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Climatic Variation

By HAROLD JEFFREYS, D.Sc., F.R.S.

The explanation of the variation of climate that has taken place on the earth's surface during geological time has long been one of the thorniest problems of geophysics. Few questions have received so many attempted answers, yet the record is one of almost continuous failure. That Mr. C. E. P. Brooks has already gone a long way towards a solution is well known to readers of his previous book, *The Evolution of Climate,* and of his papers in recent numbers of the *Quarterly Journal of the Royal Meteorological Society.* In the present work* he has advanced several further stages. His fundamental method is to investigate statistically the present relations between temperature and the quantities of water, land, and ice in the neighbourhood of the place considered. Having expressed these relations in quantitative form, he can then apply the results to find what distribution of temperature would correspond to distributions of land and sea different from the present one. The results have hitherto seemed very promising. Brooks's chief recent advance has been in the extension he has made in the theory of the effects of ice, and an account of this forms the subject of the first chapter of his new book. Mere changes in the amount of land in high latitudes, he has found, would alter the mean annual temperature by a few degrees. For some of the

* "Climate through the ages." By C. E. P. Brooks, size $8\frac{1}{2} \times 5\frac{1}{2}$, pp. 439. *Illus.* London. E. Benn Ltd. 1926. 15s. net.

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phenomena to be explained this would be quite adequate, but the full change of temperature in middle latitudes from a warm period, such as the Eocene, to a glacial period appears from the evidence of fossils to have been about 30° F.; also the presence of ice complicates the matter. Suppose that the conditions were such that the temperature at the North Pole was just above the freezing point of sea water, say 28° F., and that the land area was then reduced to such an extent that the mean annual temperature in high latitudes was raised by 2°. Then that would be the end of the matter. But suppose instead that the land was increased so as to lower the mean temperature by 2°. This would be only the immediate effect. The ocean would then proceed to freeze at the pole ; this would be a slow affair, because water cooled at the poles sinks and flows away as a bottom current, so that the whole ocean would have to be cooled before ice could form at the surface. But in time an ice sheet would form. Now the cooling effect of ice is much greater than that of unglaciated land ; there are numerous theoretical reasons why this should be so, and Brooks's previous work has given an estimate of the amount. Hence an ice sheet once started would cool the ocean around it further, and freezing would extend. A simple calculation with reasonable data shows that a uniform ocean in such circumstances would freeze down to latitude 65°, and that the temperature at the pole would ultimately be lowered by 45°. Conversely, if such a state had been attained, and the general temperature rose a little, melting would begin on the southern edge of the ice sheet. The reduction in the area of the ice would reduce its cooling effect, and melting would gradually proceed till the whole ocean was again ice-free. Thus quite a slight change in the external factors governing the temperatures in high latitudes may make all the difference between a mild climate and an intense glaciation.

Brooks sums up the external factors by means of a hypothetical "non-glacial" temperature. This is the temperature that would exist if the ocean had just the same physical properties as it actually has, except that its freezing point was sufficiently low for freezing never to take place, so that the influence of ice would not arise. This can be calculated more directly than the actual temperature, and forms an intermediate stage in finding the latter. If the non-glacial temperature is above 28° F., it is of course equal to the actual temperature ; but if it is lower, the ultimate actual temperature will be much lower still. The present non-glacial temperature at the North Pole in January is estimated as about 26° F. Consequently quite a small rise of temperature would suffice to clear the Arctic Ocean of ice completely. It is, therefore, inferred that during the warm periods, which constitute much the largest part of geological time, the poles were free from ice. Glacial periods occur when the non-glacial temperature at the poles falls enough to form ice-sheets at the poles, and if this condition persists the ultimate result is extensive glaciation ; the actual temperature falls far more than the non-glacial temperature. At present we are in a glacial period, but not at its height ; the extensive low-lying continents around the North Pole become hot in the summer and reduce the glaciated area, and the ice is slowly retreating.

On these lines Brooks has little difficulty in accounting for the last glaciation. A barrier in the North Atlantic shut out the Gulf Stream from the Arctic Ocean, and led to the formation of an extensive ice-cap, which then lowered the temperatures all over the Northern Hemisphere. A surprising fact that arises in the course of his discussion is that the Arctic was probably free from ice from about 500 to 1000 A.D. ; the Scandinavian settlement of Greenland at this time would certainly have been impossible in present conditions.

The Permo-Carboniferous glaciation presents greater difficulties. At this period there was ice in comparatively low southern latitudes, combined with an extensive development of coal and glaciation almost side by side in North America. A reconstruction of the distribution of land and sea at that time, already inferred by geologists on purely geological grounds, leads Brooks to a very plausible explanation. An extensive continent called Gondwanaland connected South America, Africa and Australia. North of it the trade winds drove a warm central Pacific current into an extended Mediterranean, a broad arm of which went up into the Arctic by way of a Volga Sea. Thus warm conditions were maintained in Europe and Central Asia. At the same time an arm from the Arctic extended into the North Atlantic by way of Baffin Bay. This was blocked at the southern end, and explains the local glaciations in America at the time. The southern glaciations are attributed to glaciers from an extensive plateau in the interior of Gondwanaland.

The main lines of Brooks's theory seem extremely plausible. In places, however, his statements do not agree with what we know of the theory of the atmospheric circulation. It is quite certain that if the sun radiated as at present, but there were no atmosphere, the tropics would be much hotter than they are, and the temperature at the poles would be near the absolute zero. If the atmosphere were present, but did not move so as to redistribute the heat, the results would be qualitatively the same. The reason why the mean difference of temperature between poles and equator is only 60° F. is that north and south displacements of air redistribute the heat (partly indirectly, by driving ocean currents with them). A warm period arises when wide seas admit warm currents to the Arctic Ocean in such quantities as to melt its ice. Brooks considers that in these conditions the difference of temperature between the poles and the equator would be small, and the atmospheric circulation much reduced in intensity. But if so the main factor that maintains the ocean currents and keeps the temperature differences down would be reduced, and these differences would become greater than ever. It seems more probable that the differences of temperature from place to place in a warm period were much the same as at present, and that the intensity of the atmospheric circulation also was only slightly less than it is now. Also it seems to be suggested (p. 225) that the atmospheric circulation would be easterly up to latitude 70°. As the area of the surface in higher latitudes is only about 6 per cent. of the whole, the friction of the air over the surface would in these conditions push the air systematically westwards, and convert the circulation into one involving east and west winds over comparable areas, in about a week. An absence of the ordinary temperate region cyclones is also implied ; but these cyclones are necessary to maintain the circulation against friction. It seems to me that the number and intensity of cyclones were probably much the same as at present, and that the dryness of the ground shown by deserts and salt beds was really due to special local conditions, the atmospheric movements and the rainfall remaining in their main outlines much as at present.

The experiment of F. Ahlborn, described on p. 58, has nothing to do with the explanation of the atmospheric circulation. In this experiment a sphere was rotated in a vessel filled with water, and produced an outward current in its equatorial plane, an inward one approaching the sphere again in middle latitudes. This is merely an instance of the well-known fact* that rotatory motion in a fluid is unstable if the angular momentum per unit mass increases inwards. G. I. Taylor's† experiment with fluid between two rotating cylinders is another instance. The fixed containing vessel is an essential part of the conditions of Ahlborn's experiment, and has no analogue in the atmospheric problem. It can be shown easily that the atmosphere would rotate with the earth like a rigid body if it were not for differences of temperature over level surfaces within it.

The idea of a star radiating energy at the expense of its mass, attributed to Prof. Eddington, on p. 112, was originally due to Dr. J. H. Jeans ; and the giant and dwarf theory of stellar evolution, described as if it was created by Eddington in 1924, really received a most damaging blow from him then. With

* Lord Rayleigh, *London Proc. R. Soc. A.*, 1916, pp. 148-154.
† *London Phil. Trans. R. Soc. A.*, 223, 1923, 289-343.

regard to the passage on p. 115 on the change of the obliquity of the ecliptic, Sir G. H. Darwin's work on tidal friction showed that a secular increase in the obliquity has probably proceeded ever since the moon was formed. On p. 140 it is said that cloudiness would lower the mean temperature even if solar and terrestrial radiation were reflected equally. This is not the case ; a " grey body," that is, a body with surface composed partly of black regions and partly of perfectly reflecting regions, would take up the same temperature as a black body ; the only difference is that it would take longer to do it. The estimate of 30 to 180 miles, given on p. 253, for the thickness of the sial or granite layer is probably excessive ; 10 miles would probably be nearer the mark. It might be inferred from p. 256 that Prof. Joly's theory is the only modern form of the thermal contraction theory of mountain formation, which is not the case.

A curious result is obtained in an Appendix, with reference to the geological time scale. Taking some geological determinations of the mean height of the land during the various periods, Brooks assumes that the rate of denudation was proportional to this height, and infers the lengths of the periods from the thicknesses of the sediments deposited. The results are in surprisingly good agreement with those obtained from the Uranium-Lead ratio. This fact suggests, incidentally, that the rate of denudation requires no great corrections for variations in rainfall, which would support the view expressed above that cyclonic disturbances in the warm periods were about as plentiful as at present.

Though Brooks's theory seems to require modification in some points, its fundamental ideas are highly plausible and well supported by the facts. There is a creditable dearth of misprints in his book, and the illustrations and maps are clear and abundant.

"Old Fashioned" Winters.

By M. T. Spence, B.Sc.

An " old fashioned " winter may be defined as a winter in which frost and snow are prevalent ; this implies that cold winters occur less frequently now than they have done ; temperature records might, therefore, be expected to afford the necessary evidence in support of a conclusion which is so generally accepted. The difficulty immediately presents itself, however, of determining exactly when frost and snow first became " old fashioned." It is not improbable that what is " old fashioned " now, was " old fashioned " many years ago and, if so, it may be inferred that there has ever been a popular delusion with regard to winter weather. If that is the case, can an explanation of the delusion be found ?

The longest homogeneous series of temperature records in the British Isles is the Greenwich series from 1841. There was, however, a change in the site of the thermometers in January, 1899, when they were moved to a more open site in the Magnetic Pavilion enclosure. There is the further point, that the expansion of London during the past 85 years may possibly have had its influence on the temperature at Greenwich. The frequency with which winter months in the Greenwich series in each five year-period have been above or below the average for the whole period, is shown in the following table (months which are exactly normal are given alternatively to " above average " and " below average ;" there are, however, only 3 such months in the whole period) :—

	December		January		February		3 Winter Months	
	Above average	Below average	Above average	Below average	Above average	Below average	Above average	Below average
1841-45 ..	3	2	2	3	1	4	6	9
1846-50 ..	3	2	2	3	4	1	9	6
1851-55 ..	3	2	4	1	2	3	9	6
1856-60 ..	2	3	3	2	2	3	7	8
1861-65 ..	4	1	2	3	3	2	9	6
1866-70 ..	2	3	2	3	4	1	8	7
1871-75 ..	2	3	4	1	2	3	8	7
1876-80 ..	3	2	2	3	4	1	9	6
1881-85 ..	2	3	3	2	4	1	9	6
1886-90 ..	0	5	1	4	0	5	1	14
1891-95 ..	3	2	0	5	2	3	5	10
1896-1900 ..	3	2	4	1	4	1	11	4
1901-05 ..	3	2	3	2	2	3	8	7
1906-10 ..	3	2	2	3	2	3	7	8
1911-15 ..	5	0	3	2	5	0	13	2
1916-20 ..	3	2	3	2	2	3	8	7
1921-25 ..	3	2	5	0	4	1	12	3
	47	38	45	40	47	38	139	116

There is here no indication of a progressive change in the frequency of cold or mild winters, the highest frequency of mild winters does occur towards the end of the period but the highest frequency of cold winters occurs about the middle of the period. The further analysis of the series as given below is, however, instructive and may, it is thought, explain the popular conception of a cold winter as " old fashioned."

Taking the winter months in sequence, *i.e.*, December, January, February, December, January, etc., and basing the mathematical probability of a run of mild or cold months on the fact that 139 are above average and 116 below average, and noting that the ratio of mild Decembers to cold Decembers is approximately the same as the ratio of mild Januaries to cold Januaries and also of mild Februaries to cold Februaries, we have :—

No. of months in run.	Mathematical probabilities of runs of winter months which are mild or cold.		Actual frequency of occurrence of runs of winter months which are mild or cold.	
	Mild.	Cold.	Mild.	Cold.
2	1 in 3	1 in 5	1 in 3	1 in 4
3	,, 6	,, 11	,, 5	,, 7
4	,, 11	,, 23	,, 8	,, 13
5	,, 20	,, 51	,, 14	,, 21
6	,, 37	,, 113	,, 23	,, 31

This analysis shows that there are two factors operating to give runs of mild winter months without assuming any change of climate ; firstly, the mathematical probability based on pure chance of a run of mild winter months is greater than the mathematical probability of a run of cold winter months (a run of 6 mild winter months might be expected to occur approximately 3 times as often as a run of 6 cold winter months) ; secondly, the observed frequency of those runs compared with the mathematical probability of them indicates that a month is predisposed to be mild or cold according as the preceding months have been mild or cold. It may be deduced from these considerations that a series of mild winters such as has occurred since 1911 is no indication of a change of climate and that similar runs have probably occurred in the past. Furthermore, it is not difficult to understand how such runs when they occur give rise to the impression that cold winters are " old fashioned."

Another series of data which is of interest in this connexion and which deals more specifically with frost is the record of days of skating in Regent's Park kept by the National Skating Club from 1830 to 1904, given in Sir Richard Gregory's *British Climate in Historic Times*, as follows :—

Mean Annual number of days of Skating.		Mean Annual number of days of Skating.	
1830-35	7.6	1865-70	7.2
1835-40	12.8	1870-75	11.6
1840-45	18.8	1875-80	21.4
1845-50	12.2	1880-85	4.2
1850-55	10.0	1885-90	16.0
1855-60	7.0	1890-95	31.2
1860-65	10.0	1895-1900	2.4

1900-4 (4 years), mean, 7.7 days.

It is unfortunate that this series does not extend beyond 1904, but so far as it goes there is no indication in it of a progressive change in the number of days of skating.

Luke Howard in his *Climate of London* (2nd edition), gives the following values of mean monthly temperature for London for the period 1797 to 1816 :—

December, 38·7° F. ; January, 36·3° F. ; February, 39·6° F.
The normal at Greenwich for the period 1881-1915 is :—
December, 40.2° F. ; January, 38·5° F. and February, 39·8° F.

The exposures of the thermometers, however, used for Howard's values make his records quite incomparable with later records, for instance, the height of the thermometers above ground varied from 3 feet to 10 feet, and almost any position which was not exposed to direct sunlight appears to have been regarded as satisfactory for registering air temperatures. In the same publication there appears the following description of winter weather :—

> " Continued frost in winter is always an exception to the general rule of the climate. The winter even passes, occasionally, almost without frost ; in return for which we have, at uncertain intervals, a rigorous season of many weeks' duration, attended with deep snows and clear atmosphere common to more northern latitudes. Our seasons of frost go off, like those of great heat, with a wind from the Atlantic."

The second edition of the *Climate of London* was published in 1833, and the author states that he was about 60 years of age at the time of preparing it for press. The remarks of so conscientous an observer as Luke Howard who had devoted so many years to observational work may be taken as accurate and suggest that winters during the first half of the nineteenth century were much the same as they now are.

The frequent references to severe winters and to a frozen Thames appearing in Lowe's *Chronology of the Seasons*, and in Sir Richard Gregory's *British Climate in Historic Times*, and the comparative absence of reference to mild winters might possibly be regarded as an indication of change, but it is not improbable that mild winters might pass unrecorded whereas severe frosts would be generally noted. There is, however, one reference in *British Climate in Historic Times* to a mild winter which is not without significance : " 1775, April 11th. From November till a fortnight ago we had warmth that I should often be glad of in summer." With regard to the freezing of the Thames Sir Richard Gregory points out that in former times the arches of London Bridge impeded the flow of the river and were easily blocked with ice.

The question as to whether winters with frost and snow are " old fashioned " is one to which the available observations give no conclusive answer, but an analysis of the Greenwich series makes it clear that a run of mild winter months is no evidence that cold winters are becoming " old fashioned " and the comparative frequence of runs of mild winter months may possibly explain the title given to the less frequently occurring cold, but often impressively cold, winter months. The records outside the Greenwich series do not afford satisfactory evidence on which to base conclusions of a change within, say, the last two centuries.

The Detonating Meteor of October 2nd, 1926

Additional Notes

The following notes, which are supplementary to my article in the December number of the *Meteorological Magazine*, should, I think, be placed on record.

The position of the radiant of the meteor is given by Mr. King as defined by Right Ascension 303°, Declination 14° S. Mr. Denning gives 305°, 13° S and remarks (The *Observatory*, November, 1926, p. 344) that this is a centre from which numerous meteors diverge during the months of July and August.

The track shewn on the map is not quite correct ; the line should have been drawn to pass to the east of Worthing and to cross the Thames nearer London.

It is probable that the meteor began to break up a little south of Hitchin and that some of the fragments retained their luminosity as far as Holwell. Mr. B. Taylor, who saw the phenomenon from near Pegsdon about 5 km. southwest of Holwell, gives a sketch of a ball of fire followed by numerous stars. The ball which was yellow " burst open and disappeared almost at once." " The noise was like a clatter of machine guns two or three miles away and quite terrifying." To Mr. Arthur Moody, who saw the phenomenon from Coventry, the meteor was " of a bluish incandescent tint." It burst into a number of pieces, about a dozen, " which immediately turned red like coal cinders and died away."

The speed of the meteor as determined by Messrs. Denning and King was 20 km. per sec.

As the meteor was moving about 70 times as fast as sound, the ballistic wave must have taken the form of a very sharp cone, nearly a cylinder. That the sound was not heard beyond the end of the meteor's track may be analagous to the fact that the ballistic wave from a shell is not heard behind the gun.

The west wind at great heights, which was postulated to account for the time the sound took to reach Reading, may be the explanation of the greater extension of the region of audibility to the east.

Houghton appears on the map as the position of an observer who gave a good estimate of the elevation of the end point of the track. At Ipswich, which is also shewn on the map, there were two observers who heard noises. Mr. Hodson's report is circumstantial—" I saw the meteor burst but do not remember hearing an explosion ; soon after it had vanished, however, I heard a sound as if somebody had clapped." May we regard this as evidence that it was a single ballistic wave that reached Ipswich ?

The hypothesis, which was new to me, that the bursting of a meteor is due to centrifugal force was current as long ago as 1809. In the abridged *Philosophical Transactions of the Royal Society*, Vol. 6, there is a summary of a paper written by Edmund Halley, in 1714. To this paper one of the editors, probably Charles Hutton, adds a long footnote which includes the following paragraph :

> " That they commonly burst and fly in pieces in their rapid flight, is a circumstance exceeding likely to happen, both from the violent state of fusion on their surface, and from the extreme rapidity of their motion through the air. If a grinding stone, from its quick rotation, be sometimes burst and fly in pieces ; and if the same thing happens to cannon balls, when made of stone, and discharged with considerable velocity, merely by the friction and resistance of the air ; how much more is the same to be expected to happen to the atmospheric stones, moving with more than 50 times the velocity, and when their surface may well be supposed to be partly loosened or dissolved by the extremity of the heat there."

F.J.W.W.

Official Publications

The following publication has recently been issued :—

Advisory Committee on Atmospheric Pollution. Twelfth Annual Report ; for the year ending March 31st, 1926.

The report is divided into four sections. In the first section which deals with the deposit of impurity at 61 gauges, an increase of twelve over the previous year, it is shown that the deposit of impurity was less than the average for the previous five years at about two-thirds of the stations. Section 2 deals with the impurity suspended in the air as measured by the automatic filter. In London the percentage of hazy days as determined by the filter was definitely higher than in the previous year but at Blackburn and Stoke-on-Trent it was lower. An account of observations made with the jet dust counter is given under Section 3. Section 4 describes various researches carried out including an attempt to correlate the obstruction of ultra-violet radiation with the quantity of suspended impurity in the atmosphere.

An appendix to this report written by Dr. J. R. Ashworth, of Rochdale, describes an instrument designed by himself for measuring the amount of deposit from the atmosphere day by day or hour by hour. The results obtained with the instrument are described, including a discussion of the effects of wind and rain on the quantity of matter deposited.

Discussions at the Meteorological Office

December 6th. *On the theory of monsoon rainfalls in the Far East.* By D. Nukiyama, (National Research Council of Japan, Tokyo, Jap. J. Astron. Geoph., II., 1924, pp. 75—90). *Opener*—Mr. R. H. Mathews, B.A.

This paper is concerned, not with the rainfall, which is small, but with the excessive cloudiness during the period of the winter north-north-west monsoon over the East China Sea, between Formosa and the Luchu Islands. The area is traversed by a warm south-west current, while northern China, the source of the wind, is very cold and has clear skies. The northerly monsoon winds have a velocity of 8-18 m/s ; the winds associated with cyclonic disturbances are generally weaker. The difference between the air temperature and dew point, and hence the height of cloud formation with a normal vertical temperature gradient, are greater with northerly winds than with those from other directions, but in spite of this the amount of cloud is greatest with northerly winds, averaging between eight and nine tenths of the sky at Nafa.

Since there is no question of forced ascent of air by mountains, and the loss of heat by radiation is also unable to account for the cloud formation, the author investigates the effect of warming of the lower layers from below by the sea surface, and obtains a mathematical expression from which he deduces that this cause is sufficient.

The subjects for discussion for the next meetings will be :—

January 31st, 1927. *The way of the wind.* By W. J. Humphreys (Philadelphia, Pa., J. Franklin Inst. 200, 1925, pp. 279-304). *Opener*—Mr. M. J. Thomas, B.Sc.

February 14th, 1927. *The cup anemometer.* By J. Patterson (Ottawa, Trans. R. Soc., Canada, Sec. 3, 20, 1926, pp. 1-54). *Opener*—Mr. T. W. Vernon-Jones, B.Sc.

A paper on " The forecasting and control of cholera epidemics in India " will be read before the Royal Society of Arts, by Lieut.-Col. Sir Leonard Rogers, C.I.E., M.D., F.R.S., on Friday, January 28th, at 4.30 p.m. Tickets may be obtained upon application to the Secretary, Royal Society of Arts, John Street, Adelphi, W.C. 2.

Royal Meteorological Society

The monthly meeting of this Society was held on Wednesday, December 15th, at 49, Cromwell Road, South Kensington, Sir Gilbert Walker, C.S.I., F.R.S., President, in the Chair.

N. K. Johnson, M.Sc.—Some meteorological observations at sea.

This paper gives a brief account of some meteorological readings which were taken over a period of 24 hours on a ship steaming eastwards in the Mediterranean Sea. The observations include measurements of wind velocity and direction, air temperature and humidity, sea temperature and the vertical distribution of temperature in the air up to a height of 22 m. The last quantity was measured by means of a specially designed apparatus, and precautions were taken to determine all the other quantities as accurately as possible. The observations were made on May 12th-13th, 1926, and the sky was practically clear throughout the 24 hours. The readings of air temperature show a diurnal variation of 1·9° F. There are also indications of a small diurnal variation in the sea temperature. The vertical temperature gradient between heights of 5 m. and 22 m. was found to possess the dry adiabatic value throughout the day but exceeded this value during the night. This result, which is exactly the reverse of what occurs on land, is discussed and reasoning is given to show that it probably represents the normal occurrence at sea.

N. K. Johnson, M.Sc., and E. L. Davies, M.Sc.—Some measurements of temperature near the surface in various kinds of soil.

This paper contains an account of a series of measurements made throughout the year 1925 of the maximum and minimum temperatures recorded at a depth of about 1 cm. below the surface of six kinds of "soil." It is found that in summer the maximum soil temperatures are considerably in excess of the maximum air temperatures recorded in a Stevenson screen. This excess is 37° F. in the case of tarmac, and 14° F. in the case of grass covered soil. In mid-winter the soil maxima are all practically equal to the screen maximum. The minimum temperatures recorded in the "soils" agree closely throughout the year with the minimum air temperature in the screen. The only exception is in the case of the grass covered soil in which the minimum averages about 5° F. higher than the air minimum. A pair of recording thermometer bulbs buried in undisturbed chalky soil enabled the conductivity of the soil to be calculated, firstly from the decrease with depth of the diurnal temperature wave, and secondly from its change of phase with depth. The values deduced by the two methods are in good agreement. By employing this value it then becomes possible to extrapolate the temperature observations up to the actual surface of the soil.

In this way it is found that the average summer maximum for the surface of tarmac is about 115° F., and for earth and sand about 100° F. The extreme maxima for these "soils" are calculated as about 140° F. and 130° F. respectively. It is also concluded that in the tropics an extreme maximum surface temperature for ordinary soils may be estimated as about 180° F.

A. N. Puri, Ph.D.—Investigation on the behaviour of hair hygrometers.

A study has been made of four types of hair hygrometers in which the total load on the hairs consists of a weight. These were taken through a series of humidity changes controlled by sulphuric-acid water mixtures. It is shown that, when the hair is loaded with a weight of two grams, or more, it undergoes a slow extension which extends over a period of several weeks. Hair under a smaller load shows no such effect and the readings at various humidities can be reproduced with sufficient accuracy to measure humidity within two per cent. Alterations in the length of the hair due to changes in humidity show a hysteresis effect which is apparently in the reverse direction to that when measurements are taken in terms of change in weight. A simple form of weight hair hygrometer has been described, which can be used for measuring the vapour pressure of moist substances.

The Buchan Prize of the Royal Meteorological Society for 1927 has been awarded to Mr. C. K. M. Douglas, B.A., for the following papers, contributed to the *Quarterly Journal* of the Society during the years 1922-25 :—" Observations of upper cloud drift as an aid to research and to weather forecasting " ; " Further researches into the European upper air data, with special reference to the life history of cyclones " ; " On the relation between the source of the air and the upper air temperature up to the base of the atmosphere."

Correspondence

To the Editor, *The Meteorological Magazine*

Land Waterspouts

I was much interested in Mr. Fallows' letter in your November issue and should like to add an observation of mine to his. I also feel that it is time that someone with scientific experience took up the cudgels on behalf of the many sea captains who write both to the *Meteorological Magazine* and to *Nature* iterating that water spouts are tubular. Their stories are generally followed by an editorial comment to the effect that water spouts are formed by the condensation of water vapour by rapid expansion in a vortex, and as such cannot be tubular, but consist of " solid " (if the term can be applied) mist.

The waterspout illustrated here occurred on the land, 150 miles from the nearest sea, at Naft-i-Safid, Bakhtiari Country, in Persia, on Monday, December 27th, 1915. Its distance from myself as observer was about two miles, and it was viewed through a pair of Zeiss glasses with a magnification of eight. As the pendant gradually dropped from the cloud, a hollow column of dust from the plain rose to meet it. The pendant and column eventually joined, the whole swaying about in a particularly beautiful manner. The height of column from the plain to the

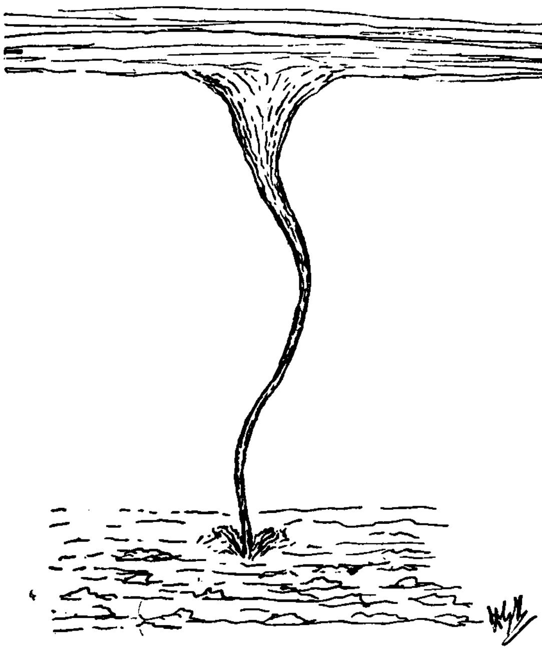

FIG. 1. GENERAL VIEW.

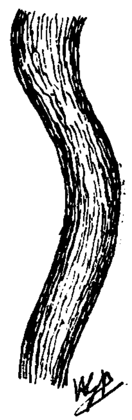

FIG. 2. PORTION OF COLUMN AS SEEN THROUGH GLASSES.

cloud was about 2,000 feet (surely Mr. Fallows' column was more than 200 feet ?), and the motion of the column about fifteen miles per hour, but very irregular. I have no note on the direction of rotation of the column. The whole phenomenon lasted about fifteen minutes, and the pendant portion withdrew into the cloud first, leaving the lower portion rotating at the bottom. At the base of the column there was a fountain of large fragments thrown out, stones, sticks and anything that was loose. The whole column appeared like a translucent glass tube, but flexible, that is, there was a dark edge and a brighter middle, just as I have drawn it. A solid column of mist would have given an exactly opposite effect, namely, a dark middle and a bright edge. There is no doubt in my mind at any rate that the column was hollow, and that the lower part of it was composed of dust, which was of a browner colour than the cloud above it.

Such a " landspout " is, of course, not to be confused with the ordinary dust devil, which is quite common in any desert on a bright day.

I have frequently seen waterspouts at sea, and the tubular effect is always there.

H. G. BUSK.

Old Vicarage House, Milford-on-Sea, Hants. November 22nd, 1926.

Short Period Oscillations of Pilot Balloons

Captain Brunt in his interesting note on this subject in your last issue comes to the conclusion that the oscillations must be ascribed to oscillations in the form of the balloon and not to changes of wind or temperature in the surrounding atmosphere. The conclusion that the cause is inherent in the balloon is borne out by some observations on the rate of ascent of balloons made by the writer in an airship shed at South Farnborough and in the Albert Hall some years ago.

The balloons liberated in these enclosed buildings always went up in a series of " waggles." The period of the oscillations was not noted but from memory I should say that it did not differ greatly from the 2-2½ seconds mentioned by Captain Brunt. It would be interesting to know whether the period depends upon the size of the balloon, a point that could easily be investigated. It has always seemed to me that the irregular movements were due to instability in the wake of the air behind the balloon and that there was no need to look for irregularities of shape as their cause.

J. S. DINES.

November 30th, 1926.

NOTES AND QUERIES

Remarkable Temperature Inversion, December 30th, 1926

A remarkable temperature inversion was observed by aeroplane at Duxford on December 30th, 1926, the temperature readings being 34° F. at 890 mb. (3,700 ft.), 51° F. at 850 mb. (4,900 ft.), and 52° F. at 830 mb. (5,500 ft.) giving a total rise of 18° F. The temperature at the upper level appears to be the highest yet recorded in the British Isles for the period December to April inclusive. The high readings were confirmed by another aeroplane ascent from Stag Lane Aerodrome, Hendon. Next day the inversion had vanished, the temperature having fallen 18° F. at 850 mb., and on the average 15° F. from 850 to 650 mb. (about 5,000 to 12,000 ft.). This change was surprising considering that there was a stationary anticyclone off southwest Ireland, with no change either in the general conditions, in the source of the lower air, or in the surface pressure. It was amply confirmed by a large fall of upper air temperature observed at Utrecht, in Holland. Similar phenomena on a smaller scale are, however, fairly frequent, provided there is a considerable upper wind.

It is worthy of note that the pilot reported "altitude of inversion unreliable owing to its variation with cloud undulations." It is important to keep these small scale variations in mind when comparing the heights of inversions at different stations or on successive days. Though the undulations of large winter inversions only amount to a few hundred feet, there may be local variations up to 2,000 ft. in the height of smaller summer inversions when there are irregular convectional clouds below. There may also be great local variations in the sharpness of inversions, due to changes just below or just above them.

C.K.M.D.

First Greenland Expedition of the University of Michigan

We learn from *Science* for October 8th that Professor W. H. Hobbs with a party of scientists has successfully carried out a nine-weeks exploration of south-west Greenland, a preliminary to the more prolonged expedition which is planned to commence in 1927. A base was established on July 7th on the shores of Maligiak Fiord, about fifty miles east of Holstensborg, and a journey was undertaken to the margin of the inland ice, where a depot of equipment was laid down. Pilot balloon ascents were made both from the base camp and by the exploring party, some of the balloons being followed over the surface of the ice itself ; in all some ninety ascents were made, the greatest height reached being 14,000 metres. In addition ballon-sondes were sent up and one of the meteorographs was recovered after reaching a height of 8,000 metres.

Tornadoes Started by an Oil Fire.

The *Scientific American* for December, 1926, contains a vivid description of the effects of a fire which destroyed nearly six million barrels of oil at San Luis Obispo, California. An account of the event was given by Mr. J. E. Hissong, of the local weather bureau of California city. He states that the fire was started by lightning and that initially four tanks, each containing 750,000 barrels of oil, "boiled over." An immense quantity of burning oil was spread over an area which was estimated at about 900 acres or nearly 4 sq. km. Flames seemingly leaped up to a height of 1,000 feet, and at the same time violent whirlwinds formed over the fire. During the period when the large reservoirs were burning, and the convection was probably at its strongest, the whirls were numerous and violent. Some hundreds of whirls were observed simultaneously, many of them presenting the features of true tornadoes, with gyrating funnel shaped clouds, the condensation of vapour in the central portions showing up clearly against the dark background of smoke. It is reported that some of the central funnels were not more than about a foot in diameter.

One of the whirls travelling downwind to a cottage about a thousand yards away, picked up the cottage, and carried it a distance of 150 feet, where it was dropped, a complete wreck, the two occupants being killed.

Mr. Hissong reports that strong southerly winds prevailed initially, shifting later to west, and eventually to northwest. He attributes the formation of the whirls to the veering of the wind, which coincided more or less with the formation of the whirls. It is difficult to see how this in itself could account for the whirls, and the present writer suggests that the whirls were such as might have occurred, independently of any wind, by the convection currents removing large masses of air, which would be replaced by the convergence of air from all sides. The converging air by retaining its original moment of momentum about the centre of the rising column, would after convergence, have acquired a large velocity of rotation about the centre, and would give rise to whirls of the nature observed.

A rough estimate of the energy liberated by the fire can be readily made. A given weight of oil will raise the temperature of 1,000 times its own weight of water through 10° C. The fire of six million barrels, assuming a barrel to be half a cubic metre, is equivalent to the burning of $3 \cdot 10^9$ kg. and would produce $3 \cdot 10^{13}$ kg. calories; taking the specific heat of air to be 1/4, we find that this would heat $12 \cdot 10^{12}$ kg. of air through 10° C. This amount of air is about 10^{13} c.m., or 10^4 c.km.

If there were no wind initially, then if we assume that 10^4 c. km. of air is removed through a funnel vertically over the fire, this amount of air must drift in sideways to the zone of the fire, and be replaced by air pushing in from further distances. Taking the zone of fire to be a circle of 1 km. radius, this involves the convergence to the edge of the zone of fire of air from 50 km. away. The angular momentum of this air remains constant, in space, and if the velocity in the whirl about the fire be v at the edge of the fire (at 1 km. from the centre) we then have

$$(50)^2 \omega \sin \phi = 1. (v + \omega \sin \phi).$$

$$\begin{aligned} \text{Thus } v &= \text{approximately } (50)^2 \omega \sin \phi \\ &= 2500 \times 5 \cdot 7 \; 10^{-5} \text{ km. per sec.} \\ &\doteq 142 \text{ metres per sec.} \end{aligned}$$

Thus the whirl formed in still air would have a whirling velocity of 142 metres per sec. at 1 km. from its centre, with velocity decreasing outward in inverse proportion to distance from the centre.

In the case in question, the air was not initially still, and so the ascending cylinder of air was replaced by a sheet of air, and the one whirl was replaced by a number of smaller whirls. Enough has been said, however, to show that the supply of energy available from the fire was ample to account for the formation of violent tornadoes without assuming any special properties of the wind distribution. Moreover, it has been assumed above that only air heated through 10° C. will ascend, whereas it is certain that in the region of such a fire as this air heated through a much smaller range of temperature would ascend readily. If we decrease the necessary range of temperature we increase the volume of air removed by convection in inverse proportion, and increase the intensity of the whirl in proportion to the mass of air removed.

It may be recalled that during the fires which completed the destruction of Tokyo after the earthquake of September 2nd, 1923, Dr. Fujiwhara reported the formation of a number of whirls.*

D. BRUNT.

The Last British Glacier

With reference to his letter of November 4th,† Mr. R. P. Dansey points out that Aonach Mt. should be Aonach Mor, and Aonach Beas should be Aonach Beag. He also writes : "Personally I am of the opinion that the scree mound below the bed has been pushed up there by the bed, against your deduction that the rock face has been bare for hundreds of years and has been preserved in its clean state by the bed. The other bed under Aonach Mor which in most years never melts but which had gone in 1918 ought, I think, if your deduction is right, also to have shown smooth clear rocks, but it did not."

The Rainfall of 1926

The rainfall of the year 1926 was similar to that of 1925 in being slightly in excess of the average. Since the dry year 1921 the rainfall of each year has reached or exceeded the average, the percentage values for the British Isles for the years 1921 to 1926 being 82, 100, 114, 117, 104 and 103 respectively. Excesses predominated over England and Wales and in Scotland, but in Ireland excesses were confined to considerably less than half the country. In England and Wales there were two large areas with excess, one to the south-east of a line from the mouth of the Severn to the Wash, and the other covering the north of England

*Vide *Meteorological Magazine*, December, 1923, p. 247.

† See *Meteorological Magazine*, 61 (1926), *p.* 262.

and northern and central Wales. Practically everywhere the fall was within 85 and 115 per cent. of the average. In Scotland the fall exceeded 120 per cent. over the west of the Southern Uplands, to the south of the Grampians from Crieff to Dundee and to the north of Bute from Rothesay to Inveraray. The fall was below the average along the greater part of the west and north coasts and over the Valley of the River Spey. In Ireland falls of more than the average were confined to the north-east, from Galway to Belfast, while in the neighbourhood of Londonderry more than 110 per cent. was recorded.

While the rainfall of the whole year over the British Isles was close to the normal, the distribution in time was very erratic. Apart from the very wet January and dry March, the year includes the wettest November and the driest December in 57 years of comparable statistics. While separately November and December gave extreme values, together the fall was very close to the average for the two months.

The rainfall of December is worthy of special comment. The map showing the rainfall of the month as a percentage of the average presents a fairly uniform gradient from the south to the north in each of the three countries. Over England and Wales the percentage varied from less than 10 per cent. along the south coast of Dorset and Devon to 75 per cent. in the Lake District ; in Scotland from less than 25 per cent. in the south-east to more than 100 per cent. in the north-west, and in Ireland from less than 10 per cent. in Co. Cork to over 50 per cent. in Londonderry. Many observers reported the driest December on record. At stations as widely distributed as Slough in Buckinghamshire, Lyme Regis in Dorset, Church Stretton in Shropshire and Darrynane Abbey in Kerry, the total was the smallest recorded in December in over 50 years' records. At Kew Observatory it was the smallest total since records began there in 1866 and at Ross-on-Wye since 1818.

Obituary

We regret to learn of the death of Mr. Charles Harding, at Eastbourne, on January 9th, at the age of 80.

News in Brief

The past and present members of the Staff of the Meteorological Office, Edinburgh, and their friends, together with members from Eskdalemuir Observatory and Leuchars Aerodrome, to a total number of 25, held a most successful social gathering in Edinburgh, on December 4th. As on the first occasion, a year ago, the party met for dinner at Ferguson and Forrester's Restaurant, and the remainder of the evening was spent in dancing at the *Palais de Danse.*

The Weather of December, 1926

In striking contrast to November the rainfall of December was unusually low and pressure unusually high. Westerly winds prevailed during more than half the month, but after the 21st the winds were mainly easterly. Cold anticyclonic misty weather occurred on the 1st, but the passage of a depression south-eastwards across the North Sea caused strong north-westerly winds and hail, sleet and thunder locally in the north and west on the 3rd. Subsequently an anticyclone spread north-eastward from the Azores and was associated with fog at times; day temperatures, however, rose frequently above normal between the 6th and the 11th. By the 12th the anticyclone was withdrawing towards Switzerland and a shallow depression was approaching from Iceland. Northerly winds in the rear of the latter were associated with a temporary drop in temperature about the 15th, when the lowest grass minimum temperature for the month, 11° F., was recorded at Dumfries. Snow and sleet were reported from most districts and "snow lying" from a few places in the north. Further depressions travelling south of Iceland in an east-south-east direction caused a renewal of generally mild conditions on the 16th with freshening westerly winds. After the 20th pressure became high across Scotland to Scandinavia giving cold north-easterly winds and snow or sleet locally. The winds freshened considerably at times, rising to gale force in the western part of the English Channel, and temperature readings were low, the lowest screen minimum for the month, 14° F., being recorded at Balmoral on Christmas Day. On the 24th the barometer rose unusually high in Scotland, readings exceeding 1,050 mb. in several places, but during the next few days the anticyclone moved south-westwards and became less intense. A comparatively warm current from the Atlantic caused a marked rise in temperature in Scotland on the 27th, the maximum at Aberdeen that day being 53° F., 17° F. higher than at Kew. Milder conditions spread to the southern counties also on the 28th and 29th.

The rainfall for the month and year is discussed on p. 294.

Pressure was above normal over western and central Europe and the North Atlantic, the excess being as much as 17·6 mb. at Donaghadee, and below normal over Spitsbergen, northern Scandinavia and Nova Scotia. Rainfall was generally below normal except in northern Norway and temperature below normal in Scandinavia except Jämtland, Ireland and Spain, but above normal elsewhere. In Svealand, Sweden, the rainfall was only 66 per cent. of the normal.

Extensive floods occurred in the south of France during the first days of the month owing to the previous heavy rains. By the 4th the rain had turned to snow and abundant falls were reported from the Auvergne, Pyrenees and Puy de Dôme. Heavy snow also occurred in Asturias, the neighbourhood of Madrid, and as far south as Almeria. Ten monks from the Great St. Bernard Hospice were overtaken by an avalanche coming from the Col de Fenêtre on the 7th, and landslides occurred in Oviedo (Spain) and the Pyrenees owing to torrential rains. An unusually black high fog occurred in Paris on the 10th. Mild weather prevailed in Lorraine to about the 18th, and fine sunny weather in Switzerland from the 8th to 18th, when a severe snowstorm occurred there. Later, heavy snow also fell in the Black Forest and severe cold and snow were reported from Switzerland, France, Spain and Portugal for the rest of the month.

On the 10th a thunderstorm ended the drought which was being experienced in Jerusalem. Following on a week's rain, floods occurred in Malaya on the 27th causing much damage to the mines and railways. Floods also occurred along the Beira-Mashonaland railway (Portuguese East Africa) on the 29th.

Disastrous bush fires raged intermittently in New South Wales from the 4th to 14th. Steady soaking rains, however, fell after the 18th in Queensland and after the 27th in New South Wales, where floods were reported in low lying parts.

On the 4th more than 100 steamers were held up in the St. Lawrence at Sault Ste. Marie by an ice blockade said to be the worst ever experienced. It was broken up on the 9th. Heavy snow occurred in New York on Christmas night and at the same time almost tropical rains swelled the rivers of Tennessee, Arkansas, Mississippi and Kentucky, till they overflowed their banks. Twelve people were drowned. Unusually severe weather was experienced in the Rocky Mountain States towards the end of the month.

A violent storm passed over Funchal, Madeira, on the 15th. The wind at first was SE, but later veered to W, and large seas dashed against the island, doing much damage to shipping, several vessels being sunk.

The special message from Brazil that the rainfall in the central districts was 48 mm. above normal and in the southern districts very abundant with 109 mm. above normal. The weather was generally favourable to crops and vegetables. Many depressions passed across the southern part of the country. At Rio de Janeiro pressure was 1·3 mb. below normal and temperature 1·1° F. below normal.

Rainfall, 1926—General Distribution

	Dec.	Year	
England and Wales	26	102	per cent. of the average 1881-1915.
Scotland	57	109	
Ireland	30	99	
British Isles	34	103	

Rainfall: December, 1926: England and Wales

CO.	STATION.	In.	mm.	Per-cent. of Av.	CO.	STATION.	In.	mm.	Per-cent of Av.
Lond.	Camden Square	·43	11	18	*War.*	Birminghm, Edgbaston	·41	11	15
Sur.	Reigate, The Knowle	·48	12	16	*Leics*	Thornton Reservoir	1·00	25	37
Kent.	Tenterden, Ashenden	·74	19	24	,,	Belvoir Castle	·91	23	37
,,	Folkestone, Boro. San.	·96	24	...	*Rut.*	Ridlington	·64	16	...
,,	Margate, Cliftonville	·44	11	19	*Linc.*	Boston, Skirbeck	·76	19	35
,,	Sevenoaks, Speldhurst.	·75	19	...	,,	Lincoln, Sessions House	·64	16	29
Sus.	Patching Farm	·33	8	10	,,	Skegness, Marine Gdns.	·58	15	26
,,	Brighton, Old Steyne	·46	12	15	,,	Louth, Westgate	·79	20	28
,,	Tottingworth Park	·53	13	14	,,	Brigg	·85	22	35
Hants	Ventnor, Roy.Nat.Hos.	·43	11	13	*Notts.*	Worksop, Hodsock	·85	22	36
,,	Fordingbridge, Oaklnds	·45	11	11	*Derby*	Mickleover, Clyde Ho.	·81	21	31
,,	Ovington Rectory	·53	13	13	,,	Buxton, Devon. Hos.	1·96	50	35
,,	Sherborne St.JohnRec.	...	..	...	*Ches.*	Runcorn, Weston Pt.	1·09	28	34
Berks	Wellington College	39	10	14	,,	Nantwich, Dorfold Hall	1·00	25	...
,,	Newbury, Greenham	·44	11	14	*Lancs*	Manchester, Whit. Pk.	1·46	37	45
Herts.	Benington House	·31	8	12	,,	Stonyhurst College	2·92	74	60
Bucks	High Wycombe	·50	13	17	,,	Southport, Hesketh Pk	1·16	29	36
Oxf.	Oxford, Mag. College	·51	13	22	,,	Lancaster, Strathspey	1·39	35	...
Nor.	Pitsford, Sedgebrook	·56	14	23	*Yorks*	Sedbergh, Akay	...	..	...
,,	Eye, Northolm	...	..	...	,,	Wath-upon-Dearne	·83	21	35
Beds.	Woburn, Crawley Mill	·40	10	17	,,	Bradford, Lister Pk.	1·06	27	32
Cam.	Cambridge, Bot. Gdns.	·27	7	14	,,	Wetherby, Ribston H.	·89	23	36
Essex	Chelmsford, CountyLab	·43	11	19	,,	Hull, Pearson Park	·79	20	33
,,	Lexden, Hill House	·49	12	...	,,	Holme-on-Spalding	·64	16	...
Suff.	Hawkedon Rectory	·84	21	35	,,	West Witton, Ivy Ho.	1·08	27	...
,,	Haughley House	·67	17	...	,,	Felixkirk, Mt. St. John	1·14	29	47
Norf.	Beccles, Geldeston	·78	20	34	,,	Pickering, Hungate	1·21	31	...
,,	Norwich, Eaton	1·30	33	50	,,	Scarborough	1·08	27	45
,,	Blakeney	1·06	27	48	,,	Middlesbrough	1·12	28	58
,,	Swaffham	·89	23	37	,,	Baldersdale, Hury Res.	1·30	33	...
Wilts.	Devizes, Highclere	·69	18	23	*Durh.*	Ushaw College	·70	18	28
,,	Bishops Cannings	·62	16	19	*Nor.*	Newcastle, Town Moor.	·69	18	29
Dor.	Evershot, Melbury Ho.	·40	10	8	,,	Bellingham, Highgreen	·49	13	...
,,	Creech Grange	·52	13	50	,,	Lilburn Tower Gdns.	·75	19	...
,,	Shaftesbury, Abbey Ho.	·39	10	11	*Cumb*	Geltsdale	1·20	30	...
Devon	Plymouth, The Hoe	·57	15	11	,,	Carlisle, Scaleby Hall	·85	21	26
,,	Polapit Tamar	1·52	39	30	,,	Seathwaite M.	14·01	356	86
,,	Ashburton, Druid Ho.	·65	17	9	*Glam.*	Cardiff, Ely P. Stn.	·46	12	9
,,	Cullompton	·52	13	12	,,	Treherbert, Tynywaun	·53	13	...
,,	Sidmouth, Sidmount	·59	15	15	*Carm*	Carmarthen Friary	·60	15	10
,,	Filleigh, Castle Hill	1·12	28	...	,,	Llanwrda, Dolaucothy.	1·94	49	28
,,	Barnstaple, N.Dev.Ath.	·96	24	22	*Pemb*	Haverfordwest, School	...	..	...
Corn.	Redruth, Trewirgie	1·24	31	20	*Card.*	Gogerddan	1·89	48	38
,,	Penzance, Morrab Gdn.	1·20	31	21	,,	Cardigan, County Sch.	1·06	27	...
,,	St. Austell, Trevarna	1·09	28	18	*Brec.*	Crickhowell, Talymaes	1·00	25	...
Soms	Chewton Mendip	·66	17	12	*Rad.*	Birm.W.W.Tyrmynydd	1·89	48	23
,,	Street, Hind Hayes	·51	13	...	*Mont.*	Lake Vyrnwy	1·03	26	15
Glos.	Clifton College	·65	17	17	*Denb.*	Llangynhafal	1·49	38	...
,,	Cirencester, Gwynfa	·43	11	12	*Mer.*	Dolgelly, Bryntirion	2·38	60	35
Here.	Ross, Birchlea	·47	12	16	*Carn.*	Llandudno	·97	25	31
,,	Ledbury, Underdown.	·57	14	20	,,	Snowdon, L. Llydaw 9	3·97	101	...
Salop	Church Stretton	·70	18	21	*Ang.*	Holyhead, Salt Island.	·81	21	19
,,	Shifnal, Hatton Grange	·55	14	21	,,	Lligwy	·81	21	...
Staff.	Tean, The Heath Ho.	·98	25	30	*Isle of Man*				
Worc.	Ombersley, Holt Lock.	·39	10	15		Douglas, Boro' Cem.	1·24	32	25
,,	Blockley, Upton Wold.	·57	14	18	*Guernsey*				
War.	Farnborough	·82	21	28		St. Peter P't, Grange Rd	1·61	41	39

Rainfall: December, 1926: Scotland and Ireland

CO.	STATION	In.	mm.	Per-cent. of Av.	CO.	STATION.	In.	mm.	Per-cent of Av.
Wigt.	Stoneykirk, Ardwell Ho	1·86	47	45	*Suth.*	Loch More, Achfary...	16·12	409	174
,,	Pt. William, Monreith.	1·65	42	...	*Caith*	Wick	3·53	90	115
Kirk.	Carsphairn, Shiel.	4·84	123	...	*Ork.*	Pomona, Deerness	5·46	139	130
,,	Dumfries, Cargen.....	1·28	33	24	*Shet.*	Lerwick	4·61	117	96
Roxb	Branxholme	·51	13	14		———			
Selk.	Ettrick Manse........	1·67	43	...	*Cork.*	Caheragh Rectory	·40	10	...
Berk.	Marchmont House	·61	15	22	,,	Dunmanway Rectory.	·37	9	5
Hadd	North Berwick Res....	·38	10	18	,,	Ballinacurra	·39	10	8
Midl	Edinburgh, Roy. Obs..	·62	16	29	,,	Glanmire, Lota Lo. ...	·72	18	13
Lan.	Biggar	1·16	29	34	*Kerry*	Valentia Obsy........	1·43	36	22
,,	Leadhills............	2·79	71	...	,,	Gearahameen	...	..	...
Ayr.	Kilmarnock, Agric. C..	2·44	62	57	,,	Killarney Asylum.....	1·55	39	21
,,	Girvan, Pinmore......	2·54	65	42	,,	Darrynane Abbey	1·78	45	30
Renf.	Glasgow, Queen's Pk..	1·61	41	38	*Wat.*	Waterford, Brook Lo..	·90	23	19
,,	Greenock, Prospect H..	3·63	92	57	*Tip.*	Nenagh, Cas. Lough...	·88	22	19
Bute.	Rothesay, Ardencraig.	4·13	105	82	,,	Tipperary	...	..	...
,,	Dougarie Lodge	2·63	67	...	,,	Cashel, Ballinamona ..	·79	20	18
Arg.	Ardgour House	10·89	277	...	*Lim.*	Foynes, Coolnanes	1·27	32	27
,,	Manse of Glenorchy..	10·84	275	...	,,	Castleconnell Rec.	1·20	30	...
,,	Oban	4·12	105	...	*Clare*	Inagh, Mount Callan ..	2·35	60	...
,,	Poltalloch	4·85	123	86	,,	Broadford, Hurdlest'n.	1·68	43	...
,,	Inveraray Castle......	6·83	173	81	*Wexf*	Newtownbarry	·60	15	...
,,	Islay, Eallabus.......	4·41	112	82	,,	Gorey, Courtown Ho...	·73	19	19
,,	Mull, Benmore	15·80	401	...	*Kilk.*	Kilkenny Castle	·86	22	25
Kinr.	Loch Leven Sluice	·38	10	11	*Wic.*	Rathnew, Clonmannon	·53	13	...
Perth	Loch Dhu	5·30	135	61	*Carl.*	Hacketstown Rectory.	1·41	36	34
,,	Balquhidder, Stronvar.	2·51	64	...	*QCo.*	Blandsfort House.....	1·26	32	34
,,	Crieff, Strathearn Hyd.	·59	15	14	,,	Mountmellick	2·72	69	...
,,	Blair Castle Gardens ..	...	..	...	*KCo.*	Birr Castle..........	·98	25	30
,,	Coupar Angus School..	1·86	47	67	*Dubl.*	Dublin, FitzWm. Sq...	·84	21	34
Forf.	Dundee, E. Necropolis.	·31	8	12	,,	Balbriggan, Ardgillan.	·71	18	25
,,	Pearsie House........	·71	18	...	*Me'th*	Drogheda, Mornington	...	..	...
,,	Montrose, Sunnyside..	...	..	...	,,	Kells, Headfort......	·95	24	25
Aber.	Braemar, Bank	·36	9	10	*W.M*	Mullingar, Belvedere.	1·05	27	29
,,	Logie Coldstone Sch. ..	1·13	29	40	*Long*	Castle Forbes Gdns....	·94	24	24
,,	Aberdeen, King's Coll..	·96	24	30	*Gal.*	Ballynahinch Castle ..	2·56	65	34
,,	Fyvie Castle	1·87	47	...	,,	Galway, Grammar Sch.	·86	22	...
Mor.	Gordon Castle........	1·82	46	68	*Mayo*	Mallaranny..........	2·72	69	...
,,	Grantown-on-Spey....	1·60	41	59	,,	Westport House......	1·68	43	29
Na.	Nairn, Delnies........	1·66	42	75	,,	Delphi Lodge	4·10	104	...
Inv..	Ben Alder Lodge	4·00	102	...	*Sligo*	Markree Obsy.	2·15	55	45
,,	Kingussie, The Birches	2·26	57	...	*Cav'n*	Belturbet, Cloverhill..	1·26	32	34
,,	Loch Quoich, Loan....	16·00	406	...	*Ferm*	Enniskillen, Portora ..	...	..	...
,,	Glenquoich	...	..	...	*Arm.*	Armagh Obsy.	1·22	31	39
,,	Inverness, Culduthel R.	2·38	61	...	*Down*	Warrenpoint	...	..	...
,,	Arisaig, Faire-na-Squir	5·47	139	...	,,	Seaforde	·94	24	23
,,	Fort William.........	6·29	160	62	,,	Donaghadee, C. Stn...	1·04	27	33
,,	Skye, Dunvegan......	...	..	...	,,	Banbridge, Milltown.	·85	22	29
,,	Barra, Castlebay	1·66	42	...	*Antr.*	Belfast, Cavehill Rd..	1·36	35	...
R&C	Alness, Ardross Cas. ..	2·78	71	67	,,	Glenarm Castle.......	2·58	66	...
,,	Ullapool.............	5·26	133	...	,,	Ballymena, Harryville	2·05	52	46
,,	Torridon, Bendamph..	6·35	161	62	*Lon.*	Londonderry, Creggan	2·69	68	61
,,	Achnashellach	11·53	293	...	*Tyr.*	Donaghmore	1·56	40	...
,,	Stornoway	5·27	134	84	,,	Omagh, Edenfel......	1·75	44	41
Suth.	Lairg	5·71	145	...	*Don.*	Malin Head	1·80	46	54
,,	Tongue Manse........	4·67	119	94	,,	Dunfanaghy	2·04	52	39
,,	Melvich School.......	4·20	107	98	,,	Killybegs, Rockmount.	3·06	78	42

Climatological Table for the British Empire, July, 1926

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	mm.	mm.			
London, Kew Obsy.	1016·8	+ 1·0	85	51	71·6	56·1	63·9	+ 1·2	57·3	83	7·0	44	− 11	16	5·4	33
Gibraltar	1015·7	− 1·1	90	62	81·3	67·5	74·4	− 0·4	65·1	76	3·9	0	− 1	0	...	...
Malta	1014·4	− 0·9	87	65	80·3	69·3	74·8	− 3·5	69·4	82	2·5	0	− 1	0	11·3	79
St. Helena	1016·7	+ 3·2	66	52	60·8	54·2	57·5	− 1·5	56·1	89	3·5	68	− 34	17	...	...
Sierra Leone	1013·7	+ 1·0	87	70	83·9	72·8	78·3	− 0·3	74·8	87	7·8	548	−356	30	...	...
Lagos, Nigeria	1011·8	− 2·0	85	69	81·7	74·1	77·9	− 0·1	74·2	83	7·6	256	− 15	13	...	...
Kaduna, Nigeria	1014·3	+ 0·3	90	62	83·0	66·7	74·9	+ 1·3	70·6	85	2·2	344	+136	22	...	...
Zomba, Nyasaland	1024·5	0·0	80	47	71·5	53·1	62·3	+ 0·3	...	78	5·8	18	+ 10	6	...	...
Salisbury, Rhodesia	1019·6	− 0·9	79	37	69·5	42·9	56·2	+ 0·1	48·6	57	3·1	0	− 1	0	8·2	74
Cape Town	1023·6	+ 2·3	79	35	61·8	45·0	53·4	− 1·3	47·3	85	4·5	112	+ 19	16	...	...
Johannesburg	1025·7	− 0·1	65	21	56·8	36·2	46·5	− 4·0	38·3	58	1·4	22	+ 14	1	9·2	87
Mauritius	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Bloemfontein	...	...	67	12	59·3	25·2	42·3	− 5·0	33·5	69	1·5	4	− 6	1	...	...
Calcutta, Alipore Obsy.	998·9	− 0·3	97	75	89·0	78·9	83·9	+ 0·4	79·6	90	9·3	644	+326	20*	...	...
Bombay	1002·4	− 1·5	89	74	86·2	78·7	82·5	+ 1·2	78·5	86	8·0	784	+168	27*	...	...
Madras	1004·2	− 0·3	101	74	96·5	78·7	87·6	+ 0·2	76·9	70	8·3	69	− 31	7*	...	...
Colombo, Ceylon	1008·3	− 0·9	87	73	85·8	76·6	81·2	+ 0·1	77·9	82	9·1	301	+137	26	4·7	38
Hongkong	1005·8	+ 1·0	91	73	86·9	78·4	82·7	+ 0·2	78·2	80	7·6	757	+417	21	7·2	54
Sandakan	...	...	92	74	88·3	75·7	82·0	+ 0·2	76·4	83	...	149	− 17	8	...	...
Sydney	1016·5	− 2·0	78	42	64·0	47·0	55·5	+ 2·8	48·8	75	4·3	60	− 63	11	6·4	63
Melbourne	1015·7	− 3·4	69	36	57·5	45·4	51·5	+ 2·9	47·1	83	6·6	37	− 9	18	4·6	47
Adelaide	1016·6	− 3·8	73	37	61·8	46·7	54·3	+ 2·6	48·0	72	5·5	50	− 17	16	5·5	55
Perth, W. Australia	1013·3	− 5·7	67	40	61·4	50·1	55·7	+ 0·5	52·9	80	8·0	312	+146	27	3·2	31
Coolgardie	1015·3	− 4·6	71	31	61·8	42·9	52·3	+ 1·1	46·9	72	4·4	22	− 1	12	...	...
Brisbane	1018·1	− 0·4	81	42	69·5	47·9	58·7	+ 0·2	51·7	70	3·3	22	− 37	5	8·0	76
Hobart, Tasmania	1011·0	− 2·8	65	36	54·3	42·7	48·5	+ 3·1	42·8	76	6·9	41	− 13	16	4·2	45
Wellington, N.Z.	1014·9	+ 1·0	60	32	54·5	42·7	48·6	+ 0·9	46·2	79	6·4	73	− 70	17	4·1	44
Suva, Fiji	1013·3	− 0·9	83	62	78·0	67·5	72·7	− 0·9	68·5	83	7·0	233	+116	17	4·3	39
Apia, Samoa	1012·1	+ 0·1	87	67	84·1	73·0	78·5	+ 1·3	75·0	78	4·9	116	+ 49	11	8·0	70
Kingston, Jamaica	1013·7	− 1·0	93	71	90·3	74·1	82·2	+ 0·5	72·7	78	3·4	47	+ 5	6	5·2	40
Grenada, W.I.	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Toronto	1014·3	+ 0·2	91	46	77·8	57·8	67·8	− 0·4	60·0	65	4·1	45	− 32	8	9·8	65
Winnipeg	1013·6	+ 0·9	98	37	80·1	55·8	67·9	+ 1·7	...	...	3·6	51	− 29	5	10·0	63
St. John, N.B.	1013·8	+ 0·1	79	48	68·8	52·7	60·7	+ 0·3	57·6	81	5·6	76	− 16	15	7·7	50
Victoria, B.C.	1016·9	+ 0·2	85	50	70·0	53·0	61·5	+ 1·2	56·0	67	5·0	0	− 9	0	11·2	71

*For Indian stations a rain day is a day on which 0·1 in. (2·5 mm.) or more rain has fallen.