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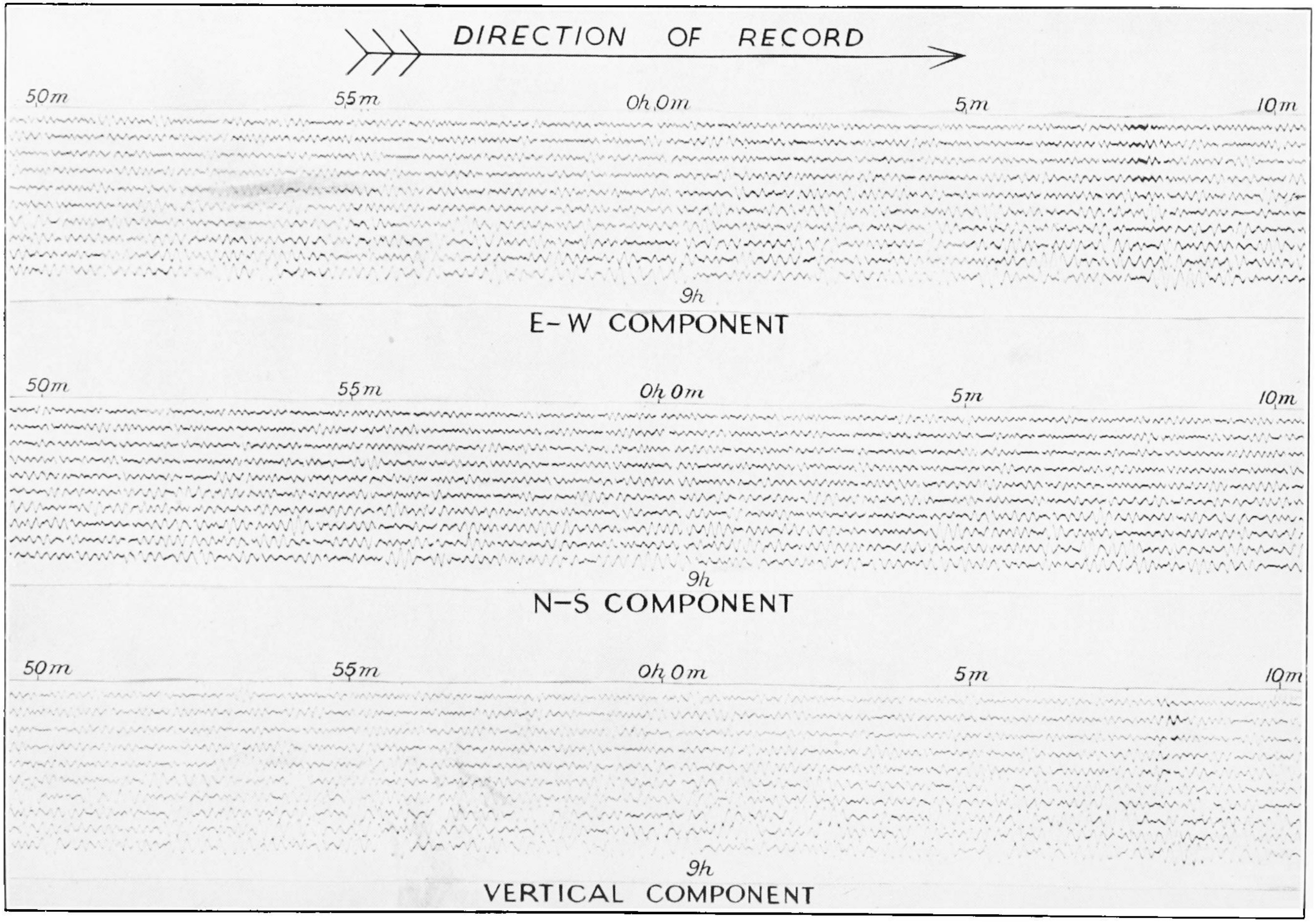

FIG. I.—MICROSEISMS RECORDED AT KEW OBSERVATORY, NOVEMBER 28TH, 1938

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MICROSEISMS AND WEATHER

By A. W. LEE, D.Sc.

Microseisms are the minute oscillations of the ground so aptly represented by the German designation *Bodenunruhe*, literally ground unrest. Long before seismographs were invented it had been noticed that in certain delicate experiments the instruments were disturbed owing to persistent movements of the ground. Early in the nineteenth century Kater found that determinations of gravity from pendulum observations in London were affected by these vibrations. Mention may also be made of the attempts of G. and H. Darwin to measure the effect of lunar attraction upon gravity; the experiments were carried out at Cambridge from 1880 to 1882, but had to be abandoned owing to the incessant vibration of the ground. More recently, since seismographs have been brought into use for detecting the tremors from earthquakes and continuous records of the earth movements have been obtained, much has been learned about the nature of the microseisms and the causes which produce them. It has been found that the effects of traffic or machinery in the vicinity are generally shown in the seismograms as a series of very rapid oscillations of periods not more than a second or two; at some observatories rather irregular oscillations with periods greater than about 10 seconds can be attributed to local strong winds and possibly also to frost. The most regular and most widely observed movements, however, are those with periods 3 to 10 seconds. These movements, which are nearly always visible in the records of sensitive seismographs, are larger in winter than in summer. It has been established that they are generated from storms and are not related to local causes. Throughout the remainder of this article the term microseisms is restricted to these movements, sometimes referred to as " ordinary " microseisms.

Fig. 1 shows typical records of microseisms obtained from the Galitzin seismographs at Kew Observatory. Three components of the earth movement are recorded—the vertical, and the horizontal in the directions north–south and east–west; the time interval between the successive breaks in the records is exactly a minute. These records were obtained during the early hours of 28th November, 1938, when there was a progressive change in the microseisms, the amplitudes* increasing from about 3μ at 0h. to about 10μ at 9h. and the period lengthening from near 6 sec. to over 9 sec.

Microseisms occur in all parts of the world. The amplitudes and periods of the waves recorded at any observatory are continually changing, and there are occasions when the movements are exceptionally large; during these " microseismic storms " the disturbances are widespread, vibrations of nearly the same period being recorded, for instance, throughout the whole of northern Europe and western Siberia or over the greater part of North America. The observations which have been made of the microseisms over such large areas show that the amplitudes of the earth waves diminish as the disturbances are propagated to greater distances; for example, the amplitudes may exceed 10μ at 500 miles from the storm centre and fall off to 2μ at 2,000 miles.

The most satisfactory records for the study of microseisms are those obtained from instruments which record photographically. In seismographs with mechanical registration there is friction between the stylus and the smoked sheet, which is neglected in the calculation of the ground movement corresponding with a given displacement on the record, and the amplitudes tend to be underestimated. The uncertainties due to friction add considerably to the difficulties of determining the genuine differences between the amplitudes in different regions. It has also been found that, at some observatories with seismographs recording mechanically, the amplitudes of the microseisms are systematically larger by day than in the night, although the amplitudes obtained with photographic recording do not show any regular variations throughout the 24 hours. Dr. Whipple has suggested that the friction, inherent with mechanical registration, may change regularly, being overcome by day when there are very rapid oscillations of the ground due to traffic, etc. The diurnal variations would be greatest at observatories subject to these influences; examples supporting this suggestion are found at Copenhagen where with little disturbance near the seismographs there are no diurnal variations, and at Hamburg where traffic passes near the observatory and the variations are large.

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* The amplitudes are expressed in microns, the micron (1μ) being 0·001 mm.

Lord Rayleigh was responsible in 1881 for the development of the theory of propagation of waves along the surface of a solid. The

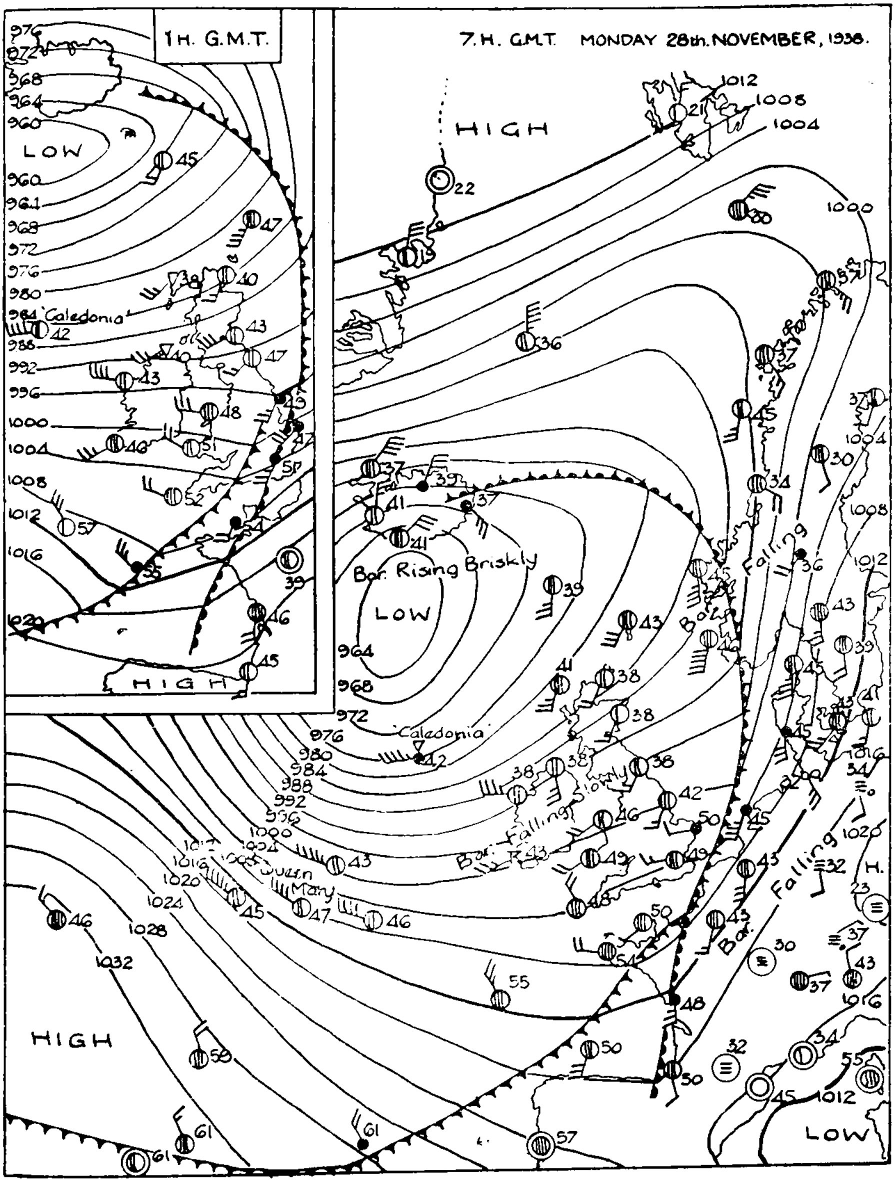


FIG. 2.—SYNOPTIC CHARTS, NOVEMBER 28TH, 1938

(*See explanatory notes on page 141*)

waves he investigated are in some respects analogous to gravity waves on water, but for a solid the wave motion is controlled by the elastic properties instead of by gravity; the motion of the particles, as the waves pass a given point, is in the vertical plane containing the direction of propagation. From comparisons between the horizontal and vertical components of the microseisms it has been demonstrated that the movements are elastic waves of Rayleigh type travelling through the outer layers of the earth's crust. These waves are subject to changes of type according to the local geological conditions, being large at a place like de Bilt on weak formations and small at one like Abisko on rock. In preparing maps, of the type shown in Figs. 3 & 4, to represent the microseismic distributions for particular occasions, it is necessary to make allowance for the effects of local conditions. The amplitude shown on one of these maps for any particular observatory is intended to be that which would have been recorded if the surface layers in the vicinity had been transformed into solid rock.

In Rayleigh waves the earth particles move round ellipses or circles in a vertical plane, and the direction of motion is opposite to that of a point on a wheel rolling along the ground in the direction of propagation of the waves. Thus if Rayleigh waves are coming from the west the earth moves in succession eastwards, upwards, westwards and downwards. We may say that the vertical component of motion lags 90° behind the east component. Actually the phase differences between the components are variable but the values appropriate for the general direction of approach are dominant. The method has been applied to determine the direction of approach of the microseisms shown in Fig. 1; in a sequence of 50 phase comparisons at minute intervals from 6h. 35m. to 7h. 24m. on November 28th, 1938, the vertical component tended to be 90° in advance of the north component and 90° behind the east component; this result implies that the microseisms were then reaching Kew from the north-west, the direction to the centre of the depression which was the most conspicuous feature of the weather map for that time (Fig. 2).

The general similarity between the characteristics of the microseisms and those of the sea waves, and especially the close agreement between the periods, led to the belief that the phenomena are related, and the theories which have been propounded to explain the origin of microseisms have mostly endeavoured to show how they could be generated from the waves caused by depressions over adjacent seas.

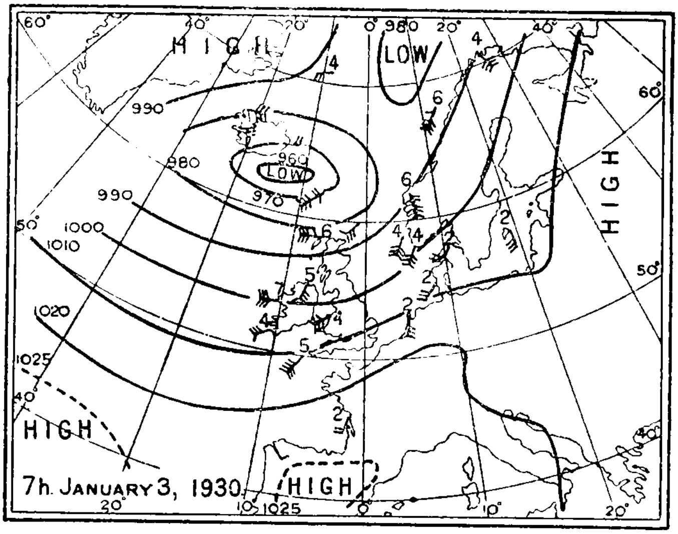
The best known hypothesis was developed by Wiechert, Linke and Gutenberg. The microseisms are attributed to the sea waves breaking on steep rocky coasts. Gutenberg believes that the microseisms are best developed in Europe and in North America when depressions are situated off the coasts, and that storms over the continents do not generate microseisms. He claims that the large microseisms recorded in Europe are mainly caused by the beating of waves along the precipitous western coast of Norway. A steep rocky coast is postulated in this hypothesis to ensure that the waves break violently and transfer the energy to the ground with a minimum amount of friction. Gutenberg has considered the order of magnitude of the quantities involved in the process and concludes that the energy transferred to the coast by the breakers is large enough to cause the microseisms. No exact explanation of how the surf sets the ground in oscillation is given, but presumably Gutenberg envisages each breaker as a tiny earthquake generating surface waves. A difficulty at once confronts such an hypothesis, for the impact of the waves would not occur simultaneously along the whole coastline affected, and consequently the agreement between the periods of the microseisms and of the sea waves is not explained.

Among the opponents of this hypothesis are S. K. Banerji and E. Gherzi, who have noted occasions on which large microseisms were recorded when the seas near the coasts were undisturbed. Banerji has shown that with a storm approaching India from the Bay of Bengal the largest microseisms occur several hours before it reaches the coast, and that the microseisms diminish when it crosses the coastline. To explain these observations Banerji put forward the hypothesis that the sea waves cause changes of pressure over the sea bed, thus setting up forced oscillations which are propagated as microseisms when they reach the coast. The difficulty encountered in this type of explanation is that the sea waves are superficial phenomena and diminish rapidly with the depth ; this is illustrated, for example, from experience with submarines. Gherzi has shown that large microseisms are recorded at Zi-Ka-Wei in China when there are cyclones in the surrounding regions, but not when the sea waves are due to high monsoon winds. The hypothesis which he put forward, and which has been elaborated by D. Bradford, is that the microseisms are caused by atmospheric oscillations or " pumping " near the centre of a cyclone. It is thought that the atmospheric oscillations not only generate microseisms when the storms pass over the land, but that they are also effective over the oceans, the oscillations being propagated through the water to the sea-bed and there transformed into microseisms.

The connexion between microseisms and weather is so well established that in some parts of the Far East the observations of microseisms give indications of the development of storms over the oceans and are a valuable aid in forecasting. Observations of microseisms at de Bilt were utilised in Holland during the war when meteorological reports for the Atlantic were not available, and the method was found to be useful under these difficult conditions. Really satisfactory results cannot be expected, however, from such applications until the mechanism of the production of microseisms is better understood, and there are some perplexing characteristics which are inexplicable with the current hypothesis. The deep depression, appropriately situated, is a necessary condition for the development of microseisms, but some other agency or combination of circumstances must be involved, and at present we have no idea of what this can be. The difficulty is apparent from our maps for

November 28th, 1938 (Fig. 2); from 1h. to 7h. on that day, while the microseisms were increasing, there was not any change in the

PRESSURE, WIND AND SEA DISTURBANCE



HORIZONTAL "STANDARD AMPLITUDES" OF THE MICROSEISMS

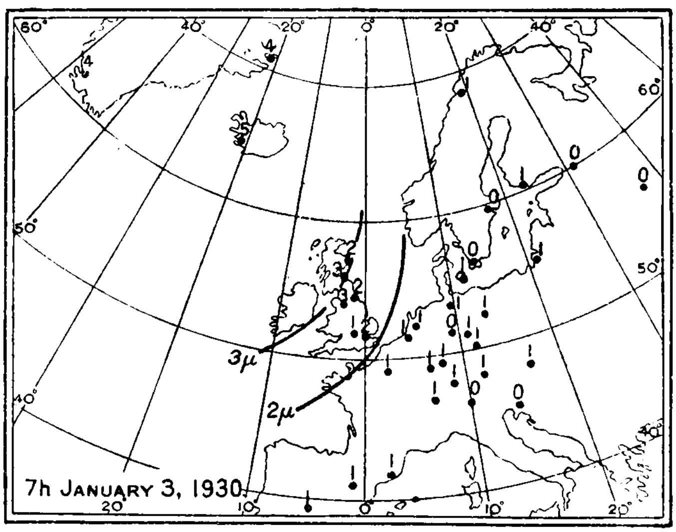


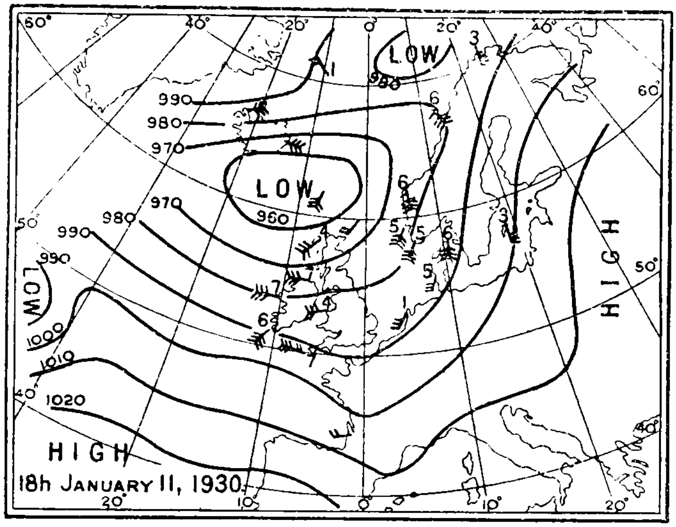
FIG. 3.—METEOROLOGICAL CONDITIONS AND PREVALENCE OF MICROSEISMS

(Pair of charts for January 3rd, 1930)

intensity of the depression south of Iceland and the winds over the British Isles were diminishing.

Moreover, deep depressions, of the same type and located over the same parts of the oceans, are not equally effective in producing

PRESSURE, WIND AND SEA DISTURBANCE



HORIZONTAL "STANDARD AMPLITUDES" OF THE MICROSEISMS

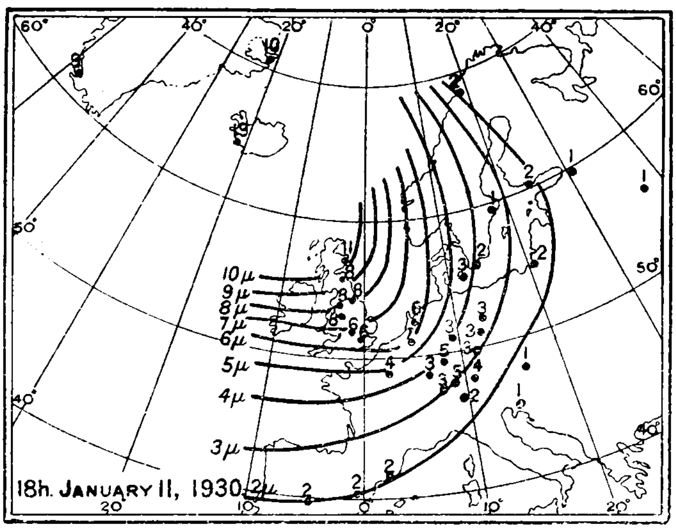


FIG. 4.—METEOROLOGICAL CONDITIONS AND PREVALENCE OF MICROSEISMS

(Pair of charts for January 11th, 1930)

microseisms. An excellent example is found in a comparison of the conditions round north-western Europe on January 3rd and January

11th, 1930. The synoptic charts and maps of the microseismic distributions for these two occasions are shown in Figs. 3 & 4. The synoptic charts for the two days are very similar, each showing a deep depression between Scotland and Iceland and a secondary off northern Norway, with strong winds and rough seas round north-west Europe. The lines of equal microseismic activity conform with the run of the isobars, but there is a striking contrast between the amplitudes of the microseisms, those for the earlier occasion being only about a third of those for the latter. Similar anomalies have been noticed in other parts of the world, and until these can be explained the problem of microseisms remains a challenge to meteorologists and seismologists alike.

PRESENTATION TO MR. R. G. K. LEMPFERT

Mr. R. G. K. Lempfert, Assistant Director of the Meteorological Office, retired on Saturday, December 31st, 1938, after more than 36 years service. A presentation from the staff of the Office was made to Mr. Lempfert in the Library at South Kensington on December 30th.

Mr. N. K. Johnson, Director, presided and spoke of his own indebtedness to Mr. Lempfert for his assistance during the preceding 4 months; and of the reputation for courtesy which Mr. Lempfert had gained. He then asked Mr. E. Gold, Assistant Director, who had been for so many years a colleague of Mr. Lempfert's, and Mr. Tarrant, who entered the office a few days before Mr. Lempfert, to speak. Mr. Gold said:

"Mr. Lempfert entered the Meteorological Office on May 1st, 1902—as Scientific Assistant to the Director, Dr. W. N. Shaw—particularly for scientific investigations with reference to forecasts of weather. He had been one of the workers at the Cavendish Laboratory in the Golden Lustrum 1896–1900 when among others, Langevin, Lyman, McLennan, Zeleny, the Wilsons—H. A. and C. T. R., Townsend, V. W. Richardson and Ernest Rutherford were there. He was soon busy in the Office completing Carpenter's London Fog Inquiry, investigating with Dr. H. R. Mill a fall of red rain and arranging for experiments with a captive balloon at Bushy House to provide information about the vertical distribution in fog.

The fog report called attention to the gravity and difficulty of the various problems associated with the atmosphere of London and the extent to which they are aggravated by the common practice of the inhabitants as regards the production of smoke. The red constituent of the red rain was traced back to North West Africa—by the method of trajectories—then being explored by Lempfert and Shaw. The balloon blew away with its instruments to the north coast of France, whence it was subsequently brought back in a somewhat damaged condition by Mr. Pigeon, Master of the coasting schooner *Eagle*—an appropriate example of our national capacity for arranging a humorous setting for events which might be "cause for tears". The investigation culminated in the "Life History of Surface Air Currents", the classic foundation of frontal and air-mass meteorology.

[*Facing page 324*

R. G. K. Lempfert, C.B.E., M.A.

Although it had been expressly stated when the Scientific Assistant to the Director was appointed, that he was not expected to take part in the administration of the office, he was soon inspecting stations, and on July 31st, 1905, he became acting Superintendent of Instruments. In 1906 (March 31st) he became Superintendent of Statistics, and in that capacity I first met him and learned from him that the correct way for me to reply to letters was to impute my own lame efforts to the Director by beginning : " I am instructed by the Director to ....". It was Lempfert, too, who introduced me to the Royal Meteorological Society.

In 1910 (October 1st) he became Superintendent of the Forecast Division—in the then palatial new office, whose polished floor induced a passion for cyclo-strophic motion. I think he was the first to introduce to the Division the idea that the smoothest curves were not necessarily the best isobars, and that observations which indicated a discontinuity of direction in the isobars were not due to the observer's ignorance and incompetence, but constituted an important aid to forecasting. Naturally it was not easy for him to get new ideas put into operation—it never is. Almost before he could turn round he had to adapt the service to millibars and millimetres, and no sooner were the new arrangements running smoothly than the war came—and all the developments which observations from the Atlantic offered were arrested. If the synoptic meteorologist of to-day—accustomed as he is to extensive charts every 6 hours and intermediate charts for smaller areas—could look at the charts of 1915, he might wonder how any forecast in those days could be right. Well, Mr. Lempfert produced the goods—organized 1 a.m. reports, comforted those in anxiety or distress, and showed a considerateness and approachableness which made everyone go to him for advice and help in their difficulties. (I still treasure the pocket medicine case he gave me in 1915 when I left for a half-known destination.)

In 1919 he was made Assistant Director. In the new organisation he became responsible for personnel and publications—among other things. In the first his insight into character and his considerateness have earned him the affection and respect of all and in the second his early training in physics and his wide experience in all the branches of meteorology have been of the greatest service to the increasing number of authors of scientific memoirs among the staff of the office.

One or two incidents—Lempfert was the first to give meteorological lectures for airmen—at the Central Flying School, Upavon, when Trenchard (now Lord Trenchard) was Commandant—and we all gathered to celebrate their successful conclusion by a dinner paid for out of the honorarium. The balance I believe went in a fiddle.

I remember when Dr. Hesselberg, now President of the International Meteorological Committee, proposed in 1925 to resign from his position as Secretary of the International Upper Air Commission, and was besought to continue, he agreed only on condition that Mr. Lempfert would be Joint Secretary with him—and that was typical. "

Mr. Tarrant referred especially to the early days when a typewriter was a person and not a machine, and to the introduction of night work in the Forecast Division during the war, when the tedium of intervals between the preparation of forecasts and reports was relieved by violin solos.

Mr. Johnson then asked Mr. Lempfert to accept a book of signatures of the staff and a cheque, with the good wishes of all.

Mr. Lempfert in reply expressed his appreciation of the gift, and referred to the happy relations which he had always had with the staff.

The proceedings terminated with a presentation to Mrs. Lempfert in recognition of her contributions to the success of many social functions of the office.

MR. R. CORLESS

Following upon the retirement of Mr. R. G. K. Lempfert, Mr. R. Corless was promoted to the rank of Assistant Director of the Meteorological Office as from January 1st, 1939. Mr. Corless is a native of Lancashire and entered the Preston Grammar School in 1897. He proceeded to Cambridge as a Scholar of Sidney Sussex College in 1903, and took his B.A. degree in 1906, proceeding later to M.A. In the Mathematical Tripos, Part I, 1906, he was sixteenth wrangler and he also obtained a First Class, Natural Sciences Tripos, Part I, 1907.

Mr. Corless joined the staff of the Meteorological Office in October, 1907, as Special Assistant to the Director, Dr. W. N. Shaw (now Sir Napier Shaw). He became Clerk of Publications in 1910 and Secretary to the Director in 1913. After serving for a time as Acting Superintendent of Statistics, Mr. Corless was appointed Superintendent of Instruments in 1916. Under war conditions there was a great increase in the scope of the work of the Instruments Division, and Mr. Corless's services were recognized by the award of the Order of the British Empire (O.B.E.) in 1918. Since the war he has occupied in succession the posts of Superintendent of the British Climatology Division and British Rainfall Organization (1925), the Forecast Division (1929) and the combined Forecast and Aviation Divisions (1934). He was Secretary of the Royal Meteorological Society from 1924 to 1926 and Vice-President in 1927.

Among the papers of which Mr. Corless was author or joint author, special references may be made to the paper on "Line Squalls and Associated Phenomena" written in collaboration with Mr. R. G. K. Lempfert and published in Q.J.R. Meteor Soc., 1910, page 135.

During his long and varied career Mr. Corless has gained practical experience of nearly every aspect of meteorological work and we wish him all success in his new post.

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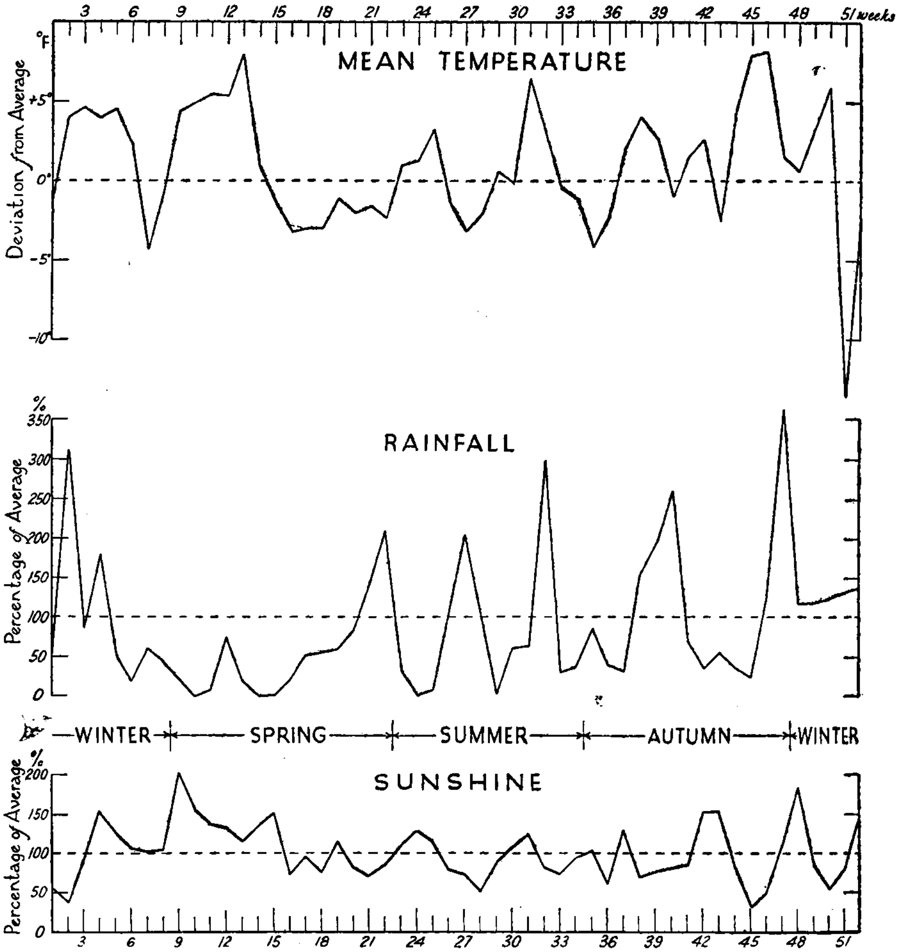
R. Corless, O.B.E., M.A.

The Weather of 1938

Great variability marked the weather of the year in the British Isles. Among the most notable features were the magnificent display of aurora observed throughout the British Isles on the evening of January 25th, the exceptional mildness of March and November, the drought of February to April, the severe gales at the beginning and end of June, the remarkable series of thunderstorms during the period August 1st to 12th and the severe frost and widespread snow of December 17th to 26th. From the limited information at present available it appears that mean temperature for the year exceeded the average generally, while sunshine was below the average on the whole, though an excess occurred in some small scattered areas. A detailed description of the rainfall distribution is given in a subsequent article.

Mean temperature for the year exceeded the average. Of the individual months, May and July were cool and mean temperature in December was also below the average owing to an exceptionally severe spell of wintry weather from the 17th to the 26th. The coolness of May was most marked in the east and south-east of England, while that of July was most pronounced in Ireland and in the western half of England. Keen frosts were registered at times during the first ten days of May; a screen minimum of 18° F. was recorded at Braemar on the 2nd and at Thetford, Norfolk, on the 8th. During the cold spell of the 17th to 26th of December, temperature was continuously below the freezing point in some areas for several days. In the other nine months temperature exceeded the average on the whole though April was cool in east and south-east England and June in Ireland and west Scotland, while during a cold spell in February snow lay continuously at Canterbury from the evening of the 13th to the morning of the 18th. March, November and the first half of December were unusually mild. March was by far the warmest March on record for the British Isles generally and November was also exceptionally mild. In many places the absolute maximum temperature recorded in November, registered as a rule on the 4th, 5th or 6th, was the highest on record for November; at a number of stations in east and south-east England 70° F. was registered on the 5th. January was also mild; at numerous places in England, temperature in the screen did not fall to 32° F. throughout the month. A warm spell occurred during the first 12 days of August; a maximum temperature of 80° F. or above was registered at some station or other on each of these days. The highest temperature of the year was recorded in each country during this spell, namely 87° F. at Camden Square (London) and at Reading on the 1st, 82° F. at Ardtornish and Ruthwell on the 10th and at Fort Augustus, Kilmarnock and Forres on the 11th and 78° F. at Birr Castle and Foynes on the 3rd.

Sunshine was almost everywhere deficient; there was an excess, however, in parts of Scotland, at a few places in south-east England and locally in north-west England. January was sunny in east Scotland and north-east England but excessively dull locally in the north of Ireland, March was unusually sunny in east and south-east England and the Midlands and markedly dull in the west and north of Scotland and April was exceptionally sunny in western districts.



THE WEATHER IN 1938 IN SOUTH-EAST ENGLAND

Weekly variations from long period averages computed from observations at five representative stations.

The summer months May to September were dull on the whole, particularly July ; a notable excess was enjoyed, however, in Scotland and locally in north Ireland in August. Broadly speaking, in October, sunshine exceeded the average in the eastern districts of Great Britain and the Midland counties of England and was somewhat deficient in the west. In November sunshine was very variable, and December was mainly sunny ; at Valentia Observatory it was the sunniest December in a record back to 1880.

Gales occurred frequently during the year and were unusually severe at times. Amongst the highest speeds recorded in gusts were 108 m.p.h. at St. Ann's Head, Pembroke on November 23rd, 104 m.p.h. at St. Ann's Head on October 4th, 101 m.p.h. at St. Ann's Head on January 15th and at Bidston on January 29th and 100 m.p.h. at Kirkwall on January 23rd. The gales of January 14th to 15th, of June 1st to 2nd and 27th to 29th and of November 23rd are described on pages 4, 139 and 306.

The diagram on page 328 shows the weekly variations in temperature, rainfall and sunshine in south-east England in 1938. The variations are given in the form of deviation from the average of temperature and percentages of the average of rainfall and sunshine. The district value is the arithmetic mean of the values for the following stations:—Kew Observatory, Margate, Hastings, Southampton and Marlborough.

L. F. Lewis.

The Rainfall of 1938

The rainfall of 1938 presents features of unusual interest, both as regards the incidence of rainfall throughout the year and the variation in the annual totals from place to place. Over the British Isles generally the three months February to April were unusually dry; the summer months May, June and July gave more than the average, June being especially wet in Scotland; while October and November were unusually wet.

The distribution of the rainfall in 1938 stands out in sharp contrast with that of the previous year, when January to May gave more rain than in any similar period back to 1870, while for the remainder of the year dry months predominated. A comparison of the rainfall during the two years for the periods January to May and June to December is given below:—

	British Isles.	
	Jan-May	*June-December*
	in.	in.
Average...	15·4	26·0
1937	21·9	21·2
1938	13·2	32·3

General values for each month are set out in the following table, both as percentages of the average and in inches of rainfall.

The rainfall of March was most remarkable over England and Wales. The general rainfall was 0·7 in., the smallest value for March since 1870 with but two exceptions *viz.* those of 1893 and 1929 with 0.6 in. and 0·3 in. respectively. The general rainfall for April over England and Wales amounted to only 0·3 in. and so far as can be ascertained April, 1938 was the driest April since before 1727. The driest months since 1870 are February, 1891, June, 1925, April, 1912 and March, 1929 with 0·1, 0·1, 0·3 and 0·3 in. respectively. April, 1938 ranks therefore amongst the five driest months on record since 1870. The rainfall of the three months

	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
	%	%	%	%	%	%	%	%	%	%	%	%
England and Wales	147	52	27	13	124	96	115	100	94	126	141	121
Scotland ...	162	80	97	34	136	201	143	68	127	186	157	84
Ireland	144	66	65	7	139	155	163	83	105	193	156	105
British Isles ...	150	62	52	17	130	133	132	89	105	154	147	109
	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.
England and Wales	4·4	1·3	·7	·3	2·9	2·3	3·3	3·4	2·4	5·0	4·9	4·7
Scotland ...	7·9	3·4	3·9	1·0	4·1	5·7	5·4	3·1	5·1	9·1	8·3	4·9
Ireland	5·8	2·3	2·2	·2	3·8	4·4	5·5	3·5	3·3	7·9	6·7	5·2
British Isles ...	5·7	2·0	1·7	·4	3·4	3·5	4·3	3·4	3·2	6·6	6·2	5·1

February to April, 1938 over England and Wales amounted to only 2·3 in., less than in any similar period back to 1785, when the general rainfall was estimated to be 2·1 in. Further details of this spring drought are given on pp. 81–84.

The general rainfall over the British Isles for October and November was 12·8 in., exceeding that for any similar period since before 1870, the October and November of 1929 giving 12·6 in.

The range in the monthly totals reported during the year was from 0 to 50 inches. During the whole of April numerous areas in southern Ireland, in parts of Hampshire, Dorset, Cornwall and Pembroke received no measurable rain. On the other hand as much as 50·03 in. was recorded at Loan, above Loch Quoich, in Inverness-shire for March.

Of the daily amounts recorded during the year mention should be made of the following :—

Watendlath Farm, Cumberland ...	5·95 in.	July 29th.
Torquay (Abbey Gardens) Devon...	5·61 in.	August 3rd.
Kinlochquoich, Inverness-shire ...	5·35 in.	February 3rd.
East Overton House, Lanark ...	5·10 in.	August 11th.

Details of the thunderstorm rains of August 1st to 12th are given on pp. 202–4.

Provisional estimates of the general rainfall for 1938 are given below, both in actual inches and as percentages of the average :—

	in.	Per cent.
England and Wales	35·6	101
Scotland...	61·9	123
Ireland	50·8	117
British Isles	45·5	110

The rainfall over Scotland was most remarkable. Only four years since 1870 were as wet or wetter than 1938, viz., 1872, 1877, 1903 and 1928 with 134, 131, 129 and 123 per cent. respectively. Over both Ireland and the British Isles as a whole 1938 ranks as the wettest year since 1930. The rainfall over England and Wales slightly exceeded the average, but was less than that since 1934.

Falls of less than 80 per cent. were confined to the east of Norfolk, east Berkshire and the north of Hampshire. There was less than the average over most of England to the south of a line from Liverpool to Lincoln, near Durham, Berwick-on-Tweed, in the north of Aberdeenshire and Banffshire, and near Cork. Over most of Devon and Cornwall, however, the totals exceeded the average, more than 110 per cent. being recorded from Bideford to Torquay, in the region of heavy rain on August 3rd and 4th. Over the Pennines and the area to the west the rainfall exceeded 110 per cent. and there was more than 130 per cent. in the English Lake District. At Keswick, October and November together gave 28·3 in. or more than half the average for the whole year. October, 1938 ranks as the wettest month on record there since December, 1852.

The rainfall exceeded the average over most of Wales, and there was more than 110 per cent. along the south coast and from Montgomery to Anglesey. The totals over the western half of Scotland generally exceeded 120 per cent. and large areas received more than 150 per cent. near Paisley and from Fort William to Inveraray. At Inveraray Castle the total was 143·8 in. and 66·6 in. or 86 per cent. in excess of the average. In Ireland the percentages were generally greater in the west and north, where values exceeding 120 per cent. were widespread. There was more than 130 per cent. at Limerick, Birr Castle, Londonderry and to the north-west of Galway.

In parts of the Western Highlands of Scotland 1938 ranks as the wettest year since before 1868. The value of 186 per cent. for Inveraray Castle is, so far as can be ascertained, the largest value for any station since before 1868. The wettest period was the 60 days, October 2nd to November 30th, with 44·0 in. or 57 per cent. of the average for the whole year. The 12 days, October 2nd to 13th, gave 14·1 in. or more than one-sixth of the annual average.

J. GLASSPOOLE

Royal Meteorological Society

By arrangement with Messrs. Science Films, Ltd., the usual monthly meeting of the Society was held on Thursday, December 15th, 1938, at the Gaumont British Theatre, Film House, Wardour Street, London, W.1. Dr. B. A. Keen, F.R.S., President, was in the Chair.

By the courtesy of the Air Council, two meteorological instructional sound films, "Fog" and "Ice Formation", were shown. These were followed by a discussion.

The Physics of the Atmosphere

By Professor D. Brunt

The making of a research meteorologist is a long, often tedious, and sometimes painful process. The young man who aspires to become a research worker in meteorology must first master the general outlines of the physics and dynamics of the atmosphere, while also acquiring a clear idea of the limitations of the methods of observation used in meteorology. When, in the next stage of his progress, he desires to acquire more than a textbook acquaintance with some particular branch of the subject in which he wishes to specialise, he finds the most serious obstacle to progress in the lack of a complete and reasonably compact account of this branch. In pure physics the needs of the research worker have been largely met by such series of books as Methuen's monographs, and the *Reports on Progress in Physics* published by the Physical Society of London. But in meteorology the corresponding needs have in the past been very inadequately provided for. The book under review meets this want in five sections of the Physics of the Atmosphere.*

The present volume, the third of the series, entitled *Ergebnisse der kosmischen Physik*, under the general editorship of Dr. V. Conrad of Vienna, is in five sections, each by a different author, dealing respectively with the physics of the higher atmosphere, the investigation of cosmic rays during the last five years, " Dämmerungsforschung," atmospheric condensation nuclei, and the vertical distribution of ozone.

The first section, by J. Zenneck of Munich, deals mainly with the ionosphere, describing the methods of investigation, the measurements which have been made of the ionisation, the difference between ionisation by waves and corpuscles, the distinction between the corpuscular and visual eclipses of the sun, and the interpretation of the variations of ionisation in terms of the variations of pressure and temperature in the upper layers of the atmosphere.

In the second section, R. Steinmaurer of Innsbruck describes the advances made in the investigation of cosmic rays during the last five years. These advances he describes as in the main consisting of an increased knowledge of the facts of observation, the ultimate problem of the origin of the rays and of the exact nature of their interaction with matter being still obscure.

In the third section, P. Gruner of Berne describes the study of the changes in colour of parts of the sky when the sun is below the horizon, including sunset glows, the purple light, and the brightness of the night sky. These are parts of what is known in German as " Dämmerungsforschung ".

* *Ergebnisse der kosmischen Physik*, **III**, hrsg. von V. Conrad. Leipzig, Akademische Verlagsgesellschaft, M.B.H.

The fourth section alone is written in English, and is by H. Landsberg of Pennsylvania. It deals with condensation nuclei, and gives by far the most comprehensive account of what is known of their nature, distribution and effects on condensation. The author begins with a discussion of the physical process of condensation, considering in turn the effects of curvature of the surface, hygroscopic action, and electric charge. The origin and chemistry of nuclei are then discussed, and the author gives a very complete account of the methods used for the observation of nuclei, the diurnal and annual variation of their number, their distribution over the globe, and their correlation with other meteorological factors. An appendix gives a table of nuclear concentrations made by various authors at 170 land stations, and in 36 oceanic areas.

In the fifth section, by F. W. Paul Götz, we find a very complete discussion of the vertical distribution of ozone in the atmosphere. The author begins with a valuable discussion of the spectrum of ozone in the ultra-violet, in the Chappuis bands in the green, and in the infra-red, followed by a description of the spectrum of oxygen in the far ultra-violet. These descriptions of spectra are very pertinent to the discussion which follows, but are not readily accessible to most readers. The account which follows, of the latest methods used for the observation of ozone in the atmosphere, and of the theory of the interpretation of the observations of ozone absorption in terms of the vertical distribution, is in sufficient detail to enable the reader to understand the details of the computation of the vertical distribution of ozone. It will be noted that the different methods of observations, whether by measurement of absorption made at the ground, as is done by Dobson and his collaborators, by spectographs sent up on sounding balloons, as is done by Regener, or by direct photography of the spectrum, as was done on board the *Explorer II*, the American stratosphere balloon, all lead to substantially the same distribution of ozone in the vertical. The theories of the formation and distribution of ozone due to Chapman and to Mecke, and the computations of the effect of ozone absorption on the vertical distribution of temperature in the atmosphere, are also briefly but clearly summarised.

It is not possible in the space available in a review to summarise effectively the contents of a volume which might itself be described as a summary of a vast amount of work in the fields of activity mentioned, and all that can be done is to give an indication of the scope of the volume. The literature of the subjects covered in this volume has hitherto only been available in a scattered form, often in publications which are not readily available to most readers. The editor of the book may, therefore, be congratulated on having produced a volume which will meet the needs of many workers, and will not fail to provide a stimulus for further research into the many problems discussed in it. The five sections are each followed by a bibliography, which total over 1,700 references. This may be taken as some indication of the amount of work involved in the compilation of this volume.

Correspondence

To the Editor, *Meteorological Magazine*

Snow in the Chiltern Hills after Thaw

On December 29th, 1938, there was just the right amount of snow left from the heavy Christmas falls in the south-east of England to show up interesting topographical relationships. Thus in the course of a railway journey from London to High Wycombe and back on that date it was noticeable that the amount of snow lying about was greater around High Wycombe in accordance with geneial increase of altitude in the heart of the Chilterns than nearer London. On the other hand all the Chiltern " bottoms " which are so well developed around High Wycombe contained much larger and thicker patches of snow than the ridges and open table-land. The explanation of this interesting inversion of the normal altitudinal distribution of snow-cover is, no doubt, that the " bottoms " were more sheltered from the damp thaw winds and also more exposed to the ground frosts which occurred every night during the rather cold thaw. Had the snowfalls occurred with high wind the effect might have been attributed in part to mass drifting, but the easterly gales had subsided when the first heavy snowfall of December 21st came. But whatever the correct explanation the fact emphasizes two important principles : firstly, the importance in questions of snow-cover of associating mere altitude above sea-level with surrounding configuration ; secondly, the importance in all climatological questions of remembering that hill or mountain valleys are an integral part of the uplands themselves. The common loose phraseology merely opposing " hills " to " valleys " regardless of whether the latter are lowland vales or hill-country dales or mountain ravines is painfully ungeographical.

L. C. W. Bonacina

13, Christchurch Hill, Hampstead, N.W.3
December 30th, 1938.

" From Up to Up "

The following letter has been forwarded by Mr. D. E. Smith of the Nigerian Meteorological Service, in the hope that one of our readers may be able to furnish an explanation.

The Education Officer's house here is near the top of a hill and some 1,500 feet above sea level. Some three or four years ago my wife and I heard rain falling, but looking all around we could see no place where it was raining. The sound was as though it were quite near and *appeared to come from above where we stood.*

Mystified we turned to an intelligent Yoruba carpenter who was nearby and asked where it was raining. He replied, " From up to up,"(!) meaning from one cloud level on to another. There were certainly heavy tornado clouds all around and above us. We could scarcely believe this explanation and have always been rather curious about the matter.

I am writing to you now because on November 28th, 1938 I was staying here with three friends from Ilorin and we all heard exactly the same phenomenon at the same place. They were as sceptical as my wife and I, but could not think of an explanation. My steward gave the same explanation as the carpenter had done on the earlier occasion. It has occurred to me, however, that rain may have been falling at a distance and the sound was reflected from the heavy cloud above. I should be interested to know whether the " up to up " hypothesis is possible or not.

J. D. CLARKE,
Education Officer.

Ilorin, Nigeria, November 30th, 1938.

NOTES AND QUERIES

Height calculations: a simple method

In the October 1938 number of this Magazine, Mr. E. Gold gave an easy rule for finding the approximate height to which an observation of pressure and temperature in the upper atmosphere refers, but he left the explanation as an exercise for the enquiring student. One might in fact expect to be able to derive the height from the tephigram by means of the dry adiabatics, on which a given difference of temperature corresponds invariably with the same height interval; thus 10° F. corresponds with about 1,860 ft. An approximation to the height interval between any two pairs of readings (p_0, T_0), and (p_1, T_1) may then be obtained directly from the temperature difference intercepted between the isobars p_0 and p_1, on a dry adiabatic, a process which would be further facilitated by placing a suitable scale, reading height in place of temperature, along the adiabatic. If the adiabatic used is the one passing the lower point (p_0, T_0), then the estimated height is too small; if on the other hand the adiabatic passes through the upper point (p_1, T_1), the estimated height is too large. Evidently a correct result can be obtained by choosing an adiabatic in an intermediate position, roughly halfway between the two extremes, but its precise position will depend on the shape of the observed temperature-pressure curve.

A modification, which is more troublesome but more precise, is to evaluate the height by using a series of adiabatic steps :—starting from the lowest point on the observed curve, proceed along an adiabatic for an interval of 10° F., then return to the curve along an isobar, and repeat the process as often as necessary, finally converting the total adiabatic temperature drop into height. This process becomes theoretically exact when the stages are made indefinitely small.

It is easily seen that Gold's formula corresponds with the former of the above processes, with the adiabatic taken through the highest point; the positive error which results from applying the adiabatic lapse rate is compensated by reducing the equivalent of 10° F. to 1,800 ft.

As these methods depend in part on the adiabatic lapse rate, the precise value of this constant may be conveniently looked into here. It is expressed by either of the following formulae—

$$\frac{\gamma - 1}{\gamma} \cdot \frac{g}{R} \text{ or } \frac{g}{J\, c_p},$$

where $\gamma = Cp/Cv$ is the ratio of the specific heats of dry air, R is the gas constant, J the mechanical equivalent of heat, g the acceleration due to gravity, and also

$$R = J\,(c_p - c_v).$$

The formulae for the lapse rate are derived from the assumption that dry air behaves as a perfect gas. The value of J $(Cp - Cv)$, $2 \cdot 8842 \times 10^6$, differs slightly from the value of R, $2 \cdot 8703 \times 10^6$, and indicates that the assumption of the characteristics of a perfect gas is not wholly justifiable.

A. F. CROSSLEY

Height calculation from the tephigram—Another simple method

Mr. Gold's method, given in the issue of this Magazine for October, 1938, for estimating approximate heights from the tephigram is delightful and will, no doubt, be tried out by many people working with the tephigram. Aviation meteorologists will have noticed that, as the estimate depends only on the pressure difference between the ground and the height of flight together with the temperature at that height, the formula performs precisely the same function as the "computor" used by the pilot to correct his altimeter reading for temperature. As is well known, no formula which takes account only of the temperature at the height of flight can be very accurate; the practical rule of allowing one part in 500 for each degree Fahrenheit by which the average air temperature below differs from that assumed in the construction of the altimeter computor, is sufficient to indicate the probable error of the corrected reading. Errors consistently less than 300 ft. at 20,000 ft. can hardly be claimed on this basis.

The following method, which as far as I know is novel, provides a very simple and theoretically accurate method of measuring height from the tephigram with perfect generality. The only errors are due to ignoring the effect of humidity on air density and to the limitations imposed by the scale of the chart. The precision is, in other words, similar to that of any other reading on the tephigram.

One of the properties of the tephigram noted by Sir Napier Shaw is that geodynamic height is represented by area. If, in Fig. 1, showing a portion of the tephigram, A and B are two points on a curve representing an upper air sounding, then the geodynamic height difference between them is given by the shaded area bounded by the curve AB and the two isobars through A and B continued down to the absolute zero of temperature. If now we draw between the same two isobars an adiabatic line CD cutting the curve at O

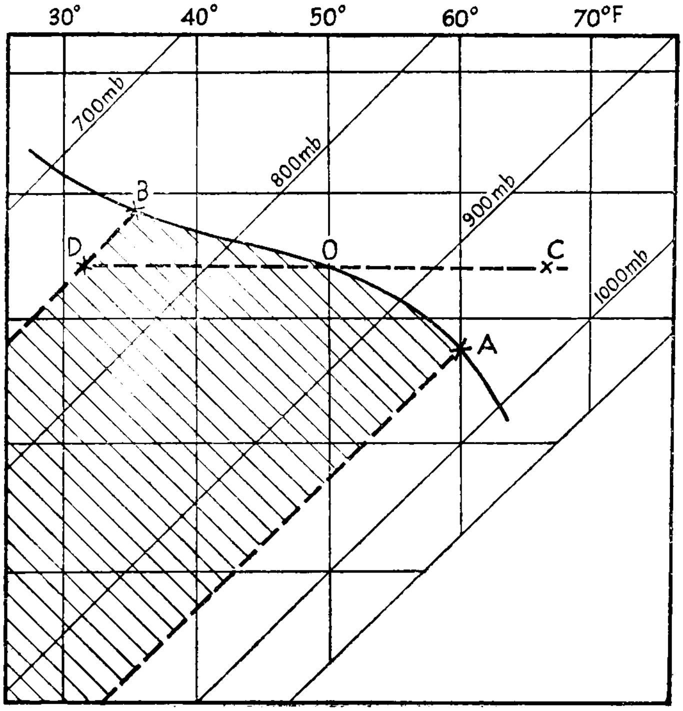


FIG. 1.—PORTION OF A TEPHIGRAM

in such a position that the area DOB = COA then, plainly, by the above proposition, the height between A and B is equal to the height of the isentropic atmosphere CD. But the height of an isentropic atmosphere is given by dividing the temperature range by the adiabetic lapse rate (5·4° F. per 1,000 ft. very accurately). Furthermore, the temperature scale on the tephigram is uniform and the height interval AB is represented simply and directly by the length of the line CD.

In practice all that is desired is a transparent scale upon which is engraved an " adiabatic height scale " (1,000 ft. = 1·08 cm.).

R. C. SUTCLIFFE

Note on the above Communications

Mr. Crossley makes the interesting suggestion that the divergence between the values of the adiabatic lapse rate deduced from the two formulae is due to the divergence of dry air from a perfect gas. An alternative explanation may be that the determination of the values of the specific heats is less accurate than the determination of the ratio between them.

Mr. Sutcliffe remarks that the formulae I gave cannot be very accurate. Occasionally no doubt there will be appreciable errors. But it is surprising how accurate in fact the formula is. That is partly because the percentage errors arising from the formula are greatest at the lower levels. At altitudes of 15,000 and 20,000 ft. the percentage error is usually very small and the actual errors are practically within the tolerance of the instruments from which the basic values of pressure and temperature are obtained. If the average temperature gradient up to 20,000 ft. is 3·5° F. per 1,000 ft.—i.e. approximately the same as in the I.C.A.N. standard atmosphere—the error in my formula is practically nil.

I picked up one or two *Upper Air Supplements* to the *Daily Weather Report* at random and computed the height of the 500 mb. surface at Mildenhall from the formula. In the first case, November 19th, 1938, the height from the formula agreed exactly with the height given in the *Daily Weather Report.* In the second case, November 29th, 1938, the height from the formula was about 200 ft. less than that given in the *Daily Weather Report*, but in this case the height from the formula agreed within 100 ft. with the height found by using Mr. Sutcliffe's elegant geometric method and with the height found by step by step computation.

I then looked out two exceptional cases, October 31st and November 8th, and found the following results :—

Height of 500 *mb. surface above M.S.L.*

November 8th, 1938, *Mildenhall*

D.W.R.	18,870 ft.
Formula (E.G.)	19,070 ,,
Step by step computed	18,680 ,,
Estimated by Sutcliffe's method	18,500 ,,

October 31*st*, 1938

D.W.R.	18,530 ft.
Formula (E.G.)	18,600 ,,
Step by step computed	18,410 ,,
Estimated by Sutcliffe's method	18,220 ,,

The values " estimated by Sutcliffe's method " were derived from the formula given below.

The greatest error in the value given by the formula is less than 400 ft., even in the exceptional case of November 8th.

Nevertheless, I ought to make it clear that I did not put forward the formula as a strictly accurate formula but as a convenient approximate formula. No one could have been more surprised than myself at the accuracy with which it gave heights when applied to actual upper air ascents. The explanation is briefly this: the height given by the formula is represented by the length of a line parallel to the line DC in Mr. Sutcliffe's diagram but at a distance of about 3 cm. (15° F. of Potential Temperature on the tephigram) below the level of B. I think this method of interpreting the formula makes the reason for its accuracy clearer than Mr. Crossley's interpretation of it as representing the height by a line through B parallel to CD, but measured with an adjusted scale.

Owing to the variation in the dimensions of the paper of the tephigram—particularly with humidity—a greater accuracy can be obtained by reading the temperatures T_C, T_D, at the point C and D in Mr. Sutcliffe' diagram and using the formula

$$H = 1{,}000 \frac{T_D - T_C}{5 \cdot 4}$$

than by actual measurement with a scale. There are frequently errors of ½ per cent. or more in the dimensions of the paper.

E. GOLD

Measuring a Halo with a Theodolite

From time to time accounts are published in the *Meteorological Magazine* of unusual halos or other optical phenomena. In some cases the account includes measurements made by means of a theodolite of the type normally used for pilot balloon observations. Following upon the account, in our October issue, of an elliptical halo observed at Leuchars on May 30th, 1938, we have received a letter from Mr. A. E. Mayers (Linton-on-Ouse) pointing out that an error was made in determining the horizontal diameter. As the source of error may not be familiar to some readers of the Magazine, we think it worth while to direct attention to it here.

If a theodolite is set up and adjusted in the usual way, the azimuth of any object at which the telescope is pointed is given by reading on the horizontal circle. If azimuth readings are taken successively on the left and right margins of a halo, it seems natural to assume that the difference in the readings represents the angular horizontal diameter of the halo. That assumption is, however, incorrect. What we want to know is the angle subtended by the horizontal diameter, measured in the plane containing the diameter and the point of observation. This plane is inclined to the horizontal at an angle equal to the sun's altitude, and it is easily seen by simple geometry that the required relationship is

$$\tan \beta = \cos \alpha \tan \beta'$$

where β is the true semi-diameter, α is the sun's altitude and β' is the apparent semi-diameter as measured on the horizontal circle of the theodolite. At Leuchars the theodolite measurement gave $\beta' = 32°$ and α was 43°. The corrected value of β works out at $24\frac{1}{2}$ and the halo was therefore only slightly elliptical.

It may be noted that the correct value would have been obtained directly if the telescope had been set at zero on the altitude scale, and the whole theodolite had then been inclined so as to bring the plane of the azimuth circle into coincidence with the plane containing the horizontal axis of the halo and the point of observation. On enquiry it was learnt that this method was actually adopted at Aberdeen, where an elliptical halo was also observed on May 30th (*see Met. Mag.* 1938, p. 775). It seems preferable, in general, however, to set up the theodolite in the normal way and apply the cosine correction.

Measurements made on the altitude circle of the theodolite do not require a correction of the type discussed above. Thus the vertical axis of a halo is measured directly by subtracting the altitude of the lower margin from the altitude of the upper margin.

Abnormal Weather in Iraq in July, 1938

It has been customary in the past to associate the summer in Iraq with cloudless skies, no precipitation, constant northwest winds, hot days and cool nights. This year, however, the weather has behaved in unusual fashion since there have been days when the sky has been practically overcast, heavy showers of rain have fallen, winds have been from the northeast and night minimum temperatures have been abnormally high. No parallel case of such a divergence from the normal could be found from an examination of the charts of previous years and it was considered that such unusual phenomena should be put on permanent record.

This year the sky was cloudless from May 25th except for traces of cirrus on June 11th, 13th and 14th, but on June 26th one tenth of altocumulus had formed by 0900 G.M.T., and the upper winds on that day had changed from northwest to between north and northeast. From then until July 16th, (with the exception of July 7th when the upper winds had temporarily returned to northwest and there was only a trace of cirrus in the sky) there was an average of five-tenths of cloud observed each day. On two occasions the sky was eight-tenths, and on one occasion nine-tenths, covered with cloud. Pilot balloon ascents were made at frequent intervals on July 7th, in connection with the long distance flight between Cranwell and the Persian Gulf so that the variations in upper winds could be observed more closely than usual. At 2040 G.M.T., the upper winds were northwest, while at 2245 G.M.T. they had veered to northeast, the surface wind still remaining northwest. With the arrival of these northeast upper winds, clouds were seen to form. It would appear that these northeast upper winds, while passing over the Iranian mountains (extending in places up to

12,000 feet, densely wooded and on which the snow was still melting), had become moisture laden and the formation of high strato-cumulus and medium cloud had subsequently resulted. Showers were reported during this period at various parts of the country. Heavy showers occurred at Baghdad on the evening of July 9th and slight showers at Habbaniya and Hilla. This is perhaps worthy of note in view of the fact that observations which have been kept at Baghdad since 1887 show that rain has never occurred before in July. An unpleasant consequence of these clouds being present at this time of the year was the fact that, at Habbaniya, the minimum temperatures were from 6°F. to 9°F. above normal. During this period the daily maximum temperatures were also above normal and on July 8th the temperature had reached 120°F. which, as far as can be traced, is the highest temperature recorded in Central Iraq at such an early date.

The simplest explanation which suggests itself to account for the unusual occurrence of northeast instead of northwest winds is that the permanent low which covers Baluchistan and Tibet in summer deepened more rapidly than usual and that the low pressure system which normally is stationary over southern Iran in summer deepened more slowly owing to the late melting of the snows. Hence, the latter acted as though it were a secondary to the former and moved in a counter-clockwise direction to a position over the Arabian desert, thus causing the winds to veer from northwest to northeast. The continued heating of the Iranian plateau caused this pseudo-secondary to move northwards again and the weather accordingly reverted to type on July 17th.

G. G. MACDONALD.

Christmas Weather, 1739

The following extract from the parish register of Saunderton, Bucks, has been forwarded by Mr. W. H. Challen of Carshalton. The note is recorded on the first parchment page of the register book 1729–1812, and is in the handwriting of Dr. Christopher Willoughby, Rector of Saunderton from September 13th, 1734, until his death in July, 1743, aged 47 :—

MEM : 1739

"The Frost began on Christmas Day ; the Saturday, Sunday, and Monday following, Three the sharpest daies were ever known. Wind N.E.

The Frost continued without any intermission till Saturday the 16 of Feb. when it began to thaw, but froze again all the next week till the Sunday following, when it thawed again & froze for some daies after.

No Rain from the end of Harvest till the 12 of Apr. which lasted 3 daies, Apr. 20. It began to snow & continued for 3 daies.

Frost lasted a Nights till the middle of May, on the 4 of the same month a good deal of Rain & on July 30 a thunder-shower after that no rain till sometime in Harvest."

January 6th, 1839. "The Great Wind"

A centenary broadcast on January 6th dramatised the storm of January 6th to 7th, 1839, which almost rivalled that of 1703 in the fury of the wind. In Northern Ireland houses were unroofed or swept away, chimney stacks blown down and many thousands of trees uprooted. Menai Suspension Bridge was damaged and many ships wrecked, with great loss of life. The gale sprang up rapidly from south-west but lasted for only a few hours. Details are lacking, but probably an exceptionally deep secondary depression passed quickly northeastwards along the north coast of Ireland and across Scotland, while pressure remained high to the southward.

An interesting account of the Liverpool hurricane of January, 1839, occurs in *The Times* of January 9th, 1939. In addition to great damage on shore, the Mersey was strewn with wrecks and many lives were lost. Snow, thunder and lightning occurred during the night and many fires resulted.

A point of interest is that sea-spray "incrusted windows half way across the Kingdom and whole hedges were carried away like chaff."

Mr. W. J. Gibson of Waringstown, Co. Down recalls that the pressure of the wind was 30 lbs. per sq. ft., which is equivalent to a velocity of about 100 miles an hour.

NEWS IN BRIEF

New Year's Honours.—We have pleasure in announcing that Miss D. G. Chambers, Assistant I in the Meteorological Office has been awarded the M.B.E., and that a Knighthood has been conferred upon Professor R. G. Stapledon of the University College of Wales and the Welsh Plant Breeding Station.

The Weather of December, 1938

The Siberian anticyclone extended far to the north-west over Finland and Scandinavia. At Moscow the mean pressure was 1036 mb., 18 mb. above normal; in northern Sweden 1026 mb. (+ 16 mb.) and Oslo 1021 mb. (+ 11 mb.). At the Azores the pressure of 1022 mb. was 1 mb. above normal, while the Icelandic low with 994 mb. was 3 to 4 mb. below. There was also an area of low pressure (— 5 mb.) over the Bay of Biscay. This distribution was favourable for abnormally strong southerly winds between Iceland and northern Siberia. In East Greenland, Jan Mayen, Norway and Spitsbergen the air supply came from the Atlantic Ocean and temperatures were from 5° to 16° F. above normal. Further east the air supply was derived from the continent of Europe and temperatures decreased rapidly. In Europe and the southern half of the British Isles the anticyclone over Finland caused easterly winds to predominate and temperatures were below normal, the deficit exceeding 5° in most of Germany. The abnormal conditions are clearly shown by the isotherm of 30° F., which runs south of New York, north-eastwards to beyond Spitsbergen, then returning almost due south to Switzerland before turning eastwards again. Rainfall nowhere differed greatly from normal except in Portugal, where there was an excess of more than 4 inches.

In North America pressure was abnormally low (995 mb.) over the Aleutian Islands with a steep gradient for westerly winds to the southward. Temperatures were from 5° to 10° F. above normal over most of Canada. No data were received from Australia or New Zealand.

The most notable feature of the weather of the month in the British Isles was the very cold spell from the 17th to the 26th, which was the most severe cold spell experienced since February 1929. During this period temperature remained below freezing point at many places in some areas for several days: Lympne had a maximum of 22° F. on the 20th. Minimum temperatures were correspondingly low during this period, Dalwhinnie having a minimum of 7° F. on the 19th. There was snow locally in the south-east on the 19th and more general and heavier falls on the 20th and 21st causing severe dislocation of road and rail transport over the few days before Christmas.

On the 1st a very deep depression off the north-west of Scotland moved slowly eastwards and associated secondary depressions moved eastward from the west of Ireland on the 2nd; this resulted in widespread gales on the 1st and caused showers in most places on the 1st and 2nd. A ridge of high pressure passed eastward across the British Isles on the 3rd giving good sunshine records on the whole. Secondary depressions moving north-eastwards along the western seaboard, associated with a depression south-west of Iceland, caused heavy rain generally on the 4th but the depression became less intense on the succeeding days; a complex trough of low pressure approaching Ireland from the west on the 7th resulted in heavy rain locally in Ireland and northern Scotland while its passage over the country on the 8th gave some rain in most places. A depression, approaching Ireland from the Atlantic on the 9th, became almost stationary west of Ireland on the 10th and spread north-eastwards on the 11th: there was rainfall generally, which was heavy at times, during this period. The depression which was over the north of Ireland on the 12th moved northwards, and a new disturbance situated over the Atlantic north-west of Ireland on the 13th spread slowly eastwards, giving gales in northern Scotland. The associated trough of low pressure gave moderate to heavy rain in most places.

Subsequently an intense anticyclone situated over Russia extended its influence westwards and by the 17th cold continental air reached the British Isles causing a fall in temperature which became more pronounced by the 18th. Snow fell in all districts at times during this period until about the 25th and was particularly heavy in eastern and south-eastern England.

A ridge of high pressure passed across the British Isles in a south-easterly direction on the 25th and was followed by a trough of low pressure which extended from southern Norway across England and Wales on the 26th. Temperatures rose quite quickly again on the 26th and 27th although in the eastern and south-eastern districts of England there was a further fall of snow on the 26th. A depression to the west of Iceland on the 28th moved eastwards and then south-eastwards on the following days until the end of the month when it was centred over Norway: there was rainfall generally on the 28th and 29th.

Gales were reported on many days during the month, the worst period being the 12th to 18th when Wick and Lerwick reported gales on each of these days.

The distribution of bright sunshine for the month was as follows:—

	Total hrs.	Diff. from average hrs.		Total hrs.	Diff. from average hrs.
Stornoway ..	36	+14	Chester ..	52	+11
Aberdeen ..	37	0	Ross-on-Wye	62	+14
Dublin	59	+13	Falmouth ..	62	+ 9
Birr Castle ..	59	+16	Gorleston ..	47	+ 6
Valentia ..	76	+37	Kew.. ..	50	+13

Kew temperature, mean, 40·3°F.: diff. from average, —1·1°F.

Miscellaneous Notes on Weather Abroad

An unusually severe cold spell began in Siberia on December 9th, 70°—90° of frost were reported in the following week. This cold wave swept across Europe in the middle of the month. Temperatures fell rapidly on the 17th and 18th, 20° of frost being reported from many places in France, and 30° in Germany. Rivers and lakes froze, and navigation and transport were seriously impeded. Snow fell in Switzerland on the 20th, and a slight rise of temperature in western Europe on the 21st was accompanied by snow generally. Trains were delayed, air services interrupted, many schools were closed, and in northern France nearly 18,000 miners and steel workers were unable to work owing to frost damage. Lyons reported 45° of frost on the 22nd. The intense cold spread to northern Italy on the 25th, when Milan reported 19° of frost. In Rome, however, temperatures remained higher, but snow fell on Vesuvius. Heavy snow storms in Rumania caused a serious railway accident on the 24th, in which more than 100 people were killed. After further heavy snow, a thaw set in over western Europe on the 27th, but temperatures remained low in the east, Sopron in Hungary recording 41° of frost. During a typhoon which passed across the Philippines on the 8th, the barometer fell to 28·50 in. at Lugon. Much damage was caused and 19 deaths were reported. Eight people lost their lives in an aeroplane crash in dense fog at Mexico City on the 2nd.

Blizzards swept across the United States from Alaska on the 27th: low temperatures were general and many deaths resulted. All Canada, except British Columbia, also experienced extreme cold, Edmonton registering 51° below zero towards the end of the month. Severe gales caused widespread damage in Victoria and Sydney on the 9th and 10th. Winds frequently reached hurricane force, and fires followed the gale. The damage is estimated at £500,000. (*The Times*, December 3rd–31st, 1938.)

Daily Readings at Kew Observatory, December, 1938

Date	Pressure, M.S.L. 13h.	Wind, Dir., Force 13h.	Temp. Min.	Temp. Max.	Rel. Hum. 13h.	Rain	Sun	REMARKS
	mb.		°F.	°F.	%	in.	hrs.	
1	993·8	SW. 4	40	48	66	0·06	4·6	r 6h, prq 14h.
2	1006·3	SW. 4	39	49	76	0·03	4·1	r_0–r 18h.–20h.
3	1015·1	W. 4	40	47	62	—	4·3	f–F 21h.–24h.
4	1018·6	SSE. 2	28	49	82	Trace	0·6	F–f 0h.–11h., d_0 21h.–
5	1008·4	W. 3	49	55	68	0·06	1·4	ir_0–r 1h.–9h. [24h.
6	1015·5	SW. 3	37	50	80	—	1·7	
7	1010·6	S. 3	45	50	74	—	1·6	
8	995·1	SSW. 4	42	51	87	0·05	0·1	ir_0 3h.–9h., d 13h.–
9	998·4	S. 4	34	49	74	0·33	3·5	r–r_0 17h.–24h. [14h.
10	993·5	SSE. 3	48	52	86	0·17	0·1	r_0 0h.–4h., d_0 15h.–
11	995·8	SE. 2	48	53	83	0·02	0·0	ir_0 3h.–8h. [16h.
12	1005·8	SSW. 4	51	54	79	0·05	3·9	ir_0 3h.–7h.
13	1011·7	S. 3	42	52	85	—	0·3	
14	1014·1	SW. 2	49	53	89	0·10	0·0	r_0 2h.–9h., f 19h.–24h.
15	1014·6	S. 3	37	51	84	0·02	1·5	F–f 0h.–12h., r_0 21h.–
16	1014·6	SE. 2	47	49	96	1·03	0·0	r_0–r 4h.–23h. [23h.
17	1025·7	E. 3	42	42	76	Trace	0·0	ir_0 1h.–6h.
18	1023·2	ENE. 6	26	30	58	Trace	3·3	is_0 22h.–24h.
19	1018·6	NE. 4	27	28	81	Trace	0·0	is_0 0h.–14h.
20	1010·4	N. 5	22	27	58	Trace	2·5	s_0 15h.
21	1004·9	N. 2	21	29	92	0·45	0·0	s_0–s 8h.–24h.
22	1007·0	CALM	28	35	92	0·29	0·0	$r_0 s_0$ 13h.–15h. & 18h.–
23	1015·0	SE. 2	30	31	81	0·04	0·0	is_0 0h.–13h. [24h.
24	1020·6	NNE. 4	29	35	83	0·01	0·0	s_0 12h.–15h.
25	1032·3	ENE. 3	32	33	79	Trace	0·0	r_0 s_0 f 13h.
26	1025·8	SSW. 3	29	36	90	0·28	0·0	s_0–s 5h.–13h., d_0 21h.
27	1017·3	NW. 3	35	44	77	—	5·6	
28	1019·4	NW. 2	39	42	75	0·04	2·2	r_0–d_0 f 21h.–24h.
29	1011·2	SW. 2	38	45	96	0·23	0·0	r–r_0 15h.–21h., q 21h.
30	1002·6	W. 4	37	43	71	Trace	3·4	d_0 15h.
31	1006·2	W. 3	33	42	77	0·03	5·1	d_0 7h., d 20h.–21h.
*	1011·4	—	37	44	79	3·29	1·6	*Means or totals.

General Rainfall for December, 1938

England and Wales	121	per cent of the average 1881–1915.
Scotland	84	
Ireland	105	
British Isles ...	109	

Rainfall : December, 1938 : England and Wales

Co.	Station.	In.	Per cent of Av.	Co.	Station.	In.	Per cent of Av.
Lond .	Camden Square..........	3·55	149	*War* .	Birminghm, Edgbaston	4·39	163
Sur .	Reigate, Wray Pk. Rd..	4·01	126	*Leics* .	Thornton Reservoir ...	3·85	144
Kent .	Tenterden, Ashenden...	4·10	132	,, .	Belvoir Castle...........	4·07	165
,, .	Folkestone, I. Hospital.	3·07	...	*Rut* .	Ridlington	3·73	149
,, .	Margate, Cliftonville....	2·19	96	*Lincs* .	Boston, Skirbeck.........	4·43	206
,, .	Eden'bdg., Falconhurst	4·03	122	,, .	Cranwell Aerodrome...	4·13	187
Sus .	Compton, Compton Ho.	3·93	94	,, .	Skegness, Marine Gdns.	2·95	134
,, .	Patching Farm..........	4·00	119	,, .	Louth, Westgate.........	4·40	158
,, .	Eastbourne, Wil. Sq....	3·54	101	,, .	Brigg, Wrawby St.......	4·01	...
Hants.	Ventnor, Roy.Nat.Hos.	3·49	106	*Notts* .	Mansfield, Carr Bank...	4·48	155
,, .	Southampton,East Park	3·97	108	*Derby*.	Derby, The Arboretum	3·68	136
,, .	Ovington Rectory.......	4·78	121	,, .	Buxton, Terrace Slopes	8·26	146
,, .	Sherborne St. John......	3·66	111	*Ches* .	Bidston Obsy.............	3·31	125
Herts .	Royston, Therfield Rec.	3·55	153	*Lancs*.	Manchester, Whit. Pk.	3·56	110
Bucks.	Slough, Upton............	2·88	114	,, .	Stonyhurst College......	5·57	115
Oxf .	Oxford, Radcliffe.........	2·89	117	,, .	Southport, Bedford Pk.	4·02	124
N'hant	Wellingboro, Swanspool	3·73	159	,, .	Ulverston, Poaka Beck	5·82	105
,, .	Oundle	2·84	...	,, .	Lancaster, Greg Obsy.	4·69	108
Beds .	Woburn, Exptl. Farm...	3·47	148	,, .	Blackpool	3·69	113
Cam .	Cambridge, Bot. Gdns.	2·68	139	*Yorks*.	Wath-upon-Dearne......	3·05	129
,, .	March.......................	3·22	153	,, .	Wakefield,Clarence Pk.	3·28	135
Essex.	Chelmsford,County Gdns	2·43	109	,, .	Oughtershaw Hall.......	8·19	...
,, .	Lexden Hill House......	3·13	...	,, .	Wetherby, Ribston H..	4·84	198
Suff .	Haughley House.........	2·28	...	,, .	Hull, Pearson Park......	3·99	166
,, .	Rendlesham Hall........	2·94	125	,, .	Holme-on-Spalding......	4·86	198
,, .	Lowestoft Sec. School...	2·10	90	,, .	Felixkirk, Mt. St. John.	4·46	185
,, .	Bury St. Ed., WestleyH.	2·85	118	,, .	York, Museum...........	4·01	179
Norf. .	Wells, Holkham Hall...	3·30	160	,, .	Pickering, Houndgate...	4·50	179
Wilts .	Porton, W.D. Exp'l. Stn	4·30	137	,, .	Scarborough..............	3·36	141
,, .	Bishops Cannings........	3·96	121	,, .	Middlesbrough...........	2·87	148
Dor .	Weymouth, Westham.	3·12	90	,, .	Baldersdale, Hury Res.	4·14	112
,, .	Beaminster, East St....	5·25	110	*Durh* .	Ushaw College...........	4·65	186
,, .	Shaftesbury...............	3·34	92	*Nor* .	Newcastle, Leazes Pk...	3·62	154
Devon.	Plymouth, The Hoe....	3·77	75	,, .	Bellingham, Highgreen	3·97	109
,, .	Holne, Church Pk. Cott.	8·58	101	,, .	Lilburn Tower Gdns....	3·12	119
,, .	Teignmouth, Den Gdns.	3·26	77	*Cumb*.	Carlisle, Scaleby Hall...	2·95	92
,, .	Cullompton	5·02	114	,, .	Borrowdale, Seathwaite	10·75	70
,, .	Sidmouth, U.D.C.........	3·62	...	,, .	Thirlmere, Dale Head H.	8·67	79
,, .	Barnstaple, N. Dev.Ath	4·02	91	,, .	Keswick, High Hill......	5·31	79
,, .	Dartm'r,Cranmere Pool	10·90	...	,, .	Ravenglass, The Grove	5·28	115
,, .	Okehampton, Uplands.	7·03	100	*West* .	Appleby, Castle Bank...	3·86	97
Corn .	Redruth, Trewirgie......	6·93	111	*Mon* .	Abergavenny, Larchf'd	5·77	129
,, .	Penzance, Morrab Gdns.	4·10	72	*Glam* .	Ystalyfera, Wern Ho....	6·85	82
,, .	St. Austell, Trevarna...	6·14	101	,, .	Treherbert, Tynywaun.	10·19	...
Soms .	Chewton Mendip.........	5·51	102	,, .	Cardiff, Penylan..........	4·38	97
,, .	Long Ashton............	3·57	92	*Carm* .	Carmarthen,M. & P. Sch.	5·91	99
,, .	Street, Millfield..........	3·59	108	*Card* .	Aberystwyth	3·38	...
Glos .	Blockley	4·16	...	*Rad* .	BirmW.W.Tyrmynydd	7·20	88
,, .	Cirencester, Gwynfa....	3·24	97	*Mont* .	Lake Vyrnwy	6·41	93
Here .	Ross-on-Wye..............	3·83	129	*Flint* .	Sealand Aerodrome......	3·07	125
,, .	Kington, Lynhales.......	3·22	86	*Mer* .	Blaenau Festiniog	9·26	80
Salop .	Church Stretton.........	4·29	128	,, .	Dolgelley, Bontddu......	6·50	95
,, .	Shifnal, Hatton Grange	2·36	92	*Carn* .	Llandudno	3·65	126
,, .	Cheswardine Hall........	2·78	99	,, .	Snowdon, L. Llydaw 9..	15·00	...
Worc .	Malvern, Free Library...	3·93	142	*Ang* .	Holyhead, Salt Island...	4·35	105
,, .	Ombersley, Holt Lock.	3·10	118	,, .	Lligwy	...	...
War .	Alcester, Ragley Hall...	3·29	134	*I. Man*	Douglas, Boro' Cem....	4·30	87

Rainfall : December, 1939 : Scotland and Ireland

Co.	Station.	In.	Per cent of Av.	Co.	Station.	In.	Per cent of Av.
Guern.	St.Peter P't.Grange Rd.	5·48	134	*R&C* .	Stornoway, C.GuardStn.	4·41	74
Wig .	Pt. William, Monreith.	3.99	88	*Suth* .	Lairg	2·94	73
,, .	New Luce School	4·73	85	,, .	Skerray Borgie	3·09	...
Kirk .	Dalry, Glendarroch	5·14	72	,, .	Melvich	2·96	69
Dumf.	Eskdalemuir Obs	4·61	66	,, .	Loch More, Achfary	7·45	81
Roxb .	Hawick, Wolfelee	3·46	83	*Caith* .	Wick	1·96	64
,, .	Kelso, Broomlands	1·84	79	*Ork* .	Deerness	4.42	106
Peeb .	Stobo Castle	3·08	81	*Shet* .	Lerwick Observatory	4·82	100
Berw .	Marchmont House	2·86	102	*Cork* .	Cork, University Coll	...	...
E.Lot.	North Berwick Res	...	...	,, .	Roches Point, C.G. Stn.	3·48	65
Midl .	Edinburgh, Blackfd. H.	2·13	91	,, .	Mallow, Longueville	4·89	100
Lan .	Auchtyfardle	2·53	...	*Kerry.*	Valentia Observatory	5·86	88
Ayr .	Kilmarnock, Kay Park	2·22	...	,, .	Gearhameen	9·00	72
,, .	Girvan, Pinmore	4·93	82	,, .	Bally McElligott Rec	4·35	...
,, .	Glen Afton, Ayr San.	5·71	89	,, .	Darrynane Abbey	4·39	75
Renf .	Glasgow, Queen's Park	2·78	66	*Wat* .	Waterford, Gortmore	4·82	105
,, .	Greenock, Prospect H.	6·73	90	*Tip* .	Nenagh, Castle Lough.	4·20	91
Bute .	Rothesay, Ardencraig	5·42	99	,, .	Cashel, Ballinamona	4·97	116
,, .	Dougarie Lodge	3·69	67	*Lim* .	Foynes, Coolnanes	3·99	84
Arg .	Loch Sunart, G'dale	8·92	102	,, .	Limerick, Mulgrave St.	4·33	93
,, .	Ardgour House	11·09	...	*Clare* .	Inagh, Mount Callan	6·12	...
,, .	Glen Etive	10·78	88	*Wexf* .	Gorey, Courtown Ho	5·94	155
,, .	Oban	6·88	...	*Wick* .	Rathnew, Clonmannon.	6·99	...
,, .	Poltalloch	6·66	104	*Carl* .	Bagnalstown, Fenagh H.	4·79	127
,, .	Inveraray Castle	8·98	90	,, .	Hacketstown Rectory	6·99	171
,, .	Islay, Eallabus	6·50	110	*Leix* .	Blandsfort House	4·73	129
,, .	Mull, Benmore	9·30	55	*Offaly.*	Birr Castle	3·31	101
,, .	Tiree	...	...	*Kild* .	Straffan House	2·82	92
Kinr .	Loch Leven Sluice	3·03	77	*Dublin*	Dublin, Phoenix Park	3·00	118
Fife .	Leuchars Aerodrome	2·55	103	*Meath.*	Kells, Headfort	3·55	93
Perth .	Loch Dhu	9·05	90	*W.M* .	Moate, Coolatore	2·92	...
,, .	Crieff, Strathearn Hyd.	3·55	79	,, .	Mullingar, Belvedere	2·83	77
,, .	Blair Castle Gardens	3·48	91	*Long* .	Castle Forbes Gdns	...	...
Angus.	Kettins School	3·83	116	*Gal* .	Galway, Grammar Sch.	3·59	79
,, .	Pearsie House	3·99	...	,, .	Ballynahinch Castle	6·45	86
,, .	Montrose, Sunnyside	3·25	117	,, .	Ahascragh, Clonbrock.	4·11	87
Aber .	Balmoral Castle Gdns.	3·11	92	*Rosc* .	Strokestown, C'node	3·36	90
,, .	Logie Coldstone Sch.	2·57	91	*Mayo.*	Blacksod Point	4·42	72
,, .	Aberdeen Observatory.	3·83	119	,, .	Mallaranny	6·95	...
,, .	New Deer School House	3·30	96	,, .	Westport House	...	...
Moray	Gordon Castle	1·27	47	,, .	Delphi Lodge	...	...
,, .	Grantown-on-Spey	1·71	63	*Sligo* .	Markree Castle	5·72	121
Nairn.	Nairn	·97	44	*Cavan.*	Crossdoney, Kevit Cas.	3·95	...
Inv's .	Ben Alder Lodge	6·85	...	*Ferm* .	Crom Castle	4·00	97
,, .	Kingussie, The Birches.	2·78	...	*Arm* .	Armagh Obsy	3·35	107
,, .	Loch Ness, Foyers	...	...	*Down.*	Fofanny Reservoir	9.44	...
,, .	Inverness, Culduthel R.	2·06	76	,, .	Seaforde	5.49	133
,, .	Loch Quoich, Loan	12·25	...	,, .	Donaghadee, C. G. Stn.	3.05	96
,, .	Glenquoich	12·49	85	*Antr* .	Belfast, Queen's Univ	4.45	121
,, .	Arisaig House	7·84	108	,, .	Aldergrove Aerodrome.	3.37	98
,, .	Glenleven, Corrour	9·58	104	,, .	Ballymena, Harryville.	3.98	90
,, .	Fort William, Glasdrum	9·34	...	*Lon* .	Garvagh, Moneydig	4.73	...
,, .	Skye, Dunvegan	6·95	...	,, .	Londonderry, Creggan.	5.65	129
,, .	Barra, Skallary	4·73	...	*Tyr* .	Omagh, Edenfel	5.03	119
R&C.	Tain, Ardlarach	1·56	50	*Don* .	Malin Head	4.96	120
,, .	Ullapool	4·15	66	,, .	Dunfanaghy	4·74	105
,, .	Achnashellach	7·78	77	,, .	Dunkineely	5·56	...

Climatological Table for the British Empire, July, 1938

STATIONS.	PRESSURE. Mean of Day M.S.L.	PRESSURE. Diff. from Normal.	TEMPERATURE. Absolute. Max.	TEMPERATURE. Absolute. Min.	TEMPERATURE. Mean Values. Max.	TEMPERATURE. Mean Values. Min.	TEMPERATURE. Mean Values. ½ Max. and Min.	TEMPERATURE. Mean Values. Diff. from Normal.	TEMPERATURE. Mean Wet Bulb.	Relative Humidity	Mean Cloud Am'nt	PRECIPITATION. Am'nt.	PRECIPITATION. Diff. from Normal.	PRECIPITATION. Days	BRIGHT SUNSHINE. Hours per day.	BRIGHT SUNSHINE. Percentage of possible.
	mb.	mb.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	%	0–10	in.	in.			
London, Kew Obsy....	1014·7	− 1·1	81	48	70·0	55·0	62·5	− 0·3	55·3	79	7·5	1·02	− 1·15	8	4·7	29
Gibraltar..................	1016·7	− 0·1	97	61	78·5	65·9	72·2	− 2·6	64·9	80	3·3	0·00	...	0	...	...
Malta.......................	1015·5	+ 0·8	92	65	83·1	70·5	76·8	− 1·5	68·9	70	0·4	0·00	− 0·05	0	12·8	90
St. Helena	1019·8	− 1·3	68	53	63·5	56·0	59·7	+ 1·9	57·7	95	8·8	2·59	− 1·48	22	...	...
Freetown, Sierra Leone	1013·8	+ 2·8	86	69	81·5	72·8	77·1	...	73·7	84	8·3	28·91	− 6·67	27	...	...
Lagos, Nigeria	1014·0	+ 0·8	85	66	80·7	72·3	76·5	− 1·5	73·0	89	8·5	3·48	− 7·02	8	3·8	31
Kaduna, Nigeria	1012·4	...	92	65	82·9	68·2	75·5	+ 1·3	70·0	88	9·0	7·30	− 3·32	20	4·5	36
Zomba, Nyasaland	1017·9	− 0·7	84	50	73·3	54·9	64·1	+ 2·1	60·7	79	5·3	0·00	− 0·35	0	...	...
Salisbury, Rhodesia...	1020·6	− 1·0	77	35	69·5	43·5	56·5	+ 0·4	48·5	56	3·3	0·02	...	1	7·8	70
Cape Town	1021·1	− 0·2	79	40	65·3	49·5	57·4	+ 2·7	51·0	92	5·3	2·72	− 0·90	17	...	...
Johannesburg	1022·0	− 1·0	69	33	60·6	41·5	51·1	+ 0·7	41·3	54	2·6	0·20	− 0·13	3	8·6	80
Mauritius	1020·2	− 0·3	78	52	74·8	63·3	69·1	+ 0·8	65·5	75	5·5	1·79	− 0·49	18	6·4	58
Calcutta, Alipore Obsy.	999·8	+ 0·6	94	77	89·5	79·6	84·5	+ 0·8	79·9	88	9·2	6·11	− 6·59	14*	...	...
Bombay	1003·8	− 0·1	88	72	85·2	76·3	80·7	− 0·7	77·4	87	9·3	16·06	− 8·21	26*	...	...
Madras	1003·9	− 0·6	99	75	95·5	79·5	87·5	− 0·1	74·6	64	8·7	1·96	− 1·88	7*	...	...
Colombo, Ceylon	1008·9	− 0·2	86	73	84·4	76·8	80·6	− 0·6	76·3	76	7·8	4·10	− 0·33	13	5·7	46
Singapore	1008·9	0·0	90	71	86·4	76·5	81·5	+ 0·2	77·4	77	6·3	6·21	− 0·58	12	7·6	62
Hongkong.................	1006·1	+ 1·4	94	76	87·4	79·0	83·2	+ 0·7	78·9	81	7·2	12·23	− 2·19	21	6·6	50
Sandakan	1008·6	...	89	72	86·9	74·8	80·9	− 0·9	76·3	85	7·7	10·63	+ 3·91	16	...	...
Sydney, N.S.W..........	1018·3	0·0	70	39	61·1	44·5	52·8	+ 0·1	46·7	74	4·5	2·92	− 1·88	15	5·5	54
Melbourne	1019·6	+ 0·7	61	34	56·1	40·8	48·5	− 0·2	42·8	86	6·9	2·24	+ 0·38	17	3·1	32
Adelaide	1020·3	+ 0·1	66	39	60·0	44·7	52·3	+ 0·4	48·1	77	6·4	1·88	− 0·76	16	3·8	38
Perth, W. Australia ...	1017·7	− 1·3	70	43	63·6	48·7	56·1	+ 0·9	50·9	73	6·0	5·42	− 1·14	17	5·6	55
Coolgardie	1019·9	0·0	75	36	59·5	43·1	51·3	+ 0·1	46·6	76	5·5	2·41	+ 1·54	12	...	...
Brisbane..................	1018·5	+ 0·1	73	45	65·6	50·3	57·9	− 0·6	51·6	74	5·1	1·43	− 0·77	12	6·1	58
Hobart, Tasmania......	1019·8	+ 6·1	55	34	50·8	38·6	44·7	− 1·0	40·6	85	7·4	3·78	+ 1·60	14	3·6	38
Wellington, N.Z.	1013·1	− 0·8	57	33	49·4	40·7	45·1	− 2·9	42·8	81	7·8	4·69	− 0·94	23	3·1	33
Suva, Fiji	1013·8	− 0·2	88	62	81·5	69·5	75·5	+ 2·1	71·0	86	4·4	14·32	+ 9·39	17	5·5	49
Apia, Samoa	1012·2	+ 0·3	87	72	84·8	75·4	80·1	+ 2·9	79·6	93	4·5	5·86	+ 2·88	17	9·4	82
Kingston, Jamaica	1014·5	− 0·2	92	71	88·8	73·5	81·1	− 0·6	71·7	74	3·9	0·62	− 1·00	6	7·0	53
Grenada, W.I.	1011·4	− 1·9	89	70	86	73	79·5	+ 0·3	73	74	6	10·09	+ 0·66	18	...	...
Toronto..................	1014·0	− 0·4	92	53	81·4	62·2	71·8	+ 2·7	63·8	78	5·5	2·62	− 0·22	12	8·3	55
Winnipeg	1012·6	+ 0·3	93	48	79·4	57·7	68·5	+ 2·1	58·0	87	5·6	4·08	+ 0·98	18	8·3	52
St. John, N.B.	1015·1	+ 1·5	80	50	66·8	54·0	60·4	0·0	57·7	92	8·2	6·40	+ 2·77	21	4·1	27
Victoria, B.C............	1017·6	+ 0·3	84	47	68·9	52·3	60·6	+ 0·5	55·4	76	2·8	0·41	− 0·01	5	10·8	69

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