airfield ...	2·34	137
Salop	Church Stretton ...	4·70	180	*Perth*	Loch Dhu	3·83	55
"	Shrewsbury, Monkmore	3·16	186	"	Crieff, Strathearn Hyd.	1·84	61
Worcs.	Worcester, Diglis Lock	4·12	242	"	Pitlochry, Fincastle ...	2·21	80
Warwick	Birmingham, Edgbaston	4·94	224	*Angus*	Montrose Hospital ...	2·34	125
Leics.	Thornton Reservoir ...	3·09	147	*Aberd.*	Braemar	3·30	123
Lincs.	Cranwell Airfield ...	2·69	162	"	Dyce, Craibstone ...	3·90	173
"	Skegness, Marine Gdns.	3·48	227	"	New Deer School House	3·68	155
Notts.	Mansfield, Carr Bank...	3·54	174	*Moray*	Gordon Castle	3·23	176
Derby	Buxton, Terrace Slopes	7·77	196	*Inverness*	Loch Ness, Garthbeg ...	2·21	67
Ches.	Bidston Observatory ...	4·00	207	"	Fort William	3·58	50
"	Manchester, Ringway...	4·34	183	"	Skye, Duntulm... ...	3·25	83
Lancs.	Stonyhurst College ...	8·96	246	"	Benbecula	4·28	142
"	Squires Gate	5·73	263	R. & C.	Fearn, Geanies ...	1·89	143
Yorks.	Wakefield, Clarence Pk.	4·34	205	"	Inverbroom, Glackour...	7·34	156
"	Hull, Pearson Park ...	4·22	231	"	Loch Duich, Ratagan...	6·00	95
"	Felixkirk, Mt. St. John...	3·80	187	"	Achnashellach	7·26	107
"	York Museum	3·56	212	*Suth.*	Stornoway	3·54	132
"	Scarborough	4·10	228	*Caith.*	Lairg, Crask	4·54	106
"	Middlesbrough... ...	2·84	180	"	Wick Airfield	5·01	251
"	Baldersdale, Hury Res.	6·32	201	*Shetland*	Lerwick Observatory ...	2·31	70
Nor'l'd	Newcastle, Leazes Pk....	4·67	265	*Ferm.*	Belleek	4·76	145
"	Bellingham, High Green	2·82	110	*Armagh*	Armagh Observatory ...	3·90	176
"	Lilburn Tower Gdns. ...	3·53	160	*Down*	Seaforde	4·77	167
Cumb.	Geltsdale	4·16	170	*Antrim*	Aldergrove Airfield ...	3·76	157
"	Keswick, High Hill ...	5·99	143	"	Ballymena, Harryville...	4·35	149
"	Ravenglass, The Grove	5·32	184	*L'derry*	Garvagh, Moneydig ...	5·05	178
Mon.	A'gavenney, Plâs Derwen	7·30	214	"	Londonderry, Creggan	4·84	153
Glam.	Cardiff, Penylan ...	5·75	192	*Tyrone*	Omagh, Edenfel ...	3·68	116

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