The Meteorological Magazine

Vol. 74

(Twentieth of the New Series)

1939

Published by the Authority of the Meteorological Committee. Air Ministry. Meteorological Office.

LONDON
PRINTED AND PUBLISHED BY HIS MAJESTY'S STATIONERY OFFICE
To be purchased directly from H.M. STATIONERY OFFICE at the following addresses:
York House, Kingsway, London, W.C.2; 120 George Street, Edinburgh 2;
26 York Street, Manchester 1; 1 St. Andrew's Crescent, Cardiff;
80 Chichester Street, Belfast;
or through any bookseller

INDEX

ILLUSTRATIONS

ERRATA AND CORRIGENDA

THE METEOROLOGICAL MAGAZINE

M.O. 422

AIR MINISTRY : METEOROLOGICAL OFFICE

Vol. 74 | February 1939 | No. 877

FOREWORD

This issue of the *Meteorological Magazine* introduces a new volume, and the occasion has been taken to make certain changes both in its appearance and in its contents. Thanks to the co-operation of H.M. Stationery Office, the magazine is now printed in bolder type on a better quality of paper, whilst the stiffer cover carries a simplified decorative design. At the same time the original size of page has been retained so that bound volumes will be uniform with those of previous years. The nature and arrangement of the contents have also been modified. Certain features which were deemed to be of little general interest have been omitted, whilst it is proposed to include regularly authoritative articles upon a variety of meteorological subjects and problems. These articles will treat their subjects as simply as possible, and all highly technical matter will be excluded. The introduction of a " Notes and News " column will provide information upon minor events which are of general interest.

It is hoped that these changes, many of which have been suggested by Mr. E. G. Bilham, will render the *Meteorological Magazine* more acceptable to its present readers and will also increase its appeal to a wider range of readers who, whilst not participating actively in meteorological work, are nevertheless interested in its progress and problems.

N. K. JOHNSON.

THE FILM AS A METEOROLOGICAL INSTRUMENT

By J. S. Farquharson, M.A.

Sir Napier Shaw(1)* was the first, or among the first of meteorologists to perceive the possibilities of the cinematograph camera as an aid to the observation and analysis of visible atmospheric phenomena. On September 23rd, 1911, at Sheringham, in front of an advancing depression, photographs were taken with a cinematograph camera, under his supervision, of cirrus, cirro-cumulus and alto-cumulus. The photographs were taken at intervals of 5 or 10 seconds over a period of about three-quarters of an hour and were used to illustrate the view that, under falling pressure, cloud (in this case cirrus) cools to a less extent than the air of its environment and instability develops in consequence at the upper surface of the cloud. Between the time of this early adoption of the cinematograph camera for meteorological purposes and later work of a similar type, there appears to be a large gap. Sir Napier Shaw himself, however, made at least one other meteorological film. This, like the earlier film, showed how far in advance of his time Sir Napier was, in that the technique of the animated diagram was used to illustrate the development and advance of a depression.

From about the year 1925 interest in the cinematograph camera as an instrument for the increase of meteorological knowledge appears to have revived, particularly on the continent. Since that year an increasing number of films on clouds have been made using speeded up photography. By the choice of a suitable ratio of camera speed to ultimate projection speed, the movements of a changing cloud can be shewn speeded up to any desired extent. This technique is employed in all of the modern films of clouds. Beautiful and striking effects are so achieved, cloud masses being shewn in a constantly changing state of development or dissipation, like masses of steam. Devaux, in 1928, was able to deduce from films made in this way that the intervals between the

* The numbers refer to the list of references at the end.

rolls of strato-cumulus clouds over the Pic du Midi were areas of descending currents. In the same year, Masanao Abe(2), based an analysis of the nature of the turbulence near the summit of Mount Fuji in Japan, on the information conveyed by a similar type of film, while in a later, more ambitious study(3), involving similar technique, he arrived at conclusions as to the velocity and direction of air flow, which were supported by experiments on a model of the mountain placed in a wind tunnel. Included among French meteorologists who have used the technique of accelerated cinematography in the analysis of cloud developments are P. Idrac(4) and Kampé de Feriet(5). The films discussed by the latter shed considerable light on the influence of topography on the formation, maintenance and dissipation of clouds.

In this country attention was first directed to the renewed interest in the cinematography of clouds at the British Association meeting of 1933, at which were shewn some films of clouds made by Prof. Linke of Frankfurt, using the technique indicated above. M. G. Bennett, describing these films in Vol. 68 of this Magazine stated that the photographs were taken at intervals of from 3 to 6 seconds and projected at the normal projection speed of 16 pictures per second. Late in the same year, or early in 1934, photographs of similar type were taken for the first time, so far as is known, in this country, by Mr. F. A. Goodliffe of Messrs. Science Films Ltd., an amateur meteorologist and professional cinematographer. He has a collection of beautiful films of developing clouds, made in this way, and brief excerpts from his collection are incorporated in the two films entitled "Fog" and "Ice Formation" which were made for the Air Ministry. These were shewn at the meeting of the Royal Meteorological Society on December 15th, 1938. Some idea of the results achieved may be obtained from Figs. 1 to 4. These are reproductions of individual pictures or "frames" taken from one of Mr. Goodliffe's films. The photographs were taken at Leatherhead in the afternoon of a day last summer in the evening of which heavy thunderstorms developed in the neighbourhood of London. The camera pointed north-westwards. Surface winds were south-westerly, but a change of wind occurred aloft, the fragments of cloud visible at the top edge of the photographs being remains of a cumulonimbus or large cumulus south-east of the camera. Exposures were made every two seconds but the time interval in the photographs reproduced is ten minutes between Figs. 1 and 2 and five minutes each between Figs. 2 to 4, Fig. 1 representing conditions at 5 p.m. (summer-time). The obvious change in the field of view from Fig. 2 to Fig. 3 is due to a change of lens and to a slight adjustment of the orientation of the camera. The "boiling-up" of the central cumulus cloud and the general turbulence is well shewn in these photographs, together with the ultimate development of the anvil. The great complexity of the turbulent developments is more plainly apparent in the cinematograph pictures projected on a screen. The tendency for the large cumulus to be eclipsed by other clouds, which is apparent in these photographs, is noteworthy because it exemplifies one of the greatest difficulties in making cinematographic studies of individual cloud masses. Another difficulty is that the rate of movement of the cloud under observation may be such as to carry it beyond the effective range of the camera before the photographic study of its life history is complete. These difficulties, however, could be overcome if unrestricted means were available so that batteries of cinematograph cameras might be used instead of individual cameras.

The most ambitious study of clouds by means of what may be termed "accelerated cinematography" is that made by Prof. Mügge in the Black Forest and western Germany in 1936 and 1937. He made a series of films and analysed the air movements disclosed by them in a number of papers whose titles give some indication of the clouds photographed: "Fine Weather Cumulus", "Cloud Formation in Non-Ascending Air Currents", "Stable Sliding Processes", "Castellatus Processes" and "Spreading and Drooping". The papers are not

[*Facing page 1*

FIG. 1

FIG. 2

(*Photographs from film by F. A. Goodliffe, reproduced by permission of Messrs. Science Films Ltd.*)

FIG. 3

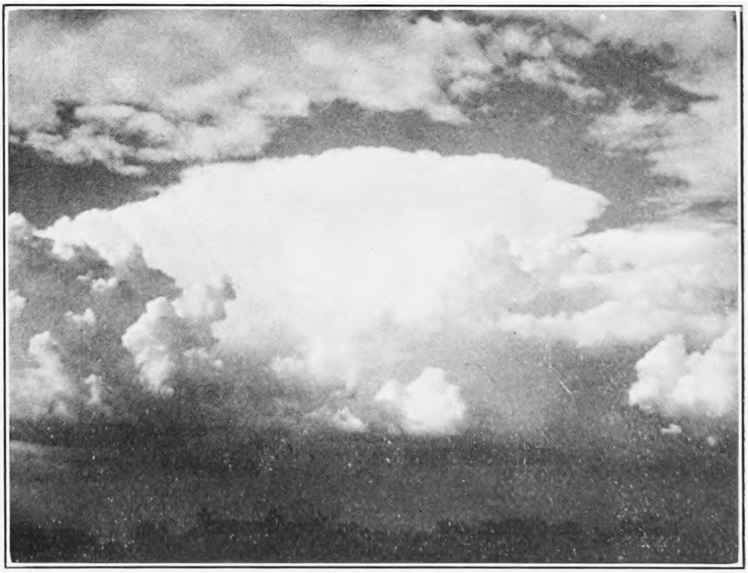


FIG. 4

(Photographs from film by F. A. Goodliffe, reproduced by permission of Messrs. Science Films Ltd.)

published but are written as commentaries on the films, copies of which were bought by the Meteorological Office. Prof. Mügge appears to have been in the fortunate position of being able to take some of his photographs from the summit of one or more of the peaks in the Black Forest region so that portions of his films are free from the first difficulty referred to above. A description of one of these films is given by Prof. Linke(6) in the *Quarterly Journal of the Royal Meteorological Society.*

The criticism was made of Prof. Mügge's films, based on the projected pictures, that the highest photographic technique and the best photographic material had not been employed in making them. Though the limit of the possibilities of the cinematograph camera, as used so far, as a means of research into the air movements in and near clouds appears to have been reached, nevertheless it is thought that further progress along these lines might be made if the highest available photographic technique were used in collaboration with expert meteorological knowledge. More might be learned if, during the period covered by the photographs, simultaneous observations of temperature and humidity in and near the cloud under observation were made. No technical difficulty is foreseen in the synchronisation of cinematograph photographs with self-recording instruments. The difficulty of interpretation of some microbarograph records might disappear if a synchronised film of cloud developments were available during the period covered by the records. Numerous fields for the employment of the cinematograph camera in meteorological research suggest themselves. Prof. Brunt(7) of the Imperial College, London, has already employed it to secure pictures supporting his theory as to the movements of air in cloud sheets of strato cumulus type. As mentioned above, Sir Napier Shaw made a film, of a rudimentary character, some years ago of a weather map using the technique of the animated diagram. It is a moot point whether the meteorologist has nothing to learn from a film of this character, and it would be interesting to have such a film made covering the sequence of events on the weather map, complete with fronts of, say, north-west Europe, using technique which has progressed considerably since the time Sir Napier's film was made.

In this country complete meteorological films have been made only for educational purposes, apart from those made by Sir Napier Shaw. Since the processes involved in meteorological phenomena are frequently complicated it is not immediately apparent that the film is a particularly suitable teaching medium. That it is so, however, is due to the fact that the ideas it is desired to convey must first be simplified so as to be readily assimilable in the form of pictures. Further, to drive home a point the producer of the educational film can perform " experiments " which it would be physically impossible to perform in the laboratory though the physical basis of the " experiment " were perfectly sound. The educational film has recently been adopted by the Air Ministry as an aid to the training of young pilots in the fundamentals of meteorology with which they should be familiar. A great advantage of such films is that there is no limit to the number of times the points in a lesson may be gone over since the film may be projected as often as necessary.

REFERENCES.

(This list is not exhaustive.)

(1) Dines, W. H. " The Free Atmosphere in the Region of the British Isles ", *London, Geophys. Mem.* 2, 1912, with a preface by W. N. Shaw, p. 18.
(2) Abe, Masanao. " Cinematograph Studies of Rotary Motion of a Cloud Mass near Mt. Fuji ", *Tokyo, Geophys. Mag.* I, 1928, pp. 211–228.
(3) Abe, Masanao. " Local Air Current of Mt. Fuji, as observed by the motion of cloud by the aid of the Cinematograph ", *Tokyo, Geophys. Mag.* III, 1930, pp. 45–58.
(4) Idrac, P. " Sur l'étude des mouvements internes des masses nuageuses par la cinématographie accelerée ", *Paris, C.R. Acad. Sci.* 197, 1933, pp. 1341–1342.
(5) Kampé, de Feriet, J. " Atmospherische Stromungen; Wolkenstudien nach Kinoaufnachmen im Hochgebirge (Jungfrau und Matterhorn) ", *Met. Z. Braunschweig,* 53, 1936, pp. 277–280.
(6) Linke, F. " An Account of Prof. Mügge's Film Clouds in Motion; The Thunderstorm ", *London, Quart. J.R. Met. Soc.,* LXIII, 1937, pp. 73–75.
(7) Brunt, D. " Natural and Artificial Clouds " (Symons Memorial Lecture, March, 1937), *London, Quart. J.R. Met. Soc.,* 63, 1937, pp. 277–288.

THE EVOLUTION OF THE EARTH'S ATMOSPHERE

BY THE ASTRONOMER ROYAL,
DR. H. SPENCER JONES, F.R.S.

From the Fourteenth Annual Norman Lockyer Lecture, delivered under the auspices of the British Association, December 6th, 1938.

From theoretical considerations it is possible to decide whether or not any planet may be expected to possess an atmosphere. The natural tendency of an atmosphere is to diffuse away into space. The molecules of the atmosphere are flying about in all directions at high speeds, continually colliding with one another and rebounding. In the upper layers of the atmosphere, the preponderant tendency is for them to be pushed outwards. They are prevented from escaping only by the gravitational pull of the planet.

In order to overcome this pull and to fly away into space, any particle, whether large or small, must acquire a velocity greater than a certain minimum value, determined by the mass and radius of the planet. If the radial component of the outward velocity is greater than this minimum value, the particle will escape from the planet, provided its motion is not impeded by collision with another particle.

In a simple gas, at a uniform temperature, the velocities of the molecules are distributed according to a law, discovered by Maxwell, which he first announced at the meeting of the British Association in 1859. The mean velocity of the molecules increases with the temperature, being proportional to $\sqrt{T}$; the number of fast-moving molecules with velocities much in excess of the mean velocity falls off very rapidly with increase of velocity. In a mixture of gases, the average energy of each type of molecule is the same; the lighter the molecules the faster they move in the mean.

There are definite proportions of molecules with speeds of 10, 20 or 100 times the mean speed, so that there must be a progressive loss of fast-moving molecules from the upper layers of the atmosphere of any planet. The rate at which this loss takes place depends upon the relative magnitudes of the velocity of escape and of the mean velocity of the molecules. The rates of escape were calculated by Jeans. He found that if the velocity of escape is four times the mean molecular velocity, the atmosphere would be practically completely lost in fifty thousand years; if the velocity of escape is four and a half times the mean molecular velocity, the atmosphere would be lost in thirty million years; whilst if the velocity of escape is five times the mean molecular velocity, twenty-five thousand million years would be required for the loss to be almost complete. The age of the planets is believed to be of the order of three or four thousand million years, so that if the velocity of escape is as great as five times the mean molecular velocity of hydrogen the atmosphere will be practically immune from loss.

Coming to the Earth, the escape velocity is 11·2 km./sec., which is almost exactly six times the mean molecular velocity of hydrogen at 0° C. Hence the atmosphere of the Earth should be immune from loss of hydrogen and all other gases.

At the present time the amounts of hydrogen and of helium in the Earth's atmosphere are very small. The spectrum of the aurora does not contain the lines of helium, an indication that the high regions of the atmosphere cannot contain very much helium. The total helium content of the atmosphere has been estimated to be about five parts in a million. The supply is being gradually replenished by the weathering of the igneous rocks of the earth's crust, which contain uranium and thorium and also, consequently, helium. Yet the atmosphere does not now contain more than a fraction of the amount of helium that it has gained in geological times in the process of the formation of sedimentary rocks as a result of the weathering of the igneous rocks. We may therefore say that there is direct observational evidence that helium is being lost from the atmosphere at the present time. It is believed that there may be a state of equilibrium between the rate of supply and the rate of loss.

Even if the Earth had remained hot, in the early stages of its existence, for a sufficient time for the hydrogen and helium then present in its atmosphere to escape entirely, it still remains to explain how helium continues to be lost when, according to the theoretical results, which are based on the accepted principles of the kinetic theory of gases, it should be immune from loss. There is one process by which the escape of helium can be brought about. It is well known that the night sky is faintly luminous. In addition to the light from the stars there is a faint luminescence from the upper atmosphere, whose brightness seems to vary with the sun-spot cycle, being greater at sun-spot maximum than at sun-spot minimum. Lord Rayleigh has termed this the non-polar aurora. In the spectrum of the night sky the characteristic green auroral line, as well as the two red lines, are always present. These lines are emitted by oxygen atoms that are in what the physicists term a metastable state. An atom, when excited or loaded up with energy, usually unloads its energy, with the emission of radiation, within a short interval of time of the order of one hundred-millionth of a second. But a metastable state is characterised by the peculiarity that the atoms in that state have a very slight tendency to unload their energy. They may remain for an average time of a second or longer in that state before emitting their energy in the form of radiation. There is a high probability that before this occurs the atom will have collided with another atom. When a collision of a metastable oxygen atom with another atom occurs, the energy of the oxygen atom will be unloaded and converted into kinetic energy. The two atoms will rebound with a greatly increased speed. By such a collision an atom of helium could acquire a speed of more than 12 km./sec., which is greater than the velocity of escape from the Earth. Hydrogen atoms would acquire a still higher speed, but heavier atoms, such as those of nitrogen or oxygen, would not by this process acquire sufficient speed to escape. They would receive an equal amount of energy but, being heavier, they would not move so fast. The loss of hydrogen and helium from the atmosphere of the Earth is thus made possible by the fact that free oxygen is present in the atmosphere.

It appears probable that the primitive Earth must have remained hot sufficiently long for most of its initial atmosphere to have been lost. It was pointed out by Russell and Menzel that in the stars and the nebulæ neon is as abundant as argon, whereas in the Earth's atmosphere argon is five hundred times more abundant than neon. Nitrogen is far less abundant on the Earth than in the stars; it is ten thousand times more abundant in the Sun than on the Earth. These large differences in relative terrestrial and solar abundance demand explanation, because in general the relative abundance of elements on the Earth is in close agreement with their relative abundance in the Sun and other stars. These facts can be accounted for on the supposition that the rate of loss of atmosphere was very rapid when the Earth was hot. When the cooling had proceeded sufficiently far for the escape of the atmosphere to cease, neon had been depleted to a much greater extent than the heavier argon. If this supposition is correct, much of the original oxygen, nitrogen, and water-vapour and all the original helium and free hydrogen must have been lost. As the molten Earth cooled, great quantities of water-vapour, carbon dioxide and other gases must have been evolved from the solidifying magma; these, with the residual gases from the initial atmosphere, formed the new atmosphere which, as the Earth was then relatively cool, could not escape.

It has been recognized for more than a century that the presence of free oxygen in the atmosphere of the Earth, which we are apt to take for granted without a thought, needs explanation. Oxygen is an element that is chemically active and processes are in continual operation that are depleting the store of oxygen in the atmosphere. One of the principal sources of depletion arises from the weathering of the igneous rocks to form sedimentary deposits—sand, clay and mud. The iron contained in the igneous rocks is not completely oxidised.

The greyish hue of these rocks results from the iron being present mainly in the form of ferrous oxide. During the process of weathering, much of the ferrous oxide is oxidised into ferric oxide, which gives the red or brown tints to the weathered deposits. The amount of oxygen that is withdrawn from the atmosphere by this process is very considerable and it has been estimated that during geological times the amount of oxygen thus depleted from the atmosphere is about twice the quantity now present. It is clear that some process must be in operation which replenishes the oxygen in the atmosphere. The vegetation over the Earth's surface provides the means for this replenishment. The green plant absorbs carbon dioxide from the air and uses energy from sunlight to decompose it, the energy-transformer being the green colouring matter, called chlorophyll, contained in the plant cells. The carbon is used to build up the complex organic substances found in living plants, the oxygen being returned to the atmosphere as a by-product.

The supply of carbon dioxide is in turn renewed by the decay of vegetable matter and other organic materials. During the decay of such matter, oxygen is absorbed and carbon dioxide is liberated. This carbon dioxide is again available for building up new plant cells. Whenever organic matter is buried, as in coal measures and oil deposits, so that it cannot become oxidised and decay, there is a net gain of oxygen to the atmosphere. It seems probable that the present abundance of oxygen in the atmosphere has been provided in this way and that if the coal, oil and other organic deposits could be unburied and completely burned, the whole of the oxygen in the atmosphere would be used up.

FROST AND SNOW IN DECEMBER AND JANUARY

By C. K. M. Douglas, B.A.

On the evening of December 17th, 1938, cold east winds of Siberian origin reached south-east England and ushered in the coldest succession of days and the longest period of continuous frost since February, 1929, when there was a still colder spell which originated in a rather similar manner. Temperature remained below freezing point over a large area from December 18th to 21st inclusive, and in Kent for two more days. At Lympne the maximum temperature was 22° F. on 20th and 24° F. on 21st. The proximity of the Continent made south Kent distinctly the coldest area, but on the Continent itself temperature was much lower, the 13h. temperature on 20th being from 10° to 12° F. over Holland, Belgium and north-east France. By 19th the cold air had extended over the whole of the British Isles, the maximum temperature at Valentia being 35° F. from 19th to 21st. The cold air was about 20,000 feet deep on 20th at both Mildenhall and Aldergrove.

Pressure was high in Siberia throughout the month, but the actual anticyclonic centre which proved the decisive feature developed on the north coast of Siberia, in the neighbourhood of Dickson, 73° N. 80°E., where pressure rose to 1056 mb. on December 12th. By the 15th the centre had moved 1,000 miles to S.W. and intensified to 1064 mb. at about 62° N. 48° E., i.e., westward of the Urals. An old anticyclone over south Russia was absorbed, and winds over European Russia became easterly on 14th, three days before the cold air reached England. In February, 1929, the anticyclone also moved a considerable distance westward.

The distribution of snowfall was very different in the 1929 and 1938 cold spells. In the earlier period the snowfall was very heavy in the SW, but in the SE there was none, except locally on the east coast. In the recent case the south-eastern area had most snow, and experienced its heaviest fall since December, 1927. In the lower parts of London the 1927 fall was wet, but the

1938 fall was dry, and lay deeper than in the earlier year. Perhaps someone with long experience of the London streets and parks can say when the Metropolis last had a similar fall.

On December 19th and 20th there were snowfalls of instability type which even in the south-east exceeded an inch locally, in spite of the fact that the air had only crossed a short expanse of sea. On 19th the Mildenhall

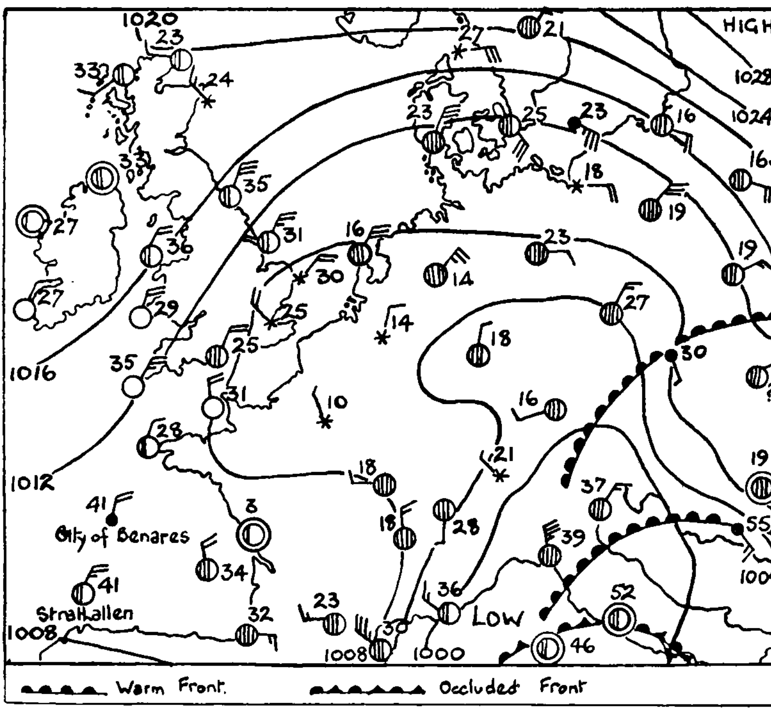


FIG. 1.—WEDNESDAY, DECEMBER 21ST, 1938, 7H.

observations showed that instability only extended to 5,000 feet, and that the clouds were only 2,000 feet thick. Locally they were probably 3,000 feet thick, but even so the amount of precipitation was surprisingly large, and could only have occurred at low temperatures, when ice crystals form readily.

On the 21st about 6 inches of snow fell over a large area in the south-east, and on 22nd there were further falls, so that aggregates were up to 9 inches at many places. The area most affected was east of a line from

Yorkshire to Dorset. From the meteorological point of view, the chief interest of this snowfall was the excellent example it provided of the development of precipitation at an upper warm front. The sea level chart for 7h. on 21st is shown on Fig. 1 with the nearest surface warm front over south-east Germany. Surface

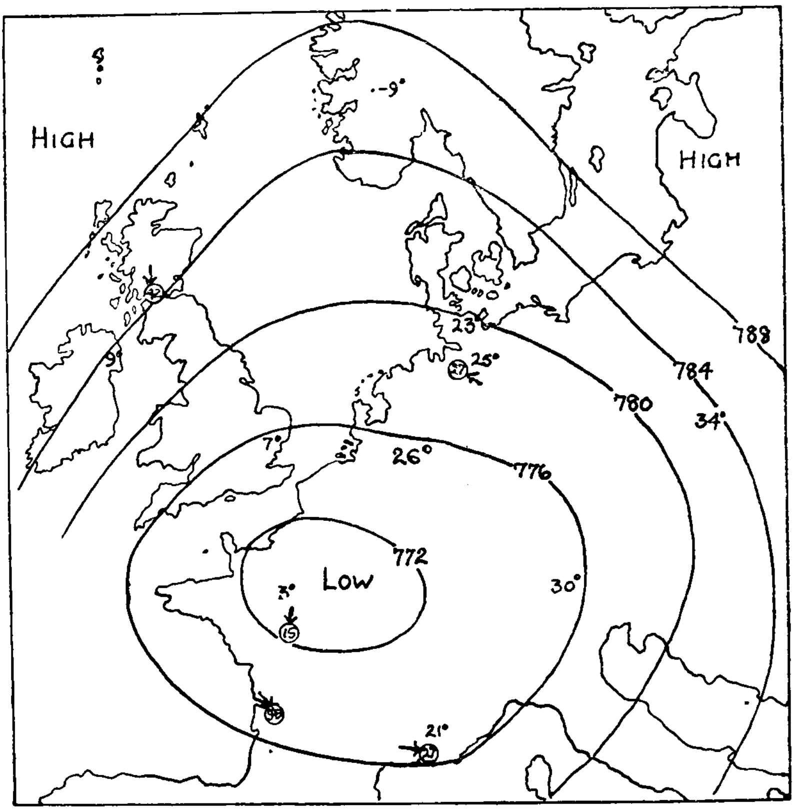


FIG. 2.—WEDNESDAY, DECEMBER 31ST, 1938, 7H.

Isobaric chart at 2 kilometre level, also showing temperature in °F at certain places and wind in kilometres per hour.

temperatures had risen at some places in advance of this front, but the precipitation area was over south-east England and adjacent parts of the Continent, mostly to westward of the region of lowest temperatures up to the 2,700 feet level. There was no appreciable precipitation over Germany during the 36 hours ending 7h. on 21st, but snow commenced in Belgium and north-east France during the night of 20th–21st and soon spread to

England; the belt of precipitation increased in size and intensity and moved slowly westward. Fig. 2 shows the synoptic chart at the level of 2 kilometres, and it can be seen that the temperature over Cologne was 19° F warmer than at Mildenhall, showing the upper warm front in the right position for the precipitation area. (The temperature of 31° over Munich is from the 13h. observations; there was evidently an error of transmission in the 6h readings). The coldest air was over France. There was an unusually large inversion over Germany, with an angle of slope from Breslau to Cologne of less than 1 in 2,000. From Cologne to Mildenhall the angle of slope of the surface of discontinuity seems to have been about 1 in 200, but there was no inversion over Mildenhall, only a thick transitional layer, so that accurate computation is impossible. Considering the negligible angle of slope over Germany, there seems to have been a genuine development of an upper warm front. The warm air had come from the Mediterranean, circulating round the upper depression over France, and since its relative humidity was high it must have passed just east of the Alps.

The arrival of warmer air aloft reacted on the surface temperature, especially where the air had a long sea track, and on 22nd there was a thaw except in the extreme SE, but over a large area in the Midlands and in eastern districts south of the Wash the thaw was very slight and temporary, and the snow did not melt appreciably till the evening of December 26th, when the severe spell ended.

The snowfalls of January were of a commoner type, occurring on the north sides of depressions moving directly over the British Isles. Six such depressions crossed the country, of which four gave widespread snow, and finally a depression moved up the English Channel and caused heavy snowfall in the south. Some of the depressions moved further south than could have been anticipated from sea level observations, notably that of January 21st, which gave no snow owing to the general mildness. In no case was the general temperature (best shown at coast stations) really low, and the snow lay chiefly on the high ground, though some low areas also had snow. In most northern districts the period from January 1st to 6th was more severe than the

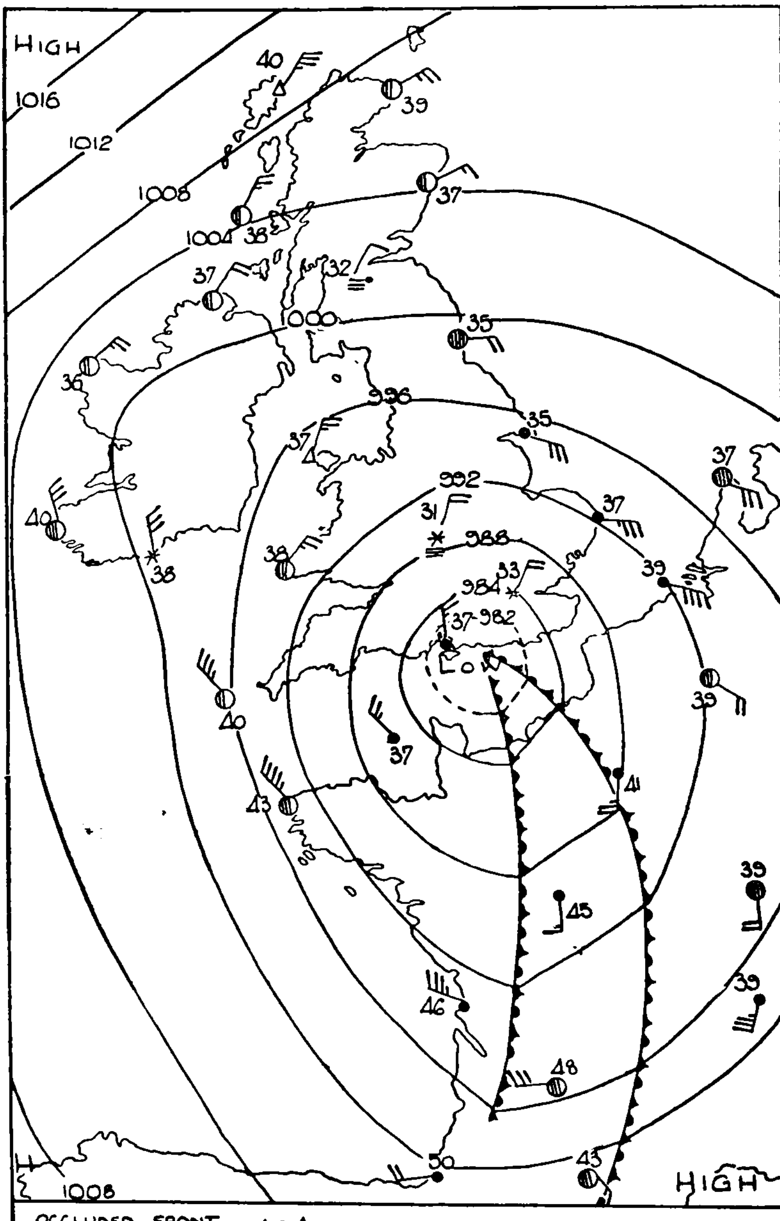


FIG. 3. WEDNESDAY, JANUARY 25TH, 1939, 18H.

December spell, and there was renewed wintry weather from 10th to 14th. There were a number of " radiation nights ", and the screen minima at Dalwhinnie from 4th to 6th were 1° F., 8° F. and 3° F. respectively. Other notable minima were 14° F. at Aldergrove on 5th and 12° F. at Manchester (Barton) and 14° F. at Sealand on 6th. On 5th fog prevented temperature at Manchester from rising above 23° F.

On 25th (see Fig. 3) a heavy snowfall occurred in the south, and round London the interference with traffic was as great as during the December snowfall. The amount of precipitation was greater, but on low ground most of the snow melted as it fell. The snow was of the clinging type and great damage was done to overhead wires. A railway accident occurred near Hatfield on 26th in consequence of the breakdown of telephone lines and signals. A train was snowed up in Wales. On 24th temperature exceeded 40° F. generally. There was a touch of frost in the night, but the continuance of snow inland all day in spite of a fresh east wind, when east coast temperatures were 35° F. to 37° F. with rain, can only be attributed to the intensity of the precipitation. (It may be noted that the December 1927 storm only gave sleet near the East Anglian Coast). Had the precipitation been moderate, temperature would have been appreciably higher and very much less snow would have lain. The heaviest precipitation so far reported was in the form of rain in the south and south-east coasts, but Kew Observatory had snow and sleet and recorded 1·18 in. rainfall in the 30 hours ended 7 hours on 26th. Twenty miles further north, at Welwyn Garden City, the rainfall was 1·54 in. for the 30 hours ending 9h. on 26th, and 9 inches of wet snow were found to contain 1·51 in. rainfall, the remaining 0·03 in. having soaked away. It is difficult to explain the amount of precipitation. The depression was well occluded but deepened from 995 to 980 mb. at the centre between 7h. and 18h. on 25th, as it moved up the Channel, apparently owing to a secondary warm sector between the main occlusion and the back-bent occlusion. The Mildenhall upper air temperature observations at 7h. on 25th showed marked stability from 750 to 500 mb. (7,600 to 17,600 ft.), a state of affairs typical of continuous precipitation. The height of the base of the stable layer was of course determined by the distance of the front, at that time 200 miles off.

The heavy rainfall, following a long wet spell, gave severe flooding, notably round Ipswich, and melting snow also caused floods in the Thames Valley and elsewhere. The depression moved away southwards and filled up, and a spell of east winds set in, but in the absence of cold air on the Continent the temperature remained above freezing point, except high up, and the snow melted away, though above 300 feet there was still a little at the end of the month. There was severe drifting on the hills, especially on the higher hills in south-west England and Wales, where much snow must have remained till February.

OFFICIAL PUBLICATION

An investigation of the lapse rate of temperature in the lowest hundred metres of the atmosphere. By N. K. Johnson, M.Sc., and G. S. P. Heywood, M.A., D.Sc., *Geophysical Memoirs,* No. 77, 1938. (M.O. 419e).

In an earlier *Geophysical Memoir* (No. 46) an account was given of the investigation at Porton of the lapse rate of temperature in the lowest seventeen metres of the atmosphere. The present paper describes the instrumental equipment used at Leafield for the extended investigation, and gives a detailed analysis of the five-years' records, with various tables and diagrams. Stress is laid on the steps taken to determine the characteristics and possible sources of error in the more important of the instruments, while the paper concludes with a more detailed discussion of some of the observational results.

LETTERS TO THE EDITOR

On "Gradient Winds"

Dr. Harold Jeffreys, in 1922, observed that pressure gradient is important in all types of air motion and based his well-known " classification of winds " on the relative importance of the other factors. He did not employ the term " gradient wind ", and one may justly ask: by what peculiar virtue can this name be applied to any special type of motion when gradient is a controlling factor in all winds? It is, I suggest, an objectionable term for anything—it is doubly objectionable when it is used differently by different writers as is the case at present.

In most foreign publications, and pretty widely also in England (not excepting a recent official publication) gradient wind is used as a synonym for geostrophic wind. In the Meteorological Glossary and in other English text-books, the term is used for the geostrophic wind " corrected " by allowing for curvature. The former usage is understandable, for to obtain the geostrophic wind the meteorologist in practice simply measures the pressure gradient—he regards geostrophic wind as merely a function of gradient and calls it naturally enough the gradient wind. But to use " gradient " to describe something which depends on curvature is, at best, illogical. The confusion is not unimportant for, at present, if one comes across " gradient wind " in any work, one simply does not know what is meant, unless the context gives a clue. One school of thought should, I think, withdraw publicly and perhaps the *Meteorological Magazine* will provide a medium for discussion. I give my first vote for dropping " gradient wind " altogether and my second choice to using it as an equivalent for " geostrophic wind ". This is not only in deference to what I believe will be a majority vote but because I never quite know what is the precise definition of the other more complicated " gradient wind ". In the case of uniform, stationary, circular motion, it is plain enough, but if I were asked what is this gradient wind on any ordinary weather map I should hesitate. Does it depend on the curvature of the isobars or on the unknown curvature of the path of the air? Does it include the isallobaric term or is this an additional factor? Does it, in general, form a legitimate second approximation to the true wind? My impression is that it is a theoretical wind, based on the assumption that the fields of pressure and of motion are stationary and that the air is moving with constant speed along the isobars, so that tangential acceleration is ignored. As such, it is a highly hypothetical wind of very limited practical application and has no call whatever to monopolize the " gradient ".

In so far as there is a wind defined by the stationary isobars, it may properly be called the " isobaric wind " to which the " isallobaric wind " might with certain approximations be taken as simply additive. If we wish to deal with the mathematically consoling case of uniform circular motion, let us use a very special term—the geo-cyclostrophic wind—which will be sufficient to keep it from being misused on a real weather map.

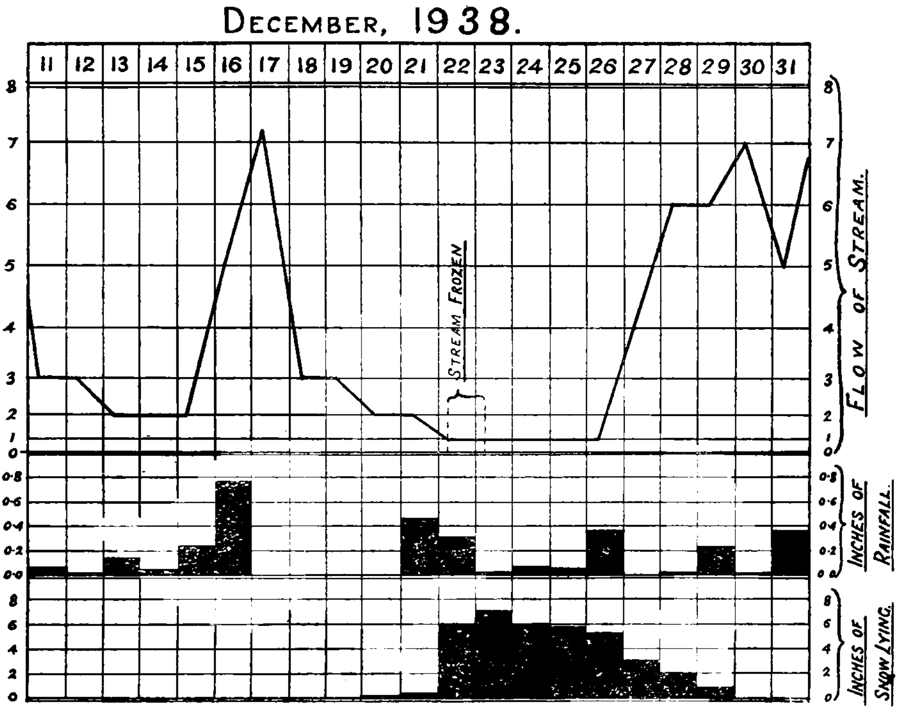
R. C. SUTCLIFFE.

Thorney Island, January 9th, 1939.

Snowfall and Stream Flow

The cold spell of December last, produced an excellent demonstration of delayed stream flow at Cuffley Brook, Herts. Observations of the flow of this stream, and details of the catchment area have been described in this Magazine, 1937 pp. 180–2, and the scale of flow shown in the accompanying figure is in accordance with that previously described viz. 0 = bed dry to 8 = more than 24 inches over the concrete invert of a bridge. As will be seen in this figure, the rainfall of 0·96 in. during December 15th and 16th, 1938, gave a usual rise in flow from 2·0 to 7·2 on the morning of the 17th. The flow fell abruptly during the next 24 hours to 3·0 and then more gradually to 1·0 by the morning of the 23rd. Considerable snow fell during the eight days 18th to 25th, lying

7 inches in depth at 7h. on the 23rd, equivalent in aggregate to 0·86 in. rainfall, of which 0·75 in. fell during the 21st and 22nd. In spite of this heavy snowfall (the heaviest in this district since December 1927) the stream continued to flow at 1·0, i.e., less than 1 inch in depth, except during the 22nd and 23rd, when in fact it ceased to flow owing to its being completely frozen. The



SNOWFALL AND STREAM FLOW AT CUFFLEY BROOK

stream flow did not increase in volume until the combined effects of the thaw and rainfall of 0·34 in. on the 26th raised the flow to 4·0 at 7h. 45m. on the 27th. No precipitation was observed on the 27th, but the thawing snow further increased the stream flow to 6·0 on the morning of the 28th, thereafter the flow resumed its normal volume in relation to rainfall. Thus it will be seen that the snowfall delayed the stream flow for approximately five days. The thaw itself took four days completely to remove the snow cover, possibly this was due to the hard wind-crust, about 1½ inches in thickness, having formed on the snow surface during the 24th and 25th.

DONALD L. CHAMPION.

Meteorological Station, 7, Robinson Avenue, Goff's Oak, Herts. January 24th, 1939.

A Lunar Halo

On looking up at the sky on the morning of January 8th, at 24h. 50m., I observed a lunar halo, in the form of a pale white ring, of 22°. A sheet of " cirro nebula " covered the sky, and there were also a few small pieces of fracto-stratus cloud moving rapidly across it.

Ten minutes later, that is, at 1h., I saw that the sky was now practically covered with the fracto-stratus cloud, on which was thrown a corona by the moon. Where there were gaps in the layer, the halo could still be seen on the " nebula " cloud.

Finally, on looking out at 1h. 5m., I observed that the sky was completely covered with " alto-stratus opacus " cloud, on which there was no longer either halo or corona.

KENNETH R. PATRICK.

" San Mateo ", Castlemaine Avenue, Ewell, Epsom, Surrey. January 8th, 1939.

NOTES AND NEWS

" Windy Tuesday " February 18th, 1662.

There will be little difference of opinion that the greatest English storm of which any record remains was that of November 26th, 1703. A storm of the first magnitude, however, occurred on Tuesday, February 18th, 1662, and like that of 1703 the main brunt was confined to the southern half of the country and the Midlands. The gale was not exceptional in Yorkshire, the north and Scotland.

Many accounts of this storm by eye-witnesses survive and we may mention those of Samuel Pepys, Evelyn, Rugge and Dr. Robert Plot amongst others. An early printed account appeared a few days after the event in the journal *Kingdom's Intelligencer* as follows:—This morning about four of the clock, February 18, began a most violent storm of rain mixt with lightning, which lasted about two hours, after which followed such an impetuous tempest of wind that I think the like was never known in these parts. It continued till almost noon. There was scarce any safety within doors or without. There is not a church nor house in this city but hath received some considerable loss. The highways are so full of fallen trees that travellers can hardly pass.

A tract was speedily published with the title " A Full and Certain Account of the last Great Wind and Storms . . . . " There is also a full account in the remarkable tract " Mirabilis Annus Secundus ", published late in 1662. Daniel Defoe quoted this account in full in the early chapters of his work on the greater storm of 1703.

There were many casualties to persons in the southern half of England in this storm of 1662, including several in London, notably the Stamford attorney, Mr. Luke Blith, who was killed while walking in Piccadilly by the collapse of a Riding-house. Another notable victim was Lady Sanderson who was killed in her bed at Covent Garden by the fall of the house. The damage done to churches was very great. Windows were blown in at Tewkesbury, and the cathedrals at Worcester and Hereford were damaged. Finchinfield church, Essex, suffered the loss of its spire which fell into the nave. The spire of the Tower church at Ipswich was similarly blown off and fell, upper end foremost, into the Church. Audley End House was very badly damaged and barns, windmills, smaller property, and trees innumerable were destroyed. In the New Pond in St. James' Park, Westminster, the water was blown out of the pond and the fish were mostly left stranded on the banks. The date of this notable storm came to be known as Windy Tuesday.

Samuel Pepys describes how the streets " were everywhere full of brick-batts and tyles flung down by the extraordinary winde last night " and proceeds to give an account of the damage in various places including his own property at Brampton. Evelyn describes the damage done to his house at Sayes and his London residence. So violent was the storm at Hereford that the Scottish chronicler John Nicoll was moved to give an account of it in his Diary of Public Transactions. Another Scottish diarist, Alexander Brodie, notes on this occasion that there was " veri tempestuous wether ". The learned Dr. Robert Plot braved the elements at Oxford in order to see a very uncommon spectacle. He says of the wind:—" . . . it was yet so violent that it laved water out of the River Cherwell, and cast it quite over the Bridge at Magdalen College, above the surface of the river near 20 foot high; which passage, with advantage of holding by the College wall, I had then the curiosity to go to see my self, which otherwise perhaps, I should have as hardly credited as some other persons may now do."

Commenting on this storm, Dr. Plot quotes the opinion of an " able-Seaman of Bristol " to the effect that " this wind was the fag-end of a Hurricane which began in New England about three hours before ".

C. E. Britton.

Low barometric reading.

A depression a few hundred miles off west Ireland on January 15th, 1939, attained an abnormal depth. A ship at 13h. recorded 944 mb., and from two ships' readings near the centre at 18h. it is evident that the pressure at the centre was still at least as low as 944 mb. The depression filled up remarkably rapidly between 16th and 17th, pressure at the centre rising about 30 mb. in 24 hours.

Royal Meteorological Society.

The Annual General Meeting of the Society was held on January 18th. Dr. B. A. Keen, who was re-elected President, was in the chair. He delivered an address on " What happens to the rain?" and a brief summary of this follows: —

An annual rainfall of 30 inches means that 3,000 tons of water fall on an acre of land. In the course of the year this all disappears, by run-off, evaporation, transpiration through vegetation, and by downward percolation. The relative importance of these factors in British and overseas conditions were discussed. Many of the traditional beliefs among farmers and gardeners were based on a theory of water movement that was attractively simple to understand—but incorrect. It is only in recent years that the true picture of the movement of water in the soil has been built up. In consequence, some of the traditional practices need revision, while others now have a different explanation. The new work has also clarified some of the concepts used in hydrology.

Lieutenant-Commander F. W. Reichelderfer.
The appointment of Chief of the United States Weather Bureau, rendered vacant by the untimely death of Dr. W. R. Gregg in September 1938, remained unfilled until recently, when the President appointed Lieutenant-Commander F. W. Reichelderfer of the U.S. Navy as the new Chief. The selection of such a world-renowned aviator-meteorologist to fill this important appointment has succeeded in re-awakening public interest in the status and organization of the Weather Bureau, which is a part of the Department of Agriculture.

Commander Reichelderfer has been closely associated with this Department and with both the Army and the Navy and is held in high esteem by the whole aviation industry.

Mountain Meteorologists in Japan.
A meteorological observatory has been in operation on the summit of Mt. Fuji in Japan for the past seven years. The observatory is at a height of 12,388 feet and the observers have to face severe conditions in winter, severe blizzards being frequent—winds up to 90 miles an hour with temperatures in the neighbourhood

of 0° F. In order to keep the anemometer working during a blizzard, the observers have to remove icicles about once every five minutes. A minor trouble is that at the station pressure of about 630 mb. water boils at a temperature of only 87° C., so that special high-pressure kettles have to be used for cooking rice. Recently a party of medical officers has also been stationed at the observatory for " aero-medical " researches.

Radiation from the Sun and the Sky.

The importance of measurements of radiation from the sun and sky have long been recognized in Europe and North America. In India systematic investigations of solar radiation were commenced a few years ago, and are now proceeding actively; in a recent Memoir (Vol. 26, Part 8) of the Indian Meteorological Department, P. K. Raman, describes the work at the Agricultural Meteorological Observatory of Poona. The clear skies of November to May are especially favourable for measurements of solar radiation, the chief difficulty being dust from the roads. A Gorczynski Moll solarigraph gave records of the total solar and sky radiation, which are tabulated and discussed for the year 1935.

Meteorological Tables, Kew Observatory.

The table of daily readings at Kew Observatory (*see* page 29) has been reproduced each month since January 1934. The following elements are included: pressure and the strength and direction of the wind in the middle of the day (at 13h.); the extremes of temperature (night minimum and day maximum) and, for comparison with this maximum temperature, the relative humidity at 13h.; rainfall for the calendar day and the duration of bright sunshine. Short notes on the weather of the day are also set out, some of the letters of the Beaufort Weather code being used for brevity: The following Beaufort letters are the ones employed:—d, drizzle; f, fog; h, hail; i, intermittent; l, lightning; p, shower; q, squall; r, rain; s, snow; t, thunder; x, hoar frost. A capital letter is used to indicate intensity and a suffix o to indicate slight.

Sunshine, January 1939.

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

	Total hrs.	Diff. from average hrs.		Total hrs.	Diff. from average hrs.
Stornoway ..	61	+34	Chester ..	33	−20
Aberdeen ..	42	− 5	Ross-on-Wye	43	−12
Dublin ..	42	− 7	Falmouth ..	51	− 9
Birr Castle ..			Gorleston ..	44	−12
Valentia ..	42	− 2	Kew.. ..	45	+ 1

Kew temperature, mean, 42·1° F. : diff. from average, +0·8° F.

REVIEW

Science in Africa. By E. B. Worthington, $8\frac{1}{2} \times 5\frac{1}{2}$, pp. XVI + 746, *illus.*, Oxford Univ. Press, Humphrey Milford, London, 1938. Price 10*s.* 6*d.* net.

This impressive volume is one of the results of the comprehensive study of conditions in Africa made over a period of five years by Lord Hailey, and described at length in his great book " An African Survey ". Dr. Worthington's companion volume consists of eighteen chapters, of which the first is entitled " Some Problems of Research ", while the rest deal with different branches of science and were mostly written with the help of specialists. One chapter of 34 pages is devoted to meteorology and is by far the most comprehensive guide we have to the activities of the various governments in providing climatological data for agriculture and health services and upper air information and forecasts for aviation. It includes also a section on changes of climate, in which the suggestion is made that full understanding of climatic cycles in Africa may eventually lead to long-range weather forecasting. A discussion of " alleged progressive desiccation " reaches the conclusion that there is little evidence of an actual decrease of rainfall but that the destruction of forests may have altered the character of the rain and has certainly led to a more rapid run-off.

Even by itself this chapter shows that meteorology is of great importance in African economy, but it does not stand alone. Almost every other science has need to call upon meteorology for enlightenment on its own especial problems. Much of the continent is on the borderline of aridity, and problems of water supply are urgent. Africa is mainly agricultural, and climate is now recognised as one of the most important factors determining the character of the soil as well as the possible range of crops. The question of the probable results of short-circuiting the sudd areas on the Nile involves meteorological considerations, especially the rate of evaporation. The debatable effects of forests on rainfall, soil moisture and the encroachment of deserts are referred to again and again. Climate even comes into the fish-curing industry!

The part played by meteorological conditions in the origin and development of locust outbreaks was recognised by the International Locust Conference in London in 1934 and a series of detailed maps of Africa are now being prepared in the Meteorological Office to study this connexion; meanwhile the interesting suggestion is made that locusts, like some other animals, have a definite periodicity of population which may be related to the sunspot cycle in meteorological elements. Finally there is the highly important but not yet fully understood problem of the effect of tropical sunshine, humidity and temperature on the human body and brain.

If any further evidence is required of the economic importance of meteorology, it is enough to compare the map of annual rainfall on p. 94 with that of density of population on p. 559. Apart from certain areas such as the irrigated Nile valley and the still undeveloped basin of the Congo, the two maps have sufficient resemblance to claim a fair degree of correlation—the Congo of course has too much of a good thing.

The book has a very full bibliography covering 77 pages and an exhaustive index, both of which add greatly to its value for reference. The price of half a guinea is low for a book of this calibre.

C. E. P. B.

Daily Readings at Kew Observatory, January 1939

Date.	Pressure, M.S.L. 13h.	Wind, Dir. 13h.	Force	Temp. Min.	Temp. Max.	Rel. Hum. 13h.	Rain	Sun	REMARKS
	mb.			°F.	°F.	%	in.	hrs.	
1	991·5	SW	3	38	50	77	0·16	1·4	r_0–r 2h–9h.
2	993·0	W	3	40	40	90	0·02	0·0	pr_0– 2h & 17h.
3	1008·9	W	2	33	39	75	trace	2·2	is_0 5h–6h.
4	994·4	WSW	2	31	45	96	0·37	0·0	s_0–r 2h–12h, r_0 17h–[23h.
5	1012·8	NW	2	32	37	68	trace	5·1	pr_0 1h.
6	1022·0	WSW	2	25	36	85	trace	3·3	f 8h–19h, r_0 23h.
7	1015·4	SSW	3	31	52	99	0·36	0·0	r–r_0 3h–9h.
8	1016·4	SW	4	49	53	80	trace	0·2	ir_0 21h–22h.
9	1007·5	SSW	4	48	51	93	0·02	0·0	d_0–r_0 13h–14h.
10	1011·4	NNE	2	42	46	56	0·09	0·0	f 15h, r–r_0 17h–24h.
11	995·5	SW	4	41	47	71	0·08	0·5	r 3h–5h.
12	997·0	SW	3	35	41	71	—	5·5	
13	1002·4	SW	3	33	44	75	—	6·8	f–F 19h–24h.
14	1002·8	ESE	2	26	44	87	0·29	0·0	F 0h–11h, r–r_0 17h–24h.
15	993·9	SSW	5	43	54	74	0·35	2·2	p RQ 7h. r–r_0 18h–23h.
16	998·6	SSW	5	50	52	73	0·44	2·3	r_0–R 18h–21h.
17	988·4	SE	2	45	53	96	0·12	0·0	d 14h, r–r_0 17h–18h.
18	987·2	S	4	50	51	88	0·16	0·0	r–r_0 2h–4h. & 22h–24h.
19	1008·5	WNW	3	48	49	87	0·16	0·1	r 0h–2h & 22h–24h.
20	999·0	SSE	3	44	52	90	0·26	0·6	r 0h–1h & 16h–18h.
21	989·0	S	2	42	52	99	0·15	0·0	r 7h–10h, d_0 15h.
22	1002·6	S	3	47	49	84	0·05	0·4	pr_0 13h, 16h. & 23h.
23	998·0	NW	5	47	49	71	0·04	0·0	pr_0 9h, 13h & 17h.
24	1019·6	NW	3	39	43	62	—	7·0	f 20h–24h.
25	991·1	ENE	2	34	35	96	1·15	0·0	rs–S 4h–22h.
26	991·3	NNE	5	33	38	86	0·01	0·0	r_0 18h & 23h–24h.
27	1009·0	NNE	3	35	41	66	0·04	1·5	r_0 0h–3h & 7h–9h.
28	1014·2	NE	4	35	40	60	trace	3·3	pr_0 5h, 20h. & 23h.
29	1015·4	ENE	6	37	40	63	trace	0·0	pr_0 1h.
30	1017·5	ENE	5	38	39	69	—	0·0	
31	1018·5	ENE	4	36	39	72	—	3·0	
*	1003·3	—		39	45	79	4·32	1·5	* Means or Totals.

General Rainfall for January 1939

	Per cent.
England and Wales	220
Scotland	130
Ireland	128
British Isles	179

Rainfall : January 1939 : England and Wales

Co.	Station.	In.	Per cent of Av.	Co.	Station.	In.	Per cent of Av.
Lond .	Camden Square......	4·67	251	*War* .	Birminghm, Edgbaston	5·81	288
Sur .	Reigate, Wray Pk. Rd.	5·71	238	*Leics* .	Thornton Reservoir...	4·99	252
Kent .	Tenterden, Ashenden.	6·01	280	,, .	Belvoir Castle........	4·06	229
,, .	Folkestone, I. Hospital	5·41	..	*Rut* .	Ridlington	5·26	284
,, .	Margate, Cliftonville..	4·37	263	*Lincs*.	Boston, Skirbeck.....	4·36	269
,, .	Eden'bdg.,Falconhurst	5·65	231	,, .	Cranwell Aerodrome..	3·75	218
Sus .	Compton, Compton Ho	6·69	210	,, .	Skegness, Marine Gdns	4·42	255
,, .	Patching Farm.......	5·90	227	,, .	Louth, Westgate.....	3·74	172
,, .	Eastbourne, Wil. Sq..	5·74	218	,, .	Brigg, Wrawby St....	3·72	..
Hants.	Ventnor, Roy.Nat.Hos.	5·72	223	*Notts* .	Mansfield, Carr Bank..	5·49	255
,, .	Southampton, East Pk	5·92	222	*Derby*.	Derby, The Arboretum	5·04	241
,, .	Ovington Rectory....	6·48	240	,, .	Buxton, Terrace Slopes	8·76	196
,, .	Sherborne St. John...	5·07	218	*Ches* .	Bidston Obsy........	4·25	200
Herts .	Royston, Therfield Rec	4·79	277	*Lancs*.	Manchester, Whit. Pk.	4·64	185
Bucks.	Slough, Upton.......	4·81	259	,, .	Stonyhurst College...	5·33	125
Oxf .	Oxford, Radcliffe.....	4·45	246	,, .	Southport, Bedford Pk	4·34	170
N'hant	Wellingboro,Swanspool	5·27	285	,, .	Ulverston, Poaka Beck	5·12	119
,, .	Oundle	3·97	..	,, .	Lancaster, Greg Obsy.	4·10	117
Beds .	Woburn, Exptl. Farm.	4·26	249	,, .	Blackpool	3·87	142
Cam .	Cambridge, Bot. Gdns.	4·11	274	*Yorks*.	Wath-upon-Dearne ...	4·85	253
,, .	March	3·64	228	,, .	Wakefield,Clarence Pk.	5·31	276
Essex.	Chelmsford,CountyGdns	5·06	331	,, .	Oughtershaw Hall....	10·64	..
,, .	Lexden Hill House....	5·79	..	,, .	Wetherby, Ribston H.	4·39	213
Suff .	Haughley House.....	4·39	..	,, .	Hull, Pearson Park...	3·87	215
,, .	Rendlesham Hall.....	5·17	284	,, .	Holme-on-Spalding...	4·08	216
,, .	Lowestoft Sec. School.	4·78	286	,, .	Felixkirk, Mt. St. John	4·94	247
,, .	Bury St. Ed.,WestleyH	5·66	316	,, .	York, Museum.......	3·46	195
Norf..	Wells, Holkham Hall.	4·02	277	,, .	Pickering, Houndgate.	3·87	185
Wilts .	Porton, W.D. Exp'lStn	4·71	205	,, .	Scarborough.......	3·58	179
,, .	Bishops Cannings	5·19	224	,, .	Middlesbrough.......	3·93	246
Dor .	Weymouth, Westham.	5·67	233	,, .	Baldersdale, Hury Res.	6·59	203
,, .	Beaminster, East St ..	7·24	207	*Durh* .	Ushaw College.......	4·91	239
,, .	Shaftesbury	..	..	*Nor* .	Newcastle, Leazes Pk.	4·16	210
Devon.	Plymouth, The Hoe...	6·72	202	,, .	Bellingham, Highgreen	5·44	190
,, .	Holne, Church Pk.Cott	12·69	205	,, .	Lilburn Tower Gdns..	5·16	249
,, .	Teignmouth, Den Gdns	6·74	231	*Cumb*.	Carlisle, Scaleby Hall.	4·72	190
,, .	Cullompton	6·98	215	,, .	Borrowdale,Seathwaite	16·25	129
,, .	Sidmouth, U.D.C.....	5·98	..	,, .	Thirlmere,DaleHeadH.	14·07	169
,, .	Barnstaple,N. Dev.Ath	5·81	178	,, .	Keswick, High Hill...	8·85	175
,, .	Dartm'r,Cranmere Pool	13·30	..	,, .	Ravenglass, The Grove	4·99	149
,, .	Okehampton, Uplands.	8·78	172	*West* .	Appleby, Castle Bank.	6·19	193
Corn .	Redruth, Trewirgie...	7·48	177	*Mon* .	Abergavenny, Larchf'd	8·71	258
,, .	Penzance, MorrabGdns	8·12	214	*Glam* .	Ystalyfera, Wern Ho..	9·40	149
,, .	St. Austell, Trevarna..	8·41	197	,, .	Treherbert, Tynywaun	14·78	..
Soms .	Chewton Mendip.....	6·74	175	,, .	Cardiff, Penylan......	6·59	179
,, .	Long Ashton	5·76	201	*Carm* .	Carmarthen,M.&P.Sch.	8·81	196
,, .	Street, Millfield	4·85	205	*Card* .	Aberystwyth	6·21	..
Glos .	Blockley	6·18	..	*Rad* .	Birm.W.W.Tyrmynydd	11·07	176
,, .	Cirencester, Gwynfa ..	5·83	232	*Mont* .	Lake Vyrnwy........	12·19	216
Here .	Ross-on-Wye	5·67	234	*Flint* .	Sealand Aerodrome...	4·78	257
,, .	Kington, Lynhales....	5·77	205	*Mer* .	Blaenau Festiniog....	10·99	117
Salop .	Church Stretton......	8·04	318	,, .	Dolgelley, Bontddu...	8·39	147
,, .	Shifnal, Hatton Grange	4·88	252	*Carn* .	Llandudno	5·00	207
,, .	Cheswardine Hall	5·53	250	,, .	Snowdon, L. Llydaw 9	22·50	..
Worc .	Malvern, Free Library.	5·98	271	*Ang* .	Holyhead, Salt Island.	6·04	208
,, .	Ombersley, Holt Lock.	4·87	254	,, .	Lligwy.............	7·89	..
War .	Alcester, Ragley Hall.	4·83	250	*I.Man*	Douglas, Boro' Cem...	6·19	185

Rainfall: January 1939: Scotland and Ireland

Co.	Station.	In.	Per cent of Av.	Co.	Station.	In.	Per cent of Av.
Guern .	St.PeterP't.GrangeRd.	6·91	236	*R&C* .	Stornoway, C.G.Stn...	4·86	99
Wig .	Pt. William, Monreith.	5·18	158	*Suth* .	Lairg	3·94	120
,, .	New Luce School.....	7·50	185	,, .	Skerray Borgie.......	5·16	..
Kirk .	Dalry, Glendarroch...	5·89	106	,, .	Melvich	5·01	152
,, .	Eskdalemuir Obs.....	7·02	130	,, .	Loch More, Achfary..	7·47	103
Roxb .	Hawick, Wolfelee	6·33	198	*Caith* .	Wick	3·69	150
,, .	Kelso, Broomlands....	4·82	275	*Ork* .	Deerness	5·02	146
Peeb .	Stobo Castle.........	4·20	140	*Shet* .	Lerwick Observatory.	5·42	127
Berw .	Marchmont House....	5·81	258	*Cork* .	Cork, University Coll.	5·70	141
E.Lot.	North Berwick Res...	3·47	201	,, .	Roches Point, C.G.Stn.	4·97	120
Midl .	Edinburgh, Blackfd. H	3·25	185	,, .	Mallow, Waterloo	4·51	116
Lan .	Auchtyfardle	3·53	..	*Kerry*.	Valentia Observatory.	7·22	132
Ayr .	Kilmarnock, Kay Park	3·64	..	,, .	Gearhameen	16·90	166
,, .	Girvan, Pinmore	4·47	95	,, .	Bally McElligott Rec.	5·22	..
,, .	Glen Afton, Ayr San..	5·72	112	,, .	Darrynane Abbey....	6·82	136
Renf .	Glasgow, Queen's Park	4·71	141	*Wat* .	Waterford, Gortmore.	4·70	129
,, .	Greenock, Prospect H.	4·96	77	*Tip* .	Nenagh, Castle Lough.	4·76	120
Bute .	Rothesay, Ardencraig.	4·35	97	,, .	Cashel, Ballinamona..	3·70	99
,,	Dougarie Lodge......	4·69	109	*Lim* .	Foynes, Coolnanes....	4·56	121
Arg .	Loch Sunart, G'dale..	4·08	58	,, .	Limerick, Mulgrave St.	4·66	122
,,	Ardgour House	6·05	..	*Clare* .	Inagh, Mount Callan..	7·08	..
,,	Glen Etive	4·45	42	*Wexf* .	Gorey, Courtown Ho..	4·81	154
,,	Oban	2·95	..	*Wick* .	Rathnew, Clonmannon	5·71	..
,,	Poltalloch	3·43	68	*Carl* .	Bagnalstown FenaghH	3·74	119
,,	Inverary Castle	5·25	64	,, .	Hacketstown Rectory.	4·61	130
,,	Islay, Eallabus	4·61	99	*Leix* .	Blandsfort House	3·74	114
,, .	Mull, Benmore.......	..	..	*Offaly*.	Birr Castle	5·03	178
,,	Tiree	2·76	65	*Kild* .	Straffan House.......	4·35	169
Kinr .	Loch Leven Sluice....	4·91	156	*Dublin*	Dublin, Phoenix Park.	3·34	147
Fife .	Leuchars Aerodrome..	4·19	230	*Meath*.	Kells, Headfort......	5·34	170
Perth .	Loch Dhu	7·55	83	*W.M* .	Moate, Coolatore.....	4·53	..
,, .	Crieff, Strathearn Hyd.	3·53	88	,, .	Mullingar, Belvedere..	5·55	173
,, .	Blair Castle Gardens..	2·73	82	*Long* .	Castle Forbes Gdns ..	5·11	153
Angus.	Kettins School.......	3·29	126	*Gal* .	Galway, Grammar Sch.	4·18	112
,, .	Pearsie House	3·21	..	,, .	Ballynahinch Castle ..	6·90	111
,, .	Montrose, Sunnyside..	2·94	148	,, .	Ahascragh, Clonbrock.	4·60	119
Aber .	Balmoral Castle Gdns.	3·50	127	*Rosc* .	Strokestown, C'node..	4·50	144
,, .	Logie Coldstone Sch ..	3·61	163	*Mayo*.	Blacksod Point	4·44	87
,, .	Aberdeen Observatory.	3·73	171	,, .	Mallaranny..........	7·20	..
,, .	New Deer SchoolHouse	4·37	188	,, .	Westport House......	4·30	92
Moray	Gordon Castle	3·51	174	,, .	Delphi Lodge........	9·25	93
,, .	Grantown-on-Spey ...	7·15	295	*Sligo* .	Markree Castle.......	3·43	87
Nairn.	Nairn..............	2·77	139	*Cavan*.	Crossdoney, Kevit Cas.	5·91	..
Inv's .	Ben Alder Lodge.....	5·11	..	*Ferm* .	Crom Castle	4·79	144
,, .	Kingussie, The Birches	4·05	..	*Arm* .	Armagh Obsy........	3·20	127
,, .	Loch Ness, Foyers....	4·46	106	*Down*.	Fofanny Reservoir ...	12·04	..
,, .	Inverness, Culduthel R	3·08	121	,, .	Seaforde	5·34	170
,, .	Loch Quoich, Loan...	6·87	..	,, .	Donaghadee, C. G. Stn.	3·96	156
,, .	Glenquoich	6·55	48	*Antr* .	Belfast,Queen's Univ .	4·40	154
,, .	Arisaig House	4·38	71	,, .	Aldergrove Aerodrome	3·60	131
,, .	Glenleven, Corrour ...	..	..	,, .	Ballymena, Harryville.	4·47	120
,, .	Fort William, Glasdrum	6·03	..	*Lon* .	Garvagh, Moneydig...	3·54	..
,, .	Skye, Dunvegan	4·72	..	,, .	Londonderry, Creggan.	2·78	77
,, .	Barra, Skallary	3·20	..	*Tyr* .	Omagh, Edenfel......	3·27	92
R&C.	Tain, Ardlarach......	3·23	114	*Don* .	Malin Head..........	3·02	92
,, .	Ullapool	3·18	69	,, .	Dunfanaghy	3·09	88
,, .	Achnashellach	5·80	60	,, .	Dunkineely..........	3·79	..

Climatological Table for the British Empire, August 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	1015·4	+ 0·1	84	45	71·8	55·9	63·9	+ 2·2	56·4	87	8·1	2·70	+ 0·46	12	5·1	35
Gibraltar	1014·2	− 2·3	83	64	78·4	66·5	72·5	− 3·5	65·7	82	3·0	0·00	—	0	—	—
Malta	1013·1	− 1·7	101	70	85·0	74·0	79·5	+ 0·4	71·5	70	1·9	0·15	+ 0·01	4	11·7	86
St. Helena	1019·5	− 1·6	67	53	61·4	55·4	58·4	+ 1·4	56·4	95	9·7	4·15	+ 1·66	22	—	—
Freetown, Sierra Leone	1013·1	+ 2·0	83	70	80·1	72·6	76·3	—	72·6	91	9·1	33·11	− 3·46	27	—	—
Lagos, Nigeria	1012·9	− 0·1	85	67	80·7	71·8	76·3	− 1·6	72·9	89	8·0	1·61	− 1·03	3	4·8	39
Kaduna, Nigeria	1011·5	—	87	64	80·7	67·9	74·3	+ 0·1	69·8	92	9·3	13·40	+ 1·08	25	3·1	25
Zomba, Nyasaland	1016·4	− 0·5	82	50	75·0	54·6	64·8	− 0·1	61·3	80	2·7	0·25	− 0·12	4	—	—
Salisbury, Rhodesia	1017·8	− 1·3	84	34	73·3	46·5	59·9	− 0·3	49·4	44	1·9	0·00	—	0	9·5	83
Cape Town	1021·7	+ 1·4	82	37	65·5	45·6	55·5	− 0·1	47·8	80	3·3	2·78	− 0·59	11	—	—
Johannesburg	1019·6	− 0·6	76	29	65·4	42·5	53·9	− 0·5	43·5	55	1·9	0·35	− 0·16	3	8·9	79
Mauritius	1019·2	− 1·4	78	54	75·6	60·4	68·0	− 0·5	63·7	68	5·0	1·21	− 1·04	14	7·7	67
Calcutta, Alipore Obsy.	1001·4	+ 0·4	92	77	88·8	79·1	83·9	+ 0·7	79·6	89	8·4	9·64	− 3·74	17*	—	—
Bombay	1004·7	− 1·2	88	73	85·5	76·6	81·1	+ 0·3	77·1	86	8·2	16·77	+ 2·32	21*	—	—
Madras	1004·5	− 1·0	97	73	93·1	78·0	85·5	− 0·5	76·1	73	6·8	4·24	− 0·30	4*	—	—
Colombo, Ceylon	1008·9	− 0·4	85	74	84·4	76·8	80·6	− 0·6	76·7	78	8·1	4·77	+ 1·53	24	5·9	48
Singapore	1009·0	− 0·5	88	72	84·3	76·2	80·3	− 0·8	77·1	80	8·1	9·35	+ 1·40	21	4·6	38
Hongkong	1004·7	− 0·1	90	76	87·1	78·5	82·8	+ 0·7	78·7	82	7·5	7·89	− 6·51	19	5·1	40
Sandakan	1008·6	—	91	74	88·3	75·7	82·0	+ 0·2	77·3	83	6·8	5·73	− 2·16	12	—	—
Sydney, N.S.W.	1019·5	+ 1·3	76	37	62·7	47·0	54·9	− 0·1	49·3	69	5·0	8·31	+ 5·34	15	5·9	54
Melbourne	1020·4	+ 2·4	71	29	59·2	42·2	50·7	− 0·3	45·9	75	6·7	0·99	− 0·88	17	4·4	42
Adelaide	1021·0	+ 1·8	70	36	61·5	44·9	53·2	− 0·8	48·8	72	6·3	2·69	+ 0·15	16	5·3	49
Perth, W.Australia	1022·7	+ 3·8	76	41	64·6	49·7	57·1	+ 1·1	51·5	70	6·7	5·51	− 0·14	18	5·9	54
Coolgardie	1021·8	+ 2·5	77	35	64·1	42·6	53·3	− 0·3	47·3	63	3·6	0·57	− 0·42	5	—	—
Brisbane	1020·7	+ 1·5	80	41	68·7	49·8	59·3	− 1·1	52·0	69	3·6	1·21	− 0·80	6	7·4	66
Hobart, Tasmania	1017·0	+ 3·6	66	33	55·2	41·6	48·4	+ 0·4	44·0	73	5·0	1·11	− 0·72	16	4·9	47
Wellington, N.Z.	1018·6	+ 3·5	61	33	53·0	42·5	47·7	− 0·9	45·3	79	7·5	7·00	− 2·51	13	4·9	47
Suva, Fiji	1014·9	+ 0·7	88	66	80·9	71·2	76·1	+ 2·5	71·7	85	6·8	7·05	− 1·24	21	3·9	34
Apia, Samoa	1012·2	− 0·1	86	71	84·4	74·2	79·3	+ 1·5	75·3	79	6·1	5·26	+ 1·63	23	8·2	70
Kingston, Jamaica	1012·8	− 0·7	93	72	89·0	74·1	81·5	0·0	72·8	80	3·8	6·23	+ 2·68	10	8·6	68
Grenada, W.I.	1010·6	− 2·0	89	70	87	73	80·0	+ 0·3	73	74	6	13·60	+ 4·27	27	—	—
Toronto	1014·9	− 0·5	92	53	82·7	63·1	72·9	+ 5·7	64·5	82	3·6	2·06	− 0·73	8	8·9	64
Winnipeg	1012·0	− 1·2	92	41	80·1	54·2	67·1	+ 3·3	54·4	83	4·4	1·74	− 0·42	10	9·3	64
St. John, N.B.	1013·9	− 1·4	84	47	71·9	56·9	64·4	+ 3·8	59·9	86	6·6	3·95	+ 0·09	15	7·4	52
Victoria, B.C.	1018·2	+ 1·3	78	48	66·7	51·1	58·9	− 0·8	54·5	81	3·3	0·55	− 0·09	5	10·3	72

* For Indian stations a rain day is a day on which 0·1 in. or more rain has fallen.

(45883) Wt. 20/31 1,250 2/39 Hw. G.377/6

THE METEOROLOGICAL MAGAZINE

M.O. 441

AIR MINISTRY : METEOROLOGICAL OFFICE

Vol. 74 March 1939 No. 878

THE COMPOSITION OF THE ATMOSPHERE THROUGH THE AGES

By G. S. Callendar

Last month we had an article(1) by the Astronomer Royal explaining some of the physical laws which determine the type of atmosphere possessed by a planet, and it was shown that the atmosphere of the Earth has been greatly changed by organic action and rock weathering. In the present note an attempt is made to estimate the most probable changes which our atmosphere has undergone throughout geological time.

To begin at the beginning when the Earth was detached from the sun as a mass of very hot gas, is to enter a most speculative region; however, it might be assumed that the observed differences in the proportions of the lighter elements on the Earth and Sun were determined at this early stage, when gravitational attraction in the outer parts of the earth cloud was too small to hold the light and volatile elements.

Temperatures may have fallen rapidly whilst the material was distended, and about the time condensation to form the nucleus was well under way, they would have fallen to levels where chemical action begins, then there must have been a terrific struggle for the available oxygen supply because we know that there is a great deficiency of this element to satisfy all the earth materials. The first to be successful in capturing this much sought after element would be the carbon and the light metals, when temperatures were around 6,000° F., but in the cooler outer regions there must have been a great formation of water vapour as the rapidly escaping hydrogen encountered free oxygen. Perhaps the departing Moon relieved the earth of a superabundance of water vapour.

About this time the atmosphere started its separate existence and formed a great heat insulating cover over the hot core; at first it would carry the whole of the water, oxides of carbon, nitrogen, etc., and the pressure at the bottom would be some 5,000 lbs. per square inch; but a slow cooling would continue and enable the materials of the core to dissolve quantities of the water vapour, somewhat lightening the atmosphere. Gradually solid crusts of the more refractory silicates would form on the surface, cooling of the lower atmosphere would become quicker and temperatures suitable for a variety of interesting reactions between the water vapour, carbon monoxide, and nitrogen, probably a certain amount of ammonia and methane would be formed, certainly any carbon monoxide would be changed to the dioxide at the expense of the water vapour.

Meanwhile the water would start to condense at about 700° and heat loss from the surface could proceed at an accelerated rate; and now with the crust fairly solid, the water condensed and partially desolved in the materials of the core, the atmosphere would be much smaller, consisting mainly of carbon dioxide with about the present quantity of nitrogen and argon, but perhaps a considerable amount of helium. From the observed amount of carbon in the sedimentary rocks I estimate the total amount of carbon dioxide which has passed through the atmosphere as ten times the present mass of air. The larger proportion of this is now fixed in the carbonate rocks (limestones, etc.), but the plants have reduced about one seventh, equal to 7,000 billion tons (7×10^{15}), leaving their carbon in the dark coloured shales and a small part concentrated in coal seams. Of the oxygen released when this organic debris was buried beyond the reach of decay, about one quarter remains in the atmosphere, the rest having been absorbed by the unsaturated materials of the crust.

Whether this vast store of carbon dioxide formed the primal atmosphere, or was largely given off during volcanic action in subsequent ages, is an interesting question, but the presence of ferric oxide in the magma suggests that only the gaseous oxides of carbon existed in the early stages, and that the carbon dioxide known to come from volcanoes is recycled gas given off by the metamorphism of siliceous carbonates. It therefore seems probable that the early atmosphere was several times denser than at present and had great heat insulating capacity, for the carbon dioxide of which it was mainly composed reflects the dark heat rays to a considerable extent, and there would be quantities of water vapour with clouds to complete the heat insulation of the surface.

Under such conditions nearly all heat reaching the surface would have to be dissipated by convection and there may have been much rainfall, with a considerable heat loss to space from the highest levels of the atmosphere which could become intensely cold and laden with ice crystals (cirrus). This cirrus could reflect most of the sunlight and at the surface a stifling heat and gloom would prevail, broken at times by lightning flashes and swept by gusts of heavy " air ".

After many millions of years the carbonation of the alkalies washed from the surface would have lightened the atmosphere and enabled the sea to dissolve a part of it, then perhaps an occasional gleam of sunlight would penetrate the various cloud layers and fall upon some pool of water saturated with carbon dioxide and iron salts; now free oxygen could be released and carbohydrates syntheticised. Possibly the organization of the latter proceeded in such a way as to give the simplest life, in any case it may have been long before life was able to feed directly upon the carbon dioxide of the atmosphere. This basic life process, which enables the plant to detach the carbon with the aid of solar energy, has been of the greatest importance to the composition of the atmosphere because it is the only considerable source of free oxygen.

With the passing of millions of years a continuous attack would be made upon the vast stores of carbon dioxide, at first by the alkalies of the crust, later the plankton of the water would deposit its carbon on lake and sea bottoms, releasing the equivalent amount of oxygen; probably the remains of these first oxygen producers are represented by the graphite which impregnates great thicknesses of pre-Cambrian schists.

By the beginning of the Palaeozoic (about 450 million years ago), life in the seas was highly organized and already the air must have contained much oxygen. Probably at this time any methane and ammonia had been oxidized out and most of the helium had escaped.

Gradually forms of plant developed which could live on the land, and, when they had become rapid-growing in the Carboniferious period, a tremendous assault upon the atmospheric carbon dioxide developed. From the known areas of carboniferous deposits and their average carbon contents, I calculate that the plants of this period used up more than 100 times as much carbon dioxide as there is in the air at present. It is perhaps significant that this period was accompanied by great deposits of limestone(2), for when the pressure of carbon dioxide in the atmosphere was much reduced the sea would be forced to give up part of its reserve supply, and this is accompanied by the precipitation of carbonates*.

But always fresh alkali was dissolved from the igneous rocks and the depletion of the carbon dioxide went on until it became a mere trace in the barren and cold Permian period; meanwhile oxygen had become very abundant and was eagerly absorbed by the iron salts of the crust to give the red rocks of the Permian and later series.

Once the rank growth of the plants had been eliminated by their own reckless exhaustion of the carbon dioxide supply the gas commenced to increase again, perhaps by

* When the alkaline earth metals are dissolved by carbonic acid, two equivalents of CO_2 are required to hold them in solution and one equivalent is released when the carbonate is precipitated.

this time the metamorphism of siliceous carbonates was giving nearly enough carbon dioxide to cancel that used to carbonate alkali, and the oxidization of the exposed carboniferous formations would form a great source of supply.

In the early Mesozoic, about 200 million years ago, the atmosphere must have been remarkably similar to the one which we know at present, composed almost entirely of nitrogen and oxygen with traces of ozone formed at high altitudes. The cirrus layer would have dispersed below a well formed stratosphere, for unlike the old carbon dioxide atmosphere nitrogen and oxygen have no power of heat radiation at low temperatures and do not form a vertical temperature lapse rate without convection, or the presence of a moderate amount of water vapour.

During the long periods free from polar ice quiet conditions would prevail in our latitudes with deficient rainfall in many parts and much sunshine. At later times, as when the great lignite beds of western North America were laid down, there would be an intensified assault on the remaining carbon dioxide; but during those periods when most of the land was below sea level there would be little fixation of the gas by alkalies or by the plants, and the organic precipitation of the chalk would force the sea to give great quantities of carbon dioxide to the atmosphere*.

At present the sea holds 60 times as much CO_2 as the air, although only about half of this would become available as the gas was exhausted in the atmosphere.

It is very tempting to suppose that the slow cooling of high latitudes, which is known to have occurred in the late Cainozoic and to have culminated in the large oscillations of the glacial periods, was due to the slowly diminishing heat protection of the atmospheric carbon dioxide during periods favourable to alkali weathering and luxuriant plant growth. However that may be the final oscillations could hardly be accounted for by

* For various reasons organic carbon is not deposited on the floors of the great oceans.

variations of this gas because, unless our heat absorption coefficients are very much at fault, the time scale of the glacial periods is much too short to allow for natural fixation or formation of the necessary quantities.

It is a commonplace that man is able to speed up the processes of Nature, and he has now plunged heavily into her slow-moving carbon cycle by throwing some 9,000 tons of carbon dioxide into the air each minute. This great stream of gas results from the combustion of fossil carbon (coal, oil, peat, etc.)*, and it appears to be much greater than the natural rate of fixation, in spite of the rather rapid deposit of carbon in bogs and lakes caused by the disturbance to local drainage of the recent glacial period. From the known areas and rates of growth I calculate that organic carbon deposit in " mosses " and stagnant waters is not more than 15 per cent. of that used for fuel, and analyses of drainage waters from igneous rock areas gives only 4 per cent. used to carbonate alkali.

Hence nearly all the man-made carbon dioxide is effective in increasing its atmospheric percentage, and the best observations show an increase from 0·028 per cent. about the year 1900 to 0·030 per cent. of recent years. This increase is equal to three quarters of the gas from combustion during the period, the rest has doubtless been absorbed by the sea which will claim a greater proportion as the atmospheric excess accumulates.

As man is now changing the composition of the atmosphere at a rate which must be very exceptional on the geological time scale, it is natural to seek for the probable effects of such a change. From the best laboratory observations it appears that the principal result of increasing atmospheric carbon dioxide, apart from a slight speeding up of rock weathering and plant growth, would be a gradual increase in the mean temperature of the colder regions of the earth(3).

---

* A few hundred million tons per year are also released by:—cultivation of humic soils, drainage of land, cement manufacture, lime burning, sulphate manures and ore burning (give – SO_3 base exchange), etc., etc.

To detect a small secular change of this kind only long continued temperature readings of the highest accuracy are of any use, and only a few records of perhaps a century's duration can claim to satisfy such a stringent test. However nearly all the best of these are located in west Europe, and the figure showing successive 30 year means of temperature includes some of the most accurate long records in existence; it shows that a marked increase commenced from about the time that carbon dioxide production became rapid.

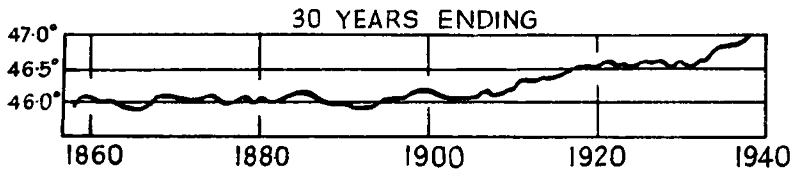


FIG. 1.—THE MARCH OF TEMPERATURE IN WEST EUROPE 1830–1938.

The 30 year moving average from the combined means at: Edinburgh, Oxford, Greenwich, De Bilt, Bergen, Oslo, Stockholm, Copenhagen, Wilno and Berlin.

The five years 1934–38 are easily the warmest such period at several stations whose records commenced up to 180 years ago.

It may be remarked that the rate of increase (0·025°/yr), shown by the curve for the present century, is a lot greater than the rate calculated from the heat absorption coefficients, but the latter can only be approximate and secondary effects would cause large local variations; for instance the Australian stations give an almost flat curve whereas those of the Arctic(4) show a very steep rise commencing late in the period.

REFERENCES.

(1) Jones, H. Spencer. *Met. Mag., London,* 74, 1939, p. 7.
(2) Chamberlain, J. C. *Chicago, J. Geol.* 6, 1898.
(3) Callendar, G. S. *London, Quart. J. R., Met. Soc.,* 64, 1938.
(4) Brooks, C. E. P. *Met. Mag., London,* 73, 1938, p. 20.

CLIMATOLOGY AND FORECASTING

By S. T. A. Mirrlees, M.A.

The meteorologist has been reproached for the habit of storing or hiding, squirrel-like, more data than he can ever possibly use, with some appearance of intelligent provision for the future but really (the critics say) in unreasoning obedience to some instinct. The forecaster has also sometimes been reproached for relying on " experience ". There is some inconsistency in the criticism here unless " experience " refers to such methods as uncritical cataloguing of isobaric situations or depression tracks, or to what may be called " subconscious " forecasting, for we have accumulated data representing long experience and more than any forecaster will acquire in a lifetime. Criticism might also apply to the indiscriminate collecting of " weather rules ", many of which can be rewritten in the light of more recent ideas. A number of rules in the old " sailing directions ", for instance, might be rewritten as " the local name for a line-squall is . . "

Most forecasters to-day are using to a greater or lesser extent the ideas of air-mass analysis. Having decided what air-mass* will to-morrow occupy the region in question, the forecaster writes down the weather appropriate to the air-mass in that region with any incidentals involved in a change from one air-mass to another. This presupposes some idea of what weather is associated with each of the usual air-masses, an idea which the forecaster gets from his experience or from the published ideas of some other forecaster. For one or two stations there are available " air-mass calendars " which give frequencies of occurrence of various air-masses. The making of

* That discrete air-masses exist has become axiomatic; but one does not yet find the forecaster using a " table for the identification of air-masses " which has precision, like, for instance, the " table for the separation of the groups " which the chemist uses.

these lists was proposed by Bergeron* in 1930, when he gave the term " dynamical climatology " for a study based on frequencies and intensities of well-defined systems, dynamically and thermodynamically more or less self-contained.

The data, volumes of which occupy so much space in meteorological libraries, are not, however, in their present form adapted in general for immediate use on these lines by the forecaster. Many of the data available in this country are in the form of means and extremes, as for example in the *Monthly Weather Report.* How can these data be put into a form which will be of more use to the forecaster?

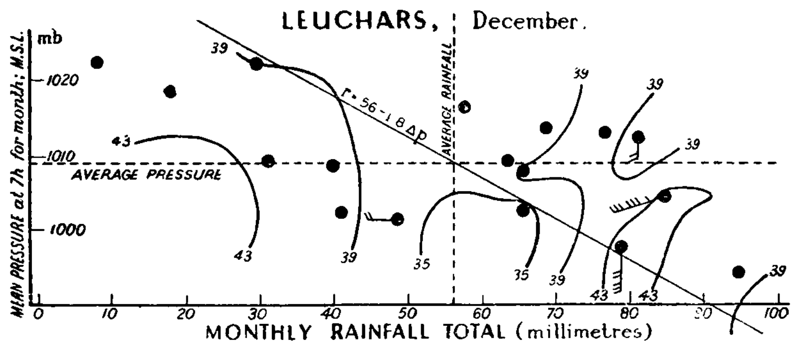


FIG. 1

In Fig. I, I have plotted monthly mean barometric pressures against rainfall totals for December (17 years) as measured at Leuchars, Fife, a station which experiences a rather complicated régime of orographic and coastal effects. The diagram shows that in general high pressure goes with low rainfall but the correspondence is not really close; extreme values give the formula $r = 49 - 3 \Delta p$, and " least square " methods give $r = 56 - 1 \cdot 8 \Delta p$. To the diagram may be added isopleths of other elements and resultant winds; for

* Bergeron, T., 1930, *Met. Z. Braunschweig,* 47, pp. 246-62.

simplicity only some isopleths of mean temperature and some resultant winds are shown. The net result is that no obvious forecasting rule can be deduced in this way, for, as is well known and need not be discussed at length, the month is too long a unit and the mixing-up of different weather types too much. For economy in space only a few of the extreme values are given in Table I. A good instance is December, 1937—the mean temperature for December 1–20 was 33·7° F. and for December 21–30, 41·1° F., thus in a sense two Decembers are involved. A minute analysis of the figures in Table I might have some result but would take much time.

TABLE I.

Leuchars, Fife: monthly values for December. Years and elements as specified.

Year	p	t	r	ss	s	w
1925 ..	1002·6	*33·9*	65·8	46·3	8	W 4
1926 ..	**1022·5**	40·3	*8·1*	53·6	2	W 6
1929 ..	*994·0*	39·9	**94·8**	**66·3**	1	SW 5
1934 ..	997·7	**44·3**	79·0	*15·6*	*0*	S 5
1937 ..	1012·3	36·1	81·1	43·7	**11**	S 2

p mean barometric pressure at 7h., millibars, at M.S.L.
t mean temperature in screen, from $\frac{1}{2}$ (max. + min.).
r total rainfall in millimetres.
ss total hours of bright sunshine.
s total number of days with snow.
w resultant wind direction and Beaufort force, *not* a vector mean but computed graphically from the gradients of mean pressure.

Consider now what can be learnt from examination of extreme values. As an illustration I have collected data for the various days of extreme maximum temperature (7h. to 18h.) in September at Leuchars. The date of the highest temperature recorded in each month is given in the *Monthly Weather Report* together with the temperature attained. The data are then classified according to the direction of wind at the 500-metre level measured about mid-day and mean values are shown in Table II.

TABLE II.

Leuchars. September: days of extreme maximum temperature for the month.

Wind at 500 metres above ground	Direction Mean speed, m.p.h.	SE 15	S 22	SW 21	W 24
Vapour pressure at 13h.	Mean in millibars	18·2	16·6	16·2	15·9
Sunshine for day	Mean in hours ..	1·7	4·6	6·6	7·2
Temperature, extreme for day.	Mean °F. ..	68	69	69	70
Number of occasions.	.. .. ..	1	4	5	9

Here there is some appearance of regularity; the figures can be partly interpreted as follows, and comments are added in brackets. The highest temperatures are experienced with fresh westerly winds (föhn effect, combined with warming over land); if winds are light or have an appreciable easterly component the temperature will not exceed the seasonal average (effect of the incursion of sea-breezes); if winds are SE or S unusually high temperature tends to be accompanied by deficiency of bright sunshine. Other details appear from consideration of individual values. Consideration of synoptic charts is not included because comparatively few forecasters have ready access to more than a few years' synoptic charts.

The point is that an extension of the method of considering extremes for representative stations which is indicated in the above example seems to offer an indication of air-mass characteristics for regions, which could be used in forecasting where the dynamical climatology has not been investigated.

Some indication of the characteristics of sub-tropical air-masses in winter, for example, might be expected from an examination of cases of highest night minimum.

As regards the question of utilising the upper-air data, it seems that emphasis must be laid on the dynamical rather than on the climatological aspect because of the few data available, and the same applies to the questions of forecasting fog and thunderstorms, but for a different reason—the nature of the data available. These are the two questions which Mr. Boyden, in this magazine for May, 1937, suggested for co-operative research, and since the thunderstorm, although more spectacular, has only a temporary and local effect on human affairs in general, as compared with a persistent fog, the problem of forecasting fog should be regarded as the more urgent. The first step in the co-operative research might well be the consideration of the most effective method of presenting data of fogs for the use of the forecaster.

OFFICIAL PUBLICATIONS

PROFESSIONAL NOTES.

No. 87. *Upper winds at Nicosia (Cyprus).* By J. Durward, M.A.

Upper winds from Cyprus are of considerable importance for aerial navigation on the direct air route from Athens to the East. In 1934, therefore, a pilot-balloon station was established near Nicosia and the results communicated to the forecast centre at Heliopolis.

The results are here presented in the form of I.C.A.N. tables as well as by means of "direction constancy" diagrams. The latter are not very convincing, though they do show that the resultant wind above 5,000 feet in all months is westerly and that winds have the greatest constancy during the winter months and the least constancy during the transitional seasons April–May, October–November.

LUNAR RAINBOWS IN THE WEST OF IRELAND

By D. A. Davies, B.Sc.

The conditions necessary for the formation of lunar rainbows are very simple and obvious—they are (*a*) the presence of a moon and (*b*) the simultaneous occurrence of showers. Despite the simplicity of these conditions, lunar rainbows are rarely observed, or at least recorded, as is borne out by the fact that in the last decade (1929–38) only two examples of the phenomenon are recorded in the *Meterological Magazine* as being observed in the British Isles.

Suitable weather conditions for their formation are provided when the country is in a more or less direct polar air stream, for under such circumstances instability showers are of frequent occurrence. Generally speaking, however, one of the salient features of polar air conditions over land areas is the marked decrease in cloudiness, and hence in the frequency of showers, during the night. Conditions favourable for the formation of lunar rainbows will, therefore, not normally obtain over land even in polar air.

Over the sea, however, there is little or no diurnal variation in cloud amount (or for that matter, in any meteorological element), and instability showers are as frequent and intense by night as by day in polar air. This was amply demonstrated to the writer during a recent year's voyaging on the North Atlantic Ocean for the purpose of meteorological investigation. Moreover, the observations recorded by N. K. Johnson in the Mediterranean Sea in 1926 (*London, Quart. J.R. Met. Soc.*, 53, pp. 59–64) show that on this particular occasion at least, there was actually a steeper lapse rate near the surface by night than by day. Conditions are, therefore, more favourable for the occurrence of lunar rainbows over the sea than over the land. In this connection it is interesting to note that during the last decade (1929–38), nine examples of lunar rainbows are recorded in the *Marine Observer* as having been observed by British ships on the North Atlantic Ocean, and numerous other examples on other oceans. In seven of the nine examples witnessed on the North Atlantic, colours were observed in the rainbows and in practically all cases the accompanying cloud type was cumulo-nimbus.

The types of weather experienced on and near the west coast of Ireland approximate very closely to those characteristic of the Atlantic Ocean. This was illustrated very clearly during the fortnight November 19th to December 2nd, 1938. The British Isles was in a polar air stream for practically the whole of this period, and it was interesting to note that as far inland as Foynes, which is some 35 miles from the mouth of the Shannon on its southern shore, the weather conditions experienced simulated very closely those to be anticipated over the ocean, the instability showers showing no diurnal variation either in frequency or intensity. This is demonstrated by the Foynes autographic rainfall records, which show that there was no significant difference between the amounts of rain that fell between 18h. and 07h. and between 07h. and 18h. during the period under consideration, and that practically all the rain fell in the form of showers, which were at times very heavy and not infrequently of hail. The local nature of the showers is brought out by a comparison of the autographic rainfall records of Foynes and Rineanna, Co. Clare (the latter being only about 10 miles from Foynes and on the north shore of the Shannon), which reveals no relationship whatsoever between the times of occurrence of the showers at the two places.

Under such circumstances, it is not surprising that a lunar rainbow was observed by the writer on November 29th, 1938, between 2100h. and 2115h. G.M.T. at Glin, a village about 30 miles from the mouth of the Shannon. At first, only a small arc was visible, but later it increased in size and for about five minutes the full arc was visible from horizon to horizon. It then became less distinct and eventually disappeared.

The rainbow took the form of a distinct white band, but no colours could be seen. The distinctness of the rainbow was perhaps rather remarkable since the moon was only in the first quarter at the time.

There were frequent instability showers from cumulonimbus clouds during the evening, and it was raining when the phenomenon was observed, but not heavily. An interesting feature is that the moon was only faintly visible through the clouds from the point of observation throughout the period the rainbow was seen, although it was completely unobscured at intervals before and after the event in the frequent breaks in the cloud.

The following night (30th) the writer assumed the same point of observation (this time equipped with a prismatic compass), in the hope of witnessing a re-appearance of the phenomenon, as the weather conditions were of the same unstable type. This time, however, the lunar rainbow was not observed; there were instead numerous flashes of lightning, culminating in a thunderstorm. The altitude and bearing of the moon were measured on this occasion as 27° and SW by S respectively at about the same time as the rainbow had been observed the previous evening.

The altitude of the vertex of the arc of the rainbow was estimated as about 20°. This is probably an over-estimate, since if we assume that the moon's altitude was the same as it was the following evening at the same time (i.e. 27°), then the sum of the altitudes of the moon and vertex of the rainbow is 47°, and not 42° as it should be.

The writer's optimism in hoping to witness a re-appearance of the phenomenon was perhaps justified by the fact that the next night (December 1st) a lunar rainbow was observed by Mr. C. D. Barrow (a member of the meteorological staff at Foynes) at Rathkeale, a town about 42 miles from the coast. On this occasion the full arc was visible for about two minutes, and again took the form of a white band.

LETTERS TO THE EDITOR

The Snowfalls of December and January

Mr. Douglas, in his valuable article in the February issue of this magazine asks if anyone can say how long it is since the central part of the Metropolis experienced a snowfall comparable with that of December, 1938. The question can only be answered with careful reference to definitions. For combination of depth, dryness and duration of the snow cover, it is probably necessary to go back to March, 1909, when for many days carts and lorries were removing the huge dumps. It should be remembered, however, that there have been many heavy snowfalls since, especially in the suburbs. Dry snow, incidentally, is common in London in small quantities, but rarely heavy.

The January snowfall was, as Mr. Douglas implies, of the more common "altitudinal" type, moist at low levels but of blizzard-like intensity over 500 feet. His estimate that the drifts on the higher hills of SW England and of Wales would last into February was, however, much too conservative. Even here at Hampstead old lumps were still to be seen as late as February 8th, and Mr. Hawke tells me that in parts of the Chilterns where the storm was extremely severe some of the drifts are fairly sure to linger into March.

L. C. W. BONACINA.

13, Christchurch Hill, Hampstead, N.W.3.
February 26th, 1939.

An Anomaly in Atmospheric Electricity

It is well known that in all parts of the world potential gradient is, in fine weather, nearly always positive, i.e., potential increases with increasing height above the ground. On the other hand in periods of rain the gradient is more often negative than positive. In countries where dust storms prevail, it is observed that the storms are frequently accompanied by negative gradient.

At Kew Observatory potential gradient has been recorded almost continuously since 1861, when the first of W. Thomson's electrographs was set up. Little is known about the frequency of negative gradient in the earlier years, but from 1911 onwards all the electrograms have been scrutinised with a view to the detection of periods in which negative gradient occurred. Until 1933 it was regarded as almost an invariable rule that negative gradient occurred only with precipitation at the station, or at any rate threatening, but from November 1933 onwards it was noticed that spells of negative gradient were apt to occur in fine weather, especially with the wind in the north.

As the anomaly persisted an effort was made to ascertain whether it was spread over a considerable area in London. For this purpose Benndorf electrographs were operated at South Kensington and Kingsway for several months in 1934 and 1935. The result was that, although negative gradient in fine weather continued to be recorded at Kew Observatory, it never occurred at either of the other stations, whatever the direction of the wind. Thus it seemed likely that the effect originated at some place not very far north of the observatory.

A hopeful suggestion was that the source was at the Brentford gasworks, about a mile away in about the right direction. To check this idea a Benndorf electrograph was set up, by kind permission of the Director of the Royal Gardens, in his office by Kew Green. During the following months it was found that anomalous negative gradient occurred rather more frequently at the Royal Gardens than at the Observatory and with the wind from the same quarters. As the gasworks are to the west of the office, and negative gradient occurred with N-E wind, it became clear that the anomaly did not originate in the gasworks.

At this stage a new line of attack was developed, an electrometer was mounted in a motor car so that on any suitable occasions the area affected could be mapped out.

On Saturday, May 7th 1938, Mr. E. Boxall and I found that the area extended to the north of Gunnersbury

Park, about three miles from the observatory and on the far side of the gasworks. Between two observations the gradient changed sign, and subsequent examination of the observatory electrogram suggested that this was not because we had run out of the affected area but because the anomaly had faded out.

Success in identifying the source of the negative ionization seemed to be assured but, strangely enough, the frequency of the phenomenon was to fall off rapidly. In the last four months, November 1938 to February 1939, the only occasion on which there has been negative gradient at the observatory in circumstances unfavourable for precipitation was during a fog on 3rd February 1939.

Thus it appears that somewhere north of Brentford some installation began to discharge negative ions into the atmosphere in 1933, continued to do so until the middle of 1938, and stopped entirely in October. I should be very glad to hear from anyone who knows of a factory to which this statement could possibly apply.

F. J. W. WHIPPLE.

Kew Observatory, Richmond.
March 2nd, 1939.

The Film as a Meteorological Instrument

My attention has been drawn to the article on page 2 of the February issue of your widely and happily refurbished journal. No one who has read Sir Napier Shaw's plea for the collaboration of the photographer, and especially of the cine-photographer, in his " Manual of Meteorology ", and in his more popular " Drama of the Weather ", could fail to realise how much could be done if only someone would tell them what to do and how to do it. The words I like best in that article occur on page 6 and are " . . . the ideas it is desired to convey must first be simplified so as to be readily assimilable . ." If further work is to be done, and if that work is to induce the growth of interest and knowledge, then simplicity must be the keynote. There are now hundreds of skilled and observant cine-photographers, most of whom live abroad in places where many of the difficulties suggested do not occur, largely because almost everyone has slightly more cash, always possesses a good car and lives in places where there are no obstructions to rapid transport in any direction, and have many more opportunities of air-flight with freedom to use cameras. Most of these men would welcome some primary education on weather processes, but first of all they must be taught what to look at, how to recognise it, and what to select. This involves some very patient work, but it must be done before long if, at first, better educational films are to be made and, if later, the cinematograph is to be used for routine observation and record. One of the first necessities is a course in perspective, in order that any particular process or cloud-form is recognisable from below (the ground), above (the air) or from any angle and at any distance. Things are not always what they seem to be if the principles of perspective are unknown. Perhaps one of your readers would enlighten observers.

JOHN F. SHIPLEY.

Victoria Street, London, S.W.1.
February 25th, 1939.

An Unusual Cloud-bow

You may be interested in an account of what I believe to be a rare manifestation of a common phenomenon—a rainbow. At 15h. on Saturday, February 18th, there was a bank of alto-cumulus, spread across the sky in the form of a band from NW to N. Superimposed on this cloud was a faint white arch, similar in curvature to a rainbow and in the position with regard to the sun in which one would expect a rainbow to be. In appearance the form of the arch was similar to that of a halo except that the upper edge was tinged with a faint pink-orange coloration and along the lower edge there was a suggestion of green. At the time, there was a thin veil of cirro-stratus obscuring the face of the sun and apart from a little more alto-cumulus, there was no other cloud type present but large cumulus and strato-cumulus had been observed earlier in the afternoon. At 15h. 20m. a sheet of strato-cumulus appeared from the west at about 3,500 feet and eclipsed the bank of alto-cumulus against which the bow was visible; the bow then disappeared. This account has been confirmed by an independent observer, a local man, but he was unable to distinguish any green colour along the lower edge. As there was a definite arch which did not follow the outline of the cloud, the phenomenon was not confused with iridescence. No precipitation occurred during the afternoon, nor was any seen in the vicinity of the station. No virga was noticed at the time. It is the first time I have seen a " rainbow " in such conditions of settled weather when there was nothing visible to the eye to account for it, and it would be rather interesting to discover if this is fairly common. On page 143 of the " Meteorological Glossary " it is stated that, " . . . with still smaller drops about ·05mm. in diameter the rainbow degenerates into a white fog bow with faint traces of colour at the edges . . . " This appears to be an apt description of what I saw.

C. EDMUNDSON.

The Observatory, Lerwick, Shetland.
February 21st, 1939.

OBITUARY

MR. JOHN LAUGHTON, J.P., died on 25th February last. In 1897, when factor on the Eallabus Estate in Islay, Mr. Laughton began to make rainfall observations. Later at Logan House, Wigtownshire, and from 1930 at Corstorphine, Edinburgh, he maintained his records, thus assuring continuity of these observations at one place or other over a period of 42 years. The record at Corstorphine is to be continued by his daughter.

NOTES AND NEWS

Royal Meteorological Society.

The usual monthly meeting of the Society was held on Wednesday, the 15th instant, in the Society's rooms at 49, Cromwell Road, South Kensington. Dr. B. A. Keen, F.R.S., President, was in the Chair.

The following papers were read and discussed:—

A practical method of determining the visibility number V at night.—By Ernest Gold, M.A., D.S.O., F.R.S.

The paper contains an account of a method of ascertaining the visibility number V of the International Scale of Visibility from observations of light at fixed distances smaller than the actual distance of visibility. The method depends on the use of a meter with a filter in which the obscuring power varies continuously from zero to a value large enough to obscure the selected lights when the atmosphere is clear. The construction of the meter and its method of use are described. A unit of obscuring power is defined such that 100 units reduce the intensity of light to 1/1000th part of its incident value. This unit is of a convenient practical size for use in the graduation of the meter. In view of its utility the name "nebule" is proposed for this unit.

The paper also contains an account of a method of estimating the distance of "sure" visibility of lights of different candle-powers at different distances in conditions of atmospheric turbidity corresponding with the different numbers of the standard scale of visibility, and suggestions for the construction of a more logical scale of visibility than the existing International Scale.

The diurnal variation of wind over tropical Africa.—By J. S. Farquharson, M.A.

In the Central Sudan, wind speed decreases from morning to mid-day. Upper wind observations made twice daily at Khartoum during 1935 and 1936 provided data for the investigation of this unusual type of variation. It is shown that this diurnal variation is typical of a wide belt of tropical Africa and, based on upper air temperature observations at Khartoum, the suggestion is made that it is due to the mid-day rise in temperature within the region of the thermal equator being less than that in regions north and south of it, at the height of the geostrophic wind level.

Mr. F. J. Scrase.

Mr. F. J. Scrase, M.A., B.Sc., has been approved for the degree of doctor of science by the Senate of the University of Cambridge.

Auroral Notes for February, 1939.

Reports received indicate that the finest displays, those on the nights of the 6th and 24th, were more clearly observed in the southern and midland counties of England than in the northern half of Great Britain. Persistently cloudy conditions over Scotland, especially in the far north, made observations difficult and frequently impossible throughout the north.

The display on the 6th was observed by Mr. J. M. Brierley at South Petherton, Somerset, at 18h. 45m. as a greenish white glow along the northern horizon. Ten minutes later rose-coloured streamers, like many coloured searchlights, stretched from the horizon to an altitude of about 40 degrees. These gradually faded until at 19h. 15m. nothing remained. A short-lived but quite remarkable display was also seen about the same time at Peterborough. Mr. G. E. J. Alcock noted that at 18h. 53m. the greenish perpendicular streamers began to fade rapidly and very soon only a luminous cloud remained low in the north-west. Aurora was seen on the night of the 23rd as far south as Holyhead.

Owing to the passage of clouds, the aurora on the 24th was only faintly seen at Lerwick Observatory. At Edinburgh conditions were rather better and Mr. J. Paton secured a photograph of an auroral corona, from which it was possible to make some measurements. Further south conditions were almost perfect. Mr. R. Forbes-Bentley of Holyhead described the display as "exceptionally brilliant". Detailed accounts have been received from Mr. S. E. Ashmore of Wrexham, Mr. Frank Edwards of Greave, Cheshire, and Mr. J. Tutton of Kingswood School, Bath. At Greave the phenomenon was observed from 19h. 15m. until 21h. 30m. Low cloud interfered with observation from about 20h. to 20h. 30m. but later the sky became almost cloudless with a well-marked arch of light with its apex due north and occasional "drapery" effects. Faint pencils of light were detected running from the arch almost to the zenith and about 21h. one bright patch was seen to eastward. At Bath the most striking phase was at 20h. 5m. when a greenish curtain of light appeared in the north-east sky running approximately from north to east. It was about 20 degrees above the horizon and was slowly quivering. There was a long white ray from the western sky which merged into the luminous arc in the northern sky. Other nights on which aurora was seen from Lerwick Observatory were February 7th, 9th, 13th, 15th, 16th, 17th, 19th and 25th, but meteorological conditions were mostly rather unfavourable for observation. The display of 25th included a double homogeneous arc and later a rayed arc.

H. E. CARTER.

The aurora was first observed at Leuchars at 18h. 30m. on February 24th, 1939.

At 18h. 30m. a faint diffused glow with a distinct reddish coloration was observed to the north. It extended upwards to an elevation of about 60°. The elevation quickly increased until the red curtain which formed was almost overhead. From this curtain white rays extended downwards to an elevation of 10°, where a white, sharply defined arc formed. This formation took about an hour to develop.

At 19h. 30m. the curtain faded and was replaced by white rays which formed an almost complete corona overhead. From this, short rays spread southwards to an elevation of approximately 80°. This formation, with only minor changes in structure, lasted till 21h. 15m. At 21h. the rays became crimson in the west. The corona quickly faded, and at 21h. 20m., parallel rays of a very pale green extended in an east-to-west direction at elevations ranging from 15° to 85°.

No major changes were observed until, at 22h., a layer of strato-cumulus at 5,000 ft., which had been rapidly approaching from the west, temporarily prevented observations. At 22h. 30m., white flickering waves stretching across the sky in an east-west direction and moving rapidly towards the zenith, were observed through a break in the cloud layer. At 22h. 50m. the cloud layer again covered the sky, and observations were abandoned. All measurements are approximate owing to the rapid change of form and the diffused nature of the aurora.

D. K. G. HAMILTON.
A. SIMPSON.

The Great Aurora Borealis of 1716.

The auroral phenomena seen on March 6th, 1716, seem to have been the most magnificent of which there is any record. Several pamphlets soon made their appearance with accounts of the display as seen in various parts of the country. The most informative of these is that by William Whiston entitled " An Account of a Surprizing Meteor seen in the Air, March the 6th, 1715/16, at Night ". After detailing his own observations he gives a series of extracts from a large number of letters he had received with accounts of this brilliant phenomenon from Edinburgh, Watford, Oxford, Grantham, King's Lynn, Salisbury, Wakefield, Lewes, and many other parts of the country. Other learned men gave accounts of the aurora, notably Edmond Halley and Roger Cotes, whose contributions will be found in the Philosophical Transactions of the Royal Society for 1716.

It is difficult to give a summary of these accounts but all the various ways in which the aurora borealis can appear seem to have been present in great splendour. Curtains, streamers, rays, coronæ were all reported and the display, which was continually changing with rapidity, filled the whole northern sky from east to west and, according to some reports, it extended beyond the zenith into the southern sky. The predominating colour was red. All observers agree as to the unprecedented magnificence of the display.

The aurora was not confined to this country but was widely seen on the Continent, especially in Scandinavia.

C. E. BRITTON.

The Thames Floods of 1774.

No month can be said to be especially productive of great floods but those of March, 1774 in the Thames valley were certainly the most notable of the eighteenth century. They were at peak level on the 12th after very heavy rains over the Thames basin.

At Kingston the flood water reached the Town Hall, undermined the Church and did damage in the grave-yard. The waters also entered the church at Teddington and rose in the building to a considerable height. The bridge at Henley was washed away. At a number of places the water rose to record levels and marks were made to commemorate the event. At Eton College Buttery the level of this flood was not surpassed by the great inundation of November 1894. There is also a commemoration mark at the Old Ferry House, Hampton, which was not reached by the 1894 floods.

Coaches from the west country were unable to reach London and had to terminate their journeys at Slough or Staines. At Chesham and Amersham there were boats in the streets, the water having reached a level at least 12 inches above that of any previous recorded flood. No later inundation seems to have approached the 1774 floods in magnitude until those of November, 1894.

C. E. BRITTON.

Meteorological Office, Shoeburyness.

The staff of the Meteorological Office, Shoeburyness, held their Eighteenth Annual Dinner at the Palace Hotel, Southend, on February 11th. The guests of the staff were Mr. J. S. Dines, the Superintendent for Army Services, and Colonel F. N. C. Rossiter, Superintendent of Experiments, Shoeburyness. In the absence of the Meteorologist in Charge (Mr. C. E. Britton) the chair on this occasion was taken by Dr. J. Pepper, a former member of the Shoeburyness staff. After the usual toasts, an entertainment was provided by present and past members of the staff.

Sunshine, February, 1939.

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

	Total hrs.	Diff. from average hrs.		Total hrs.	Diff. from average hrs.
Stornoway ..	39	−16	Chester ..	82	+20
Aberdeen ..	65	− 5	Ross-on-Wye	87	+18
Dublin ..	60	−15	Falmouth ..	78	− 2
Birr Castle ..	52	−14	Gorleston ..	107	+32
Valentia ..	44	−22	Kew.. ..	105	+44

Kew temperature, mean, 43·1° F. : diff. from average, +2·0° F.

Note: In the January table (*see* page 27) the values for Dublin and Birr Castle were transposed owing to the non-receipt of the data from the former station.

OFFICIAL PUBLICATION

The Monthly Weather Report, 1939.

With the issue for January 1939 some changes are made in the Monthly Weather Report. Owing to the great and increasing interest in meteorology in this country, the number of climatological stations continues to grow. It is naturally desirable to publish in the Report records from all stations which conform to scientific standards of observation, except where they are practically adjacent to one another so no useful public purpose would be served by so doing. The decision to print all representative records has resulted in an increase of 57 stations. Records from 6 former stations are no longer available so that the net increase is 51. The increase has necessitated the addition of two more pages of tables.

The opportunity has been taken to simplify production by reproducing the two pages of maps by a similar process to that used for the tables. The maps therefore appear in black and white instead of in various shades of blue. Reference in Table III is facilitated by printing the names of the major geographical divisions in heavy type and by leaving spaces so that the row of figures appropriate to any station can be more conveniently followed.

REVIEW

Daily variations of temperature and pressure at different levels over Agra associated with passage of western disturbances. By S. P. Venkiteshwaran, Simla. Ind. Met. Dept., Sc. Notes, VII, 73, 1937.

From approximately the beginning of December until early April the weather in the extreme north-west of India undergoes, at intervals, marked variations. It becomes unsettled, then fair; there is occasional rain or drizzle—then showers with bright intervals; temperature leaps above normal and then falls considerably below. In fact, one is reminded, pleasantly or otherwise, of the weather in England!

The India Meteorological Department connects these changes in the weather with " disturbances " rather than with " depressions ". Certainly, one rarely gets on an Indian weather map the same low-pressure system of closed isobars with intriguing kinks and curves as on a European weather map. Nevertheless, there is such a close resemblance between the weather conditions associated with a western (because it generally arrives from the west) disturbance and an extra-tropical depression that one naturally looks for a similar structure.

The writer knows from experience, however, how difficult it is to locate fronts on an Indian weather chart from surface observations alone, and how essential it is to have adequate upper air data! During recent years several officers of the India Meteorological Department have published investigations on the upper air conditions associated with the passage of western disturbances. Scientific Note No. 73 is the latest of these.

The author analyses the temperature and pressure observations obtained from five series of sounding balloon ascents when disturbances passed over or near to Agra. He finds that the rapid decrease of lapse-rate usually observed at about 12–13 kms. over Agra during the winter months is associated with a fall of temperature practically at all heights below 12 kms., a rise of temperature above this height, and a fall of pressure extending practically throughout the troposphere. Instances of an increase in the lapse-rate at about 12–13 kms. are associated with a rise of temperature at levels below about 12 kms., a fall above and a rise of pressure at all heights. From these observations the author concludes that both the decrease and the increase in lapse-rates in this region may be the result of advection over Agra of air from higher and lower latitudes respectively.

From his own experience in north-west India the writer is convinced that, in the winter months, there is frequently a replacement of relatively cold air (probably originating from the Siberian high to the north) by relatively warm air from the south or south-west, and vice-versa. The Agra observations undoubtedly confirm this, but how this replacement of one air mass by the other takes place is not yet clear. Presumably, the western disturbances are the result of instability at a surface of discontinuity. They may possess a warm sector or they may be completely occluded by the time they reach Agra—probably the latter in most cases. It is to be expected that the advection of the air masses is accompanied by upward movement or subsidence and that the changes of pressure are bound up with convergence and divergence.

It is hoped, therefore, that the author or his colleagues will be able in the near future to examine the structure of the western disturbances in greater detail. One would like to see some synoptic charts complete with fronts and the use of upper winds as well as upper air temperatures. The location of the fronts would, of course, be facilitated by means of autographic records and wet-bulb potential temperatures (or specific humidities).

R. G. Veryard.

Daily Readings at Kew Observatory, February 1939

Date.	Pressure, M.S.L. 13h.	Wind, Dir. 13h.	Force	Temp. Min.	Temp. Max.	Rel. Hum. 13h.	Rain.	Sun.	Remarks.
	mb.			°F.	°F.	%	in.	hrs.	
1	1018·7	ENE	4	35	39	80	—	0·6	
2	1021·1	ENE	4	35	39	79	—	2·3	
3	1025·4	CALM		30	34	96	—	0·0	f–F all day.
4	1028·5	SW	2	31	46	84	—	0·0	f till 3h.
5	1027·0	SSW	2	29	50	84	—	3·5	f 1h–9h & 22h–23h.
6	1026·5	S	2	32	51	83	—	7·6	f 8h–9h.
7	1023·7	S	4	33	52	58	0·04	6·9	ir_0–r 18h–24h.
8	1025·0	S	3	46	50	89	0·05	0·0	ir_0 0h–7h, 15h & 21h.
9	1022·3	WSW	3	48	53	66	0·08	3·1	r_0 1h–3h & 16h–20h.
10	1031·2	SW	3	48	56	78	—	0·0	
11	1030·7	SSW	4	50	56	77	—	4·4	
12	1019·0	WSW	6	49	54	52	trace	3·1	pr_0 15h.
13	1020·4	NW	4	39	46	65	—	3·3	
14	1035·1	SW	2	37	48	63	—	6·0	
15	1027·7	WSW	2	39	55	78	—	5·1	
16	1024·6	W	4	43	50	55	—	6·7	
17	1014·4	SW	4	33	46	75	0·02	0·8	r_0–d 20h–24h.
18	1018·2	WNW	2	39	47	62	trace	6·4	r_0 0h–1h.
19	1019·4	NW	4	42	52	55	trace	4·1	d_0 8h–9h.
20	1028·0	SW	2	32	49	71	—	7·6	f 20h–24h.
21	1018·4	S	4	29	49	63	—	7·6	
22	999·3	SSE	4	41	45	87	0·20	1·2	r_0 7h–12h & 19h–23h.
23	989·5	SW	4	39	48	54	—	7·5	
24	1006·3	NNE	3	30	47	53	trace	3·6	f 9h, pr_0 21h.
25	1007·5	SW	4	39	48	91	0·17	0·0	ir_0–r 13h–24h.
26	1010·9	WSW	3	36	48	55	trace	6·8	r_0 0h–1h.
27	1014·9	SSW	4	34	48	59	—	6·3	
28	989·4	S	5	43	50	81	0·24	0·4	ir_0–r 7h–16h.
*	1018·7	—		38	49	71	0·80	3·7	* Means or Totals.

General Rainfall for February 1939

	Per cent.
England and Wales	85
Scotland	124
Ireland	118
British Isles	100

Rainfall: February, 1939: England and Wales

Co.	Station.	In.	Per cent of Av.	Co.	Station.	In.	Per cent of Av.
Lond	Camden Square	·89	53	*War*	Birminghm, Edgbaston	1·40	83
Sur	Reigate, Wray Pk. Rd.	1·67	76	*Leics*	Thornton Reservoir	1·19	71
Kent	Tenterden, Ashenden.	1·33	68	,,	Belvoir Castle	·78	47
,,	Folkestone, I. Hospital	1·36	..	*Rut*	Ridlington	·69	42
,,	Margate, Cliftonville	1·18	86	*Lincs*	Boston, Skirbeck	·49	34
,,	Eden'bdg., Falconhurst	1·38	62	,,	Cranwell Aerodrome	·67	45
Sus	Compton, Compton Ho	1·99	75	,,	Skegness, Marine Gdns	·68	44
,,	Patching Farm	1·53	69	,,	Louth, Westgate	1·02	53
,,	Eastbourne, Wil. Sq.	1·75	79	,,	Brigg, Wrawby St.	·92	..
Hants	Ventnor, Roy.Nat.Hos.	1·62	77	*Notts*	Mansfield, Carr Bank	1·42	74
,,	Southampton, East Pk	1·30	57	*Derby*	Derby, The Arboretum	1·12	67
,,	Ovington Rectory	1·78	68	,,	Buxton, Terrace Slopes	3·97	106
,,	Sherborne St. John	1·55	71	*Ches*	Bidston Obsy	2·15	128
Herts	Royston, Therfield Rec	·61	40	*Lancs*	Manchester, Whit. Pk.	3·65	190
Bucks	Slough, Upton	·97	57	,,	Stonyhurst College	4·74	141
Oxf	Oxford, Radcliffe	1·05	64	,,	Southport, Bedford Pk	2·03	97
N'hant	Wellingboro,Swanspool	·86	53	,,	Ulverston, Poaka Beck	3·96	107
,,	Oundle	·43	..	,,	Lancaster, Greg Obsy.	2·94	102
Beds	Woburn, Exptl. Farm.	·72	49	,,	Blackpool	2·28	102
Cam	Cambridge, Bot. Gdns.	·42	33	*Yorks*	Wath-upon-Dearne	·73	45
,,	March	·51	40	,,	Wakefield,Clarence Pk.	1·25	73
Essex	Chelmsford,CountyGns	·87	59	,,	Oughtershaw Hall	8·46	..
,,	Lexden Hill House	·80	..	,,	Wetherby, Ribston H.	..	..
Suff	Haughley House	·81	..	,,	Hull, Pearson Park	·99	60
,,	Rendlesham Hall	·75	54	,,	Holme-on-Spalding	1·06	63
,,	Lowestoft Sec. School.	·93	66	,,	Felixkirk, Mt. St. John	1·52	90
,,	Bury St. Ed.,WestleyH	·93	62	,,	York, Museum	1·65	109
Norf.	Wells, Holkham Hall.	·78	53	,,	Pickering, Houndgate.	1·38	79
Wilts	Porton, W.D. Exp'lStn	1·71	86	,,	Scarborough	1·31	78
,,	Bishops Cannings	1·33	63	,,	Middlesbrough	·63	48
Dor	Weymouth, Westham.	1·99	92	,,	Baldersdale, Hury Res.	3·99	133
,,	Beaminster, East St	3·08	102	*Durh*	Ushaw College	1·02	64
,,	Shaftesbury	2·02	87	*Nor*	Newcastle, Leazes Pk.	·80	52
Devon	Plymouth, The Hoe	1·97	66	,,	Bellingham, Highgreen	2·26	89
,,	Holne, Church Pk.Cott	4·65	84	,,	Lilburn Tower Gdns	1·58	79
,,	Teignmouth, Den Gdns	1·89	71	*Cumb*	Carlisle, Scaleby Hall.	3·94	177
,,	Cullompton	1·79	64	,,	Borrowdale,Seathwaite	21·00	188
,,	Sidmouth, U.D.C.	1·39	..	,,	Thirlmere,DaleHeadH.	13·06	167
,,	Barnstaple,N. Dev.Ath	1·50	54	,,	Keswick, High Hill	8·16	165
,,	Dartm'r,Cranmere P'l	4·60	..	,,	Ravenglass, The Grove	4·64	151
,,	Okehampton, Uplands.	3·94	90	*West*	Appleby, Castle Bank.	3·01	102
Corn	Redruth, Trewirgie	2·64	70	*Mon*	Abergavenny, Larchf'd	2·55	80
,,	Penzance, MorrabGdns	2·27	68	*Glam*	Ystalyfera, Wern Ho.	7·47	145
,,	St. Austell, Trevarna	2·81	73	,,	Treherbert, Tynywaun	9·81	..
Soms	Chewton Mendip	2·70	80	,,	Cardiff, Penylan	2·84	97
,,	Long Ashton	2·28	97	*Carm*	Carmarthen,M.&P.Sc.	5·82	151
,,	Street, Millfield	1·31	67	*Card*	Aberystwyth	4·04	..
Glos	Blockley	1·60	..	*Rad*	Bir. W. W. Tyrmynydd	7·62	145
,,	Cirencester, Gwynfa	1·47	65	*Mont*	Lake Vyrnwy	7·16	158
Here	Ross-on-Wye	1·39	69	*Flint*	Sealand Aerodrome	2·55	167
,,	Kington, Lynhales	2·00	80	*Mer*	Blaenau Festiniog	11·87	160
Salop	Church Stretton	2·51	114	,,	Dolgelley, Bontddu	5·89	132
,,	Shifnal, Hatton Grange	·75	46	*Carn*	Llandudno	1·83	94
,,	Cheswardine Hall	1·54	87	,,	Snowdon, L. Llydaw 9	20·00	..
Worc	Malvern, Free Library.	1·10	61	*Ang*	Holyhead, Salt Island.	3·06	125
,,	Ombersley, Holt Lock.	·79	48	,,	Lligwy	4·27	..
War	Alcester, Ragley Hall.	·85	52	*I.Man*	Douglas, Boro' Cem.	3·45	108

Erratum: Church Stretton, January, *for* 8·04/318 *read* 6·31/249

Rainfall : February 1939 : Scotland and Ireland

Co.	Station.	In.	Per cent of Av.	Co.	Station.	In.	Per cent of Av.
Guern .	St.PeterP't.GrangeRd.	2·07	84	*R&C* .	Stornoway, C.G.Stn...	5·43	128
Wig .	Pt. William, Monreith.	3·23	105	*Suth* .	Lairg	3·56	115
,, .	New Luce School.....	4·44	116	,, .	Skerray Borgie.......	3·04	..
Kirk .	Dalry, Glendarroch...	7·11	140	,, .	Melvich.............	2·51	84
Dumf.	Eskdalemuir Obs.....	9·26	187	,, .	Loch More, Achfary..	8·03	122
Roxb .	Hawick, Wolfelee	4·43	136	*Caith* .	Wick	1·25	55
,, .	Kelso, Broomlands....	1·23	72	*Ork* .	Deerness	3·83	127
Peeb .	Stobo Castle.........	4·18	151	*Shet* .	Lerwick Observatory.	3·57	113
Berw .	Marchmont House....	1·87	90	*Cork* .	Cork, University Coll.	4·38	117
E.Lot.	North Berwick Res...	1·14	73	,, .	Roches Point, C.G.Stn.	3·59	97
Midl .	Edinburgh, Blackfd. H	1·46	88	,, .	Mallow, Waterloo	4·56	134
Lan .	Auchtyfardle	4·92	..	*Kerry*.	Valentia Observatory.	4·99	96
Ayr .	Kilmarnock, Kay Park	5·03	..	,, .	Gearhameen	11·70	131
,, .	Girvan, Pinmore	4·90	115	,, .	Bally McElligott Rec.	4·47	..
,, .	Glen Afton, Ayr San..	10·39	236	,, .	Darrynane Abbey....	3·95	85
Renf .	Glasgow, Queen's Park	6·14	209	*Wat* .	Waterford, Gortmore.	3·94	122
,, .	Greenock, Prospect H.	8·79	166	*Tip* .	Nenagh, Castle Lough.	3·40	109
Bute .	Rothesay, Ardencraig.	5·88	147	,, .	Cashel, Ballinamona..	3·82	121
,,	Dougarie Lodge......	5·57	148	*Lim* .	Foynes, Coolnanes....	2·88	90
Arg .	Loch Sunart, G'dale..	8·35	139	,, .	Limerick, Mulgrave St.	3·45	110
,,	Ardgour House	16·73	..	*Clare* .	Inagh, Mount Callan..	5·55	..
,,	Glen Etive	14·84	174	*Wexf* .	Gorey, Courtown Ho..	4·39	156
,,	Oban	8·92	..	*Wick* .	Rathnew, Clonmannon	3·09	..
,,	Poltalloch...........	6·42	149	*Carl* .	Bagnalstown FenaghH	3·51	138
,,	Inverary Castle	13·75	203	,, .	Hacketstown Rectory.	3·01	100
,,	Islay, Eallabus	4·72	113	*Leix* .	Blandsfort House	3·39	126
,, .	Mull, Benmore.......	12·70	114	*Offaly*.	Birr Castle	2·74	120
,,	Tiree	4·45	129	*Kild* .	Straffan House.......	..	..
Kinr .	Loch Leven Sluice....	3·76	133	*Dublin*	Dublin, Phoenix Park.	1·99	111
Fife .	Leuchars Aerodrome..	2·22	127	*Meath*.	Kells, Headfort......	..	..
Perth .	Loch Dhu	11·50	154	*W.M* .	Moate, Coolatore.....	2·82	..
,, .	Crieff, Strathearn Hyd.	3·73	106	,, .	Mullingar, Belvedere..	3·54	127
,, .	Blair Castle Gardens..	2·93	105	*Long* .	Castle Forbes Gdns ..	3·49	123
Angus.	Kettins School.......	2·98	127	*Gal* .	Galway, Grammar Sch.	2·63	87
,, .	Pearsie House	..	..	,, .	Ballynahinch Castle ..	5·91	115
,, .	Montrose, Sunnyside..	2·29	124	,, .	Ahascragh, Clonbrock.	3·25	105
Aber .	Balmoral Castle Gdns.	2·76	106	*Rosc* .	Strokestown, C'node..	3·27	123
,, .	Logie Coldstone Sch ..	1·78	86	*Mayo*.	Blacksod Point	6·72	166
,, .	Aberdeen Observatory.	2·60	127	,, .	Mallaranny..........	6·45	..
,, .	New Deer SchoolHouse	2·37	111	,, .	Westport House......	3·97	101
Moray	Gordon Castle	1·48	77	,, .	Delphi Lodge........	11·22	133
,, .	Grantown-on-Spey ...	..	..	*Sligo* .	Markree Castle.......	4·46	127
Nairn.	Nairn..............	1·60	89	*Cavan*.	Crossdoney, Kevit Cas.	2·78	..
Inv's .	Ben Alder Lodge.....	7·48	..	*Ferm* .	Crom Castle	3·08	105
,, .	Kingussie, The Birches	3·99	..	*Arm* .	Armagh Obsy........	2·04	92
,, .	Loch Ness, Foyers....	..	..	*Down*.	Fofanny Reservoir ...	4·35	..
,, .	Inverness, Culduthel R	2·43	108	,, .	Seaforde	2·60	85
,, .	Loch Quoich, Loan...	27·49	..	,, .	Donaghadee, C. G. Stn.	2·44	106
,, .	Glenquoich..........	19·11	185	*Antr* .	Belfast,Queen's Univ .	2·76	112
,, .	Arisaig House	7·74	156	,, .	Aldergrove Aerodrome	2·76	115
,, .	Glenleven, Corrour ...	..	..	,, .	Ballymena, Harryville.	3·94	122
,, .	Ft. William, Glasdrum	14·58	..	*Lon* .	Garvagh, Moneydig...	3·11	..
,, .	Skye, Dunvegan	9·03	..	,, .	Londonderry, Creggan.	4·76	149
,, .	Barra, Skallary	4·73	..	*Tyr* .	Omagh, Edenfel......	4·02	135
R&C.	Tain, Ardlarach......	2·11	85	*Don* .	Malin Head..........	3·85	130
,, .	Ullapool	4·65	109	,, .	Dunfanaghy	3·47	113
,, .	Achnashellach	12·36	170	,,	Dunkineely..........	3·76	..

Climatological Table for the British Empire, September 1938

STATIONS.	PRESSURE. Mean of Day M.S.L. mb.	PRESSURE. Diff. from Normal. mb.	TEMPERATURE. Absolute. Max. °F.	TEMPERATURE. Absolute. Min. °F.	TEMPERATURE. Mean Values. Max. °F.	TEMPERATURE. Mean Values. Min. °F.	TEMPERATURE. Mean Values. ½ Max. and Min. °F.	TEMPERATURE. Mean Values. Diff. from Normal. °F.	TEMPERATURE. Mean. Wet Bulb. °F.	Relative Humidity. %	Mean Cloud Am'nt 0–10	PRECIPITATION. Am'nt. in.	PRECIPITATION. Diff. from Normal. in.	PRECIPITATION. Days.	BRIGHT SUNSHINE. Hours per day.	BRIGHT SUNSHINE. Percentage of possible.
London, Kew Obsy	1016·4	− 1·0	76	42	66·2	51·3	58·8	+ 1·5	53·0	90	7·2	1·94	+ 0·07	15	4·2	33
Gibraltar	1016·4	− 0·8	78	60	74·3	63·0	68·7	− 3·7	61·6	83	3·8	1·20	—	4	—	—
Malta	1017·0	+ 0·7	83	61	78·9	70·2	74·5	− 1·5	68·3	74	4·6	2·75	+ 1·48	2	8·4	68
St. Helena	1020·0	+ 0·3	65	51	58·7	53·5	56·1	− 0·4	54·4	94	9·9	4·14	+ 1·96	23	—	—
Freetown, Sierra Leone	1013·1	+ 2·6	86	70	81·7	73·0	77·3	—	73·0	93	8·2	24·88	− 3·60	27	—	—
Lagos, Nigeria	1012·8	+ 0·6	85	68	82·3	72·7	77·5	− 1·2	74·2	88	8·5	4·55	− 1·04	19	4·0	33
Kaduna, Nigeria	1011·6	—	90	65	85·0	67·0	76·0	+ 0·1	70·1	89	8·2	10·98	− 0·52	20	6·2	51
Zomba, Nyasaland	1013·8	+ 0·2	87	52	81·2	60·0	70·6	+ 1·1	64·8	70	4·3	0·00	− 0·34	0	—	—
Salisbury, Rhodesia	1014·7	− 0·2	88	41	79·6	52·1	65·9	− 0·5	53·8	41	1·0	0·00	—	0	10·5	87
Cape Town	1019·3	+ 0·2	82	42	65·5	50·1	57·8	− 0·1	52·8	84	5·7	3·35	+ 1·11	14	—	—
Johannesburg	1016·7	+ 0·2	82	31	71·4	46·4	58·9	− 0·5	47·8	49	1·8	0·75	− 0·21	4	9·6	81
Mauritius	1020·5	+ 0·4	80	59	77·2	63·0	70·1	0·0	64·6	66	5·7	1·08	− 0·32	23	7·7	64
Calcutta, Alipore Obsy	1003·8	− 0·7	97	78	91·2	79·9	85·5	+ 2·3	80·5	87	6·8	2·21	− 7·80	5*	—	—
Bombay	1007·0	− 1·0	87	73	85·3	75·9	80·6	− 0·3	76·6	89	7·0	10·35	− 0·33	13*	—	—
Madras	1005·1	− 1·4	95	73	91·0	76·7	83·9	− 1·3	76·4	80	7·5	5·81	+ 0·96	7*	—	—
Colombo, Ceylon	1009·5	− 0·4	87	73	84·6	76·9	80·7	− 0·5	77·0	80	8·1	5·74	+ 0·98	19	5·5	45
Singapore	1009·4	− 0·4	89	72	85·6	76·3	80·9	− 0·2	77·8	81	8·6	6·29	− 0·50	19	4·6	38
Hongkong	1008·2	− 0·1	91	75	86·3	78·5	82·4	+ 1·4	77·3	78	7·1	4·27	− 5·42	14	5·2	43
Sandakan	1008·3	—	91	73	88·0	75·4	81·7	0·0	77·2	84	7·3	17·71	+ 8·38	19	—	—
Sydney, N.S.W.	1019·1	+ 3·0	81	45	67·2	51·3	59·3	+ 0·1	53·6	62	4·5	1·89	− 0·97	11	6·7	56
Melbourne	1018·5	+ 2·7	76	35	64·7	44·3	54·5	+ 0·4	49·2	61	6·9	0·73	− 1·71	9	5·5	47
Adelaide	1017·6	+ 1·6	97	42	74·8	50·4	62·6	+ 0·7	54·6	43	5·7	0·70	− 1·04	4	7·4	57
Perth, W. Australia	1017·9	− 0·1	81	45	69·2	52·6	60·9	+ 2·7	54·7	65	4·8	3·72	+ 0·30	14	7·3	61
Coolgardie	1017·4	+ 0·2	93	37	74·8	48·4	61·6	+ 2·9	53·9	60	2·4	0·27	− 0·40	3	—	—
Brisbane	1020·8	+ 3·2	87	46	73·5	53·3	63·4	− 1·8	57·3	62	3·2	0·99	− 1·01	4	8·7	73
Hobart, Tasmania	1011·9	+ 0·9	73	36	61·4	42·9	52·1	+ 1·1	46·4	64	5·6	0·91	− 1·16	9	6·4	54
Wellington, N.Z.	1017·4	+ 2·8	63	37	55·6	45·0	50·3	− 1·3	48·7	80	7·3	5·94	+ 1·97	15	4·8	41
Suva, Fiji	1014·4	+ 0·1	88	68	81·0	71·0	76·0	+ 1·5	71·7	84	8·1	15·68	+ 7·99	21	4·2	35
Apia, Samoa	1012·4	+ 0·2	86	70	84·7	73·7	79·2	+ 1·0	75·1	72	4·1	2·13	− 2·98	8	9·9	83
Kingston, Jamaica	1012·2	0·0	91	70	88·4	73·4	80·9	− 0·6	72·6	86	3·9	5·95	+ 1·92	8	8·3	68
Grenada, W.I.	1011·7	− 0·1	89	71	86	73	79·5	− 0·8	74	74	4	13·57	+ 5·58	24	—	—
Toronto	1016·2	− 1·6	82	42	67·2	50·7	58·9	− 1·4	51·7	84	5·8	3·98	+ 1·31	11	6·3	50
Winnipeg	1017·4	+ 3·6	90	28	73·3	45·4	59·3	+ 5·6	44·5	78	3·8	0·24	− 1·98	3	7·7	61
St. John, N.B.	1016·3	− 1·1	76	41	64·0	49·5	56·7	+ 0·8	51·5	85	5·4	8·26	+ 4·52	14	6·5	52
Victoria, B.C.	1017·5	+ 1·1	80	49	66·0	51·7	58·9	+ 2·8	56·5	88	5·4	1·62	− 0·19	10	6·1	48

(46926) Wt. 21/31 1250 3/39 Hw. G.377/6

THE METEOROLOGICAL MAGAZINE

M.O. 441

AIR MINISTRY : METEOROLOGICAL OFFICE

Vol. 74 | April 1939 | No. 879

CLIMATIC CHANGES

By C. E. P. Brooks, D.Sc.

Man, in his short life, rarely sees much change in his natural environment. That there have been great changes, however, the rocks themselves show, for almost everywhere the dry land was once part of the ocean floor. Likewise, within living memory changes of climate (as distinct from weather, which varies from year to year) have been barely appreciable without the aid of instruments, yet primitive man saw great ice sheets advance and retreat across England, where at still earlier periods coral reefs had fringed islands rich with sub-tropical plants.

The various periods recognised by geologists are set out in table I, which also gives their approximate ages in millions of years and brief indications of the prevailing geographical and climatic conditions. The story of the measurement of geological time is a romance in itself; the ages given here depend on determinations of the amounts of radio-active elements and their end-products —lead and helium—in lavas and similar rocks which were once molten(1).

The geological formations are divided into five unequal groups by the horizontal lines. The lowest, which includes a number of very old, altered and fragmentary formations, has a variety of names, of which "Pre-Cambrian" is the least controversial; the remaining four are known in ascending sequence as Palaeozoic, Mesozoic, Tertiary or Cenozoic, and Quaternary, the latter passing upwards into the deposits which are still in process of formation.

Age in million Years.	Formation.	Geographical Conditions.	Climate of Middle Latitudes.
	Recent ..	Mountainous, continental, volcanic.	Becoming warmer.
	Pleistocene		Glacial.
1			
	Pliocene ..		Temperate to cold.
15			
	Miocene ..	Local mountains ..	Sub-tropical.
34			
	Oligocene ..		Cooler.
50			
	Eocene ..	-Volcanic	Sub-tropical.
70			
	Cretaceous	Low ground, insular	Cooler.
110			
	Jurassic ..		Tropical to Sub-tropical.
140			
	Triassic ..		Sub-tropical.
190			
	Permian ..	Mountainous, Continental, volcanic.	Cool.
225			Glacial, mainly in southern hemisphere.
	Carboniferous		
270			
	Devonian ..	Low ground, insular	Tropical to Sub-tropical.
310			
	Silurian ..	Rather mountainous	Cooler.
340			
	Ordovician	Low ground, insular	
390			Tropical to Sub-tropical.
	Cambrian ..		
500			
		Mountainous, volcanic.	Glacial.
750	Pre-Cambrian.		
			Unknown.
1000			Glacial ?
1250			
			Unknown.
1500			
			Glacial.
1750	Oldest known rocks.		

Table. I.—Geological Formations.

The geological record shows a series of great outbreaks of mountain building, alternating with long intervals during which the earth's crust was relatively steady. In these orogenic periods the crust was thrown into great folds, both above and below the surface of the sea. The waters retired into the hollows, leaving large continents with a high average elevation above sea level. After the disturbances ceased, the ordinary processes of weathering gradually wore down the mountains and carried the detritus into the oceans, which encroached upon the land. In this way the lofty continents were broken up into large relatively low islands.

The greatest periods of mountain building have occurred at intervals of about 250 million years, at the end of the Pre-Cambrian, in the Carboniferous and Plio-Pleistocene. The last column gives an outline of the climatic changes recorded in the rocks of what are now known as the " temperate " regions. The evidence for these changes is manifold; warm periods are indicated by the remains of plants and animals whose nearest living relatives are only found in low latitudes, by minerals in salt deposits which can only form at certain temperatures, by soil types, etc. The evidence for glaciation is provided mainly by grooved rocks, far-travelled boulders, moraines and tumbled deposits of a type familiar around the ice-sheets and glaciers of to-day. In the earliest deposits the few doubtful fossils are useless as a guide, so that apart from the existence of glaciers indicated by isolated vestiges at two or three levels, we have no evidence as to climatic changes, but from the Cambrian onwards the record becomes increasingly complete and reliable. Beginning with the topmost Pre-Cambrian there have been two great oscillations, from glacial to genial and back to glacial, each of which was interrupted by one or more relatively cool but not glacial periods. From the last Ice Age we have not yet completely emerged.

Table I shows a close parallelism between geography and climate. Each of the great epochs of mountain building was accompanied by widespread glaciation, times of minor disturbance tended to be cool with local mountain glaciers, while during the quiet insular periods mild climates extended to high latitudes. The association of mountains with glaciation is readily understood; high ground with its low temperature and heavy snowfall is necessary for the development of glaciers, but this does not explain the general lowering of temperature which enables these glaciers to expand over the lowlands as great ice sheets. For this we must turn to three other factors which accompany folding of the crust. Probably most important is the formation of ridges of land connecting the continents and preventing the access of warm tropical waters to high latitudes. The effect of a land bar between Greenland and Scotland on the climate of Norway can readily be imagined and may have been one of the prime causes of the Quarternary glaciation of northern Europe. Secondly, in middle and high latitudes large land masses have a lower average temperature than islands, especially where the ground is covered by a persistent snow cover in winter, and this would aid the growth of the ice-sheets. Finally, crustal disturbance is commonly accompanied by volcanic action, and W. J. Humphreys(2) has shown that a veil of volcanic dust may be an effective agent in lowering the temperature. Conversely, the breaking up and partial submergence of the continents into large low islands means the free circulation of ocean currents from equator to poles, the absence of heavy snow and gathering grounds for glaciers, and a generally mild oceanic climate. Qualitatively the explanation is clear; elsewhere(3) I have endeavoured to show that it is also quantitatively sufficient.

There is one interesting point. At present the Arctic Ocean is mostly covered by a large sheet of floating ice. The air temperature is very low, but this is due mainly to the ice itself, and calculations show that if the ice could all be swept away, the " non-glacial " temperature would be only a few degrees below the freezing point of sea water. Of course the ice would form again, first as a small nucleus in the coldest area, and then more and more rapidly as the growing ice-sheet cooled the air around it. But if the non-glacial temperature rose above the freezing point, once the ice was swept away it could not form again. During the oceanic periods, instead of a single Gulf Stream, two or three great currents warmed the Arctic, quite sufficient to raise the temperature well above freezing. With no ice to depress the temperature, a mild climate would prevail up to the Pole itself, permitting fairly rich vegetation at least on the shores of the islands.

There is one other terrestrial factor which may have had some effect on climate, namely the constitution of the atmosphere. There are two gases which strongly absorb long-wave radiation, namely water vapour and carbon-dioxide. During mild oceanic periods the moisture content of the atmosphere would be high, and this would tend to raise the temperature still further, but would be off-set to some extent by increased cloudiness. The amount of carbon-dioxide in the air has also varied within wide limits, as was shown in G. S. Callendar's interesting article in the issue of this Magazine for March 1939, and he considers that this may have been one of the causes of climatic changes.

On the whole these purely terrestrial factors appear to give an adequate explanation of the slow changes of climate from one geological epoch to another. They do not account for the more rapid oscillations which can sometimes be recognised within the limits of a single period. Thus while the Quaternary was on the whole cold, the ice sheets and glaciers fluctuated greatly in magnitude and for at least one long interval disappeared almost completely. These fluctuations are best known from the Alps, where they are the subject of a classic work by Penck and Brückner(4). These authors recognised four glaciations, Gunz, Mindel, Riss and Wurm, the latter ending about 20,000 years ago. The Gunz-Mindel and Riss-Wurm interglacial periods were relatively short, but the Mindel-Riss lasted for about 240,000 years. Similar advances and retreats have been recognised in other parts of the world, and they have been the subject of many theories. Sir George Simpson(5) attributes them to cyclic changes of solar radiation, the balance between accumulation and ablation of snow being so delicately adjusted that glaciation occurs at intermediate stages. At the maxima of radiation precipitation is heavy but temperature is too high for ice sheets to exist, while at the minima, temperature is low but snowfall is insufficient. This theory is supported by the evidence for great pluvial periods in equatorial regions. Milankovitch(6) relates the advances and retreats of the glaciers to variations in the obliquity of the ecliptic and the eccentricity of the earth's orbit, combined with the precession of the equinoxes. With certain assumptions the changes of summer radiation resulting from these astronomical variables do resemble the advances and retreats of the ice. In earlier geological periods certain rocks which are made up of annual layers of sediment seem to show the effect of the precession of the equinoxes very clearly(7). The same rocks also show the eleven-year sunspot cycle and possibly other solar periodicities but nothing of the length required by Simpson's theory.

There was one remarkable occurrence which seems to violate all orthodox meteorology. The Carboniferous Period takes its name from the great beds of coal which characterise it in the northern hemisphere, and which bear the aspect of a rich tropical vegetation. Yet in low southern latitudes in Australia, Africa and America and even across the equator in India, great ice sheets co-existed with the northern forests. It is hard to escape from the inference that in the Carboniferous the equator did traverse Europe and North America while the southern continents were grouped around the South Pole. A mere shifting of the earth's axis will not suffice, the continents must be crowded together, beginning by fitting South America into the bight of Africa. That is the theory of the late A. Wegener (8, 9) who developed it with great ingenuity, moving his continents like pieces on a chess-board to cover all the major climatic changes which earlier in this article were associated with geographical conditions. If Wegener is right, other theories are redundant, but there are many difficulties, which are discussed at length of H. Jeffreys(10).

With so many conflicting opinions it may be asked if the climatic changes of the last few thousand years in northern Europe, for which all the factors are known with some exactitude, do not give a casting vote. The answer is, unfortunately, no. After the retreat of the ice there followed first a period of continental climate, with hot summers and cold winters, then a more equable period of warmth, the "Climatic Optimum", and finally a return to existing conditions. The continental period fits the increased obliquity of the ecliptic about 8000 B.C., while the Climatic Optimum is claimed by Simpson in support of his solar theory but can also be interpreted as the result of an enlarged Baltic, open to the warm waters of the North Atlantic. The rise of temperature in recent years is, according to Callendar, the result of human activity in adding millions of tons of carbon-dioxide to the air. Finally, determinations of longitude have so far failed to decide whether or not the continents are drifting. The problem of climatic changes is still unsolved.

BIBLIOGRAPHY

(1) Holmes, A. "The age of the earth", 2nd Ed. *London* (*Nelson*), 1937.
(2) Humphreys, W. J. "Volcanic dust and other factors in the production of climatic changes and their possible relation to ice-ages". *Philadelphia, J. Frankl. Inst.*, 176, 1913, p. 131.
(3) Brooks, C. E. P. "Climate through the ages. A study of the climatic factors and their variations". *London* (*Benn*), 1926.
(4) Penck, A. und E. Brückner. "Die Alpen im Eiszeitalter". *Bd. I–III. Leipzig* (*Tauchnitz*), 1909.
(5) Simpson, Sir G. "World climate during the Quaternary period". *London, Q.J.R. Meteor. Soc.*, 60, 1934, p. 425.
(6) Milankovitch, M. "Mathematische Klimalehre und astronomische Theorie der Klimaschwankungen. Handb. der Klimatologie, Bd. I. Teil. A.". *Berlin* (*Borntraeger*), 1930.
(7) "Some American papers and notes on climatic variations". *Milton, Mass., Bull. Amer. Met. Soc.*, 19, 1938, pp. 161–224.
(8) Wegener, A. "The origin of continents and oceans". *London* (*Methuen*), 1924.
(9) Köppen, W. und A. Wegener. "Die Klimate der geologischen Vorzeit". *Berlin* (*Borntraeger*), 1924.
(10) Jeffreys, H. "The earth: its origin, history and physical constitution". 2nd Ed. *London* (*C.U.P.*), 1929.

FOREST FIRES IN AMERICA AND THEIR EFFECT ON THE WEATHER

By A. H. Gordon, M.S. (Pasadena)

The North American continent is perhaps unique among the regions of the globe which are inhabited by white peoples in its ability to produce such a variety of destructive natural phenomena, nearly all of which are either an instantaneous or consequent result of a meteorological effect. Raging West Indian hurricanes,

Fig. 1. Sketch of Western North America.

whirling tornadoes, extensive floods, prolonged droughts, intense heat and cold waves, blinding blizzards and searing dust storms are all too frequent in demonstrating how ably the weather can destroy man's works and disrupt his way of living. Finally, but by no means the least of this formidable array, there is the huge forest fire, to the occurrence of which a great deal of study has been given in order that precautions may be taken and outbreaks averted or controlled in their early stages. Although the forest fire is not an atmospheric phenomenon in itself, its occurrence is very largely dependent on existing meteorological conditions in relation to the general climatology of the region. In addition the fire exerts its own rather limited influence on local weather.

Regions in which forest fires occur with any degree of regular frequency are confined mainly to the western and Rocky Mountain areas of the United States. At times of unusual dryness they also occur in the southern portion of the Canadian provinces of Alberta and British Columbia. A great deal of the western half of the United States, especially that part north of an approximate parallel 40° North Latitude, is covered with vast forests of fir, pine and redwood. South of this parallel the timber is mainly found in the more mountainous type of country. In the hilly districts of southern California there is a great deal of brush; in the dry season this makes excellent fuel upon which a conflagration may feed once it has been started by a carelessly dropped match or piece of lighted tobacco ash. Real forest fires usually do not break out unless the season has been a particularly dry one. In some seasons there may be none at all while in others they burn in hundreds throughout a vast area, ravaging thousands of square miles of land, destroying towns and villages, and driving all kinds of wild animal life before them. Brush fires are kindled with much greater ease and blaze furiously although they cover less ground and burn out more rapidly. As a rule, however, they present the greatest danger to human life and property because of the great speed with which the flames leap from bush to bush when blown by a strong and very dry wind. The unfortunate occupants of an exclusive mountain resort hotel or elaborately constructed house or cabin which may happen to be in the path of the oncoming flames frequently have no time in which to save their belongings and can only barely save their lives. Dangerous indeed is the life of the fire fighter. In the bad Griffith Park fire near Hollywood a few years ago a sudden shift of wind caused a small backfire to creep round to the rear of a score or more of men who were valiantly stemming the main outbreak. Trapped in a narrow canyon by a roaring inferno they all perished.

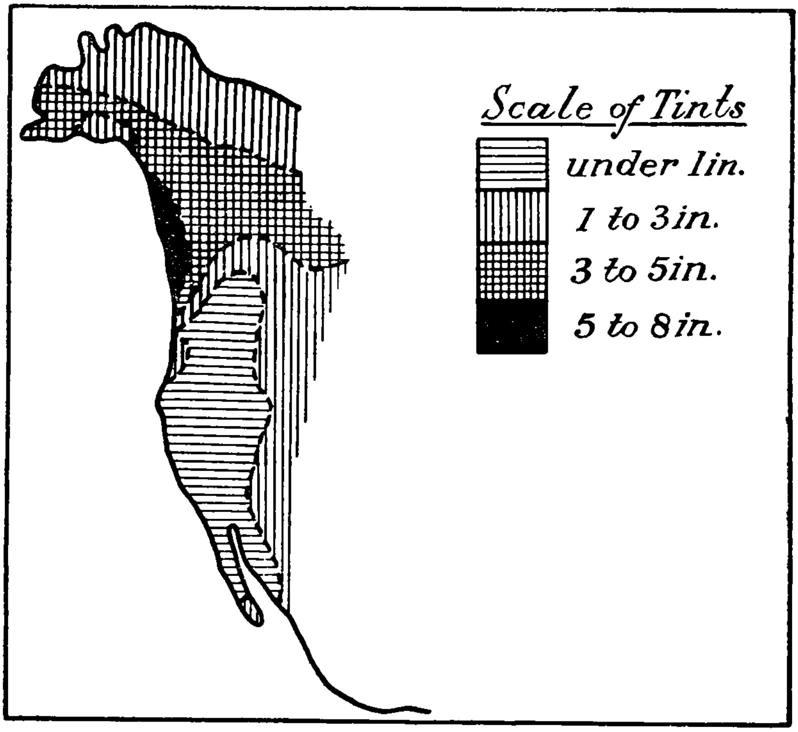


FIG. 2. COMBINED RAINFALL, JULY AND AUGUST, IN WESTERN NORTH AMERICA.

The underlying conditions which are favourable for the kindling and growth of fires in the huge timber forests are an unusually large deficit of rainfall extending back over a considerable period, coupled with high temperatures and very low desert-like humidities. The rainfall régime in those regions which possess the greatest frequency of bad type fires is distinctly seasonal in character and distribution. Along the narrow strip of country between the Pacific coastline and the coast ranges the mean annual rainfall north of the Oregon California border amounts to a total of over one hundred inches. Southwards this value diminishes rapidly to fifty inches near Cape Mendocino and then more slowly to twenty five inches at San Francisco, and to ten inches along the Mexican frontier. Of these annual totals the average combined amount for July and August is approximately two inches north of the Oregon California border, a quarter of an inch near Cape Mendocino, and nil at San Francisco. At this time of the year San Diego comes under the influence of tropical type thunderstorm rain to the extent of about a quarter of an inch. North of the 36th parallel the wider belt of valley country lying between the coast and the High Sierra ranges possesses a considerably smaller mean annual total of rainfall than the coastal strip but the monthly distribution curve is very similar. South of the 36th parallel the territory to the east of the coast ranges is mainly desert and has a very scanty rainfall. The Rocky Mountain region to the east of the High Sierras possesses a different type of rainfall regime altogether with a moderate fall of thunderstorm character in summer. However, the high temperatures and low humidities of this region are sufficient to create quite favourable conditions for the occurrence of fires.

In the Pacific northwest the forest fire hazard seldom becomes dangerous until the latter part of August. The worst period is usually in early September although it may persist until October if the early autumn rains are delayed. On days when the wind is from the interior of the continent and thus extremely dry the risk of fires is greatly enhanced and special precautions are taken by the forest rangers. It is believed that fires result from natural causes in only a very small proportion of cases and that the majority occur purely through carelessness on the part of motorists and campers. Very strict regulations have had to be issued and enforced. In the danger areas smoking and camping are only permitted in definite supervised open spaces, and if the hazard becomes particularly bad these areas are completely closed to the public. A huge organized fire prevention campaign is launched each year by the district authorities. In the cinema, in the papers, on the roads, in trams, trains and buses every individual is kept aware continually of the part that he must play in safeguarding the nation's already depleted wooded preserves; he is warned that neglect and carelessness in this respect can be a penal offence. It is fully realized that prevention is the best cure. Once an outbreak has started it rapidly spreads beyond all control and in bad years outbreaks occur in such numbers that available resources of men and material can do little to curb them.

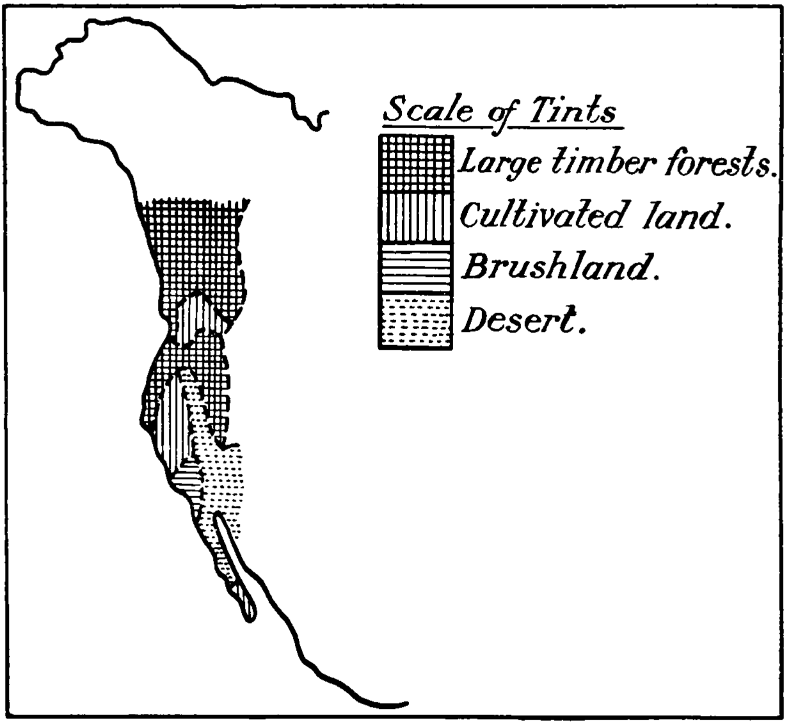
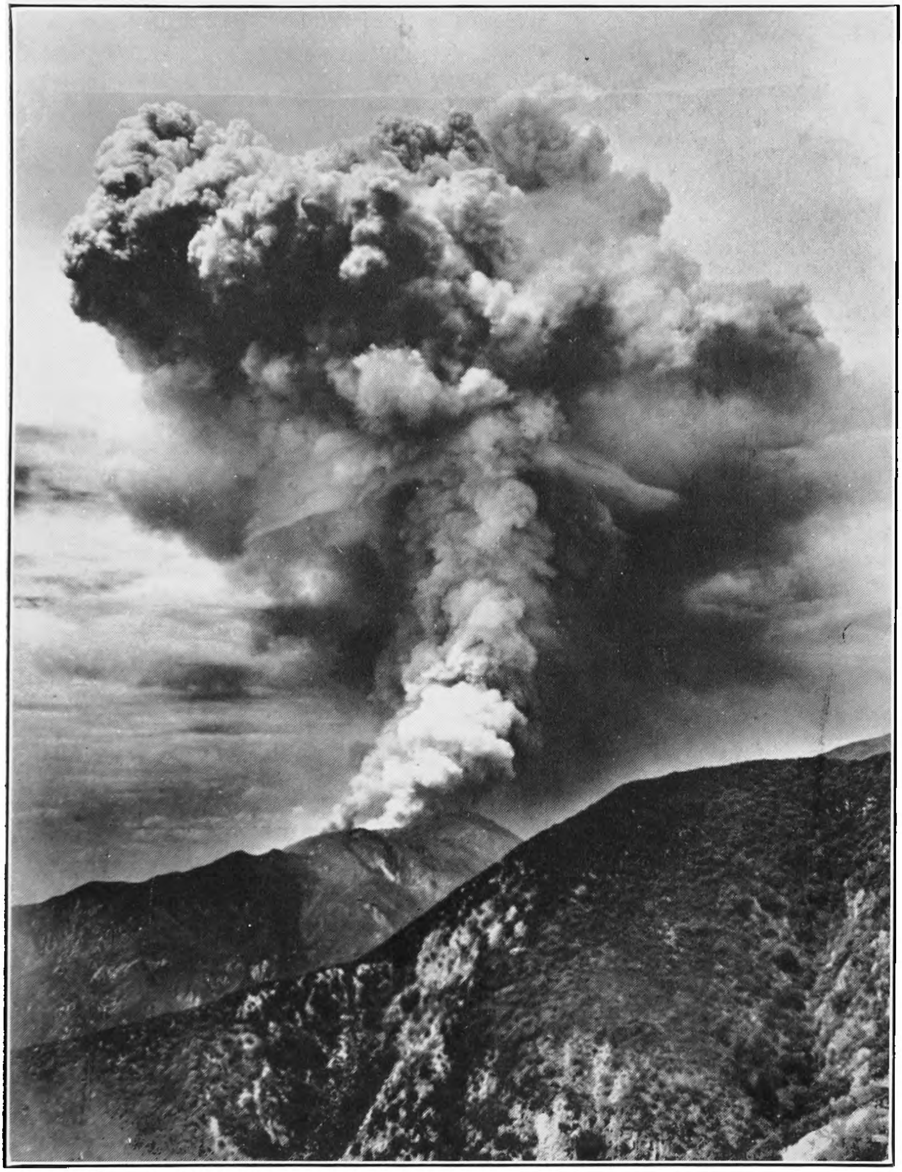


FIG. 3. TYPES OF VEGETATION IN REGIONS WHERE FOREST FIRES OCCUR.

Naturally enough the main effect of the forest fire on local weather is the deterioration of visibility. When a large area of forest land is burning a dark yellow pall of smoke covers the sky for miles around giving it an appearance very like that imparted by a November fog in London, but in place of the raw feeling of a cold and damp atmosphere there is the stuffy and enclosed sensation of a warm and very dry atmosphere. The pressure distribution which is most favourable for the



Photographer: O. H. Lawrence.

CUMULUS CLOUD FORMED BY CONVECTION OVER FIRE ON SISTER ELSIE PEAK, CALIFORNIA, SEPTEMBER 13TH, 1913.

(Reproduced from "Physics of the Air," by W. J. Humphreys, by permission of the United States Weather Bureau and of the publishers.)

development of forest fires is the presence of a subsiding anticyclone centred over the Rocky Mountain region; thus the inversion aloft forces the smoke pall to remain in the surface layers of air. At times, under the influence of several evenly distributed fires thousands of square miles become affected by the smoke haze. The visibility falls to an average value of 1,000 to 2,000 yards over the region, decreasing to almost nil to the lee of the fire. Aviation is hindered and many phases of industry are handicapped. Many roads are closed to all but those who are engaged in combating the flames. Extensive inhabited areas become isolated and wholesale evacuations of towns are ordered. Ashes and cinders fall continuously and cover everything with a coat of dust and dirt. In recent years the city of Portland, Oregon, has suffered particularly from this last-mentioned inconvenience. When such conditions exist throughout a large area very little can be done to remedy the situation. Even though the actual flames may be extinguished, red hot glowing embers will last for days, and the most exhaustive vigilance must be kept to prevent sparks from catching alight the nearby undergrowth until a break in the dry weather spell eases the tinder-dry state of the vegetation. In the autumn, especially along the coastal plains, the rains may begin at any time and greatly reduce or entirely eliminate the existing hazard, but if it should be midsummer the position is a most unfortunate one. Thunder showers in the interior are a great help in dampening the ground and increasing the humidities, but they are rather infrequent in occurrence and as a rule extremely local in character. Thunder and lightning often develop with little or no fall of rain and in cases such as these the discharge to earth is quite an important agent in starting a fire in the first place. Moreover, a fire often has been observed to create its own convective cloud. If there is a tendency towards instability, trigger action caused by the tremendous local heating effect may be responsible for the occurrence of a shower or thunderstorm. Thus it is quite conceivable that a forest fire may be the initial cause in putting itself out!

In contrast to the slow burning timber fires of the north, the brush fires of the southland coastal regions are of relatively short duration and create little smoke nuisance. The worst type of fire usually occurs in November or December in a year when the winter rains are late in arriving, and five or six months of high temperatures and almost absolute drought have extracted almost every available drop of moisture from plant growth. Conditions in summer are not so favourable for the starting of fires also because the humidities are higher at that season of the year. The Pacific anticyclone creates a prevailing northwest wind along the coastal plain and the consequent welling up of cold sea water forms a permanent low level inversion. The surface layer of air offshore is thus a cool foggy one which drifts inland becoming warmer and drier as it does so. In the early hours of the morning the low cloud layer occasionally extends fifty or sixty miles inland, but it dissipates rapidly under the sun's rays.

In November the mean pressure distribution has changed entirely. The oceanic "high" has moved far southwards and the Aleutian "low" has intensified greatly. A Polar type anticyclone has developed over the western interior plateau. At times this Polar Basin "high", as it is called, builds up very rapidly and creates a steep gradient between the plateau and the coastal plain. The cold dry air is forced down the mountain slopes and attains gale force upon reaching the valleys. This wind is known as the Santa Ana and it frequently does a great deal of damage. Its worst effect is not found in structural injury, but in the loss of crops caused by the searing heat and great dryness of the dust-laden air. It has a most uncomfortable and depressing effect upon human beings and in this respect is very similar to the Scirocco of the Mediterranean. The abrupt mountain descent has been known to give midnight temperatures of over 80° F. in midwinter. This amounts to an adiabatic increase of temperature of some 40° to 50° F. The relative humidity in the Santa Ana is usually between 5 per cent. and 15 per cent. A very recent example of most unusual adiabatic heating occurred during the second week of December, 1938, when all temperature records for the month in Los Angeles were broken. A five day spell brought a mean maximum of 88° F. and the mercury on one day touched 92° F!

Under this type of weather a fire can almost start by itself! The only way to check a bad conflagration in these conditions once it has become out of control is to attempt to confine it to a limited space by means of making, and carefully guarding, wide and extensive fire breaks. To use water, of which there is probably none within miles anyway, is as unpractical as to try and put the sun out. The heat is intense and is felt for miles around. At night the fire is a stupendous sight; it can be seen for 50 or 60 miles and at times possesses a 20 or 30 mile front itself. It appears to resemble some titanic firework display and but for the constant reminder that it is really a terrible catastrophe it is a most thrilling sight to watch. Crowds of cars turn out with the purpose of approaching the flames as near as possible; the traffic problem alone is a serious matter with which to contend. The dangerous areas, however, are rapidly closed to the public. The immediate vicinity of the fire is particularly unsafe because of the violent turbulent currents generated by the huge lapse rate. Excellent examples of tornadoes can be seen twisting their way over the burning brush, sucking up flaming embers and casting them away.

One of the most essential phases of the work of the U.S. Weather Bureau is the information and advice given out to the forest rangers as to the advisability of opening or closing to the public various wooded natural preserves. When weather conditions become unusually warm and dry, a detailed section of its daily forecasts is devoted to the issuance of a fire hazard warning. It is just one more way in which the science of meteorology as a whole, and the art of weather forecasting in particular, are becoming of invaluable aid in a practical way to the progress of social life and civilization in our present-day world.

PROFESSOR GUSTAV HELLMANN

3rd July, 1854–12th February, 1939.

The death of Professor Gustav Hellmann in his 85th year closed a long life of devotion to the science of meteorology in general, and to the study of rainfall distribution in particular. Unlike most of the leaders in nineteenth century meteorology, Gustav Hellmann was a meteorologist from the first, resembling in this respect his English friend George James Symons. After taking his degree at the University of Göttingen he obtained an appointment in the Prussian meteorological service and worked his way steadily upwards, until on the death of Professor von Bezold, in 1907, he succeeded as Director of the Prussian Meteorological Institute. At the same time he became Professor of Meteorology in the University of Berlin. He was a member of the International Meteorological Committee from 1903 until the War put a stop for a time to its activities, and he acted as Secretary for seven years. During that time he collaborated with Professor Hildebrandsson of Upsala in compiling the important International Meteorological Codex, and at the meetings of the Committee his remarkable knowledge of languages enabled him to maintain easy communication with members from every country.

The work of the Prussian Meteorological Institute differed from that of the British Meteorological Office in being confined to the equipment and supervision of observing stations and to the climatological treatment of the results. The department dealing with rainfall was that in which he took most interest and pleasure and he was in close correspondence with Symons on the problems involved in deciding on the best form of raingauge and on the distribution of stations. Each took many hints from the other although they did not agree as to a uniform system applicable to both countries. Hellmann made experiments which led him to adopt the plan of placing the raingauge on a post with its rim one metre above the ground, while Symons saw good reasons for making one foot the standard height in the British Isles. Hellmann, with the command of State funds and a rigid system of inspection, had satisfaction in a fixed number of observing stations set out singly at equal distances, while Symons, who had to depend on voluntary observers, strove to increase the number of gauges even in crowded areas, and in thin areas preferred not single gauges, but groups of several (a mile or so apart) the intervals between groups being as uniform as possible. I have had many discussions with Professor Hellmann on the relative advantages and drawbacks of the two systems.

Professor Hellmann recognized that climatology depended as much on geography as on meteorology and it was natural that he should have served for many years as President of the Berlin Geographical Society, and have been an Honorary Member both of the Royal Meteorological and the Royal Geographical Societies in London.

Hellmann's most important published work on rainfall was the fine series of average rainfall maps of the provinces of North Germany, with the accompanying memoir on the rainfall of the river basins concerned, entitled " Die Niederschläge in den Norddeutschen Stromgebieten ", published in 1906. Another very valuable research, in which he was assisted by Dr. G. v. Elsner, was a consequence of the serious flooding in the German plains in 1903, which was also the wettest year in this country. By means of close mapping of the rainfall for individual days in comparison with maps of barometric pressure and temperature, he investigated the causes of the floods of the Oder valley and deduced a method of flood warnings sufficiently in advance of the rise of the water-level to allow precautions to be taken by persons in danger. A large volume entitled " Meteorologisches Untersuchungen über die Sommerhochwasser der Oder ", and an Atlas of charts was published in 1911.

Professor Hellmann represented German meteorologists at the Jubilee of the Royal Meteorological

Society in 1900 and in 1908 he delighted the Society with his lecture on The Dawn of Meteorology, for he had made a special study of the early history of the science of the air which he pursued as a hobby closely related to his professional work but different enough to serve as relaxation.

Professor Hellmann was a pleasant companion with wide sympathies and courteous manners. The hospitality he and his charming wife dispensed in their Berlin flat remains one of my pleasantest memories of that city. Nor was he less agreeable as a guest when staying in this country with the friends he liked.

HUGH ROBERT MILL.

LIGHT SOURCES FOR PILOT BALLOONS

The following points of interest are taken from an article " On Pilot Balloons and Sources of Light for High Altitude Upper-wind Observations," by W. H. Wenstrom in the *Monthly Weather Review,* September, 1937, p. 326.

Experiments with 16-in. balloons (weight 3½ oz.) inflated to a free lift of 40 oz. showed that, if a weight up to 10 oz. was hung by a string 50 ft. below the balloon the rate of ascent not only was not reduced, but became more uniform with height. With a 5-oz. weight the rate was actually increased, probably owing to a reduction of oscillation and to the improved stream-line shape of the balloon.

As regards light sources, it was found that a 2·3-volt 0·25-amp electric bulb with two 1·5-volt dry cells gave about the same range as a single candle in a paper lantern, both being visible at distances of 3 to 6 miles. These were used with 6-in. balloons. This does not accord with British experience, where it has been found that a considerably more powerful electric bulb is necessary to give results equal to those given by the candle. For 16-in. balloons various sources of light were tried, viz. candles, electric lamps, acetylene and pyrotechnic flares. A paper lantern with four candles was found to be visible two or three times as far as the single candle, i.e. 8 to 15 miles. The candles were fixed in holes in a piece of plywood.

Six candles gave slightly better performance than four, but an 8-candle lantern caught fire too easily and was not successful. There seems, however, no reason why any number of candles should not be used provided the lantern were big enough, but the number is limited by the burning time required and the weight allowable.

Another arrangement consisted of four short and four long candles. The long candles were lit first, the short ones lighting from them after about 20 minutes. This was only tested on the ground, but it was considered promising. An 8-volt electric bulb with six 1·5-volt dry cells gave a good light at first, but the efficiency fell off quickly and the range was rather less than that of the 4-candle lantern. Electric lamps suffer from the disadvantages of high cost, weight, diminishing candle-power and danger to objects on the ground when they fall.

An acetylene burner gave a brilliant light, but tended to blow out when the rate of ascent was as great as 1,200 ft./min. This was, however, considered to be worth further experiment; it has the advantage of cheapness and lightness. The acetylene was contained in a small balloon attached to the main balloon. The best light of all was given by a red pyrotechnic flare. Starting from small standard flares used by the United States railways, various modifications were made with a view to prolonging the burning time and securing that the candle-power should increase as the flare burned away. Considerable progress was made, but complete reliability was not attained. The flares tended to go out at about 10,000 ft., possibly through deficiency of oxygen. A safety balloon was necessary to prevent the burning flare from dropping to the ground if the main balloon burst prematurely.

D. N. HARRISON.

LETTERS TO THE EDITOR

A Fine Sun-pillar, March 8th, 1939

On March 8th, 1939, at Gausdal* in the Gudbrandsdal district of Central Norway I watched the sun go down in an almost cloudless sky. The moment the orb itself had disappeared, a delicate, golden pillar of considerable brightness and glitter appeared in the sky where the sun had gone down. Its width was the same as the sun's diameter, and it reached some 3° or 4° above the skyline to where it was lost in the last bright remnants of degenerating cumulus.

Mr. G. A. Clarke of Aberdeen has shown me a photograph of such a sun-pillar, with the sun itself in view shining through cirrostratus cloud. On this occasion there was no cirrostratus to be seen; but the sky was a very delicate blue, and there was no redness about the sunset. The cloud must have existed in a diffuse, nebular form: which explains the fact that the pillar certainly did not reach more than 5° above the skyline and only came into view once the sun itself was hidden. The sun had set behind a rugged mountain ridge and by going a few hundred yards further over the hill one could bring it into view again. Immediately the pillar of light vanished, but reappeared once the sun was hidden again.

I cannot say how long the phenomenon lasted altogether, as it was unfortunately obscured after five or six minutes by the one remaining patch of low cloud. The time was about 16h. 45m. G.M.T., and the general weather conditions were outstandingly clear with a northerly wind current and a light frost over the snow-covered landscape.

H. H. Lamb.

Meteorological Office, Donibristle, Fife.
March 20th, 1939.

---

* Gausdal is 61.3° N., 10° E.

A Lunar Halo Observed on February 28th, 1939

On Tuesday February 28th, 1939, at 19h. G.M.T., there was a lunar halo in the form of a white ring of 22°. This lasted for about half an hour and then the cirrus cloud dispersed. At 20h. the sky was clear except for drifting patches of strato-cumulus at about 5,000 feet. On observing that one of these patches was about to pass in front of the moon, I decided to watch its passage across it.

Firstly a normal corona was thrown on the edges of the cloud. As the cloud passed, the corona became denser in colour, and finally when the thick portion of the cloud was passing, I observed that two coronæ were visible, one inside the other. The inner one had a diameter about three times that of the moon, and the outer one about five times that of the moon. The space between the rings was coloured pale blue nearest the inner corona, and pale green towards the outer one. The phenomenon was visible for about five minutes, and as the sky was soon clouded over, it was not observed to occur again.

D. C. MASON.

Meteorological Office, South Farnborough, Hants.
March 3rd, 1939.

NOTES AND NEWS

Retirement of Dr. F. J. W. Whipple.

Dr. F. J. W. Whipple retired on March 31st at the age of 63. He was educated at Merchant Taylors School and Trinity College, Cambridge, where he took his B.A. in 1897. In 1899 he returned to Merchant Taylors School as Assistant Master. In 1901 he received the degree of M.A. and in 1928 that of Sc.D.

In 1912 he joined the staff of the Meteorological Office as Superintendent of Instruments, subsequently taking charge in 1916 of the Statistics Division, which dealt with all climatological work, and in 1923, after the death of Mr. Carle Salter, of the British Rainfall Organization. He was promoted to Assistant Director in 1925 when he became Superintendent of Kew Observatory, a post which he held until his retirement. He was joint editor with Mr. Salter of the *Meteorological Magazine* from 1920 to 1923, and subsequently sole editor until 1925. He has also taken a large part in the work of the Royal Meteorological Society, serving as President in 1936 and 1937.

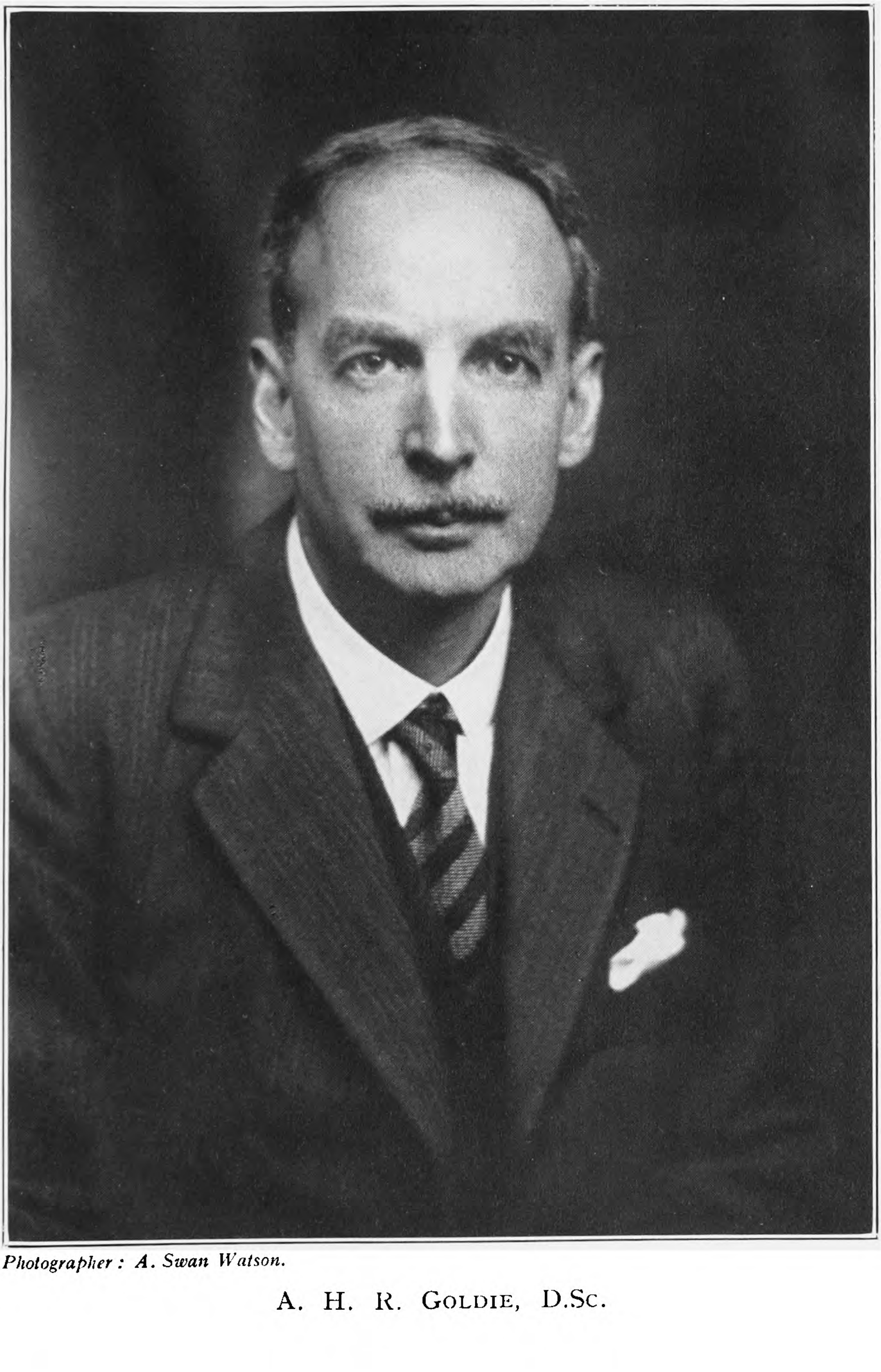
Dr. Whipple's family has been closely associated with Kew Observatory since 1854, when his grandfather, Robert Beckley, became an assistant, at first the only one. His father, G. M. Whipple, went to the Observatory in 1858 and was Superintendent from 1876 to 1883 and his brother, R. S. Whipple, who was until recently Managing Director of the Cambridge Instrument Company, was there from 1886 to 1896. It was most appropriate that Dr. F. J. W. Whipple, two of whose christian names, John and Welsh, were given in memory of the first Superintendent under whom his father and grandfather had served, should take charge of the Observatory in his turn.

Dr. Whipple's scientific interests are very wide, extending beyond meteorology over the whole domain of geophysics and he has written purely mathematical papers, mostly on the theory of series. Much of his work is connected with air waves and abnormal acoustic phenomena in the atmosphere, and in 1935 he delivered the Symons Memorial Lecture on the subject of "The propagation of sound to great distances". He is keenly interested in seismology, meteorological optics, meteors, atmospheric electricity, hygrometry and upper air investigation (he designed the pilot balloon slide-rule now in general use), and he has written, and will we hope continue to write, on almost every aspect of geophysics.

Dr. A. H. R. Goldie.

On April 1st, Dr. A. H. R. Goldie became an Assistant Director of the Meteorological Office. Dr. Goldie was born in Linlithgowshire but his early life was spent at Glenisla, Angus, a few miles from the early home of

[*Facing page 86*

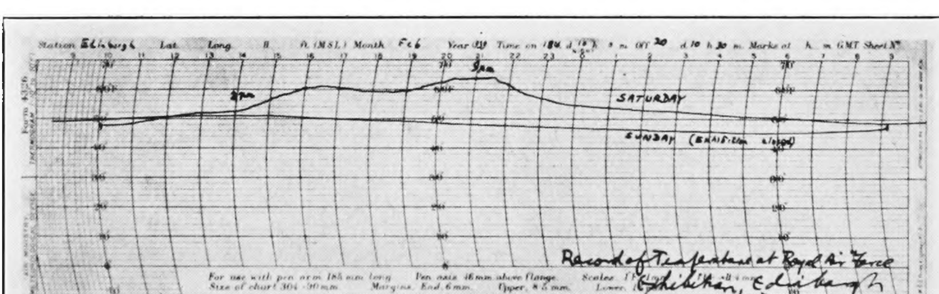


Photographer: A. Swan Watson.

A. H. R. GOLDIE, D.Sc.

Photographer: H. E. Carter.

METEOROLOGICAL OFFICE EXHIBIT AT R.A.F. AIRCRAFT EXHIBITION, FEBRUARY, 1939.



RECORD OF TEMPERATURE AT THE EXHIBITION, FEBRUARY 18th, 10H. TO FEBRUARY 20TH, 10H. 30M.

Dr. C. Chree. Dr. Goldie was educated at Harris Academy, Dundee, St. Andrew's University, where he received the degree of M.A. with first class honours in Mathematics and Natural Philosophy, and St. John's College, Cambridge, where in 1913 he was a Wrangler in Part II of the Mathematical Tripos. Dr. Goldie entered the Meteorological Office in 1913 as a Professional Assistant, serving in the Forecast Division, Falmouth Observatory and Farnborough and later as Senior Assistant at Eskdalemuir Observatory. In June, 1915 he obtained a commission in the Meteorological Section, R.E., he served in France and Italy and was twice mentioned in Despatches. After the war he became Superintendent of the Aviation Services Division until 1924, when he took charge of the Meteorological Office at Edinburgh. He was awarded the degree of D.Sc. at St. Andrew's in 1936.

Dr. Goldie's interests have been chiefly in the direction of atmospheric electricity and terrestrial magnetism—since 1936 he has been Secretary of the International Association for those subjects in the International Union for Geodesy and Geophysics—wind structure and the dynamics of depressions. His Geophysical Memoirs on the latter subject are well known as also is his revision of Abercromby's famous book on " Weather ".

Meteorology at the Royal Air Force Exhibition in Edinburgh.

A Royal Air Force Aircraft Exhibition was opened in the Waverley Market, Edinburgh, on February 14th, 1939, by the Secretary of State for Air, Sir Kingsley Wood, in the presence of a distinguished company which included the Lord Provost of Edinburgh, the Secretary of State for Scotland and senior members of the Services. The exhibition included a replica of a meteorological observing station as provided at R.A.F. and civil aerodromes with a Stevenson screen containing thermometers, a recording thermograph and a hygrograph. A Dines' tilting bucket raingauge, standard 5-inch raingauge, Campbell-Stokes sunshine recorder, Besson nephoscope, Dines' meteorograph and the latest type of pilot balloon theodolite were attractively arranged on a square of imitation turf. The new theodolite fitted with night illuminating gear attracted particular attention. In addition there were displayed a series of synoptic weather charts and diagrams illustrating official meteorological wireless services. Members of the staff of the Meteorological Office were in attendance and explained the exhibit to a constant stream of inquirers.

The exhibition remained open for 11 days during which nearly 180,000 people visited it. The mornings were reserved for those interested in the manufacture of aircraft and parts thereof. The daily influx of the general public commenced at 2 p.m., and continued until the tea hour when numbers remained almost stationary, then rose to its peak in the evenings; the effect of this was reflected exactly in the records of the thermograph. These show a characteristic diurnal variation with the principal maximum about 9 p.m. and a rapid fall after 10 p.m. when the doors of the exhibition were closed. The daily range is of the order of 15 degrees, except on the Sundays when the exhibition was closed and the traces are smooth with a range of only 3 or 4 degrees.

H. E. C.

Royal Meteorological Society.

The usual monthly meeting of the Society was held on Wednesday, the 15th instant, in the Society's rooms at 49, Cromwell Road, South Kensington. Dr. B. A. Keen, F.R.S., President, was in the Chair.

The following papers were read and discussed:—

The influence of the Dead Sea on the climate of its neighbourhood.—By D. Ashbel.

The topography of the Dead Sea is described and it is shown how the difference in depth and area betwen the northern and southern basins is reflected in the thermal relations with the surrounding land and in variations of the sea breeze, resulting in a morning maximum and mid-day minimum temperature. An account is given of the effect of the sea breeze from the Mediterranean, which reaches the Jordan valley in the afternoon as a hot, dry wind and produces a second maximum temperature. Examples are quoted of the extent in different directions of the influence of the sea breeze from the Dead Sea; and its effect on khamseen days, when the afternoon temperature maximum disappears, is discussed. Data are given in tables of wind direction and velocity, with autographic records of temperature and humidity, and brief particulars of the amount of precipitation are included.

Local climate and the growth of trees, with special reference to frost.—By W. R. Day, M.A., B.Sc.

The type of forest is largely determined by the general climate, but local climatic conditions exercise considerable influence. The natural forest in this country is composed of species, some of which are relatively hardy to frost, whereas others are, in comparison, easily injured by it. The latter species usually form the final woodland, and their successful growth is made possible by the development of favourable conditions of climate and soil within woodland formed first of all by hardy species. Examples are given to illustrate the effect of overhead and side shelter on the temperature of the air over the ground. The influence of topography on frost is also illustrated and discussed. The effect of accessory factors, such as soil fertility, local warm or cold situations, and the general suitability of the exotic species to the climate to which they are introduced are also shortly discussed in relation to the occurrence of frost injury.

High latitude ozone measurements.—By R. A. Hamilton, M.A.

Observations were made at North-East Land to determine the amount of ozone in the upper atmosphere by measuring the absorption of the ultra-violet light in the spectrum of the Pole star. A quartz spectrograph was used and the spectra were examined by a photometer. The densities of the spectra for wavelength 3290 and 3092A were compared with equal densities on an image on the plate of a source of light whose intensity varied along the image according to a known law. The constants were determined by carrying out a similar experiment at Oxford at night when the amount of ozone on the previous and following days had been measured by the standard method. Trouble was caused by the fogging of the plates caused by auroral light, but this was corrected for by a statistical method. The mean error of each determination was of the order of 30×10^{-3} cm., but the day-to-day fluctuation was found to be far greater than this and than the fluctuation observed in lower latitudes. There was no apparent connexion between the amount of aurorae and the amount of ozone. The results show that the autumn fall in the amount of ozone, observed at all latitudes, is continued through the winter and is followed by a sudden rise in spring.

Easter Weather in 1284.

In the present year Easter Day falls upon April 9th. It also fell upon that day in 1284 and John Everisden, monk of St. Edmund's Abbey, tells us of a notable thunderstorm which happened at Bury St. Edmund's on that occasion. He writes: On Easter Day, which fell on the fifth of the Ides of April, about the first hour of the day, there was at St. Edmund's such a sudden and unexpected flash of lightning, and such loud and continued claps of thunder, that those who heard them could scarcely hold their footing. And although the storm was so violent in that place, it did no harm in the country, or but very little. We have heard that the same storm occurred in parts beyond the seas, the same day and hour.

This storm was certainly experienced in Oxfordshire also. The writer of the contemporary Annals of Osney Abbey records: On Easter Day, which fell this year on the fifth of the Ides of April, it being a leap year, at about sunrise in the morning, such a thickness of the air obscured the sky, that the morning, which should have grown light unto the day, was like the darkness seen in the night time, and suddenly a horrible storm began to burst forth; first hail and rain, and then a heavy snow was loosed, which covered the whole ground; third, such horrid lightnings and concussions of thunder, that the souls of the beholders and the hearers likewise were brought to amazement . . . .

In 1413, April 9th was Passion Sunday and also the Coronation Day of Henry V. The weather was very stormy and a number of contemporary writers comment on this. The lawyer, Adam of Usk, who was present at the ceremony, writes: On the same day an exceeding fierce and unwonted storm fell upon the hill country of the realm, and smothered men and beasts and homesteads, and drowned out the valleys and the marshes in marvelous wise, with losses and perils to men beyond measure.

Thomas Walsingham, scriptoriarus and precentor of St. Albans Abbey, adds: On which day there was a great tempest of snow, everyone wondering at the sharpness of the weather.

C. E. Britton.

New climatological stations.

Mr. R. G. Sandeman of Crickhowell (Dan-y-Parc), who has forwarded rainfall observations to the Office since

1929 has maintained a climatological station for some years. Arrangements have now been made for a summary of the records to be included in the *Monthly Weather Report* to which they form a useful addition.

A well-equipped station, with a Dines tube anemograph has been set up by the Borough Council at Southgate (Oakwood Park).

Professor D. Brunt.

We have pleasure in announcing that Professor David Brunt has been elected to the Fellowship of the Royal Society.

Mr. P. A. Sheppard.

Mr. P. A. Sheppard, B.Sc., has been appointed to the University Recordership in Meteorology tenable at the Imperial College of Science and Technology.

REVIEW

Normal monthly percentage frequencies of surface and upper winds up to 3 km. at Allahabad, Begumpet, Delhi, Sambalpur, Sandoway, Silchar and Victoria Point. Simla, Ind. Met. Dept. Sc. Notes VII, 72, 1937.

The India Meteorological Department have already published in Scientific Note No. 17, tables of monthly percentage frequencies of upper winds for heights up to 3 km. at 32 stations in or near India. The publication under review contains similar tables for seven more stations (two in Burma) although the data are arranged in a slightly different form. The extension of these tables up to 10 km. has already been completed for 34 stations in Scientific Note No. 66 and one may confidently expect the India Meteorological Department to publish in the near future the data up to 10 km. for the remaining stations.

A word of caution is perhaps desirable regarding the use of these tables. For a number of reasons pilot-balloon ascents may be terminated after a comparatively short interval. If the early termination of ascents is mainly associated with certain meteorological conditions, the summaries will be biassed against those conditions. For example, the early loss of the balloon in low cloud may be more frequent with certain winds than with others. Again, it is not practicable to make a pilot balloon ascent when it is raining; or high winds may carry the balloon out of the field of view before it reaches an appreciable height. Rain, low cloud and rather high winds are all very frequent during the monsoon season. Hence in this period the summaries must be biassed in favour of clear days at the greater heights.

It is significant that, during the monsoon months the ratio of the number of observations at 3 kms. to the number of observations at or near the surface, falls to a third or an even smaller fraction. The ratio is noticeably higher during the non-rainy months. Perhaps, with the upper air temperature data which they have at their disposal, the India Meteorological Department may be able, by means of computation, to remedy to some degree the inevitable deficiency in summaries based on pilot-balloon observations alone?

R. G. VERYARD.

Sunshine, March, 1939.

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

	Total hrs.	Diff. from average hrs.		Total hrs.	Diff. from average hrs.
Stornoway ..	124	+15	Chester ..	89	−25
Aberdeen ..	95	−14	Ross-on-Wye	80	−36
Dublin ..	90	−25	Falmouth ..	126	−10
Birr Castle ..	93	−18	Gorleston ..	101	−27
Valentia ..	100	−16	Kew.. ..	93	−15

Kew temperature, mean, 43·7° F. : diff. from average, −0·2° F.

Daily Readings at Kew Observatory, March 1939

Date.	Pressure, M.S.L. 13h.	Wind, Dir. 13h.	Force	Temp. Min.	Temp. Max.	Rel. Hum. 13h.	Rain.	Sun.	REMARKS.
	mb.			°F.	°F.	%	in.	hrs.	
1	1007·7	WSW	3	39	49	56	trace	3·4	pr_0 6h.
2	14·2	S	4	45	57	66	—	0·3	
3	14·1	S	3	42	58	66	—	6·6	
4	10·5	S	3	49	53	80	0·06	0·7	r_0–r 14h–16h.
5	11·7	SW	5	46	55	47	0·06	5·3	r_0–r 2h–4h.
6	18·3	SW	4	45	54	58	—	3·2	
7	22·0	NW	4	41	49	50	—	6·7	
8	17·5	WSW	5	41	52	55	0·14	0·8	q RH 19h, r_0 19h–
9	21·5	N	3	37	49	56	—	5·1	[21h.
10	28·6	NE	2	33	49	54	—	7·8	f 22h–24h. [–24h.
11	24·6	S	2	29	45	90	0·17	0·0	f–F 0h–12h, r–r_0 19h
12	32·9	NNE	3	41	45	66	0·02	0·4	r_0 0h–2h & 6h–8h.
13	37·0	NW	3	32	49	49	—	4·1	
14	29·6	NW	3	44	53	73	—	0·0	
15	29·7	NNW	4	44	46	58	trace	0·7	pr_0 4h & 5h.
16	21·9	WNW	3	39	51	66	0·07	0·3	ir_0 5h–7h & 15h–18h.
17	16·2	NNE	5	40	46	72	0·05	1·4	pr_0h_0 12h, 15h & 16h.
18	26·4	NNE	4	33	40	52	trace	1·3	pr_0 19h.
19	18·9	NNE	4	37	45	66	0·04	0·1	r_0 1h–5h & 6h–7h.
20	17·4	WNW	3	38	48	62	trace	0·3	pr_0 18h.
21	15·1	NW	5	41	49	59	trace	4·1	pr_0 9h, 10h & 13h.
22	01·8	W	5	39	50	46	0·21	8·2	r_0–r 4h–7h, q 6h.
23	00·3	NW	5	36	49	50	0·06	6·1	r_0 6h–8h, pr 14h.
24	01·9	NW	3	31	48	50	—	7·6	
25	09·5	N	3	35	43	52	0·02	4·2	f 2h, pr_0s_0 17h & 18h.
26	20·1	NNE	6	35	43	68	trace	0·0	pr_0 4h, 7h & 9h.
27	11·1	N	4	35	41	82	0·06	0·0	ir_0–d_0 6h–17h, r_0 19h–
28	04·9	WNW	2	37	42	80	0·04	0·0	id_0 13h–24h. [22h.
29	08·3	SSE	1	34	50	70	—	4·5	
30	10·7	ENE	4	38	51	52	—	4·5	
31	1011·9	ENE	4	40	56	58	—	5·7	
*	1016·7	—		39	49	62	1·00	3·0	* Means or Totals.

General Rainfall for March 1939

	Per cent.
England and Wales	88
Scotland	102
Ireland	104
British Isles	95

Rainfall: March, 1939: England and Wales

Co.	Station.	In.	Per cent of Av.	Co.	Station.	In.	Per cent of Av.
Lond .	Camden Square......	1·32	72	*War* .	Birminghm, Edgbaston	1·64	86
Sur .	Reigate, Wray Pk. Rd.	1·66	71	*Leics* .	Thornton Reservoir...	2·06	112
Kent .	Tenterden, Ashenden.	2·12	99	,, .	Belvoir Castle........	1·85	102
,, .	Folkestone, I. Hospital	2·31	..	*Rut* .	Ridlington	1·80	103
,, .	Margate, Cliftonville..	1·72	108	*Lincs*.	Boston, Skirbeck.....	1·98	127
,, .	Eden'bdg.,Falconhurst	1·42	57	,, .	Cranwell Aerodrome..	1·95	139
Sus .	Compton, Compton Ho	1·63	59	,, .	Skegness, Marine Gdns	1·79	108
,, .	Patching Farm.......	1·56	73	,, .	Louth, Westgate.....	2·24	106
,, .	Eastbourne, Wil. Sq..	1·46	65	,, .	Brigg, Wrawby St....	2·01	..
Hants..	Ventnor, Roy.Nat.Hos.	1·49	73	*Notts* .	Mansfield, Carr Bank..	1·83	88
,, .	Southampton, East Pk	1·31	57	*Derby*.	Derby, The Arboretum	1·37	77
,, .	Ovington Rectory....	1·52	59	,, .	Buxton, Terrace Slopes	3·43	83
,, .	Sherborne St. John...	1·34	60	*Ches* .	Bidston Obsy........	1·56	82
Herts .	Royston, Therfield Rec	2·09	114	*Lancs*.	Manchester, Whit. Pk.	1·60	71
Bucks.	Slough, Upton.......	1·25	71	,, .	Stonyhurst College...	2·30	62
Oxf .	Oxford, Radcliffe.....	1·57	95	,, .	Southport, Bedford Pk	1·88	84
N'hant	Wellingboro,Swanspool	1·59	89	,, .	Ulverston, Poaka Beck	3·04	78
,, .	Oundle	1·30	..	,, .	Lancaster, Greg Obsy.	2·06	65
Beds .	Woburn, Exptl. Farm.	1·74	101	,, .	Blackpool	2·16	91
Cam .	Cambridge, Bot. Gdns.	1·70	116	*Yorks*.	Wath-upon-Dearne...	1·93	111
,, .	March	1·34	85	,, .	Wakefield,Clarence Pk.	1·81	101
Essex.	Chelmsford,CountyGns	1·56	90	,, .	Oughtershaw Hall....	5·23	..
,, .	Lexden Hill House....	1·58	..	,, .	Wetherby, Ribston H.	..	..
Suff .	Haughley House.....	1·79	..	,, .	Hull, Pearson Park...	2·35	129
,, .	Rendlesham Hall.....	2·00	119	,, .	Holme-on-Spalding...	2·14	118
,, .	Lowestoft Sec. School.	1·99	124	,, .	Felixkirk, Mt. St. John	2·43	123
,, .	Bury St. Ed.,WestleyH	2·52	133	,, .	York, Museum.......	1·79	107
Norf..	Wells, Holkham Hall.	1·95	120	,, .	Pickering, Houndgate.	2·60	131
Wilts .	Porton, W.D. Exp'lStn	·99	50	,, .	Scarborough.......	1·83	102
,, .	Bishops Cannings	1·67	74	,, .	Middlesbrough.......	2·03	129
Dor .	Weymouth, Westham.	..	..	,, .	Baldersdale, Hury Res.	3·77	122
,, .	Beaminster, East St ..	1·55	53	*Durh* .	Ushaw College.......	2·69	122
,, .	Shaftesbury	1·10	47	*Nor* .	Newcastle, Leazes Pk.	3·16	153
Devon.	Plymouth, The Hoe...	1·19	41	,, .	Bellingham, Highgreen	3·94	134
,, .	Holne, Church Pk.Cott	2·32	43	,, .	Lilburn Tower Gdns..	3·16	119
,, .	Teignmouth, Den Gdns	1·54	59	*Cumb*.	Carlisle, Scaleby Hall.	2·74	112
,, .	Cullompton	1·29	47	,, .	Borrowdale,Seathwaite	11·50	110
,, .	Sidmouth, U.D.C.....	·95	..	,, .	Thirlmere,DaleHeadH.	7·37	110
,, .	Barnstaple,N. Dev.Ath	1·43	55	,, .	Keswick, High Hill...	5·58	124
,, .	Dartm'r,Cranmere P'l	3·60	..	,, .	Ravenglass, The Grove	3·00	97
,, .	Okehampton, Uplands.	1·74	42	*West* .	Appleby, Castle Bank.	3·10	116
Corn .	Redruth, Trewirgie...	2·21	61	*Mon* .	Abergavenny, Larchf'd	1·83	60
,, .	Penzance, MorrabGdns	2·02	63	*Glam* .	Ystalyfera, Wern Ho..	3·19	60
,, .	St. Austell, Trevarna..	2·40	70	,, .	Treherbert, Tynywaun	4·05	..
Soms .	Chewton Mendip.....	1·93	54	,, .	Cardiff, Penylan......	1·69	54
,, .	Long Ashton	1·67	66	*Carm* .	Carmarthen,M.&P.Sc.	4·11	104
,, .	Street, Millfield	1·24	62	*Card* .	Aberystwyth	2·39	..
Glos .	Blockley	1·73	..	*Rad* .	Bir. W. W. Tyrmynydd	4·29	80
,, .	Cirencester, Gwynfa ..	2·11	91	*Mont* .	Lake Vyrnwy........	4·04	94
Here .	Ross-on-Wye	1·23	61	*Flint* .	Sealand Aerodrome...	1·67	97
,, .	Kington, Lynhales....	1·42	58	*Mer* .	Blaenau Festiniog....	4·58	59
Salop.	Church Stretton......	2·63	..	,, .	Dolgelley, Bontddu...	3·92	80
,, .	Shifnal, Hatton Grange	1·49	81	*Carn* .	Llandudno	2·06	101
,, .	Cheswardine Hall	1·52	72	,, .	Snowdon, L. Llydaw 9	11·25	..
Worc .	Malvern, Free Library.	1·37	71	*Ang* .	Holyhead, Salt Island.	2·58	98
,, .	Ombersley, Holt Lock.	1·17	69	,, .	Lligwy..............	3·28	..
War	Alcester, Ragley Hall.	1·44	84	*I Man*	Douglas, Boro' Cem...	3·28	111

Rainfall: March 1939: Scotland and Ireland

Co.	Station.	In.	Per cent of Av.	Co.	Station.	In.	Per cent of Av.
Guern .	St.PeterP't.GrangeRd.	2·24	91	*R&C* .	Stornoway, C.G.Stn...	4·08	105
Wig .	Pt. William, Monreith.	2·64	93	*Suth* .	Lairg	3·17	102
,, .	New Luce School.....	4·94	140	,, .	Skerray Borgie.......	3·36	..
Kirk .	Dalry, Glendarroch...	5·27	117	,, .	Melvich............	2·25	79
Dumf.	Eskdalemuir Obs.....	..	..	,, .	Loch More, Achfary..	5·87	91
Roxb .	Hawick, Wolfelee	4·26	127	*Caith* .	Wick	1·95	86
,, .	Kelso, Broomlands....	2·63	135	*Ork* .	Deerness	2·30	82
Peeb .	Stobo Castle.........	2·85	98	*Shet* .	Lerwick Observatory.	3·01	95
Berw .	Marchmont House....	2·92	110	*Cork* .	Cork, University Coll.	2·93	98
E.Lot.	North Berwick Res...	1·70	90	,, .	Roches Point, C.G.Stn.	2·60	86
Midl .	Edinburgh, Blackfd. H	2·51	127	,, .	Mallow, Waterloo	3·27	113
Lan .	Auchtyfardle	3·43	..	*Kerry*.	Valentia Observatory.	3·63	80
Ayr .	Kilmarnock, Kay Park	3·52	..	,, .	Gearhameen	6·70	83
,, .	Girvan, Pinmore	4·97	132	,, .	Bally McElligott Rec.	2·55	..
,, .	Glen Afton, Ayr San..	5·96	142	,, .	Darrynane Abbey....	3·01	74
Renf .	Glasgow, Queen's Park	3·91	150	*Wat* .	Waterford, Gortmore.	1·93	71
,, .	Greenock, Prospect H.	4·40	95	*Tip* .	Nenagh, Castle Lough.	3·17	103
Bute .	Rothesay, Ardencraig.	4·11	114	,, .	Cashel, Ballinamona..	2·41	89
,,	Dougarie Lodge......	3·33	95	*Lim* .	Foynes, Coolnanes....	..	..
Arg .	Loch Sunart, G'dale..	5·32	96	,, .	Limerick, Mulgrave St.	2·74	93
,,	Ardgour House	7·37	..	*Clare* .	Inagh, Mount Callan..	4·13	..
,,	Glen Etive	7·64	97	*Wexf* .	Gorey, Courtown Ho..	2·41	104
,,	Oban	3·64	..	*Wick* .	Rathnew, Clonmannon	2·62	..
,,	Poltalloch..........	4·23	110	*Carl* .	Bagnalstown FenaghH	2·34	96
,,	Inverary Castle	6·63	105	,, .	Hacketstown Rectory.	2·89	103
,,	Islay, Eallabus	3·59	94	*Leix* .	Blandsfort House	3·26	124
,, .	Mull, Benmore.......	7·65	72	*Offaly*.	Birr Castle	2·70	112
,,	Tiree	2·74	82	*Kild* .	Straffan House.......	..	..
Kinr .	Loch Leven Sluice....	2·75	92	*Dublin*	Dublin, Phoenix Park.	2·76	142
Fife .	Leuchars Aerodrome..	2·06	106	*Meath*.	Kells, Headfort......	3·09	112
Perth .	Loch Dhu	..	..	*W.M* .	Moate, Coolatore.....	2·37	..
,, .	Crieff, Strathearn Hyd.	2·67	83	,, .	Mullingar, Belvedere..	2·78	103
,, .	Blair Castle Gardens..	2·78	106	*Long* .	Castle Forbes Gdns ..	2·66	90
Angus.	Kettins School.......	2·00	82	*Gal* .	Galway, Grammar Sch.	2·22	74
,, .	Pearsie House	2·62	..	,, .	Ballynahinch Castle ..	3·03	59
,, .	Montrose, Sunnyside..	2·42	116	,, .	Ahascragh, Clonbrock.	2·86	86
Aber .	Balmoral Castle Gdns.	2·68	94	*Rosc* .	Strokestown, C'node..	2·43	88
,, .	Logie Coldstone Sch ..	..	..	*Mayo*.	Blacksod Point	3·54	86
,, .	Aberdeen Observatory.	1·97	82	,, .	Mallaranny..........	4·09	..
,, .	New Deer SchoolHouse	2·86	110	,, .	Westport House......	2·93	75
Moray	Gordon Castle	2·17	94	,, .	Delphi Lodge........	5·98	72
,, .	Grantown-on-Spey ...	2·01	76	*Sligo* .	Markree Castle.......	3·41	99
Nairn.	Nairn..............	1·74	93	*Cavan*.	Crossdoney, Kevit Cas.	2·51	..
Inv's .	Ben Alder Lodge.....	5·25	..	*Ferm* .	Crom Castle	3·14	101
,, .	Kingussie, The Birches	2·81	..	*Arm* .	Armagh Obsy........	3·02	129
,, .	Loch Ness, Foyers....	..	..	*Down*.	Fofanny Reservoir ...	5·52	..
,, .	Inverness, Culduthel R	1·88	85	,, .	Seaforde	3·51	120
,, .	Loch Quoich, Loan...	13·89	..	,, .	Donaghadee, C. G. Stn.	2·79	127
,, .	Glenquoich	11·19	115	*Antr* .	Belfast,Queen's Univ .	3·96	155
,, .	Arisaig House	4·43	95	,, .	Aldergrove Aerodrome	3·61	144
,, .	Glenleven, Corrour ...	6·17	106	,, .	Ballymena, Harryville.	4·74	150
,, .	Ft. William, Glasdrum	..	..	*Lon* .	Garvagh, Moneydig...	3·97	..
,, .	Skye, Dunvegan	5·95	..	,, .	Londonderry, Creggan.	5·17	162
,, .	Barra, Skallary	3·45	..	*Tyr* .	Omagh, Edenfel......	3·96	126
R&C.	Tain, Ardlarach......	2·75	111	*Don* .	Malin Head..........	3·78	131
,, .	Ullapool	2·74	66	,, .	Dunfanaghy	..	..
,, .	Achnashellach	..	..	,, .	Dunkineely..........	3·76	..

Climatological Table for the British Empire, October 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	1012·6	− 1·4	64	33	57·2	45·3	51·3	+ 0·4	46·3	89	7·3	2·06	− 0·64	15	3·6	33
Gibraltar	1017·1	− 0·1	76	53	70·2	60·7	65·5	− 0·9	59·4	81	5·5	1·35	—	5	—	—
Malta	1016·8	+ 0·8	79	58	75·1	66·1	70·6	− 0·3	64·8	76	4·6	1·24	− 1·63	8	7·1	63
St. Helena	1018·6	− 0·4	61	51	58·5	53·4	55·9	− 1·6	55·0	99	9·9	3·06	+ 1·75	25	—	—
Freetown, Sierra Leone	1012·3	+ 2·4	91	71	85·8	73·5	79·7	—	73·5	91	7·5	12·83	+ 0·21	23	—	—
Lagos, Nigeria	1011·6	+ 0·6	88	69	84·4	73·0	78·7	− 1·0	76·0	91	7·4	8·62	+ 0·85	18	5·4	45
Kaduna, Nigeria	1010·8	—	93	57	89·7	64·9	77·3	− 0·4	70·4	79	4·4	1·16	− 1·59	4	8·5	71
Zomba, Nyasaland	1010·5	− 0·3	93	59	85·9	66·1	76·0	+ 1·9	68·2	61	5·5	0·42	− 1·10	2	—	—
Salisbury, Rhodesia	1010·8	− 0·4	91	51	84·4	59·0	71·7	+ 1·0	58·7	41	0·9	0·71	—	5	10·1	81
Cape Town	1018·3	+ 0·9	81	42	70·0	52·1	61·1	− 0·1	55·9	77	5·0	2·41	+ 0·76	10	—	—
Johannesburg	1013·8	+ 0·7	83	43	74·5	52·3	63·4	+ 0·6	54·4	63	5·2	2·84	+ 0·28	15	8·1	64
Mauritius	1019·8	+ 1·6	83	62	79·9	66·4	73·1	+ 0·4	66·6	61	5·5	0·83	− 0·84	20	8·9	71
Calcutta, Alipore Obsy.	1007·7	− 1·7	96	65	91·1	75·0	83·1	+ 3·8	76·8	86	4·0	3·77	− 1·13	6*	—	—
Bombay	1008·8	− 1·0	93	71	84·9	74·2	79·5	− 2·9	74·2	83	4·6	15·17	+13·50	7*	—	—
Madras	1008·3	− 0·6	97	71	91·8	76·4	84·1	+ 1·8	74·4	84	5·7	7·90	− 3·25	7*	—	—
Colombo, Ceylon	1011·0	+ 1·0	89	69	85·3	74·2	79·7	− 0·8	76·0	74	6·8	4·86	− 8·50	16	8·1	67
Singapore	1009·8	+ 0·1	89	72	86·2	75·3	80·7	− 0·4	77·8	77	7·6	6·33	− 1·74	14	5·9	49
Hongkong	1012·0	− 1·7	89	66	82·7	73·9	78·3	+ 1·4	72·6	72	5·0	6·09	+ 1·15	12	7·5	65
Sandakan	1009·0	—	90	72	87·3	74·8	81·1	− 0·3	74·4	92	8·2	11·41	+ 1·08	18	—	—
Sydney, N.S.W.	1016·7	+ 1·9	89	52	72·0	58·2	65·1	+ 1·5	60·8	66	6·7	2·93	+ 0·08	12	5·5	43
Melbourne	1016·4	+ 1·6	87	41	71·6	48·3	59·9	+ 2·2	53·1	55	6·4	1·18	− 1·45	9	7·1	55
Adelaide	1017·6	+ 1·6	97	42	74·8	50·4	62·6	+ 0·7	54·6	43	5·7	0·70	− 1·04	4	7·4	57
Perth, W. Australia	1017·7	+ 0·9	85	44	70·5	52·2	61·3	+ 0·5	54·7	63	4·2	1·75	− 0·47	10	8·8	69
Coolgardie	1014·3	− 0·6	98	46	79·9	53·0	66·5	+ 2·8	55·2	48	2·4	0·00	− 0·66	0	—	—
Brisbane	1018·6	+ 2·4	86	55	78·6	61·3	69·9	+ 0·1	64·7	65	5·3	3·45	+ 0·92	8	8·9	70
Hobart, Tasmania	1012·3	+ 2·0	85	37	64·3	46·4	55·3	+ 1·2	49·4	57	6·2	1·83	− 0·43	13	6·5	49
Wellington, N.Z.	1015·5	+ 2·4	67	40	60·5	48·3	54·4	0·0	51·7	72	5·9	3·25	− 0·83	10	7·0	53
Suva, Fiji	1014·2	+ 1·0	89	68	82·3	71·8	77·1	+ 1·3	72·7	83	7·3	19·61	+11·32	21	4·2	34
Apia, Samoa	1012·5	+ 1·0	87	69	84·9	73·8	79·3	+ 0·9	75·3	73	5·4	8·04	+ 1·66	15	9·3	75
Kingston, Jamaica	1011·2	− 0·3	93	70	88·5	73·4	80·9	+ 0·4	72·3	86	3·6	3·26	− 4·20	4	7·7	65
Grenada, W.I.	1010·3	− 0·5	90	70	86	73	79·5	− 0·6	73	74	5	13·10	+ 5·34	26	—	—
Toronto	1020·3	+ 2·8	82	33	60·4	43·8	52·1	+ 3·5	44·4	86	5·5	1·03	− 1·54	9	6·2	56
Winnipeg	1015·9	+ 1·0	82	21	59·6	37·4	48·5	+ 7·8	37·4	76	4·7	0·40	− 0·97	5	5·3	49
St. John, N.B.	1018·3	+ 2·5	75	32	56·5	42·3	49·4	+ 4·1	44·0	87	5·8	2·38	− 2·16	13	5·3	48
Victoria, B.C.	1016·1	− 1·0	65	39	57·2	46·1	51·7	+ 1·4	47·9	76	6·6	2·61	+ 0·04	16	4·6	42

* For Indian stations a rain day is a day on which 0·1 in. or more rain has fallen.

(46740) Wt. 22/31 1,250 4/39 Hw. G.377/6

THE METEOROLOGICAL MAGAZINE

M.O. 441

AIR MINISTRY : METEOROLOGICAL OFFICE

Vol. 74 | May 1939 | No. 880

ATMOSPHERIC TURBULENCE

BY O. G. SUTTON, B.SC.

In one of his books, Eddington speaks feelingly of the pure mathematician thrown into an irrational universe, but for whom " there will remain undisturbed a corner of knowledge where he may happily hunt for the roots of the Riemann Zeta function ". The parallel is not inapt for meteorology; in its broader aspects it does not take kindly to the bonds of mathematical thought, but the art of the mathematician does seem to have come into its own in that part of the subject which deals with conditions in the lowest layers of the atmosphere. Atmospheric turbulence has long provided a happy hunting ground for mathematical theorists, but in the last ten or fifteen years the concepts and methods of modern aerodynamical theory have wrought a profound change here with the result that there has been a spate of publications whose very number and variety might well cause a newcomer to pause in dismay. Meteorologists are now in the debt of Dr. Heinz Lettau, of Leipzig, who has undertaken the heavy task of bringing order to this chaos, and whose efforts have borne fruit in an attractively produced volume of some 300 pages*. It is a pleasure to record that Dr. Lettau has been largely

* " Atmosphärische Turbulenz " by Dr. Heinz Lettau. Med. 8vo., pp. XI + 283. Leipzig Akademische Verlagsgesellschaft M.B.H. 1939.

successful in his task, and that there is now available a full and well written account of this fascinating branch of meteorology.

There is no exact mathematical definition of turbulent flow. The situation is perhaps best summed up in Oseen's dictum that a state of fluid motion is said to be turbulent when it is impossible to specify the details of the motion, and we have to be content with a knowledge of the mean flow. As far back as 1883, Osborne Reynolds, in a famous experiment, demonstrated the existence of two types of fluid motion, "laminar" and "turbulent", and he established for pipe flow a criterion for the generation of turbulence which gave rise to the "Reynolds' number", the basic parameter of aerodynamics. In the lower atmosphere, the wind is normally turbulent (i.e. consists of a series of gusts and lulls), but the degree of turbulence present fluctuates considerably, mainly due to the opposing effects of solar and terrestial radiation. Solar radiation promotes the generation of turbulence by day by setting up an unstable state in the lowest air layers, indicated by the presence of a high lapse rate; at night, turbulence tends to be damped out whenever the flow of outgoing radiation can cool the surface of the earth sufficiently to set up a large inversion of temperature gradient near the ground. This diurnal variation of turbulence is shown clearly by the records of the pressure tube anemometer, but if this were the only manifestation of eddies in the atmosphere, the gustiness of the wind would remain as a meteorological curiosity and little more. Turbulence, however, is the great atmospheric diffusing agency; anyone who has watched a weed fire in the country will have observed how rapidly the smoke is dispersed in the hours around noon, but on a clear evening, when turbulence is low, the smoke remains in the form of a thin ribbon which drifts away without any appreciable mixing. This effect is not confined to the diffusion of matter, for the upward spread of heat from the ground, resulting in the change of the amplitude and phase of the diurnal temperature wave with height, and the downward diffusion of momentum replacing that absorbed by the drag of the ground, and which reveals itself in the form of the velocity-height curve, are chiefly due to the eddying of the wind. It is perhaps not immediately obvious how much civilized life depends on this steady churning of the lower atmosphere, but without it the great cities and industrial areas of the world could not be inhabited except by a race living perpetually in gas masks. Let the turbulence of the air near large factories fall for a few days, and we have the situation which developed near Liege, Belgium, in 1930, when, in an abnormally calm period, many deaths resulted from the inhalation of industrial smoke hitherto regarded as innocuous. Evaporation, the distribution of pollen and the lighter seeds, all depend on this enhanced diffusion in the air, so that man does not merely live in a turbulent atmosphere—his very life depends on it!

To appreciate the changes which have appeared in the treatment of atmospheric turbulence in the last decade, it is necessary to interpolate here some remarks on modern aerodynamical theory. The classical hydrodynamics can claim a fair measure of success in predicting the lift of an aerofoil, but the problem of the drag (i.e., resistance), of a body placed in a viscous fluid presented almost insuperable difficulties which were somewhat mitigated by Prandtl's introduction of the concept of the *boundary layer* in 1904. This theory, in brief, postulates that the resistance of a body is largely determined by what happens in a thin layer of fluid near the surface, where inertia and viscous forces are of comparable magnitude. This concept has proved extraordinarily fruitful, and may be said to be at the heart of modern aerodynamics, but in dealing with anything except very low velocities it is necessary to distinguish between two possible types of boundary layer, namely, the " laminar layer " in which the flow may be slightly undulatory but is non-turbulent, and the " turbulent boundary layer ", of much greater thickness, and having very different characteristics, particularly as regards velocity distribution. For smooth surfaces, the turbulent boundary layer envelops a very shallow surface layer, termed the " laminar sub layer ", in which the flow is again non-turbulent. The calculation of the drag of a plate is then possible if the velocity profile (i.e., the shape of the velocity-height curve) is known throughout the boundary layers.

But, it may be objected, why should the meteorologist, whose concern is with the properties of the atmosphere, trouble himself with the niceties of the calculation of skin friction? The relevancy arises from the fact that the resistance offered by the plate shows itself in the curvature of the velocity profile near the surface, for the drag is, in effect, a measure of the rate at which momentum is being absorbed from the stream. To keep matters steady, there must be a continual downward flow of momentum, brought about by an exchange of air masses in the vertical, i.e., by turbulence. Such an exchange must simultaneously cause a transfer of heat and mass, so that a knowledge of the mechanism of momentum transfer is bound to yield information on such apparently dissimilar matters as the cooling of a hot body, or the removal of vapour from a moist surface. Thus we have to consider, in addition, temperature and mass boundary layers. The turbulent boundary layer theory has yielded remarkable results in the hands of Prandtl, von Kármán and their associates, but it must be realised that much of their work is of an empirical or tentative nature. There is still no wholly satisfactory theory of turbulence, even for the relatively simple cases outlined above.

In the atmosphere, conditions are more complex. The boundary layers referred to above start at the leading edge of the plate, and form a kind of a blanket over the surface, increasing in depth with distance downwind according to certain well established laws. For atmospheric flow, it is necessary to distinguish between small scale phenomena, where the surface under investigation may be looked upon as developing its own relatively shallow boundary layer, and phenomena which take place in the boundary layer of the earth itself. Evaporation from a small sheet of water, or the diffusion of smoke from a factory can be regarded as belonging to the former class, whilst the approach of the surface wind to the gradient wind is typical of phenomena controlled by the permanent boundary layer (some 2,000 feet deep) of the earth's atmosphere, and which is termed by Lettau the " planetary boundary layer ".

In the kinetic theory of gases, diffusion, conduction of heat and viscosity are explained as the inevitable effects of the random motion of the molecules, and the earlier attempts to treat both the large and small scale problems of atmospheric turbulence were founded on a supposed analogy between molecules and eddies as transport agents. The pioneer development of this theory was carried out more or less simultaneously by Schmidt, in Austria, and by Taylor and Richardson in this country. Taylor, in particular, was successful in devising a theory of vorticity transport, having its roots in the classical hydrodynamics, which gave good agreement with observations on such diverse aspects as the slowing down of the gradient wind by the drag of the earth's surface, and the temperature distribution in the fogs of the Grand Banks. For the most part however, the work of this period consisted largely in applying the classical equations of diffusion, heat conduction and viscous motion to the problems of turbulence with little or no change, the difference between molecular and eddy phenomenon being assumed to be in the order of magnitude of the corresponding coefficients. This simple theory failed completely to account for the details of the observations, particularly those made near the ground. In the kinetic theory of gases the value of the diffusion coefficient depends, among other things, on the length of the mean free path of the molecules, and Prandtl, in 1925, introduced for turbulent fluids the concept of a " mixing length " (*Mischungsweg*), analogous to the molecular free path, but with the vital difference that the mixing length depends upon the position of the reference point with respect to the boundary. Later, von Kármán was able to show that (for pipe flow at least) the nature of turbulent mixing is determined by the characteristics of the mean flow at the given point—in other words, the mixing length depends essentially on the spatial derivatives of the mean velocity. It is not possible here to enter further into discussion of this theory, which in the hands of the Göttingen mathematicians has become one of the outstanding successes of modern fluid motion theory, and the reader who is anxious to know more will find an excellent introduction to the subject in Dr. Lettau's book.

Pipe flow is, however, relatively simple compared with the movement of air over the earth's surface. The meteorologist, seeking to apply the above ideas to his problems, finds himself in difficulties at once, mainly owing to two factors, the roughness of the ground (due to obstacles of such varying magnitude as grass, trees, houses and hills), and the ever changing stability of the flow, as indicated by the vertical gradient of temperature near the ground. Nevertheless, considerable progress has been made towards the solution of the difficult problems presented by these factors. The effects of surface roughness and stability have been investigated by Rossby, Sverdrup and Paeschke, with encouraging results, whilst the present reviewer has been able to show how the rate of evaporation from a free liquid surface is intimately linked with the vertical gradient of wind velocity, and thence with the degree of turbulence in the atmosphere. Speaking broadly, it may be said that there is now a considerable body of knowledge relating to the development of the mass and momentum boundary layers at the surface of the earth.

Dr. Lettau has given a clear and interesting account of the large scale phenomena taking place in the planetary boundary layer, but it is somewhat disappointing to find little prominence given to Taylor's vorticity theory and its application to the problem of the approach to the gradient wind. This still remains as one of the most striking and satisfactory investigations ever made in meteorology, and the vorticity transport theory is to this day in some respects superior to the later momentum transport theory of the German school. The problem of the propagation of the diurnal temperature wave through the atmosphere still awaits a satisfactory solution, but here the situation is complicated (perhaps hopelessly) by variations in the stability of the air motion and by the effects of radiation.

The function of turbulence as a diffusing agent is perhaps, to the meteorologist, its chief interest, but there is a vast field of research open to the investigator on wind structure, a matter of prime importance to the airman. It is impossible here to deal adequately with this aspect, which covers such matters as soaring flight ("dynamical" soaring, for example, as opposed to "thermal" soaring, is only possible in a fluctuating wind), and the disaster to the airship R.101, or with turbulence as it affects the dissipation of energy in the atmosphere. Having covered, at least in some part, almost every theoretical aspect of his subject, Dr. Lettau has not forgotten that the bulk of meteorological observations are taken well inside the earth's turbulent boundary layer, and has devoted a chapter to meteorological instruments. Meteorologists are normally interested in mean values only, and these at one level, but the present reviewer would like to put forward a plea for more measurements of the gradients of wind and temperature near the surface. These are the raw material out of which the theory of atmospheric turbulence must ultimately shape itself towards its final perfection.

RADIOMETRIC SCALES

By D. N. Harrison

The radiometers used for meteorological purposes measure intensity of radiation either from the sun alone or from the sun and sky, the units commonly employed being milliwatts per sq. cm. or calories per sq. cm. per minute. They cannot be regarded, however, as absolute instruments, but have to be calibrated by comparison with some standard designed to reproduce the absolute scale of intensity. From time to time various instruments, absorbing and measuring the incident radiation in various ways, have been produced and used as standards. It is difficult to make an instrument which will give an absolute measure of intensity within one per cent. and it is therefore important to know how the standards compare with one another and how accurately they realise the true scale. Since they are in different countries, they have to be compared by means of substandards.

A recent paper by J. Guild* describes two new absolute radiometers made at the National Physical Laboratory and the results of comparisons between these and certain well-known standards.

The principle of the new instruments is as follows: Two thick copper discs are placed 1 cm. apart and connected by seven pieces of eureka wire soldered to their inner faces; a copper lead is also soldered to each disc. This arrangement constitutes seven thermocouples in parallel, and the E.M.F. will depend on the mean difference of temperature of the discs. To the outer face of one disc is cemented an insulated grid through which a current can be passed; this face is smoked black and exposed to the radiation. The rise in a given time of the temperature of this disc, as indicated by the thermoelectric current, is used to compare the energy absorbed from the radiation with that absorbed from the grid when a measured current is passed through it. These being

* London, *Proc. roy. Soc.* (A) No. 904, 161, pp. 1–38 (July, 1937).

made practically equal, the method becomes one of substitution, and the result does not depend on the properties of the indicating system.

In order to test the effect of the difference between the paths of the heat absorbed from the radiation and the heat generated electrically, the grids of the two instruments were made different, in such a way that one was expected to over-estimate and the other to under-estimate the intensity of radiation. The two instruments agreed to within one part in a thousand: therefore there could be no significant systematic error from this cause.

These instruments also agreed within one part in a thousand with the N.P.L. standard, an improved Callendar radio-balance. Since the radio-balance differs widely in principle and mode of operation from the new radiometers, the agreement is strong evidence of the absolute accuracy of both types.

Other instruments tested were: (1) the lamp standardised by Callendar and used as a source of radiation for the calibration of radiometers, (2) several standard lamps issued by the National Bureau of Standards of Washington, (3) an Abbot silver-disc pyrheliometer calibrated on the Smithsonian scale, and (4) an Angström pyrheliometer. The results were:

(1) Callendar's scale agrees with the N.P.L. scale within ± 5 parts in a thousand.

(2) The N.B.S. scale agrees with the N.P.L. within ± 2 parts in a thousand.

(3) The error of 2·3 per cent. over-estimation, found by the Smithsonian workers for their own scale, was confirmed to within one part in a thousand.

(4) The Angström scale under-estimates radiation by 5 parts in a thousand.

An important point brought out in Guild's paper is that a pyrheliometer may not read correctly on the scale on which it was calibrated if the angular distribution of intensity of the radiation received is different for calibration and for observation. For instance, it is concluded that part of the difference found by other workers between the Abbot and Angström instruments, when used for solar observations, was due to the larger amount of skylight taken in by the Abbot. In discussing comparisons of the high accuracy now attainable it has also to be remembered that there is a certain probability of error in the calibration of the substandard instruments which must necessarily be used in any such comparison. The paper includes a valuable discussion of sources of error and of the methods adopted to ensure strict comparability in the readings of instruments of different types.

CAUSE AND EFFECT

By A. F. Crossley

During the Monday evening discussion at the Meteorological Office on November 28th, 1938, I referred to a published statement by Dr. H. Jeffreys to the effect that if two related events occur simultaneously, then neither can be the cause of the other, but both may usually be traced to some cause earlier than either. As the truth of this statement was received doubtfully at the time, and as the question is of some importance in meteorology it may be desirable to reproduce a passage from Jeffreys' argument in his book "Scientific Inference" (Cambridge 1931, pp. 209–212). The passage which is of most interest in this connexion concerns the use of the words *cause, effect,* and *because* (p. 211). "If a scientific law involves a number of variables, then a knowledge of all but one of them determines that one. We say that it has a certain value *because* the others have certain values. The notions of cause and effect involve rather more than this; there is an asymmetry about them that is absent from the word *because*. Thus we may say either that a triangle has the angles at the base equal because it is isosceles, or that it is isosceles because the angles at the base are equal. When we speak of a cause and an effect, we pick out the one as the cause and the other as the effect, and they cannot be interchanged. The distinction seems to be one of time; the events under discussion are connected by a scientific law, and we pick out the earlier and call it the cause, and the later the effect. There is no distinction of cause and effect for contemporaneous events ".

In meteorology one is concerned among other things with the relation between pressure and wind. It is to be noted however that a meteorological situation in which there is no horizontal temperature gradient is a special case which results when the potential energy of previous temperature inequalities has been converted wholly or partly into kinetic energy. In this special case, pressure and wind are interchangeable in the sense mentioned by Jeffreys; there is a relation between them which ensures that knowledge of either determines the other, and it is clear that neither can be cited as the cause of the other.

It follows that in any discussion of cause and effect in meteorological hydrodynamics, temperature differences (present or past) must be taken into account. The position of temperature can be illustrated by considering motion starting from rest (or change of motion from an initially steady state). Suppose there is no horizontal temperature gradient initially, but that one is produced by absorption of more heat in some places than in others. One commonly introduces in explanation of the consequences a spurious time-order of events. Thus it is supposed that the air at first expands vertically, leaving the surface pressure unchanged, while at other levels the isobaric surfaces become inclined and so produce a flow of air which, again, produces variations in the surface pressure—and so on, the various effects interacting on one another more and more. In point of fact, however, this interaction must exist right from the beginning. Absorption of heat, the related pressure gradients and wind must all come into existence simultaneously, a fact which is necessarily made use of in the statement of any equations of motion. At any time from the initial instant, knowledge of the distribution of any two of pressure, wind and temperature suffice to determine the

the third, at least in theory. The three events play interchangeable parts and occur simultaneously, so that no one of them can be singled out as a cause of the other two.

The quest for a cause then takes us back a stage further to the method by which the heat is introduced. The only method of transference which does not itself depend on variations in the atmosphere previously produced is by radiation from the sun, and this is seen also to be the only relevant event definitely earlier in time than the related temperature, pressure and wind variations. Hence we conclude that solar radiation is the only cause, in the true sense of the word, of the subsequent variations of temperature, pressure and wind.

It was also urged against my remark at the discussion that it obviously broke down when applied to force and acceleration, since force is certainly the cause of acceleration, but the two events nevertheless occur simultaneously. The catch here lies in the assumption that two events are involved. The relationship between force and acceleration is of a more intimate kind than that, e.g., which gives the connexion between pressure and wind; these two are entirely distinct events connected by a known physical law. The equation $P = mf$ on the other hand is no more than a definition which makes it possible to measure force in terms of acceleration; force cannot in fact be measured in any other way, but we do not have to read the barometer before we can find what the wind is, or vice versa. Force and acceleration cannot therefore be regarded as separate events, but only as two aspects of the same event, and no cause-effect relationship between them can arise.

This is not the first time that this subject has been considered in this magazine. An earlier discussion was started by Sir Napier Shaw in the issue for October, 1930, and continued by him and by me in February, 1931.

LETTERS TO THE EDITOR

A Rare Halo Phenomenon, March 31st, 1939

The following note may be of interest. At 12h. 30m. (G.M.T.) on March 31st, 1939, a faint halo of about 22° was present with the addition of a brilliant circumscribed upper arc of contact. Each end of the latter

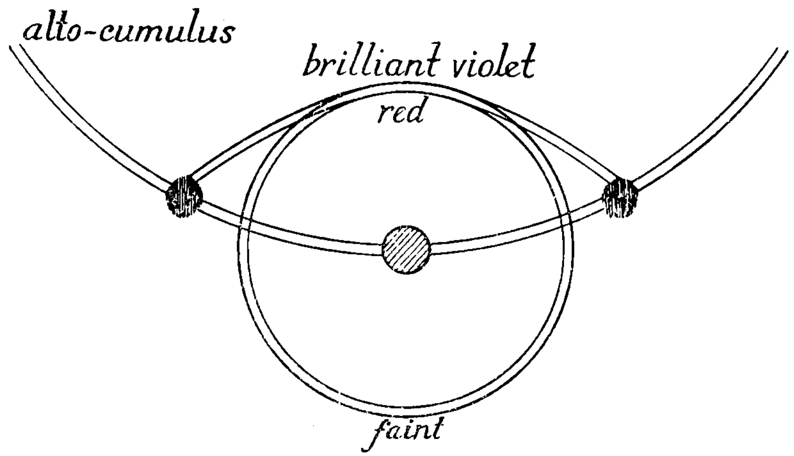


FIG. 1.—HALO SYSTEM OBSERVED AT HASTINGS, MARCH 31ST, 1939, 12H. 30M., G.M.T.

terminated in a parhelion, and through these and the sun passed a large segment of the parhelic circle. It was particularly noticed that the latter extended inside the ordinary halo, right up to the sun which was sufficiently obscured to render observation with the naked eye practicable. By holding up a card so that it obscured the sun completely the parhelic circle was even more plainly visible in close proximity to the former. The whole phenomenon did not last long after 12h. 30m. and had completely faded by 13h.

A. E. MOON.

39, Clive Avenue, Clive Vale, Hastings.
April 3rd, 1939.

A Double Rainbow

On the evening of April 24th, 1939, at 18h. G.M.T., during a heavy shower, there was one of the most brilliant rainbows I have witnessed. Both primary and secondary were complete. The primary was narrow and the colours distinct and brilliant red, orange, yellow, green, indigo, violet. At the crown of the arch were two or three green and purple spurious bows. In view of discussions as to the position of the bow it is interesting to note that to me one end of the bow appeared to be in front of the landscape and to terminate about 150 yards away.

CICELY M. BOTLEY.

Guildables, 17, Holmesdale Gardens, Hastings.
April 24th, 1939.

Lunar Rainbows

Mr. Davies' interesting article on Lunar Rainbows in the March issue of this magazine prompts me to write of my experiences of lunar rainbows, especially as the meteorological conditions under which they are occasionally seen here are quite different to those referred to by Mr. Davies.

I live on the eastern border of Dartmoor and lunar rainbows are sometimes seen here in the warm sector of a depression. Given a strong westerly wind with thick orographic drizzle over Dartmoor, a break in the low stratus clouds often occurs just to the lee of Dartmoor. This local break in the clouds (about 4 to 5 tenths of blue sky can be seen) often persists for some hours, and at the same time the drizzle over Dartmoor is blown over us. Thus the presence of a bright moon shining through this break produces a lunar rainbow. In the five years that I have lived here I have observed four such rainbows. All the rainbows were quite distinct, but no colours could be seen, the bows appearing white. One of these rainbows lasted for two hours.

It might be added that solar rainbows under these conditions are fairly common and on one occasion a rainbow was seen for five hours continuously.

No doubt others living on the lee side of large hill masses experience the same.

G. B. DAVIE.

North Harton Farm, Lustleigh, Devon.
March 25th, 1939.

Height Calculation from the Emagram

Dr. R. C. Sutcliffe(1) gave an easy rule for finding the approximate height from the tephigram. The following method corresponding with Sutcliffe's process provides

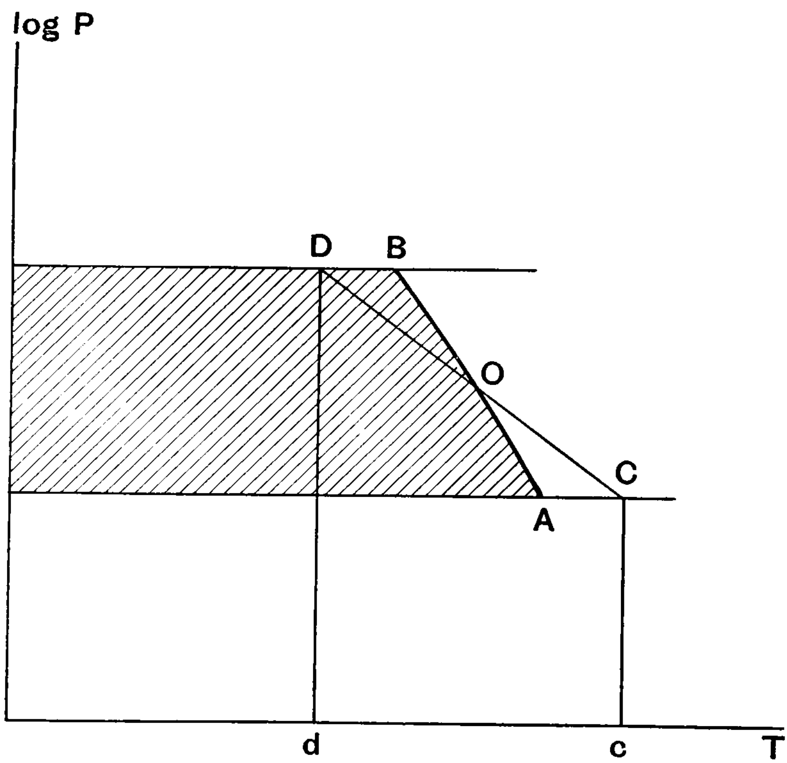


FIG. 1.—HEIGHT CALCULATION FROM THE EMAGRAM.

a very simple and theoretically accurate method of measuring height from the emagram with generality. One of the properties of the emagram noted by the present author(2) is that geodynamic height is equal to R (gas constant) times the area. If, in Fig. 1, showing a portion of the emagram, 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 in such a position that the area COA = DOB then, plainly, by the above proposition, the height between A and B is equal to the height of the isentropic atmosphere CD. But the temperature range must be multiplied by 102 to give heights of an isentropic atmosphere in metres. 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 the case of the damp air, the virtual temperature instead of the temperature itself should be used.

I think this method of interpreting Stüve's formula makes the reason simpler and clearer than Stüve's(3) or Harrison's(4) interpretation of it.

H. ARAKAWA.

Tokyo.
March, 1939.

---

(1) R. C. Sutcliffe. "Height calculation from the tephigram—another simple method". *Met. Mag., London,* 73, 1939, pp. 336-337.

(2) H. Arakawa. "Höhenberechnungen und energetische Betrachtungen mittels Emagramm". *Leipzig, Beitr. Geophys.,* 51, 1937, pp. 321–324.

(3) G. Stüve. "Aerologische Untersuchungen zum Zwecke der Wetterdiagnose, Die Arbeiten des Preussischen Aeronautischen Observatoriums bei Lindenberg". *Braunschweig, Arb. preuss. aero. Obs.* XIV, 1922, pp. 104–116.

(4) Louis P. Harrison. "Mathematical Theory of the Graphical Evaluation of Meteorograph Soundings by Means of the Stüve (Lindenberg) Adiabatic Chart". *Mon. Weath. Rev., Washington,* 63, 1935, pp. 123–135.

The Winter's Snowfall in the Chiltern Hills

In the March issue of this magazine Mr. Bonacina quoted my estimate that the deepest of the snowdrifts left on the Chiltern Hills by the blizzard of January 25th to 27th, 1939, were likely to linger into March. Though unable to produce evidence that any of them did so, I can vouch for this much: in spite of 108 hours of sunshine and screen maximum temperatures of 50° F. to 55° F. on seven days during February at the Whipsnade Park climatological station, the final traces of one drift which was initially some 15 ft. deep did not disappear from Bison Hill (700–750 ft. above M.S.L.) until the morning of February 28th.

The 48-hour snowstorm of January, 1939, is said by old folk hereabouts to have rivalled in severity any experienced since January, 1881. A number of motor-cars, lorries and tractors were buried for several days, and at one point a double-decker omnibus was almost completely engulfed. In my grounds (550–600 ft. above M.S.L.) 25 measurements gave 15·5 in. as the average depth of snow over three acres at 9h. on January 27th. This was exceeded by 2·5 in. on December 26th, 1938, after a week's intermittent fall, but the drifting was not then so great as in the later storm. It may be of interest to add that out of the 73 days from December 18th, 1938, to February 28th, 1939, there were not more than twelve on which Dunstable Downs were free from either a snow-cover or patches of snow. According to my records, kept on the eastward-facing hillside above Dagnall, the integrated depth of all the numerous falls during the last fortnight of December and the period January 1st to 29th was of the order of 45 in.

E. L. HAWKE.

Ivinglea, Dagnall, Bucks.
April 1st, 1939.

NOTES AND NEWS

High-Altitude Records from the Northern Pennines, 1938–39.

In the April, 1938, issue of this magazine, a summary was given of the temperatures recorded during 1937 at Moor House, Upper Teesdale (1,840 ft.), and of those recorded during the winter at the nearby mountain-top station on Dun Fell (revised altitude, screen, 2,735 ft.). The latter station has been set up by the writer in connexion with the investigation of the " helm wind ", and a preliminary summary of results has been published in *Nature* (March 4th, 1939, p. 377).

TABLE I.—MOOR HOUSE (1,840 FT.).

1938.	Temperature.					Rainfall.
	Mean.	Mean Max.	Mean Min.	Extremes and Dates.		
	°F.	°F.	°F.	°F.	°F.	inches.
Jan.	35·2	38·3	32·1	46 (23)	17 (10)	10·73
Feb.	34·7	38·3	31·1	47 (26)	23 (22)	4·36
Mar.	42·1	46·5	37·7	54 (13)	27 (26)	5·66
Apr.	39·0	46·4	31·6	59 (12)	23 (17)	2·28
May	42·8	50·2	35·5	59 (21) (22)	19 (8)	4·35
June	49·1	55·7	42·5	71 (17)	35 (23)	7·38
July	51·6	58·2	45·0	68 (23)	32 (5)	8·37
Aug.	52·5	60·2	44·8	73 (10)	32 (31)	6·51
Sept.	48·9	54·7	43·1	63 (26)	34 (15)	3·91
Oct.	43·5	47·8	39·3	55 (1)	32 (29)	19·41
Nov.	41·3	44·6	38·0	55 (13)	28 (22)	9·66
Dec.	33·8	36·9	30·7	46 (13)	16 (20)	9·43
1939.						
Jan.	30·8	34·6	27·0	43 (8)	9 (4)	10·52
Feb.	35·6	39·1	32·1	48 (9)	12 (2)	9·21
Mar.	35·5	39·6	31·8	47 (3) (16)	27 (9)	5·98

At Moor House, which has now been in operation for seven years, new low records were set up with regard to minimum temperatures in May (18·5° F.) and July

(31·5° F.) while October was almost free from frost in the screen. The lowest maximum temperature, 23° F. on December 20th, was not quite as low as that recorded at several stations in south-east England. The year was excessively wet; rainfall in October was particularly heavy. At the same time the year was exceptionally free from snow; snow-cover was only recorded on approximately 30 days, and the road to the house was not blocked for more than two weeks in the year.

On Dun Fell, three miles west of Moor House, a continuous record has been maintained throughout all

TABLE II.—DUN FELL (2,735 FT.).

1938.	Temperature.					Snow-Cover (Approx. No. of Days).
	Mean.	Mean Max.	Mean Min.	Extremes and Dates.		
	°F.	°F.	°F.	°F.	°F.	
Jan.	31·9	34·8	29·0	43 (22)	23 (27)	17
Feb.	30·6	34·1	27·1	44 (26)	20 (11) (15)	13
Mar.	38·0	41·5	34·5	49 (11)	23 (26)	2
Apr.	36·2	42·2	30·2	55 (13)	21 (17)	3
May	39·7	45·8	33·6	55 (22)	23 (8)	—
June	45·2	50·1	40·3	64 (17)	33 (2)	—
July	47·5	51·9	43·2	62 (23)	36 (5)	—
Aug.	51·0	56·7	45·4	69 (10)	36 (20)	—
Sept.	47·0	51·5	42·5	63 (10)	33 (15)	—
Oct.	40·4	44·3	36·5	52 (1) (13)	29 (27)	1
Nov.	38·0	40·9	35·0	51 (12) (13)	24 (22)	14
Dec.	30·3	33·3	27·3	43 (14)	12 (20)	17
1939.						
Jan.	28·7	31·5	26·0	41 (15)	17 (4)	21
Feb.	32·0	35·1	28·9	45 (8)	20 (3)	15
Mar.	31·1	34·5	27·7	43 (3)	23 (27)	18

but a few days. At this altitude conditions are liable to be very severe in winter, and no method has been found of ensuring that the instruments in the screen are always kept free from snow. It appears that if the temperature is below about 27° F. during snowfall the snow will not accumulate in the screen, but almost every fall has occurred with temperature higher than this. Five examples of observations made during visits may be cited as an indication of prevailing weather conditions: —

January 29th, 16h., 24° F., wind E 9, cloudy, surface-drift of snow.
May 1st, 7h., 30° F., wind NE 8, fog with rime-deposit.
July 10th, 9h., 43° F., wind W 5, fog.
August 26th, 15h., 55° F., wind W 2, cloudy.
November 19th, 14h., 33° F., wind WSW 8, c PRS.

From November to early March the apparent daily range of temperature is very largely an expression of irregular variations due to the advent of differing supplies of air. After March the diminishing amount of low cloud, in combination with the increased power of the sun, gives a much more regular daily variation. The spring and autumn "lag" of temperature, characteristic of mountain stations, was strongly marked in 1938. While persistent low temperatures occurred in May, August, September and nearly four weeks in October were all free from frost on the summit, during which months lowland stations in the Eden Valley suffered. The tendency for minima to occur soon after sunset, characteristic of summit stations, is well marked in quiet weather. Under similar conditions in the valley below, the evening katabatic wind ("the fell wind") is sufficiently regular to be regarded locally as an augury of a fine day to follow.

As a whole the Dun Fell summit station reproduces the characteristics of Moor House in exaggerated degree. The frequency with which winter temperatures remain persistently close to the freezing-point, accompanied by strong wind, is notable. The difference of altitude, 900 ft., was sufficient to result in a snow-cover on the summit for 64 to 67 days, against 30 at Moor House. The lowest maximum, 18° F., and minimum, 12° F., both occurred on December 20th. One may also comment on a maximum of 37° F. on June 2nd, after sleet. During August 5th to 12th lowland inversions were particularly well developed at night, and the temperature did not fall below 51° F. on the summit. The highest for the year was 69° F., on August 10th; temperature exceeded 60° F. on sixteen days, and touched 32° F. or lower on 138 days, in a mild year.

The means given in the tables refer throughout to the period 0h. to 24h. It may be of interest to point out that a third station in a well-exposed situation has been maintained at Milburn Grange (675 ft.) at the foot of the Crossfell escarpment immediately below Dun Fell. This station and Newton Rigg are however in close accord; it is abundantly clear that the Eden valley between them, e.g. at Appleby, frequently forms a notable frost-hollow.

Acknowledgments are due to the Leverhulme Trustees, and to the Council of the Durham Colleges, for grants-in-aid.

GORDON MANLEY.

Cumulus Cloud formed by Smoke Column

An interesting example of the development of cumulus cloud from a smoke column was observed at Wittering between 10h. 30m. and 12h. on November 15th, 1938. Shortly after 10h. 30m. a thin smoke column was noticed to be rising straight up some distance to west-north-west of the aerodrome. It is possible the smoke may have been from a quarry some three miles distant (the quarry is not visible from Wittering).

At an estimated height of between 1,000 to 1,500 ft. the smoke spread out into a long plume across the western sector of the sky and there was a small extension towards north-west. By 10h. 45m. the smoke column increased in intensity and a small bulge began to form in the smoke streamer above this column. Very slowly during the next 15 minutes this bulge increased in size and assumed a dome shape. A short while after 11h. the smoke column thickened considerably and the dome shaped cloud which had formed at its top began to grow rapidly in size. It is estimated that by 11h. 30m. the top of the cloud was between 2,500 and 3,000 ft. with base about 1,200 ft. The cloud was similar to large cumulus but had a soft appearance and so far as could be seen showed no tendency to break up or disperse. The " cauliflower " top was apparent but was quite soft and woolly. Owing to distance it was not possible to observe fully the turbulence effects but it could be seen that the upper part of the cloud was continually changing its shape.

By 12h. the intensity of the smoke column diminished considerably and the cloud began to disperse. There was little actual movement or rapid breaking up into fragments, the effect was rather a more gradual dissolution from the summit downwards, but portions of the base broke up and began to drift slowly away. These portions, however, disappeared very quickly when but a short distance from the cloud. Between 10h. and 12h. the surface conditions were: —

Wind.—Generally calm, but occasional light puffs from a south-easterly point.
Weather.—Hazy, visibility varying 3,000 yards to 5 miles.
Cloud.—A trace of small cumulus cloud in the south-west.

W. F. WATSON.

Royal Meteorological Society.

The usual monthly meeting of the Society was held on Wednesday, April 19th, in the Society's rooms at 49, Cromwell Road, South Kensington. Dr. B. A. Keen, F.R.S., President, was in the Chair.

Prof. E. J. Salisbury, D.Sc., F.R.S., delivered the Symons Memorial Lecture on the subject of " Ecological aspects of meteorology ". The lecturer described first the relative importance of extreme and mean climatic conditions from the point of view of their influence upon the persistence of species, and the biological significance of summations of temperature. He referred to the importance of absolute minima, even when infrequently paralleled, in influencing geographical distribution, the relation of frost severity to the survival of " winter annuals " and " summer annuals ", and the effect of maximum temperatures on the production of flower and seed. Another meteorological condition to which he referred was the nature of the soil surface and its effect on air temperatures, and he pointed out that the influence of meteorological conditions upon plant life is modified by the biology of the species.

Among the meteorological factors discussed were:— The importance of katabatic winds on plant life by the modifications of temperature which they bring about; the effect of duration and intensity of sunshine on reproduction and the phenomenon of "photoperiodism"; the role of precipitation as a source of raw material, an agent in erosion and in leaching the soil, and the significance to plant life of the seasonal incidence and intensity of precipitation.

It was remarked that meteorological factors also influence the development of soils, that they are in turn modified by the plant covering and that wind is another ecological factor, producing both direct and indirect effects. Finally the lecturer discussed the influence of meteorological factors on the conditions of life in a changing plant community, and illustrated his remarks by reference to dune soils.

At the meeting on April 26th, 1939, the President took the Chair and Major H. C. Gunton presented the Phenological Report for 1938.

Severe thunderstorms on May 19th, 1251.

Matthew Paris gives the following account:—

About the same time of the year, that is, in summer on the day of St. Dunstan, a thick cloud arose in the morning over the whole world, as it seemed, darkening east as well as west, south as well as north, and thunder was heard as if at a great distance, with lightning preceding it. And about the hour of prime, the thunder and lightning approached, one clap being more terrible than the others, as if the sky bore down on the earth, the ears and hearts of all who heard being suddenly struck dumb. With that crash a thunderbolt fell upon the queen's bedroom, where she was then staying with her sons and family, and crashing the fireplace to powder, threw it to the ground and shook the whole house. And in the neighbouring forest, namely that of Windsor, 35 oaks were thrown down or split asunder. In addition, certain mills with their millers, and sheep pens with their shepherds and several farmers and travellers were crushed. And much damage was inflicted upon mortals such that we who write this have not seen nor heard before. At St. Albans also lightning fell upon a washing place in that monastery but not much damage was done: but traces appeared in the wall for many years after.

C. E. BRITTON.

Sunshine, April, 1939.

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

	Total hrs.	Diff. from average hrs.		Total hrs.	Diff. from average hrs.
Stornoway ..	174	+24	Chester ..	161	+22
Aberdeen ..	149	+ 5	Ross-on-Wye	177	+35
Dublin ..	179	+20	Falmouth ..	207	+20
Birr Castle ..	169	+17	Gorleston ..	182	+18
Valentia ..	177	+16	Kew.. ..	174	+28

Kew temperature, mean, 49·1° F. : diff. from average, +1·4° F.

REVIEWS

The Admiralty Weather Manual, 1938. $9\frac{1}{2} \times 5\frac{3}{4}$, pp. 496 *illus.*, H.M. Stationery Office, 1938. Price 10*s.* 6*d.* *net.*

Before 1914 meteorology was purely a science of civil life. Meteorologists could advise the farmer when to cut his hay, or the skipper of a fishing vessel when not to leave harbour, while facilities were available for issuing forecasts to the general public, but the military mind had apparently failed to realise the strategic importance of a pre-knowledge of weather. There had been famous occasions when weather changed the course of history, but for sixty years British campaigns had been fought in distant climatically stable regions and history was forgotten. In 1914 a meteorological organization had to be improvised in the field, but the lesson, driven home by the coming of the aeroplane, was well and truly learnt. Meteorology, and trained meteorologists, now form an integral part of our defence plans. But scientific training requires text-books, and where the purpose of the training is highly technical, the books must be specially written. The problems of the Navy, both afloat and in the air, are not the same as those of the forces operating from land bases, and so the Admiralty Weather Manual has been written for the use of naval meteorological officers.

The book is very thorough. It is divided into three sections, dealing respectively with meteorological instruments and observations, general meteorology, and synoptic meteorology. Most of the instruments are common to land and sea, but accurate observations on or from a moving ship require special adaptations which are described at length in the first chapter. This and the second chapter on non-instrumental observations and the coding of messages call for little remark. Velocities are expressed in knots even in the free air, and distances on the visibility scale in cables and miles, but even if the latter are " sea " miles equating one mile to two kilometres surely exceeds the limits of tolerance. The last two chapters in this section deal with the difficult problems of measuring upper winds and upper air temperatures over the sea.

The second section on General Meteorology, which forms more than half the book, is very good. The text is clear, concise and thorough, the illustrations helpful and the mathematics rarely overdone. The simple dynamical treatment in the chapter on wind is especially satisfactory. There is a valuable glossary of local winds and the descriptions of sky types in tropical regions form an unusual but welcome feature. The short chapter on Optical Phenomena, which for some reason is not illustrated, would have been improved by a diagram of the various types of halo; incidentally it is strange to find " atmospherics " in this company. The last section, on Synoptic Meteorology, is mostly up-to-date, with the modern developments of air-mass and frontal analysis applied to various parts of the world; upper air data as aids to forecasting are also described in some detail.

The book contains no fewer than 167 illustrations, many of them full page plates. There are a few slips, for example in fig. 7 the wet-bulb thermometer reads higher than the dry-bulb and the neck of the water-vessel is non-existent rather than small, but such blemishes are rare and on the whole naval meteorologists could not have asked for a better text-book from the author*, who remains strictly anonymous.

C. E. P. B.

Aeronautical Meterology, by George F. Taylor, Ph.D. London: Sir Isaac Pitman & Son, Ltd. $9 \times 5\frac{3}{4}$, pp. XVII + 430 *illus.*, price 18*s. net.*

Under the name " Aeronautical Meterology " or some such title, the story of the progress of Meteorology since she entered the service of her flourishing master Aviation, has been told a dozen times in recent years and in at least five languages. Inevitably one compares Dr. Taylor's latest contribution with its predecessors, and particularly with the well known volume by Dr. Byers† with which it has a great deal in common. It is especially interesting to note the echo in the introduction. The earlier volume was " intended for airline pilots and students of meteorology . . . . from the practical point of view "; Dr. Taylor, we find, " has attempted to write a thoroughly practical book that may be used by the

---

* It is understood that this book was written by Dr. A. G. Forsdyke, of the Naval Meteorological Branch, Admiralty, in collaboration with Naval Meteorological Officers.

† " Synoptic and Aeronautical Meteorology," by Horace R. Byers, Sc.D., McGraw Hill Publishing Co. Ltd., 1937, 21*s*. net, Review: *Met. Mag.*, 1938, page 20, by C. K. M. Douglas.

airline pilot, as well as by the general student of meteorology ". Such an object has its difficulties, for, unless the pilot is expected to be of necessity an expert meteorologist, any attempt to supply the needs of the two professions implies a compromise, with the danger that neither will find quite what it wants. Dr. Taylor has succeeded in his task better than one might think possible but it is only fair to point out that the meteorologist will find some of the treatment too cursory to be of much value (as for example the chapters on Observational Material, the Weather Chart, Weather Chart Analysis and Climatology) while the average pilot will find some heavy going amongst the technicalities of Rossby and Refsdal diagrams, thetagrams and tephigrams, Bjerknes solenoids and Ekmans Spiral, Petterssen's computations and so on. Although the author attempts to reduce these to elementary form the trained scientific mind is apt to forget that the pilot is a busy, practical man with, as a rule, no natural leaning towards abstract thinking. As meteorological instructor and examiner to air pilots, the reviewer has come up against some severe criticism of the sort of meteorological knowledge required of a pilot. We are accused of impressing him more with the abstruseness of our subject than with its practical importance to himself so that many a keen beginner is frightened away at the start. As a reference book in the aeronautical library Dr. Taylor's work should certainly find a place, but as a textbook for the pilot it cannot, with a clear conscience, be very strongly recommended.

Every aviation meteorologist must, however, make a point of reading it. Naturally there is a geographical bias which detracts from its immediate usefulness in England but in the present state of our science we have all much to learn from practice in other countries. The thorough treatment of air-mass analysis is really impressive. Dr. Taylor lists 16 types of air-mass for North America and gives each detailed attention—nothing at all comparable is available for this side of the Atlantic. The author follows Byers in devoting a chapter headed " Forecasting " almost exclusively to

Petterssen's methods of making extrapolations on the field of pressure. On the basis of investigations made on these methods in England they would hardly justify such prominence and one wonders whether their formal attractiveness to the text-book writer, lending a welcome air of mathematical respectability to the wizardry of forecasting, rather outweighs their practical limitations. One feels that the discussion of a few actual synoptic charts (not one is given), might have had as strong a claim to space, particularly for the general reader.

A great feature, which gives the work an atmosphere of its own, are the frequent startling statements on matters of theory which bring the reader up with a salutary jerk. The following, selected from a large number, will serve to illustrate. On p. 80 we are told that without friction " no circulation could exist " in the atmosphere. On p. 227: " it is generally only in regions where weather reports are scanty that the bent-back occlusion survives careful scrutiny!" On p. 282: " only rarely does fog form below freezing point because the heat of fusion retards the cooling process greatly " and lastly, on p. 294: " convergence is generally due to the retardation of a front due to frontogenesis or cyclogenesis ". Such remarks, taken in their context, may be regarded sometimes as shrewd, sometimes as intriguing and sometimes as positively annoying, according to taste, but they are always provoking and stimulating.

Finally a human note. In Dr. Taylor's words " a man who is a poor ' mixer ' will rarely be successful in airline meteorology, no matter how skilled he may be in technical knowledge ". In serving her new-rich master, Meteorology has sold her aristocratic scientific soul to the devil. Meteorological Services might usefully note this clause in their contract, but it would be unwise to infer that social accomplishments will altogether obscure technical blundering. Aviation is, outside the Club or Officers' Mess, a hard master.

R. C. SUTCLIFFE.

Daily Readings at Kew Observatory, April 1939

Date.	Pressure, M.S.L. 13h.	Wind, Dir. 13h.	Wind, Force 13h.	Temp. Min.	Temp. Max.	Rel. Hum. 13h.	Rain.	Sun.	REMARKS.
	mb.			°F.	°F.	%	in.	hrs.	
1	1010·4	SSE	2	38	57	69	0·06	0·0	f 5h–12h, r_0 19h–23h.
2	1002·6	SW	3	47	52	87	0·43	0·0	r 2h–6h, R 4h.
3	995·2	SSE	4	35	48	85	0·07	0·0	pr_0 17h, r_0 21h–24h.
4	986·3	SW	3	47	54	86	0·26	2·1	ir_0–r 0h–3h & 11h–13h.
5	996·3	S	4	46	55	80	0·20	2·1	R 10h, r_0 21 h–22h.
6	1009·2	NE	4	40	46	73	0·15	0·0	r_0–r 3h–8h, ir_0 8h–10h.
7	1018·5	E	3	38	49	58	—	3·8	
8	1018·2	SW	2	32	54	62	—	9·7	
9	1017·0	SSW	1	37	62	54	—	11·1	
10	1014·0	ENE	4	43	64	52	—	7·7	
11	1012·3	ENE	3	46	72	51	—	10·3	
12	1016·1	SW	4	44	69	56	—	10·1	f 7h.
13	1013·1	SSW	5	49	60	69	0·02	3·4	r_0 18h–20h.
14	1006·0	SW	3	49	59	88	0·01	2·7	pr_0 11h, 18h & 20h.
15	1016·1	SW	3	45	57	55	trace	4·4	pr_0 15h & 16h.
16	1017·1	WSW	4	53	61	76	trace	3·0	pr_0 9h. & 10h.
17	1017·4	W	5	47	57	49	0·02	8·0	r_0 2h–3h, pr_0 13h.
18	1035·5	NNE	4	41	54	57	0·01	12·0	r_0 1h–2h.
19	1036·4	NW	2	39	63	52	—	11·8	
20	1030·7	W	2	42	68	42	—	12·0	
21	1024·5	SW	3	43	67	32	—	10·4	
22	1014·1	NW	5	46	54	38	trace	8·4	pr_0 13h, 17h & 21h.
23	1009·8	W	3	43	52	76	0·04	0·8	r_0 9h–13h & 21h–24h.
24	996·0	WNW	4	48	55	60	0·14	5·7	r_0 5h–9h, t rh 12h.
25	1003·1	N	3	38	51	62	—	8·3	
26	1013·6	N	4	35	49	60	trace	6·6	pr_0 13h, 14h & 17h.
27	1023·8	N	3	35	49	74	0·09	9·6	prh 12h, pRh 18h.
28	1024·3	NNE	2	35	51	49	0·15	7·3	rh–R 18h–19h.
29	1021·9	NNE	4	37	50	63	0·07	2·9	pr_0 16h, r_0 17h–22h.
30	1014·9	NNE	3	41	45	88	0·49	0·0	r_0–r 5h–13h & 15h–24h.
*	1013·8	—		42	56	63	2·21	5·8	*Means or Totals

General Rainfall for April 1939

	Per cent.
England and Wales	125
Scotland	81
Ireland	76
British Isles	104

Rainfall: April, 1939: England and Wales

Co.	Station.	In.	Per cent of Av.	Co.	Station.	In.	Per cent of Av.
Lond	Camden Square	2·58	168	*War*	Birminghm, Edgbaston	2·11	121
Sur	Reigate, Wray Pk. Rd.	2·99	179	*Leics*	Thornton Reservoir	1·83	108
Kent	Tenterden, Ashenden.	2·21	136	,,	Belvoir Castle	2·16	141
,,	Folkestone, I. Hospital	3·09	..	*Rut*	Ridlington	2·22	141
,,	Margate, Cliftonville	2·31	171	*Lincs*	Boston, Skirbeck	2·05	152
,,	Eden'bdg.,Falconhurst	2·37	127	,,	Cranwell Aerodrome	1·85	140
Sus	Compton, Compton Ho	2·77	138	,,	Skegness, Marine Gdns	2·09	156
,,	Patching Farm	2·93	167	,,	Louth, Westgate	2·48	148
,,	Eastbourne, Wil. Sq.	2·11	116	,,	Brigg, Wrawby St.	1·74	..
Hants	Ventnor, Roy.Nat.Hos.	3·04	181	*Notts*	Mansfield, Carr Bank	1·55	90
,,	Southampton, East Pk	2·15	116	*Derby*	Derby, The Arboretum	1·63	96
,,	Ovington Rectory	2·15	114	,,	Buxton, Terrace Slopes	2·84	97
,,	Sherborne St. John	2·77	156	*Ches*	Bidston Obsy	2·02	124
Herts	Royston, Therfield Rec	3·06	195	*Lancs*	Manchester, Whit. Pk.	2·13	111
Bucks	Slough, Upton	2·66	186	,,	Stonyhurst College	2·23	82
Oxf	Oxford, Radcliffe	3·02	189	,,	Southport, Bedford Pk	2·08	112
N'hant	Wellingboro,Swanspool	1·92	129	,,	Ulverston, Poaka Beck	2·26	75
,,	Oundle	2·28	..	,,	Lancaster, Greg Obsy.	2·49	111
Beds	Woburn, Exptl. Farm.	3·41	227	,,	Blackpool	2·51	134
Cam	Cambridge, Bot. Gdns.	2·81	207	*Yorks*	Wath-upon-Dearne	1·29	82
,,	March	1·85	140	,,	Wakefield,Clarence Pk.	1·26	75
Essex	Chelmsford,CountyGns	3·45	270	,,	Oughtershaw Hall	3·30	..
,,	Lexden Hill House	2·48	..	,,	Wetherby, Ribston H.	1·21	69
Suff	Haughley House	2·12	..	,,	Hull, Pearson Park	1·37	88
,,	Rendlesham Hall	..	..	,,	Holme-on-Spalding	1·16	70
,,	Lowestoft Sec. School.	2·46	166	,,	Felixkirk, Mt. St. John	1·07	64
,,	Bury St. Ed.,WestleyH	2·89	189	,,	York, Museum	1·28	80
Norf.	Wells, Holkham Hall.	2·58	202	,,	Pickering, Houndgate.	1·26	75
Wilts	Porton, W.D. Exp'lStn	2·45	147	,,	Scarborough	1·72	110
,,	Bishops Cannings	3·65	181	,,	Middlesbrough	1·19	87
Dor	Weymouth, Westham.	2·11	127	,,	Baldersdale, Hury Res.	1·95	81
,,	Beaminster, East St	2·72	115	*Durh*	Ushaw College	1·04	55
,,	Shaftesbury	2·14	..	*Nor*	Newcastle, Leazes Pk.	·99	62
Devon	Plymouth, The Hoe	2·79	123	,,	Bellingham, Highgreen	2·60	120
,,	Holne, Church Pk.Cott	4·99	138	,,	Lilburn Tower Gdns.	1·36	69
,,	Teignmouth, Den Gdns	2·33	116	*Cumb*	Carlisle, Scaleby Hall.	1·32	68
,,	Cullompton	2·58	114	,,	Borrowdale,Seathwaite	7·50	109
,,	Sidmouth, U.D.C.	2·16	..	,,	Thirlmere,DaleHeadH.	3·96	81
,,	Barnstaple,N. Dev.Ath	2·35	111	,,	Keswick, High Hill	2·94	96
,,	Dartm'r,Cranmere P'l	5·80	..	,,	Ravenglass, The Grove	2·25	91
,,	Okehampton, Uplands.	4·74	149	*West*	Appleby, Castle Bank.	1·20	62
Corn	Redruth, Trewirgie	3·66	127	*Mon*	Abergavenny, Larchf'd	3·07	121
,,	Penzance, MorrabGdns	3·48	143	*Glam*	Ystalyfera, Wern Ho.	5·17	163
,,	St. Austell, Trevarna	3·84	136	,,	Treherbert, Tynywaun	7·20	..
Soms	Chewton Mendip	4·33	146	,,	Cardiff, Penylan	3·37	135
,,	Long Ashton	3·27	150	*Carm*	Carmarthen,M.&P.Sc.	3·79	133
,,	Street, Millfield	2·61	133	*Card*	Aberystwyth	1·93	..
Glos	Blockley	2·95	..	*Rad*	Bir. W. W. Tyrmynydd	4·62	125
,,	Cirencester, Gwynfa	4·01	214	*Mont*	Lake Vyrnwy	3·45	115
Here	Ross-on-Wye	2·54	134	*Flint*	Sealand Aerodrome	1·90	131
,,	Kington, Lynhales	1·96	99	*Mer*	Blaenau Festiniog	5·90	106
Salop	Church Stretton	2·76	..	,,	Dolgelley, Bontddu	3·25	89
,,	Shifnal, Hatton Grange	1·53	91	*Carn*	Llandudno	1·91	113
,,	Cheswardine Hall	1·84	105	,,	Snowdon, L. Llydaw 9	8·25	..
Worc	Malvern, Free Library.	2·35	131	*Ang*	Holyhead, Salt Island.	1·90	91
,,	Ombersley, Holt Lock.	1·78	117	,,	Lligwy	1·87	..
War	Alcester, Ragley Hall.	2·03	120	*I.Man*	Douglas, Boro' Cem.	2·31	95

ERRATUM: Middlesbrough, March, *for* 2.03/129 *read* 2·08/132.

Rainfall: April, 1939: Scotland and Ireland

Co.	Station.	In.	Per cent of Av.	Co.	Station.	In.	Per cent of Av.
Guern.	St.PeterP't.GrangeRd.	1·89	94	*R&C.*	Stornoway, C.G.Stn.	2·57	89
Wig	Pt. William, Monreith.	1·69	77	*Suth*	Lairg	2·32	100
,,	New Luce School	2·09	79	,,	Skerray Borgie	1·97	..
Kirk	Dalry, Glendarroch	2·29	75	,,	Melvich	1·55	67
Dumf.	Eskdalemuir Obs.	2·47	73	,,	Loch More, Achfary	4·07	84
Roxb	Hawick, Wolfelee	1·11	49	*Caith*	Wick	·99	50
,,	Kelso, Broomlands	1·01	64	*Ork*	Deerness	1·52	73
Peeb	Stobo Castle	..	..	*Shet*	Lerwick Observatory.	2·70	118
Berw	Marchmont House	1·57	78	*Cork*	Cork, University Coll.	2·08	79
E.Lot.	North Berwick Res.	·85	61	,,	Roches Point, C.G.Stn.	1·91	71
Midl	Edinburgh, Blackfd. H	1·18	80	,,	Mallow, Waterloo	1·69	69
Lan	Auchtyfardle	1·67	..	*Kerry.*	Valentia Observatory.	2·26	62
Ayr	Kilmarnock, Kay Park	2·22	..	,,	Gearhameen	4·10	71
,,	Girvan, Pinmore	2·32	78	,,	Bally McElligott Rec.	1·11	..
,,	Glen Afton, Ayr San.	3·31	110	,,	Darrynane Abbey	1·81	53
Renf	Glasgow, Queen's Park	1·71	87	*Wat*	Waterford, Gortmore.	1·18	47
,,	Greenock, Prospect H.	3·66	106	*Tip*	Nenagh, Castle Lough.	1·21	48
Bute	Rothesay, Ardencraig.	3·06	103	,,	Cashel, Ballinamona	1·45	59
,,	Dougarie Lodge	2·10	74	*Lim*	Foynes, Coolnanes	1·24	51
Arg	Loch Sunart, G'dale	..	..	,,	Limerick, Mulgrave St.	1·66	69
,,	Ardgour House	4·97	..	*Clare*	Inagh, Mount Callan	2·70	..
,,	Glen Etive	5·54	100	*Wexf.*	Gorey, Courtown Ho.	1·84	84
,,	Oban	2·57	..	*Wick.*	Rathnew, Clonmannon	1·31	..
,,	Poltalloch	2·70	89	*Carl*	Bagnalstown FenaghH	1·57	69
,,	Inveraray Castle	4·34	94	,,	Hacketstown Rectory.	1·63	62
,,	Islay, Eallabus	1·62	56	*Leix*	Blandsfort House	2·19	84
,,	Mull, Benmore	3·75	48	*Offaly.*	Birr Castle	1·08	50
,,	Tiree	..	..	*Kild*	Straffan House	..	..
Kinr	Loch Leven Sluice	1·49	78	*Dublin*	Dublin, Phoenix Park.	2·04	113
Fife	Leuchars Aerodrome	·88	55	*Meath.*	Kells, Headfort	2·05	82
Perth	Loch Dhu	3·95	83	*W.M*	Moate, Coolatore	1·83	..
,,	Crieff, Strathearn Hyd.	1·83	84	,,	Mullingar, Belvedere	..	..
,,	Blair Castle Gardens	1·78	84	*Long*	Castle Forbes Gdns	1·98	83
Angus.	Kettins School	1·09	60	*Gal*	Galway, Grammar Sch.	1·46	62
,,	Pearsie House	1·17	..	,,	Ballynahinch Castle	3·58	101
,,	Montrose, Sunnyside	·61	34	,,	Ahascragh, Clonbrock.	1·78	70
Aber	Balmoral Castle Gdns.	1·21	56	*Rosc*	Strokestown, C'node	1·49	68
,,	Logie Coldstone Sch	1·14	57	*Mayo.*	Blacksod Point	2·34	81
,,	Aberdeen Observatory.	·84	45	,,	Mallaranny	3·29	..
,,	New Deer SchoolHouse	1·62	81	,,	Westport House	1·63	60
Moray	Gordon Castle	1·38	79	,,	Delphi Lodge	5·45	95
,,	Grantown-on-Spey	1·73	88	*Sligo*	Markree Castle	1·77	67
Nairn.	Nairn	1·17	78	*Cavan.*	Crossdoney, Kevit Cas.	1·59	..
Inv's	Ben Alder Lodge	2·37	..	*Ferm*	Crom Castle	1·96	77
,,	Kingussie, The Birches	1·67	..	*Arm*	Armagh Obsy	2·39	114
,,	Loch Ness, Foyers	2·27	105	*Down.*	Fofanny Reservoir	4·50	..
,,	Inverness, Culduthel R	1·16	70	,,	Seaforde	2·28	87
,,	Loch Quoich, Loan	7·65	..	,,	Donaghadee, C. G. Stn.	1·80	90
,,	Glenquoich	6·52	100	*Antr*	Belfast,Queen's Univ	2·46	110
,,	Arisaig House	3·73	104	,,	Aldergrove Aerodrome	2·18	103
,,	Glenleven, Corrour	4·53	111	,,	Ballymena, Harryville.	2·33	88
,,	Ft. William, Glasdrum	3·38	..	*Lon*	Garvagh, Moneydig	2·20	..
,,	Skye, Dunvegan	3·43	..	,,	Londonderry, Creggan.	1·82	71
,,	Barra, Skallary	..	..	*Tyr*	Omagh, Edenfel	2·46	94
R&C.	Tain, Ardlarach	2·28	116	*Don*	Malin Head	1·69	70
,,	Ullapool	2·85	92	,,	Dunfanaghy	1·44	62
,,	Achnashellach	6·79	120	,,	Dunkineely	1·58	..

Climatological Table for the British Empire, November 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	1011·1	− 3·5	66	32	54·5	45·0	49·7	+ 6·2	47·0	90	8·4	2·60	+ 0·38	17	2·1	23
Gibraltar	1021·0	+ 3·0	69	49	65·6	57·0	61·3	+ 1·3	56·3	83	5·3	0·86	—	7	—	—
Malta	1019·3	+ 3·4	70	52	67·5	59·6	63·5	− 0·4	58·7	78	6·0	4·20	+ 0·63	12	6·1	60
St. Helena	1017·2	− 0·4	75	52	62·1	54·2	58·1	− 0·4	55·1	89	9·2	0·84	− 0·34	11	—	—
Freetown, Sierra Leone	1011·7	+ 2·5	90	72	86·3	74·4	80·3	—	73·6	91	7·4	5·10	− 0·02	18	—	—
Lagos, Nigeria	1010·3	+ 0·2	89	69	85·5	72·6	79·1	− 2·6	76·0	90	7·2	6·24	+ 3·57	12	6·3	53
Kaduna, Nigeria	1009·8	—	95	57	91·6	62·4	77·0	− 0·9	64·8	51	3·6	0·00	− 0·21	0	9·5	82
Zomba, Nyasaland	1008·9	0·0	94	55	84·9	65·7	75·3	− 0·3	68·6	69	6·4	1·73	− 3·35	3	—	—
Salisbury, Rhodesia	1010·9	− 0·1	91	50	80·3	58·0	69·1	− 1·6	59·5	54	5·9	3·41	—	11	6·8	53
Cape Town	1017·2	+ 1·4	93	45	74·8	54·3	64·5	+ 0·1	57·8	66	4·5	0·93	− 0·16	8	—	—
Johannesburg	1012·1	+ 0·7	88	34	77·1	53·1	65·1	+ 1·4	52·7	49	4·0	1·02	− 3·94	9	8·9	66
Mauritius	1017·8	+ 1·7	85	62	82·2	66·9	74·6	− 0·9	68·4	62	5·4	0·77	− 0·99	18	8·7	67
Calcutta, Alipore Obsy.	1012·9	− 0·4	88	57	83·8	63·9	73·9	+ 0·4	65·7	82	3·1	0·11	− 0·54	0*	—	—
Bombay	1011·9	− 0·1	92	65	86·0	70·3	78·1	− 2·5	68·6	71	1·9	1·13	+ 0·68	1*	—	—
Madras	1011·5	+ 0·2	90	64	85·9	70·6	78·3	− 0·6	71·7	76	5·7	0·25	−13·36	1*	—	—
Colombo, Ceylon	1011·3	+ 1·3	90	67	86·3	73·1	79·7	− 0·3	74·7	69	4·8	3·82	− 7·94	7	8·7	74
Singapore	1009·5	+ 0·1	89	71	85·9	74·5	80·2	− 0·4	77·2	79	8·5	6·44	− 3·47	20	4·6	38
Hongkong	1017·9	+ 0·3	81	57	74·2	65·7	69·9	+ 0·3	61·8	62	6·6	0·53	− 1·21	3	5·2	47
Sandakan	1008·3	—	89	72	85·7	74·5	80·1	− 0·8	77·1	88	8·9	22·78	+ 8·06	24	—	—
Sydney, N.S.W.	1013·1	− 0·7	95	57	75·9	62·8	69·3	+ 2·3	64·3	66	7·2	1·73	− 1·12	14	7·1	51
Melbourne	1013·4	− 1·0	99	45	75·8	52·4	64·1	+ 2·8	56·6	50	6·1	1·47	− 0·76	11	7·3	52
Adelaide	1014·2	− 1·1	102	47	82·5	55·7	69·1	+ 2·1	58·0	36	5·2	0·50	− 0·64	6	9·4	68
Perth, W. Australia	1013·4	− 2·0	98	47	76·0	57·4	66·7	+ 0·6	59·8	55	5·7	1·79	+ 0·99	5	9·6	70
Coolgardie	1011·5	− 1·9	108	41	86·9	59·2	73·1	+ 2·4	61·8	54	2·0	0·39	− 0·30	1	—	—
Brisbane	1013·6	− 1·0	94	62	81·3	66·2	73·7	+ 0·2	68·0	68	6·8	4·76	+ 1·03	13	7·4	58
Hobart, Tasmania	1011·3	+ 1·7	92	44	66·6	49·2	57·9	+ 0·7	54·2	62	7·0	2·24	− 0·23	14	6·4	44
Wellington, N.Z.	1015·2	+ 3·1	71	44	64·4	50·5	57·5	+ 0·7	55·2	76	8·1	1·99	− 1·53	14	6·4	44
Suva, Fiji	1009·2	− 1·9	87	71	83·8	73·3	78·5	+ 1·4	74·9	82	7·3	20·77	+10·98	22	5·2	40
Apia, Samoa	1008·0	− 1·5	87	72	83·1	74·4	78·7	0·0	75·8	84	8·7	33·35	+23·52	29	3·3	26
Kingston, Jamaica	1011·1	− 1·3	93	69	88·7	71·8	80·3	+ 1·0	72·1	94	4·6	0·52	− 2·51	4	8·1	72
Grenada, W.I.	1013·3	+ 2·7	87	71	85·8	72·3	79·1	− 0·4	73	75	7	14·45	+ 5·99	25	—	—
Toronto	1019·0	+ 1·7	69	14	48·7	33·7	41·2	+ 4·2	35·4	81	5·9	1·45	− 1·18	12	3·9	40
Winnipeg	1016·1	− 1·3	53	−14	27·8	9·9	18·9	− 2·4	15·6	74	7·4	0·86	− 0·21	9	2·4	26
St. John, N.B.	1018·6	+ 4·0	62	10	45·6	31·5	38·5	+ 1·8	34·3	84	6·6	4·11	− 0·30	16	4·1	43
Victoria, B.C.	1020·5	+ 4·6	55	31	47·8	39·7	43·7	− 0·8	41·6	84	7·3	2·96	− 2·45	17	3·3	35

* For Indian stations a rain day is a day on which 0·1 in. or more rain has fallen.

Erratum—Wellington, N.Z. August 1938, Precipitation Diff. from Normal, *for* −2·51 *read* +2·51.

(47163) Wt. 22/31 1,375 5/39 Hw. G.377/6

THE METEOROLOGICAL MAGAZINE

M.O. 441

AIR MINISTRY : METEOROLOGICAL OFFICE

Vol. 74 June 1939 No. 881

ATMOSPHERIC ELECTRICITY

BY P. A. SHEPPARD, B.SC.

Of all meteorological phenomena the thunderstorm is perhaps the most impressive and awe-inspiring, and it was with the thunderstorm that the study of atmospheric electricity began when Benjamin Franklin and others demonstrated the similarity between lightning and the electric spark produced in a laboratory. The thunderstorm preserves its position to-day as a subject for study in the modern field of atmospheric electricity, not only because of its intrinsic interest and unsolved problems but on account of the important part it appears to play in the electrical characteristics of the atmosphere in fine weather as well as in thundery areas.

The major problem of atmospheric electricity, progress towards the solution of which has been considerable in the last two decades, is to discover the mechanism whereby the negative charge, which resides on the earth's surface in fine weather areas, is maintained against the positive ion conduction current flowing from the air to the ground and tending always to annihilate the charge on the ground. Alternatively and more fully stated, a difference of potential, E, of about one million volts, exists between the upper conducting atmosphere and the ground due to a separation of charge. On account of the small though by no means negligible conductivity of the intervening atmosphere this separation of charge tends continuously to be nullified by the air-earth current, i, of fine weather areas, given by Ohm's law, i = E/R, where R is the effective total resistance between the ground and the upper conducting atmosphere. The problem presented is then to discover a charge separation process (positive charge upward, negative downward) which effectively counterbalances the downwardly directed stream of positive charge and so maintains the electric field of fine weather areas.

It was first suggested by C. T. R. Wilson that the origin of the required charge separation process (or processes) is to be found in regions of disturbed weather. It has long been known that rain is in general electrically charged, and most observers agree that a preponderance of positive charge is transferred from air to earth by this means. Thus the "precipitation" current due to rain is on the whole in the same direction as the fine weather conduction current. In thunderstorms, however, there are additional types of charge transference which may play a major role in the atmospheric electric balance. These are:—

(i) lightning discharges between the cloud and the ground, and between the cloud and the upper atmosphere,

(ii) point discharge currents between pointed objects on the ground (grass blades, bushes, trees, etc.), and the air above—occasionally visible, when it is termed St. Elmo's Fire,

(iii) ionic conduction currents between the cloud and the ground, and between the cloud and the upper atmosphere.

In order that these agencies shall maintain the fine weather field they must on the whole bring negative electricity to the ground and positive electricity to the upper atmosphere. This can only be the case if the polarity of the thundercloud is positive, i.e. positive charge at the top of the cloud and negative at the bottom. The importance of determining the general polarity of thunderclouds, and of obtaining a quantitative measure of the three types of charge transference enumerated above, is, therefore, apparent.

The results of several workers show that thunderstorm clouds are mainly of positive polarity, though this is not to say that the cloud base is wholly negative and the cloud top wholly positive. Further, the charge transference occasioned by lightning flashes has been measured by means of the electric field changes which they produce, and continuous records of point discharge current have been obtained. These measurements all go to show that the thunderstorm is quite capable of producing the flow of charge required to counteract the fine weather flow. As an example of the balance sheet which may be drawn up, a table, due to Wormell (1), is given below, for a square kilometre of ground at Cambridge.

	Coulomb/sq. km./annum.
By natural point discharge current	- 100
By lightning	- 20
By ionic conduction current ...	+ 60
By precipitation current	+ 20
Net flow of charge to ground ...	- 40

Such an estimate is only very rough, but it shows that in this locality the four processes may balance or even give rise to an excess negative charge. It is to be noted that the charge transference produced by thunderclouds is not confined between cloud and ground but may be equally active in passing positive charge from cloud to upper atmosphere.

Thus the thunderstorm (or shower cloud, not necessarily producing thunder) may be regarded as an electrical generator which transports positive charge from the ground and supplies it to the conducting layers of the high atmosphere, where it is rapidly distributed so as to maintain those levels at an approximately constant potential of about a million volts. From time to time during the life of this generator its internal resistance, generally high on account of the immobilisation of ions by attachment to cloud droplets, may be less than that of the " external circuit ", i.e. from cloud to ground and from cloud to upper atmosphere. If a sufficient voltage difference has been generated by the cloud the generator may then be " short-circuited " by a lightning flash passing from pole to pole of the cloud. A highly schematic picture of these charge transference processes is given in Fig. 1.

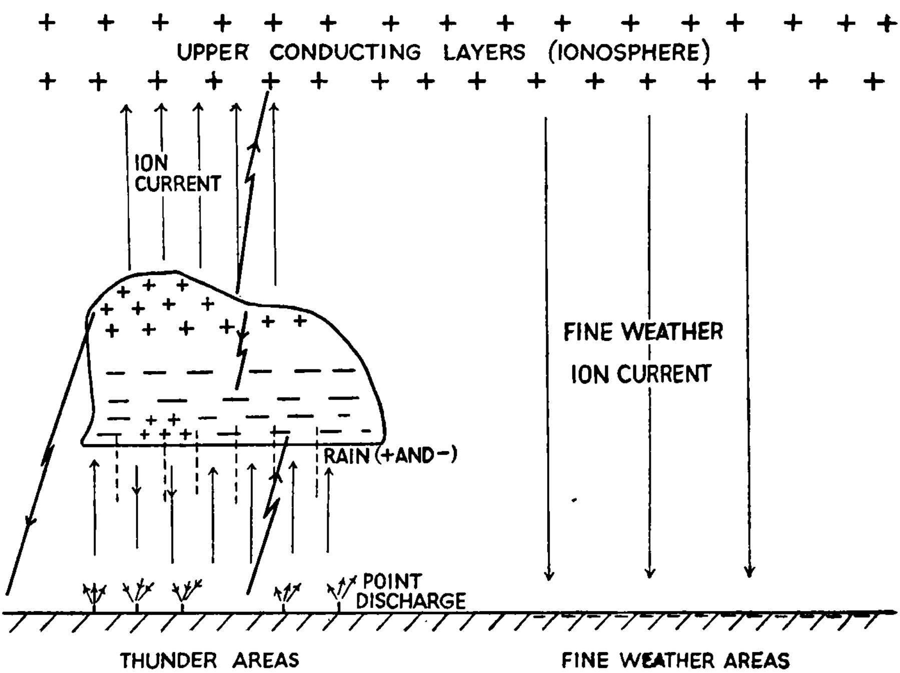


FIG. 1.—THE CIRCULATION OF ELECTRICITY IN THE ATMOSPHERE. (SCHEMATIC.)

Lightning is shown by zigzag lines, ion current by vertical lines, point discharge by branched lines, and precipitation current by pecked lines. The arrows indicate the direction of positive charge transference.

If the above view be accepted certain consequences are to be expected in regard to the variation of the electric field in fine weather areas. When thunderstorms are most active the potential of the upper conducting layers will be a maximum and this will be reflected in the magnitude of the fine weather field near the ground unless atmospheric pollution or other local influences exert a dominating effect. Whipple (2) has in fact shown that a marked parallelism exists between the diurnal variation in electric field strength over the oceans and in the Arctic and the diurnal variation in thunderstorm activity integrated over the whole globe. (Fig. 2.)

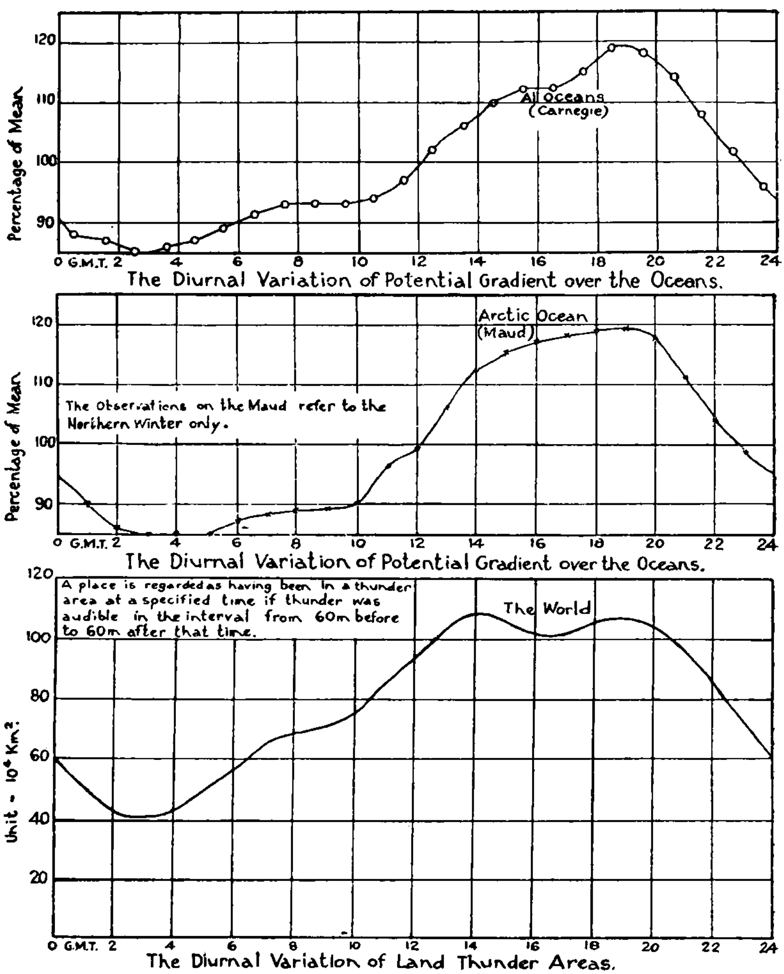


FIG. 2.—A. VARIATION OF POTENTIAL GRADIENT WITH UNIVERSAL TIME. (UPPER TWO CURVES.)

B.—VARIATION OF THUNDERSTORM ACTIVITY OVER THE EARTH'S SURFACE. (LOWER CURVE.)

The charge circulation process described above is thus able in a general way to account for the maintenance of the earth's electric field. The important question of the mechanism whereby the charge separation is brought about is not yet, however, completely answered. Of recent investigations the most significant is that of Simpson and Scrase(3) who explored the charge distribution below, in, and above thunderclouds by means of sounding balloons which carried an original type of potential gradient recorder. Their results are consistent with those of earlier ground observers that thunderclouds are mostly of positive polarity, but in addition they found that the main region of charge separation is above the freezing point level. From this they infer that one at least of the major charge separation processes is connected with the frictional charge developed by colliding ice particles. Electric field observations in clouds of drift snow show that considerable charge separation occurs in such clouds. Simpson and Scrase also found local centres of large positive charge near the base of some thunderclouds, which they attribute to the positive charge acquired by water drops when disrupted by an air blast. The possible processes giving rise to ionisation and charge separation in thunderclouds are not, however, confined to the two mechanisms already mentioned, and it remains a question which of the possible processes are most responsible for the electric fields produced. Further experimental investigations must be made before a solution can be given.

There is no space in this article to consider other aspects of atmospheric electricity in any detail. Some additional features may, however, be mentioned.

Observations in atmospheric electricity have, in the past, most frequently been concerned with the electric field near the ground. This has been a rather unfortunate choice in some respects, since the field is here markedly controlled by the electrical characteristics of the atmosphere near the ground. On this account the more fundamental variations in the fine weather field, as shown e.g. in Fig. 2, were for long obscured. The more fundamental entity is the air-earth current, which, controlled by the potential difference between the ground and the upper conducting layers and by the total effective resistance of the atmosphere between these levels, shows much smaller local influence than does the field. The current, under equilibrium conditions, must be the same at all heights, whilst the electric field at any height adjusts itself to the value of the resistance at that height.

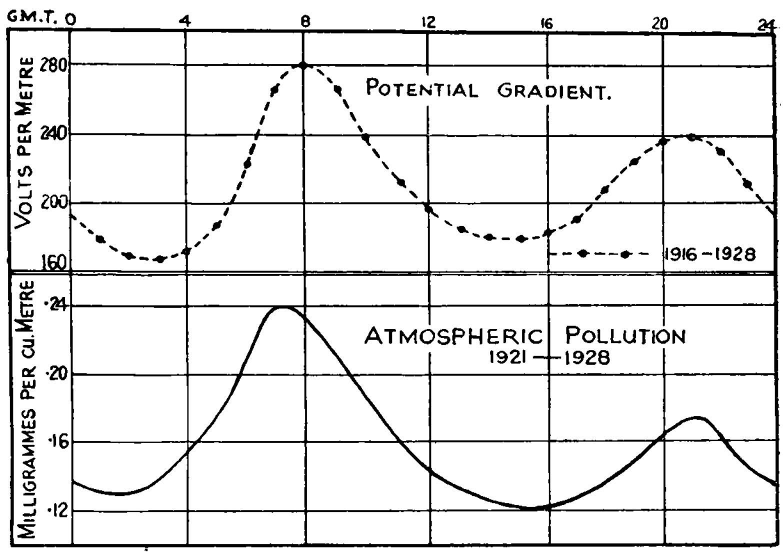


FIG. 3.—DIURNAL VARIATION OF POTENTIAL GRADIENT AND OF ATMOSPHERIC POLLUTION IN SUMMER AT KEW OBSERVATORY.

Continuous records of field strength are, however, much more easily obtained than those of current, and it has been of interest to see how the variations of field strength in urban areas may be accounted for by a combination of the effects of atmospheric pollution production (more strictly, sub-microscopic nuclei) and wind turbulence. Diurnal variation in the rate of production of nuclei and in atmospheric diffusion together give a curve for diurnal variation in the concentration of nuclei near the ground, which is in very marked sympathy with the diurnal curve of field strength, as shown by Whipple(4) for Kew. (Fig. 3.)

The conductivity of the atmosphere arises from ionising radiations having their origin in the earth's crust (earth radiation), in the air (air radiation), and in outer space (cosmic radiation). Near the earth's surface, except over the sea, the main source of ionisation is earth and air radiation, whose intensities vary with locality, with state of surface and other meteorological factors. It may be that the intensity of these radiations has some connection with the enervating or invigorating quality of local climate; at least this factor should not be overlooked in seeking an explanation of these climatic differences.

To conclude, atmospheric electricity is a subject possessing considerable interest on its own account. It is also very much a part of meteorology as normally considered since it and weather are so closely inter-related. Certainly an understanding of weather processes is essential to the unravelling of atmospheric electrical problems and it may be that, in the reverse sense, the study of the subject will aid materially in our knowledge of some of the more direct meteorological problems of our atmosphere.

REFERENCES.

(1) Wormell, T. W. London, *Proc. roy. Soc. A,* 1930, 127, p. 589.
(2) Whipple, F. J. W. London, *Quart. J. R. Met. Soc.,* 1929, 55, p. 1.
(3) Simpson, Sir G. C., and Scrase, F. J. London, *Proc. roy. Soc. A.,* 1937, 161, p. 309.
(4) Whipple, F. J. W. London, *Quart. J. R. Met. Soc.,* 1929, 55, p. 351.

REMARKABLE PRESSURE FLUCTUATION IN THE VALE OF YORK

By R. G. Veryard, B.Sc.

At 7h. G.M.T. on February 12th, 1939, the synoptic report from Catterick gave the pressure reduced to sea-level as 1005·6 mbs. and the wind as W by S, force 8, i.e. gale force. Since this pressure did not seem to fit with the general run of the isobars it was thought that the barometer might have been read incorrectly, and the reading was therefore not published in the British Section of the *Daily Weather Report.* An examination of the barograph chart from Catterick showed, however, that the pressure of 1005·6 mbs. was quite correct and that as reported by the observer, there had been a fall of 6 mbs. between 4h. and 7h. G.M.T. The anemograph also confirmed the westerly gale which lasted for more than an hour.

Fig. 1 shows the pressure distribution over the British Isles at 7h. G.M.T. on February 12th, after isobars have been drawn to conform as accurately as possible to all the available data. It will be seen that there is a small low-pressure system in the Vale of York with its centre a little to the north of Catterick.

At first it was thought that the drawing of the isobars over Durham and north Yorkshire as a trough might be the correct solution. There was a strong westerly gradient and it was not unreasonable to consider whether, in these circumstances, the chain of the Pennines, which runs mainly north and south, might not account for a trough of low-pressure on the lee-side, such a trough being not uncommon with a strong wind blowing at right angles to a range of hills. An examination of the barograph chart from Tynemouth showed, however, that such a drawing of the isobars would have been incorrect since the pressure there did not fall below 1008 mbs. at or about

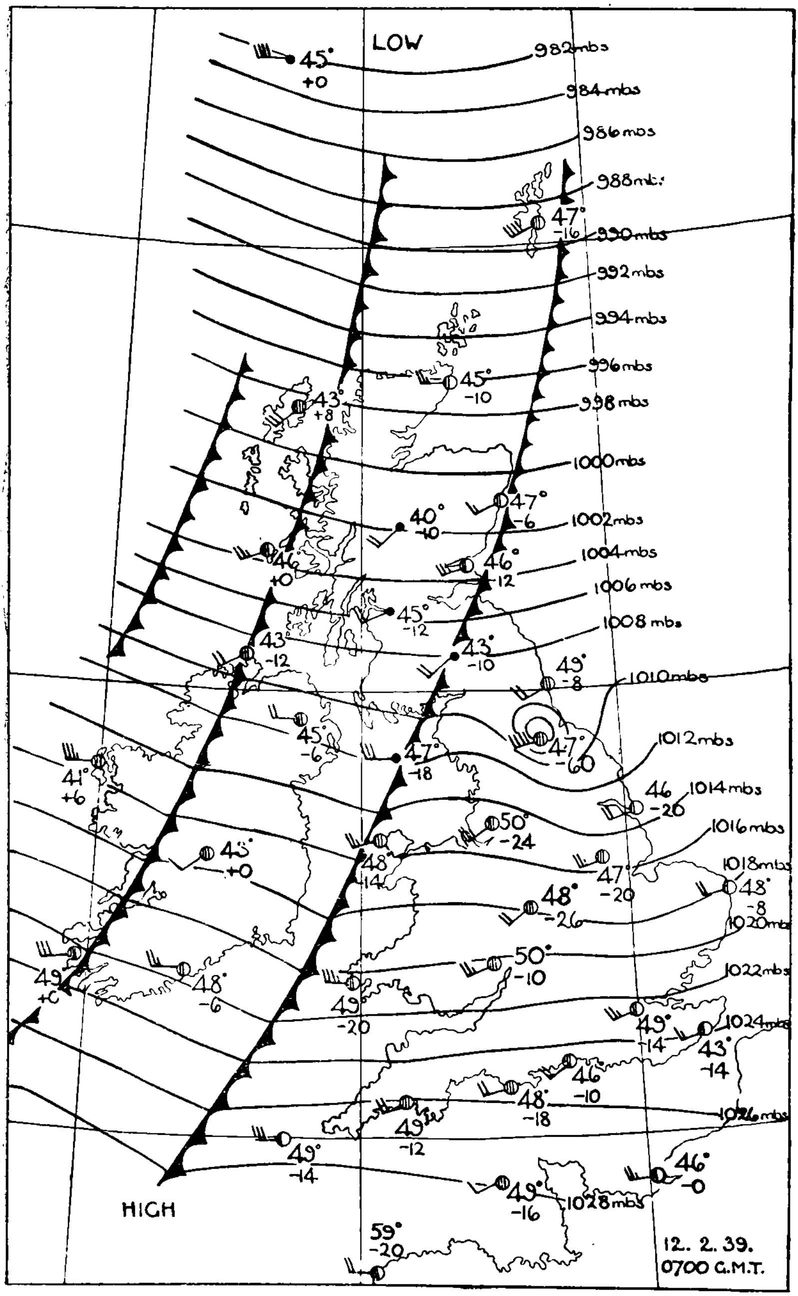


FIG. 1.—PRESSURE DISTRIBUTION OVER THE BRITISH ISLES AT 7H. G.M.T. ON FEB. 12TH, 1939.

the time in question. On the other hand, the anemograph chart from Durham shows that the wind was from a westerly point all the morning. The closed isobars must therefore have embraced a very small area. Unfortunately, no useful observations are available for the area between Catterick and Durham, but barograph charts from Dishforth and Linton-on-Ouse confirm the existence of the low-pressure system to the south of Catterick.

Charts of recording instruments from stations to the west of Catterick were carefully examined to see whether the disturbance could be identified on the windward side of the Pennines but the result was negative; neither was any indication found of the persistence or development of the disturbance in an easterly direction. There is little doubt, therefore, that this small rotary system had a very short life and that it was formed " locally ", i.e. on the lee side of the Pennines.

On February 11th, a cold front passed across the British Isles bringing in its wake a stream of rather unstable polar air. Pressure, which had been falling ahead of this front, steadied and rose temporarily with the passage of the front but then continued its downward path ahead of a secondary cold front which at 7h. G.M.T. on the 12th extended, approximately, from the east coast of Scotland through the Isle of Man to St. George's Channel. (At the same time there was a second but less well defined minor cold front along the west of Scotland and probably a third about 90 miles farther to the west.) This secondary cold front passed through Catterick, at least at the surface, between 9h. and 9h. 30m. G.M.T.: Fig. 2 shows the relevant portions of the autographic records at Catterick. It will be noted that the passage of the front was not accompanied by any noticeable drop of temperature at the surface. (The upper air temperature observations at Aldergrove show a fall of five to six degrees up to about 10,000 feet between 7h. 45m. on the 12th and 7h. 15m. on the 13th—see Fig. 3.) At Durham a sudden fall of 2° F. occurred at 9h. 30m.; there was also a sharp drop of temperature with the passage of the

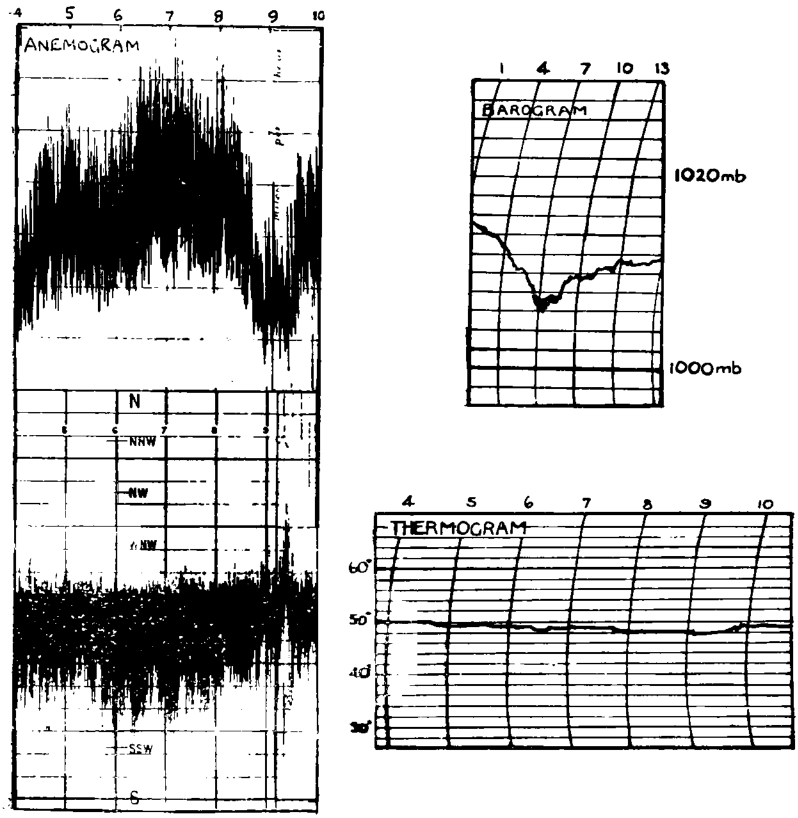


FIG. 2.—AUTOGRAPHIC RECORDS AT CATTERICK, FEB. 12TH, 1939.

front at Dun Fell in Durham, 2,735 ft. above M.S.L. Light showers occurred just ahead of the front at Catterick but none in the immediate rear of the front because, presumably, the lower layers of the air over Catterick were then descending*.

The observations at Catterick show that at no time was the sky completely overcast. At 7h. there were seven to eight tenths of strato-cumulus cloud, before 8h. a layer of alto-cumulus appeared, and cumuli-form cloud, both low and medium, persisted behind the front, although after its passage at the surface the amount of

* Very squally showers of rain, hail and snow were experienced over the Pennines.

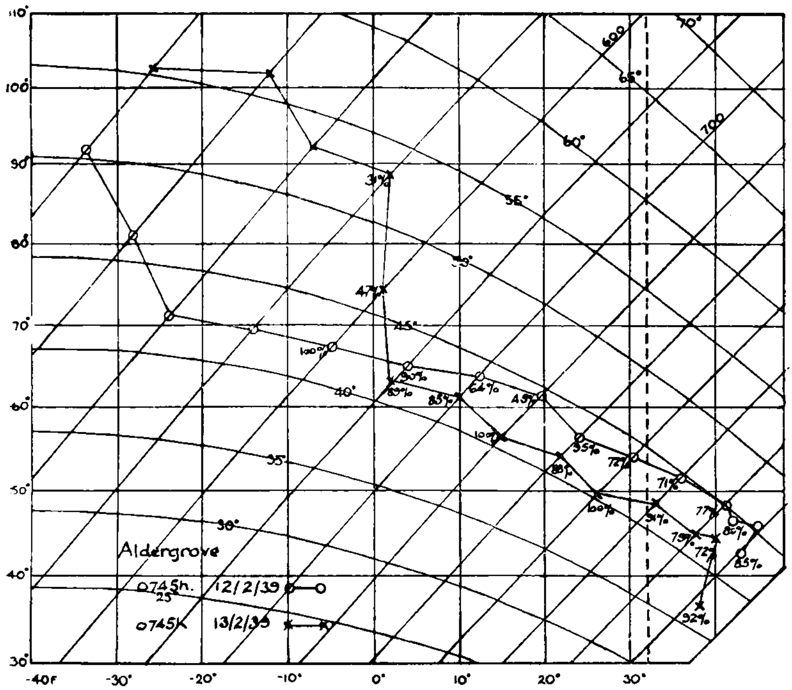


FIG. 3.—UPPER AIR TEMPERATURES AT ALDERGROVE.
FEB. 12TH, 1939, 7H. 45M. to FEB. 13TH, 1939, 7H. 15M.

low cumulus cloud decreased to less than four tenths. Similar conditions were observed at Linton-on-Ouse to the south and at Acklington to the north. An indication that the small low-pressure system was very shallow is given by the barogram from Ampleforth which showed a fall of 2 mbs. only, between 4h. and 7h. compared with 6 mbs. at Catterick during the same period. Ampleforth, which is 25 miles east-south-east of Catterick, is over 400 feet above sea level. At 9h. a pilot balloon ascent was made at Catterick and the observations revealed winds of 65 km/hr. from 270° at 1,000 metres, 100 km/hr. from 260° at 500 metres, and 50 km/hr. from 260° at the surface. Pressure ceased to fall at Catterick at 7h., rose slightly for about 2 hours and then jumped by more than 2 mbs. in a few minutes.

It is tempting to imagine that by 7h., the " nose " of the cold air had advanced across the Pennines to a point almost above Catterick, but, as Mr. C. K. M. Douglas has pointed out to the writer, actual overhanging of the "nose" of cold air at the front itself has a much smaller horizontal scale. No upper air temperatures are available to indicate the thermal state of the air in which the rotary system actually formed, but it is known that a fall of temperature aloft often precedes a cold front at the surface. The fact that there had been showers indicates that the air was unstable, or potentially so. Hence the overrunning cold air, or, shall we say, the fall of temperature up above, would increase the local instability of the air over the Vale of York.

It is therefore thought that this instability was partly responsible for the formation of the disturbance. It is known that small rotary systems often form in unstable air but as yet there has been no detailed investigation of these phenomena. Such an investigation cannot be carried out without adequate data and the data required in this case would, in view of the small size of the disturbance, necessitate a close net-work of observing stations and adequate upper-air as well as surface observations. Unfortunately, the data available are very scanty.

An important but not the sole cause of the phenomenon would appear to have been the effect of the hills in producing eddies. It is suggested that, in this connection, the work of Fujiwhara (1) who observed the behaviour of whirls in water, may furnish a clue to the formation of the small disturbance in question (although it is realised that Fujiwhara's work may not account for the formation of really large low-pressure systems). He found that small whirls tend to approach and amalgamate, giving larger whirls. The existence of eddies on the leeward side of hills is very well known. The work of Georgii and others (2) shows that the turbulence is most pronounced with strong winds and unstable air. Fig. 4 gives an idea of the position of

---

(1) Brunt, D., "Physical and Dynamical Meteorology," 1934, pp. 300–1.

(2) Morgans, W. R., *Air Ministry R. & M. Report, No. 1456,* 1932, pp. 18–27.

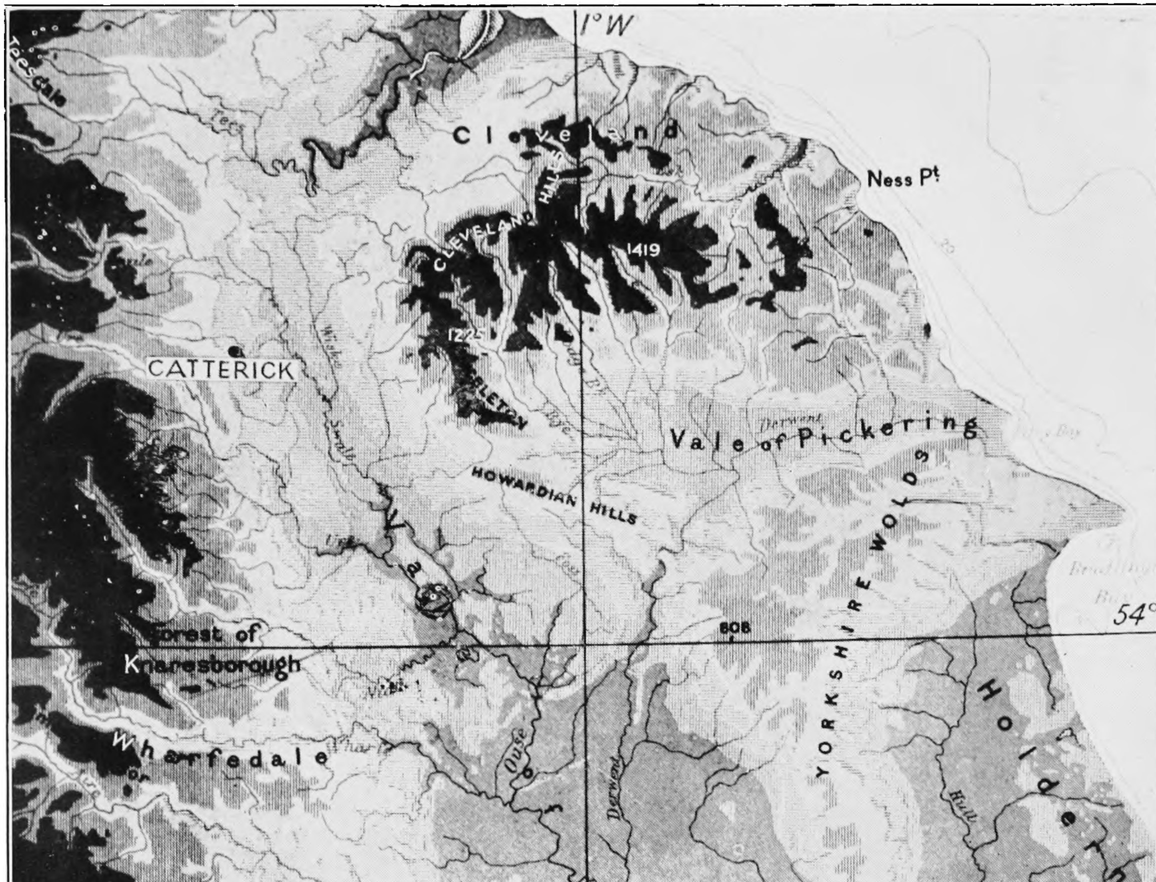


Fig. 4.—Topography of the area around Catterick.

Catterick in relation to the Pennines. It will be seen how the chain of hills is broken by the valleys of the Swale, Ure, and Nidd. There is little doubt that topography was a contributory factor in the formation of the whirl.

One may presume that the general fall of pressure ahead of the secondary cold front was due to divergence in the upper layers, but about one-half of the fall of pressure at Catterick must have been due to divergence associated with the whirl itself. That is to say, in addition to general convergence in the lower layers ahead of the front, there must have been local convergence associated, probably, with thermal convection. As the mechanism of these small rotary systems, embedded in a more or less solid current of air, is unknown and since adequate data are not available it is not possible to explain the actual eviction of air which must have taken place. One might say that the reduction of pressure at the core of the disturbance was due to spin, or vice-versa ! Perhaps the theory of Durst and Sutcliffe (3) concerning the development of tropical revolving storms might apply in this case?

It would appear that the phenomenon in question is not entirely new to the Vale of York. Mr. Burridge, of the Catterick Meteorological Office states that, when there is a flow of unstable air from a westerly point, there is often a marked oscillation in the wind direction and velocity; in fact, the wind-vane sometimes makes several revolutions in quite a short period. An example of this is shown in Fig. 5 which gives a section of the anemograph charts for March 8th and 9th, 1938. These occasions were brought to the notice of the writer by Mr. F. Davies of the Dishforth Meteorological Office. Mr. Davies states that, when there is a westerly gradient, the force of the wind at the surface at Dishforth is often as much as the geostrophic wind-speed, or even a little more. He adds that on such occasions pilots have often reported

(3) Durst, C. S., and Sutcliffe, R. C., London, *Q. J. R., Meteor. Soc.*, 64, 1938, p. 75.

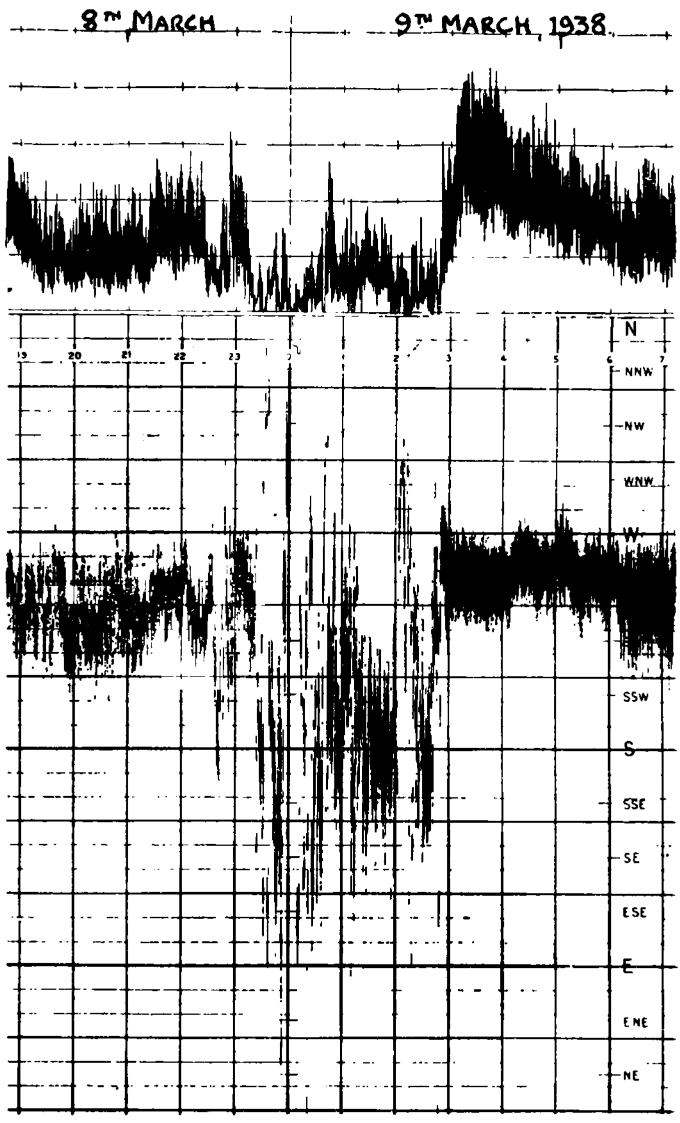


FIG. 5.—CATTERICK ANEMOGRAM.
MARCH 8TH, 1938, 19H. TO MARCH 9TH, 1938, 6H.

excessive bumpiness. It may be that, with westerly winds, the valleys such as Wensleydale which intersect the Pennines roughly from east to west produce some kind of funnel effect similar to that which is known to occur in the Firth of Forth.

LETTERS TO THE EDITOR

Circumzenithal Arc at Wittering, Northants

The circumzenithal arc was noted twice between February 17th and 19th, 1939. On February 17th at 11h. 20m. G.M.T. a sheet of thin alto-stratus was breaking up and a sheet of apparently very thin cirro-stratus could be seen. By 11h. 40m. G.M.T. the 22½° halo was visible with a well coloured parhelion to the left of the sun and a much fainter one to the right. The halo itself displayed faint colour effects only. A small upper portion of the 46° halo was also visible together with the circumzenithal arc (the latter being rather poor as regards colours). During the next hour the phenomena slowly faded with the exception of the circumzenithal arc—this gradually increased in its intensity and at 12h. 25m. G.M.T. was very brilliant against blue sky (the only cirro-stratus visible at this time being in another sector of the sky). The arc continued brilliant for another 15 minutes and was then obscured by the passage of lower cloud.

The second occasion was on February 19th between 12h. and 13h. G.M.T. In this case the sky was partly covered with thick and coarse looking bands of cirrus—no typical cirro-stratus could be seen. The 22½° halo was visible (as a whitish ring) with finely marked parhelia to the right and left of the sun (the colour effects were strong). A very faint upper portion of the 46° halo was noted at 12h. 45m. G.M.T. with a good circumzenithal arc, the latter showing strong colours. The whole phenomenon remained visible for some 20 minutes from 12h. 45m. and then quickly faded as the clouds thickened and fused together.

The circumzenithal arc was again noted on March 2nd. The time of the arc's appearance was 15h. 50m. A very small portion of the 22½° halo was also visible. The general conditions of the sky at the time of observation to-day were: —Alto-cumulus and alto-stratus with patches of lenticular alto-cumulus (the latter displaying subdued irisation and resembling the rare nacreous clouds in the merging of the colours), these medium clouds covered some seven-tenths of the sky. There was however about two-tenths of striated cirro-stratus in which the circumzenithal arc was plainly visible for a period of ten minutes. The colours were of a moderate intensity.

W. F. WATSON.

Meteorological Office, Wittering, Northants.
March 2nd, 1939.

Cirriform Clouds observed in Southern Rhodesia

In connection with Mr. S. T. A. Mirrlees' article " Some unusual observations of cirriform clouds ", in this Magazine for November, 1938, similar clouds are illustrated in an article " The Contax and Cloud Study at Manila " by Rev. C. E. Depperman, S.J., published by Zeiss Ikon in *Photographie und Forschung,* October, 1936. In the discussion the author states—

" Attention is especially invited to the two Figures III and IV, in which we have profuse virgae *below* what seems definitely Alto-cumulus. Note that the virgae appear to be of Cirrus type, but yet Cirrus is formed of ice-crystals and Alto-cumulus of water droplets; how then could the ice-crystals be below the water droplets? A possible explanation might be that the Alto-cumulus is just above a decided temperature inversion, the virgae just below, and hence the temperature below could be lower than that above; but the writer is inclined to believe that the virgae shown are formed of water droplets in spite of their delicate texture and are only a clever imitation of Cirrus virgae."

Similar phenomena were observed recently over a wide area of Southern Rhodesia. The cause appears to have been a stationary occlusion. A polar air outbreak had surrounded and was slowly lifting a body of moist equatorial air. Virga was seen below thick alto-stratus clouds for several days. The alto-stratus gradually thinned out and finally broke up into alto-cumulus on November 25th, virga still being present. An aeroplane flight by the Rhodesian Air Unit recorded a temperature of 0° C. at 14,000 feet, and just reached the alto-cumulus level at 17,000 feet, where the temperature was - 5° C., but showing definite signs of an inversion. It therefore appears probable that the alto-cumulus cloud would be composed mainly of liquid and frozen water drops, while turbulence in the lower part of the cloud would result in the formation of ice crystals. Under these circumstances, one would expect both frozen water drops and ice crystals in the virga.

J. S. PEAKE.

Rhodesia Meteorological Service.
December 12th, 1938.

River Temperatures

On looking through the records of the temperature of the River Clwyd at Trefnant for last winter I came across the following facts.

At mid-day on January 6th, 1939, the temperature of the water was 33·9° F. The grass minimum temperature the previous night was 3° F. and the air temperature at mid-day had risen to about 26° F., as the thaw was approaching. There was some ice in the river which is very unusual owing to the rapid current. The air temperature reached 33° F. by 21h. on the same day, and it gradually rose until at mid-day on January 8th it was 52° F. At this hour the temperature of the river water was 47·2° F., a remarkable rise of 13·3° F. in 48 hours.

I should be glad if anyone could explain how such a big rise of temperature could take place. The river flooded very badly, but this was chiefly due to melting snow from the mountains, not to rainfall. As so much of the heat transferred from the warm air to the snow goes to provide the latent heat of the snow-water, I am at a loss to account for the large rise of temperature of that water in so short a time.

S. E. ASHMORE.

Llannerch Gardens, St. Asaph, Flintshire, North Wales.
April 14th, 1939.

NOTES AND NEWS

The First Pressure-Tube Anemometer.

Among recent acquisitions of the Science Museum is one of particular interest to meteorologists, namely the recording portion of a pressure tube anemometer, which is believed to be the first instrument of this type ever manufactured. The introduction of the pressure tube anemometer marked a new epoch in anemometry, as by its record of the gusts it enabled the detailed structure of the wind to be studied whereas former instruments which were almost exclusively of the " cup " type, gave the mean wind over a period only. In 1892 Mr. W. H. Dines described the principle of the pressure tube anemometer in the *Quarterly Journal of the Royal Meteorological Society,* and at about the same date the first instrument was set up in his house at Oxshott, Surrey, being subsequently transferred to Pyrton Hill, Oxfordshire, and later to Benson. The instrument was in continuous use for almost 40 years, after which it was stored until its presentation to the Science Museum by Mr. Dines' eldest son, Mr. L. H. G. Dines. The recorder was made by Mr. R. W. Munro, the founder of the present firm of that name, who collaborated with Mr. Dines in the design. It was not, unfortunately, given a serial number, and there is therefore no absolute proof that this was the first instrument manufactured. The indirect evidence however is very strong as there can be little doubt that Mr. Dines would have received the first instrument made by Mr. Munro for test before other instruments were made for sale. Another early instrument of similar pattern is to be found in the Meteorological Office Museum at South Kensington. This is probably the first pressure tube anemometer which was used by the Meteorological Office. One detail in its construction proves that it was of slightly later date than the one recently presented to the Science Museum. These old instruments differ from the modern pattern in that the buoyancy portion of the float surrounds the vertical cylinder instead of being contained within it. The float is therefore of much larger diameter and the whole instrument more bulky. The velocity scale is identical, namely ·6 in. per 10 mi/hr. The pressure tube anemometer has, since its introduction, become known over almost the whole of the globe. It is in wide use in this country and in the Dominions and Colonies, while instruments have also been sold to many foreign countries.

J. S. D.

Royal Meteorological Society.

The usual monthly meeting of the Society was held on Wednesday, May 17th, in the Society's rooms at 49, Cromwell Road, South Kensington. Dr. F. J. W. Whipple, F.Inst.P., Vice-President, was in the Chair.

The following papers were read and discussed:—

The seasonal and geographical distribution of absolute drought in England.—By Miss L. F. Lewis, B.Sc.

Records at nine stations with long records show that a large number of absolute droughts is experienced in south-east England and the southern Midlands compared with north-east England, although the average annual rainfall is approximately the same in each case; a greater number of absolute droughts is recorded at Liverpool than at Stonyhurst, due to the shelter afforded to Liverpool from the moist south-west winds by the Welsh mountains and the greater height of Stonyhurst above mean sea level; a larger number of absolute droughts is experienced on the south-east coast than on the more unsettled south-west coast. The seasonal incidence of absolute drought is next investigated. The results are shown graphically on a single diagram, with the days of the year as abscissæ and the number of occasions of absolute drought as ordinates. Finally the odds to one against a "drought-day" (a day which has been included in a period of absolute drought) are evaluated for each calendar month at each station.

Evaporation over catchment areas, II.—By D. Lloyd, M.Eng.

Information has been extracted from Government sources relating to drainage areas situate in northern Italy. Values of general rainfall, loss and weather details are tabulated. The provisional formula, advanced recently to estimate the probable loss by evaporation over catchment areas, is applied to these data. The values of loss, expected on account of the weather and permeability of sub-surface, are shown to be of the right magnitude.

The distribution of wet-bulb potential temperature in four selected cyclones.—By A. M. Firesah, M.Sc.

The distribution of wet-bulb potential temperature has been investigated in four cyclones, each by means of serial sounding balloon ascents made at one station. The results are plotted as though they represented observations along a vertical cross-section through the moving cyclone. Lines of equal wet-bulb potential temperature are drawn, and these are found to show a characteristic form of distribution at warm fronts, cold fronts and occlusions. At warm fronts the lines are closely crowded together. At cold fronts they show a nose raised some kilometres above the ground, the wet-bulb potential temperature decreasing with height in the air below the nose. The air in this region usually shows marked latent instability capable of being realised after only relatively small upward displacement. At occlusions the lines of equal wet-bulb potential temperature have a pronounced V-shaped form.

Magnetic Observations in Bavaria

In 1840 J. von. Lamont founded the Magnetic Observatory of Munich. Observations and investigations of terrestrial magnetism continued regularly until 1925, after which they have been carried on at a provisional magnetic observatory in Maisach. We learn from Dr. Friedrich Burmeister that this work will now be continued at the Observatory for Terrestrial Magnetism at Fürstenfeldbruck, 26 km. west of Munich. In February 1940 the centenary of the regular observation of terrestrial magnetism in Bavaria will be celebrated.

Auroral Notes for April 1939

Active aurora was seen on the nights of April 17th and 24th. For the night of the 17th the only report comes from Lerwick Observatory (Shetland). Coronae and pulsating surfaces were seen from 21h. 0m. till 21h. 30m. G.M.T. The corona then faded, and aurora of the type known as " flaming " in Störmer's classification, with a period of 1 second, was observed for a few minutes. Activity continued, with rays and pulsating surfaces, till shortly after 22h., when cloud prevented further observation. The greatest intensity was at 21h. 42m.

On the night of the 24th–25th aurora was seen until 3h. from several places in the east and north of Scotland, including Lerwick, and until daylight from Dunnet Head Lighthouse (Caithness). From Leuchars, Mr. A. Simpson of the Meteorological Office reports that at 22h. 45m., when the clouds broke, there was an almost perfect corona of white rays overhead. A curtain of white rays extended northwards and spread till it reached from west round to east. The corona moved eastward and faded soon afterwards. At 23h. 30m. the curtain in the north became very bright and of a faint green colour; five minutes later another white corona formed overhead, moved away to the east and faded, while the curtain increased in intensity and became reddish in tinge. A corona formed again a little to the west at 23h. 50m., very bright and faintly green, extending westward to a homogeneous arc at an elevation of about 20°. At this time aurora was first seen at Holyhead, where Mr. Forbes-Bentley of the Meteorological Office reports that there was a steady white arc from about west to north-east. Cloud then began to interfere with observations at Leuchars, but there were signs of activity until 1h. G.M.T.

At Holyhead conditions were perfect after 1h. 15m. At about this time flaming aurora was seen, the waves occurring at the rate of nine per second. The flaming continued until after 3h., with maximum intensity at 2h. 0m.

A report from Mr. E. L. Hawke says that at 3h. 5m. G.M.T. on the same morning the Rev. H. E. Ruddy of Aston Clinton Rectory, near Aylesbury, Bucks, saw a broad upright streamer about 15° west of north and a few minutes later a second thinner streamer beside it at 20° west of north.

On April 26th two large sunspots passed the sun's central meridan.*

D. N. HARRISON.

Severe thunderstorms with heavy rain on June 19th, 1256

Matthew Paris gives us the following account:—

And the third day following, an extraordinary storm of wind and rain, or rather driving rain, with hail and thunder and vivid lightning, filled the souls of men with fear and immense damage was sustained through the disturbance. The mill wheels were seen to be wrenched

---

* *Nature*, Vol. 143, p. 717 (April 29th, 1939).

off their axles, and transported by the force of the waters to great distances, destroying neighbouring houses. And what the waters did to the water mills, the wind did not spare to do to the windmills. The piles of bridges, stacks of hay, huts of fishermen, with their nets and poles, and even babies in cradles were suddenly carried away, so that it looked as if the floods of Deucalion were come again. And not to mention other cases, Bedford, which is watered by a river called Ouse, as it did a few years before, suffered damage beyond estimation. Indeed, in one place, a block of six adjacent houses was transported by the rapid torrents, the inhabitants hardly being able to crawl out of them. And other places on the banks of this river were exposed to similar perils.

C. E. BRITTON.

Sunshine, May 1939

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

	Total hrs.	Diff. from average hrs.		Total hrs.	Diff. from average hrs.
Stornoway ..	175	− 4	Chester ..	189	+23
Aberdeen ..	160	−10	Ross-on-Wye	194	+ 8
Dublin ..	194	+14	Falmouth ..	240	+33
Birr Castle ..	189	+20	Gorleston ..	210	−13
Valentia ..	255	+71	Kew.. ..	194	− 4

Kew temperature, mean, 53·2° F. : diff. from average, −1·3° F.

OBITUARY

SIR FRANK DYSON, D.Sc., F.R.S. It is with much regret that we announce the death on May 25th, 1939, of Sir Frank Dyson, Astronomer Royal at Greenwich, 1910–33. Sir Frank had been associated with Greenwich Observatory since 1894 when he was appointed chief assistant. In 1905 he became Astronomer Royal for Scotland, and held that post until he returned to Greenwich in 1910. The work of Greenwich Observatory was extended in various new directions under Dyson's administration, and he took especial care that the observational work was of the highest quality. One aspect of his work that interested him greatly and which had wide public attention was the research on solar eclipses, and the expeditions arranged in connection with these, notably those of 1919 and 1927. His "Eclipses of the Sun and Moon" written in collaboration with Dr. R. Woolley, published in 1937, is the standard work on the subject. Another of his interests was time-keeping and the craft of clock-making; he initiated the "six-pips" time signal now so well known to listeners. Sir Frank was for many years a fellow of the Royal Meteorological Society and the meteorological work at Greenwich was continued under his directorship on the well-established lines subsisting from the days of Airy and Glaisher. He was a man of engaging personality and his charm of manner and gentle humour will long be remembered by those who had the privilege of associating with him.

MR. C. L. BROOK, who died on May 9th, 1939, in his 84th year, started a rainfall record at Harewood Lodge, Meltham, Yorkshire, in 1881 and a second record on the moors at Royd Edge in 1891. His rainfall record at Harewood Lodge covers therefore over 58 years. In addition earth thermometer records were forwarded for publication in the *Meteorological Record* of the Royal Meteorological Society from 1899 to 1911 and general meteorological observations were published in the *Monthly Weather Report* from 1912 up to date.

Mr. Brook was one of the Trustees of the British Rainfall Organization from 1910 until it was taken over by the Government in 1919. The following comments are quoted from Dr. Mill's article in *British Rainfall*, 1909, p. 36: "It appeared to me that the first Trustees of the British Rainfall Organization should be chosen from amongst the rainfall observers, especially from those who were intimately acquainted with the work of the organization . . . . The nine Observers who have joined me as Trustees are known to most of my readers . . . . Mr. C. L. Brook was an old friend of Mr. Symons, and one of the most liberal supporters of the Rainfall Organization; he represents in a special sense the north of England."

With the death of Mr. Brook we lose one of our few remaining links with G. J. Symons and the pioneers in the study of British Rainfall.

CHARLES WEBSTER. We regret to learn of the death on May 9th of Mr. Charles Webster in his 81st year. Mr. Webster was formerly head gardener to the Duke of Richmond and Gordon and maintained full climatological observations at Gordon Castle, Morayshire, from 1891 until his retirement in 1937. His meteorological observations actually covered the long period of 58 years as he assisted his father who had charge of the station from 1879. Mr. Webster's capabilities as a grower and judge, especially in the culture of fruit, were widely recognised.

REVIEWS

British Health Resorts. (Official Handbook of the British Health Resorts Association) London, 1939. $9\frac{1}{2} \times 6$, pp. 320, illus. Price 2*s*. 6*d*. net.

Our varied coasts, looking west to the Atlantic, or east and north to the North Sea, and south to the Channel, provide a great variety of climates. Inland we have a number of spas and hot springs, such as Bath, and some bracing hill stations, and the seeker after health, whether holiday-maker or invalid, has a wide choice from which to satisfy his individual requirements. The British Health Resorts Association is doing a great public service by making readily available, in its Official Handbook, climatological data and medical information for a wide range of these resorts. The Association is a purely voluntary body, including many well-known doctors, and the medical parts of the Handbook are revised by a representative Medical Advisory Committee. The Handbook deals first with the spas, then with the seaside resorts in alphabetical order, next with some inland resorts and finally with the healthful attractions of Australia, Cyprus and South Africa. The climatological statistics are mostly those of interest to invalids, being limited to the winter months (November to March), while the temperatures are expressed as the numbers of "outdoor" and "indoor" days. The figures show that quite a number of places in Great Britain are suitable for winter resorts. There are interesting articles by Mr. Bonacina on "Climate, health and the British resorts" and by the Editor, Dr. R. Fortescue Fox, on "The climates of the British coast."

Meteorological Organization for Airmen. New Delhi, India, Met. Dept., M.O.A. Pamphlet, 1939.

Meteorological services are among the essential ancillary facilities necessary for safe air navigation. The keenness of a government's perception of the importance of air services may be judged by the nature of the facilities provided and on this basis it appears that the Government of India is very wide awake to the value to that great country and the Empire of the new means of transport. Details of the comprehensive meteorological facilities provided for both private and air-line pilots in India are given in this pamphlet. A notable advance since the publication of the 1937 edition is the change from the use of local forms to international forms of messages and altogether the India Meteorological Department is to be congratulated on the form and substance of this pamphlet, which with its appendices runs to 66 pages and includes a map indicating the position and type of numerous meteorological stations.

J. S. F.

Rainfall: May 1939: England and Wales

Co.	Station.	In.	Per cent of Av.	Co.	Station.	In.	Per cent of Av.
Lond'n	Camden Square......	1·33	76	*Warw*	Birminghm, Edgbaston	1·09	51
Surrey	Reigate, Wray Pk. Rd.	1·58	87	*Leics* .	Thornton Reservoir...	1·50	75
Kent .	Tenterden, Ashenden.	1·56	99	,, .	Belvoir Castle........	1·11	53
,, .	Folkestone, I. Hospital	1·38	..	*Rutl'd*	Ridlington	·74	37
,, .	Margate, Cliftonville..	2·01	127	*Lincs*.	Boston, Skirbeck.....	·81	46
,, .	Edenb'dg.,Falconhurst	1·45	78	,, .	Cranwell Aerodrome..	1·01	56
Sussex	Compton, Compton Ho	1·63	73	,, .	Skegness, Marine Gdns	·66	39
,, .	Patching Farm.......	1·28	69	,, .	Louth, Westgate.....	1·24	61
,, .	Eastbourne, Wil. Sq..	·97	58	,, .	Brigg, Wrawby St....	1·29	..
Hants.	Ventnor, Roy.Nat.Hos.	1·56	92	*Notts* .	Mansfield, Carr Bank..	1·29	61
,, .	Southampton, East Pk	1·30	65	*Derby*.	Derby, The Arboretum	·98	49
,, .	Ovington Rectory....	1·17	54	,, .	Buxton, Terrace Slopes	1·47	47
,, .	Sherborne St. John...	1·37	71	*Ches* .	Bidston Obsy........	1·30	68
Herts .	Royston, Therfield Rec	1·93	99	*Lancs*.	Manchester, Whit. Pk.	1·91	90
Bucks.	Slough, Upton.......	1·66	99	,, .	Stonyhurst College...	1·01	35
Oxford	Oxford, Radcliffe.....	1·18	63	,, .	Southport, Bedford Pk	1·14	55
N'hant	Wellingboro,Swanspool	·83	43	,, .	Ulverston, Poaka Beck	·68	21
,, .	Oundle	·57	..	,, .	Lancaster, Greg Obsy.	1·30	52
Beds .	Woburn, Exptl. Farm.	1·26	65	,, .	Blackpool	·76	35
Cambs	Cambridge, Bot. Gdns.	·92	52	*Yorks*.	Wath-upon-Dearne...	1·47	72
,, .	March	·73	42	,, .	Wakefield,Clarence Pk.	1·86	94
Essex.	Chelmsford,CountyGns	1·85	128	,, .	Oughtershaw Hall....	1·18	..
,, .	Lexden Hill House....	1·37	..	,, .	Wetherby, Ribston H.	..	..
Suff .	Haughley House.....	·68	..	,, .	Hull, Pearson Park...	1·53	79
,, .	Rendlesham Hall.....	..	..	,, .	Holme-on-Spalding...	1·91	95
,, .	Lowestoft Sec. School.	·61	38	,, .	Felixkirk, Mt. St. John	1·75	93
,, .	Bury St. Ed.,WestleyH	1·16	64	,, .	York, Museum.......	1·37	69
Norf..	Wells, Holkham Hall.	·59	37	,, .	Pickering, Houndgate.	1·65	84
Wilts .	Porton, W.D. Exp'lStn	·99	58	,, .	Scarborough.........	1·62	85
,, .	Bishops Cannings	1·48	76	,, .	Middlesbrough.......	1·48	77
Dorset	Weymouth, Westham.	·99	61	,, .	Baldersdale, Hury Res.	·71	28
,, .	Beaminster, East St ..	·70	34	*Durhm*	Ushaw College.......	1·10	51
,, .	Shaftesbury	·92	..	*Norl'd*	Newcastle, Leazes Pk.	1·20	61
Devon.	Plymouth, The Hoe...	1·07	52	,, .	Bellingham, Highgreen	·77	32
,, .	Holne, Church Pk.Cott	·78	25	,, .	Lilburn Tower Gdns..	1·12	48
,, .	Teignmouth, Den Gdns	·41	22	*Cumb*.	Carlisle, Scaleby Hall.	2·09	87
,, .	Cullompton	·60	28	,, .	Borrowdale,Seathwaite	..	..
,, .	Sidmouth, U.D.C.....	·90	..	,, .	Thirlmere,DaleHeadH.	1·63	34
,, .	Barnstaple,N. Dev.Ath	1·06	51	,, .	Keswick, High Hill...	·79	25
,, .	Dartm'r,Cranmere P'l	1·60	..	,, .	Ravenglass, The Grove	·44	16
,, .	Okehampton, Uplands.	·77	29	*West* .	Appleby, Castle Bank.	·70	32
Cornw	Redruth, Trewirgie...	1·39	60	*Mon* .	Abergavenny, Larchf'd	·70	26
,, .	Penzance, MorrabGdns	·78	35	*Glam* .	Ystalyfera, Wern Ho..	1·09	31
,, .	St. Austell, Trevarna..	2·11	87	,, .	Treherbert, Tynywaun	1·36	..
Soms .	Chewton Mendip.....	1·03	37	,, .	Cardiff, Penylan......	·83	34
,, .	Long Ashton	·89	42	*Carm* .	Carmarthen,M.&P.Sc.	1·90	67
,, .	Street, Millfield	·56	30	*Card* .	Aberystwyth	1·78	..
Glostr.	Blockley	·94	..	*Radn'r*	Bir. W. W. Tyrmynydd	1·25	36
,, .	Cirencester, Gwynfa ..	·90	44	*Mont* .	Lake Vyrnwy........	1·12	36
Here .	Ross-on-Wye	·70	33	*Flint* .	Sealand Aerodrome...	1·64	90
,, .	Kington, Lynhales....	·69	29	*Mer* .	Blaenau Festiniog....	1·26	24
Salop .	Church Stretton......	1·01	..	,, .	Dolgelley, Bontddu...	1·12	34
,, .	Shifnal, Hatton Grange	1·23	60	*Carn* .	Llandudno	·77	43
,, .	Cheswardine Hall	1·17	53	,, .	Snowdon, L. Llydaw 9	2·40	..
Worc .	Malvern, Free Library.	1·02	47	*Angl* .	Holyhead, Salt Island.	·66	34
,, .	Ombersley, Holt Lock.	1·08	53	,, .	Lligwy..............	·59	..
Warw	Alcester, Ragley Hall.	·86	42	*I.Man*	Douglas, Boro' Cem...	·65	26

Rainfall: May 1939: Scotland and Ireland

Co.	Station.	In.	Per cent of Av.	Co.	Station.	In.	Per cent of Av.
Guern.	St.PeterP't.GrangeRd.	1·10	65	*R&C.*	Stornoway, C.G.Stn...	1·20	49
Wig .	Pt. William, Monreith.	1·00	43	*Suth* .	Lairg...............	·98	39
,, .	New Luce School.....	1·29	45	,, .	Skerray Borgie.......	1·02	..
Kirk .	Dalry, Glendarroch...	1·02	32	,, .	Melvich.............	1·16	57
Dumf.	Eskdalemuir Obs.....	1·20	36	,, .	Loch More, Achfary..	1·79	41
Roxb .	Hawick, Wolfelee	1·25	53	*Caith* .	Wick	·78	38
,, .	Kelso, Broomlands....	·67	35	*Orkney*	Deerness	·69	35
Peebs .	Stobo Castle.........	·86	38	*Shet* .	Lerwick Observatory.	1·09	52
Berw .	Marchmont House....	·87	35	*Cork* .	Cork, University Coll.	1·08	48
E.Lot.	North Berwick Res...	·82	41	,, .	Roches Point, C.G.Stn.	1·20	49
Midl .	Edinburgh, Blackfd. H	·97	47	,, .	Mallow, Waterloo....	1·05	47
Lanark	Auchtyfardle	·50	..	*Kerry.*	Valentia Observatory.	1·78	56
Ayr .	Kilmarnock, Kay Park	·84	..	,, .	Gearhameen.........	2·70	51
,, .	Girvan, Pinmore	1·15	39	,, .	Bally McElligott Rec.	1·25	..
,, .	Glen Afton, Ayr San..	·77	26	,, .	Darrynane Abbey....	1·58	53
Renf .	Glasgow, Queen's Park	·84	34	*Wat* .	Waterford, Gortmore.	1·01	44
,, .	Greenock, Prospect H.	1·41	43	*Tip* .	Nenagh, Castle Lough.	1·62	66
Bute .	Rothesay, Ardencraig.	1·38	46	,, .	Cashel, Ballinamona..	1·31	56
,,	Dougarie Lodge......	1·25	45	*Lim* .	Foynes, Coolnanes....	·62	27
Argyll	Loch Sunart, G'dale..	2·69	75	,, .	Limerick, Mulgrave St.	1·47	62
,,	Ardgour House	2·82	..	*Clare* .	Inagh, Mount Callan..	1·54	..
,,	Glen Etive	2·43	49	*Wexf* .	Gorey, Courtown Ho..	1·51	68
,,	Oban	1·45	..	*Wick* .	Rathnew, Clonmannon	1·37	..
,,	Poltalloch...........	1·67	58	*Carlow*	Bagnalstown FenaghH	·86	35
,,	Inveraray Castle	1·61	41	,, .	Hacketstown Rectory.	·86	33
,,	Islay, Eallabus	1·22	46	*Leix* .	Blandsfort House	1·31	54
,, .	Mull, Benmore.......	4·95	66	*Offaly.*	Birr Castle	1·33	60
,,	Tiree	1·19	48	*Kild* .	Straffan House.......	..	..
Kinr .	Loch Leven Sluice....	1·71	70	*Dublin*	Dublin, Phoenix Park.	·67	32
Fife .	Leuchars Aerodrome..	1·31	67	*Meath.*	Kells, Headfort......	1·27	47
Perth .	Loch Dhu	1·35	30	*W.M* .	Moate, Coolatore.....	·79	..
,, .	Crieff, Strathearn Hyd.	1·37	55	,, .	Mullingar, Belvedere..	1·15	47
,, .	Blair Castle Gardens..	·99	49	*Long* .	Castle Forbes Gdns ..	1·24	48
Angus.	Kettins School.......	1·91	71	*Galway*	Galway, Grammar Sch.	1·19	48
,, .	Pearsie House	1·42	..	,, .	Ballynahinch Castle ..	1·97	55
,, .	Montrose, Sunnyside..	1·24	61	,, .	Ahascragh, Clonbrock.	1·30	47
Aberd.	Balmoral Castle Gdns.	·95	41	*Rosc* .	Strokestown, C'node..	1·03	43
,, .	Logie Coldstone Sch ..	·79	31	*Mayo.*	Blacksod Point	1·74	62
,, .	Aberdeen Observatory.	1·13	48	,, .	Mallaranny..........	1·72	..
,, .	New Deer SchoolHouse	·97	44	,, .	Westport House......	·90	32
Moray	Gordon Castle	·97	46	,, .	Delphi Lodge........	3·71	61
,, .	Grantown-on-Spey ...	1·02	44	*Sligo* .	Markree Castle.......	·90	32
Nairn.	Nairn..............	·71	39	*Cavan.*	Crossdoney, Kevit Cas.	1·05	..
Inv's .	Ben Alder Lodge.....	1·23	..	*Ferm* .	Crom Castle	1·41	51
,, .	Kingussie, The Birches	·63	..	*Arm'h*	Armagh Obsy........	1·26	53
,, .	Loch Ness, Foyers....	·97	40	*Down.*	Fofanny Reservoir ...	2·40	..
,, .	Inverness, Culduthel R	·83	45	,, .	Seaforde	1·56	59
,, .	Loch Quoich, Loan...	3·50	..	,, .	Donaghadee, C. G. Stn.	1·37	60
,, .	Glenquoich..........	2·01	37	*Antrim*	Belfast,Queen's Univ .	·82	35
,, .	Arisaig House	1·87	54	,, .	Aldergrove Aerodrome	·83	37
,, .	Glenleven, Corrour ...	1·38	36	,, .	Ballymena, Harryville.	1·56	55
,, .	Ft. William, Glasdrum	1·91	..	*Lon* .	Garvagh, Moneydig...	1·05	..
,, .	Skye, Dunvegan	2·23	..	,, .	Londonderry, Creggan.	1·37	52
,, .	Barra, Skallary	1·02	..	*Tyrone*	Omagh, Edenfel......	·99	38
R&C.	Tain, Ardlarach......	·48	21	*Don* .	Malin Head..........	1·31	53
,, .	Ullapool	·73	29	,, .	Dunfanaghy	1·18	52
,, .	Achnashellach	2·40	54	,, .	Dunkineely..........	1·72	..

Climatological Table for the British Empire, December 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	1011·3	− 2·4	55	21	44·4	35·2	39·8	− 1·6	37·7	87	7·6	3·29	+ 1·00	19	1·6	20
Gibraltar	1015·9	− 4·4	67	39	58·7	48·9	53·8	− 2·2	49·3	79	5·0	7·55	—	14	—	—
Malta	1011·9	− 4·3	65	43	61·3	53·5	57·4	− 0·5	52·8	74	6·0	4·37	+ 0·66	19	6·3	65
St. Helena	1015·5	− 1·5	67	53	63·0	56·4	59·7	− 1·2	57·5	93	9·8	3·30	+ 1·97	26	—	—
Freetown, Sierra Leone	1010·7	+ 1·5	90	72	87·3	75·1	81·2	—	73·1	85	5·9	0·02	− 1·40	1	—	—
Lagos, Nigeria	1009·3	− 0·7	89	70	87·7	73·2	80·5	− 1·3	76·1	91	5·3	0·16	− 0·65	2	7·7	66
Kaduna, Nigeria	1009·5	—	96	55	92·2	60·7	76·5	+ 2·2	59·4	38	2·0	0·01	+ 0·01	1	9·9	86
Zomba, Nyasaland	1006·7	− 1·8	86	62	79·7	65·6	72·7	− 0·4	69·4	84	8·0	14·12	+ 3·25	24	—	—
Salisbury, Rhodesia	1009·9	− 1·2	81	55	76·0	60·1	68·1	− 1·5	62·3	78	8·7	9·59	—	21	4·1	31
Cape Town	1014·1	− 0·2	86	48	76·9	57·9	67·4	− 0·5	59·5	63	2·3	1·21	+ 0·40	4	—	—
Johannesburg	1009·7	− 0·7	83	50	74·6	55·2	64·9	− 0·6	58·2	75	7·2	9·33	+ 3·90	19	6·6	48
Mauritius	1014·2	+ 0·5	89	65	84·4	69·6	77·0	− 1·3	71·1	65	5·3	1·74	− 2·94	16	8·7	65
Calcutta, Alipore Obsy.	1014·2	− 1·5	84	50	80·2	54·3	67·3	+ 0·8	55·7	84	0·7	0·00	− 0·24	0*	—	—
Bombay	1011·9	− 1·6	93	66	87·4	69·6	78·5	+ 1·1	66·7	69	3·0	0·00	− 0·05	0*	—	—
Madras	1012·8	− 0·7	86	63	83·3	69·1	76·2	− 0·5	69·7	78	5·8	2·34	− 3·01	2*	—	—
Colombo, Ceylon	1009·7	− 0·6	90	70	86·1	72·7	79·4	− 0·1	73·9	76	5·5	4·63	− 0·49	14	6·7	57
Singapore	1008·9	− 0·8	90	73	85·7	74·2	79·9	0·0	76·4	76	7·8	10·78	+ 0·22	20	4·7	39
Hongkong	1018·1	− 1·6	78	51	69·5	60·9	65·2	+ 2·2	59·3	69	7·7	0·01	− 1·02	0	4·0	37
Sandakan	1007·6	—	87	72	84·7	74·6	79·7	− 0·5	76·2	89	9·0	19·96	+ 1·32	26	—	—
Sydney, N.S.W.	1011·3	− 0·6	98	54	79·8	63·0	71·4	+ 1·3	63·3	52	5·5	0·46	− 2·40	3	8·8	61
Melbourne	1012·4	− 0·3	97	46	75·9	53·5	64·7	− 0·1	55·3	47	6·9	0·69	− 1·58	6	7·6	51
Adelaide	1014·2	+ 0·9	103	47	83·9	57·3	70·6	− 0·5	58·8	36	5·9	0·49	− 0·54	4	9·3	65
Perth, W. Australia	1012·7	− 0·5	98	50	80·6	61·1	70·9	+ 0·1	62·3	51	4·5	0·25	− 0·31	5	10·2	72
Coolgardie	1010·5	− 0·7	107	52	92·8	63·7	78·3	+ 2·6	64·6	52	3·2	0·64	− 0·05	3	—	—
Brisbane	1012·7	+ 0·7	102	61	86·4	69·3	77·9	+ 1·5	70·0	60	4·1	0·41	− 4·48	2	10·6	77
Hobart, Tasmania	1006·0	− 3·7	88	41	67·6	48·0	57·8	− 2·4	51·6	57	6·3	2·27	+ 0·28	17	8·0	52
Wellington, N.Z.	1004·9	− 7·3	71	44	62·9	50·4	56·7	− 3·5	54·4	75	7·8	7·41	+ 4·19	16	6·2	41
Suva, Fiji	1008·5	− 0·1	89	69	83·9	73·5	78·7	− 0·3	74·9	84	7·9	30·52	+ 18·00	26	4·2	32
Apia, Samoa	1008·8	+ 0·5	86	72	84·6	75·0	79·8	+ 0·5	76·7	80	6·7	20·94	+ 7·05	27	7·7	60
Kingston, Jamaica	1013·1	− 0·9	91	66	87·4	69·5	78·5	+ 0·8	67·0	80	1·3	0·10	− 1·49	3	7·5	68
Grenada, W.I.	1011·5	− 0·3	89	70	87	73	80	+ 1·8	73	74	7	9·17	+ 1·97	20	—	—
Toronto	1016·9	− 0·7	51	9	36·0	25·8	30·9	+ 3·8	27·7	76	8·7	2·23	− 0·24	22	2·0	22
Winnipeg	1016·1	− 2·6	36	−35	17·3	3·6	10·5	+ 4·7	—	—	6·3	1·18	+ 0·24	10	2·3	28
St. John, N.B.	1015·4	+ 1·4	54	0	35·0	21·5	28·3	+ 3·9	24·2	81	6·8	4·58	+ 0·41	15	3·1	34
Victoria, B.C.	1019·5	+ 2·8	55	31	46·4	38·6	42·5	+ 1·4	40·5	88	6·1	6·34	+ 0·60	22	2·8	33

* For Indian stations a rain day is a day on which 0·1 in. or more rain has fallen.

Climatological Table for the British Empire, Year 1938

STATIONS.	PRESSURE. Mean of Day M.S.L. mb.	PRESSURE. Diff. from Normal. mb.	TEMPERATURE. Absolute. Max. °F.	TEMPERATURE. Absolute. Min. °F.	TEMPERATURE. Mean Values. Max. °F.	TEMPERATURE. Mean Values. Min. °F.	TEMPERATURE. Mean Values. ½ Max. and Min. °F.	TEMPERATURE. Mean Values. Diff. from Normal. °F.	TEMPERATURE. Mean Wet Bulb. °F.	Relative Humidity. %	Mean Cloud Am'nt 0–10	PRECIPITATION. Am'nt. in.	PRECIPITATION. Diff. from Normal. in.	PRECIPITATION. Days.	BRIGHT SUNSHINE. Hours per day.	BRIGHT SUNSHINE. Percentage of possible.
London, Kew Obsy	1016·9	+ 1·5	84	21	58·4	45·1	51·7	+ 1·5	46·3	84	7·5	18·15	− 5·65	140	4·0	33
Gibraltar	1018·2	—	97	35	67·2	57·4	62·3	− 1·9	56·5	80	4·8	22·33	—	68	—	—
Malta	1016·5	− 1·2	101	42	69·4	59·9	64·6	− 1·5	59·0	75	4·3	27·98	+ 8·12	92	8·6	71
St. Helena	1017·3	− 0·9	75	51	64·3	57·4	60·8	—	58·5	93	9·1	34·32	+ 4·30	235	—	—
Freetown, Sierra Leone	1011·7	+ 1·9	92	68	85·6	74·0	79·7	—	74·3	83	6·3	128·62	−28·61	170	—	—
Lagos, Nigeria	1011·0	+ 0·1	92	73	85·5	74·0	79·8	− 0·9	75·5	88	7·0	58·68	−13·30	120	5·6	46
Kaduna, Nigeria	1010·6	—	102	55	89·4	65·9	77·7	+ 0·6	65·9	74	5·6	47·13	− 6·77	106	7·8	64
Zomba, Nyasaland	1012·1	− 0·3	94	50	78·7	61·1	70·1	+ 0·7	66·5	79	5·8	68·00	+13·46	105	—	—
Salisbury, Rhodesia	1014·7	− 0·7	91	34	76·7	53·7	65·2	− 0·1	56·9	60	4·1	32·55	—	87	8·1	67
Cape Town	1017·3	+ 0·3	93	35	71·9	54·0	62·9	+ 0·6	55·9	79	4·4	25·15	+ 0·11	120	—	—
Johannesburg	1015·1	− 1·8	88	29	70·9	50·2	60·5	+ 0·8	51·2	61	3·5	30·52	− 2·70	99	8·2	68
Mauritius	1016·0	− 0·1	90	52	80·7	67·5	74·1	+ 0·1	69·5	71	5·3	36·44	−13·31	208	8·1	67
Calcutta, Alipore Obsy.	1006·8	− 0·8	107	50	88·8	71·6	80·2	+ 1·5	72·5	85	4·9	47·58	−16·74	76*	—	—
Bombay	1008·1	− 1·1	94	60	86·2	73·8	80·0	− 0·6	72·9	78	4·4	92·01	+19·82	97*	—	—
Madras	1007·9	− 0·9	108	63	90·7	75·5	83·1	0·0	74·5	75	6·2	26·46	−23·10	38*	—	—
Colombo, Ceylon	1009·6	0·0	92	67	86·0	75·4	80·7	− 0·3	76·4	76	6·6	64·76	−15·37	196	6·8	56
Singapore	1009·4	− 0·1	94	70	86·2	75·5	80·8	− 0·1	77·4	78	7·4	94·44	− 0·68	200	5·6	46
Hongkong	1012·4	− 0·2	94	47	77·9	69·3	73·6	+ 1·3	68·5	75	6·9	55·36	−30·37	128	5·4	45
Sandakan	1008·7	—	91	71	86·4	75·1	80·7	− 0·5	76·7	86	8·0	173·32	+48·53	211	—	—
Sydney, N.S.W.	1015·9	0·0	98	37	71·8	56·9	64·3	+ 1·2	58·3	67	5·3	39·17	− 8·31	132	6·6	54
Melbourne	1016·1	− 0·2	103	29	69·4	49·6	59·5	+ 1·1	52·3	63	6·5	17·63	− 7·84	132	5·6	46
Adelaide	1017·3	+ 0·2	107	36	73·4	52·9	63·1	+ 0·1	55·1	55	5·9	19·26	− 1·89	119	6·6	54
Perth, W. Australia	1016·7	+ 0·3	103	41	73·3	55·3	64·3	+ 0·1	56·7	61	5·1	29·64	− 4·73	109	8·1	67
Coolgardie	1016·0	+ 0·1	108	35	77·2	53·3	65·3	+ 0·7	56·0	63	3·6	8·14	− 2·13	41	—	—
Brisbane	1016·0	+ 0·1	102	41	77·6	61·0	69·3	+ 0·4	62·9	69	5·0	43·49	− 1·80	110	7·6	63
Hobart, Tasmania	1013·1	+ 0·6	92	33	62·5	46·8	54·7	+ 0·3	49·4	68	6·2	31·22	+ 7·43	169	5·7	47
Wellington, N.Z.	1015·8	+ 1·2	81	33	61·3	49·8	55·5	+ 0·2	53·1	79	7·3	58·20	+10·16	171	5·4	45
Suva, Fiji	1011·4	+ 0·1	92	62	83·5	72·9	78·2	+ 1·2	73·8	84	6·3	158·85	+41·71	260	5·0	41
Apia, Samoa	1010·2	− 0·1	90	69	84·9	74·6	79·7	+ 1·2	76·2	79	5·8	139·45	+29·74	230	7·3	60
Kingston, Jamaica	1013·6	− 0·1	93	63	87·3	71·1	79·2	− 0·1	69·7	81	3·2	20·94	−12·65	60	7·0	58
Grenada, W.I.	1011·3	− 1·1	90	70	86·2	72·9	79·5	+ 0·7	73·7	76	5·8	122·15	+47·56	252	—	—
Toronto	1016·7	+ 0·1	92	− 5	56·4	40·3	48·3	+ 3·2	—	—	6·1	25·65	− 5·64	154	5·4	44
Winnipeg	1015·8	− 0·4	93	−41	48·8	27·3	38·1	+ 3·5	—	—	5·1	16·10	− 4·08	109	5·7	46
St. John, N.B.	1016·2	+ 1·7	84	−12	50·1	35·3	42·7	+ 1·5	38·1	83	6·7	53·54	+ 5·46	187	5·1	42
Victoria, B.C.	1017·1	+ 0·5	84	28	56·4	44·3	50·4	+ 1·0	47·3	82	5·8	23·90	− 6·41	145	6·7	55

* For Indian stations a rain day is a day on which 0·1 in. or more rain has fallen.

Daily Readings at Kew Observatory, May 1939

Date.	Pressure, M.S.L. 13h.	Wind, Dir. 13h.	Force	Temp. Min.	Temp. Max.	Rel. Hum. 13h.	Rain.	Sun.	REMARKS.
	mb.			°F.	°F.	%	in.	hrs.	
1	1015·8	NNE	3	43	47	88	0·45	0·0	r_0–r 0h–11h & 14h–22h.
2	1014·7	NNE	4	42	50	71	0·02	0·1	d_0–d 19h–21h.
3	1015·7	NNE	3	41	54	55	—	7·1	
4	1011·0	S	3	37	56	64	—	5·2	
5	999·0	SSE	4	40	55	75	trace	1·5	pr_0 8h, 11h & 13h.
6	999·6	E	3	42	59	58	0·02	2·6	pr_0 t 16h, f–F 21h–24h.
7	1010·2	N	2	38	65	58	trace	9·9	F–f early.
8	1018·8	NW	2	44	67	50	—	12·4	
9	1024·2	Calm		46	68	51	—	8·8	
10	1025·6	NNE	3	49	68	64	—	3·7	
11	1025·9	NNE	5	52	60	63	—	4·7	
12	1019·8	N	4	43	53	72	0·02	1·4	r_0 7h–8h, id_0 13h–16h.
13	1020·3	NE	5	47	63	42	—	14·2	
14	1015·1	NNW	3	40	60	68	trace	2·7	ir_0 12h–17h.
15	1005·2	NNW	3	47	51	83	0·16	0·0	r_0–r 2h–4h & 18h–24h.
16	1007·1	NNE	5	45	57	55	0·46	1·0	r–r_0 0h–10h.
17	1003·9	N	2	45	53	83	0·26	0·0	r_0–r 0h–12h, r_0 16h.
18	1007·8	NNE	2	43	56	67	trace	0·0	id_0 about 7h.
19	1010·9	NE	2	45	57	47	—	8·7	
20	1012·6	SW	2	41	60	58	—	5·5	
21	1015·6	W	3	44	62	52	—	6·4	
22	1022·3	WSW	2	44	68	61	—	7·2	
23	1029·0	WSW	1	47	73	51	—	11·0	
24	1029·0	NW	2	48	74	35	—	11·9	
25	1029·0	N	3	56	64	66	trace	0·9	pr_0 14h & 15h.
26	1028·9	N	2	47	67	46	—	13·9	
27	1025·4	N	4	51	69	58	—	6·2	
28	1030·9	NNE	4	50	63	54	—	10·7	
29	1030·8	NE	3	45	66	56	—	12·0	
30	1028·4	NNE	4	48	65	52	—	12·1	
31	1024·5	NE	4	48	71	50	—	12·3	
*	1018·0	—		45	61	60	1·39	194·1	*Means or Totals.

General Rainfall for May 1939

	Per cent.
England and Wales	56
Scotland	44
Ireland	49
British Isles	52

(47721) Wt 22/31 1,375 6/39 Hw. G.377/6

THE METEOROLOGICAL MAGAZINE

M.O. 441

AIR MINISTRY : METEOROLOGICAL OFFICE

Vol. 74 | July 1939 | No. 882

CONDENSATION AND PRECIPITATION IN THE ATMOSPHERE

BY F. J. SCRASE, SC.D., F. Inst. P.

Until comparatively recent years it was thought that the process of condensation and precipitation of water from the atmosphere was a simple and straightforward one. The water was supposed to remain entirely in the vapour form until the relative humidity reached 100 per cent., after which it condensed into a visible cloud of liquid droplets. It was thought that in favourable conditions the process would continue until the droplets became large enough to fall as rain. These ideas fall far short of the true representation of the facts; it is now known, for example, that condensation can commence at humidities well below 100 per cent. and that precipitation, although it naturally follows condensation, is not merely a continuation of the same process on a more intense scale.

A factor which plays a vital part in the process of condensation in the atmosphere is the presence of hygroscopic nuclei; these consist chiefly of salt particles produced by sea spray and of certain products of combustion such as nitrous and sulphuric acids. In the complete absence of nuclei, condensation cannot take place except with a very high degree of supersaturation (equivalent to a relative humidity of more than 300 per cent.). Owing to their hygroscopic nature, condensation nuclei are able to grow by absorbing water vapour even though the humidity may be as low as 80 per cent. In unsaturated air, however, the rate of growth of nuclei with increase in humidity is small, for although there is a reduction of vapour pressure due to the fact that the growing nucleus is a solution instead of pure water this decrease is opposed by an increase of vapour pressure due to the curvature of the surface of the particle. As the relative humidity approaches the saturation value the rate of growth increases; for each size of nucleus (the initial radius usually lies between 10^{-5} and 10^{-6} cm.) there is a critical humidity, higher than 100 per cent., at which further growth can occur without any further increase in humidity. When this stage is reached there is a rapid growth to the visible droplets, with radii lying between 10^{-3} and 10^{-4} cm., which constitute cloud or fog. The critical humidity for rapid growth depends on the size and nature of the nucleus; for the smaller and less hygroscopic nuclei the critical value may be as high as 110 per cent., whilst for the larger and more hygroscopic nuclei it is between 100 and 101 per cent. On this account only a portion of the nuclei present in the air may grow into cloud or fog droplets, for the rapid growth of the larger nuclei tends to prevent the humidity from increasing to the higher critical values that are necessary for rapid growth of the smaller ones. This explains why the number of droplets per unit volume in a cloud or fog is usually very much smaller than the number of nuclei. The rapid growth of droplets when slight supersaturation is reached also explains why the base of a cloud is often sharply defined.

The size which cloud droplets ultimately attain by condensation is limited by the amount of water vapour available; after the critical humidity for the larger nuclei is reached the rate of increase in humidity is checked and there is no further increase when the amount of vapour condensing on the droplets is equal to the amount supplied to the air. If the number of larger nuclei is relatively small, or if the rate of supply of water vapour is high, the condensation on the larger nuclei may be insufficient to check the increase in humidity, in which case the critical values for smaller nuclei will be reached and more nuclei will take part in rapid condensation. Thus it is found that in fogs, where the rate of cooling is small and the relative humidity seldom exceeds saturation value by more than 1 per cent., there are fewer droplets than in convexion clouds in which the rate of cooling is rapid and in which higher degrees of super-saturation are known to occur. Measurements indicate that the amount of suspended water in clouds is never likely to exceed 10 gm./m.^{3} and if we take the minimum number of droplets in a cloud to be 20 per c.c. (the average number is more of the order of 200 per c.c.) then we find that the maximum radius which cloud droplets can attain by condensation is 3×10^{-3} cm. The limiting velocity of fall of droplets of this size is only 10 cm./sec. and such droplets would evaporate long before reaching the ground. Drops falling from a cloud at a height of 1 km. must have an initial radius at least three times as great (or a volume 30 times as great) as that of the largest cloud droplets in order that they can reach the ground without evaporating completely. It would seem that the only occasions when precipitation is caused solely by direct condensation are those when drizzle falls from fog or low-lying cloud. How, then, are we to account for the formation of raindrops of the sizes that usually occur in moderate and heavy rain? For it is clear that when the growth of droplets by condensation ceases some other process or processes must operate to cause either the coalescence of the small cloud particles into raindrops or the growth of some of the cloud elements at the expense of others.

The idea of coalescence of droplets has received much support from those who consider that clouds and fogs may be regarded as colloidal suspensions of water in the air. The colloidal state is one in which the movement of particles suspended in a medium is governed by molecular bombardment rather than by gravity and colloidal solutions have the property of persisting with their particles unchanged until a condition occurs that causes coagulation and precipitation of the particles. It was argued that in the case of clouds and fogs coalescence takes place only with drops of equal size, which can remain near together long enough for hydrodynamical attraction to act. A more likely cause of coalescence is the difference in size of the droplets, the larger ones falling relatively to the smaller ones and absorbing those with which they collide. It seems fairly certain that the electrical state of the droplets has some effect on the stability of fogs, for the electric repulsion between droplets carrying high charges of like sign may be sufficient to prevent their coalescence; on the other hand it is not likely that the attraction between droplets carrying charges of opposite sign is sufficient, by itself, to cause coalescence. Although it is probable that coalescence of droplets does occur in natural clouds and fogs and may in some circumstances be responsible for light rain, there appears to be no very clear evidence that it is the main mechanism in the production of precipitation in general.

In recent years the idea has gained ground that the essential factor in the production of precipitation of at least moderate intensity is the co-existence of water in the solid and liquid states; in other words there must be ice crystals present in the clouds in addition to water droplets. This, of course, means that the temperature in some parts of the cloud must be below the freezing point and since it is a well known fact that water droplets can undergo a high degree of super-cooling before solidifying, it is certainly possible for the ice and water phases to occur together. The extent of the super-cooling probably depends on the size of the droplets, the smaller droplets being more likely to remain in the liquid state at lower temperatures. We may say that as a general rule water droplets predominate in the layers of cloud which are at temperatures above -10° C; in the layers with temperatures between -10° C to -20° C there is a mixture of both ice crystals and water droplets, whilst ice crystals predominate where the temperature is below −20° C. It is in the region where ice crystals and droplets exist together that we can expect precipitation to originate, for since the saturation pressure over ice is less than that over water there is a strong tendency for the water vapour present in the air to sublime (i.e. to pass directly from the vapour state to the solid state) on the ice crystals and for the droplets to evaporate. The ice crystals are thus able to grow at the expense of the droplets and eventually they become large enough to sink. It is probable that they then continue to grow by collision and coalescence with each other and with droplets that they meet in falling; if the temperature in the lower layers is sufficiently high the crystals will turn to rain before reaching the ground. In brief, the theory is that all precipitation of appreciable intensity starts as snow.

As to the origin of ice crystals in clouds that consist initially of super-cooled drops, it has been suggested that in addition to nuclei of condensation there are nuclei of sublimation (possibly very fine dust or sand-grains) on which ice crystals will form when the temperature is sufficiently low for the vapour pressure in the air to be greater than that over an ice surface. Whether such nuclei exist or not at cloud levels remains to be confirmed. It is possible that some ice crystals are formed in water clouds when super-cooled drops collide with each other, for it is well known that disturbance of super-cooled water can cause immediate crystallisation. High clouds are, we know, composed of ice crystals and some of these crystals may be carried into a lower-lying water cloud by gravitational settling or turbulent mixing. The co-existence of the ice and water (and vapour) phases is, at any rate, physically possible and it affords a reasonable explanation as to how precipitation can take place after the process of condensation ceases to produce further growth of cloud elements. It also explains the persistence of low clouds that do not produce any appreciable rain; such clouds must be devoid of ice crystals either because they are below the level of the freezing point isotherm or, if they are above this level, because their super-cooled droplets remain in the liquid state on account of their uniform size and freedom from disturbance by collision; absence of nuclei of sublimation would also account for the absence of ice crystals.

The Levanter cloud, which is a characteristic feature of Gibraltar*, is a good example of persistent rainless cloud; this cloud, which forms over the Rock and extends over the neighbouring Bay, may persist for days and although on occasions it may look as black and as threatening as a thunder-cloud it is very rarely that any appreciable rain falls from the cloud itself, presumably because the temperature in the cloud is never low enough for ice formation. When rain does occur during Levanter conditions there is usually higher cloud present as well.

One of the objections that is often raised against the idea that the presence of ice is necessary for appreciable precipitation is that heavy tropical rains are observed to fall from clouds in which the temperature must everywhere be above freezing point. Such cases are rarely supported by concrete evidence as to the temperature at all levels in the clouds and as to whether higher layers of cloud are present.

The problems connected with the co-existence of the ice, water and vapour phases in the atmosphere are of importance not only in connexion with the formation of precipitation, but also with the phenomenon of ice accretion on aircraft and it is to be hoped that the solution of these problems will not only be of assistance in the forecasting of precipitation but will help to overcome what still remains one of the greatest dangers to aviation.

---

* A photograph of a typical Levanter cloud is reproduced in the April 1935 issue of this Magazine.

SOME VARIATIONS OF TEMPERATURE

By A. C. Best, M.Sc.

Air temperatures as high as 136° F. and as low as - 94° F. have been measured in the thin layer of the atmosphere in which we normally live. The former occurred in Tripoli (*Meteor. Mag.*, 1926, p. 157) and the latter at Verkhoyansk in Siberia (*Meteor. Mag.*, 1926, p. 158). Between these two extremes many variations occur and if the temperature of the surface of the earth is also considered, even higher temperatures have been measured under natural conditions. It is proposed to discuss some of the more extreme variations of temperature which are on record.

The temperature with which we are most familiar is that usually known as the " shade temperature ". This is the temperature of the air at a height of about four feet above the earth. It varies from hour to hour, from month to month and from place to place. Even simultaneous measurements made within fifty feet of each other may differ by one or two degrees. The height at which the shade temperature is normally measured is mentioned above because large differences of temperature frequently exist between different heights at the same place, even if consideration is limited to the first fifty feet above the surface of the earth.

While considering all these variations one point should be borne in mind, viz. that one of the main factors affecting the temperature of the air is the temperature of the surface of the earth, since the air absorbs but little of the radiation of the sun. The earth, however, absorbs heat from the sun more or less readily, depending on the nature of the surface, and in turn warms the air by day and cools it by night. This heating and cooling spreads upwards from the surface.

Thus we are led to consider the temperature attained by the earth's surface as a starting point. This will depend upon the nature and the colour of the surface. Some experiments carried out on Salisbury Plain* (1, Johnson and Davies, 1927) indicate that in summer in England a tarmac surface may attain a temperature of about 140° F. and a sand or earth surface may reach a maximum temperature of about 10° F. lower. The corresponding air temperature at a height of four feet would be about 75° to 80° F. In winter the difference between air and surface maximum temperatures amounts to a few degrees only. Some figures for Egypt (2, Ministry of Public Works, Egypt) show that the average surface temperature of a locomotive rail and of a stone roof between 1 p.m. and 2 p.m. in summer are about 130° F., the surface temperature of limestone rock being some 14° F. lower. In winter the three surfaces are very similar with a temperature of about 80° F. at 1.30 p.m., some 12° to 13° F. above the air temperature. These figures for Egypt are average figures and to compare with the figure of 140° F. mentioned above for England we may consider the occasion when the temperature of some undisturbed fallow land at Giza was found to reach a value of 150° F. In India a temperature of 156° F. has been recorded for the surface of the soil (3, Shaw, p. 54) and in the Sahara a value of 172° F. has been attained. The highest value the temperature of any surface is likely to reach anywhere in the world is a matter for speculation. In this connection it is of interest to note that the average daily maximum temperature as indicated by a special type of thermometer called the "Absolute Black Bulb" thermometer at Aswan (in Egypt) for the four months May to August is just over 176° F. This thermometer is designed to absorb as much radiation from the sun as possible and to lose the minimum amount of heat by conduction, etc. Thus we may reasonable assume that the reading of an absolute black bulb thermometer represents the highest

* The numbers refer to the list of references at the end.

temperature that any type of surface can attain under similar conditions. The figure 176° F. is the average daily maximum over four months. The writer has not found any published figures giving the highest temperature reached by this thermometer on any one day, but there seems little doubt that it must sometimes exceed 180° F. in Egypt. [In the Karakoram Mountains a value of 204° F. has been attained at a height of 17,322 ft. (*Meteor. Mag.*, 1926, p. 213).] Bearing in mind the fact that a sand surface temperature has been measured in Arizona which was 11° F. higher than the highest earth surface temperature measured in Egypt, it seems probable that the highest temperature likely to be attained by any surface at any time and at any place is between 190° and 200° F.

Having seen how hot the surface of the earth can be let us now turn to the other side of the question and consider the lower limits of temperature. The available figures are not nearly so impressive. In the Salisbury Plain experiments referred to above it was found that the minimum surface temperature differed very little from the minimum air temperature at a height of four feet. This is supported by observations from other parts of the world; at Giza, for example, the normal reading of the grass minimum thermometer is only a few degrees below that of the air thermometer. On occasions, however, even in England the reading of the grass minimum thermometer may be 10° to 15° F. below the reading of the screen minimum thermometer. The only reference to really notably low surface temperatures which the writer has encountered is contained in the statement (3, Shaw, p. 54) that frosts are sometimes experienced in the desert at night even during summer months.

Since surface temperatures attain values much higher than air temperatures it is clear that under suitable conditions there must be considerable variation in the temperature of the air at different heights even when only small heights, say up to 50 feet above the surface, are considered. Some experiments carried out over close-cropped grass on Salisbury Plain (4 and 5, Johnson, 1929, and Best, 1935) provide the data for considering the variations likely to occur in England. These experiments were concerned with the temperature differences between the heights 1 inch, 1 foot, 4 feet, 23 feet and 56 feet above the surface. It was shown that temperature generally decreases upwards during the daytime and increases upwards at night, the changes from one type of variation to the other occurring just after sunrise and just before sunset. The rate of increase upwards at night showed little variation either during the night or from month to month. The rate of decrease upwards during the daytime however increases to a maximum round about noon and this maximum value increases in turn from winter to summer. As would be expected the greatest rates of increase or decrease occurred in the lowest layers. The largest temperature differences recorded were 9·7° F. between 1 inch and 1 foot, 4·6° F. between 1 foot and 4 feet, 3·8° F. from 4 feet to 23 feet and 4·6° F. from 4 feet 56 feet. Although these maximum values were not recorded simultaneously they do indicate the possibility that the air temperature 1 inch above closs cropped grass may be nearly 20° F. higher than the air temperature at a height of 56 feet. Over a black surface (e.g. tarmac) the difference might be greater still. The greatest temperature differences obtained at night showed an increase of temperature upwards of 7·8° F. from 1 inch to 1 foot, 6·3° F. from 1 foot to 4 feet, 7·0° F. from 4 feet to 23 feet and 10·2° F. from 4 feet to 56 feet. These figures amply explain the greater frequency of ground frosts as compared with occasions when the air temperature (4 feet above the ground) falls to freezing point.

Some similar experiments to those just described have been carried out in Egypt (6, Flower, 1937). Only one comparable height interval was used there, viz. 4 feet to 53 feet. The greatest temperature differences recorded over this layer were 4·7° F. in the daytime and 13·4° F. at night.

One effect of the vertical variation in temperature is found when we examine figures for the diurnal range of temperature. This decreases rapidly from the surface upwards. We have seen that the surface temperature in the desert may vary from 32° F. at night to 172° F. in the day, a range of 140° F. An occasion is on record (7, Kendrew, p. 26) when the air temperature in the Sahara varied from 31°F . to 99° F. in the same day. The diurnal range of temperature is very much influenced by the topography of the neighbourhood. In a valley the maximum and minimum temperatures are likely to be respectively higher and lower than those measured at a more normal site. Some data are available for a valley station at Rickmansworth in England (8, Hawke, 1936). On one occasion there the temperature rose from 34° F. at 0545 G.M.T. to 84·9° F. at 1430 G.M.T., giving a variation of nearly 51° F. in nine hours. Some figures are available for England (5, Best, 1935) which indicate that the average diurnal range on clear summer days on a more normal site may vary from about 32° F. at a height of one inch above grass to about 20° F. at a height of 56 feet. In so far as records are available it appears that the average diurnal range of temperature has a maximum value at Calama (3, Shaw, p. 45) where it reaches 41° F. In contrast to these big changes of temperature during the day we have a diurnal range of only one or two degrees in the temperature of the air over the oceans.

The annual range of temperature is also a matter of considerable interest. At Verkhoyansk (7, Kendrew, p. 176) the mean monthly temperature varies from -59° F. in January to 60° F. in July, giving a mean yearly range of 119° F. The absolute maximum at this place is 93° F. and the absolute minimum as mentioned above is -94° F. so that temperatures there have varied over a range of 187° F. For comparison it may be mentioned that the highest and lowest temperatures recorded in the British Isles are 100·5° F. and -17° F. (9, Bilham, pp. 174, 5).

We saw at the beginning that an air temperature as high as 136° F. has been measured. It is worth noting that temperatures between 120° F. and 130° F. are recorded nearly every year in various parts of the world. Similarly, to compare with the low value of - 90° F., we may remember that temperatures as low as - 75° F. are recorded somewhere nearly every year.

These very high and very low temperatures are measured in regions in which man can live. There are, naturally, no long series of records for the other type of region, but some temperatures measured in the polar regions may be of interest. At the north pole the lowest temperature measured so far is - 33° F. (3, Shaw, p. 45) and in the south polar regions a value of - 76° E. has been recorded on the Ross Barrier (7, Kendrew, p. 384). Still less data are available of the temperatures on Mount Everest but the lowest temperature measured there so far appears to be - 2·2° F. at a height of about 21,000 feet (3, Shaw, p. 45).

In conclusion the writer does not claim that all the extreme values mentioned above are world records; the figures do show, however, what variations in temperature are possible from time to time and from place to place.

References.

(1) Johnson, N. K., and Davies, E. L. London *Q.J.R. Meteor. Soc.*, Vol. 53, 1927, pp. 45–59.
(2) Ministry of Public Works, Egypt. " Climatological Normals ", 1938.
(3) Shaw, Sir Napier. " Manual of Meteorology ", Vol. 2. Cambridge University Press, 1928.
(4) Johnson, N. K. *Geophysical Memoir No.* 46. Meteorological Office, London, 1929.
(5) Best, A. C. *Geophysical Memoir No.* 65. Meteorological Office, London, 1935.
(6) Flower, W. D. *Geophysical Memoir No.* 71. Meteorological Office, London, 1937.
(7) Kendrew, W. K. " The Climates of the Continents ", Oxford University Press, 2nd Edition, 1927.
(8) Hawke, E. L. London *Meteor. Mag.*, Vol. 71, 1936, pp. 186–187).
(9) Bilham, E. G. " The Climate of the British Isles ", London, Macmillan and Co., Ltd., 1938.

THE RAINFALL AT SHORT HEATH LODGE, FARNHAM, SURREY, 1899–1938, MAINTAINED BY THE LATE COL. GEORGE CHRYSTIE

By A. Hampton Brown

A record of rainfall maintained in the same position for 40 consecutive years is not too common and particulars of the figures for Shortheath, Farnham, for that period may be of interest. Shortheath is one mile south of Farnham, overlooking the town on a ridge of high ground running practically NE and SW. The height of the ground at the rain gauge is 360 ft. and the ridge falls away quickly both to the north and south. The Hampshire border to the north of Farnham is about three miles away with hills reaching the height of 600 ft. To the south and south-east are both Hampshire and Surrey with Hindhead to the south-east about seven miles distant and rising to practically 900 ft. The observations were recorded by Col. G. Chrystie and his gardener and there appear to be no gaps in the readings.

The monthly averages are given in Table I and it will be seen that December is the wettest month with 3·49 in. and June the driest with 2·00 in. The rainfall is markedly of the autumn and early winter type, no less than 42 per cent. of the annual total falling in the four months October to January. After February the amount falls away rapidly and from March to June the monthly average is two inches or a little over. There is no secondary maximum in July such as is found in many records further to the east and usually associated with thunderstorm rains, and there is a local tradition that severe thunderstorms are not common in the district. There is, however, a marked minor minimum in September followed by a sharp rise of over one inch in October, the second wettest month of the year. December is appreciably wetter than October.

TABLE I

Month	Average 40 years			Monthly Extremes			
	Inches	Millimetres	Rain-days	Greatest		Least	
				in.	date	in.	date
January	2·88	73·1	19	6·77	1937	·62	1914
February	2·34	59·4	15	5·16	1915	·06	1934
March	2·08	52·8	15	4·31	1905	·13	1929
April	2·09	53·1	15	4·36	1907	·05	'12, '38
May	2·05	52·1	14	5·04	1932	·20	1919
June	2·00	50·8	12	5·00	1905	·02	1925
July	2·34	59·4	13	5·80	1918	·29	1921
August	2·44	62·0	14	5·55	1917	·78	1906
September	2·18	55·4	13	5·50	1918	·17	1929
October	3·22	81·8	17	8·80	1903	·57	'21, 31
November	2·94	74·7	16	7·91	1929	·51	1909
December	3·49	88·7	19	9·24	1914	·31	1926
Year	30·05	763·3	182	42·85	1903	14·32	1921

The average number of rainfall days with amounts of ·01 in. or more is 182, December and January having 19 each and June 12.

With the monthly extremes (Table I) the maximum amount is 9·24 in. in December 1914 the next highest being 8·80 in October 1903. These are the only monthly totals in the 40 years exceeding eight inches. There are altogether five months with totals of less than one tenth inch, all occurring between February and June.

Of the daily falls (Table II) the highest outstanding amount is 3·36 in. which fell on July 25th, 1901. This was due to a thunderstorm which must have been very local as Colonel Chrystie states the sun was shining most of the time at the village of Rowledge less than 2 miles to the SW. Other falls of two inches or above occurred in December 1914 and October 1915. During the 40 years, only on three occasions did the annual extreme fail to reach one inch. No month during the period was

TABLE II

Month	Daily Extremes				Days of Rain			
	Greatest		Least		Most		Least	
	in.	date	in.	date		date		date
January	1·71	1908	·21	1914	27	1906	8	1935
February	1·26	1923	·02	1934	25	'16, '23	2	1932
March	1·03	1916	·07	'29, '38	28	1909	3	1929
April	1·05	1919	·04	'12, '38	24	1920	2	'12, '38
May	1·77	1932	·06	1919	25	1902	4	1901
June	1·63	1906	·02	'21, '25	21	'07, '12	1	1925
July	3·36	1901	·09	1921	24	1936	4	1911
August	1·44	1925	·19	1906	26	'02, '12	6	'99, '20, '33, '37
September	1·92	1912	·12	1929	24	1918	2	1929
October	2·09	1915	·18	1921	29	1903	7	'21, '31
November	1·57	1899	·22	'09, '17	26	'03, '26	7	1901
December	2·00	1914	·15	1926	28	'11, '34	6	1932
Year	3·36,	1901 July 25	·02	Feb. '34 June, '21, '25	235	1903	124	1921

entirely rainless but June 1925 received only ·02 in. on one day. Four other months had measurements on two days only but none of these occurred in 1921, the outstanding driest year of the series. On the other hand months with 25 days or more are fairly common, 28 being registered in March and December and 29 in October 1903.

No rain fell on the 27 days from May 30th to June 25th, 1925, or on the 26 days from September 2nd to 27th, 1912. On the four days following this last date, September 28th to October 1st, no less than 3·57 in. was recorded. In 1929 for the nine months January to September 10·02 in. was registered but the last three months of the year yielded 19·59 in., November and December totalling 15·74 in.

In the historic snowstorm of April 25th, 1908, which was particularly severe in the east Hampshire area, Colonel Chrystie notes that drifts four feet deep were formed in the road near his home. There have been later snowstorms than April 25th, but surely none so severe as the blizzard on that date in 1908.

Colonel Chrystie died on June 14th, 1939, in his 98th year, while this note was being written, and it is to be hoped that arrangements can be made for the continuation of the record.

DR. EDWARD KIDSON

In the unexpected death of Dr. E. Kidson on 12th June, meteorology, especially meteorology in the southern hemisphere, has suffered a grevious loss. Dr. Kidson was not only a first rate scientist but he was an outstanding administrator with wide views embracing the whole world based on personal knowledge of America, Europe and Australasia.

Kidson was born at Bilston, Staffordshire on March 12th, 1882, of New Zealand parents. He was educated in New Zealand and graduated at the University of New Zealand with first class honours in Physics in 1904. He commenced his scientific career as an observer in terrestrial magnetism first at the Magnetic Observatory at Christchurch and then on the staff of the Department of Terrestrial Magnetism of the Carnegie Institution of Washington. During the war he served with distinction in the Meteorological Section of the Royal Engineers with the Salonika Force.

In 1921 Kidson joined the Australian Meteorological Service and for six years was the Assistant Director of the Melbourne Weather Bureau. In 1927 he was appointed Director of the New Zealand Meteorological Service.

Kidson from the first realised the coming development of aviation in Australasia and especially the important part which New Zealand, from its geographical position, would play in trans-Pacific aerial transport. He therefore looked ahead and laid plans for a meteorological service in New Zealand capable of dealing with air lines between Australia and New Zealand across the Tasman Sea and between New Zealand and North America across the whole expanse of the Pacific Ocean.

When Kidson became Director of the Meteorological Office, Wellington, his staff consisted of four persons only, none of whom had had an adequate scientific training. It now consists of 45, several of whom are university trained men, and the latest methods of scientific meteorology are employed. Kidson himself twice visited Bergen to discuss with Dr. Bjerknes the application of his methods to southern hemisphere conditions.

Kidson attended the Conference of Empire Meteorologists in 1935 and then took part in the International Conference of Directors of Meteorological Services which met that year in Warsaw. Kidson was an excellent member of a Conference, very critical and always ready to stand up for his own views, but at the same time helpful with practical suggestions. He was a member of the International Meteorological Committee and took an active interest in all the doings of the International Meteorological Organization.

Kidson published many papers on meteorology and was an authority on Antarctic meteorology, having himself published a very complete discussion of the meteorological results of Shackleton's first Antarctic Expedition (1907–09). He was engaged on the results of Mawson's Antarctic Expeditions at the time of his death.

With the present rapid expansion of the Meteorological Services in Australia and New Zealand and the approaching retirement of Mr. Watt from the Directorship of the Melbourne Weather Bureau the advice and influence of such an experienced meteorologist as Dr. Kidson would have been invaluable to the local authorities. To lose such a councillor at this moment is a serious blow from which meteorology in Australasia will recover with difficulty.

G. C. S.

LETTERS TO THE EDITOR

Upward Discharge of Lightning from Cloud

In the interesting article on Atmospheric Electricity in the June number of the *Meteorological Magazine* mention is made of lightning discharges " between the cloud and the upper atmosphere " and Fig. 1 shows, diagrammatically, such a discharge going upwards to the ionosphere. But have any such discharges actually been observed? I have watched very many distant thunderstorms at night, and have sometimes seen what appeared to be flames going upwards for short distances above the thunder clouds, but these were very obviously streamers of cirriform cloud lit up by flashes inside the main cloud. I have never seen a flash of lightning going upwards from the top of a thunder cloud. C. J. P. CAVE.

Stoner Hill, Petersfield, Hants.
June 28th, 1939.

I am aware of no direct evidence for the occurrence of lightning discharges between a thundercloud and the upper atmosphere, but they are, I think, likely to occur on occasion. The pressure at great heights being low, the critical value of the field necessary to initiate a disruptive discharge is much lower in these regions than nearer the ground. If a thunder storm is large in vertical extent the critical field may, therefore, be reached above the cloud before it is reached within the cloud or between the cloud and the ground. Large dissipation of charge from the base of the cloud may have a similar effect. C. T. R. Wilson, in his article, " Atmospheric Electricity ", in the Dictionary of Applied Physics, Vol. III, suggests that some forms of " sheet lightning " may be due to disruptive discharges between a thundercloud and the upper atmosphere. P. A. SHEPPARD.

Imperial College of Science and Technology, S.W.7,
July 7th, 1939.

Terrestrial Radiation in May, 1939

The month of May, although not so cold as May 1938, has been marked by extreme terrestrial radiation. In this rather open position on the border of Hampshire at the very moderate elevation of 370 ft., the mean grass minimum temperature was 9·2° F. below the mean of the screen minimum and on no fewer than 19 nights the difference between the two thermometers has equalled or exceeded 10° F. This is greater than in any month since January 1936 when the observations began, the next highest being 15 in April 1938 when the mean difference between the two thermometers was 9·1° F. On the 29th the difference was 17·3° F. the readings being, screen 43·1° F., grass 25·8° F. On the first of the month, on a dull rainy night, the difference was only 0·1° F. There were 13 nights with a grass minimum temperature of 30·4° or lower.

A. HAMPTON BROWN.

Badgecote, Boundstone, Farnham, Surrey,
May 31st, 1939.

[Mr. Hampton Brown states that since the above letter was written a difference of 19° F. between the screen and grass minimum has been recorded. This was on June 4th, the readings being, screen 46° F., grass 27° F.]

Range of Temperature in June, 1939

Attention may be called to the phenomenal range of temperature in northern England during the recent dry weather. At Houghall, in the Wear valley-bottom just outside Durham, four days in succession have given a range of over 40° F., breaking the previous records set up in 1929 and 1933. Screen temperatures were, June 3rd, max. 77° F., min. 30° F.; 4th, max. 84° F., min. 37° F.; 5th, max. 82° F., min. 40° F.; 6th, max. 87·4° F., min. 45° F. The maximum on the 6th was a record for this station. At Durham Observatory, the screen max. of 86·2° was the highest on record for June since at least 1881, and almost certainly, since 1850.

A maximum of 76° F. was recorded on Dun Fell (2,735 ft.) where, on the 12th, snow lay for several hours, with max. 41·5° F., min. 30° F.

GORDON MANLEY.

Wray Cottage, Long Garth, Durham.
June, 1939.

NOTES AND NEWS

Mr. J. S. Dines.

Mr. J. S. Dines retired from the Meteorological Office on June 30th, 1939, after a service of nearly 32 years. The younger son of the late Mr. W. H. Dines, F.R.S., he was educated at Emmanuel College, Cambridge, and obtained honours in the Mathematical Tripos, 1906. Dines and his elder brother have been connected with meteorology probably for a longer period than anyone now employed in the Meteorological Office. W. H. Dines was well known as one of the pioneers of upper-air meteorology in this country, and when quite a youth, Dines and his brother assisted their father in the work of flying kites carrying self-recording instruments from a steam-yacht at Crinan, in SW Scotland. This enterprise was supported by a Joint Committee of the British Association and the Royal Meteorological Society.

After leaving Cambridge, Dines spent a year assisting his father at their delightful home at Pyrton Hill near Watlington where kite flying for obtaining meteorological observations aloft was regularly carried out. This close association with his father, who was by profession an engineer, gave Dines the intimate knowledge and practice of engineering and instrument making which has been so great an asset to him in the position which he last held at the Meteorological Office, viz., Superintendent of Instruments and of Army Services.

Dines holds the distinction of being the first meteorologist in charge of an outstation (South Farnborough) where the meteorological work was specifically designed to assist aviation.

On the outbreak of the Great War he was transferred to London and took a prominent part in the work of the Forecast Division. In 1919 he became Superintendent of that Division.

He was author or joint-author of many papers, including several in the Reports of Wind Structure which were published before the War for the Advisory Committee for Aeronautics. A monograph on the wind

[*Facing page 180*

J. S. DINES, M.A.

at St. Helena and on the SE trade winds was his first work which he prepared when he entered the Meteorological Office in 1907. Dines was keenly interested, with Mr. C. J. P. Cave, in the rate of ascent of pilot balloons. After the disastrous flooding of the River Thames in London in 1928 he determined the meteorological factors which were favourable for a recurrence of the phenomenon.

Probably his best known work is the second and subsequent editions of " The Weather Map ", which describes in simple language the basic principles which are now used in the Meteorological Office for forecasting weather by means of synoptic charts.

His many friends both inside and outside the Office will join in wishing him every happiness in his retirement.

R.C.

The Dewpond " Myth ".

To the summer wanderer on the arid downs, the occasional isolated pond may well be amazing and mysterious. Its shelving banks merge so gradually into the surrounding levels that it appears at first glance to be filled to the brim, and one naturally wonders how it can be maintained. Thus, when the term " dewpond " was given wide currency by the Hubbards' fascinating book, it speedily became popular, for to some minds, labelling a thing is as good as explaining it. The facile explanation was not wanting however; dewponds are " insulated " by a layer of non-conducting straw, they grow cold by radiation at night, and dew forms on them.

Mr. E. A. Martin tried to dispose of this idea by observing the temperature of the water surface of a dewpond at night; he found, as was to be expected, that it very rarely falls to the dew point. This should have killed the dewpond myth, but " the body won't lie down". That is the excuse for this agreeable little book.* As the source of supply, the author pours scorn on dew and has little more respect for Martin's idea of hill fogs.

* *Dewponds in Fable and Fact.* By Alfred J. Pugsley. Pp. X+ 62, illus. London, Country Life Ltd., 3/6.

He adopts instead, the idea favoured by most meteorologists that these ponds are simply open-air reservoirs for the rain which runs down their wide, sloping margins, often as much as twice the area of the pond itself. With the main points of his argument there is already general agreement, but the details are open to criticism. He quotes figures to show that in a normal year rainfall exceeds evaporation by a considerable figure, but he does not discuss how far this is true in a dry summer. That the point is important the following figures will show: at Camden Square in 1921 the evaporation exceeded the rainfall for the year as a whole and in each month from April to August inclusive, while for May to July the evaporation was 10·9 inches compared with a rainfall of only 1·5 inches. It is true that on the hill tops the rainfall is greater than at Camden Square, but in view of the much stronger winds it is doubtful if the evaporation is less.

The arguments about temperature of the water surface are sound enough, but no one seems to have discussed the possibility that dew may form on the surround and trickle down into the pond. The conductivity of earth or cement is so low that an insulating layer of straw would be an unnecessary refinement; in any case the underlying dry chalk with abundant air spaces would serve the same purpose. All that is required is a smooth, impervious slope; under suitable conditions some access of water in this way seems certain.

It is quite possible therefore for the " body " to sit up and argue that it is not really so dead as all that! In normal times rainfall is ample to maintain a pond, but in a dry summer the balance tips heavily the other way, and even a few gallons of water delivered by trickles of dew, by sea fogs and in other " occult " ways may just possibly make the difference between a pond drying up and maintaining a precarious existence. None the less, the exponents of the " pure rainfall " theory have a very strong case, and it is good that it should be presented again.

C. E. P. B.

Royal Meteorological Society.

A meeting of the Society was held on Wednesday, the 21st instant, in the Society's rooms at 49, Cromwell Road, South Kensington; Dr. B. A. Keen, F.R.S., President, was in the Chair.

The following papers were read and discussed:—

The nature of atmospheric opacity: a study of visibility observations in the British Isles.—By H. L. Wright, M.A.

A station may be classified, as to visibility, by using visibility frequencies to evaluate the atmospheric opacity, which is directly proportional to the extinction coefficient. Mean values of the atmospheric opacity on clear and foggy days at various stations in the British Isles are used to infer the contribution of various types of nuclei and particles to the opacity and to the production of fog. It is concluded that sea-salt nuclei and smoke particles play a leading part in the determination of visibility but that the effect of combustion nuclei, unless they are extremely numerous, is negligible. Water fogs are due to sea-salt nuclei and if supersaturation is attained they may thicken considerably owing to condensation of water on the nuclei. Such condensation does not occur on combustion nuclei if sea-salt nuclei are present.

The variation in opacity with relative humidity is calculated theoretically and the calculations are applied to observations of nuclei, particles, and relative humidity at Kew Observatory in the afternoon. Fair agreement is found between the calculated values of opacity and those which correspond to the visibility as observed.

One appendix gives factors for comparing the visibility of reflecting objects with the visibility of a black object silhouetted against the sky. In a second appendix the increase in opacity during precipitation is calculated.

A new theodolite for following fast-moving objects, especially for making pilot balloon observations of greater accuracy.—By Prof. L. W. Pollak, Ph.D.

A new pilot balloon theodolite is described, the essential feature of which is that the reading arrangements (verniers) remain stationary relatively to the vertical and horizontal scales from one reading until the next, so that the observer is able to follow the balloon continuously.

Correlations between monthly rainfall at eleven stations in the British Isles.—By D. A. Boyd, B.A.

The paper is based upon rainfall records for the months of January, April, July and October at eleven stations in the British Isles over a period 1870–1929. The means, variances and covariances were computed. Percentage standard errors were obtained and mapped, the general distribution proving fairly similar in all months.

A correlation coefficient for each pair of stations in each of the chosen months was evaluated and transformed to z. The value of z was dependent to a considerable extent on the inter-station distance and bearing. The linear regression of z on distance between stations was significant in each month, but the quadratic term was small and non-significant. The remaining two terms of the regression, associated with the bearing between pairs of stations, reached significance on only two occasions out of the possible eight; but as a whole, they gave a reasonably coherent picture of monthly changes in the inter-station bearing at which correlation reached a maximum.

To account for such changes, and for changes in z, data given by other workers were examined. The variations appeared to be closely associated with the persistence of a pressure gradient for winds from the south-westerly quadrant.

A large part of the residual variance is shown to be due to a marked regional variation, the association between monthly rainfalls being greatest in the south and least in the north. Maps of the residual z's show that the association within groups of stations on the west coast or on the east coast was greater than that between the west and east coast groups.

The Howard Prize, 1939.

The Council of the Royal Meteorological Society has awarded the Howard Prize (an aneroid barometer, given annually for the best essay on a selected meteorological subject) to Cadet V. A. McMillan, of H.M.S. *Conway* School Ship. Cadet C. D. Thorpe, also of H.M.S. *Conway*, was placed second in the competition. The subject of the essays was " The barometer and its use in meteorology ".

A Shower of Frogs.

An account of a shower of frogs at Trowbridge, Wilts in the afternoon of June 16th appeared in *The Times* of the 17th. Mr. E. Ettles, superintendent of the municipal swimming pool stated that about 4.30 p.m. he was caught in a heavy shower of rain and, while hurrying to shelter, heard behind him a sound as of the falling of lumps of mud. Turning, he was amazed to see hundreds of tiny frogs falling on the concrete path around the bath. Later, many more were found to have fallen on the grass nearby.

A trough of low pressure was moving eastwards on that day, rain was reported from many places in the area and Torquay reported a line-squall in the afternoon. It is possible that the squall occurred also at Trowbridge, and that this was strong enough to have forced the frogs from the water, although Mr. Norman's theory given below may be the more probable explanation.

Showers of frogs are not uncommon and have been reported from time to time. Several subsequent letters have appeared in *The Times* citing instances at home and abroad.

Showers of fish have been reported from very early days, notably in India during stormy weather. Accounts and suggested explanations are given by Dr. S. L. Hora in the *Journal of the Asiatic Society of Bengal* 1933 and by J. R. Norman in the *Natural History Magazine* 1928. Mr. Norman suggests that in the case of frogs it is possible that numbers of tadpoles may undergo metamorphosis simultaneously, hide if the weather is at all dry and come out into the open with the first rain so suddenly that they appear to have fallen from the sky.

A letter to *The Times* of June 29th reports rains of fishes from Bourke, N.S.W. with the engaging theory that the spawn is drawn up from lakes and rivers in waterspouts, that it germinates in the clouds and that when full grown the fish fall to the ground.

Other extraordinary " showers " are on record, birds, larvæ, worms, oranges, pebbles, and so on; an amusing account " Showers of What Not " is given by Ivan E. Houk in *Tycos Rochester* April 1930. Perhaps the most remarkable was a shower of fossils (partly fossilised hazel nuts) at Dublin in 1867.

Coloured rains and snows of various hues are also on record, notably "showers of blood!" in desert areas. The theory of the formation of coloured rain is discussed by C. J. Boyden in the *Quarterly Journal of the Royal Meteorological Society* 1937.

An Unusual Electrical Discharge at Wellington.

At 23h. 25m. New Zealand Standard Time, on April 12th, 1939, the writer and two friends came out of a house on Kelburn Parade, Wellington, New Zealand, altitude about 130 metres, and were immediately arrested by what appeared to be a searchlight playing on the under surface of broken clouds lying over the Wellington

Harbour. The clouds were very low fracto-cumulus, at about 200 metres, as judged by their level on the hills. As no searchlight beam was visible, one observer said that he thought that the phenomenon was due to " lightning ".

The writer then descended Mount Street, where he had a much better view. It was seen that the clouds were moving very slowly from the south, were about six-tenths in amount (mostly overhead and towards the east) and were illuminated almost continuously by silent discharges which passed comparatively slowly, like " blushes " (though the light was whitish) over their surfaces. The slower discharges were estimated to take as long as half a second to pass over the surface of a cloud. Others were much quicker and seemed to be brighter. Occasionally a bright but silent flash passed very rapidly from one cloud to the next. Although now and then several clouds discharged simultaneously, for the most part the " blushes " affected first one cloud and then another.

The clouds were kept under observation until 23h. 40m. Standard Time, when the writer went indoors. During the whole of this period there was no cessation of the discharges.

At 22h. 30m. Standard Time, on the same night, Mr. Thompson, of the store in Kelburn Park, saw on the southern horizon a bright light which he took to be the aurora australis. This is confirmed by reports of the aurora in the South Island received by Mr. Geddes of the Carter Observatory, Wellington.

C. E. PALMER.

In forwarding this note Dr. E. Kidson remarked, " On the date in question, New Zealand was covered by a rather intense anticyclone and Wellington was not far from the centre, which was to the southwest. The sky was clear above the low inversion in which the cloud mentioned by Mr. Palmer occurred, and the atmosphere must have been very stable. Dry weather had been experienced for a long time throughout most of the country. The phenomenon could not have been due to any such effect as reflection of auroral lights."

Sunshine, June 1939

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

	Total hrs.	Diff. from average hrs.		Total hrs.	Diff. from average hrs.
Stornoway ..	163	−4	Chester ..	234	+39
Aberdeen ..	209	+28	Ross-on-Wye	217	+10
Dublin ..	205	+23	Falmouth ..	261	+34
Birr Castle ..	209	+49	Gorleston ..	237	+26
Valentia ..	249	+76	Kew.. ..	220	+17

Kew temperature, mean, 59·5° F. : diff. from average, −0·4° F.

OBITUARY

SIR FRANCIS DYKE ACLAND. We regret to announce the death on June 8th, 1939, of the Rt. Hon. Sir Francis Dyke Acland, Bart., P.C., of Killerton, Devon. A climatological station has been maintained by Sir Francis and other members of his family since 1900 and the records have been published regularly since 1907, in the *Meteorological Record* of the Royal Meteorological Society till 1911 and from 1912 in the *Monthly Weather Report.*

DR. A. E. KENNELLY. We regret to announce the death on June 18th, 1939, of Dr. A. E. Kennelly, co-discoverer with Oliver Heaviside of the ionized layer surrounding the earth.

COLONEL GEORGE CHRYSTIE. We regret to announce the death on June 14th, 1939, of Colonel Chrystie who for 40 years maintained a rainfall record at Short Heath Lodge, Farnham. An account of this record is given on page 173.

Erratum

With reference to the note on page 25 of the February issue of the Magazine we now learn that Lieutenant-Commander F. W. Reichelderfer was commissioned Commander in the U.S. Navy on June 23rd, 1938.

Rainfall : June 1939 : England and Wales

Co.	Station.	In.	Per cent of Av.	Co.	Station.	In.	Per cent of Av.
Lond'n	Camden Square......	1·20	59	*Warw*	Birminghm, Edgbaston	1·61	69
Surrey	Reigate, Wray Pk. Rd.	1·36	65	*Leics* .	Thornton Reservoir...	1·48	69
Kent .	Tenterden, Ashenden.	1·70	89	,, .	Belvoir Castle........	2·81	147
,, .	Folkestone, I. Hospital	1·75	..	*Rutl'd*	Ridlington	2·27	118
,, .	Margate, Cliftonville..	1·32	75	*Lincs*.	Boston, Skirbeck.....	1·87	103
,, .	Edenb'dg., Falconhurst	·84	38	,, .	Cranwell Aerodrome..	1·88	112
Sussex	Compton, Compton Ho	2·12	85	,, .	Skegness, Marine Gdns	2·08	116
,, .	Patching Farm.......	1·08	53	,, .	Louth, Westgate.....	3·25	150
,, .	Eastbourne, Wil. Sq..	1·44	78	,, .	Brigg, Wrawby St....	2·40	..
Hants.	Ventnor, Roy.Nat.Hos.	1·78	97	*Notts* .	Mansfield, Carr Bank..	2·14	95
,, .	Southampton, East Pk	1·92	96	*Derby*.	Derby, The Arboretum	·82	35
,, .	Ovington Rectory....	2·47	106	,, .	Buxton, Terrace Slopes	2·83	88
,, .	Sherborne St. John...	1·45	68	*Ches* .	Bidston Obsy........	2·54	115
Herts .	Royston, Therfield Rec	2·31	103	*Lancs*.	Manchester, Whit. Pk.	2·58	98
Bucks.	Slough, Upton........	1·26	61	,, .	Stonyhurst College...	4·58	149
Oxford	Oxford, Radcliffe.....	1·97	88	,, .	Southport, Bedford Pk	3·12	144
N'hant	Wellingboro, Swanspool	1·78	85	,, .	Ulverston, Poaka Beck	3·18	98
,, .	Oundle	1·62	..	,, .	Lancaster, Greg Obsy.	3·69	144
Beds .	Woburn, Exptl. Farm.	2·92	149	,, .	Blackpool	3·01	138
Cambs	Cambridge, Bot. Gdns.	1·96	93	*Yorks*.	Wath-upon-Dearne ...	1·82	82
,, .	March	2·02	103	,, .	Wakefield, Clarence Pk.	1·48	69
Essex.	Chelmsford, CountyGns	1·38	73	,, .	Oughtershaw Hall....	4·52	..
,, .	Lexden Hill House....	1·45	..	,, .	Wetherby, Ribston H.	..	..
Suff .	Haughley House.....	1·64	..	,, .	Hull, Pearson Park...	3·19	155
,, .	Rendlesham Hall.....	..	..	,, .	Holme-on-Spalding ...	2·31	105
,, .	Lowestoft Sec. School.	1·25	69	,, .	Felixkirk, Mt. St. John	2·46	112
,, .	Bury St. Ed., WestleyH	2·02	96	,, .	York, Museum	1·67	81
Norf..	Wells, Holkham Hall.	2·57	131	,, .	Pickering, Houndgate.	1·97	93
Wilts .	Porton, W.D. Exp'lStn	1·73	90	,, .	Scarborough.........	3·21	174
,, .	Bishops Cannings	2·59	107	,, .	Middlesbrough.......	2·08	110
Dorset	Weymouth, Westham.	2·19	123	,, .	Baldersdale, Hury Res.	2·43	103
,, .	Beaminster, East St ..	3·38	150	*Durhm*	Ushaw College.......	2·61	121
,, .	Shaftesbury	2·97	..	*Norl'd*	Newcastle, Leazes Pk.	2·07	98
Devon.	Plymouth, The Hoe...	3·61	167	,, .	Bellingham, Highgreen	2·36	103
,, .	Holne, Church Pk.Cott	5·07	177	,, .	Lilburn Tower Gdns..	1·89	91
,, .	Teignmouth, Den Gdns	2·55	133	*Cumb*.	Carlisle, Scaleby Hall.	3·09	123
,, .	Cullompton	3·17	150	,, .	Borrowdale, Seathwaite	12·00	197
,, .	Sidmouth, U.D.C.....	2·82	..	,, .	Thirlmere, DaleHeadH.	6·20	146
,, .	Barnstaple, N. Dev.Ath	1·07	48	,, .	Keswick, High Hill...	4·68	161
,, .	Dartm'r, Cranmere P'l	4·90	..	,, .	Ravenglass, The Grove	3·78	145
,, .	Okehampton, Uplands.	3·54	128	*West* .	Appleby, Castle Bank.	2·80	122
Cornw	Redruth, Trewirgie...	3·00	120	*Mon* .	Abergavenny, Larchf'd	2·28	93
,, .	Penzance, MorrabGdns	2·36	106	*Glam* .	Ystalyfera, Wern Ho..	5·46	145
,, .	St. Austell, Trevarna..	3·02	116	,, .	Treherbert, Tynywaun	6·36	..
Soms .	Chewton Mendip.....	3·76	127	,, .	Cardiff, Penylan......	1·85	74
,, .	Long Ashton	2·11	83	*Carm* .	Carmarthen, M.&P.Sc.	3·83	130
,, .	Street, Millfield	3·52	170	*Card* .	Aberystwyth	2·31	..
Glostr.	Blockley	2·45	..	*Radn'r*	Bir. W. W. Tyrmynydd	3·28	100
,, .	Cirencester, Gwynfa ..	2·25	94	*Mont* .	Lake Vyrnwy........	3·69	117
Here .	Ross-on-Wye	1·61	74	*Flint* .	Sealand Aerodrome...	2·00	98
,, .	Kington, Lynhales....	1·88	80	*Mer* .	Blaenau Festiniog....	7·06	118
Salop .	Church Stretton......	1·45	..	,, .	Dolgelley, Bontddu...	3·82	110
,, .	Shifnal, Hatton Grange	1·69	76	*Carn* .	Llandudno	1·74	92
,, .	Cheswardine Hall	2·22	91	,, .	Snowdon, L. Llydaw 9	12·45	..
Worc .	Malvern, Free Library.	2·00	86	*Angl* .	Holyhead, Salt Island.	1·62	75
,, .	Ombersley, Holt Lock.	1·81	80	,, .	Lligwy..............	1·92	..
Warw	Alcester, Ragley Hall.	2·16	95	*I.Man*	Douglas, Boro' Cem...	1·97	81

Erratum : Aberystwyth, May *for* 1·78 *read* 1·06.

Rainfall: June 1939: Scotland and Ireland

Co.	Station.	In.	Per cent of Av.	Co.	Station.	In.	Per cent of Av.
Guern.	St.PeterP't.GrangeRd.	2·18	118	*R&C.*	Stornoway, C.G.Stn...	1·30	59
Wig .	Pt. William, Monreith.	1·71	73	*Suth* .	Lairg	1·47	70
,, .	New Luce School.....	2·58	89	,, .	Skerray Borgie.......	2·11	..
Kirk .	Dalry, Glendarroch...	3·37	121	,, .	Melvich.............	1·82	94
Dumf.	Eskdalemuir Obs.....	4·23	134	,, .	Loch More, Achfary..	3·51	95
Roxb .	Hawick, Wolfelee	2·83	121	*Caith* .	Wick	1·23	68
,, .	Kelso, Broomlands....	1·63	77	*Orkney*	Deerness	1·20	65
Peebs .	Stobo Castle.........	1·55	66	*Shet* .	Lerwick Observatory.	1·62	91
Berw .	Marchmont House....	1·80	78	*Cork* .	Cork, University Coll.	1·78	70
E.Lot.	North Berwick Res...	1·55	93	,, .	Roches Point, C.G.Stn.	1·50	56
Midl .	Edinburgh, Blackfd. H	1·31	65	,, .	Mallow, Waterloo	1·88	85
Lanark	Auchtyfardle	1·76	..	*Kerry.*	Valentia Observatory.	3·13	98
Ayr .	Kilmarnock, Kay Park	2·08	..	,, .	Gearhameen	4·80	96
,, .	Girvan, Pinmore	2·28	79	,, .	Bally McElligott Rec.	2·48	..
,, .	Glen Afton, Ayr San..	2·82	94	,, .	Darrynane Abbey....	2·01	64
Renf .	Glasgow, Queen's Park	1·80	78	*Wat* .	Waterford, Gortmore.	2·44	93
,, .	Greenock, Prospect H.	1·72	55	*Tip* .	Nenagh, Castle Lough.	2·14	87
Bute .	Rothesay, Ardencraig.	2·88	94	,, .	Cashel, Ballinamona..	2·73	120
,,	Dougarie Lodge......	2·66	98	*Lim* .	Foynes, Coolnanes....	2·28	88
Argyll	Loch Sunart, G'dale..	3·40	106	,, .	Limerick, Mulgrave St.	1·85	77
,,	Ardgour House	5·92	..	*Clare* .	Inagh, Mount Callan..	3·28	..
,,	Glen Etive	3·97	84	*Wexf* .	Gorey, Courtown Ho..	2·02	83
,,	Oban	2·66	..	*Wick* .	Rathnew, Clonmannon	2·03	..
,,	Poltalloch	..	..	*Carlow*	Bagnalstown FenaghH	2·11	85
,,	Inveraray Castle	4·22	107	,, .	Hacketstown Rectory.	2·04	73
,,	Islay, Eallabus	1·97	75	*Leix* .	Blandsfort House	2·45	95
,, .	Mull, Benmore.......	6·70	85	*Offaly.*	Birr Castle	2·28	99
,,	Tiree	2·01	79	*Kild* .	Straffan House.......	..	..
Kinr .	Loch Leven Sluice....	1·77	81	*Dublin*	Dublin, Phoenix Park.	2·12	107
Fife .	Leuchars Aerodrome..	1·41	84	*Meath.*	Kells, Headfort......	2·10	79
Perth .	Loch Dhu	4·20	101	*W.M* .	Moate, Coolatore.....	2·02	..
,, .	Crieff, Strathearn Hyd.	1·94	73	,, .	Mullingar, Belvedere..	2·09	80
,, .	Blair Castle Gardens..	1·38	70	*Long* .	Castle Forbes Gdns ..	3·86	148
Angus.	Kettins School.......	1·62	78	*Galway*	Galway, Grammar Sch.	1·42	55
,, .	Pearsie House	1·43	..	,, .	Ballynahinch Castle ..	2·10	59
,, .	Montrose, Sunnyside..	1·33	80	,, .	Ahascragh, Clonbrock.	2·95	105
Aberd.	Balmoral Castle Gdns.	1·80	106	*Rosc* .	Strokestown, C'node..	2·40	102
,, .	Logie Coldstone Sch ..	..	..	*Mayo.*	Blacksod Point	2·24	80
,, .	Aberdeen Observatory.	1·29	75	,, .	Mallaranny..........	2·94	..
,, .	New Deer SchoolHouse	1·50	75	,, .	Westport House......	2·52	93
Moray	Gordon Castle	1·48	73	,, .	Delphi Lodge........	6·63	115
,, .	Grantown-on-Spey ...	2·54	113	*Sligo* .	Markree Castle.......	1·98	66
Nairn.	Nairn...............	1·62	92	*Cavan.*	Crossdoney, Kevit Cas.	2·77	..
Inv's .	Ben Alder Lodge.....	2·11	..	*Ferm* .	Crom Castle	4·63	171
,, .	Kingussie, The Birches	1·27	..	*Arm'h*	Armagh Obsy........	1·94	77
,, .	Loch Ness, Foyers....	1·42	64	*Down.*	Fofanny Reservoir ...	4·65	..
,, .	Inverness, Culduthel R	1·08	57	,, .	Seaforde	1·63	59
,, .	Loch Quoich, Loan...	4·14	..	,, .	Donaghadee, C. G. Stn.	1·80	77
,, .	Glenquoich	4·25	87	*Antrim*	Belfast,Queen's Univ .	1·86	75
,, .	Arisaig House	2·33	71	,, .	Aldergrove Aerodrome	1·87	78
,, .	Glenleven, Corrour ...	3·27	97	,, .	Ballymena, Harryville.	2·29	79
,, .	Ft. William, Glasdrum	3·51	..	*Lon* .	Garvagh, Moneydig...	4·21	..
,, .	Skye, Dunvegan	2·19	..	,, .	Londonderry, Creggan.	2·50	89
,, .	Barra, Skallary	1·69	..	*Tyrone*	Omagh, Edenfel......	2·41	85
R&C.	Tain, Ardlarach......	1·27	62	*Don* .	Malin Head..........	2·03	77
,, .	Ullapool	1·15	49	,, .	Dunfanaghy	1·80	75
,, .	Achnashellach	2·53	64	,, .	Dunkineely..........	1·71	..

Reference Table: Climatological Table of the British Empire.

Stations.	Lat.	Long.	Height above M.S.L.	*Hour of Observation	Authority.	Period of Normals. Pressure.	Temperature.	Rainfall.
			Ft.					
London, Kew Obsy...	51°28′N.	0°19′W.	34	7	Meteorological Office, Air Ministry, London.	'81–'15	'01–'30	'81–'15
Gibraltar	36° 6′N.	5°21′W.	400	7	Do. do.	'52–'30	'52–'32	—
Malta..	35°54′N.	14°31′E.	233	7	Do. do.	'52–'23	'53–'23	'53–'23
St. Helena	15°57′S.	5°40′W.	2,000	6½	W. E. Jackson, Esq., Longwood Villa	'25–'35	'25–'36	'25–'35
Sierra Leone ..	8°29′N.	13°14′W.	181	7	British West African Meteorological Service.	'77–'20	—	'74–'20
Lagos, Nigeria ..	6°27′N.	3°24′E.	10	7	Do. do.	'91–'26	'91–'27	'91–'26
Kaduna, Nigeria ..	10°32′N.	7°25′E.	1,915	7	Do. do.	—	'17–'31	'16–'31
Zomba, Nyasaland ..	15°23′S.	35°18′E.	3,020	9	Director of Agriculture	'08–'32	'92–'26	'92–'26
Salisbury, Rhodesia..	17°48′S.	31° 5′E.	4,831	9	Department of Agriculture.. ..	'21–'36	'97–'23	—
Cape Town	33°56′S.	18°29′E.	40	8½	H.M. Astronomer	'41–'28	'57–'24	'41–'28
Johannesburg ..	26°11′S.	28° 4′E.	5,925	8½	The Union Astronomer, Johannesb'g	'04–'28	'04–'28	'88–'24
Mauritius	20° 6′S.	57°33′E.	181	9	Royal Alfred Observatory	'75–'30	'61–'19	'71–'30
Calcutta, Alipore Obsy.	22°32′N.	88°20′E.	22	8	Director General of Observatories, Poona.	'89–'10	'77–'20	'29–'20
Bombay	18°54′N.	72°49′E.	37	8	Do. do.	'47–'16	'78–'20	'47–'16
Madras	13° 4′N.	80°15′E.	22	8	Do. do.	'89–'20	'75–'20	1813–1920
Colombo, Ceylon ..	6°54′N.	79°52′E.	24	9½	Surveyor-General, Colombo ..	'69–'20	'69–'20	'69–'20
Singapore	1°18′N.	103°53′E.	9	10	Malaya Meteorological Service, Singapore.	'98–'22	'98–'22	'69–'20
Hongkong	22°18′N.	114°10′E.	109	9	Director, Royal Observatory ..	'84–'28	'84–'18	'84–'28
Sandakan	5°50′N.	118° 7′E.	182	9	Principal Medical Officer, N. Borneo	—	'79–'95; '04–'29	'79–'95; '04–'29
Sydney	35°51′S.	151°13′E.	138	9	Commonwealth Meteorologist, Melbourne.	69 years	69 years	69 years
Melbourne	37°49′S.	144°58′E.	115	9	Do. do.	70 years	72 years	72 years
Adelaide	34°56′S.	138°35′E.	140	9	Do. do.	80 years	80 years	98 years
Perth, W. Australia..	31°57′S.	115°51′E.	197	9	Do. do.	43 years	31 years	52 years
Coolgardie	30°57′S.	121°10′E.	1,389	9	Do. do.	'97–'31	'97–'21	'93–'27
Brisbane	27°28′S.	153° 2′E.	125	9	Do. do.	41 years	41 years	'41–'50; '59–'32
Hobart, Tasmania ..	42°53′S.	147°20′E.	177	9	Do. do.	43 years	57 years	85 years
Wellington, N.Z. ..	41°16′S.	174°46′E.	394	9	Meteorological Office, Wellington ..	'64–'23	66 years	'62–'23
Suva, Fiji	18° 8′S.	178°26′E.	12	8	The Harbour Master, Suva ..	'86–'28	'86–'28	'86–'28
Apia, Samoa ..	13°48′S.	171°46′W.	6½	9	The Director, Apia Observatory ..	'90–'24	'90–'23	'90–'24
Kingston, Jamaica ..	17°55′N.	76°12′W.	111	7	Government Meteorologist ..	'81–'98; '08–'22	'80–'99; '07–'18	'70–'19
Grenada, W.I. ..	12° 5′N.	61°46′W.	617	9	Supt. of Prisons, Richmond Hill ..	'91–'25	'87; '91–'29	'91–'29
Toronto	43°40′N.	79°24′W.	379	8	Director, Meteorological Service of Canada.	'86–'21	'73–'20	'74–'20
Winnipeg	49°53′N.	97° 7′W.	760	7	Do. do.	'86–'20	'73–'20	'86–'20
St. John, N.B. ..	45°17′N.	66° 4′W.	119	9	Do. do.	'02–'26	45 years	'61–'10
Victoria, B.C. ..	48°24′N.	123°19′W.	230	9	Do. do.	'00–'24	'91–'25	'91–'25

* Local or zone time.

***Notes*:—The mean wet bulb. relative humidity and mean cloud amount refer to the morning hour of observation only. The pressure is reduced to mean of day.**

Climatological Table for the British Empire, January, 1939

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	1003·4	−14·2	54	26	45·5	38·3	41·9	+ 1·5	39·9	88	8·7	4·32	+ 2·56	20	1·5	18
Gibraltar	1020·0	− 1·5	68	43	59·8	50·3	55·1	+ 0·2	50·2	81	4·7	2·50	—	11	5·9	59
Malta	1015·7	− 1·3	73	46	59·8	50·6	55·2	− 0·1	49·9	78	5·5	1·26	− 1·95	10	6·5	65
St. Helena	1015·4	− 0·6	70	57	66·6	59·6	63·1	− 0·3	60·5	95	9·7	2·19	+ 0·15	18	—	—
Freetown, Sierra Leone	1011·3	+ 2·2	89	71	86·7	74·6	80·7	—	72·9	87	6·2	1·22	+ 0·81	4	—	—
Lagos, Nigeria	1010·0	+ 0·4	89	66	87·3	71·9	79·6	− 1·3	72·9	96	4·1	0·34	− 0·70	3	6·7	57
Kaduna, Nigeria	1011·2	—	97	53	87·8	58·8	73·3	− 0·3	51·8	40	2·5	0·00	0·00	0	9·2	80
Zomba, Nyasaland	1006·8	− 0·8	85	62	79·0	65·4	72·2	− 0·6	68·7	84	7·6	19·33	+ 8·23	21	—	—
Salisbury, Rhodesia	1010·7	+ 0·3	83	56	76·2	59·6	67·9	− 1·8	62·4	78	8·2	9·47	—	21	5·6	43
Cape Town	1014·0	+ 0·6	93	56	80·8	61·7	71·3	+ 1·4	62·5	67	3·4	0·00	− 0·68	0	—	—
Johannesburg	1010·4	+ 0·4	87	49	76·4	55·0	65·7	− 1·0	57·6	73	6·0	3·74	− 2·43	15	7·3	54
Mauritius	1012·3	+ 0·6	91	66	88·0	71·4	79·7	+ 0·4	73·4	65	5·0	1·56	− 6·60	16	9·5	72
Calcutta, Alipore Obsy.	1015·6	+ 0·4	89	51	82·5	56·3	69·4	+ 2·8	57·6	90	1·6	0·06	− 0·36	0*	—	—
Bombay	1013·0	− 0·6	92	64	84·8	68·4	76·6	+ 1·1	66·6	72	1·5	0·00	− 0·10	0*	—	—
Madras	1013·8	− 0·3	86	63	83·8	68·0	75·9	− 0·3	69·2	78	5·0	0·65	− 0·49	1*	—	—
Colombo, Ceylon	1011·2	+ 0·4	88	67	84·9	71·1	78·0	− 1·5	72·4	74	5·0	6·61	+ 3·36	12	7·8	66
Singapore	1009·6	− 0·8	89	72	85·3	73·9	79·6	− 0·1	76·2	76	7·7	10·69	+ 0·80	19	5·5	46
Hongkong	1020·2	+ 0·5	74	50	65·5	56·8	61·1	+ 0·9	57·1	80	7·6	1·10	− 0·22	7	4·2	39
Sandakan	1009·4	—	86	72	84·1	75·0	79·5	− 0·3	76·2	88	9·1	23·35	+ 3·95	25	—	—
Sydney, N.S.W.	1011·2	− 1·2	114	60	78·6	65·9	72·3	+ 0·7	66·9	67	6·2	3·23	− 0·44	13	6·3	45
Melbourne	1011·0	− 1·9	114	49	81·7	58·3	70·0	+ 2·6	60·1	52	5·5	0·31	− 1·58	5	8·6	60
Adelaide	1009·5	− 3·5	118	55	95·1	65·0	80·1	+ 6·4	64·6	32	3·6	1·30	+ 0·58	4	10·6	75
Perth, W. Australia	1009·7	− 2·8	98	51	79·4	60·1	69·7	− 4·1	62·5	57	5·7	0·68	+ 0·34	5	10·3	85
Coolgardie	1007·6	− 3·8	110	55	88·1	64·9	76·5	− 0·9	64·8	63	5·2	6·43	+ 5·97	6	—	—
Brisbane	1010·6	− 0·7	100	65	85·6	70·6	78·1	+ 1·6	71·9	73	7·4	1·93	− 4·52	10	6·9	50
Hobart, Tasmania	1011·2	− 0·9	93	43	70·7	50·9	60·8	− 1·2	52·1	49	5·9	0·65	− 1·18	8	8·7	58
Wellington, N.Z.	1006·8	− 6·5	74	42	66·0	51·8	58·9	− 3·6	54·8	68	6·3	0·89	− 2·44	7	8·6	58
Suva, Fiji	1005·9	− 1·6	91	70	65·6	74·3	79·9	0·0	75·7	87	8·1	30·71	+19·28	27	4·6	35
Apia, Samoa	1008·7	+ 0·8	87	72	83·6	74·2	78·9	− 0·1	75·7	83	7·8	59·57	+42·52	28	5·7	45
Kingston, Jamaica	1015·2	+ 0·1	89	64	86·2	68·2	77·2	+ 0·4	65·5	82	4·3	0·59	− 0·37	6	6·7	60
Grenada, W.I.																
Toronto	1016·5	− 1·4	52	−9	30·4	17·0	23·7	+ 1·5	—	—	8·5	2·25	− 0·54	21	1·8	19
Winnipeg	1015·9	− 5·0	27	−32	13·6	−4·7	4·5	+ 8·4	—	—	7·4	0·79	− 0·12	12	2·1	21
St. John, N.B.	1012·0	− 3·5	44	−8	26·5	10·9	18·7	− 0·5	14·2	70	5·9	3·36	− 1·44	13	4·0	43
Victoria, B.C.	1015·7	− 0·3	51	33	46·0	39·8	42·9	+ 3·9	41·3	92	8·9	4·65	+ 0·11	23	1·6	18

* For Indian stations a rain day is a day on which 0·1 in. or more rain has fallen.

Daily Readings at Kew Observatory, June 1939

Date.	Pressure, M.S.L. 13h.	Wind, Dir. 13h.	Force	Temp. Min.	Temp. Max.	Rel. Hum. 13h.	Rain.	Sun.	REMARKS.
	mb.			°F.	°F.	%	in.	hrs.	
1	1026·0	NE	4	48	64	62	—	8·1	
2	1024·5	ENE	5	50	74	45	—	12·3	
3	1025·3	NE	5	49	72	31	—	14·7	
4	1024·4	E	5	51	74	31	—	15·3	
5	1024·5	E	5	54	76	27	—	15·2	
6	1020·8	ENE	3	59	84	45	—	13·5	
7	1021·1	NNE	2	59	85	39	—	13·0	
8	1023·3	NE	3	57	72	52	—	11·1	
9	1026·7	ESE	3	49	67	45	—	13·7	
10	1015·1	SW	3	47	76	48	—	14·3	
11	1006·9	NNW	3	53	64	76	0·26	4·5	r–r_0 0h–7h, tlr 24h.
12	1011·8	W	3	47	60	40	trace	8·9	qpr_0 14h, pr_0 17h.
13	1016·3	NW	3	43	57	45	trace	6·6	pr_0 14h, 15h & 16h.
14	1013·1	SSW	4	52	64	60	trace	2·2	pr_0 15h & 16h.
15	1010·3	SSW	4	56	61	73	0·01	0·3	d_0 8h–9h, r_0 24h.
16	1007·9	S	3	57	63	91	0·22	1·4	r_0–r 0h–6h & 9h–12h.
17	1016·3	SW	3	49	63	64	—	7·6	
18	1013·3	SSW	4	54	65	75	0·10	4·4	pr_0 13h, r 17h–18h.
19	1017·8	NW	3	51	67	49	trace	8·3	pr_0 11h.
20	1017·7	NW	2	49	61	88	0·35	3·7	tlRr_0 11h–13h, t 15h.
21	1016·8	NE	5	53	68	56	0·05	3·5	r_0–r 9h–10h, pr_0 11h.
22	1016·0	NE	4	56	61	92	trace	0·8	id_0 13h–15h.
23	1011·3	NNE	2	53	59	85	0·09	0·0	R$r_0$5h, d_0 9h–10h.
24	1004·7	NNE	4	53	57	82	0·02	0·0	id_0 5h–7h, r_0 19h–20h.
25	1007·1	NNE	2	48	60	53	—	2·7	
26	1016·4	SW	2	48	65	56	trace	6·0	pr_0 16h.
27	1023·5	SSW	4	47	68	54	—	12·1	
28	1013·2	SW	4	57	63	88	trace	1·2	id_0 8h–13h. pr_0 14h.
29	1013·7	SSW	4	58	69	49	—	7·2	
30	1011·1	WSW	3	53	67	68	0·05	7·8	qpRr_0 11h, pr_0 17h & 18h.
*	1016·6	—		52	67	59	1·15	220·4	*Means or Totals.

General Rainfall for June 1939

	Per cent.
England and Wales	106
Scotland	82
Ireland	88
British Isles	96

(48187) Wt. 22/31 1375 7/39 Hw. G.377/6

THE METEOROLOGICAL MAGAZINE

M.O. 441

AIR MINISTRY : METEOROLOGICAL OFFICE

Vol. 74 | August 1939 | No. 883

A THUNDERY SPELL IN JULY, 1939, AND SOME PREVIOUS THUNDERY PERIODS

By C. K. M. Douglas, B.A.

Thunderstorms are numerous in July whenever the month is of an unsettled type, with numerous depressions, and July 1939 was no exception. The most notable thundery spell began in Ireland on the 13th and spread next day to north-west England and south-west Scotland. From then till the 21st thunderstorms occurred every day in England and Wales, and were widespread except on the 18th, when only a few districts were affected. Another widespread outbreak occurred on the 24th. The storms were mostly in the day-time but there were a few at night, though nothing approaching the number of night storms experienced on August 1st to 12th, 1938. The storms were severe locally but there is no reason to believe that there was anything comparable in intensity with the storm of August 4th, 1938. There were quite a number of cases of damage by lightning, but this was due to the lowness of the clouds. Hail was frequent, and also heavy rain, the largest daily rainfalls reported by telegram being 3·72 in. at Troon on the 5th, and 2·83 in. at Teignmouth and 2·32 in. at Shrewsbury on the 21st. During the thundery period there was much cloud and showers or periods of rain in various districts in addition to thunderstorms.

The thunderstorms were associated with depressions which originally moved south-eastward from near south Greenland and subsequently turned east or north-east and filled up over England. The first one was over Ireland on the 14th and dissipated over the Midlands on the 17th; the second was off Brittany on the 18th and filled up on the 21st, and the third moved more quickly south-eastward over England on the 24th and then away eastward.

The thunderstorms developed in maritime polar air, either behind a cold front or occlusion, or else in the central area of a depression after the occlusion had been twisted up and had ceased to be recognisable in the region in question. The air currents had their origin in the Greenland area and had gained warmth and moisture from the surface of the Atlantic, including the seas off our south-west coasts in the case of the storms up to the 21st. Upper air temperature was low, and only a little trigger action was required to start off thunderstorms. This was provided by even small amounts of sunshine, or in the case of the few night storms by convergence or orographic ascent. The table below gives the mean temperatures observed at Mildenhall and Aldergrove for the period July 15th to 21st, 1939 at pressures of 900, 700 and 500 mb., corresponding to

	Mean temperature (°F.) July 15th–21st 1939		Mean temperature (°F.) August 4th–12th 1938	
Pressure (mb.)	Mildenhall	Alder-grove	Mildenhall	Alder-grove
900	49·9 (−2·4)	50·7	60·0 (+8·2)	58·3
700	27·1 (−6·1)	30·8	36·6 (+3·7)	37·7
500	−1·3 (−7·1)	4·1	9·1 (+2·9)	9·3

height of about 3,000, 10,000 and 18,000 feet, with the differences between the Mildenhall figures and the Duxford monthly normals for the period 1927–36. For these seven days the mean temperature was lower over Mildenhall than over Aldergrove, and the storms were much more widespread in England than in Ireland or Scotland.

The corresponding figures for August 4th to 12th 1938 are included for comparison (August 1st to 3rd are omitted, because the thunderstorms were only experienced in south-west districts on those days). It can be seen that in the 1938 period the mean lapse-rate over Mildenhall from 3,000 to 18,000 feet was the same as in the recent thundery spell, but that the whole column of air was ten degrees warmer. In neither period was there much variation of upper air temperature.

Before leaving the July thunderstorms, one other point deserves mention, namely the influence of surface friction on the supply of moisture in a depression. It is almost impossible to evaluate the inflow of air accurately, but from the available pilot balloon data and the observed absolute humidity and general theoretical considerations, it must have been sufficient to produce nearly 2 mm. of rain per day over the whole of a circular area of 200 miles radius, so long as the depressions had a definite circulation. Actually, of course, the rainfall is irregularly distributed. If when a depression fills up a flat area of uniform pressure supervenes, precipitation becomes less general, but there is still a chance of severe local thunderstorms, even on successive days. The evaporation from land, especially if wet, is an appreciable factor.

The Editor has asked for a more general discussion of the normal development of the weather situation leading to widespread thunderstorms. These developments are diverse and only some of the most frequent can be discussed in a short space, with special reference to unusually prolonged thundery spells. The period August 1st to 12th 1938 (fully discussed in the *Meteorological Magazine* for September 1938) and the recent period, are good examples of two of the main thundery types. It has long been recognised that the spread of a shallow depression from France generally leads to thunderstorms in summer, and it is now known that there is a transference of air (not always including the surface layers), which brings over thundery weather, often with active storms crossing the Channel at the very onset of the thundery upper air situation. Alto cumulus castellatus clouds often give a valuable preliminary warning, corresponding with the altostratus clouds ahead of a typical warm front, but normally the thunderstorms cannot break out until the new air mass extends lower down. If this were not so, the warning given by the turret clouds would be much shorter than it actually is. Low turret clouds (stratocumulus cumuliformis) usually indicate thunder within a short period.

The storms which give spectacular displays of lightning are associated with really high temperatures, at least within some 200 miles. The supply of very warm air in Western Europe is limited, and if there are widespread frontal thunderstorms it is quickly exhausted, and stable conditions often follow with cold air below the warm air, so that the worst storms are often not associated with prolonged thundery spells. In the case of August 4th, 1938, the air behind the occlusion was itself warm and no important surface of discontinuity developed aloft, so that thunderstorms continued, but the prolongation of the thundery weather till August 12th was only made possible by the general conditions of air circulation (or in other words the general pressure distribution) over Europe and the Atlantic, and this is true of all thundery periods. On June 18th to 21st, 1936, there were spectacular storms on four successive nights in some districts, an event unequalled during the present century. The abnormal prolongation of the warm thundery south-easterly upper current was due to a combination of factors over an area which certainly included the whole North Atlantic and most of Europe. Another notable spell of south-easterly storms occurred on June 12th to 18th, 1920, but temperature was lower than in the 1936 series and the storms were mainly in the daytime.[1]

---

[1] Some facts relating to the diurnal variation of thunderstorms in hot weather are given in the *Meteorological Magazine*, 68, 1933, p. 54.

There is often a gradual fall of temperature at high levels ahead of a cold front, especially if the barometer is falling, and this should be interpreted in terms of temperature gradients aloft, and not as a frontal surface sloping the wrong way. There is usually a strong upper current from between south and south-west, or occasionally from a point east of south. The fall of temperature high up is of a type depending little on season or locality, but it helps the development of thunderstorms if conditions lower down are also suitable. The increased lapse-rate high up may be associated with the appearance of altocumulus castellatus clouds, but these clouds do not necessarily indicate falling temperature. Summer thunderstorms at or ahead of cold fronts generally involve previous heating of the warm air over land, but they occasionally occur when the warm air is pure maritime tropical, as in south-west England on the nights of July 4th–5th and 29th–30th, 1939. Thunderstorms at the warm front in maritime tropical air are distinctly rare, but there was a case near the centre of a depression on September 24th, 1935.[1]

Complications are frequent in the case of cold front thunderstorms in summer, in addition to those produced by precipitation from pre-frontal thunderstorms and consequent cooling. Temperature contrasts often develop along the west coast of France and to a lesser extent on our own western coasts, and if there is convergence of air motion frontogenesis takes place. The convergence is usually an isallobaric effect either ahead of an Atlantic cold front or ahead of a small depression moving up from Spain or North-west Africa. Frequently the two features are combined, since the strong upper current which often exists ahead of an Atlantic cold front favours the motion of any previously existing small depression in a direction more or less along the upper current. Probably actually the motion depends on the sheer between the upper and lower air.[2] A front which is

[1] See R. P. Batty's note in *Meteorological Magazine*, 70, 1935, p. 233.

[2] This statement is based on an important paper by R. C. Sutcliffe, not yet published.

originally formed chiefly just ahead of such a moving depression trails behind it as a cold front and then sweeps eastward, often with an Atlantic front following some distance behind it. This sequence has occurred over France several times this summer but the storms have all missed the British Isles. Storms travelling in a strong upper south-west current are more frequent on the Continent than over the British Isles, since the west of France is the chief breeding ground. They are more likely to reach the British Isles if the upper current is south-south-west or still better south. The severe storm in south-east England early on August 12th, 1932, was associated with a cold front which formed on the west coast of France, and the Atlantic front followed some hours later without thunder, and other examples could be given. When a steady fall of upper air temperature commences ahead of a cold front and continues afterwards, the cold front thunderstorms may start a series which is continued in the maritime polar air. On July 8th to 21st, 1918, there were thunderstorms on every day in Great Britain, recorded in the *Daily Weather Report,* most of which developed in maritime polar air, but a few at major fronts associated with brief incursions of warm continental air. There has not been such a long series of consecutive days of thunderstorms in the *Daily Weather Report* since then. (There is, of course, an element of chance in the occurrence of thunder at *Daily Weather Report* stations, but widespread storms have normally been recorded, even when there were fewer stations than there are now.)

Any one depression rarely gives thunder for more than three or four days, but on June 17th to 23rd, 1933, there were seven days of thunder in the same depression, which drifted slowly from the Faeroes to England, while pressure at the centre rose from about 980 to 1,006 mb. The thundery spell of August 1938 was associated with an indefinite belt of relatively low pressure rather than with a depression proper. The chief condition for a long thundery period is the absence of subsidence or of advection of stable air aloft. Different air masses may be involved, provided that none of them is stable.

The following account of the thunderstorm of July 16th, 1939, has been received from Mr. H. Forster of Tern Hill, Salop:—

> Thunder was first heard at 16h. G.M.T. approaching from the SSW and gradually increased in intensity, the storm arriving at Tern Hill at 16h. 45m., eventually passing over and ceasing at 18h. 20m., thunder was, however, heard until 19h. The intensity of the rain, thunder and lightning was according to local residents, of a character, that has not before been experienced, at least during the past 40 years. During the storm a row of houses (12 in number) in Garden City, Tern Hill, were shaken on five different occasions, at 17h. 10m., 17h. 17m., 17h. 25m., 17h. 40m., 17h. 45m. in a manner similar to what one would expect in slight earth tremors. No actual damage occurred.
>
> At Market Drayton, two adjoining cottages in Corn Mill Yard, Cheshire Street, were struck by lightning, on one the bricks of the chimney stack were bulged outwards and the chimney, together with some of the tiles from the roof, was deposited on the ground about 10 yards from the building. On the other, the lightning apparently travelled down the rain water pipe to approximately halfway, thence through the wall to the electricity circuit and finally to the meter in the basement, the meter being entirely burnt out. About halfway down the wall there is a burnt patch on the brick-work, as though a small explosion had occurred and the plaster on the wall inside the room opposite the burnt patch had fallen away. Villages and small towns about 4 to 5 miles east and west of the area were not affected, they experienced only slight rain or showers.

Mr. J. M. Brierley of South Petherton, Somerset, sends the following account of the storm of July 21st, 1939.

> During a violent thunderstorm on Friday, July 21st, 1939, considerable damage was done in this neighbourhood. I examined two houses in South Petherton and a Wellingtonia tree (in a row of similar trees) at Yeabridge, near South Petherton, which were struck by lightning. The fact that both houses were apparently struck on their west or north-west sides and that the highest point on the tree, where damage was visible, was also on the west side interested me very much. The storm approached from the north-west, running up the river Parrett valley from Langport. Hailstones up to half an inch in diameter fell during the height of the storm.

THE DRAMA OF WEATHER

The dictionary defines " *drama* " as " a representation of *actions* in human life; a series of deeply interesting events ". On both these counts the title of Sir Napier Shaw's book* is justified, for he represents the weather in action, as an ever present feature of human life, and he certainly makes of the process a series of deeply interesting events. The conceit is carried on through the book, but the play is the dignified drama of classical Athens, not the more lurid productions of Drury Lane.

The stage is set, but first, we must study the programme. This, as befits the occasion, is lavishly illustrated, mostly with stills from the kaleidoscopic backdrop of the sky, but not forgetting some of the chief biographical particulars of performers, Ice, Wind and Sun. Then the plot, not one of those modern trumpery affairs, but a story old as time, written and re-written a hundred times as the playwrights learned their job. In the first performance the centre of the stage was held by the persons of the actors themselves, thundering Zeus, or the demigods of the winds. Next the play took a mystical turn, with the planets cast for the leading parts, to change again in the Victorian era to the homely domestic drama, with the barometer in the rôle of heavy father. Finally, since 1920, the number of actors has become legion, and their destinies unfold in interplay of gigantic forces, no longer limited to the bare boards but enacting their whirling dances or subtle transformations high above the stage.

We glance at the press gallery or " watchers ", the world-wide corps of meteorological observers, who note and report the varying tempo, the more or less spectacular incidents, and draw their parallels from the voluminous records of past performances, but by a " marvellous contrivance " of weather maps we can

* *The Drama of Weather.* By Sir Napier Shaw (2nd edition). 8 × 5½, pp. XIV + 308 illus. Cambridge University Press, 1939, 10*s.* 6*d.* net.

look with a thousand pairs of eyes at once. These instruments are truly magical, for, through them, we can at will direct our glance backwards into the past, to see a distillation of all that the watchers have noted for a generation, or forwards, dimly and uncertainly, into the future.

The orchestra strikes up, the music of the spheres. rhythms, intrusions, synchronism, syncopation, the beating drums of the years, the piccolos of the days. The curtain rises, the barometer plays a flowing melody as cyclones and anticyclones cross the stage in stately procession, winds circling smoothly around them, lows to the left, highs to the right. The music becomes more staccato as the spotlight fades from the attendant isobars, new actors, fronts, appear and dominate the play, while the muted strings of the isobars are almost drowned in the triumphant duet of polar and tropical air. The curtain falls, to rise again for a moment on a brief glimpse of the weather map of the future, filling the stage from wing to wing to the very roof. The play is over.

The play is over, but for the latest revival the producer, not content with revising the script hands us a momento on the way out, in the shape of two new chapters " Where the rain comes from " (with a digression on the energy of winds) and " Chapter and verse for weather in relation to agriculture ". The drama has gone, but Sir Napier cannot write a dull word, even as an afterthought. Nor can he write a sentence which is not packed with insight and experience, and the reviewer, attempting, however lamely, to pass on something of the spirit of the book must not forget to add that it is also a vast storehouse of information, a " Manual " in miniature. As for the illustrations, Sir Napier might equally well have chosen as his title " The diorama of weather ", for through the covers we view a series of pictures vividly illuminated by the light of his personality and humour.

C.E.P.B.

LETTERS TO THE EDITOR

Determination of Cloud Heights

The method commonly in use for determining the height of the base of cloud at night is to use a searchlight with a vertical beam and to observe the patch of light where the beam meets the base of the cloud from a point at some distance from the base of the searchlight. If the angle of elevation of the patch of light is E and the distance of the point of observation from the searchlight is D, then the height of the base of the cloud is D tan E, i.e.

$$H = D \tan E \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

It is assumed that the point of observation is at the same level as the searchlight.

For observations from a ship at sea it would be difficult to keep the beam of the searchlight vertical, but it is not necessary to do so. In fact it is preferable to fix the searchlight permanently so that the beam of light is vertical* when the ship is steady without pitch or roll and to make no attempt to adjust the searchlight when the ship is pitching and rolling. The alidade is also fixed to the ship and the position of the patch of light on the cloud is measured by reference to an axis, fixed relative to the ship. This axis through the alidade is chosen so that it is horizontal when the ship is steady, i.e. when the searchlight beam is vertical: and the axis is in the vertical plane through the alidade and the searchlight.

Suppose this to be done and the distance of the observer from the searchlight beam (i.e. the length of the line ON from the observer at O perpendicular to the beam SNP) to be d (see Fig. 1). Let the angle between this line ON and the line OP from the observer to the patch of light on the cloud be α. Then the distance of the

* This is convenient though not essential. If the beam is in the vertical plane through the alidade and searchlight and is inclined at an angle β to the vertical (when the ship is steady), then for d tan α in para. 3 we must substitute d sin $(\alpha - \beta)/\cos \beta$. If β were large, the errors due to the pitching of the ship might become serious.

patch of light on the cloud from N is d tan α. The height H of the cloud base above N is then d tan α cos θ where θ is the angle which the searchlight beam makes with the

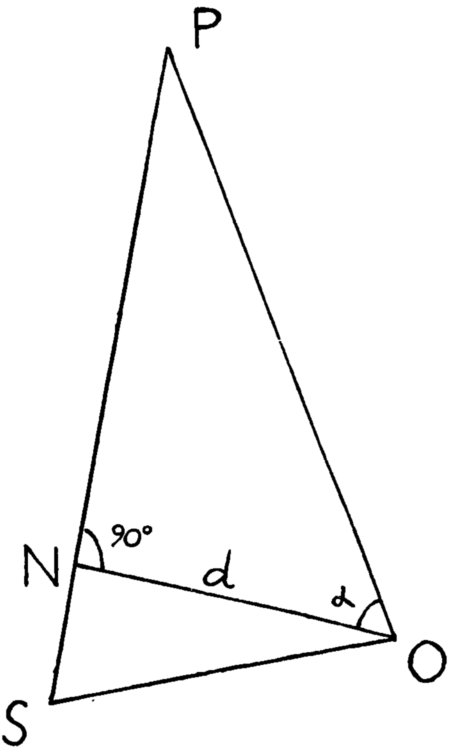


FIGURE 1.

vertical. When the ship is steady O and N are at the same level and we may therefore take the height above N to be the effective height of the cloud base above the ship.

If the height were taken to be d tan α, i.e. H = d tan α, the error in the value of H would be

$$\Delta H = d \tan \alpha \, (1 - \cos \theta) = H \, (1 - \cos \theta) \ldots\ldots (3)$$

As a general rule (1 - cos θ) is negligible for the values of θ likely to occur and the height may therefore be taken simply as d tan α. The error in H arising from the neglect of θ is less than 10 per cent. for values of θ up to 25°. It will practically always be possible to make an observation when the beam of the searchlight is within 25° of the vertical.

If on the other hand an endeavour is made to keep the searchlight beam vertical and to measure the elevation E of the light spot (above the horizon), then if the height is assumed to be H = d tan E the error due to the searchlight beam being at an angle φ from the vertical is

$$\Delta H = H \tan E \tan \varphi \quad \ldots\ldots (4)$$

Naturally if the searchlight were mounted on gimbals and its oscillations damped φ would be less than θ but this error (4) is appreciable even for small values of φ

Equation (4) may be written

$$\Delta H = H. \frac{H}{d} \tan \varphi \quad \ldots\ldots (5)$$

This shows that the percentage error in H is proportional to $\frac{H}{d}$. So long as d the length of the base line is comparable with H, the percentage error will not be large for small values of φ. But on a ship it will usually be possible to have only a relatively short base line, and if the height of the base of clouds at an appreciable height is to be measured, large values of $\frac{H}{d}$ must be allowed, i.e. values of 10 or 20. But if $\frac{H}{d}$ is 10 the error ΔH of equation (5) will be 50 per cent. of H for a value of φ less than 3° and if $\frac{H}{d}$ is 20 the error in H will be 50 per cent. for a value of φ of 1° 15′. It would be practically impossible to avoid errors of 2° or 3° in φ however carefully the searchlight might be mounted and its oscillations damped.

It follows that for observations at sea it is better to use a fixed searchlight and a fixed alidade than to endeavour to use a searchlight with a vertical beam and a sextant.

The fact that the base line on a ship is short makes it necessary to use values of d which are near 90° if the heights of clouds at a level of 4,000 or 5,000 ft. are to be measured. Consequently a small error in α produces a substantial error in tan α and consequently in H. For values of α above 85° the error in H due to an error $\Delta\ \alpha$ in α may be written

$$\Delta\ H = H.\ \frac{H}{d}.\ \Delta\ \alpha \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(6)$$

It is therefore important to know the degree of accuracy with which α can be measured. On land some tests made for me by Mr. R. M. Poulter show that careful measurement will give a value of α with an error not greater than one-tenth of a degree. But on a moving ship the error is likely to be greater than this although the fact that both the alidade and the searchlight are fixed relative to the ship and so move with it, will assist in securing a higher degree of accuracy than would be possible if the light spot on the cloud moved independently of the alidade. From the results of the tests on land I deduce that it will be possible on board ship to obtain values of α correct to the nearest two-tenths of a degree. If the height of the cloud is 20 times the length of the base, i.e. if $\frac{H}{d} = 20$, then the error in H due to an error of 0·2° in α will be approximately 7 per cent. and if $\frac{H}{d} = 30$, the error in H will be approximately 10 per cent. Thus with a base line of 200 ft. it should be possible to measure cloud heights up to 6,000 ft. sufficiently accurately for all practical purposes, provided the method of the fixed searchlight and alidade is used.

E. GOLD.

Meteorological Office,
May, 1939.

A July Frost in Herts

For the first time since the establishment of the climatological station in a deep, enclosed valley between Rickmansworth and Chorleywood, Herts, ten years ago, the air temperature there has fallen to the freezing-point during July. Early on July 2nd, 1939, a minimum of 31·8° F. was registered by the standard thermometer in the Stevenson screen. These readings from the thermograph trace indicate that the extreme occurred at about 4h.;

G.M.T.	°F.	G.M.T.	°F.
0h.	37·6	3h.	33·0
1h.	35·9	4h.	32·2 (min.)
2h.	34·2	5h.	39·5

A thermometer having its bulb one inch above short grass fell to 22° F.

On the synoptic charts for July 1st, 1939, reproduced in the International Section of the *Daily Weather Report* no cold front is marked as having crossed England that day. The appearance of the Rickmansworth thermogram strongly suggests, however, that such a front must have passed just after 18h., thus paving the way for the frosty night which followed. This supposition is upheld by the fact that a slight thunderstorm visited the neighbourhood round about 18h.

The period of the year during which the " screen " temperature at the Rickmansworth station has not fallen to 32·0° F. or lower since 1929 is now reduced to 49 days (July 3rd to August 20th). Having regard to minima of 32·2° F., 32·8° F., 34·6° F. and 36·1° F. recorded on July 31st, 1935, July 27th, 1936, July 22nd, 1936 and August 10th, 1931, respectively, there can be little doubt that over a long series of years no part of the summer would be found wholly immune from frost in this particular valley.

It may be of interest to append the lowest " screen " temperatures observed at the Rickmansworth station for each of the calendar months since registration was begun in May, 1929:—

	°F.	Year.	Date.		°F.	Year.	Date.
Jan. ..	9·0	1939	6, 7	July ..	31·8	1939	2
Feb. ..	7·5	1936	12	Aug. ..	30·0	1938	21
Mar. ..	4·7	1931	10	Sept. ..	26·0	1937	21
Apr. ..	16·4	1936	23	Oct. ..	14·8	1935	21
May ..	16·5	1935	17	Nov. ..	13·0	1937	21
June ..	28·1	1935	9	Dec. ..	6·7	1935	24

Over short grass (or at a snow-surface) – 2·8° F. was reached on March 10th, 1931, – 0·1° F. on January 18th, 1936, and 0·4° F. on December 24th, 1935. More exceptional, probably, were readings of 10·3° F. on May 17th, 1935, and 6·9° F. on October 21st, 1935.

E. L. HAWKE.

Ivinglea, Dagnall, Bucks.
July 30th, 1939.

The fronts published in the *Daily Weather Report* represent the main air mass boundaries, and cannot include all the small local fronts which form so readily in unstable polar air. The charts show a small irregularity in the isobars, and the associated front was originally a very minor one of a length not exceeding 100 miles. It intensified during the day owing to sunshine ahead of it, contrasting with a belt of cloudy, showery weather. At Welwyn, Herts, there was sunshine all afternoon, but there was a great bank of cumulonimbus clouds to north-east after 13h. G.M.T., which only approached very slowly, as the cloud motion was nearly parallel to the belt. Finally, at about 16h. G.M.T. a belt of broken cumulo-nimbus clouds came over, with a few peals of thunder and a slight shower, and surface wind veered temporarily from north-west to north-east.

C. K. M. DOUGLAS.

Unusual Electrical Discharge at Wellington

It has struck me that the "Unusual Electrical Discharge at Wellington" (described in the July issue of the magazine) might be explained by the headlights of motors shining on clouds. The clouds were very low, and it is very hilly round Wellington. The headlights of cars make curious effects on low clouds, as I know from observation here, and I think my explanation is more likely than an unknown and hitherto unrecorded form of electrical discharge. It so happened that I was out of doors at Wellington on the night of April 12th, and did not notice anything unusual, but then I must have gone to bed sometime before 23h. 25m.

C. J. P. CAVE.

Stoner Hill, Petersfield, Hants.
July 24th, 1939.

The Best Climate in the World

It would be interesting if any of your readers could put forward a local climate as generally favourable and pleasant for Europeans as that of the Nelson district of New Zealand.

The following figures compare Nelson, (N), with the South coast of England, (E):—

Season		Winter	Spring	Summer	Autumn	Year
Mean temp. °F.	N.	46	54	62	56	54·5
	E.	42	49	60	52	51·0
Mean Max. °F.	N.	54	62	70	64	62
	E.	47	55	67	58	57
Hours of Sun per day	N.	5·7	7·0	8·3	6·7	2500 (total)
	E.	2·3	6·1	7·5	4·1	1800 (total)

The chief advantage of the Nelson district compared with the best British climates is the bright winter with mild days and an absence of the long periods of overcast weather which we know so well here. The number of rain days is about 110 per year compared with about 150 in south England. There is no equivalent of our spring east winds, and the frequent strong winds which are an unpleasant feature of many parts of New Zealand, (and also some of our resorts), are not felt at Nelson, but the air is very clear with plenty of fresh cool winter mornings. Summer temperatures above 80° are almost unknown.

G. S. CALLENDAR.

Imperial College of Science, S.W.7.
June 28th, 1939.

The Best Climate in the World—A reply

If moderate warmth, equability and brightness really do represent the acme of climatological bliss then no doubt, as Mr. Callendar's comparison shows, the Nelson district on the north coast of the south island of New Zealand lies nearer the optimum than the south coast of England. In the present position of climatology however, it is unwise to use such phrases as " best climate in the World " in relation to a superficial comfort scale of this kind. Comparisons are often made between the somewhat similar climates of England and New Zealand usually to the advantage of the latter; but it is apt to be forgotten that the geographical position of England involves a more stimulating variety of temperature changes than in New Zealand, a greater complexity of weather moods and a more pronounced alteration between bracing and sedative types of weather, which are probably in the long run to be accounted as assets in their influence upon bodily and mental vigour. The mean winter temperature of 42° F. along the south coast of England is sufficiently mild but leaves a good margin for the incidence of frosts and tonic cold winds. Occasional spurts of warmth over 80° F. are probably no disadvantage in England as they save our summers from being chilly and featureless and seem, on the whole, to be thoroughly enjoyed. On the whole the south coast of England would seem to take high rank in general excellence when the combined influence of the more palpable and more subtle effects of climate are considered.

L. C. W. BONACINA.

13, Christchurch Hill, Hampstead, N.W.3.
July 2nd, 1939.

Note.—The claims of Funchal to " the finest climate in the world " are set out in *The Climate of Madeira,* reviewed by Dr. Fortescue Fox on pages 219–220.

Effect of Wind on the Temperature of a Thermometer

I have followed with great interest the discussion* on the effect of high wind speeds on the temperature indicated by a thermometer.

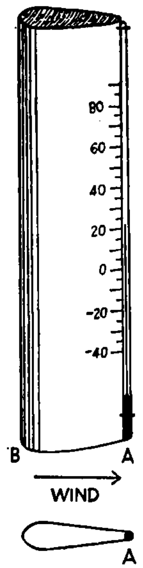


FIG. 1.

It seems that something very near the true temperature will be recorded by a thermometer set edgeways to the wind with the bulb at the trailing edge of its support. As indicated in the accompanying sketch, the usual support would be of streamline section with the thermometer at A, fitted carefully into the trailing edge and presenting a smooth finish. (Conversely, if the thermometer were placed in the leading edge, as at B, the maximum effect of adiabatic heating at the stagnation point might be expected.)

R. M. POULTER.

Meteorological Office, South Farnborough.
December 24th, 1938.

NOTES AND NEWS

Lunar Rainbows.

Although undoubtedly the majority of lunar rainbows in the vicinity of the British Isles occur during instability showers in a polar current, it is possible to observe them occasionally under other conditions provided the local topography is suitable. The number of places where it is so must be very few, but one such place is along the west Somerset coast where lunar rainbows of long duration have been seen during continuous rain. A magnificent bow occurred there during the evening of November 3rd, 1911. The synoptic charts of those days were very meagre as judged by present day standards, and " fronts "

* *Meteorological Magazine* 73, 1938, pp. 142, 211, 298.

were unknown; but from the information available it appears that the synoptic situation was approximately as follows. At 7h. on November 3rd a depression was stationary over Iceland while another vigorous one off north-west Ireland was moving north-east. At 18h. it was centred between Iceland and the Faroes, and was occluding. The occlusion was indicated from Thorshaven across north-east Scotland to Holyhead, thence as a warm front to west of Scilly, while the cold front extended south-westwards south of Ireland. This analysis fits in well with the conditions observed by the writer at Minehead.

Warm front rain accompanied by a SSW gale set in about 19h. and continued until 22h., after which the wind veered SW, moderating to a strong breeze with drizzle and further veered to WNW fresh, about midnight. The rainbow was first observed about 20h., and reached its greatest brilliance from 21h. to 22h. during the period of heaviest rain, after which it faded to a white arc as the moon became more obscured by drizzle and visibility deteriorated, finally disappearing when the cold front arrived. Peculiar conditions are necessary for such a rainbow. During strong south-westerly winds on this coast the " fohn " effect is very marked, and is sufficient to disperse even medium cloud just north of the culminating ridges of Exmoor along the coast, in spite of the fact that it may be raining. On the evening in question there were dense layers of alto-stratus and nimbo-stratus over the whole sky with some fracto-stratus over the sea and near the hills to the south, while the clear patch was unusually large and persistent. The moon was in this clear strip the whole time and a magnificent rainbow resulted, showing the four colours violet, green, yellow and red quite strongly, with a secondary bow showing the colours faintly. The elevation of the arc was roughly 15 to 20 degrees, but was not measured.

The moon's age was approximately 12 days 18 hours or 2 days 18 hours before full moon and it southed at 21h. 45m., about the time of greatest brilliance of the rainbow.

The following description appeared in the local paper and gives a fair idea of the phenomenon.

"Those students of astronomy residing in the district who were privileged to see it must have been keenly interested in the lunar phenomenon which graced the northern sky on Friday evening. Rising, as it were, from the bosom of the Channel was an enormous luminous arch, exhibiting the prismatic colours of the rainbow, while the myriad lights scintillating along the Welsh coast formed a fairy setting at the foot of the dome, altogether creating an effect which is beyond the power of the pen to adequately portray. Later the arch lost its colour, but far into the night it continued to shed its beauty over the heavens, looking like a clear white semi-circle of light traced on a background of dark cloud."

Solar rainbows of long duration are not uncommonly seen in west Somerset in similar conditions.

It would be interesting to know if there are other places in the British Isles where such a spectacle can be seen.

T. F. TWIST.

Noteworthy Cloud Formation at Hythe, Kent.

At about 17h. 50m. G.M.T., on June 22nd, a faint and prolonged rumble of thunder to the south-east attracted my attention to some noteworthy cloud formations.

Towards the south-east and in the direction of Calais, there was an ominous cloud mass, composed of cumulo-nimbus, alto-stratus, and nimbo-stratus, some distance in front of this and at a height of approximately 5,000 ft. appeared a greyish cloud of well-defined comb-like structure extending from about 150° to 210° azimuth, with the teeth uppermost and slightly curved backwards. The whole mass was moving quickly west-north-west and reached Dungeness, where a heavy thunderstorm was experienced. The peculiar comb-like cloud maintained its structure for at least 20 minutes, then became a confused, elongated mass and disappeared as it reached the coast. As this cloud dispersed a belt of extremely dense stratus cloud, moving rapidly along its own length, formed on the surface of the sea almost immediately below.

During the whole period a strong northerly wind was bringing low (500 ft. M.S.L.) fracto-stratus cloud which continually dispersed as it approached the coast-line. Thus there was a convergence of cloud with a clear area between which gradually narrowed to zero with the formation of the low stratus mentioned in the previous paragraph. At about 19h. 50m. the south-moving fracto-stratus receded about 1,000 yards and the other masses generally dispersed. After a brief interval the south-moving stratus quickly extended, and by about 20h. 30m. reached well out over the Channel. Over mid-Channel there now appeared a line of huge cumulo-nimbus clouds, which extended east to west for as far as one could see, and reached to approximately 25,000 to 30,000 feet in height; these gradually moved north and caused moderate to heavy thunderstorms for some considerable distance along the coast.

Throughout the evening and night, the wind, up to at least 1,000 feet, remained north to north northeast, with a mean velocity of 25 to 30 m.p.h. (frequent gusts of 45 m.p.h. were recorded at Lympne) until about 3h. on June 23rd, when it decreased to 10 to 15 m.p.h.

A. W. BERRY.

Dr. M. A. F. Barnett.

It is announced that Dr. M. A. F. Barnett has been appointed to the Directorship of the Meteorological Office in New Zealand in succession to the late Dr. E. Kidson. Dr. Barnett was formerly in charge of the section dealing with Aeronautical Meteorology.

A new Climatological Station.

A new " Health Resort Station " has been set up at Perranporth, Cornwall, under the auspices of the Perranporth Trustees and Hotels and Boarding Houses Association.

Mirage in Cardigan Bay.

Miss Cicely M. Botley reports a mirage on July 26th, 1939, between 12h. and 13h. G.M.T. The inverted images of buildings along the coast were seen through field glasses from the parade at Aberystwyth, looking across the Bay. The day was fine and warm with good visibility; the sky was clear overhead but cumulus was observed over the high land.

A Cloud-Pendant observed in Northern Ireland.

Mr. J. Porter reports a well-developed cloud-pendant from Garvagh, Londonderry, on July 7th, 1939, at 11h. G.M.T. The sky was almost covered with heavy clouds, chiefly cumulus and cumulo-nimbus. The pendant was estimated to be about 6 miles away in a south-easterly direction and appeared stationary until it broke up at 11h. 15m. A thunderstorm of moderate intensity was reported from a north-westerly direction during the afternoon.

Depths of Snow Lying at Nottingham

During the past winter the depth of undrifted snow lying at 9 a.m. at Nottingham has been measured at four different points from north to south in descending

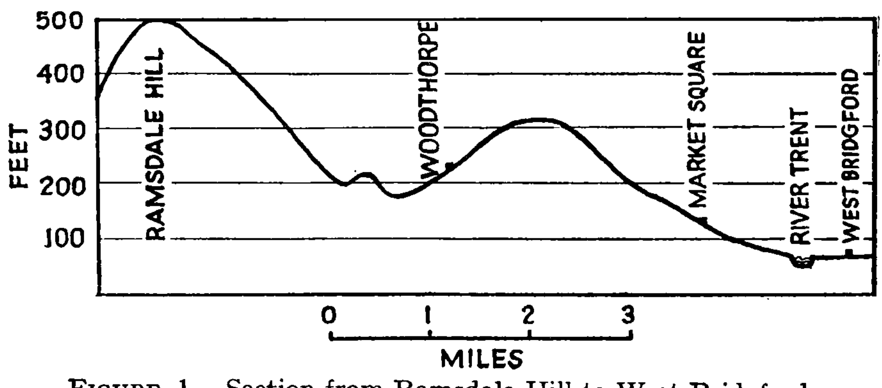


FIGURE 1. Section from Ramsdale Hill to West Bridgford.

heights. Ramsdale Hill is in open country; Woodthorpe and West Bridgford are residential suburbs, and the Market Square is in the centre of the business quarter of the city. An additional reading at 9 p.m. was made at Woodthorpe. The snow was measured on grass in each case.

The values given in Table I show how relatively small differences in height can affect the depth of snow lying. Woodthorpe, though only 150 feet higher than West Bridgford has consistently greater depths. Unfortunately the data for West Bridgford and the Market Square are incomplete.

TABLE I.—DEPTHS OF SNOW LYING

Date	Ramsdale Hill. 504 feet.	Woodthorpe 225 feet.		Market Sq. 120 feet.	West Bridgford. 78 feet.
	9 h. in.	9 h. in.	21 h. in.	9 h. in.	9 h. in.
Dec., 1938.					
19	..	..	Trace	..	
20	0·75	1·00	2·50	0·50	
21	3·25	2·75	3·00	1·75	
22	7·00	4·75	2·50	3·75	Not taken, but observer reported : "Never more than 3 in."
23	4·50	2·00	1·75	0·50	
24	4·50	1·75	1·75	0·50	
25	3·75	1·75	1·75	?	
26	4·25	2·25	1·75	?	
27	1·50	1·25	0·50	?	
28	0·50	0·50	0·00	?	
Jan., 1939.					
4	6·25	5·50	6·00	4·50	4·00
5	8·50	5·25	5·00	3·00	4·25
6	8·00	4·75	4·50	?	4·00
7	7·00	3·75	0·25	?	1·75
11	2·25	0·50	0·00	nil	nil
25	1·50	1·75	4·25	0·25	trace
26	4·50	1·50	0·00	nil	trace
27	1·00	nil	nil	nil	nil
28	0·50	0·25	nil	nil	nil

On January 4th, 1939, the Market Square and West Bridgford had similar amounts, but the reading on January 5th shows evidence of quicker thawing in the city centre.

ARNOLD B. TINN.

Engineering and Meteorology.

Recent issues of an American engineering publication *Heating, Piping and Air Conditioning* contain three articles of interest to meteorologists. Two of them deal with the effect of air conditioning on the " feel " of the air under different conditions. In the issue for July 1938 A. B. Newton and others describe " Shock experiences of 275 workers after entering and leaving cooled and air conditioned offices ". The report summarises about 22,000 daily questionnaire cards supplied by the staff of a large office in Minneapolis during 1937, each of whom described their sensations outdoors and inside the office and on entering or leaving, in terms of " ideal ", mildly or severely warm or cold. The standard of reference was the " effective temperature " which was determined from the dry bulb and relative humidity. The results are rather complex but show, as was to be expected, that the ideal indoor temperature fluctuates to some extent with that out of doors. With outside temperature below 53° F., the ideal for comfort is 66° F. or less on entering, but rises to about 70° F. for extended occupation. When the outside temperature is above 75° F. the ideal indoor temperature is 69–72° F. The ideal conditions for comfort change most rapidly when the outside temperature is about 60° F. The ideal outside temperature was also about 60° F., considerably lower than the ideal indoor temperature

In " Seasonal variations in effective temperature requirements " in the October issue F. E. Giesecke and W. H. Badgett describe experiments on ten male students under laboratory conditions at Texas. It is shown that the ideal indoor temperature has a range of 4–5° for different individuals but averages about 67° F. when the outside temperature is below that figure. As the outside temperature rises to 80 or 85° F. the ideal indoor temperature also rises to about 71° F. The results of the two investigations are thus in good agreement.

The same issue contains a description by E. C. Lundquist of experimental investigations into the air circulation in scale models of rooms. If the right air speed is selected the models fairly represent the circulation in the full size room. The experiments are reminiscent of those carried out by the late J. H. Field on a model of Gibraltar (*Geophysical Memoirs* No. 59). Mr. E. Gold suggests that other investigations into the atmospheric circulation over small scale models of mountainous regions or a steep escarpment might produce results of value.

Very severe thunderstorm with large hail on July 28th, 1205.

Ralph of Coggeshall has an account of this event in his Chronicon Anglicarium:—

Further, on the night of St. Felix (after the feast of St. James) there was so much crashing of horrible thunder and crackling of lightning, which ceased not to flash from the colliding clouds the entire night over the whole of England at one and the same time, that it was believed to be like the day of judgment: men and animals hardly breathed through the fear and trembling with anticipation which came upon the whole kingdom. For several people of both sexes in divers places were struck by lightning and perished. Also animals were similarly struck, houses thrown down and burned, crops broken by hailstones, which, in several places, were of the bigness of goose eggs and pointed on all sides. Several trees were torn up by the roots and carried away, some were twisted like ropes, and some were manifestly broken across the middle.

C. E. BRITTON.

Floods in the Tyne on August 12th, 1339.

The Chronicle of Lanercost Abbey gives an account of these floods:—

In the same year, on the third day before the assumption of the glorious Virgin, in the night, at Newcastle upon Tyne, there happened a marvellous inundation of waters whereby the wall of the town near to Walkenowe was broken down for a length of six perches, and 160 men and 7 priests, and more, were drowned.

Other records mention this calamity with varying figures for the casualties but all agree that the numbers were large. It is not possible to say whether the floods were due to heavy rains or exceptionally high tides.

C. E. BRITTON.

Sunshine, July, 1939.

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

	Total hrs.	Diff. from average hrs.		Total hrs.	Diff. from average hrs.
Stornoway ..	57	−88	Chester ..	142	−31
Aberdeen ..	118	−34	Ross-on-Wye	124	−68
Dublin ..	105	−65	Falmouth ..	152	−65
Birr Castle ..	103	−46	Gorleston ..	204	− 7
Valentia ..	101	−56	Kew.. ..	186	− 8

Kew temperature, mean, 61·7° F.: diff. from average, −2·8° F.

REVIEWS

Temperatures and Humidities up to 3 kms. over Karachi. By P. R. Krishna Rao and K. L. Bhatia. Simla, Ind. Met. Dept. Sc. Notes VII, 78, 1938.

Officers of the India Meteorological Department are to be congratulated on their enthusiasm for extracting useful information from the observations at their disposal, instead of allowing valuable data to remain hidden on a shelf accumulating dust.

The note under review contains an analysis—rather too statistical—of the observations of upper air temperature and humidity made by the Royal Air Force Station at Drigh Road, near Karachi.

Tables are given of the mean monthly dry and wet bulb temperature, lapse-rate, humidity, vapour pressure, and air density at heights up to 3 kms. above sea level.

A comparison is made of the temperature and humidity data for Karachi with those for Quetta and Peshawar.

The discussion of the results, which is admittedly brief, would have been appreciated more readily if maps showing the mean pressure distribution had been incorporated in the paper. A forecaster would like to have seen, also, a detailed examination of more than one individual case to illustrate the predominant features of the structure of the upper air over Karachi. The single example given refers to the marked inversion between 1·0 and 1·5 kms., which is so persistent during the summer months. It is suggested that the development and maintenance of this inversion is attributable to the difference in radiative powers between layers of moist and dry air as well as to turbulence and convection in the moist air at lower levels. According to the authors, a detailed study is now being made of the inversions over Karachi. The results are awaited with interest.

R. G. VERYARD.

The Climate of Madeira, with a Comparative Study, by Hugo de Lacerda Castelo Branco (translated from the French). $10\frac{1}{2} \times 6\frac{1}{2}$, pp. 118 illus., Madeira: Delegaçao do Turiso da Madeira, 1938.

The study of Climate, especially at the winter health resorts, has been given a new amplitude and interest by the great work of Piéry*. He and his collaborators adduced conclusive evidence that the changing complex of climate was actually of governing importance, not only for aviation and agriculture but for the human organism, and was indeed a primordial therapeutic agent. This should hardly be surprising, considering that atmospheric influences operate on a breathing surface greatly exceeding that of the skin.

The present work, although it is not medical, nor very systematic, contains much interesting information. It exhibits in detail the meteorological elements and

* "Traité de Climatologie Biologique et Médicale", 3 vols., 1935.

characters of what is described as the " finest climate in the world "* at Funchal on the south coast, in comparison with typical winter resorts in Europe. The outstanding feature at Funchal is the extraordinary equability of temperature, with only about eight degrees of seasonal range and none of the abrupt changes which are so injurious to winter invalids in colder latitudes. The Portuguese authority Narciso, with others, has described such climates as sedative over a wide range of functions, and as favourable to sleep and nutrition. Although often injurious in febrile diseases and advanced phthisis, they are clearly indicated in middle and later age for many nervous breakdowns and debility, the result of illness or overwork. Larger and more frequent thermal variations are undoubtedly more stimulating for healthy persons and for a different type of invalids. The winter warmth at Funchal is probably in large part due to the high temperature of the sea, 65° F. which the author compares with 53° at Estoril, 54° on the Cote d'Azur and 46° (?) at Mentone.

More precise observations on the climate of the island, both on the coast and at various altitudes in the hinterland (which rises to 1,800 metres) would undoubtedly throw light on its real value for health. Recent work shows that it is possible to measure the physiological reactions of climatic influences in various types of ill health, and that it is well to exchange the coast, at intervals, for a hill station. When these measurements can take the place of empirical impressions, the indications of a winter health resort can be put upon a scientific basis.

R. FORTESCUE FOX.

---

* See letters on the " Best Climate in the World " on pages 208–209.

Daily Readings at Kew Observatory, July 1939

Date.	Pressure, M.S.L. 13h.	Wind, Dir. 13h.	Force	Temp. Min.	Temp. Max.	Rel. Hum. 13h.	Rain.	Sun.	REMARKS.
	mb.			°F.	°F.	%	in.	hrs.	
1	1012·8	WNW	3	50	65	48	trace	8·7	pr_0 18h.
2	1019·0	W	4	49	65	52	trace	7·0	pr_0 15h.
3	1021·1	SSW	4	55	69	56	—	7·2	
4	1012·6	SE	4	58	80	48	0·02	6·1	r_0–r 9h–10h, pr_0 11h.
5	1008·7	SW	5	64	70	53	0·05	5·5	r_0–r 7h–8h, pr_0 17h.
6	1017·0	SSW	5	56	63	67	0·15	4·1	pR 10h, r_0 15h–18h.
7	1013·1	SW	5	58	70	69	0·05	9·1	r_0 0h–1h & 4h–7h.
8	1012·0	SW	5	59	66	77	0·02	0·5	pr_0 16h, 18h & 19h.
9	1014·1	WSW	4	57	68	46	—	10·7	
10	1023·2	NW	3	53	68	58	—	8·1	
11	1023·2	NW	3	50	66	49	—	9·2	
12	1020·0	WNW	1	54	70	44	—	9·6	
13	1011·3	SW	3	53	69	53	—	9·9	
14	1002·1	SSW	4	53	67	69	0·07	5·3	r 3h–4h, d_0 9h & pr_0 14h.
15	1002·4	S	4	55	72	54	trace	10·1	pr_0 7h.
16	999·9	S	4	57	71	61	0·11	9·4	r_0 5h–6h, pr_0 9h.
17	1004·3	WSW	2	57	67	77	0·06	3·5	pr 10h, pr t 12h–14h.
18	1008·9	SSE	3	56	69	80	0·17	4·2	r 17h–18h, r–R 20h.
19	1003·4	SW	3	56	68	84	0·09	5·6	pr 9h, 10h & 13 h.
20	1010·7	SW	2	53	63	82	0·55	0·6	r_0–R 11h–16h, R 21h.
21	1013·3	S	3	58	65	78	0·26	0·5	tl r–r_0 14h–15h, t 19h.
22	1010·8	WSW	3	58	65	71	0·02	0·3	ir_0–r 19h–23h.
23	1008·5	W	3	55	65	51	0·01	4·1	pr 0h.
24	1001·5	NW	2	51	61	59	0·05	4·2	pr 7h & 16h, t 15h.
25	1015·3	NW	2	49	70	43	—	11·1	
26	1016·7	Calm		55	69	66	0·01	4·5	d_0 6h–7h, pr_0 9h & 13h.
27	1020·0	SW	4	51	70	55	trace	7·3	pr_0 17h & 21h.
28	1016·6	SSW	3	60	69	75	—	3·3	
29	1010·1	SSW	4	60	67	86	0·01	0·2	ir_0 8h–9h, pr_0 17h.
30	1006·8	W	3	62	72	57	0·01	7·6	pr_0 5h.
31	1011·6	WSW	3	57	67	78	0·08	8·1	rtl 13h, pr 14h & 16h.
*	1012·0	—		55	68	63	1·79	6·0	* Means or Totals

General Rainfall for July 1939

	Per cent.
England and Wales	171
Scotland	166
Ireland	145
British Isles	164

Rainfall: July 1939: England and Wales

Co.	Station.	In.	Per cent of Av.	Co.	Station.	In.	Per cent of Av.
Lond'n	Camden Square......	1·62	68	*Warw*	Birminghm, Edgbaston	3·86	166
Surrey	Reigate, Wray Pk. Rd.	2·53	112	*Leics* .	Thornton Reservoir...	3·75	151
Kent .	Tenterden, Ashenden.	2·33	111	,, .	Belvoir Castle........	4·00	165
,, .	Folkestone, I. Hospital	1·90	..	*Rutl'd*	Ridlington	5·55	221
,, .	Margate, Cliftonville..	1·46	74	*Lincs* .	Boston, Skirbeck.....	2·25	102
,, .	Edenb'dg.,Falconhurst	2·50	109	,, .	Cranwell Aerodrome..	2·46	106
Sussex	Compton, Compton Ho	3·72	131	,, .	Skegness, Marine Gdns	1·95	87
,, .	Patching Farm.......	2·33	97	,, .	Louth, Westgate.....	2·68	107
,, .	Eastbourne, Wil. Sq..	1·72	79	,, .	Brigg, Wrawby St....	5·09	..
Hants .	Ventnor, Roy.Nat.Hos.	2·43	120	*Notts* .	Mansfield, Carr Bank..	3·92	150
,, .	Southampton, East Pk	4·71	207	*Derby* .	Derby, The Arboretum	4·51	183
,, .	Ovington Rectory....	5·51	214	,, .	Buxton, Terrace Slopes	8·72	222
,, .	Sherborne St. John...	3·72	167	*Ches* .	Bidston Obsy........	6·12	236
Herts .	Royston, Therfield Rec	2·16	86	*Lancs* .	Manchester, Whit. Pk.	6·12	185
Bucks .	Slough, Upton.......	2·23	116	,, .	Stonyhurst College...	6·80	176
Oxford	Oxford, Radcliffe.....	4·18	176	,, .	Southport, Bedford Pk	5·82	203
N'hant	Wellingboro,Swanspool	2·34	102	,, .	Ulverston, Poaka Beck	8·26	182
,, .	Oundle	2·76	..	,, .	Morecambe..........	5·88	185
Beds .	Woburn, Exptl. Farm.	2·28	102	,, .	Blackpool...........	5·01	172
Cambs	Cambridge, Bot. Gdns.	1·38	64	*Yorks* .	Wath-upon-Dearne...	5·13	204
,, .	March	2·63	111	,, .	Wakefield,Clarence Pk.	5·83	230
Essex .	Chelmsford,CountyGns	3·53	166	,, .	Oughtershaw Hall....	7·12	..
,, .	Lexden Hill House....	1·95	..	,, .	Harrog'te,HarlowMoor	5·81	211
Suff .	Haughley House.....	2·66	..	,, .	Hull, Pearson Park...	2·27	97
,, .	Campsea Ashe, High Ho	3·10	135	,, .	Holme-on-Spalding...	5·90	228
,, .	Lowestoft Sec. School.	2·27	100	,, .	Felixkirk, Mt. St. John	4·25	156
,, .	Bury St. Ed.,WestleyH	3·39	136	,, .	York, Museum.......	4·20	167
Norf. .	Wells, Holkham Hall.	1·82	78	,, .	Pickering, Houndgate.	2·01	75
Wilts .	Porton, W.D. Exp'lStn	5·55	280	,, .	Scarborough.........	2·32	95
,, .	Bishops Cannings	4·69	188	,, .	Middlesbrough.......	2·72	106
Dorset	Weymouth, Westham.	3·66	203	,, .	Baldersdale, Hury Res.	..	..
,, .	Beaminster, East St ..	6·27	241	*Durhm*	Ushaw College.......	3·99	143
,, .	Shaftesbury	5·37	..	*Norl'd*	Newcastle, Leazes Pk.	3·09	121
Devon .	Plymouth, The Hoe...	5·02	182	,, .	Bellingham, Highgreen	3·52	107
,, .	Holne, Church Pk.Cott	10·74	305	,, .	Lilburn Tower Gdns..	2·36	96
,, .	Teignmouth, Den Gdns	6·70	288	*Cumb* .	Carlisle, Scaleby Hall.	5·39	165
,, .	Cullompton	6·53	243	,, .	Borrowdale,Seathwaite	14·00	177
,, .	Sidmouth, U.D.C.....	4·78	..	,, .	Thirlmere,DaleHeadH.	10·42	174
,, .	Barnstaple,N. Dev.Ath	5·28	196	,, .	Keswick, High Hill...	7·69	200
,, .	Dartm'r,Cranmere P'l	12·10	..	,, .	Ravenglass, The Grove	5·86	156
,, .	Okehampton, Uplands.	8·34	257	*West* .	Appleby, Castle Bank.	3·85	122
Cornw	Redruth, Trewirgie...	7·37	242	*Mon* .	Abergavenny, Larchf'd	7·29	293
,, .	Penzance, MorrabGdns	5·15	189	*Glam* .	Ystalyfera, Wern Ho..	13·24	288
,, .	St. Austell, Trevarna..	8·15	243	,, .	Treherbert, Tynywaun	17·78	..
Soms .	Chewton Mendip.....	4·69	134	,, .	Cardiff, Penylan......	6·38	207
,, .	Long Ashton	4·46	158	*Carm* .	Carmarthen,M.&P.Sc.	..	..
,, .	Street, Millfield	4·27	174	*Card* .	Aberystwyth	7·95	..
Glostr .	Blockley	4·75	..	*Radn'r*	Bir. W. W. Tyrmynydd	9·37	228
,, .	Cirencester, Gwynfa ..	4·78	185	*Mont* .	Lake Vyrnwy........	10·46	305
Here .	Ross-on-Wye	3·95	174	*Flint* .	Sealand Aerodrome...	5·21	228
,, .	Kington, Lynhales....	6·34	261	*Mer* .	Blaenau Festiniog....	14·84	190
Salop .	Church Stretton......	6·38	..	,, .	Dolgelley, Bontddu...	9·86	231
,, .	Shifnal, Hatton Grange	5·30	236	*Carn* .	Llandudno	3·73	167
,, .	Cheswardine Hall	6·96	257	,, .	Snowdon, L. Llydaw 9	21·10	..
Worc .	Malvern, Free Library.	4·54	199	*Angl* .	Holyhead, Salt Island.	4·70	180
,, .	Ombersley, Holt Lock.	5·11	239	,, .	Lligwy.............	4·87	..
Warw	Alcester, Ragley Hall.	6·17	259	*I.Man*	Douglas, Boro' Cem...	4·10	134

Rainfall: July 1939: Scotland and Ireland

Co.	Station.	In.	Per cent of Av.	Co.	Station.	In.	Per cent of Av.
Guern.	St.PeterP't.GrangeRd.	3·18	157	*R&C*.	Stornoway, C.G.Stn.	5·66	197
Wig .	Pt. William, Monreith.	4·29	153	*Suth* .	Lairg	4·38	140
,, .	New Luce School	3·98	117	,, .	Skerray Borgie	5·25	..
Kirk .	Dalry, Glendarroch	5·35	149	,, .	Melvich	5·33	190
Dumf.	Eskdalemuir Obs	7·21	176	,, .	Loch More, Achfary	6·94	130
Roxb .	Hawick, Wolfelee	3.43	111	*Caith* .	Wick	4·66	177
,, .	Kelso, Broomlands	3·01	114	*Orkney*	Deerness	5·29	206
Peebs .	Stobo Castle	3·29	113	*Shet* .	Lerwick Observatory.	3·67	160
Berw .	Marchmont House	3·50	115	*Cork* .	Cork, University Coll.	4·20	155
E.Lot.	North Berwick Res.	2·75	107	,, .	Roches Point, C.G.Stn.	5·28	183
Midl .	Edinburgh, Blackfd. H	2·33	83	,, .	Mallow, Hazlewood	3·23	..
Lanark	Auchtyfardle	2·65	..	*Kerry*.	Valentia Observatory.	6·15	163
Ayr .	Kilmarnock, Kay Park	4·60	..	,, .	Gearhameen	8·70	151
,, .	Girvan, Pinmore	3·27	90	,, .	Bally McElligott Rec.	5·05	..
,, .	Glen Afton, Ayr San.	3·86	92	,, .	Darrynane Abbey	5·28	139
Renf .	Glasgow, Queen's Park	4·04	138	*Wat* .	Waterford, Gortmore.	5·75	181
,, .	Greenock, Prospect H.	5·39	146	*Tip* .	Nenagh, Castle Lough.	3·03	96
Bute .	Rothesay, Ardencraig.	7·24	183	,, .	Cashel, Ballinamona	3·99	139
,,	Dougarie Lodge	5·34	168	*Lim* .	Foynes, Coolnanes	3·27	106
Argyll	Loch Sunart, G'dale	7·36	158	,, .	Limerick, Mulgrave St.	3·11	107
,,	Ardgour House	11·07	..	*Clare* .	Inagh, Mount Callan	7·47	..
,,	Glen Etive	10·56	181	*Wexf* .	Gorey, Courtown Ho.	5·31	181
,,	Oban	8·12	..	*Wick* .	Rathnew, Clonmannon	3·37	..
,,	Poltalloch	7·25	176	,, .	Blessington Rectory	4·85	..
,,	Inveraray Castle	10·56	212	*Carlow*	Bagnalstown FenaghH	6·52	207
,,	Islay, Eallabus	5·15	151	,, .	Hacketstown Rectory.	4·70	136
,, .	Mull, Benmore	14·70	146	*Leix* .	Blandsfort House	3·58	114
,,	Tiree	..	..	*Offaly*.	Birr Castle	3·59	122
Kinr .	Loch Leven Sluice	4·84	168	*Dublin*	Dublin, Phoenix Park.	2·57	96
Fife .	Leuchars Aerodrome	3·13	120	*Meath*.	Kells, Headfort	4·41	139
Perth .	Loch Dhu	8·75	181	*W.M* .	Moate, Coolatore	4·14	..
,, .	Crieff, Strathearn Hyd.	5·47	184	,, .	Mullingar, Belvedere	5·48	172
,, .	Blair Castle Gardens	5·40	211	*Long* .	Castle Forbes Gdns	4·39	141
Angus.	Kettins School	3·80	147	*Galway*	Galway, Grammar Sch.	4·11	128
,, .	Pearsie House	4·70	..	,, .	Ballynahinch Castle	4·32	104
,, .	Montrose, Sunnyside	4·66	177	,, .	Ahascragh, Clonbrock.	3·90	112
Aberd.	Balmoral Castle Gdns.	4·70	184	*Rosc* .	Strokestown, C'node	4·56	163
,, .	Logie Coldstone Sch	..	..	*Mayo*.	Blacksod Point	4·63	147
,, .	Aberdeen Observatory.	4·88	174	,, .	Mallaranny	7·01	..
,, .	New Deer SchoolHouse	4.91	160	,, .	Westport House	2·70	87
Moray	Gordon Castle	4·31	135	,, .	Delphi Lodge	11·34	171
,, .	Grantown-on-Spey	5·71	186	*Sligo* .	Markree Castle	4·86	140
Nairn.	Nairn	6·31	235	*Cavan*.	Crossdoney, Kevit Cas.	4·64	..
Inv's .	Ben Alder Lodge	5·37	..	*Ferm* .	Crom Castle	5·20	149
,, .	Kingussie, The Birches	5·26	..	*Arm'h*	Armagh Obsy	4·41	153
,, .	Loch Ness, Foyers	..	..	*Down*.	Fofanny Reservoir	7·10	..
,, .	Inverness, Culduthel R	5·15	198	,, .	Seaforde	4·49	141
,, .	Loch Quoich, Loan	9·27	..	,, .	Donaghadee, C. G. Stn.	4·20	150
,, .	Glenquoich	9·23	144	*Antrim*	Belfast,Queen's Univ .	5·62	189
,, .	Arisaig House	9·02	182	,, .	Aldergrove Aerodrome	6·08	217
,, .	Glenleven, Corrour	6·89	166	,, .	Ballymena, Harryville.	5·44	159
,, .	Ft. William, Glasdrum	8·08	..	*Lon* .	Garvagh, Moneydig	4·76	..
,, .	Skye, Dunvegan	7·86	..	,, .	Londonderry, Creggan.	4·46	122
,, .	Barra, Skallary	5·62	..	*Tyrone*	Omagh, Edenfel	4·23	124
R&C.	Tain, Ardlarach	7·87	266	*Don* .	Malin Head	4·43	130
,, .	Ullapool	7·41	234	,, .	Dunfanaghy	4·28	146
,, .	Achnashellach	7·24	141	,, .	Dunkineely	3·92	..

Climatological Table for the British Empire, February, 1939

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...	1018·8	+ 2·8	56	28	48·0	37·2	42·6	+ 1·9	38·1	90	6·5	0·80	− 0·74	7	3·7	38
Gibraltar...........	1021·5	+ 1·5	63	42	58·6	49·8	54·2	− 1·6	49·3	78	5·3	3·33	—	10	6·4	59
Malta...............	1017·3	+ 1·2	62	45	59·7	51·5	55·6	+ 0·3	51·3	81	4·9	1·83	− 0·37	7	6·5	60
St. Helena	1015·1	− 0·8	72	58	69·1	60·7	64·9	− 0·3	61·8	93	9·4	5·03	+ 2·35	27	—	—
Freetown, Sierra Leone	1011·3	+ 2·2	89	72	86·4	74·7	80·5	—	72·5	85	6·0	0·22	− 0·08	2	—	—
Lagos, Nigeria	1009·3	− 0·4	90	70	87·3	74·3	80·8	− 1·7	75·0	93	6·2	1·78	− 0·12	4	5·9	50
Kaduna, Nigeria	1009·3	—	94	59	89·9	64·3	77·1	− 0·6	59·3	55	3·0	0·10	+ 0·08	1	8·1	69
Zomba, Nyasaland....	1007·5	− 0·6	87	63	80·7	65·6	73·1	+ 1·1	70·3	80	7·4	3·54	− 7·11	17	—	—
Salisbury, Rhodesia ..	1008·3	− 1·8	81	58	76·0	60·4	68·2	− 0·6	63·5	84	9·0	16·81	—	25	4·6	36
Cape Town	1012·3	− 1·1	89	54	79·6	61·3	70·5	+ 0·2	62·9	77	3·3	1·60	+ 1·02	4	—	—
Johannesburg	1008·8	− 1·8	84	54	73·6	57·5	65·5	− 0·1	60·0	89	8·8	7·33	+ 2·11	17	4·7	36
Mauritius	1012·3	+ 1·5	93	69	87·4	73·9	80·7	+ 1·4	75·4	72	5·4	4·94	− 2·57	18	8·9	70
Calcutta, Alipore Obsy.	1013·4	+ 0·1	95	53	86·6	63·3	74·9	+ 3·7	63·7	86	3·5	1·48	+ 0·49	2*	—	—
Bombay	1012·3	− 0·4	90	65	83·7	69·1	76·4	+ 0·7	67·9	74	0·2	0·00	− 0·03	0*	—	—
Madras	1013·2	+ 0·3	89	60	85·7	66·8	76·3	− 1·4	69·6	78	1·7	0·00	− 0·30	0*	—	—
Colombo, Ceylon	1011·6	+ 0·8	92	63	87·5	69·4	78·5	− 1·9	73·0	69	2·1	0·05	− 1·89	2	10·1	85
Singapore	1010·5	+ 0·3	89	71	86·7	73·6	80·1	− 0·1	75·7	73	7·6	6·33	− 0·29	14	6·4	53
Hongkong...........	1019·2	+ 0·6	76	54	67·8	59·2	63·5	+ 4·4	58·5	76	7·1	0·02	− 1·81	1	4·9	43
Sandakan	1010·1	—	86	72	83·4	74·0	78·7	− 1·5	75·6	87	8·6	25·53	+14·56	14	—	—
Sydney, N.S.W.......	1014·3	+ 0·4	102	59	80·8	67·3	74·1	+ 2·8	67·5	65	4·2	0·12	− 4·08	3	8·4	63
Melbourne	1013·5	− 1·0	107	50	80·0	58·2	69·1	+ 1·5	59·9	58	5·5	7·72	+ 6·01	10	7·3	54
Adelaide	1013·9	− 0·4	111	51	89·1	61·6	75·3	+ 1·3	62·1	38	3·4	1·74	+ 1·02	8	9·2	69
Perth, W. Australia....	1013·1	+ 0·1	105	57	86·4	63·7	75·1	+ 1·0	63·4	50	2·9	1·14	+ 0·69	6	10·2	78
Coolgardie	1012·8	+ 0·4	107	50	89·9	63·0	76·5	+ 0·3	62·8	49	3·2	0·01	− 0·84	1	—	—
Brisbane............	1015·3	+ 2·8	103	65	83·7	68·8	76·3	− 0·2	69·9	67	7·0	2·61	− 3·73	9	7·1	54
Hobart, Tasmania....	1013·0	− 0·2	95	44	71·1	52·4	61·7	− 0·6	54·9	62	5·5	2·15	+ 0·67	8	7·7	56
Wellington, N.Z.	1015·4	− 0·4	74	44	67·8	52·9	60·3	− 2·3	56·8	73	6·7	0·68	− 2·46	7	7·4	54
Suva, Fiji	1007·9	+ 0·1	90	73	86·9	75·3	81·1	+ 0·8	76·1	83	6·2	5·71	− 5·01	21	6·6	52
Apia, Samoa	1008·3	− 0·1	87	74	83·6	75·7	79·7	+ 0·7	76·4	81	7·6	18·65	+ 3·36	19	5·4	43
Kingston, Jamaica ...	1016·1	+ 0·8	91	64	85·9	67·5	76·7	+ 0·2	64·2	79	1·5	0·73	+ 0·13	3	6·7	58
Grenada, W.I.	1010·6	− 2·9	90	72	87·0	74·0	80·5	+ 3·4	74·0	79	4	3·49	+ 0·71	14	—	—
Toronto.............	1017·2	− 0·8	46	−7	32·3	17·3	24·8	+ 3·7	21·5	77	7·2	3·62	+ 1·24	14	3·4	32
Winnipeg	1020·6	− 1·2	32	−38	0·2	−18·1	−8·9	− 9·0	—	—	4·1	1·48	+ 0·74	14	5·4	53
St. John, N.B.	1017·6	+ 3·7	50	−1	30·3	10·8	20·5	+ 0·6	15·8	75	1·5	6·30	+ 2·40	18	3·7	36
Victoria, B.C........	1018·5	+ 1·9	50	24	43·8	34·4	39·1	− 1·4	36·8	88	7·3	3·54	+ 0·28	15	3·1	30
Addenda: January. Grenada, W.I..............	1009·9	− 2·9	91	72	88·0	74·0	81·0	+ 3·9	74·0	74	4	5·95	+1·57	23	—	—

* For Indian stations a rain day is a day on which 0·1 in. or more rain has fallen.

(18642) Wt. 22/31 1375 8/39 Hw. 377/6

THE METEOROLOGICAL MAGAZINE

M.O. 441

AIR MINISTRY : METEOROLOGICAL OFFICE

Vol. 74 September–October 1939 Nos. 884–885

FOREWORD

The publication of the *Meteorological Magazine* for September 1939 was unavoidably delayed. Fortunately it is now possible to resume, though on a somewhat reduced scale, and in order not to break the continuity, the present issue is regarded as a double number, 884 and 885, representing both September and October. It is hoped to continue with the regular monthly issues at least until the end of the current volume, when the position will be reviewed.

The monthly table of Rainfall, and the Climatological Table for the British Empire, both of which have formed part of the Magazine for many years, are being retained, but not the table of daily readings at Kew Observatory.

The Editor will be pleased to receive contributions, and he relies on observers and contributors to keep alive the widespread interest in meteorology. As one of our rainfall observers remarked: " Observations will be carried on as usual, unless the Boches drop a bomb on the rain gauge.—P.S. Even then, I have a spare gauge!"

THE AMATEUR FORECASTER

With the passing of " The Air Ministry's Weather Forecast " the amateur meteorologist is thrown back on his own resources. The professional forecaster has at his disposal a series of weather charts based on simultaneous observations of barometer, wind, weather, etc., at a large number of places. With these he can watch the movements of barometric depressions, anticyclones and other systems which control our weather. Observations at a single point obviously cannot be a complete substitute for this elaborate organisation; nevertheless the intelligent watcher can often form a fairly accurate picture of the changing distribution of pressure over a large part of the country merely from his own observations of pressure, wind, cloud, etc.

The first thing to remember is Buys Ballot's Law, which states that if you stand with your back to the wind, the lowest pressure is on your left hand. Actually it is a little in front of your left hand, especially in inland districts where the wind is light. Secondly, most barometric situations can be classified roughly as cyclonic or anticyclonic. While no exact limits can be given, a reading of 30 inches or 1,016 millibars at sea level can be taken as a rough dividing line. High pressure generally brings fine weather, but it must not be rashly assumed that because the barometer climbs to " Set Fair " a long spell of fine weather is imminent. One of the golden rules of meteorology is: " long foretold, long last; short notice, soon past ", and if the barometer rushes rapidly upwards after a storm it may merely indicate the approach of a wedge of high pressure between two depressions, which will give one day of glorious weather, but rarely more. It is when the barometer rises slowly but steadily for several days that we can recognise the real slow-moving anticyclone and safely leave our umbrellas at home. Fine weather is then likely to persist until a considerable fall of the barometer has again occurred. Then, especially if the wind be southerly, one should look out for signs of an approaching barometric depression or " low ".

The simplest picture of a depression is a centre of low barometer round which the winds circulate in the opposite direction to the hands of a clock, but this simple structure is usually complicated by " fronts " between air currents coming from different regions, or by distortions and " secondaries ". Depressions in our neighbourhood generally move roughly from west to east, so that the winds at any one place go through a fairly regular sequence, depending on whether the centre passes to the southwards or, as is more usual in England, to the northwards. In the latter case the course of events is somewhat as follows: As the barometer falls, the wind freshens from south-east, veering to south or south-west, while wispy cirrus thickens to form a continuous sheet of lower cloud, from which steady though not heavy rain falls. There often follows a short period of better weather, during which the barometer remains fairly steady, though low. This is terminated by a sudden squall in which the wind shifts to west with heavy rain and perhaps thunder; at the same time the barometer begins to rise and the temperature falls. Other showers occur from time to time, becoming progressively less intense, until finally the weather clears entirely.

If the centre passes to the south of the observer, the wind will *back* from south-east to north-east, and one of two things may happen. In winter, and in cool summer weather, a period of uninterrupted steady rain will probably set in, and last for many hours before it clears gradually as the barometer rises. As the proverb has it: " Rain from the east, two days at least ". In eastern Britain the most prolonged rains are of this type, but in the western hills persistent rain is usually brought by steady west or south-west winds, and is preceded by the muffling of the hill-tops in cloud. In south-east England, after hot summer weather, a south-easterly wind backing to east with a falling barometer may bring a spectacular series of thunderstorms. But every depression is a law to itself.

For the man who has no barometer, the most fruitful source of short-term weather forecasts is the sky, where almost literally, " coming events cast their shadows before ". Thus the proverb:—

" Red sky at night is the shepherd's delight;
Red sky in the morning is the shepherd's warning "

was investigated, as regards London, by the late Spencer Russell, who found that rain during the night is more probable after a yellow sunset than after a red, while rain during the day is more probable after a red sunrise than after a yellow one, but rain is still more likely to follow a sunrise or sunset which is entirely overcast or grey.

Clouds in general make a fascinating study for the amateur forecaster, but would need a volume for adequate treatment. Cirrus is often supposed to be a sign of rain or wind, but is not very reliable. Cumulus clouds, which form on many fine summer afternoons, should be watched carefully. So long as they remain of moderate size and disintegrate towards evening, the weather will probably remain settled, but if they grow immoderately big and high, there is a risk of thunder, which becomes imminent if the cloud develops a flat-topped fringe of " false cirrus ", giving it the shape of a wedge or anvil; this is the cumulo-nimbus. Another thundery type is mammato-cumulus, heavy cloud with rounded protuberances beneath. Alto-cumulus castellatus, aptly named " turret clouds ", small high clouds with castellated tops resembling small cumulus, arranged in groups or lines moving from south or west in fine weather, are often followed by thunder within 24 hours. On the other hand, strato-cumulus, a fairly low layer of large rolls or connected masses with blue sky or lighter cloud between, generally spells settled weather.

Connected with clouds are halos, rings of 22° or, more rarely, 46° radius round the sun or moon, caused by the light shining through a high layer of minute ice crystals. More than half the halos seen in London or Oxford are followed by rain within 12 hours and nearly three-quarters by rain within 24 hours.

These brief notes have barely scratched the surface of a subject to which the amateur meteorologist might well devote his attention in the chartless days ahead. Ingenious little instruments can be bought, in which dials are set at the appropriate barometric readings, winds, etc., and the forecast is worked out mechanically, but it is more interesting to do the thinking for oneself, even at the cost of some glorious failures. The student will find a great deal of information about the prognostic aspects of weather in some of the well known text books.

THEORETICAL METEOROLOGY

By R. C. Sutcliffe

Due primarily but not entirely to the demands made by aviation, meteorology in general, and English meteorology in particular, is to-day showing greater activity than ever before in its history. According to a recent announcement, the staff of the Meteorological Office, Air Ministry, now numbers no less than 800; the Admiralty also controls through its Meteorological Branch another large body of professional meteorologists, while further numbers are to be trained as recognised sections of the Volunteer Reserves of both the Royal Navy and the Royal Air Force. In view of this impressive demonstration of the importance of meteorology applied to the public service, it is particularly pleasant to be able to record less spectacular but none the less significant activity in the academic world. Almost simultaneously three events have been announced: Professor David Brunt has been elected to Fellowship of the Royal Society, his department at the Imperial College has been augmented by the establishment of a new readership and, thirdly, the second edition of his well known text-book has appeared.*

As everyone who knows the original will naturally make a point of examining this new edition of a unique and now standard work, there is little purpose to be served by a cataloguing of the few new features, corrections or omissions. The remarks on the mechanism of the condensation and freezing processes peculiar to the atmosphere are very welcome and could perhaps be elaborated, the complete revision of the large section on turbulence will certainly appeal to some—although the present writer, being no doubt prejudiced, cannot quite see why this subject should be allowed so much elbow

---

* *Physical and Dynamical Meteorology* (2nd edition) by David Brunt. 10¼ × 6¾, pp. XXIV + 428 illus. Cambridge University Press, 1939, 25/- net.

room in a general text-book—but these are personal reactions of little interest and it will be of more value if we take this opportunity of drawing attention again to the general character of the book in the hope of encouraging any who so far have fought shy to make its aquaintance.

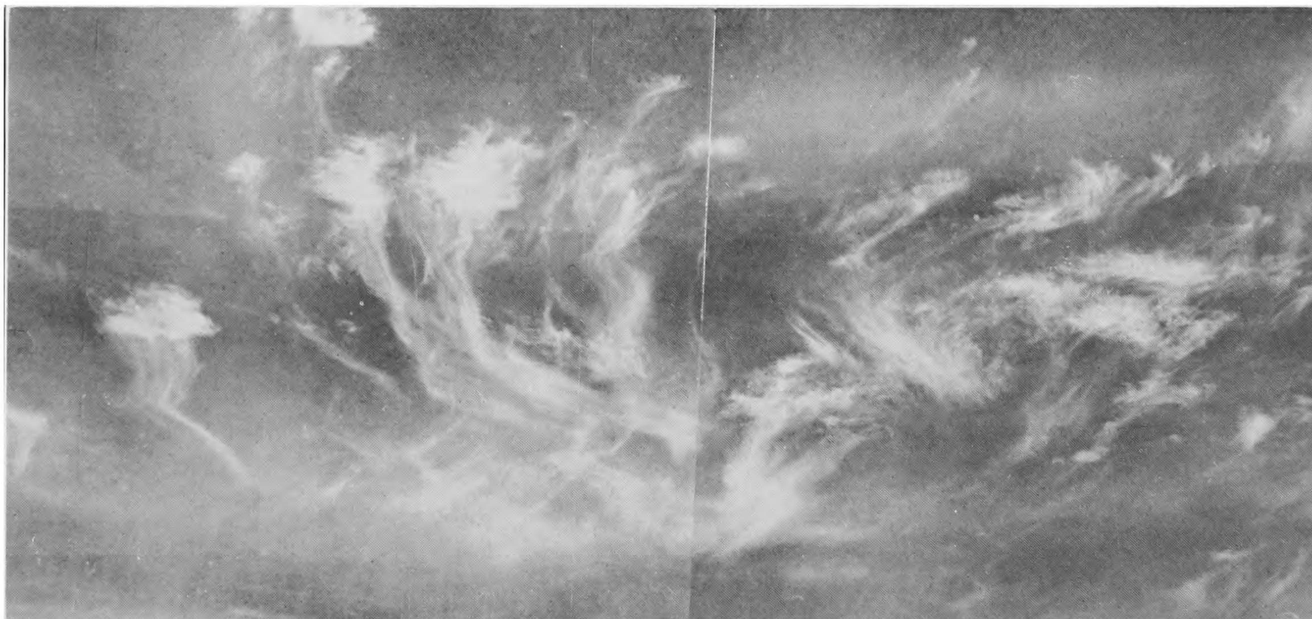
In the first place it is the only formal text-book on theoretical meteorology published in English, and so cannot be ignored by anyone who claims to be anything of a meteorologist. But it is more than this, it is methodical in development and lucid in style, a model of the university text-book comparable with the best in other branches of physics. The previous knowledge assumed in the reader is, as regards physics, hardly more than of matriculation standard, for the author finds it possible to develop almost everything from first principles, and as regards mathematics, if a little more advanced, at least quite straightforward. A mathematician himself, Professor Brunt does not regard a meteorological text-book as the proper medium for demonstrating his facility with any special mathematical tool; the avoidance of vector analysis, to take a particular point, although perhaps at the sacrifice of some economy and elegance, does also avoid frightening away the uninitiated. There is, in fact, very little to deter anyone with a modest scientific equipment from reading and understanding. If one were justified in criticising in any way such an important part of our literature, one might perhaps point out that the ground covered is a little more restricted than might be anticipated from the title or preface. Actually, attention is almost confined to the thermal and dynamical aspects of general atmospheric processes (adiabatic changes, radiation, turbulence and the changes of physical state of water in the atmosphere) together with a survey of the structure of large scale circulations. This "Physical Meteorology" does not therefore include any reference to atmospheric electricity, magnetism or meteorological optics, and even in this narrowed field one might observe that the index contains, curiously enough, no entries for dew, fog, stratocumulus cloud, dust storms, visibility, glazed frost or rime, to pick out just a few terms from our familiar vocabulary. Partly this is due to the inadequacy of the index, one may spend quite a few minutes hunting down something which one well remembers having read somewhere in the book, but it is nevertheless true that in some 400 pages of concise text, with no readable padding whatever, meteorology is hardly taken beyond its fundamentals. Of most observed "phenomena" the physics is quantitatively so uncertain, or the mathematics so involved, that theory may be little more than conjecture, but, even so, it would be very helpful to be able to "look up Brunt" for a pronouncement on the theoretical position with regard to the many special problems of weather.

Professor Brunt writes primarily for post-graduate students at the University and we may assume that the book meets their requirements admirably, but he also modestly hopes that "it may be useful to those engaged in the profession of meteorology". It is a curious feature of this profession that, in our country at any rate, it is hardly possible amongst the hundreds of personnel to find one who has studied the subject at a university. This is not the place to explain the fact or discuss the prospects of improving the position, that meteorology is almost a State monopoly is a relevant consideration and one may feel confident that both official and academic authorities are alive to the problem, but at present it is true that most working meteorologists can only fill in the necessary theoretical background to their routine professional duties at the sacrifice of private leisure after a heavy official day. To them, even more perhaps than to his own pupils, Professor Brunt has done a great service in providing a text-book systematizing and summarizing an enormous amount of work, previously available often only in original papers. Experimental or observational skill comes with practice, descriptive meteorology makes pleasant armchair reading, but theoretical quantitative meteorology demands from most of us a special effort so great that without a text-book as guide, few could ever cover the ground. Professor Brunt deals with just those essential matters which it is so tempting to slide over and which if not tackled early seem to get more and more beyond one's grasp. It is, then, the new recruit to the profession more than any other who should make up his mind to worry through this book. A year or two spent in this way, rather than in trying to jump abreast of the research worker and see his own name on a published paper, will repay him not only in self-satisfaction but in valuable time. Every professional man must at least strive to keep touch with modern advances and the ability to discard the trivial and to recognise the significant contribution amongst the volume of current literature is a talent to be gained only by building up a sound theoretical background against which the novel idea may be judged.

To the hope that no professional meteorologist will allow this text-book to remain unread may we add the hope that our small but active group of academic workers will continue their service to the profession by providing further treatises equally lucid and equally authoritative on other theoretical aspects of our science.

OFFICIAL NOTICE

SUMMER TIME, 1939. Observers are reminded that "Summer time" will continue until the night of November 18th–19th, 1939.



Photographer: R. M. Poulter.

TUFTED CIRRUS CLOUD, JUNE 21ST, 1938.

LETTERS TO THE EDITOR

Tufted Cirrus Cloud

Interesting tufted cirrus cloud of zigzag pattern was observed here at 11h. 15m. to 11h. 30m. G.M.T. on June 21st, 1938. Photographs were taken at 11h. 30m. G.M.T.

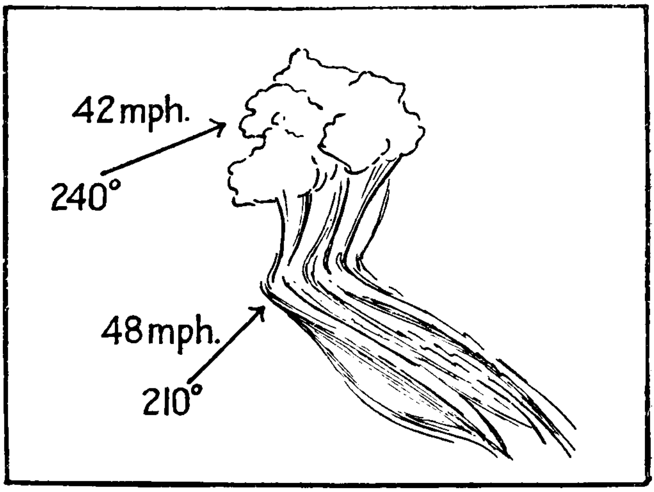


DIAGRAM OF TUFTED CIRRUS CLOUD

The tufts appeared to be moving from 240° at 42 m.p.h. and the trailing zigzags from 210° at 48 m.p.h.

R. M. POULTER.

South Farnborough, Hants.
July 4th, 1938.

Prediction of Minimum Temperatures at Habbaniya, Iraq

In the May issue of the *Meteorological Magazine,* 1934, Mr. Gold asked if his formula for the prediction of minimum temperatures, viz.,

$$T - M = 5{\cdot}5 + 0{\cdot}15T + 0{\cdot}4\ (T - D)$$

where T = 15h. temperature in ° F.
M = minimum temperature in ° F.
D = dew point temperature in ° F.

was applicable (under conditions of relative calm and clear nights) in Iraq. A test was made, using 12h. G.M.T. (15h. L.T.) observations taken at Habbaniya, and it was found that the calculated values agreed to within 2° F. of the actual value in 80 per cent. of the limited number of cases in the winter months November to February. In the summer months, however, T - M as found from the above formula was consistently above the actual value, and in one particular case when the temperature was 120° F. and the actual minimum 84° F., the formula gave 68° F.

Owing to the paucity of observations at 12h. G.M.T. here it was not possible to derive a satisfactory formula, and it was decided to turn attention to 15h. G.M.T. (18h. L.T.) readings instead. By the Method of Least Squares the following formula was obtained:—

$$T - M = 1 + {\cdot}25T + 0{\cdot}1\ (T - D)$$

$$[T - M = 1 + \tfrac{1}{4}T + 1/10\text{th}\ (T - D)]$$

or, ignoring constant 1°,

$$M = 0{\cdot}65T + 0{\cdot}1D$$

$$[M = 13/20\text{th}T + 1/10\text{th}D]$$

and this was found to apply with a sufficient degree of accuracy throughout the year.

Forecasting minimum temperatures has not the same practical value as at home since there is only an average of 17 days of frost per year. However, it is interesting to note that Mr. Gold's formula, based on 15h. L.T. readings, gives reasonably satisfactory results here in the winter months.

The thermometer screen at Habbaniya is in an enclosure covered with rather coarse grass in winter, but this dries and withers with the arrival of the hot weather.

The enclosure is almost exactly on the boundary between open sandy desert to SW and irrigated country with the Euphrates to NE.

G. G. MACDONALD.

Habbaniya.
June 6th, 1939.

A note by Mr. C. V. Ockenden states that " large departures from the normal diurnal range of temperature are comparatively infrequent in this country, except during periods of disturbed weather conditions in winter and spring. It follows that, in practice, a fairly good estimate of the minimum temperature likely during the ensuing night can be derived by subtracting a quantity which varies from about 20° in mid-winter to 36° in September from the day maximum temperature."

NOTES AND NEWS

An Observation of the End of a Waterspout.

On July 11th, 1939, two waterspouts were seen several miles at sea from Perranporth, Cornwall, about 16h. G.M.T. One of these was hanging from the base of a cumulo-nimbus, reaching about halfway to the sea. It was almost vertical and the part of the sea below the spout was hazy with thrown-up spray. The waterspout lasted about fifteen minutes after it was first sighted. For most of the time it was apparently stable, but after about ten minutes it seemed to get thinner as if it had a hollow core. Then, as it began to get shorter, the lower end gradually receding towards the cloud, the motion of the individual parts of the lower 300 or 400 feet could be followed quite easily using prismatic binoculars. Apparently there was a considerable decrease in the rotatory motion, at the lower end at least, as whiffs of vapour could be seen appearing at the end and growing inside the main thickness of the spout whilst rising in it. Although the shape of these nebulous nuclei altered rapidly, many of them could be followed quite easily for about 300 feet. In general, it seemed as if the inside of the lower end of the dying spout was formed by this vapour which appeared to be rising much more noticeably than it was rotating; but on the outside of the column small round-shaped bulges were in continual process of protruding and receding into the general column. Several large bulges were actually seen to move downward on the outside of the column much in the same way as on the sides of large cumulus whose vertical growth has proceeded beyond an inversion.

The base of the cloud was about 4,000 feet. There was a slight drift of the clouds from the north-west, while on shore there was a sea-breeze of about 15 m.p.h. The air was of polar origin moving slowly south-east around an anticyclone which lay to the south-west of Cornwall.

C. J. M. Aanensen.

Some Observations on Rainfall in the Tropics.

Mr. Robert S. Tyndale-Briscoe contributes some interesting notes on rainfall in Jamaica. During a survey by Compass Traverse over a number of years he noticed at certain times large deflections in the needles and came to the conclusion that this was due to the presence in the vicinity of finely serrated leaves over which wind was passing, the most effective being the bamboo.

This led him to consider whether this phenomenon, which he thought indicated the presence of fields of static electricity but which Dr. Whipple suggests may have been due to magnetic storms, had any influence on the rainfall. Reference to the " Rainfall Atlas of Jamaica " by Maxwell Hall showed that where rainfall at one station was greater than that of a nearby station the former was situated in an area where bamboo flourished.

He developed the theory before the Water Commission at Kingston and again at the Government Farm School at Hope. On each occasion he received corroboration from residents. The Hon. A. G. Nash, Chairman of the Water Commission, stated that the Parish of St. Mary " was one of the wettest parishes but now that they have cut down the bamboo and planted bananas they are always complaining of droughts."

Mr. Tyndale-Briscoe cites a case from his own district, the mountains of Jamaica, which are noted for a dry exhilarating climate. Within two miles of his residence is a house standing high and open to the winds, which are strong and frequent; yet the house is damp and even in the worst drought the rainwater tank is said never to be dry; it is surrounded by hedges and groups of bamboo.

Again, the parishes of Hanover and Westmoreland at the west end of Jamaica have rain nearly every day, the neighbouring hills are the lowest in the island but are clothed with bamboo on the lower slopes; on the other hand the Santa Cruz and Manchester Mountains are considerably higher, and have a much lower rainfall and bamboo is not found there.

He cites a third example, that of Moortown in the Parish of Portland in the upper valley of the Rio Grande river with an annual average rainfull of 227 inches.

" The Rio Grande Valley is a mass of bamboo from which an enormous field of static will be constantly produced; the moisture laden east trade winds coming in from the Atlantic meet the John Crow range, which runs north and south, and are forced up 2,000 ft., there they encounter the electric field and discharge some of the heaviest rain in the world. This may also explain the fact of its not being uncommon in that part of the Island for heavy rain to descend suddenly out of an apparently clear sky."

In addition to bamboo, he states that the deflection of the compass needle is apparently produced by any plant with abundance of finely serrated leaves, such as the " cutting grass " of the swamps, certain types of palm and young sugar canes.

He concludes by suggesting that an investigation of these electric fields, which apparently influence dews and humidity as well as rainfall, could profitably be undertaken, and that such investigation would be of great benefit to agriculturists in tropical countries subject to drought.

Severe thunderstorm at Troon on July 15th, 1939.

Disturbed weather prevailed over Scotland during the third week of July, and thunderstorms were frequent, especially over the southern counties. The storms were not generally severe, but that on July 15th was noteworthy for the intensity of the rain at Troon on the Ayrshire coast and for the remarkably sharp demarcation of the area of heavy rainfall.

The storm seems to have spent itself almost entirely in the immediate vicinity of Troon. Mr. M. S. Brodie, the Burgh Surveyor, reports that the morning was dull and overcast. Thunder and lightning commenced at 10h. G.M.T. and this was followed by rain of great intensity from 10h. 45m. to 11h. 35m. About 2 inches of rain fell during this period. The rate of fall, 2·40 inches per hour, qualifies for inclusion in the list of falls of " very rare " intensity. For some hours rain continued to fall, though less heavily, and the total amounted to 3·22 inches.

Considerable flooding took place and business in the centre of the town was dislocated for several hours. Over 20 shops in the main street had water in them to a depth of 2 feet and in Station Road the flood water was 4 feet deep. The portion of the municipal golf course lying between the clubhouse and the old railway line presented the appearance of a large lake. The flooding was said to be the worst due to heavy rain in living memory, although worse flooding, due to high tides, is recalled in 1912. At Prestwick, 4 miles to the south, the rainfall measured 1·66 inch—about half the Troon total—but even so Prestwick experienced the heaviest flooding for years.

In striking contrast to the Troon downpour were the small falls recorded immediately to the north of the very wet area. Kilmarnock, 8 miles north-east of Troon, registered ·38 inch, while Ardrossan, on the coast and less than 10 miles to the north-west, had only ·11 inch. Three miles further north there was no measurable rain. The falling off in other directions was less marked. From available information it would appear that the area which received more than an inch of rain extended some 15 miles south and south-east of Troon but less than 10 miles on the east side.

H. E. CARTER.

Floods at Canterbury in September, 1271.

Walter de Hemingburgh thus describes these events: In the year of our Lord 1271, on the fourteenth of the calends of October, there was at Canterbury such a flood of rain, with thunder, lightning and tempest, such that two very old men had never heard or seen anything like it for prolonged thunder, for it was as if one horrible clap sounded for the whole of the aforesaid day and night, and such a flood of water followed that trees and hedges were overthrown, whereby to proceed was not possible to men or horses, and many were imperilled by the force of the waters flowing in the streets and in the houses of the citizens. A very great famine followed throughout the whole Kingdom.

Although this account gives September 18th as the date, an earlier writer records it on the 11th of the month.

C. E. BRITTON.

Rainfall in Surrey.

The County Engineer for Surrey, Mr W. P. Robinson, C.B.E., M.Inst.C.E., M.I.T., has published a summary of the "Rainfall Statistics for the County" for 1938. The summary is based on records from twenty stations (maintained by sixteen different authorities) each station being equipped with an autographic rain-gauge and a standard rain-gauge. As two more authorities installed recording rain-gauges during 1938, it is hoped that records from at least eighteen out of a possible total of twenty-eight authorities in the County will be available for 1939.

The statistics are presented in the form of six tables and a map showing the distribution of rainfall over the county during 1938. The first four tables give the total rainfall, the monthly rainfall, the monthly duration of rainfall and the mean monthly rate of fall at each station, presented in a similar manner to that used in *British Rainfall.* The last two tables give the classification of intensity of rainfall for falls of short duration and for falls of long duration and are based on limits used in *British Rainfall.* It is interesting to note that the annual totals bear a marked relationship to the topography of the county. This distribution is shown also in the classification of heavy falls of rain within specified times. The most interesting of these heavy falls were those on August 11th, during a thunderstorm, when as much as 1·90 inch was recorded at Kingston Vale in five hours, ·40 inch of this being recorded in five minutes.

It is interesting to note that Mr. E. G. Morgan of the Highwway and Bridges Department of the Surrey County Council has recently published a book on "Stream and Channel Flow". It is hoped that the further work of the Surrey County Council will add to our knowledge and provide generalisations as to the run-off following intense rains which will prove of practical importance.

G. R. B.

Meteorology of Eastbourne.

The annual report of the meteorological observations at Eastbourne for 1938, has recently been published. It is the twentieth report prepared by Mr. A. H. Hookham, F.R. Met. S., Borough and Recording Meteorologist. Under the direction of Dr. W. G. Willoughby, who recently retired from the position of Medical Officer of Health, the reports have attained a high standard, both in the manner of presenting the information and in the amount of detail given.

The report contains not only a summary of the observations made at 9h., 17h. and 21h. each day during 1938, but also details of records maintained at Eastbourne since 1888, as well as comparisons with similar observations made at other places in the British Isles.

The report gives a number of interesting facts of which the following may be referred to:—

(1) The mean air temperature and the mean sea temperature have exceeded the average during the last six years, whereas the total sunshine has failed to reach the average during the last four years.

(2) The highest screen maximum temperature ever recorded at Eastbourne was 89·5° F. on July 22nd, 1911, and the lowest minimum 17·0° F. on January 5th, 1894.

(3) The largest amount of rain recorded on any one day was only 2·23 inches, which occurred on July 9th, 1936.

(4) In 1911 the total duration of bright sunshine was as much as 2,158 hours (almost 6 hours per day), and this is claimed to be the largest annual total on record for any station in the British Isles.

The observations are of particular interest because Eastbourne is largely protected from the prevailing south-west and west winds by Beachy Head and the South Downs. Continuous records of temperature are maintained so that the information is also available for a further study of the effect of land and sea breezes. In this connection it is interesting to recall that Mr. E. G. Bilham used the Eastbourne records in a paper on *The sea breeze as a climatic factor,* published in the Journal of State Medicine, London, 1934.

The report is accompanied by a coloured chart which shows in diagramatic form the daily rainfall, barometric pressure, maximum and minimum temperatures, sea temperature, sunshine and general wind direction. This is a feature of the report which is greatly appreciated by the inhabitants and visitors to Eastbourne, who can also see the diagram for the present year up to date displayed for their information.

J.G.

County Borough of Eastbourne: Annual Report of the Meteorological Observations for the year 1938. 8½ × 6, pp. 48. Eastbourne, 1939.

A Constant Level Water Apparatus for Wet Bulb Hygrometers.

The value of the readings of a wet bulb thermometer depend to a great extent on the rate of supply of moisture to the muslin cover of the bulb. If the water level is too far away from the thermometer, and in particular, if it is too low, the water supplied to the muslin may be insufficient, especially in warm, dry climates, and the temperature of the wet bulb thermometer will give a reading higher than the true temperature of evaporation.

In order that values of humidity may be comparable, it is essential that the methods used for moistening the wet bulb should not differ from one station to another. It has been recommended by the International Meteorological Organisation (*I.M.O., Regional Commission No. 1*, Pub. 32, 1937, Res. 27, p. 56) that the method used for moistening the wet bulb should give results equal to those obtained by maintaining the surface of the water constantly one centimetre below the level of the bulb of the thermometer and to the side.

In Egypt a special glass receptacle is used for the water —a bird fountain† ("Handbook of Instructions for Meteorological Observers in Egypt and the Sudan", 1929, p. 14)—and this ensures a constant distance between the bulb of the thermometer and the level of the water.

This type of water reservoir was also in use at a number of stations in the Sudan, but it has been found to suffer from two great disadvantages.

(i) the position of the reservoir opening in which the wick is inserted cannot be fixed.

(ii) the receptacle is difficult to clean.

(iii) it is liable to be broken.

(iv) it is difficult to fill with water.

The receptacle was seldom replaced in its previous position after being refilled with water, and isolated cases

---

† It is understood that the originator of the idea was Mr. G. W. Grabham, O.B.E., Geological Adviser, Sudan Government.

were noted where the water level was 10 cm. *above* or *below* the wet bulb and others 20 cm. *away*, while cleaning frequently resulted in a breakage of the reservoir.

To overcome these difficulties the Sudan Meteorological Service has produced a water reservoir apparatus consisting of two parts, a reservoir in glass and a metal base consisting of a connecting tube for the reservoir and an opening for the wick of the wet bulb. Full details are given in accompanying diagrams.

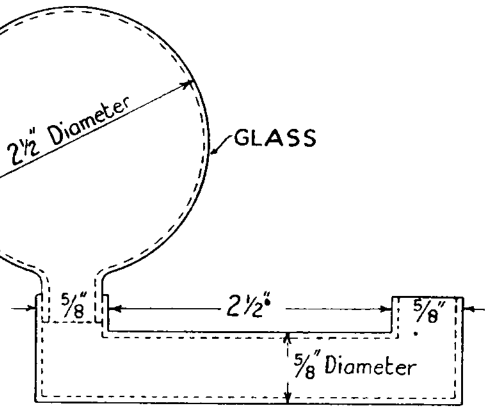


FIG. 1

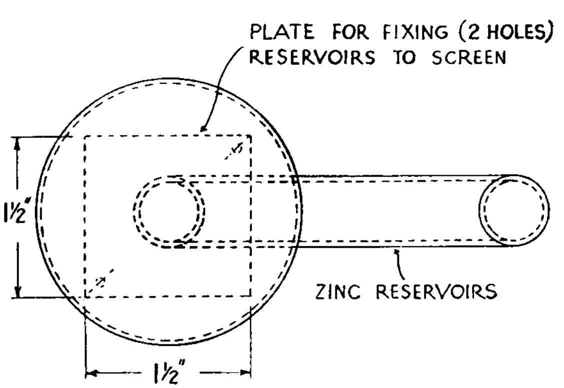


FIG. 2

This apparatus has the following advantages over the glass bird fountain.

(i) the position of the water level relative to the wet bulb thermometer can be fixed by screwing the metal base to the instrument screen.

(ii) the observer can refill the reservoir without interfering in any way with the position of the water surface relative to the wet bulb thermometer.

(iii) glass reservoir has no projection to be broken and, in view of (i), it cannot be knocked over.

(iv) the reservoir is easily cleaned.

(v) the reservoir is easily filled with water.

Further, this type of apparatus can be used in connection with the wet and dry bulb recording hygrometer as for this purpose it is only necessary to construct a metal holder with a different shaped opening for the water surface.

The apparatus complete has been supplied by Messrs. C. F. Casella & Co., Ltd., at a price of 3/-.

WILLIAM D. FLOWER.

Sunshine, August and September, 1939

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

	Total hrs.	Diff. from average hrs.		Total hrs.	Diff. from average hrs.
AUGUST					
Stornoway ..	204	+76	Chester ..	172	+13
Aberdeen ..	127	—13	Ross-on-Wye ..	169	— 3
Dublin ..	139	—15	Falmouth ..	205	+ 9
Birr Castle ..	160	+23	Gorleston ..	202	+ 5
Valentia ..	200	+52	Kew	174	— 9
SEPTEMBER					
Stornoway ..	113	+ 3	Chester ..	121	— 9
Aberdeen ..	106	—20	Ross-on-Wye ..	141	+ 5
Dublin ..	89	—41	Falmouth ..	189	+31
Birr Castle ..	98	—21	Gorleston ..	—	—
Valentia ..	133	+ 6	Kew	163	+17

Kew temp., Aug., mean, 63·7° F. diff. from average +1·0°F.
,, ,, Sept., ,, 59·9° F. ,, ,, ,, +1·4°F.

Remarkable drought in the Thames Valley on October 10th, 1114.

A number of writers allude to the extraordinary desiccation of the Thames and Medway on this date. The earliest contemporary account is that of Simeon of Durham, who records " In this year, the river which bears the name of Medway, for a distance of some miles, receded so far from its bed, on the sixth day before the ides of October, that in the very middle of it not even the smallest vessel could make the slightest way. On the same day, the river Thames was also sensible of a similar decrease; for between the bridge and the royal tower, and even under the bridge, so greatly was the water of the river diminished, that an innumerable multitude of men and boys forded it on foot, the water scarcely reaching their knees. This ebb of the tide continued from the middle of the preceding night until dark on the following night. We have heard also on good authority that on the same day a similar low tide happened at Girvemuth [i.e., Yarmouth] and other places throughout England."

C. E. BRITTON.

General Rainfall for August and September 1939

AUGUST	Per cent.
England and Wales	87
Scotland	51
Ireland	50
British Isles	70

SEPTEMBER	Per cent.
England and Wales	53
Scotland	78
Ireland	74
British Isles	63

REVIEWS

The Cyclone Season 1935—36 *and* 1936–37. By N. R. McCurdy. The Royal Alfred Observatory, Mauritius: Misc. Pubs. Nos. 19 and 20. Port Louis, 1937.

The present publications, which form part of the excellent series started in 1928, describe the storms which occurred in the western region of the South Indian Ocean during the cyclone seasons of 1935–36 and 1936–37. The cyclone season extends from November 1st to May 15th. The storms are described in a few pages of text and illustrated by means of synoptic charts. The latter are based on information obtained from the logs of ships which call at Mauritius, from weather reports broadcast by wireless telegraphy and from reports received in manuscript.

Both seasons are described as quiet. In 1935–36 there were five cyclones, none of which reached any considerable intensity except the cyclone of December 1935. This was a cyclone of small dimensions which occurred in the area between Madagascar and Réunion. The weather was extremely bad near its centre, and a ship in the vicinity recorded a pressure as low as 966 mb. and winds of hurricane force.

The six cyclones of the following season 1936–37 likewise did not develop beyond a moderate intensity, the term " moderate " apparently implying that the winds associated with the cyclones did not exceed gale force. A probable exception, however, is the cyclone of January 1937 in the Mozambique Channel where a ship 60 miles from the centre reported a wind of force 10.

The cyclone of February 1937 which developed near Rodrigues is remarkable for the exceptionally high speed of travel which it possessed in the later stages of its course. Its later positions are based on the information published in the *Marine Observer* for January 1938 from the ship *Essex* which was crossing the South Indian Ocean at this time. The speed of movement of this cyclone increased rapidly as it moved away towards the south-east and when it reached latitude 40° S. it was travelling at the rate of 42 miles per hour. We may recall in this connexion that the speed of movement of depressions near the Falkland Islands in similar southerly latitudes is frequently of the same order of magnitude.*

The cyclones of February 1936 and January 1937 travelled in an unusual direction, namely towards the east. The author remarks, however, that the increased number of observations available nowadays shows that the tracks of cyclones are less regular than they have been believed to be hitherto.

J. WADSWORTH.

The Art of Soaring Flight. By Wolf Hirth. Translated from the German by Naomi Heron-Maxwell. London. *The Sailplane and Glider.* 1939. 8vo., pp. 214. Price 5*s*. net.

The recent decision by Government to provide training in gliding for a number of those who will use power-driven aeroplanes will increase general interest in the problems of soaring; and this book contains many accounts of adventurous experiences, which will provide vivid ideas of the currents that are to be encountered. As an example may be taken that of H. Huth in a thunderstorm (pp. 105–7) in which the plane plunged " like a wild horse " with a forward speed varying between 60 m.p.h. and zero, the pilot was " at one moment lying on the edge of the cockpit and the next hanging from the safety belt." At 10,000 feet the rain was replaced by hail falling like pebbles and finally a lightning flash produced temporary unconsciousness. The pilot showed some skill in making a safe landing, for the leading edge had been perforated by hail and the gliding angle thereby spoiled.

*See *Meteor. Mag.* 61, 1926, page 195.

Faith in the possibilities of soaring flight is making steady progress. Seventeen years ago it was held that although in the tropics birds could habitually climb in " thermals," or columns of heated air, the conditions in Europe were inadequate for sailplanes which could not describe small enough circles to keep within the limited regions of ascending currents. However there has by degrees been developed the art of soaring not only under cumulous clouds and in cold fronts, but also in thermals: improvements in design and in the handling of sailplanes have reacted on each other and have gone far towards destroying our inferiority to such magnificent soarers as vultures. This progress seems to be acknowledged by the birds themselves; for Mr. P. A. Wills found in South Africa not only that the vultures served him as useful indicators of up-currents but that they appreciated him in the same way. " If ever I found a thermal on my own I would in half a minute or so be joined by one or more large brown birds with nasty looking faces, and we would all circle up together, though around 2,500 feet the birds would usually leave me. Evidently this is about their useful range of vision for spotting carrion on the ground."

The technique of soaring within an invisible ascending current of comparatively small diameter depends largely on watching the " variometer," an instrument to indicate the rate of rise or fall; but a very skilful pilot can fly by " feel " or by " natural senses "; surprising though it is, the sound within an up-current is different from that in a down-current.

It is true that much has been learned about air movements from routine observations at observatories, but under existing conditions a knowledge of the actual currents produced by turbulence or in the regions controlled by " cells " can only be obtained by going there; and perusal of such a book as that of Wolf Hirth is really essential for every student of atmospheric conditions.

G. T. W.

An Introduction to the Study of Air Mass Analysis. By Jerome Namias (4th edition, enlarged and revised); including *Characteristic properties of North American air masses* by H. C. Willett, and *The Norwegian wave-theory of cyclones,* by B. Haurwitz. 9 × 6, pp. vi + 122, illus. American Met. Soc., Milton, Mass. 75 cents.

The authors have not found it necessary to make any substantial changes in the fourth edition of this popular booklet, which was produced as " a brief, authoritative and inexpensive ' first reader ' " in those branches of meteorology which are closely related to forecasting.

After a section to acquaint the reader with the essential differences that can exist between air masses and how their identification depends on the conservation of certain properties, there follows a useful explanation of the Rossby diagram. It is unfortunate, particularly from the point of view of British meteorologists, that the limitations of space prohibit a section giving examples of the diagram in daily use. Next comes an elementary and clearly written account of fronts and the structure of the Norwegian depression, together with concise extracts from Burgeron's " Physics of fronts ". (A minor point which was noted here is that the American practice appears to be to give the name " occluded front " to the trough of warm air in an occluded depression, and a line vertically below it is drawn on charts as the "occluded front at the ground."). A valuable recent addition to this series is an article by Haurwitz on waves at the surface between two fluids, with deductions and analogies to indicate the effect of the earth's rotation in producing the depressional waves of the atmosphere. In spite of the mathematical nature of this subject, it is discussed in the same clear and readable fashion as the rest of the publication, and is quite palatable to the general reader.

Following this is a section on the tephigram as a device for forecasting showers and thunderstorms in a homogeneous air mass, and then a short but comprehensive account of the synoptic aspects of thunderstorms.

To the more serious reader perhaps the most valuable part of the booklet is the bibliography, containing over 150 references to publications of a fairly general nature, mainly in English, and of which the majority are by American writers.

The final one-third of the book is occupied by a fuller version of Willett's article in this series on "Characteristic properties of North American air masses". Any attempt by the general reader to deduce from this the characteristics of European air masses might be dangerous, and its value lies rather in the assistance it gives to the British forecaster in the fascinating study of the beginnings of our own depressions.

The editor rightly stresses the fact that the title of the booklet covers only part of the field of synoptic meteorology, and it can be said to have achieved its object very successfully. At the same time some readers will regret that no mention is made of anticyclones. Depressions are always respected because of their activity, but an anticyclone is so often regarded as the isobaric nonentity between them. Rises of pressure which do not represent merely a recovery from a departing depression are often of great importance, particularly in detailed short-period forecasting, and it is to be hoped that the cold anticyclone at least will be afforded a section in later editions of this work.

C. J. BOYDEN.

Bibliographie Météorologique Internationale. Tome IV, Année 1936. $10\frac{1}{2} \times 7\frac{1}{4}$, pp. 358, Paris, 1939. Price 15*s*. 0*d*. net.

The annual International Meteorological Bibliography regularly compiled at Paris since 1921 has been steadily growing in completeness. The enterprise has now been officially recommended by the International Meteorological Organisation to all meteorological services for their co-operation, and in the volume for 1936 no fewer than 26 countries are listed as contributing material. This volume is for the first time classified by subjects, according to the International Decimal Classification, the alphabetical arrangement by authors being continued in the index; this dual arrangement is a great improvement. The titles are given in the original language with French translations where necessary, and nearly all the more important papers have abstracts, also in French. The entries are printed on one side of the page only, to allow of cutting up to form a card index, though with over 2,500 items this would be a formidable task. The whole volume is a most valuable contribution to the organisation of meteorological research, and the price of 15*s*. 0*d*. is very moderate.

OBITUARY

The Rev. Fr. Luis Rodés, S.J.

We regret to learn of the death on June 7th in Mallorca, of the Rev. Fr. Luis Rodés, at the age of 57. Fr. Rodés was for nearly 20 years Director of the Observatorio del Ebro, Tortosa. He was a well known figure at international meteorological meetings and was a member of the Commissions for Aerology, the Study of Clouds, and Terrestrial Magnetism.

William Miller Christy.

We regret to announce the death on August 20th, 1939, of Mr. W. M. Christy, of Watergate, Chichester.

Mr. Christy was keenly interested in meteorology and contributed records of rainfall and sunshine to this office from 1898.

Rainfall: August 1939: England and Wales

Co.	Station.	In.	Per cent of Av.	Co.	Station.	In.	Per cent of Av.
Lond'n	Camden Square......	3·45	156	*Warw*	Birminghm, Edgbaston	2·62	97
Surrey	Reigate, Wray Pk. Rd.	3·03	124	*Leics* .	Thornton Reservoir...	4·59	164
Kent .	Tenterden, Ashenden.	1·79	78	,, .	Belvoir Castle........	3·80	145
,, .	Folkestone, I. Hospital	1·93	..	*Rutl'd*	Ridlington	5·86	233
,, .	Margate, Cliftonville..	1·16	60	*Lincs* .	Boston, Skirbeck.....	1·73	72
,, .	Edenb'dg., Falconhurst	2·76	105	,, .	Cranwell Aerodrome..	3·03	112
Sussex	Compton, Compton Ho	2·58	83	,, .	Skegness, Marine Gdns	1·32	54
,, .	Patching Farm.......	2·75	109	,, .	Louth, Westgate.....	1·27	45
,, .	Eastbourne, Wil. Sq..	1·97	79	,, .	Brigg, Wrawby St....	3·44	..
Hants .	Ventnor, Roy.Nat.Hos.	1·90	95	*Notts* .	Mansfield, Carr Bank..	2·58	92
,, .	Southampton, East Pk	2·04	78	*Derby* .	Derby, The Arboretum	2·33	86
,, .	Ovington Rectory....	1·52	56	,, .	Buxton, Terrace Slopes	2·78	63
,, .	Sherborne St. John...	1·76	73	*Ches* .	Bidston Obsy........	2·19	71
Herts .	Royston, Therfield Rec	3·10	121	*Lancs* .	Manchester, Whit. Pk.	1·73	50
Bucks .	Slough, Upton.......	2·10	97	,, .	Stonyhurst College...	2·03	40
Oxford	Oxford, Radcliffe.....	1·67	73	,, .	Southport, Bedford Pk	1·76	51
N'hant	Wellingboro, Swanspool	5·34	224	,, .	Ulverston, Poaka Beck	2·89	54
,, .	Oundle	..	..	,, .	Morecambe..........	1·81	45
Beds .	Woburn, Exptl. Farm.	3·43	148	,, .	Blackpool	2·25	63
Cambs	Cambridge, Bot. Gdns.	2·89	123	*Yorks* .	Wath-upon-Dearne...	1·77	74
,, .	March	2·62	110	,, .	Wakefield, Clarence Pk.	1·12	43
Essex .	Chelmsford, CountyGns	2·67	123	,, .	Oughtershaw Hall....	2·75	..
,, .	Lexden Hill House....	3·07	..	,, .	Harrog'te, HarlowMoor	2·06	70
Suff .	Haughley House.....	1·73	..	,, .	Hull, Pearson Park...	3·00	103
,, .	Campsea Ashe, High Ho	2·05	104	,, .	Holme-on-Spalding...	2·78	104
,, .	Lowestoft Sec. School.	3·90	177	,, .	Felixkirk, Mt. St. John	2·03	71
,, .	Bury St. Ed., WestleyH	3·87	149	,, .	York, Museum.......	2·09	83
Norf. .	Wells, Holkham Hall.	1·79	75	,, .	Pickering, Houndgate.	1·62	63
Wilts .	Porton, W.D. Exp'lStn	2·17	96	,, .	Scarborough.........	2·37	85
,, .	Bishops Cannings	2·54	82	,, .	Middlesbrough.......	2·45	89
Dorset	Weymouth, Westham.	2·43	114	,, .	Baldersdale, Hury Res.	3·11	89
,, .	Beaminster, East St ..	2·67	85	*Durhm*	Ushaw College.......	2·83	97
,, .	Shaftesbury	5·14	..	*Norl'd*	Newcastle, Leazes Pk.	2·45	87
Devon .	Plymouth, The Hoe...	3·07	99	,, .	Bellingham, Highgreen	3·24	92
,, .	Holne, Church Pk.Cott	4·53	101	,, .	Lilburn Tower Gdns..	1·22	43
,, .	Teignmouth, Den Gdns	2·07	92	*Cumb* .	Carlisle, Scaleby Hall.	1·80	44
,, .	Cullompton	3·00	98	,, .	Borrowdale, Seathwaite	4·00	37
,, .	Sidmouth, U.D.C.....	2·26	..	,, .	Thirlmere, DaleHeadH.	3·99	51
,, .	Barnstaple, N. Dev.Ath	2·86	87	,, .	Keswick, High Hill...	3·43	66
,, .	Dartm'r, Cranmere P'l	3·85	..	,, .	Ravenglass, The Grove	1·43	31
,, .	Okehampton, Uplands.	..	..	*West* .	Appleby, Castle Bank.	2·74	83
Cornw	Redruth, Trewirgie...	2·67	78	*Mon* .	Abergavenny, Larchf'd	2·21	74
,, .	Penzance, MorrabGdns	2·13	67	*Glam* .	Ystalyfera, Wern Ho..	4·59	74
,, .	St. Austell, Trevarna..	2·53	70	,, .	Treherbert, Tynywaun	5·36	..
Soms .	Chewton Mendip.....	4·05	90	,, .	Cardiff, Penylan......	3·66	87
,, .	Long Ashton	3·07	87	*Carm* .	Carmarthen, M.&P.Sc.	5·24	109
,, .	Street, Millfield	3·76	140	*Card* .	Aberystwyth	4·22	..
Glostr .	Blockley	1·66	..	*Radn'r*	Bir. W. W. Tyrmynydd	3·29	61
,, .	Cirencester, Gwynfa ..	2·42	81	*Mont* .	Lake Vyrnwy........	3·10	60
Here .	Ross-on-Wye	1·96	77	*Flint* .	Sealand Aerodrome...	1·35	49
,, .	Kington, Lynhales....	1·92	62	*Mer* .	Blaenau Festiniog....	5·43	53
Salop .	Church Stretton......	1·15	..	,, .	Dolgelley, Bontddu...	3·75	67
,, .	Shifnal, Hatton Grange	1·65	59	*Carn* .	Llandudno	1·51	54
,, .	Cheswardine Hall	2·43	73	,, .	Snowdon, L. Llydaw 9	7·90	..
Worc .	Malvern, Free Library.	1·87	65	*Angl* .	Holyhead, Salt Island.	2·00	63
,, .	Ombersley, Holt Lock.	1·69	63	,, .	Lligwy.............	1·94	..
Warw	Alcester, Ragley Hall.	2·41	87	*I.Man*	Douglas, Boro' Cem...	1·33	35

Rainfall: August 1939: Scotland and Ireland

Co.	Station.	In.	Per cent of Av.	Co.	Station.	In.	Per cent of Av.
Guern.	St.PeterP't.GrangeRd.	1·65	70	*R&C.*	Stornoway, C.G.Stn.	2·53	67
Wig .	Pt. William, Monreith.	1·59	41	*Suth* .	Lairg	1·38	44
,, .	New Luce School	1·61	36	,, .	Skerray Borgie	..	..
Kirk .	Dalry, Glendarroch	1·85	39	,, .	Melvich	2·28	77
Dumf.	Eskdalemuir Obs	2·34	45	,, .	Loch More, Achfary	2·35	40
Roxb .	Hawick, Wolfelee	1·74	52	*Caith* .	Wick	1·59	58
,, .	Kelso, Broomlands	1·65	56	*Orkney*	Deerness	1·96	68
Peebs .	Stobo Castle	1·62	46	*Shet* .	Lerwick Observatory.	2·96	98
Berw .	Marchmont House	2·13	64	*Cork* .	Cork, University Coll.	1·58	47
E.Lot.	North Berwick Res	1·49	47	,, .	Roches Point, C.G.Stn.	2·10	56
Midl .	Edinburgh, Blackfd. H	1·36	42	,, .	Mallow, Hazlewood	2·10	68
Lanark	Auchtyfardle	1·52	..	*Kerry.*	Valentia Observatory.	1·91	40
Ayr .	Kilmarnock, Kay Park	2·39	..	,, .	Gearhameen	2·70	36
,, .	Girvan, Pinmore	2·45	55	,, .	Bally McElligott Rec.	1·90	..
,, .	Glen Afton, Ayr San.	1·95	36	,, .	Darrynane Abbey	2·17	50
Renf .	Glasgow, Queen's Park	1·93	55	*Wat* .	Waterford, Gortmore.	1·95	51
,, .	Greenock, Prospect H.	1·79	35	*Tip* .	Nenagh, Castle Lough.	1·74	44
Bute .	Rothesay, Ardencraig.	1·64	34	,, .	Cashel, Ballinamona	1·47	42
,,	Dougarie Lodge	1·46	34	*Lim* .	Foynes, Coolnanes	1·93	50
Argyll	Loch Sunart, G'dale	3·25	57	,, .	Limerick, Mulgrave St.	2·32	65
,,	Ardgour House	4·58	..	*Clare* .	Inagh, Mount Callan	3·08	..
,,	Glen Etive	..	..	*Wexf* .	Gorey, Courtown Ho.	1·88	56
,,	Oban	3·54	..	*Wick* .	Rathnew, Clonmannon	1·71	..
,,	Poltalloch	2·37	48	,, .	Blessington Rectory	2·73	..
,,	Inveraray Castle	2·41	37	*Carlow*	Bagnalstown FenaghH	1·52	43
,,	Islay, Eallabus	1·70	39	,, .	Hacketstown Rectory.	1·96	48
,, .	Mull, Benmore	..	..	*Leix* .	Blandsfort House	1·62	41
,,	Tiree	1·70	40	*Offaly.*	Birr Castle	1·45	38
Kinr .	Loch Leven Sluice	1·25	33	*Dublin*	Dublin, Phoenix Park.	2·30	73
Fife .	Leuchars Aerodrome	1·92	62	*Meath.*	Kells, Headfort	2·17	52
Perth .	Loch Dhu	2·35	35	*W.M* .	Moate, Coolatore	1·75	..
,, .	Crieff, Strathearn Hyd.	1·69	40	,, .	Mullingar, Belvedere	2·23	53
,, .	Blair Castle Gardens	1·70	50	*Long* .	Castle Forbes Gdns	2·21	54
Angus.	Kettins School	1·58	43	*Galway*	Galway, Grammar Sch.	1·76	43
,, .	Pearsie House	..	..	,, .	Ballynahinch Castle	2·96	54
,, .	Montrose, Sunnyside	1·88	67	,, .	Ahascragh, Clonbrock.	2·84	68
Aberd.	Balmoral Castle Gdns.	2·82	93	*Rosc* .	Strokestown, C'node	1·73	46
,, .	Logie Coldstone Sch	..	..	*Mayo.*	Blacksod Point	2·19	48
,, .	Aberdeen Observatory.	1·31	48	,, .	Mallaranny	3·63	..
,, .	New Deer SchoolHouse	2.11	71	,, .	Westport House	2·03	50
Moray	Gordon Castle	1·67	53	,, .	Delphi Lodge	5·14	60
,, .	Grantown-on-Spey	..	..	*Sligo* .	Markree Castle	2·01	46
Nairn.	Nairn	1·33	55	*Cavan.*	Crossdoney, Kevit Cas.	1·66	..
Inv's .	Ben Alder Lodge	2·49	..	*Ferm* .	Crom Castle	1·03	25
,, .	Kingussie, The Birches	1·94	..	*Arm'h*	Armagh Obsy	1·61	44
,, .	Loch Ness, Foyers	1.74	57	*Down.*	Fofanny Reservoir	3·08	..
,, .	Inverness, Culduthel R	1·88	74	,, .	Seaforde	1·84	49
,, .	Loch Quoich, Loan	4·56	..	,, .	Donaghadee, C. G. Stn.	2·23	67
,, .	Glenquoich	5·23	64	*Antrim*	Belfast, Queen's Univ .	1·56	42
,, .	Arisaig House	3·01	52	,, .	Aldergrove Aerodrome	2·30	64
,, .	Glenleven, Corrour	2·40	44	,, .	Ballymena, Harryville.	2·83	66
,, .	Ft. William, Glasdrum	2.99	..	*Lon* .	Garvagh, Moneydig	1·69	..
,, .	Skye, Dunvegan	3·93	..	,, .	Londonderry, Creggan.	1·78	38
,, .	Barra, Skallary	2·11	..	*Tyrone*	Omagh, Edenfel	..	..
R&C.	Tain, Ardlarach	1·74	60	*Don* .	Malin Head	1·80	43
,, .	Ullapool	1·12	32	,, .	Dunfanaghy	1·46	39
,, .	Achnashellach	3·96	59	,, .	Dunkineely	1·99	..

Rainfall : September 1939 : England and Wales

Co.	Station.	In.	Per cent of Av.	Co.	Station.	In.	Per cent of Av.
Lond'n	Camden Square......	1·58	87	*Warw*	Birminghm, Edgbaston	·97	54
Surrey	Reigate, Wray Pk. Rd.	2·03	98	*Leics* .	Thornton Reservoir...	1·00	55
Kent .	Tenterden, Ashenden .	·51	24	„ .	Belvoir Castle........	·78	42
„ .	Folkestone, I. Hospital	1·79	..	*Rutl'd*	Ridlington	1·03	54
„ .	Margate, Cliftonville..	1·41	72	*Lincs* .	Boston, Skirbeck.....	1·06	60
„ .	Edenb'dg., Falconhurst	·90	40	„ .	Cranwell Aerodrome..	·67	38
Sussex	Compton, Compton Ho	·98	35	„ .	Skegness, Marine Gdns	2·02	112
„ .	Patching Farm.......	1·29	54	„ .	Louth, Westgate.....	1·81	90
„ .	Eastbourne, Wil. Sq..	·78	31	„ .	Brigg, Wrawby St....	·83	..
Hants .	Ventnor, Roy. Nat. Hos.	·94	38	*Notts* .	Mansfield, Carr Bank.	1·00	54
„ .	Southampton, East Pk	2·22	102	*Derby*	Derby, The Arboretum	..	..
„ .	Ovington Rectory....	1·14	50	„ .	Buxton, Terrace Slopes	1·51	47
„ .	Sherborne St. John...	·80	39	*Ches.* .	Bidston Obsy........	·75	31
Herts .	Royston, Therfield Rec	1·41	75	*Lancs.*	Manchester, Whit. Pk.	1·11	47
Bucks.	Slough, Upton.......	1·81	103	„ .	Stonyhurst College...	1·79	74
Oxford	Oxford, Radcliffe.....	·54	32	„ .	Southport, Bedford Pk	·78	28
N'hant	Wellingboro, Swanspool	·63	35	„ .	Ulverston, Poaka Beck	3·15	74
„ .	Oundle	1·28	..	„ .	Morecambe..........	1·41	46
Beds .	Woburn, Exptl. Farm.	·50	28	„ .	Blackpool	1·44	51
Cambs	Cambridge, Bot. Gdns.	1·74	108	*Yorks.*	Wath-upon-Dearne ..	2·55	161
„ .	March	1·55	86	„ .	Wakefield, Clarence Pk.	1·41	88
Essex.	Chelmsford, County Gns	·91	53	„ .	Oughtershaw Hall....	2·06	..
„ .	Lexden Hill House...	·17	..	„ .	Harrog'te, Harlow Moor	·99	49
Suff .	Haughley House.....	·45	..	„ .	Hull, Pearson Park...	1·02	51
„ .	Campsea Ashe, High Ho	·91	48	„ .	Holme-on-Spalding ..	1·22	70
„ .	Lowestoft Sec. School.	..	..	„ .	Felixkirk, Mt. St. John	2·06	113
„ .	Bury St. Ed., Westley H	2·36	119	„ .	York, Museum.......	1·30	80
Norf. .	Wells, Holkham Hall..	1·53	81	„ .	Pickering, Houndgate.	·85	45
Wilts .	Porton, W.D. Exp'l Stn	1·05	60	„ .	Scarborough.........	1·73	97
„ .	Bishops Cannings....	·92	42	„ .	Middlesbrough	..	..
Dorset	Weymouth, Westham.	..	..	„ .	Baldersdale, Hury Res.	1·30	52
„ .	Beaminster, East St..	1·18	46	*Durhm*	Ushaw College.......	1·76	88
„ .	Shaftesbury	·95	..	*Norl'd*	Newcastle, Leazes Pk.	1·06	54
Devon.	Plymouth, The Hoe...	·57	22	„ .	Bellingham, Highgreen	1·33	55
„ .	Holne, Church Pk. Cott	·94	26	„ .	Lilburn Tower Gdns..	1·89	80
„ .	Teignmouth, Den Gdns	·95	48	*Cumb.*	Carlisle, Scaleby Hall .	1·30	48
„ .	Cullompton	1·00	44	„ .	Borrowdale, Seathwaite	4·50	48
„ .	Sidmouth, U.D.C.....	1·37	..	„ .	Thirlmere, Dale Head H.	2·62	40
„ .	Barnstaple, N. Dev. Ath	·61	23	„ .	Keswick, High Hill...	1·80	43
„ .	Dartm'r, Cranmere P'l.	2·50	..	„ .	Ravenglass, The Grove	2·31	69
„ .	Okehampton, Uplands.	2·02	62	*West* .	Appleby, Castle Bank.	1·29	51
Cornw	Redruth, Trewirgie...	·96	31	*Mon.* .	Abergavenny, Larchf'd	·79	34
„ .	Penzance, Morrab Gdns	·61	21	*Glam.* .	Ystalyfera, Wern Ho..	1·13	26
„ .	St. Austell, Trevarna..	·81	25	„ .	Treherbert, Tynywaun	1·85	..
Soms .	Chewton Mendip.....	1·49	49	„ .	Cardiff, Penylan......	·80	26
„ .	Long Ashton........	1·04	44	*Carm.*	Carmarthen, M. & P.Sc.	·90	25
„ .	Street, Millfield......	1·16	52	*Card* .	Aberystwyth	1·09	..
Glostr.	Blockley	1·36	..	*Radn'r*	Bir. W. W. Tyrmynydd	·83	22
„ .	Cirencester, Gwynfa..	1·24	56	*Mont* .	Lake Vyrnwy.......	1·30	37
Here .	Ross-on-Wye	·57	30	*Flint* .	Sealand Aerodrome...	·51	26
„ .	Kington, Lynhales...	·68	32	*Mer* .	Blaenau Festiniog....	2·74	38
Salop .	Church Stretton......	·89	..	„ .	Dolgelley, Bontddu...	1·73	41
„ .	Shifnal, Hatton Grange	·55	28	*Carn.*	Llandudno	·60	28
„ .	Cheswardine Hall....	·77	38	„ .	Snowdon, L. Llydaw 9	4·75	..
Worc .	Malvern, Free Library	·44	23	*Angl* .	Holyhead, Salt Island.	1·23	46
„ .	Ombersley, Holt Lock.	·45	25	„ .	Lligwy..............	·95	..
Warw	Alcester, Ragley Hall.	·66	37	*I. Man*	Douglas, Boro' Cem...	2·45	75

Rainfall : September 1939 : Scotland and Ireland

Co.	Station.	In.	Per cent of Av.	Co.	Station.	In.	Per cent of Av.
Guern.	St.PeterP't. GrangeRd.	1·72	66	*R&C.*	Stornoway, C.G.Stn.	2·74	73
Wig	Pt. William, Monreith.	3·71	127	*Suth*	Lairg	1·85	65
"	New Luce School	3·47	97	"	Skerray Borgie	1·70	..
Kirk	Dalry, Glendarroch	2·42	66	"	Melvich	1·61	57
Dumf.	Eskdalemuir Obs.	2·88	78	"	Loch More, Achfary	2·45	43
Roxb	Hawick, Wolfelee	1·63	63	*Caith*	Wick	1·59	64
"	Kelso, Broomlands	1·00	53	*Orkney*	Deerness	..	..
Peebs	Stobo Castle	2·38	94	*Shet*	Lerwick Observatory	1·26	42
Berw	Marchmont House	1·55	64	*Cork*	Cork, University Coll.	1·65	62
E.Lot.	North Berwick Res.	1·54	74	"	Roches Point, C.G.Stn.	1·97	66
Midl	Edinburgh, Blackfd. H	1·48	72	"	Mallow, Hazlewood	2·49	..
Lanark	Auchtyfardle	1·90	..	*Kerry*	Valentia Observatory	1·80	43
Ayr	Kilmarnock, Kay Park	2·34	..	"	Gearhameen	2·80	46
"	Girvan, Pinmore	2·44	64	"	Bally McElligott Rec.	1·29	..
"	Glen Afton, Ayr San.	1·80	46	"	Darrynane Abbey	1·28	36
Renf	Glasgow, Queen's Park	2·59	94	*Wat*	Waterford, Gortmore	3·22	118
"	Greenock, Prospect H.	3·09	69	*Tip*	Nenagh, Castle Lough	1·43	51
Bute	Rothesay, Ardencraig	4·78	118	"	Cashel, Ballinamona	1·55	64
"	Dougarie Lodge	3·44	90	*Lim*	Foynes, Coolnanes	1·26	44
Argyll.	Loch Sunart, G'dale	3·31	53	"	Limerick, Mulgrave St.	1·55	59
"	Ardgour House	5·31	..	*Clare*	Inagh, Mount Callan	2·07	..
"	Glen Etive	..	..	*Wexf*	Gorey, Courtown Ho.	2·74	111
"	Oban	..	..	*Wick*	Rathnew, Clonmannon	3·32	..
"	Poltalloch	3·66	80	"	Blessington Rectory	3·09	..
"	Inveraray Castle	6·33	99	*Carlow*	Bagnalstown FenaghH	2·31	94
"	Islay, Eallabus	5·37	128	"	Hacketstown Rectory	3·36	120
"	Mull, Benmore	..	..	*Leix*	Blandsfort House	1·29	47
"	Tiree	..	..	*Offaly*	Birr Castle	2·25	98
Kinr	Loch Leven Sluice	1·92	75	*Dublin*	Dublin, Phoenix Park	2·89	151
Fife	Leuchars Aerodrome	1·69	88	*Meath.*	Kells, Headfort	2·13	80
Perth	Loch Dhu	4·20	73	*W.M.*	Moate, Coolatore	2·02	..
"	Crieff, Strathearn Hyd.	2·98	104	"	Mullingar, Belvedere	2·85	107
"	Blair Castle Gardens	2·83	119	*Long*	Castle Forbes Gdns.	2·08	72
Angus.	Kettins School	2·07	94	*Galway*	Galway, Grammar Sch.	1·50	47
"	Pearsie House	1·71	..	"	Ballynahinch Castle	1·60	34
"	Montrose, Sunnyside	2·22	112	"	Ahascragh, Clonbrock	1·33	43
Aberd.	Balmoral Castle Gdns.	2·30	96	*Rosc*	Strokestown, C'node	1·65	61
"	Logie Coldstone Sch	..	..	*Mayo*	Blacksod Point	1·78	46
"	Aberdeen Observatory	2·18	98	"	Mallaranny	2·74	..
"	New Deer SchoolHouse	2·53	100	"	Westport House	..	..
Moray	Gordon Castle	1·88	75	"	Delphi Lodge	3·17	42
"	Grantown-on-Spey	..	..	*Sligo*	Markree Castle	1·51	45
Nairn.	Nairn	..	..	*Cavan.*	Crossdoney, Kevit Cas.	2·28	..
Inv's	Ben Alder Lodge	..	..	*Ferm*	Crom Castle	2·19	78
"	Kingussie, The Birches	2·10	..	*Arm'h.*	Armagh Obsy	1·79	73
"	Loch Ness, Foyers	1·10	37	*Down.*	Fofanny Reservoir	4·93	..
"	Inverness, Culduthel R	1·42	60	"	Seaforde	2·85	104
"	Loch Quoich, Loan	1·09	..	"	Donaghadee, C. G. Stn.	2·41	101
"	Glenquoich	3·11	36	*Antrim*	Belfast, Queen's Univ.	2·46	96
"	Arisaig House	3·31	55	"	Aldergrove Aerodrome	3·21	129
"	Glenleven, Corrour	2·79	52	"	Ballymena, Harryville.	3·92	126
"	Ft. William, Glasdrum.	..	..	*Lon*	Garvagh, Moneydig	2·65	..
"	Skye, Dunvegan	3·24	..	"	Londonderry, Creggan.	2·81	85
"	Barra, Skallary	5·39	..	*Tyrone*	Omagh, Edenfel	..	..
R&C.	Tain, Ardlarach	1·69	67	*Don*	Malin Head	2·73	84
"	Ullapool	1·57	42	"	Dunfanaghy	1·82	61
"	Achnashellach	1·93	27	"	Dunkineely	2·24	..

Climatological Table for the British Empire, March, 1939

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	1016·4	+ 2·6	57	29	48·6	38·3	43·5	+ 0·3	38·6	83	8·5	1·00	− 0·69	13	3·0	26
Gibraltar	1017·4	+ 0·3	70	41	60·4	50·1	55·3	− 2·3	48·1	73	4·3	1·78	—	5	8·9	74
Malta	1012·0	− 2·2	66	41	58·2	48·3	53·3	− 3·8	47·8	67	5·3	1·12	− 0·36	10	7·5	63
St. Helena	1014·4	− 1·7	72	58	70·0	61·6	65·8	+ 0·7	63·1	91	9·2	5·89	+ 1·87	22	—	—
Freetown, Sierra Leone	1010·8	+ 1·8	92	73	87·9	75·1	81·5	—	72·4	83	6·4	0·02	− 1·14	1	—	—
Lagos, Nigeria	1008·5	− 0·4	89	71	87·2	75·2	81·2	− 2·2	75·7	92	6·9	2·99	− 0·76	8	5·9	49
Kaduna, Nigeria	1007·7	—	99	65	93·6	70·4	82·0	+ 0·4	63·8	55	3·4	1·14	+ 0·60	1	8·4	70
Zomba, Nyasaland	1005·9	− 3·7	82	58	77·2	64·5	70·9	− 0·4	67·1	84	8·7	11·18	+ 2·10	20	—	—
Salisbury, Rhodesia	1010·8	− 1·9	80	50	73·9	57·3	65·6	− 2·6	60·4	80	7·9	11·82	—	20	5·0	41
Cape Town	1014·5	0·0	98	49	79·5	58·4	68·9	+ 0·8	60·1	74	2·8	0·39	− 0·49	3	—	—
Johannesburg	1012·2	− 1·0	79	45	72·3	53·2	62·7	− 0·7	56·0	77	5·6	2·66	− 1·78	12	6·1	50
Mauritius	1009·9	− 2·0	88	71	84·4	74·1	79·3	+ 1·3	76·3	83	7·0	15·22	+ 6·63	22	6·4	52
Calcutta, Alipore Obsy.	1010·0	+ 0·1	101	63	93·4	69·8	81·6	+ 1·4	69·3	74	3·1	0·03	− 1·35	0*	—	—
Bombay	1010·0	− 0·9	92	67	85·3	71·7	78·5	− 1·0	69·8	71	0·9	0·01	− 0·01	0*	—	—
Madras	1010·0	− 0·9	96	65	88·9	71·6	80·3	− 0·8	72·9	75	3·1	0·29	− 0·05	1*	—	—
Colombo, Ceylon	1010·0	− 0·1	92	70	89·0	73·2	81·1	− 0·7	76·1	67	4·5	3·39	− 0·89	6	10·3	85
Singapore	1009·2	− 0·5	92	72	87·1	74·6	80·9	− 0·3	77·3	75	7·2	6·63	− 0·77	14	6·5	54
Hongkong	1014·0	− 2·0	78	54	68·4	61·9	65·1	+ 1·8	62·3	89	9·5	3·54	+ 0·60	15	1·4	12
Sandakan	1009·5	—	88	71	85·6	75·1	80·3	− 0·7	76·6	83	8·3	13·21	+ 4·74	12	—	—
Sydney, N.S.W.	1015·9	− 0·4	90	54	74·6	64·8	69·7	+ 0·4	65·9	80	7·6	10·86	+ 5·88	22	3·9	32
Melbourne	1017·8	+ 0·9	88	48	75·0	56·3	65·7	+ 1·2	58·3	68	5·7	0·79	− 1·39	6	7·4	59
Adelaide	1017·3	+ 0·2	91	50	80·7	57·8	69·3	− 0·6	60·0	51	3·6	1·29	+ 0·27	5	9·1	75
Perth, W. Australia	1013·9	− 1·4	99	52	84·0	61·1	72·5	+ 1·3	61·3	52	2·4	0·07	− 0·74	1	9·6	78
Coolgardie	1014·5	− 0·4	102	49	84·7	58·5	71·6	− 0·3	60·6	58	3·3	0·00	− 0·94	0	—	—
Brisbane	1012·7	− 1·7	97	59	80·7	67·9	74·3	0·0	69·5	78	6·7	15·72	+ 9·95	21	5·1	41
Hobart, Tasmania	1018·9	+ 4·7	80	41	66·0	50·9	58·5	− 0·8	52·6	69	7·0	1·69	− 0·01	9	5·2	42
Wellington, N.Z.	1022·7	+ 5·5	76	44	66·7	53·6	60·1	− 0·5	56·5	77	7·5	1·05	− 2·28	6	6·3	51
Suva, Fiji	1007·8	− 0·6	91	71	84·3	73·7	79·0	− 1·1	74·7	87	7·7	23·06	+ 8·57	24	2·9	24
Apia, Samoa	1008·9	− 0·3	87	73	84·1	74·7	79·4	+ 0·1	76·1	84	7·6	17·95	+ 3·97	23	6·0	49
Kingston, Jamaica	1015·3	+ 0·4	87	64	84·3	66·9	75·6	− 1·5	64·8	81	2·1	1·73	+ 0·71	6	6·2	52
Grenada, W.I.	1010·4	− 2·6	88	71	86·0	72·0	79·0	+ 1·2	73·0	74	7·0	6·28	+ 3·62	15	—	—
Toronto	1017·5	+ 0·2	52	4	34·8	22·6	28·7	− 0·9	24·0	79	6·0	3·15	+ 0·74	14	4·8	40
Winnipeg	1020·1	+ 0·9	53	−35	23·6	4·7	14·1	− 0·9	8·2	77	7·4	0·06	− 1·10	4	5·8	49
St. John, N.B.	1015·9	+ 1·8	47	−3	32·4	16·7	24·5	− 3·9	19·3	69	5·3	5·92	+ 1·38	14	5·2	44
Victoria, B.C.	1016·4	+ 0·5	62	30	49·4	38·7	44·1	+ 0·6	41·5	81	7·5	1·18	− 1·25	15	4·6	39

(49106) Wt. 22/31 1,375 10/39 Hw. 377/6

THE METEOROLOGICAL MAGAZINE

M.O. 441

AIR MINISTRY : METEOROLOGICAL OFFICE

Vol. 74 NOVEMBER, 1939 No. 886

THE EFFECT OF STRONG GALES ON FOLIAGE

By S. E. Ashmore, B.Sc., F.R.Met.S.

Attention was first called to the fact that leaves may be badly damaged by very high winds in a letter to the *Meteorological Magazine* in January, 1937(1)*. After a severe gale from the NNW at Llannerch Park, Trefnant, on October 19th, 1936, a large number of different kinds of trees and shrubs were found to have been damaged, the leaves having turned quite a different colour from the usual tints associated with autumn. The same occurrence was reported by the writer's father, in the *Gardeners' Chronicle*(2). Since then much discussion on the nature of the damage has arisen, and much been written on the subject.

Since October, 1936, nearly thirty reports of the blasting of foliage by strong winds have been collected. In the first case put on record, young sycamores suffered the most and elms, thorn hedges and hardy fuchsias were also affected. Since then, various observers have reported similar damage to nearly all the common deciduous trees, smaller things such as blackberries, together with a large number of the rarer shrubs and plants found in parks and gardens and, after another severe gale at Trefnant on October 3rd to 4th, 1938, it was necessary to put on the list even thistles, lettuce and artichokes, the latter being quite ruined as a crop,

* The numbers in brackets refer to the references at the end of the article.

many of the plants, tall and healthy as they were, dying outright within a short time. Nettles, mangolds and cider apple trees have also been reported damaged by the same agency. An important conclusion from the reports is that they nearly all state that the damage becomes much less severe with increasing distance from the coast, that the damage is worst in the more exposed situations and, in the case of a tree, the damage is greater on the windward side than on the leeward side.

The problem is one which interests meteorologists, forestry experts and horticulturists. In considering theories to explain the phenomenon we will confine ourselves to factors operating in the British Isles, leaving out of consideration, for instance, the scorching caused by hot, dry winds in semi-desert areas. There are three main theories to explain the damage caused in the British Isles, viz:—

(*a*) that it is owing to some effect in the leaf due simply to the high wind speed or pressure;

(*b*) that, near the coast and in some other places, it is due to sand raised and carried by the wind;

(*c*) that salt, raised as spray from the sea, and carried inland by the wind, is responsible.

Let us take the first theory and the various explanations offered as to how the damage is occasioned. M. C. Goldsworthy(3) has suggested that the effects observed are due to the friction caused between moving plant-parts due to the high wind. This theory can be disposed of, however, as mechanical buffeting would result in a battered and torn appearance in the leaves and not the blasted appearance described by observers. And this theory will not explain the discoloration of such things as lettuces and nettles. Another theory due to the same writer is that the responsible agency is the flooding of the intercellular spaces in the leaf by water driven against the surface, thereby upsetting the water-balance between roots and leaves, and killing the leaves. This theory will be mentioned later, but in this connection mention must be made of one occasion of slight damage by a gale during which there was not a single drop of rain, so that it will not explain every case. L. C. W. Bonacina(4) has propounded a theory diametrically opposed to this, in which he suggests that loss of water due to evaporation causes shrivelling of the leaf. This may explain the isolated case mentioned above but is invalid in the other cases, as all of them have been reported as being accompanied by heavy precipitation. The leaves would thus be continually wet and evaporation, if any, would take place rather from the water on the leaf than from the sap inside the cells. Another theory is one recently put forward in a leading article in the *Gardeners' Chronicle*(5), which suggests that evaporation produces such low temperature in the leaf that it dies of cold. Unfortunately the theory overlooks the fact that several degrees of frost are necessary to kill leaves on a deciduous tree. Leaves in a condition liable to be damaged by a gale are only found on deciduous trees between mid-May and October and a storm of wind and rain occurring during this period is not likely to be accompanied by a wet-bulb temperature of below 38° F., which is not low enough to harm any leaves. The last theory under this heading is that due to T. Willcocks(6), who states that the mechanical strains and stresses in the leaves result in rupture of the cell-walls, thereby causing various complex chemical substances in the leaves to come into contact, react, and produce a brownish or blackish product, thus explaining the scorched appearance. These chemical reactions are stated in detail, and this may very well be the correct explanation, but no information was given as to whether chemical analysis was actually employed and, in the absence of this, one must naturally exercise care in estimating the validity of the hypothesis.

Under the second heading comes the suggestion by E. Long(7) that sand blown against the leaf-surface is responsible for the browning, as a parallel to what happens in dry hot climates during sandstorms and dust-storms. But in this country sand is not likely to be effective owing to the rain which accompanies the gales which would cause the sand to be wet and hence difficult to be raised by the gale. Furthermore, in the one or two instances in which it was thought that sand might be responsible, further investigation showed that, at the part of the coast over which the wind had blown, the beach was composed of pebbles and not of sand at all.

We now come to the third heading, namely that of sea-salt brought in by the gale. It is well known that salt nuclei are always present to some extent in the air over Britain and further, that the quantity is increased considerably during very strong winds. A number of instances of the transport of large quantities of salt, some of them up to the remarkable distance of 100 miles or more from the coast, have been given by S. T. A. Mirrlees(8). The suggestion that such salt was responsible for the damage to foliage was first put forward by S. Ashmore(2) and the suggested mechanism of the action of the salt on the plants was put forward by the writer(1), i.e., that the strong solution of salt in contact with the leaf causes rapid loss of water from the cells through osmotic pressure, thus causing the collapse of the cells and their walls and the shrivelling of the leaf. This theory is directly opposed to that of Goldsworthy(3). Evidence has been received from W. M. Thomson(9) at Taranako, New Zealand, that south-easterly gales are apt to transport so much salt inland that serious damage is done to trees and shrubs, particularly acacias and hawthorn. On one occasion a gale completely destroyed a plantation of Pinus radiata, twelve trees thick and of average height 30 feet, by defoliation through the action of salt. It is quite reasonable to suppose that salt can be brought inland in Britain in the same manner to cause similar damage. Experimental evidence in support of the salt theory is available. Wells and Shunk(10) and Laflin and Phillips(11) have both tried the experiment of spraying leaves, shoots and plants with brine of varying strength up to that of sea-water and have obtained discoloration precisely similar to that observed after gales. Both accept that this is due to water loss by osmosis, thus bearing out the writer's original theory. Why root-action does not accelerate and make up the water-loss is an obscure question; it was raised long ago by Lewis(12), and its answer must be left to the biologists.

In summarising, it is fairly clear that the effect under discussion is either due to sea-salt or simply to the high wind speed; to decide which is operative in the majority of cases we must take into consideration that the damage is nearly always described as becoming much less with increasing distance from the coast. One expects the salt-content of the air to decrease fairly rapidly on going inland because of its precipitation with the rain but the effect of high wind-speed alone is not likely to diminish nearly so much, and this factor, to the writer's mind, weighs in favour of the sea-salt theory. In practically all the reports, the wind, even if blowing off-shore at the place where damage occurred, had recently passed over the sea and had opportunity to raise large quantities of spray. Nevertheless, there may be at work another factor, due simply to the effect of the high wind speed, either working in conjunction with the salt effect, or, on occasions, effective by itself. Mention has already been made of the solitary record of damage caused by a strong wind unaccompanied by any precipitation; this was at Trefnant on October 4th, 1939. On this occasion the wind was SE, not exceptionally strong, but sufficient to blow down small elm branches. It was dry and cold, and the damage consisted of withering of the leaves of dahlias and the withering of the flowers of dahlias and various herbaceous plants; the damage was not extensive. Now, if salt was present on this occasion, it would have had an excellent chance of being effective owing to the absence of dilution by rain, but according to data very kindly supplied to the writer by the Director of the Meteorological Office, it appears that this wind originated over central Europe the only water included in its trajectory being the English Channel, so that it is hardly likely that there was any appreciable salt content in the wind, and that this observation must go to prove that in a minority of cases, the damage is caused by some effect due to the wind strength alone.

In order to ascertain the relative frequencies in which the two effects (or possibly more) are operative, it will be desirable to conduct experiments on the following lines:—plants, small trees and shoots should be introduced into a wind-tunnel, where they can be subjected to the action of winds of the order experienced in gales, firstly with a dry air-stream, secondly with fine drops of water in the air-stream to represent rain and thirdly with fine drops of dilute brine, both constant and intermittent. The effect on the foliage could be readily observed and the discoloured leaves analysed by a chemist. This method would also settle the question why every gale occurring during the right season, and suspected of bearing salt, does not damage foliage. Capt. Cave(13) suggests that gales causing damage have periods when the precipitation ceases for a time, the wind remaining high. Evaporation from the leaf-surfaces would concentrate the salt-solution in contact with them, giving osmotic pressure a chance to work, and withdrawing water from the leaves. Until wind-tunnel experiments can be carried out it is hoped that observers with anemometers and hyetographs will, when they observe gale damage of this kind, refer to the charts to ascertain if, during the gale, there were periods of light or absent rainfall, accompanied still by high wind-speed, as Capt. Cave has suggested.

References

(1) S. E. Ashmore, *Met. Mag.*, 71, 1937, 285.
(2) S. Ashmore, *Gard. Chron.*, 100, 1936, 341.
(3) M. C. Goldsworthy, *Gard. Chron.*, 101, 1937, 75.
(4) L. C. W. Bonacina, *Met. Mag.*, 72, 1937, 12.
(5) Editor, *Gard. Chron.*, 104, 1938, 315.
(6) T. Willcocks, *Gard. Chron.*, 104, 1938, 162.
(7) E. Long, *Gard. Chron.*, 104, 1938, 219.
(8) S. T. A. Mirrlees, *Met. Mag.*, 63, 1928, 131.
(9) W. M. Thomson, *Gard. Chron.*, 105, 1939, 375.
(10) Wells and Shunk, *Bull. Torr. Bot. Club*, 65, No. 7, 1938, 485.
(11) Laflin and Phillips, *Gard. Chron.*, 105, 1939, 14.
(12) Lewis, *New Phytologist*, 11, 1912, 255.
(13) C. J. P. Cave, *Met. Mag.*, 73, 1938, 276.

LETTERS TO THE EDITOR

Static Charge

Whilst ascending the iron ladder to the roof of the Experimental Station Central Offices at 18h. 10m. G.M.T., September 8th, 1939, I received an appreciable electric shock from the iron piping that serves as a railing at the top of the ladder. About ten minutes later—whilst following a pilot balloon—I received a further and more severe shock. Blue flashes were observed playing round the theodolite and theodolite base, and a burning sensation around the throat, coupled with a tingling sensation in both hands, was experienced. A few moments later I had occasion to change the sun-card, and experienced a still further shock when I touched the metal surrounding the glass sphere—though not of such intensity as the two previous shocks.

Subsequent examination of these metal parts by the Orderly Officer and an electrician elicited no further shocks and it was assumed that by making contact with the various charged places mentioned I had discharged the stored up electrical energy through my person.

E. T. YOUNG-EVANS.

Shoeburyness, Essex.
September 8th, 1939.

Mammatus Cloud and Mirage

On August 20th, 1939, some interesting mammatus cloud was seen near Foynes. Although first noted at 7h. G.M.T., no detailed observations were made until 9h. 15m., after which time it was watched by H. H. Lamb, A. K. Dewdney and the writer. The base of the cumulo-nimbus cloud in which the mammatus structure formed was then at about 3,000 ft.; later, when the cloud had degenerated, its base was at least 1,000 feet higher. Below the cloud winds converged from east and west and an anticyclonic whirl developed between the two air-streams. Cloud fragments moving from the east below the main cloud at times formed almost complete horizontal circles. At other times similar fragments moved spirally upwards, dissolving as they ascended. North east of the whirl the cloud was continually reforming and dissolving, the lowest portions always being the last to disappear.

Downward currents existed over a wide area and a small cumulus cloud at least 10 miles away was observed to flatten rapidly and ultimately to disappear. By 9h. 50m. the cloud had thinned considerably and the mammatus form was less pronounced.

A little later, at 10h. 30m., a mirage was observed from Foynes Pier by H. H. Lamb and A. K. Dewdney. Two distinct images, one above the other, could be seen of Low Island, about 6 miles away across the Shannon and part of the water surface appeared to be tilted.

F. E. DIXON.

Hotel Ardanoir, Foynes, Eire.
August 31st, 1939.

The First Pressure Tube Anemometer

In your issue for June last you recorded the fact that the original Pressure Tube Anemometer which was used by Mr. W. H. Dines at Oxshott towards the end of last century had recently been presented to the Science Museum. This is believed to be the first instrument of the type ever constructed. While sorting some old papers at Benson I have recently obtained evidence of the date when this anemometer was first brought into use and it is perhaps worth putting the facts on record. Among the papers there were a number of early Pressure Tube records from Oxshott, the series commencing with a chart for November 9th-10th, 1893. This record and those for the following days were taken on blank paper on which horizontal lines had been ruled in pencil corresponding with 0, 10, 20, etc. miles per hour, the velocities being indicated by numbers entered in Mr. Dines' handwriting. There were no hour lines but the time of commencement and end of the record were entered. The series is not quite complete and there are several breaks of a few days. After one of these the blank forms gave way on December 12th to a printed form substantially similar to those now used. There seems good reason to believe therefore that November, 9th, 1893, was the day on which the Pressure Tube Anemometer first came into regular use. It is of interest to note that the record for May 20th, 1894, bears the pencil legend "Common ink and drawing pen" showing that Mr. Dines early found it necessary to experiment with different types of pen. The earliest records appear to have been made with a mapping pen of the type which is still in general use.

J. S. DINES.

Benson.
September 12th, 1939.

NOTES AND NEWS

The Droughts and Dry Spells of August and September.

The rainfall over the British Isles was markedly deficient during the months of August and September, the general rainfall, expressed as a percentage of the average for the period 1881–1915, being 70 and 63 respectively for these months. The records for individual stations show that there was a dry period in each month which affected many parts of the country.

In this account, the definitions adopted in *British Rainfall* will be used, namely:—

An absolute drought is a period of at least 15 consecutive days, to none of which is credited ·01 inch of rain or more.

A partial drought is a period of at least 29 consecutive days, the mean daily rainfall of which does not exceed ·01 inch.

A dry spell is a period of at least 15 consecutive days to none of which is credited ·04 inch of rain or more.

During August the largest region affected by prolonged dry weather was central Ireland together with the central portion of the west coast, the area being enclosed by a line running north-east from Ballynahinch (Galway) to Edenfel (Tyrone), thence south to Blandsfort (Leix), south-west to Cork and west to BallyMcElligot (Kerry). Almost every station within this region experienced a dry spell and at nearly 50 per cent. the drought was absolute. The most general date for the commencement of the absolute drought or dry spell was the 10th or 11th, though occasionally the start was as late as the 15th. Within the same dates, absolute drought commenced in north-west Mayo and a dry spell in north Donegal. Anglesey and part of the north Welsh coast recorded absolute drought at this time. Over Hampshire (excluding the Isle of Wight), east Wilts. and west Sussex there was a dry spell commencing on the 11th, one-third of the stations recording absolute droughts. North-east Kent, north-east Essex and most of Suffolk experienced dry spells, the drought becoming absolute inland, but at the most easterly Suffolk stations the beginning of the dry spell was the 25th. Isolated reports of dry spells were received from Ullapool (Ross and Crom.), Lairg (Suth.), Aberdeen and Blockley (Glos.)

During the latter portion of September almost the whole of Ireland experienced an absolute drought or a dry spell, the most frequent dates of commencement being the 13th or 14th. North and west of a line running from BallyMcElligott (Kerry) to Foffanny (Down) the drought was absolute at nearly all stations, in spite of the fact that, for example, the Antrim stations received over 125 per cent. of their average rainfall during the month, largely as a result of heavy rain on the 3rd.

In England and Wales, absolute drought was less common, but a line from Ventnor (I. of W.) through Ragley (Warw.) to Blaenau Festiniog (Mer.) encloses to the south and west a region within which dry spells predominated, with a tendency to conditions of absolute drought at the coastal stations. At three stations within this region, the dry conditions began as early as the 3rd, and on the 5th at another. Over almost the whole area these conditions persisted until the end of the month.

A dry spell was also experienced in east Essex beginning on the 16th.

In the north-west of England and in Scotland dry spells or absolute droughts were the rule south and west of a line from Barra, Skallary (Inv.) to Montrose (Angus) and Southport (Lancs.) although a few stations were exceptional in this respect. The more westerly portions of this region usually experienced absolute droughts.

The thunderstorms at the beginning of September interrupted the dry conditions of August and September; consequently there are only three records of partial droughts, from Margate, Kent (Aug. 5th—Sept. 17th) Lexden Hill House, Essex, (Aug. 9th—Sept. 30th) and Haughley House, Suffolk (Aug. 11th—Sept. 30th).

W. H. HOGG.

Auroral Notes for August, 1939.

A report has been received from Mr. H. H. Lamb at Foynes of the aurora observed from Imperial Airways aircraft " Caribou " on the night of August 10th, 1939, as mentioned in the Press. The " Caribou " was homeward bound and at 24h. G.M.T., when about 300 miles east of Newfoundland she reported strong aurora right across the northern sky and reaching an elevation of 40°. Aurora was observed at Foynes by Mr. F. E. Dixon and Mr. Lamb earlier on the same evening and also during the night of August 11th. On the latter occasion the sky was thinly overcast but the lighting through the cloud suggested aurora of curtain formation. Observations on this occasion were discontinued after 23h. 30m. but there was interference with wireless telegraphic communication between Foynes and Botwood, Newfoundland, from about that time until 13h. 50m. on the 12th. It is of interest to note that a " sudden commencement " was recorded in the magnetic elements at Eskdalemuir Observatory at 1h. 42m. on August 12th, magnetic disturbance persisting during the remainder of the day. A medium sized sunspot passed the sun's central meridian on August 11th. (*Nature* Vol. 144, p. 362.)

A short display of aurora was seen from St. Andrews on the evening of the 16th. The aurora which reached its maximum by 23h. and had died away an hour later was of arc formation with some rays.

A. R. PHILIP.

Mr. J. M. Brierley, of Rodwell, South Petherton, Somerset, reports:—

A brief display of the Aurora Borealis was observed here on August 11th, 1939. Beginning at 22h. 55m. G.M.T., as a faint glow in the shape of an arch from NW to NNW. At 23h. 10m. several faint streamers were observed to reach an elevation of 20°, the elevation of the arch being about 50°. At 23h. 15m. the streamers had vanished and the arch had assumed a very faint pinkish hue; by 23h. 30m. all trace of the arch had disappeared.

Auroral display on November 4th, 1322.

Matthew of Westminster gives the following account:—

" . . . . on the fourth day of November at the first hour of the night in the western parts beyond the city of London near the village of Uxbridge, there appeared in the air to many beholders a wonderful sign. For a certain pile of fire of the size and shape of a small boat, pallid, but of a livid colour, rising up from the south and crossing the firmament with a slow and grave motion, set its course towards the north. Out of the front of this pile another very fervent fire of a red colour and of greater quantity, similar in shape to the former, burst forth immediately with bright beams and great speed, flying through the air, which were seen quickly meeting against each other by many beholders. And by turns frequently approaching with collisions and engaging in fearful combat, the blows of which conflict and the sounds of the crashes were heard at a distance from the beholders ". C. E. BRITTON.

Sunshine in 1911.

The largest annual total of sunshine on record is given on page 241 as 2,158 hours at Eastbourne in 1911. Capt. J. E. Cowper points out that in the same year

2,193 hours occurred at Shanklin, Isle of Wight, although this station did not report to the Meteorological Office for inclusion in the *Monthly Weather Report.*

Sunshine, October, 1939

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

	Total hrs.	Diff. from average hrs.		Total hrs.	Diff. from average hrs.
Stornoway	134	+57	Chester	95	+ 4
Aberdeen	109	+15	Ross-on Wye	108	+ 9
Dublin	..	..	Falmouth	144	+31
Birr Castle	118	+28	Gorleston	..	..
Valentia	140	+50	Kew	90	− 6

Kew temp., mean, 47·7° F. diff. from average −3·9° F.

General Rainfall, October, 1939

	Per cent.
England and Wales	120
Scotland	79
Ireland	80
British Isles	101

OBITUARY

Vice-Admiral Sir H. Percy Douglas.

We regret to announce the death on November 4th, 1939, of Sir Percy Douglas. Sir Percy was in April 1917, appointed as the first Director of the Naval Meteorological Service. He held this post until January 1918, and in 1924 he was appointed Hydrographer of the Navy, holding this post until 1932. While Hydrographer he did much valuable work on Government and other Committees, including the Meteorological Committee and those dealing with s.s. *Discovery* and with pollution of the River Tees.

A. W. Shadick.

We regret to announce the death on October 25th, 1939, of Mr. A. W. Shadick. Mr. Shadick was responsible for the meteorological station maintained by the Clacton Urban District Council from 1901 until his death at the age of 81. Although since 1934 his failing health debarred him from taking any active part in the work of the station his interest was maintained, and he will be remembered by many as a keen observer and a genial character.

Rainfall : October 1939 : England and Wales

Co.	Station.	In.	Per cent of Av.	Co.	Station.	In.	Per cent of Av.
Lond'n	Camden Square......	6·10	232	*Warw*	Alcester, Ragley Hall.	4·25	155
Surrey	Reigate, Wray Pk. Rd.	6·71	202	" .	Birminghm, Edgbaston	3·35	121
Kent .	Tenterden, Ashenden .	7·34	205	*Leics* .	Thornton Reservoir...	4·37	156
" .	Folkestone, I. Hospital	14·11	..	" .	Belvoir Castle........	3·09	114
" .	Margate, Cliftonville..	10·28	351	*Rutl'd*	Ridlington	3·80	135
" .	Edenb'dg., Falconhurst	7·90	219	*Lincs* .	Boston, Skirbeck.....	3·48	127
Sussex	Compton, Compton Ho	6·32	138	" .	Cranwell Aerodrome..	3·52	123
" .	Patching Farm.......	6·79	189	" .	Skegness, Marine Gdns	3·67	134
" .	Eastbourne, Wil. Sq..	8·25	199	" .	Louth, Westgate.....	4·23	131
Hants.	Ventnor, Roy. Nat. Hos.	8.72	222	" .	Brigg, Wrawby St....	2·72	..
" .	Southampton, East Pk	6·05	154	*Notts* .	Mansfield, Carr Bank.	3·14	103
" .	Ovington Rectory....	5·69	141	*Derby*	Derby, The Arboretum	3·29	121
" .	Sherborne St. John...	4·75	135	" .	Buxton, Terrace Slopes	3·88	79
Herts .	Royston, Therfield Rec	4·84	178	*Ches.* .	Bidston Obsy........	2·59	79
Bucks.	Slough, Upton.......	4·63	165	*Lancs.*	Manchester, Whit. Pk.	1·50	45
Oxford	Oxford, Radcliffe.....	5·27	182	" .	Stonyhurst College...	1·47	33
N'hant	Wellingboro, Swanspool	4·49	178	" .	Southport, Bedford Pk	1·95	55
" .	Oundle	3·52	..	" .	Ulverston, Poaka Beck	2·03	37
Beds .	Woburn, Exptl. Farm.	3·83	143	" .	Morecambe..........	·97	25
Cambs	Cambridge, Bot. Gdns.	3·83	162	" .	Blackpool	1·68	45
" .	March	3·89	150	*Yorks.*	Wath-upon-Dearne ..	2·30	83
Essex.	Chelmsford, CountyGns	..	..	" .	Wakefield, Clarence Pk.	2·68	93
" .	Lexden Hill House...	7·76	..	" .	Oughtershaw Hall....	3·78	..
Suff .	Haughley House.....	5·41	..	" .	Harrog'te, HarlowMoor	2·92	85
" .	Campsea Ashe, High Ho	8·77	336	" .	Hull, Pearson Park...	3·67	123
" .	Lowestoft Sec. School.	6·45	231	" .	Holme-on-Spalding ..	2·77	92
" .	Bury St. Ed., Westley H	5·59	206	" .	Felixkirk, Mt. St. John	3·65	127
Norf. .	Wells, Holkham Hall..	4·49	160	" .	York, Museum.......	2·24	83
Wilts .	Porton, W.D. Exp'l Stn	4·85	155	" .	Scarborough.........	3·12	100
" .	Bishops Cannings....	4·26	128	" .	Middlesbrough	4·58	153
Dorset	Weymouth, Westham.	6·07	166	" .	Baldersdale, Hury Res.	..	..
" .	Beaminster, East St..	5·29	119	*Durhm*	Ushaw College	5·76	168
" .	Shaftesbury	4.25	..	*Norl'd*	Newcastle, Leazes Pk.	4·79	155
Devon.	Plymouth, The Hoe...	5·26	133	" .	Bellingham, Highgreen	4·92	126
" .	Holne, Church Pk. Cott	7·51	114	" .	Lilburn Tower Gdns..	5·87	159
" .	Teignmouth, Den Gdns	5·14	133	*Cumb*.	Carlisle, Scaleby Hall .	1·98	59
" .	Cullompton	4·23	102	" .	Borrowdale, Seathwaite	4·75	42
" .	Sidmouth, U.D.C.....	5·05	..	" .	Thirlmere, DaleHeadH.	5·45	61
" .	Barnstaple, N. Dev. Ath	2·35	52	" .	Keswick, High Hill...	3·20	57
" .	Dartm'r, Cranmere P'l.	6·80	..	" .	Ravenglass, The Grove	1·97	46
" .	Okehampton, Uplands.	4·91	81	*West* .	Appleby, Castle Bank.	2·06	59
Cornw	Redruth, Trewirgie...	..	..	*Mon.* .	Abergavenny, Larchf'd	4·19	100
" .	Bude, School House..	2·87	71	*Glam.*.	Ystalyfera, Wern Ho..	4·06	59
" .	Penzance, Morrab Gdns	3·08	66	" .	Treherbert, Tynywaun	6·81	..
" .	St. Austell, Trevarna..	4·94	94	" .	Cardiff, Penylan......	3·38	71
Soms .	Chewton Mendip.....	3·77	78	*Carm.*	Carmarthen, M. & P.Sc.	2·53	43
" .	Long Ashton........	2·93	78	*Card* .	Aberystwyth	3·07	..
" .	Street, Millfield......	2·80	88	*Radn'r*	Bir. W. W. Tyrmynydd	3·76	57
Glostr.	Blockley	4·22	..	*Mont* .	Lake Vyrnwy........	3·90	69
" .	Cirencester, Gwynfa..	3·63	110	*Flint* .	Sealand Aerodrome...	3·36	115
Here .	Ross-on-Wye	2·35	71	*Mer* .	Blaenau Festiniog....	4·42	47
" .	Kington, Lynhales...	2·61	70	" .	Dolgelley, Bontddu...	2·62	43
Salop .	Church Stretton......	3·65	..	*Carn.*	Llandudno	2·94	87
" .	Shifnal, Hatton Grange	3·51	124	" .	Snowdon, L. Llydaw 9	8·75	..
" .	Cheswardine Hall....	4·02	129	*Angl* .	Holyhead, Salt Island.	3·48	87
Worc .	Malvern, Free Library	3·32	111	" .	Lligwy.............	2·73	..
" .	Ombersley, Holt Lock.	2·73	102	*I. Man*	Douglas, Boro' Cem...	3·21	71

ERRATUM : Stonyhurst College, September, *for* 1·79/74 *read* 1·79/47.

Rainfall : October 1939 : Scotland and Ireland

Co.	Station.	In.	Per cent of Av.	Co.	Station.	In.	Per cent of Av.
Guern.	St.PeterP't.GrangeRd.	6·63	147	*R & C.*	Stornoway, C.G.Stn...	3·28	6
Wig .	Pt. William, Monreith.	3·96	100	*Suth* .	Lairg	3·14	84
„ .	New Luce School.....	4·14	89	„ .	Skerray Borgie.......	2·35	..
Kirk .	Dalry, Glendarroch...	3·40	65	„ .	Melvich	2·73	74
Dumf.	Eskdalemuir Obs.....	3·32	61	„ .	Loch More, Achfary...	3·03	39
Roxb .	Hawick, Wolfelee	3·50	91	*Caith* .	Wick	1·56	53
„ .	Kelso, Broomlands....	2·84	98	*Orkney*	Deerness	..	..
Peebs .	Stobo Castle.........	3·44	100	*Shet* .	Lerwick Observatory .	2·12	54
Berw .	Marchmont House....	4·19	110	*Cork* .	Cork, University Coll.	4·53	116
E.Lot.	North Berwick Res...	2·82	95	„ .	Roches Point, C.G.Stn.	3·84	94
Midl .	Edinburgh, Blackfd. H	1·99	73	„ .	Mallow, Hazlewood...	2·65	..
Lanark	Auchtyfardle	1·49	..	*Kerry.*	Valentia Observatory.	4·17	75
Ayr .	Kilmarnock, Kay Park	1·30	..	„ .	Gearhameen	8·40	91
„ .	Girvan, Pinmore......	2·65	53	„ .	Bally McElligott Rec.	6·23	..
„ .	Glen Afton, Ayr San..	3·98	78	„ .	Darrynane Abbey.....	3·88	77
Renf .	Glasgow, Queen's Park	2·41	74	*Wat* .	Waterford, Gortmore..	3·60	92
„ .	Greenock, Prospect H.	3·63	72	*Tip* .	Nenagh, Castle Lough.	1·19	35
Bute .	Rothesay, Ardencraig.	2·15	49	„ .	Cashel, Ballinamona..	1·41	40
„ .	Dougarie Lodge......	2·76	67	*Lim* .	Foynes, Coolnanes....	2·95	78
Argyll.	Loch Sunart, G'dale..	3·02	46	„ .	Limerick, Mulgrave St.	1·53	44
„ .	Ardgour House	2·15	..	*Clare* .	Inagh, Mount Callan..	5·34	..
„ .	Glen Etive	..	..	*Wexf* .	Gorey, Courtown Ho..	3·15	89
„ .	Oban	1·61	..	*Wick* .	Rathnew, Clonmannon	3·98	..
„ .	Poltalloch	2·63	53	„ .	Blessington Rectory...	..	..
„ .	Inveraray Castle	4·98	71	*Carlow*	Bagnalstown FenaghH	2·86	85
„ .	Islay, Eallabus.......	1·92	40	„ .	Hacketstown Rectory.	3·91	103
„ .	Mull, Benmore.......	3·70	29	*Leix* .	Blandsfort House	1·94	55
„ .	Tiree................	..	..	*Offaly.*	Birr Castle	·87	30
Kinr .	Loch Leven Sluice....	3·45	100	*Dublin*	Dublin, Phoenix Park.	2·89	109
Fife .	Leuchars Aerodrome..	3·51	135	*Meath.*	Kells, Headfort.......	3·04	91
Perth .	Loch Dhu	4·90	69	*W.M..*	Moate, Coolatore	1·50	..
„ .	Crieff, Strathearn Hyd.	3·24	82	„ .	Mullingar, Belvedere..	1·97	63
„ .	Blair Castle Gardens..	5·08	164	*Long* .	Castle Forbes Gdns....	2·62	80
Angus.	Kettins School.......	5·19	164	*Galway*	Galway, Grammar Sch.	2·98	80
„ .	Pearsie House	6·87	..	„ .	Ballynahinch Castle ..	4·53	76
„ .	Montrose, Sunnyside..	3·02	109	„ .	Ahascragh, Clonbrock.	2·91	80
Aberd.	Balmoral Castle Gdns.	6·38	177	*Rosc* .	Strokestown, C'node..	3·12	102
„ .	Logie Coldstone Sch ..	..	..	*Mayo.*	Blacksod Point	5·26	105
„ .	Aberdeen Observatory.	3·09	103	„ .	Mallaranny..........	6·13	..
„ .	New Deer SchoolHouse	4·37	115	„ .	Westport House......	4·07	90
Moray	Gordon Castle	4·08	129	„ .	Delphi Lodge	10·36	109
„ .	Grantown-on-Spey ...	..	..	*Sligo* .	Markree Castle.......	3·24	79
Nairn.	Nairn...............	2·50	106	*Cavan.*	Crossdoney, Kevit Cas.	3·00	..
Inv's .	Ben Alder Lodge.....	..	..	*Ferm* .	Crom Castle..........	2·78	86
„ .	Kingussie, The Birches	1·39	..	*Arm'h.*	Armagh Obsy........	3·59	132
„ .	Loch Ness, Foyers....	1·60	48	*Down.*	Fofanny Reservoir....	8·91	..
„ .	Inverness, Culduthel R	2·03	83	„ .	Seaforde.............	3·33	94
„ .	Loch Quoich, Loan...	4·63	..	„ .	Donaghadee, C. G. Stn.	3·08	107
„ .	Glenquoich	2·18	22	*Antrim*	Belfast,Queen's Univ..	2·38	72
„ .	Arisaig House........	1·33	23	„ .	Aldergrove Aerodrome	2·01	67
„ .	Glenleven, Corrour ...	2·62	43	„ .	Ballymena, Harryville.	2·54	69
„ .	Ft. William, Glasdrum.	2·55	..	*Lon* .	Garvagh, Moneydig...	2·23	..
„ .	Skye, Dunvegan	..	..	„ .	Londonderry, Creggan.	2·21	60
„ .	Barra, Skallary	1·23	..	*Tyrone*	Omagh, Edenfel......	2·22	60
R & C.	Tain, Ardlarach.......	1·73	57	*Don* .	Malin Head..........	2·14	56
„ .	Ullapool	1·81	37	„ .	Dunfanaghy	1·93	50
„ .	Achnashellach........	2·45	31	„ .	Dunkineely..........	1·90	..

Climatological Table for the British Empire, April, 1939

STATIONS.	PRESSURE. Mean of Day M.S.L. mb.	PRESSURE. Diff. from Normal. mb.	TEMPERATURE. Absolute. Max. °F.	TEMPERATURE. Absolute. Min. °F.	TEMPERATURE. Mean Values. Max. °F.	TEMPERATURE. Mean Values. Min. °F.	TEMPERATURE. Mean Values. ½ Max. and Min. °F.	TEMPERATURE. Mean Values. Diff. from Normal. °F.	TEMPERATURE. Mean. Wet Bulb. °F.	Relative Humidity. %	Mean Cloud Am'nt 0–10	PRECIPITATION. Am'nt. in.	PRECIPITATION. Diff. from Normal. in.	PRECIPITATION. Days.	BRIGHT SUNSHINE. Hours per day.	BRIGHT SUNSHINE. Percentage of possible.
London, Kew Obsy...	1014·0	− 0·4	72	32	55·8	41·4	48·6	+ 1·5	42·9	85	5·4	2·21	+ 0·76	16	5·8	42
Gibraltar..........	1016·1	− 0·3	72	48	62·5	52·4	57·5	− 3·4	51·1	77	4·6	2·99	—	8	9·5	72
Malta..............	1013·2	− 0·2	69	51	63·3	55·1	59·2	− 1·7	55·2	81	5·8	2·37	+ 1·51	6	8·0	61
St. Helena	1016·4	− 0·2	73	59	68·0	61·4	64·7	+ 0·4	62·9	93	8·9	4·59	+ 1·37	26	—	—
Freetown, Sierra Leone	1011·8	+ 2·7	90	73	87·5	74·4	80·9	—	71·9	83	7·4	1·59	− 2·47	4	—	—
Lagos, Nigeria	1009·9	+ 0·5	90	69	87·3	74·7	81·0	− 1·8	75·6	88	7·2	3·76	− 2·32	10	7·0	57
Kaduna, Nigeria	1008·4	—	97	61	91·9	72·2	82·1	− 0·1	71·8	81	4·9	3·01	− 0·07	6	8·7	71
Zomba, Nyasaland....	1011·7	− 0·8	84	59	78·0	62·1	70·1	+ 0·8	65·3	82	7·1	6·13	+ 2·47	11	—	—
Salisbury, Rhodesia ..	1015·2	− 0·4	82	45	75·5	52·3	63·9	− 1·8	57·5	67	3·7	0·56	—	4	8·8	75
Cape Town	1017·0	+ 0·6	87	47	72·1	53·7	62·9	− 0·3	56·4	88	6·0	1·47	− 0·40	12	—	—
Johannesburg	1015·5	− 0·6	77	28	70·0	49·4	59·7	− 0·3	49·8	55	2·0	0·28	− 1·46	4	8·3	72
Mauritius	1014·0	+ 0·1	85	67	82·4	71·6	77·0	+ 1·2	73·0	75	5·4	4·33	− 0·79	23	8·5	73
Calcutta, Alipore Obsy.	1005·8	− 0·5	107	67	100·2	78·1	89·1	+ 3·5	77·9	77	3·2	1·57	− 0·61	1*	—	—
Bombay	1008·3	− 0·5	91	73	87·9	76·0	81·9	− 1·2	74·6	74	2·1	0·00	− 0·05	0*	—	—
Madras	1007·6	− 0·8	97	68	90·4	77·2	83·8	− 1·5	77·6	76	5·5	5·23	+ 4·60	3*	—	—
Colombo, Ceylon	1008·9	+ 0·2	89	73	87·2	76·1	81·7	− 1·0	77·5	78	7·3	10·67	+ 0·94	24	6·8	55
Singapore	1008·8	− 0·1	91	73	86·9	76·0	81·5	− 0·1	77·8	77	6·4	8·73	+ 1·10	16	5·8	48
Hongkong..........	1013·0	+ 0·4	81	50	72·5	65·0	68·7	− 2·1	65·2	81	8·2	15·80	+10·15	13	3·0	24
Sandakan	1009·1	—	90	74	87·4	77·0	82·2	0·0	77·8	83	7·7	6·43	+ 1·94	11	—	—
Sydney, N.S.W.......	1018·9	+ 0·5	77	51	72·3	59·8	66·1	+ 1·4	61·1	79	6·0	3·93	− 1·59	15	4·5	40
Melbourne	1019·1	− 0·4	82	42	68·7	53·3	61·0	+ 1·5	56·0	75	7·8	4·48	+ 2·31	17	4·1	37
Adelaide	1019·3	− 0·5	90	49	74·7	56·0	65·3	+ 1·4	58·1	60	7·0	2·15	+ 0·43	14	6·3	57
Perth, W. Australia....	1018·7	+ 0·3	89	41	77·1	56·5	66·8	0·0	58·7	59	3·4	1·08	− 0·57	4	8·4	75
Coolgardie	1016·1	− 2·2	91	40	77·1	54·9	66·0	+ 1·0	58·0	69	2·9	1·44	+ 0·48	5	—	—
Brisbane	1018·5	+ 0·9	81	55	76·2	60·4	68·3	− 2·0	65·0	78	6·3	4·47	+ 0·70	18	4·8	42
Hobart, Tasmania....	1016·9	+ 2·1	79	37	65·5	49·8	57·7	+ 2·5	52·1	75	6·8	1·16	− 0·69	16	4·8	44
Wellington, N.Z.	1023·1	+ 5·0	71	42	61·4	51·3	56·3	− 0·8	53·6	79	7·0	2·95	− 0·93	10	5·1	46
Suva, Fiji	1010·8	+ 0·2	88	69	83·1	72·6	77·9	− 0·7	74·1	87	7·7	16·98	+ 4·77	24	4·0	34
Apia, Samoa	1010·2	+ 0·3	87	72	84·8	74·4	79·6	+ 0·7	76·0	81	—	9·00	− 1·15	18	6·9	59
Kingston, Jamaica ...	1014·7	+ 0·6	87	65	85·0	68·6	76·8	− 1·6	68·1	78	3·1	1·81	+ 0·57	6	5·2	42
Grenada, W.I.	1010·5	− 2·0	89	71	86·0	72·0	79·0	+ 0·1	75·0	83	5·0	6·57	+ 4·41	14	—	—
Toronto............	1013·4	− 2·7	75	24	46·7	34·4	40·5	− 1·6	34·5	78	7·6	3·43	+ 1·14	13	4·5	34
Winnipeg	1016·3	− 0·4	83	3	48·3	25·6	36·9	− 0·8	26·0	77	5·4	1·08	− 0·32	7	7·7	56
St. John, N.B.	1012·5	− 0·9	55	20	44·1	30·3	37·2	− 1·8	32·7	77	5·9	4·56	+ 1·05	20	5·3	39
Victoria, B.C........	1019·9	+ 2·4	71	36	57·4	42·8	50·1	+ 2·2	46·4	77	6·6	0·36	− 1·16	6	7·4	54

* For Indian stations a rain day is a day on which 0·1 in. or more rain has fallen.

(49739) Wt. 22/31 1375 11/39 Hw. G. 377/6

THE METEOROLOGICAL
M.O. 441 MAGAZINE
AIR MINISTRY : METEOROLOGICAL OFFICE

Vol. 74 DECEMBER, 1939 No. 887

THE LUNAR TIDE IN THE ATMOSPHERE

By Professor S. Chapman, F.R.S.

From the writer's Presidential Address to the Association for Meteorology, at the Washington Assembly (September, 1939) of the International Union for Geodesy and Geophysics.

Laplace, in 1825, seems to have been the first to try to determine, from barometric observations, whether the moon produces a tide in the air as it does in the sea. He used Paris data (8 years), as did Bouvard (11 years) in 1828, and Eisenlohr (22 years) in 1843, but all without success. Lefroy in 1842, from 17 months' bi-hourly observations at St. Helena, first determined this air-tide; in 1852 Elliot determined it at Singapore from 5 years' data. From 1871 onwards the air-tide has been determined regularly at Batavia, by Bergsma and succeeding directors, and its value there is now known with considerable accuracy. St Helena, Singapore and Batavia are of course all in the tropics, where the barometric changes are usually much smaller and more regular than in higher latitudes: in the tropics also the air-tide, according to theory, should be larger than elsewhere; these combined reasons explain why the tropical air-tide was readily determined, whereas until 1918 all efforts to find it in non-tropical records were unsuccessful—e.g., by Neumayer for Melbourne, Börnstein for Keitum, Morano for Rome, and Airy for Greenwich (20 years' data).

In 1918 I determined the Greenwich air-tide from 64 years' hourly data, by rejecting the data (about two-thirds of the whole) for all days on which the barometric range exceeded 0·1 inch: the result is shown in Fig. 1.

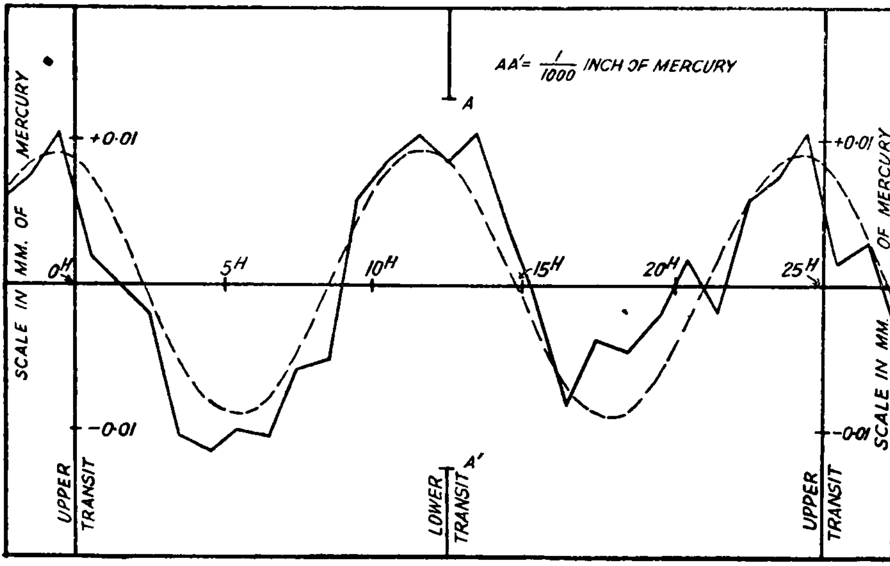


Fig. 1.—The lunar semi-diurnal tide in the atmosphere at Greenwich as determined from the Greenwich records of barometric pressure, 1854–1917.

The broken line indicates the lunar semi-diurnal component and the difference between this and the computed variation (the full line) may be attributed to accidental causes.

High tide occurs there twice daily, just before the moon's upper and lower transits: the tidal range is less than 0·001 inch of mercury: that such a small regular variation can be disentangled from the irregular variations, of range more than 3,000 times as great, is a striking illustration of the law of errors. The rejection of the days of range exceeding 0·1 inch was not due to any expectation that the tide was not present on such days, but simply because it was not possible to reduce the average of the irregular variations on such days, with the amount of material available, to the very small value needed to disclose the minute lunar tide.

In 1918 the air-tide was thus known at three tropical stations and one non-tropical: its value has since been determined at 50 more stations: these results are due as follows: to Bartels, three stations, Hamburg and Potsdam (non-tropical) and Dar-es-Salaam (Bartels has also introduced important improvements in the calculations, and in the estimation of the probable errors): to Pramanik and his colleagues, Bombay, and a pair of adjacent Indian stations at very different heights, Kodaikanal and Periyakulam: to Robb and Tannahill, Glasgow: the remainder are due to the writer and his colleagues and assistants: the rate at which we have been able to make the calculations has increased about

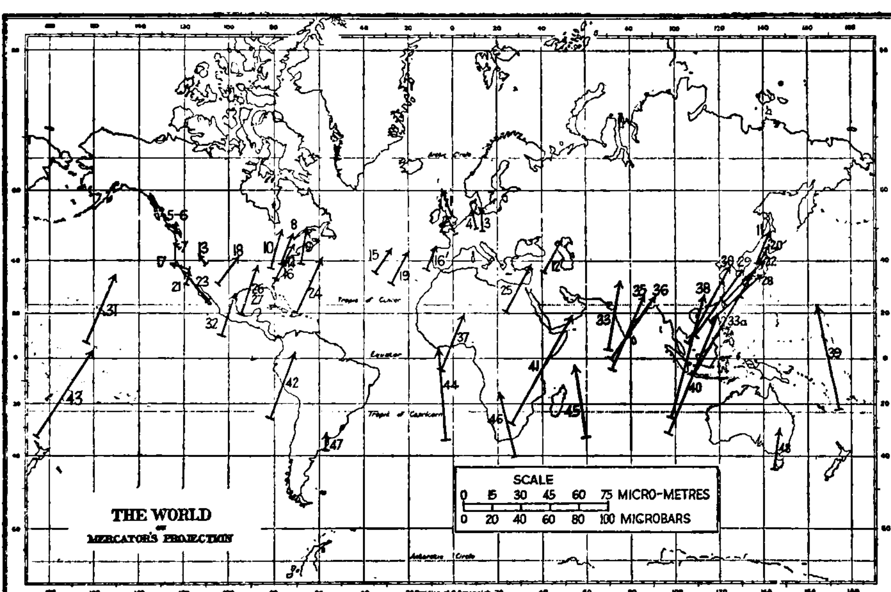


Fig. 2.—Geographical distribution of amplitude and phase of annual lunar atmospheric tide.
(Vector-arrows *centered* at stations.)

three-fold since, in 1930, a set of Hollerith punching, sorting and tabulating machines was made available for this work, by the courtesy of the British Tabulating Machine Co., Ltd.; since then no less than 28 new determinations have been made by this means, of which 17 are not yet published.

The main results are illustrated in Fig. 2, which shows the geographical distribution of the air-tide. The map shows a number of arrows, each of which refers to the air-tide at the point on the map at the centre of the arrow shaft. The length of the arrow indicates the semi-range of the tide, in mm. of mercury or in microbars, according to the scales shown: and the direction of the arrow indicates the times of high tide (twice daily) as shown by the arrow regarded as the hour-hand of a clock keeping lunar time, so that 12 o'clock corresponds to the upper or lower transit of the *moon* instead of the sun.

All the arrows point *upwards*, and the majority point towards the right, indicating high tide somewhat after lunar transit, though at some stations it occurs in advance of the moon's meridian passage.

On the whole the arrows are longest in the tropics, and shortest in the highest latitudes: this is what tidal theory would suggest. But there are notable departures from this rule (and these are in the main real, and not due merely to accidental errors, though the results are certainly affected to some extent by such errors): for example, the air-tide at Melbourne (48) is notably greater than at Buenos Ayres (47), in almost the same latitude; the numbers in brackets are those assigned to the corresponding arrow on the map. At the equator the pressure range due to the lunar air-tide is about 0·12 mm. of mercury, corresponding to the weight of about 4 feet of air of normal density.

Some specially striking irregularities in the geographical distribution of the tide are found in North America. Along the eastern part, and indeed southwards from Montreal (8) and St. John (9) as far as Mexico City (32) and Lima (42), and eastwards to Bermuda (24), the air-tide has a normal and regular distribution, with nearly the same phase at all the stations. At Dodge City (18), in the middle of the land mass, the phase is fairly regular, but the amplitude is somewhat smaller than at the more easterly stations in the same latitude. Further to the west the tide becomes increasingly abnormal, either in the smallness of its amplitude, or in its unusual phase, or in both these respects. This result was first indicated by the determinations for five Canadian stations: the amplitudes found for Victoria (6) and Vancouver (5), in the far west, were abnormally small. This is now confirmed by the determination for Portland (Oregon) (7) not far to the south. At all three stations the amplitudes are so small that the phases there (or the times of high tide) are uncertain.

The tide at Salt Lake City (13) is notable not only for its small amplitude, but also for its early maximum; also at San Francisco (17) and San Diego (23), on the western coast, the phase is unusually early—two hours before the moon transits. At the neighbouring high-level stations of Mount Wilson Observatory (21) and Mount Hamilton (Lick) the tide is similar in size (rather small for the latitude) but the phase is roughly normal, with high tide after the moon's transit. These remarkable results well repay the labour of determining the tide at these various points in the United States, and render it desirable to pursue the study further, both in North and South America. It seems scarcely open to doubt that these anomalies in the distribution of the tide are due to the great mountain-chain along the west of the continent.

In this respect the lunar pressure variation contrasts strongly with the solar 12-hourly pressure wave, whose distribution over North America shows a notable uniformity of phase, with maximum at about 10 o'clock. The distribution of the amplitudes is also regular: it depends on the latitude, but only to a slight extent on the longitude, and there is no notable reduction of amplitude on the western coast.

The great mountain chain in North and South America makes this region one of particular interest for the study of the air-tide. Determinations for the two available pairs of adjacent stations at considerably different levels show interesting differences, already referred to. Examination of the probable errors of the results shows that these differences are real, and that at Mount Wilson (height 1,783 metres) high tide in the air pressure occurs over an hour later than at San Diego (26 metres), and similarly for Mount Hamilton (1,284 metres) and San Francisco (47 metres): these differences much exceed those between the times of maximum pressure in the solar twelve-hourly wave at the same two pairs of stations. In India, on the other hand, Pramanik found no appreciable difference between the air-tides at Kodaikanal (314 metres) and Periyakulam (2,563 metres), despite the greater height-difference of these adjacent stations.

So far the annual mean value of the air-tide has been considered: but it is found that the amplitude and time of high tide are not constant throughout the year. The change in the tide from month to month or season to season has been determined at many stations. Its most notable feature at almost all stations is that in December or January high tide occurs decidedly later (by over an hour) than in April or May: this is the case both north and south of the equator, though on the western coast of North America some stations are anomalous in this as in other respects. This change of phase (that is, of the time of high tide), as well as the associated but minor changes in the amplitude, is not a seasonal change in the usual sense of this term: the seasons depend on the sun's declination, and when it is summer in one hemisphere it is winter in the other: when the sun crosses the equator, the seasons are reversed, and the hemispheres undergo opposite seasonal changes. As regards the air-tide, its phase varies similarly in both hemispheres at once, hence the change is properly called an annual one.

The well-known solar twelve-hourly variation of the barometer also undergoes an annual variation, but of smaller magnitude and different type: in this variation high pressure occurs *earliest* in December (not latest, as for the lunar air-tide) and latest in July.

The intensity of the moon's tidal force upon the earth varies by ± 20 per cent. with the moon's changing distance. The lunar air-tide would be expected to show a corresponding variation of amplitude, and this has been looked for in the determinations for many stations. A change of the right sign and of about the right magnitude is found at some stations, but at others the results have agreed less well with the theory. This is perhaps because of statistical difficulties in the computations, not yet properly understood. It is hoped that these will ere long be overcome, and that the influence of lunar distance upon the air-tide will be definitely determined.

The pressure variations in terms of which we have thus far discussed the lunar air-tide are of very low frequency: their period of half a lunar day corresponds to a frequency of 705 oscillations per year. It might well be thought that such low-frequency pressure-variations would be isothermal, and Laplace in his theory of atmospheric tides assumed this. But here he fell into the same error which he himself corrected with reference to Newton's theory of the velocity of sound. The rapid oscillations in sound waves, with a frequency of some hundreds per second, occur adiabatically, and by allowing for this Laplace was able to revise Newton's faulty value of the velocity of sound and obtain the observed value. The slow tidal pressure variations also occur adiabatically. This is because of the great length of the lunar tidal wave which moves round the earth, following the moon; the heat generated by the tidal compression cannot traverse this great distance in the time available, nor can it escape upwards or downwards at a sufficient rate. These conclusions, indicated by theoretical examination, have been confirmed from actual observation by my determination of the lunar semi-diurnal variation of air-temperature at Batavia (40), having an amplitude of 0·009° C., with maximum temperature occurring at the same time as high (air-) tide there.

Horizontal air-currents with a period of half a lunar day must be associated with the air-tide. Their expected velocity is about 2 cm/sec. or about 70 metres per hour. This is very small compared with the normal wind-velocities, but I think there is a possibility of determining a lunar semi-diurnal variation of the wind from the long series of records at Batavia, and work on this problem has already been begun. Such work would be facilitated if some observatory, especially in the tropics, would measure or tabulate the wind *components,* converting the records of velocity and direction into those of east-west and north-south velocities, preferably tabulating them with the addition of a constant which would make all the hourly values positive.

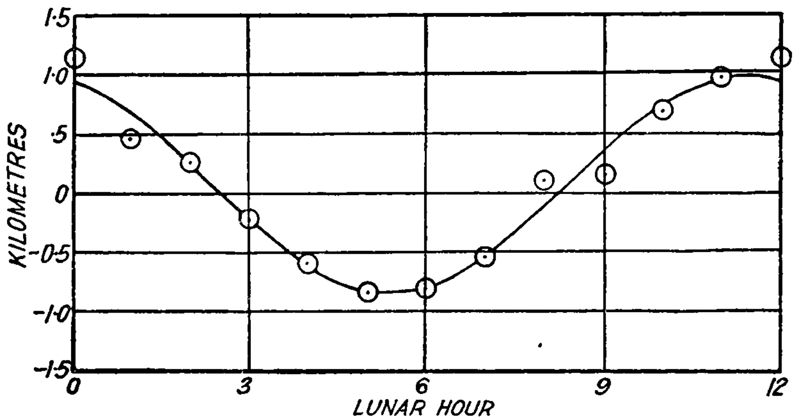


Fig. 3.—Lunar semi-diurnal oscillation of E-region of the ionosphere for the period, August 3rd, 1937 to July 11th, 1938, at Cambridge.

The preceding account of the lunar air-tide is based on the evidence for the tide to be found (like the proverbial needle) in the great haystack of old meteorological records. But the tide is also known by its effects in two other distinct ways. The lunar tidal motion of the air at high levels, where the air is ionized and therefore electrically conducting, acts like the motion of the armature in the magnetic field of a dynamo; electric currents are generated, because the air is moving in the field of the great magnet, the earth itself. These electric currents, which amount in the aggregate to 20 or 30 thousand amperes, themselves exert a minute magnetic field, which produces a lunar daily magnetic variation at the earth's surface. This can be disentangled from long series of magnetic records (or short series in low latitudes) just like the lunar tidal barometric variation. This gives us interesting information (not yet fully interpreted) about the lunar tidal air-currents at high levels in the atmosphere.

The second and most recently discovered non-meteorological indication of the lunar air-tide is a variation of level of the E-layer in the ionosphere, as found by radio determinations of the height of this layer. Figure 3 illustrates this variation, which was detected by Appleton and Weekes from radio measurements at Cambridge, England: the phase is in good accordance with the phase of the lunar pressure variation at Greenwich (Fig. 1) but the amplitude is some thousands of times larger than could have been expected until recently.

These facts about the lunar atmospheric tide, as determined from various kinds of observation, are more complex and more puzzling than would seem likely *a priori,* in view of the simplicity of the lunar tidal field of force. The complications in the tide are partly due to the irregular surface on which the atmosphere rests, and to the changes of level of this surface, due to the sea-tides and the earth-tides. But one main cause is the complex structure of the atmosphere itself, which is the dynamical system on which the moon acts. I believe that the lunar atmospheric tide has a valuable contribution to make to our knowledge of this structure, but the story of the theoretical questions connected with the tide is too long to be entered upon here.

LETTERS TO THE EDITOR

Altocumulus-castellatus Cloud observed in a Polar Current

On Sunday morning, October 22nd, 1939, at about 10h. 30m. G.M.T. I observed a fine altocumulus-castellatus cloud at Eastbourne. It was seen out at sea looking towards Beachy Head and lasted for about half an hour. The day was cold and bright with a moderate NNE wind. It seems curious that one should see this cloud in a polar current. I wonder whether the action of the warmer sea accounted for the formation of the cloud and whether other readers of *The Meteorological Magazine* have observed clouds of this kind in polar air.

J. MONGER.

46, Great Bushey Drive,
Totteridge, N.20.
October 27th, 1939.

Mr. C. K. M. Douglas remarks " Probably the clouds were at no great height. I have seen clouds quite low over the sea with a structure resembling altocumulus-castellatus."

NOTES AND NEWS

The Weather Cock.

Many people, both meteorologists and others, must have asked themselves from time to time what a cock had to do with meteorology. Sir Napier Shaw recently drew my attention to a note by Gwyneth Pennethorne in a local Magazine which may explain the origin of the connexion.

The note was to the effect that in the 9th Century the reigning Pope Nicholas I, much concerned at the prevalence of lying and prevarication, directed that cocks should be placed at the tops of spires and towers of churches so that the people might have continually before them a reminder of the denial of Peter and the lesson which it taught, and might thereby become more truthful. The Pope was in fact a propagandist and the cocks propaganda of the higher type.

It seems likely that when the cocks were first placed on churches in obedience to this wise order they were fixed cocks, and when strong winds arose they were blown down. The obvious remedy was adopted, namely, to make the cocks rotate with the wind and so present a smaller surface to its force. In this way they not only maintained their lofty situation when the storms arose and beat upon them, but they also became indicators of the direction of the wind and thereby qualified as meteorological instruments: not only warners against lying, but purveyors of truth. Indeed their original deterrent negative purpose has been forgotten, and their secondary instructive positive purpose now alone remains: but even that was perverted by the ignorance of man who called them weather-cocks, not wind-cocks as they should have been called when they lost their significance as " Peter-cocks ". Perhaps it is time they regained it.

E. GOLD.

December Frosts in Early Days (1141, 1241 and 1269)

Many references can be found in the Annals to severe frosts in this month. A picturesque incident in connection with such a frost is found in 1141 when Stephen was besieging Oxford. Henry of Huntingdon states " The same year the King besieged the Empress at Oxford from after Michaelmas to Advent. At the end of which, not long before Christmas, the Empress escaped across the Thames, which was then frozen over, and, wrapped in a white cloak, deceived the eyes of the besiegers, dazzled by the reflection of the snow."

A century later, in 1241, Matthew Paris thus describes December of that year " In the time of winter also, namely, in the advent of the Lord, frost and snow and intolerably bitter cold covered the earth and so hardened it, binding rivers, that numbers of birds gathered together and perished miserably, the like of which no one remembered having seen before."

The Annals of Oseney Abbey refer to a glazed frost during the severe wintry weather of December, 1269, " . . . . and it happened in this frost of wonderful duration that, as soon as rain fell from the sky, so it froze, so that, by reason of the slipperiness of this frost no one could ride on the same, nor turn in any direction without great peril of his life or limbs, or damage to his head."

C. E. BRITTON.

Sunshine, November, 1939

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

	Total hrs.	Diff. from average hrs.		Total hrs.	Diff. from average hrs.
Stornoway	38	− 8	Chester	45	− 8
Aberdeen	56	− 3	Ross-on Wye	44	−19
Dublin	42	−29	Falmouth	47	−29
Birr Castle	39	−22	Gorleston	..	..
Valentia	36	−27	Kew	36	−17

Kew temp., mean, 49·1° F. diff. from average +4·8° F

General Rainfall, November, 1939

	Per cent.
England and Wales	178
Scotland	142
Ireland	197
British Isles	171

OBITUARY

DR. R. A. SAMPSON, F.R.S., Astronomer Royal for Scotland and Professor of Astronomy in the University of Edinburgh from 1910 to 1937, died suddenly at Bath on November 7th.

Professor Sampson was born in County Cork in 1866. He was educated at Liverpool Institute and at St. John's

College, Cambridge, graduating as third Wrangler in 1888. In 1890 he gained the first Smith's Prize and became a Fellow of his College and in 1891 became the first Isaac Newton Student. For two years he was a lecturer in King's College, London, for a further two years Professor of Mathematics at the Durham College of Science, Newcastle-on-Tyne, and then, until 1910, Professor in the University of Durham.

Amongst his scientific work his most important researches were in connexion with the satellites of Jupiter, for which, in 1928, the Royal Astronomical Society awarded him its Gold Medal. At the Royal Observatory, Edinburgh, he conducted successfully the measurement of 64 of the brighter stars and did important work on the determination and recording of time.

Professor Sampson was an Hon. D.Sc. of Durham and L.L.D. of Glasgow and for a number of years was General Secretary of the Royal Society of Edinburgh. He represented the Royal Society of Edinburgh on the Meteorological Committee, London, and on the National Committee for Geodesy and Geophysics and represented the Royal Society of London on the Advisory Committee for the Meteorological Office, Edinburgh, of which also for a number of years he was Vice-Chairman.

In scientific work he was a pioneer and showed great foresight, as well as patience and determination and "beneath a superficial appearance of austerity he managed to conceal a capacity for enjoying life and assisting others to do likewise." The writer will always remember an expedition made in 1931 in his company to the top of Ben Nevis, the admiration he expressed for the pioneers who had planned and built the road and the Observatory, the masons whose stonework was "untouched by time and might last as long as the mountain" and the observers who maintained hourly observations for 21 years.

Professor Sampson is survived by his wife and four sons and daughters.

A. H. R. G.

Rainfall: November, 1939: England and Wales

Co.	Station.	In.	Per cent of Av.	Co.	Station.	In.	Per cent of Av.
Lond'n	Camden Square......	4·98	211	*Warw*	Alcester, Ragley Hall.	..	..
Surrey	Reigate, Wray Pk. Rd.	5·58	179	,,	Birminghm, Edgbaston	4·57	192
Kent .	Tenterden, Ashenden.	5·44	180	*Leics* .	Thornton Reservoir...	4·17	185
,, .	Folkestone, I. Hospital	5·91	..	,, .	Belvoir Castle........	3·28	147
,, .	Margate, Cliftonville..	3·83	159	*Rutl'd*	Ridlington	3·47	151
,, .	Edenb'dg., Falconhurst	6·15	17[illegible]	*Lincs*.	Boston, Skirbeck.....	3·90	195
Sussex	Compton, Compton Ho	7·97	209	,, .	Cranwell Aerodrome..	3·51	188
,, .	Patching Farm.......	7·62	214	,, .	Skegness, Marine Gdns	3·78	175
,, .	Eastbourne, Wil. Sq..	7·0	201	,, .	Louth, Westgate.....	4·45	172
Hants.	Ventnor, Roy.Nat.Hos.	7·98	249	,, .	Brigg, Wrawby St....	4·14	..
,, .	Southampton, East Pk	6·33	202	*Notts* .	Mansfield, Carr Bank..	3·77	155
,, .	Ovington Rectory....	7·07	213	*Derby*.	Derby, The Arboretum	..	..
,, .	Sherborne St. John...	6·41	225	,, .	Buxton, Terrace Slopes	8·51	182
Herts .	Royston, Therfield Rec	3·52	151	*Ches* .	Bidston Obsy........	4·41	176
Bucks.	Slough, Upton.......	4·71	212	*Lancs*.	Manchester, Whit. Pk.	5·33	202
Oxford	Oxford, Radcliffe.....	4·11	179	,, .	Stonyhurst College...	7·93	176
N'hant	Wellingboro, Swanspool	3·30	153	,, .	Southport, Bedford Pk	4·74	151
,, .	Oundle	3·15	..	,, .	Ulverston, Poaka Beck	..	..
Beds .	Woburn, Exptl. Farm.	3·59	160	,, .	Morecambe..........	4·84	128
Cambs	Cambridge, Bot. Gdns.	2·87	149	,, .	Blackpool..........	4·36	126
,, .	March	..	..	*Yorks*.	Wath-upon-Dearne...	3·40	167
Essex.	Chelmsford, CountyGns	4·01	178	,, .	Wakefield, Clarence Pk.	3·56	168
,, .	Lexden Hill House....	4·19	..	,, .	Oughtershaw Hall....	11·16	..
Suff .	Haughley House.....	3·54	..	,, .	Harrog'te, HarlowMoor	4·11	149
,, .	Campsea Ashe, HighHo	4·63	209	,, .	Hull, Pearson Park...	3·55	162
,, .	Lowestoft Sec. School.	..	..	,, .	Holme-on-Spalding...	4·01	184
,, .	Bury St. Ed., WestleyH	4·06	177	,, .	Felixkirk, Mt. St. John	2·34	94
Norf..	Wells, Holkham Hall.	3·69	172	,, .	York, Museum.......	2·80	134
Wilts .	Porton, W.D. Exp'lStn	5·37	205	,, .	Scarborough.........	2·80	113
,, .	Bishops Cannings	5·76	201	,, .	Middlesbrough.......	1·64	77
Dorset	Weymouth, Westham.	6·07	196	,, .	Baldersdale, Hury Res.	5·93	160
,, .	Beaminster, East St ..	8·80	222	*Durhm*	Ushaw College.......	2·46	97
,, .	Shaftesbury	7·46	..	*Norl'd*	Newcastle, Leazes Pk.	2·37	101
Devon.	Plymouth, The Hoe...	7·11	195	,, .	Bellingham, Highgreen	4·37	127
,, .	Holne, Church Pk.Cott	15·06	234	,, .	Lilburn Tower Gdns..	2·89	86
,, .	Teignmouth, Den Gdns	5·85	183	*Cumb*.	Carlisle, Scaleby Hall.	4·32	144
,, .	Cullompton	8·09	235	,, .	Borrowdale, Seathwaite	25·00	195
,, .	Sidmouth, U.D.C.....	4·73	..	,, .	Thirlmere, DaleHeadH	14·82	153
,, .	Barnstaple, N. Dev.Ath	7·57	193	,, .	Keswick, High Hill...	9·46	167
,, .	Dartm'r, Cranmere P'l	..	..	,, .	Ravenglass, The Grove	4·65	104
,, .	Okehampton, Uplands.	14·27	268	*West* .	Appleby, Castle Bank.	4·80	145
Cornw	Redruth, Trewirgie...	..	..	*Mon* .	Abergavenny, Larchf'd	7·22	189
,, .	Bude, School House ..	..	..	*Glam* .	Ystalyfera, Wern Ho..	16·07	245
,, .	Penzance, MorrabGdns	7·36	152	,, .	Treherbert, Tynywaun	20·44	..
,, .	St. Austell, Trevarna..	8·44	172	,, .	Cardiff, Penylan......	8·71	215
Soms .	Chewton Mendip.....	11·60	271	*Carm* .	Carmarthen, M.&P.Sc.	12·24	238
,, .	Long Ashton	7·06	223	*Card* .	Aberystwyth	8·87	..
,, .	Street, Millfield	5·70	210	*Radn'r*	Bir. W. W. Tyrmynydd	14·31	215
Glostr.	Blockley	4·22	..	*Mont* .	Lake Vyrnwy........	13·15	237
,, .	Cirencester, Gwynfa ..	5·98	201	*Flint* .	Sealand Aerodrome...	4·04	173
Here .	Ross-on-Wye	4·22	167	*Mer* .	Blaenau Festiniog....	18·98	196
,, .	Kington, Lynhales....	6·23	193	,, .	Dolgelley, Bontddu...	11·17	180
Salop .	Church Stretton......	5·66	..	*Carn* .	Llandudno	3·87	134
,, .	Shifnal, Hatton Grange	3·94	165	,, .	Snowdon, L. Llydaw 9	23·85	..
,, .	Cheswardine Hall	4·88	188	*Angl* .	Holyhead, Salt Island.	3·90	94
Worc .	Malvern, Free Library.	4·20	167	,, .	Lligwy..............	..	..
,, .	Ombersley, Holt Lock.	3·70	162	*I.Man*	Douglas, Boro' Cem...	5·39	114

Rainfall: November 1939: Scotland and Ireland

Co.	Station.	In.	Per cent of Av.	Co.	Station.	In.	Per cent of Av.
Guern .	St.PeterP't.GrangeRd.	5·06	120	*R&C* .	Stornoway, C.G.Stn...	6·36	115
Wig .	Pt. William, Monreith.	4·77	111	*Suth* .	Lairg	4·85	122
,, .	New Luce School.....	7·73	151	,, .	Skerray Borgie.......	5·55	..
Kirk .	Dalry, Glendarroch...	9·11	152	,, .	Melvich	6·71	168
Dumf.	Eskdalemuir Obs.....	9·28	160	,, .	Loch More, Achfary..	9·65	113
Roxb .	Hawick, Wolfelee	4·74	122	*Caith* .	Wick	4·11	131
,, .	Kelso, Broomlands....	2·61	113	*Orkney*	Deerness	..	..
Peebs .	Stobo Castle.........	6·84	207	*Shet* .	Lerwick Observatory.	5·04	118
Berw .	Marchmont House....	3·16	105	*Cork* .	Cork, University Coll.	9·00	224
E.Lot.	North Berwick Res...	..	..	,, .	Roches Point, C.G.Stn.	7·32	174
Midl .	Edinburgh, Blackfd. H	3·51	157	,, .	Mallow, Hazlewood ..	9·61	..
Lanark	Auchtyfardle	8·42	..	*Kerry*.	Valentia Observatory.	10·08	184
Ayr .	Kilmarnock, Kay Park	8·14	..	,, .	Gearhameen	22·2	229
,, .	Girvan, Pinmore	8·04	151	,, .	Bally McElligott Rec.	9·56	..
,, .	Glen Afton, Ayr San..	12·10	220	,, .	Darrynane Abbey....	9·26	182
Renf .	Glasgow, Queen's Park	8·23	221	*Wat* .	Waterford, Gortmore.	6·25	169
,, .	Greenock, Prospect H.	11·24	185	*Tip* .	Nenagh, Castle Lough.	10.45	260
Bute .	Rothesay, Ardencraig.	9·37	185	,, .	Cashel, Ballinamona..	9·05	262
,,	Dougarie Lodge......	7·62	145	*Lim* .	Foynes, Coolnanes....	9·00	221
Argyll	Loch Sunart, G'dale..	10·33	138	,, .	Limerick, Mulgrave St.	..	..
,,	Ardgour House	14·56	..	*Clare* .	Inagh, Mount Callan..	15·69	..
,,	Glen Etive	15·50	150	*Wexf* .	Gorey, Courtown Ho..	5·96	171
,,	Oban	..	..	*Wick* .	Rathnew, Clonmannon	5·18	..
,,	Poltalloch	10·22	182	,, .	Blessington Rectory..	..	..
,,	Inveraray Castle	15·09	179	*Carlow*	Bagnalstown FenaghH	7·22	216
,,	Islay, Eallabus	..	..	,, .	Hacketstown Rectory.	7·94	204
,, .	Mull, Benmore.......	14·90	103	*Leix* .	Blandsfort House	7·82	234
,,	Tiree	7·04	146	*Offaly*.	Birr Castle	7·39	238
Kinr .	Loch Leven Sluice....	6·04	168	*Dublin*	Dublin, Phoenix Park.	4·26	151
Fife .	Leuchars Aerodrome..	4·24	185	*Meath*.	Kells, Headfort......	6·99	206
Perth .	Loch Dhu	13·80	159	*W.M* .	Moate, Coolatore.....	6·66	..
,, .	Crieff, Strathearn Hyd.	6·44	148	,, .	Mullingar, Belvedere..	7·67	225
,, .	Blair Castle Gardens..	5·42	154	*Long* .	Castle Forbes Gdns ..	8·40	233
Angus.	Kettins School.......	5·93	191	*Galway*	Galway, Grammar Sch.	9·12	224
,, .	Pearsie House	6·32	..	,, .	Ballynahinch Castle ..	9·89	165
,, .	Montrose, Sunnyside..	3·80	143	,, .	Ahascragh, Clonbrock.	9·62	239
Aberd.	Balmoral Castle Gdns.	3·60	98	*Rosc* .	Strokestown, C'node..	7·70	226
,, .	Logie Coldstone Sch ..	3·94	128	*Mayo*.	Blacksod Point	7·64	147
,, .	Aberdeen Observatory.	3·22	109	,, .	Mallaranny..........	13·32	..
,, .	New Deer SchoolHouse	4·55	135	,, .	Westport House......	9·01	184
Moray	Gordon Castle	3·12	108	,, .	Delphi Lodge........	17·95	173
,, .	Grantown-on-Spey ...	2·75	92	*Sligo* .	Markree Castle.......	8·03	193
Nairn.	Nairn..............	2·19	93	*Cavan*.	Crossdoney, Kevit Cas.	7·18	..
Inv's .	Ben Alder Lodge.....	..	..	*Ferm* .	Crom Castle	7·58	218
,, .	Kingussie, The Birches	4·52	..	*Arm'h*	Armagh Obsy........	4·90	173
,, .	Loch Ness, Foyers....	4·65	119	*Down*.	Fofanny Reservoir ...	7·78	..
,, .	Inverness, Culduthel R	2·84	111	,, .	Seaforde	5·02	132
,, .	Loch Quoich, Loan...	16·75	..	,, .	Donaghadee, C. G. Stn.	5·27	173
,, .	Glenquoich	15·47	138	*Antrim*	Belfast,Queen's Univ .	..	..
,, .	Arisaig House	9·41	140	,, .	Aldergrove Aerodrome	4·69	145
,, .	Glenleven, Corrour ...	11·88	159	,, .	Ballymena, Harryville.	5·20	128
,, .	Ft. William, Glasdrum	11·29	..	*Lon* .	Garvagh, Moneydig...	4·88	..
,, .	Skye, Dunvegan	9·72	..	,, .	Londonderry, Creggan.	5·94	145
,, .	Barra, Skallary	5·65	..	*Tyrone*	Omagh, Edenfel......	7·12	187
R&C.	Tain, Ardlarach......	3·50	108	*Don* .	Malin Head..........	5·22	128
,, .	Ullapool	5·29	99	,, .	Dunfanaghy	..	..
,, .	Achnashellach	11·47	126	,, .	Dunkineely..........	7·97	..

Climatological Table for the British Empire, May, 1939

STATIONS.	PRESSURE. Mean of Day M.S.L. mb.	PRESSURE. Diff. from Normal. mb.	TEMPERATURE. Absolute. Max. °F.	TEMPERATURE. Absolute. Min. °F.	TEMPERATURE. Mean Values. Max. °F.	TEMPERATURE. Mean Values. Min. °F.	TEMPERATURE. Mean Values. ½ Max. and Min °F.	TEMPERATURE. Mean Values. Diff. from Normal. °F.	TEMPERATURE. Mean. Wet Bulb. °F.	Relative Humidity. %	Mean Cloud Am'nt 0–10	PRECIPITATION. Am'nt. in.	PRECIPITATION. Diff. from Normal. in.	PRECIPITATION. Days.	BRIGHT SUNSHINE. Hours per day.	BRIGHT SUNSHINE. Percentage of possible.
London, Kew Obsy	1018·1	+ 2·2	74	37	61·0	45·0	53·0	− 1·5	47·1	83	6·1	1·39	− 0·33	7	6·3	40
Gibraltar	1015·0	− 1·1	77	49	66·3	56·5	61·4	− 4·1	53·6	69	3·3	0·46	—	3	11·1	79
Malta	1012·0	− 2·5	74	54	68·3	58·8	63·5	− 2·4	58·2	74	5·5	0·42	+ 0·01	6	9·3	66
St. Helena	1017·0	− 1·2	69	58	66·5	59·1	62·8	+ 0·5	59·9	89	8·5	1·68	− 1·00	14	—	—
Freetown, Sierra Leone	1011·8	+ 2·3	90	70	87·2	74·3	80·7	—	73·2	87	8·5	8·94	− 2·53	11	—	—
Lagos, Nigeria	1010·4	− 0·2	91	69	86·8	74·3	80·5	− 1·3	75·3	93	8·0	12·43	+ 1·68	15	6·3	51
Kaduna, Nigeria	1009·8	—	94	64	86·4	69·0	77·7	− 2·2	70·9	88	6·7	7·61	+ 1·84	17	6·7	53
Zomba, Nyasaland	1014·8	− 0·6	82	52	75·5	57·8	66·7	+ 0·9	62·9	80	4·2	0·14	− 0·90	2	—	—
Salisbury, Rhodesia	1018·0	− 0·3	80	42	73·2	49·0	61·1	+ 0·5	54·7	65	3·7	0·59	—	5	8·4	74
Cape Town	1018·1	0·0	85	45	71·1	52·7	61·9	+ 3·0	54·4	84	4·0	3·98	+ 0·23	9	—	—
Johannesburg	1019·0	+ 0·4	75	37	65·5	46·1	55·8	+ 1·4	46·8	58	1·7	1·75	+ 0·99	7	8·2	75
Mauritius	1017·3	+ 1·0	83	62	79·9	67·3	73·6	+ 1·0	69·6	72	4·7	1·73	− 2·19	18	8·8	79
Calcutta, Alipore Obsy	1002·1	− 1·4	104	71	97·3	80·0	88·7	+ 2·6	80·9	79	6·5	2·74	− 2·82	6*	—	—
Bombay	1007·3	− 0·1	96	76	90·5	79·1	84·8	− 1·0	76·2	70	3·0	0·00	− 0·55	0*	—	—
Madras	1003·7	− 1·7	107	77	100·2	81·8	91·0	+ 1·2	77·4	63	5·3	0·00	− 1·84	0*	—	—
Colombo, Ceylon	1008·8	+ 0·4	88	71	86·2	78·6	82·4	− 0·4	78·6	81	7·8	13·03	+ 2·09	22	7·0	56
Singapore	1008·7	0·0	89	74	86·8	76·8	81·8	− 0·2	78·1	77	7·7	2·33	− 4·31	11	6·5	54
Hongkong	1008·0	− 1·1	89	67	80·8	72·5	76·7	− 0·7	72·7	83	8·2	20·99	+ 8·92	17	4·2	32
Sandakan	1008·4	—	91	75	87·7	77·8	82·7	+ 0·2	77·5	82	8·2	3·65	− 2·68	13	—	—
Sydney, N.S.W.	1021·3	+ 2·7	78	47	69·4	54·1	61·7	+ 2·9	55·7	83	4·4	3·16	− 2·02	11	6·4	62
Melbourne	1021·6	+ 2·4	74	38	64·3	49·1	56·7	+ 2·6	51·9	80	7·3	1·98	− 0·18	16	3·5	34
Adelaide	1021·0	+ 0·8	83	44	69·5	52·4	60·9	+ 2·9	55·0	67	6·3	1·91	− 0·81	11	4·9	48
Perth, W. Australia	1017·3	− 1·1	81	42	69·4	52·2	60·8	+ 0·1	55·8	73	5·5	7·80	+ 2·83	17	5·9	57
Coolgardie	1018·5	− 0·6	86	37	69·5	49·0	59·3	+ 1·6	52·6	70	3·6	0·32	− 1·01	4	—	—
Brisbane	1020·2	+ 1·6	81	51	73·7	58·1	65·9	+ 1·3	61·1	78	4·4	1·35	− 1·46	13	6·5	60
Hobart, Tasmania	1019·8	+ 4·5	73	37	61·9	48·5	55·2	+ 4·7	49·4	75	6·3	1·50	− 0·40	10	4·8	49
Wellington, N.Z.	1021·4	+ 5·8	64	40	56·7	47·0	51·9	− 0·9	49·6	79	6·5	2·28	− 2·40	13	3·4	34
Suva, Fiji	1012·8	+ 0·1	85	68	80·4	71·6	76·0	− 0·5	72·5	87	8·3	22·88	+12·81	28	2·2	19
Apia, Samoa	1010·6	− 0·5	88	70	85·3	73·7	79·5	+ 1·1	75·8	77	5·2	2·35	− 3·72	13	8·9	77
Kingston, Jamaica	1013·4	+ 0·3	89	68	86·4	71·4	78·9	− 0·8	71·2	77	4·2	1·38	− 3·01	7	7·4	57
Grenada, W.I.	1010·5	− 2·1	89	71	84·0	75·0	79·5	− 0·2	73·0	74	6	11·72	+ 7·53	23	—	—
Toronto	1014·6	− 0·3	86	35	67·4	48·3	57·9	+ 4·1	48·8	75	5·5	1·49	− 1·30	8	8·5	58
Winnipeg	1011·9	− 1·9	94	22	67·6	43·5	55·5	+ 3·5	44·2	75	6·6	1·37	− 0·63	13	7·5	49
St. John, N.B.	1014·2	+ 0·3	69	31	56·2	39·1	47·7	0·0	42·8	75	5·7	3·35	− 0·36	12	8·2	55
Victoria, B.C.	1017·6	+ 0·9	78	42	61·9	46·7	54·3	+ 1·3	50·1	71	5·5	1·04	− 0·09	8	9·0	59

* For Indian stations a rain day is a day on which 0·1 in. or more rain has fallen.

(50094) Wt. 22/31 1375 12/39 Hw G. 377/6

THE METEOROLOGICAL MAGAZINE

M.O. 441

AIR MINISTRY : METEOROLOGICAL OFFICE

Vol. 74 JANUARY, 1940 No. 888

TERRESTRIAL MAGNETISM AND ELECTRICITY

By Sir George Simpson, F.R.S.

The National Research Council of the U.S.A. is publishing a series of monographs on the Physics of the Earth the eighth of which has just appeared*. It is a volume of 794 pages and deals with every aspect of terrestrial magnetism and atmospheric electricity in thirteen chapters each written by an acknowledged authority of whom probably the best known to British readers are J. A. Fleming (The Earth's Magnetism and Magnetic Surveys); O. H. Gish (Atmospheric Electricity), J. Bartels (Some Problems of Terrestrial Magnetism and Electricity), L. Vegard (The Aurora Polaris) and B.F.J.Schonland (Thunder-clouds, Shower-clouds, and their Electrical Effects).

It is an imposing work, but what makes the greatest impression on me is that practically everything described in this volume has been done since I became interested in terrestrial magnetism and atmospheric electricity in 1903. The great advances described in this book can all be traced back to the discovery of ionisation at the end of the last century. Until then terrestrial magnetism consisted of little more than measurements of the

* *Physics of the Earth-VIII: Terrestrial magnetism and Electricity*. Edited by J. A. Fleming, McGraw-Hill, Publishing Company, Ltd., Aldwych House, London, W.C.2.

magnetic field at all parts of the earth and its periodic and secular changes. It is true that Balfour Stewart and Schuster had come to the conclusion that the periodic oscillations could only be explained by a " conducting layer " in the upper atmosphere; but the conductivity of that layer would have to be so high that it seemed an impossibility. Now we have the ionosphere the conductivity of which has been measured and proved to be entirely sufficient to account for the currents required to produce the observed magnetic changes—the very name " ionosphere " indicates its paternity.

In atmospheric electricity it was easy to explain the earth's negative charge when ionisation was unknown. It was just the residual electric charge which remained on the earth when the earth was separated from the sun. With a perfectly insulating atmosphere this charge remained on the surface of the earth, its variation from time to time being due to part of it being carried up into the atmosphere when water evaporated from the surface and returned in the precipitation. With the coming of ionisation all that had to go; a residual charge could not remain on the surface when the atmosphere was conducting. How and why the charge does remain on the surface has been the main problem of atmospheric electricity during the last forty years and this volume describes the attempts to explain it.

The problem of the aurora is a problem of ionisation and without ionisation there would be no thunderstorms and no lightning.

Written as they are by recognised authorities each chapter brings us right up to date in the subject dealt with. It would take too much space to give the titles of the thirteen chapters and it would be invidious to mention any as of more importance than the others. Meteorologists will be most interested in the chapters on Atmospheric Electricity, by O. H. Gish and on Thunder-clouds, Shower-clouds and their Electrical Effects, by B. F. J. Schonland.

The former is a competent survey of the electrical state of the atmosphere below the ionosphere. To one who has been in the thick of the progress made in atmospheric electricity by the European nations, it is refreshing to see the treatment of the subject by one who has been equally saturated with the work done in the U.S.A. There is no neglect of the work done outside America but naturally nearly all the examples are taken from American work, and the results obtained in the upper atmosphere by *Explorer II* and at sea by the *Carnegie* receive well deserved prominence. Schonland's chapter is, as one would expect from this author, complete and accurate; but it suffers badly from compression. In my opinion the greatest advance in recent years in the domain of the thunderstorm is Schonland's explanation of the mechanism of a lightning discharge and yet his account of this work is contained in eighteen lines!

The National Research Council in publishing their monographs on geophysical subjects are performing a service for which every English speaking geophysicist will be grateful. The standard of the monographs is well sustained in the one under review and the Editor, Mr. J. A. Fleming, is to be congratulated on the team he has got together and on the success of their work.

THE RAINFALL OF 1939

Records show that during the last 22 years the rainfall of January, over the British Isles as a whole, has exceeded the average on 18 occasions; July has given more than the average in each of the last four years; while each August of the last eight years, except one, has been relatively dry. This feature of the monthly rainfall in recent years, *viz.*, a wet January and July, together with a dry August was well marked in 1939.

Over the British Isles generally May gave least rain of any month of the year, while January was the wettest month over England and Wales, and November over Scotland and Ireland. Over England and Wales, January, 1939, ranks as the wettest January probably since 1764. Over the British Isles, since records began in 1870, May, 1939, ranks as the driest May with but four exceptions; July, 1939, was the wettest July with but two exceptions; August and September, 1939, were together drier than any similar period apart from that of 1933; and November, 1939, was the wettest November apart from that of 1929. Over Scotland, July, 1939, ranks as the wettest July, and over Ireland, November, 1939, was the wettest November on record.

The following are some of the largest daily amounts recorded during the year:—

Blaenau Festiniog (Slate Q.)	Merioneth	5·08 in.	Nov. 25
Loch Quoich (Kinlochquoich)	Inverness	5·05 in.	Feb. 10
Rhondda W. W. (Llyn Fawr Res.)	Glamorgan	4·90 in.	July 6
Rhondda W. W. (Llyn Fawr Res.)	Glamorgan	4·73 in.	Nov. 25
Blandford (Bryanston School)	Dorset	4·66 in.	Aug. 20
Langdale (Middlefel)	Westmorland	4·50 in.	Nov. 25

The total at Llyn Fawr Reservoir for the four days, July 5th to 8th amounted to 10·53 in. and at Blaenau Festiniog and Middlefel for the six days, November 25th to 30th to 12·39 in. and 10·39 in. respectively.

Intense falls of rain were most frequent in 1939 during the thundery spell from July 13th to 21st, details of which are given on pp. 193–199 and pp. 238–239. At Teignmouth 2·38 in. fell in 60 minutes on July 21st. Other striking rains were those of 2·81 in. in 60 minutes at Randalstown (Hollybrook) Co. Antrim on September 3rd and of 2·47 in. in 75 minutes at Frome (Somerset) on August 21st.

There was very little rain over England and Wales from May 18th to June 9th and over Ireland from May 24th to June 9th. At Holne, near Ashburton, there was no measurable rain for the 25 days, May 16th to June 9th, and at Ravenglass, Cumberland, the total for the 45 days, April 26th to June 9th, amounted only to ·44 in. Details of the droughts and dry spells of August and September, which were most widespread in Ireland, are given on pp. 265–7.

Provisional estimates of the general rainfall for 1939 are given below, both in actual inches and as percentages of the average:—

	in.	Per cent.
England and Wales	40·3	114
Scotland	48·2	96
Ireland	43·4	100
British Isles	44·0	106

The year 1939 was therefore the fifth consecutive year with a rainfall appreciably in excess of the average, although it was not as wet as either 1935 or 1938. Over England and Wales 1939 ranks as the wettest year since 1930, over Scotland 1939 was drier than 1938 and over Ireland 1939 was drier than each of the previous three years. The main features of the distribution were the large areas in the west of Scotland to the north of the Caledonian Canal and in the west of Ireland with less than 90 per cent. and the large areas in the south-east of England with more than 120 per cent. At Ullapool (Ross-shire) there was only 73 per cent.; while more than 140 per cent. occurred at Wolverton (Bucks), over much of Suffolk and in the east of Kent.

J.G.

LETTERS TO THE EDITOR

The Effect of Strong Gales on Foliage

With regard to the article by S. E. Ashmore in the November issue of the *Meteorological Magazine* on the above subject, the following note may be of interest.

During the very high westerly winds of the late winter and early spring of 1938 extensive discoloration of foliage occurred in the district of Dorset known as the Isle of Purbeck. On one particular occasion when a high wind was unaccompanied by precipitation, salt particles were deposited on surfaces facing the wind direction and were clearly visible on windows, where deposits collected to a thickness of one-sixteenth of an inch in places.

Hawthorn leaves were discoloured to a greater degree than any other foliage, elm was also affected. The hawthorn leaves dropped off and the trees remained bare for the remainder of the year. Damage to foliage extended from the coast to a distance of approximately five miles inland.

Similar discoloration occurred in this area early in 1939 when precipitation prevented the deposition of salt in the solid state.

H. H. COUTTS.

Meteorological Office, Honington.
December 4th, 1939.

Lunar Rainbows

Since I reported the occurrence of a lunar rainbow on the Hiraethog Mountains on June 6th, 1938 (*Met. Mag.*, 73, 1938, 148), three writers have this year described districts where such occurrences are comparatively frequent; Mr. D. A. Davies on the west coast of Ireland, Mr. G. B. Davie in the Dartmoor district and Mr. T. F. Twist on the west coast of Somerset. The mountainous districts of Wales can be placed in the same category. I have observed another lunar rainbow, this time from the centre of Wrexham, on October 1st, 1939, at 19h. 17m. Only the primary bow was visible but it was so bright that it could be seen from the driving-seat of a car proceeding under black-out regulations and its brilliance attracted the attention of ordinary pedestrians. The difference of illumination of the sky within and without the bow was clearly seen. The shower causing the bow began at 19h. 15m. It was unexpected—in fact this slight shower was the only rain experienced in Wrexham from September 14th to late on October 4th. The sky was completely overcast except for a small patch surrounding the newly-risen Harvest moon, three days past full at the time. The cloud drift was so slow as to be indefinite and it was calm at the surface, but I think that this, too, was an instability shower, influenced by the close proximity of the East Denbighshire mountains. This particular rainbow lasted nearly ten minutes; the claim of North Wales to lunar rainbow frequency does not lie with the persistence of individual bows, but with the number of bows observed.

S. E. ASHMORE.

11, Percy Road, Wrexham, N. Wales.
October, 21st, 1939.

Largest Annual Total of Sunshine in Britain

A still larger annual total of sunshine than the 2,193 hours at Shanklin for 1911, cited by Capt. J. E. Cowper in the last issue of this magazine, was registered in 1899. The aggregate for that year at Worthing is given on page 64, Vol. XIX, of *The Meteorological Record,* a one-time publication of the Royal Meteorological Society, as 2,207 hours (Campbell-Stokes recorder). At Bexhill, where instruments of both the Campbell-Stokes and Jordan type were then in use, the 1899 total was 2,186 hours by the former and 2,293 hours by the latter.

Incidentally, can anyone point to a smaller annual number of sunless days at a British or Irish station than the 39 which *The Meteorological Record* gives for the year 1906 at Geldeston (Norfolk) and Kingstown (Dublin)?

E. L. HAWKE.

Ivinglea, Dagnall, Bucks.
November 23, 1939.

A Pilot Balloon Returns to its Starting Point

At 17h. G.M.T. on February 23rd, 1939, a 150-in. pilot balloon with an assumed rate of ascent of 700 feet per minute was released from one of H.M. ships lying in Palma Bay, Majorca.

Observations were abruptly curtailed by the balloon entering a layer of stratocumulus; but up to the moment of its loss to view, it had been carried to the north-eastward at a mean velocity of 45 knots.

Twenty-four hours later a balloon was observed, partly deflated, but with only a slight negative atmospheric buoyancy, resting lightly on the surface of the sea, and drifting past the ship in a westerly surface breeze. On recovery it was identified as that which had been released the previous evening. A pin-prick leak was the cause of descent.

Taking 7h. G.M.T. on February 24th as approximately the mean instant of the balloon's flight, the synoptic chart for this hour shows a depression (about 993 mbs.) centred 100 miles north-west of the ship.

There are two possible solutions to the cause for the balloon's return.

(1) It was carried anti-clockwise round the depression, getting extremely close to the centre whilst in the lower layers, and diverging again at higher altitudes, the reverse taking place on descent.

(2) It obtained its northerly and westerly travel from the cyclonic winds in the east and north sectors of the depression, and at a height of 15,000 feet or more entered the steady north-westerly stream which exists almost continually over the Mediterranean in the upper half of the troposphere. Single theodolite observations of ascents up to assumed heights of 20,000 to 25,000 feet on the previous few days during clearer weather had shown that the predominant wind was from 290°, at speeds varying with the time of day from 20 to 35 knots. Unfortunately no Spanish reports were available from which to enable the upper winds to be traced farther afield or possibly fix the position of a front.

In any case there seems little doubt that the balloon travelled at least 400 miles, and its return to the starting point was the result of an unusual and interesting combination of wind components.

P. G. SATOW.

H.M.S. "Vernon,"
Portsmouth.
October 26th, 1939.

NOTES AND NEWS

Hail Scores Fences at Farnborough, Hants.

A squally thunderstorm visited Farnborough, Hants, on November 6th, 1939, and gave 16·1 mm. of rain and hail between 9h. 30m. and 12h. 44m. G.M.T., of which 5mm. fell in 10 minutes. The thunder was first heard at 9h. 20m. and recurred at intervals till 11h. 30m. G.M.T., and heavy hail was observed at the aerodrome at 9h. 26m. About one mile further north near Farnborough Abbey the hail storm was phenomenally heavy just after 10h., the hail lying for some time in stones the size of large peas; so fierce was the fall here that all wooden fences facing the WSW wind were scored with one or more indentations per square inch and the marks were still visible on the last day of the month in spite of frequent rain during the period.

Squalls of wind from WSW reached 53 m.p.h. at 9h. 30m. and 51 m.p.h. at 12h. 40m. with a quieter period from 10h. 30m. to 10h. 44m. with a mean speed of about 7 m.p.h. Temperature fell from 56° F. at 9h. 30m. to 46° F. at 11h. 30m., the humidity rising from 70 per cent. to 95 per cent.

R. M. Poulter.

Heavy rainfall at Preston, Canterbury, October, 1939.

Mr. J. H. Dyson sends the following account of the rainfall of October from The Old Vicarage, Preston, Canterbury:—

As much as 11·49 ins. occurred in October, compared with a total for the seven months March to September of 12·38 ins. The fall of October includes 3·67 ins. of sleet, snow and hail and thunderstorm rains between 9h. on the 26th and 9h. on the 29th: almost all the precipitation occurred in polar air, the winds having blown nearly continuously from north or east since mid-September. There was nearly an inch of hail in sheltered positions throughout the 27th. Loud thunder and vivid forked lightning were experienced intermittently, the times of the active storms overhead or in the district being 2h., 7h. 9h., 17h.-23h. at intervals, 23h. 15 m. on the 27th and intermittently until about 2h. on the 28th. This sequence of thunderstorms in polar air was remarkable and all the more interesting in view of the almost complete absence of thunderstorms during the past summer.

Heavy rainfall at Shanklin, October and November, 1939.*

The rainfall at Shanklin (Pomona Road), Isle of Wight, During October and November has been remarkably high. During October 9·49 ins. fell on 19 days, on four or more of which 1 in. or more was recorded. On the 4th there was 1·00 in., 1·12 ins. on the 8th, 1·12 ins. on the 11th and 1·85 ins. on the 13th. During November, 12·54 ins. was recorded on 26 days, of which 1·08 ins. fell on the 6th, 1·38 ins. on the 9th, 1·26 ins. on the 18th and 1·52 ins. on the 23rd.

The previous greatest monthly total since 1906, when the records were commenced, was 11·33 ins. in December, 1934. During November and December, 1934, 15·96 ins. were recorded which was until now the greatest total for two consecutive months. In October and November, 22·03 ins. was the total rainfall. Never before have 4 days in any one month given as much as 1 in. in 24 hours.

At Sandown, the totals were considerably less. The total for October was 7·83 ins. with 1·21 ins. on the 11th and 1·46 ins. on the 13th; for November it was 7·67 ins. and on no day was as much as 1 in. recorded.

Dissipation of Cloud by Aircraft at West Freugh, Stranraer.

At 10h. 15m. G.M.T., on July 18th, 1939, a sheet of stratocumulus at approximately 6,000 feet was spreading across the sky from WSW and had become 5/10, while there was 3/10 cumulus beneath with base at 2,500 feet and tops almost reaching the stratocumulus.

* Based on details supplied by Capt. J. E. Cowper.

The stratocumulus was very thin at the eastern edge and an aircraft flying through it produced clear "lanes" of approximately the width of the wing-span of the machine. The dissipation did not appear immediately behind the aircraft, there being a lag of 3 or 4 seconds between its passage and the formation of the "lane" at any point. The "lanes" had clearly defined edges and persisted for about two minutes. The height of the cloud layer at 12h. G.M.T., was found by pilot balloon to be 5,500 feet.

B. V. BISHOP.

Auroral Notes for October, 1939

In the course of autumn 1939, aurora has been seen several times as far south as Foynes, and during the first three weeks of October it was exceptionally frequent at Lerwick, being observed there on sixteen out of the first twenty nights. Two displays were outstanding, namely, those of October 3rd and October 13th.

The following extracts from notes contributed by Mr. F. E. Dixon relating to observations made by himself and Mr. H. H. Lamb at Foynes on October 3rd and 13th are of interest.

> " On 3rd a diffuse arc was observed at 20h. G.M.T. and shortly afterwards rays reached 55° elevation. There was little activity during the next 1½ hours but the arc persisted with some fluctuations in intensity. Fading always occurred first at the western end of the arc and spread slowly eastwards but the subsequent reappearance was always simultaneous along the whole arc.
>
> At 21h. 41m. when the arc was faint, a brilliant patch of blood-red glow appeared suddenly in the western sky and white rays shot up from between W and NW, some piercing the glow. Red rays also appeared during the next few minutes, and by 21h. 50m. the arc had again become distinct, now in the form of a rayed band.
>
> The red glow in the W and another patch in the NW continued with varying intensity until 22h., but faded finally in the next few minutes. At 22h. 05m. there was only a faint rayed band present and by 22h. 15m. this had dwindled to a single faint patch of glow to the NW. Nothing was seen after 22h. 30m., but a wireless fadeout lasted from about 22h. until the afternoon of October 4th.
>
> On 13th aurora was first seen at 19h. G.M.T. before the twilight glow had disappeared. The sequence of auroral types

was that normally experienced in active displays. At first the only active features were rays to 50° elevation. Multiple arcs then developed and moved S, the principal arc degenerating into a rayed band, and the others fluctuating in intensity. Rays several times passed the zenith and a partial corona formed momentarily about six times between 22h. 25m. and 22h. 45m. During this phase flame aurora also occurred, the flickering being most obvious at the base of the rayed band.

The arc retreated slowly northward after 22h. 45m. and activity diminished. By 22h. 30m. only a faint glow was present and observations were discontinued.

The predominant colour was green throughout but there were considerable patches of red glow to NE and W, and at times the upper parts of rays were of the same tinge. Pale yellow colouration also appeared, especially in the NE.

Other auroral displays occurred on August 11th, 12th and 22nd, September 4th and 17th, October 6th, 15th 16th and 17th most of them comprising only glow.

On nearly every occasion wireless communication with America was interrupted, but there were both fadeouts without aurora and aurora without fadeouts."

Mr. Seton Gordon of Upper Duntuilm, Skye, describes the display of October 3rd as "strange and magnificent." The sky was dusky red in colour low in the west horizon, between Vaternish Point and North Uist. Right overhead at the zenith a whorl of light resembling a giant nebula throbbed and glowed, and here at times the light was deep pink or crimson, waxing and waning in intensity. North, high above the Harris hills, were bright primrose-coloured rays of a greenish tinge, appearing and disappearing in isolated clusters. The whole of the heavens from horizon to horizon seemed to be in motion and the light of the moon failed to diminish the grandeur of this spectacle.

Other reports in less detail were received from Strathy, Wick, Gordon Castle, Aberdeen, Nairn, Leuchars, Paisley, Edinburgh, West Linton, St. Abbs Head and Eskdalemuir.

H. E. C.

PROFESSOR DR. E. G. MARIOLOPOULOS, has been appointed Professor of Meteorology, and Director of the Meteorological Institute in the University of Athens. The formation of the new Institute will be welcomed by all interested in meteorological science.

New Climatological Stations in Scotland.

Through the interest of Mr. J. P. Greig, Convenor of Largo Parish Community Council, a " Health Resort Station " has been set up at Lundin Links, Fife, on the north shore of the Firth of Forth. The observations are being made by Mr. J. D. Ross, M.P.S.

At Newton Stewart, Dumfries-shire, a climatological station has been started by Mr. H. W. Geddie, M.A., the Rector of Douglas-Ewart High School. Observations are under the supervision of Mr. J. C. Frame, the Science Master.

Another new school station is that at Gordonstoun, Elgin, where Mr. F. Spencer Chapman, one of the masters, was responsible for installing the instruments.

An old established climatological station in the Royal Botanic Garden, Edinburgh, has recently been brought up to date by the installation of modern equipment. Through the courtesy of Professor Sir Wm. Wright-Smith, monthly climatological registers are now regularly received in the Meteorological Office, Edinburgh.

Royal Meteorological Society, Symons Gold Medal, 1940

The Council of the Royal Meteorological Society has awarded the Symons Gold Medal for 1940 to Prof. Dr. J. Bjerknes of the Geofysiske Institutt, Bergen. The medal is awarded biennially for distinguished work in connection with meteorological science.

The award to Dr. J. Bjerknes will be very popular among British meteorologists, to whom he has become well known during his frequent visits to this country. In 1932 the Medal was awarded to his father, Prof. V. Bjerknes, and it is fitting that the son, who shared the work, should also share the honours. Dr. J. Bjerknes is well known for his numerous and penetrating memoirs on the structure of barometric depressions and on the mechanism of the atmospheric circulation. J. Bjerknes is still young and we look forward to further important research in future from him and his colleagues.

A Ground Fog, August 27th, 1938.

The photograph reproduced opposite is contributed by Mr. T. N. S. Harrower. He remarks that the fog filled the valley of the River Isla, Banffshire. The point of observation was 500 feet above M.S.L. and eight miles distant from the ridge seen on the left. The photograph was taken at 5h. G.M.T. on August 27th, 1938.

Early records of winter thunderstorms (1149, 1258, 1283, and 1791).

Thunderstorms in the winter months have, until recent times, been regarded as irrational and portentous. Everisden writing of the heavy thunderstorm of 26th December, 1283, says that " those who beheld and heard it were struck with exceeding terror and alarm ". Matthew Paris in his account of a heavy storm on 1st December, 1258, adds " in sad presage to all who heard it, thunder in winter always signifying some evil." Even as late as 1791 Richard Brothers (God Almighty's Nephew) quoted the unusually heavy thunder in January of that year as being the voice of the angel mentioned in the 18th chapter of the Book of Revelation proclaiming the Divine judgment upon London. A notable instance of a January thunderstorm is recorded in the Chronicon Scotorum as having happened at Clonmacnoise, Ireland, in 1149. These annals state " Thunder and lightning came in January and the lightning took effect upon the yew tree of Ciaran...........and it killed 113 sheep under the yew." Probably the casualties are exaggerated. This yew tree was reputed to be over 600 years old at the time of the accident. There are many instances of thunderstorms in January to be found in the Chronicles.

C. E. BRITTON.

GROUND FOG IN THE VALLEY OF THE RIVER ISLA, BANFFSHIRE, AUGUST 27TH, 1938

Sunshine, December, 1939

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

	Total hrs.	Diff. from average hrs.		Total hrs.	Diff. from average hrs.
Stornoway	19	−3	Chester	33	−8
Aberdeen	20	−17	Ross-on-Wye	49	+1
Dublin	25	−21	Falmouth	57	+4
Birr Castle	22	−21	Gorleston	..	..
Valentia	66	+26	Kew	35	−2

Kew temp., mean, 38·3° F. diff. from average −3·1° F.

General Rainfall, December, 1939

	Per cent.
England and Wales	63
Scotland	58
Ireland	72
British Isles	63

REVIEW

Air Temperature and Humidity Data at Mauritius from observations taken at the Royal Alfred Observatory, 1876–1935, by M. Herchenroder. The Royal Alfred Observatory, Mauritius, Misc. Pub. No. 21, Port Louis, 1938.

The discussion of temperature is based on records obtained during the period 1876 to 1935 at the observatory at Pamplemousses, but some reference is also made to an older series of records between 1852 and 1870 at Port Louis; while the discussion of humidity is based on continuous photographic records of dry and wet bulb temperatures during the period 1891 to 1935. The results are carefully set out in numerous tables and graphs and the text occupies 46 pages.

Between 1875 and 1903 dry and wet bulb thermometers were exposed between two open windows in a lofty room in the main building of the observatory. This exposure was regarded as the standard until 1891. Simultaneous observations during a period of 13 years show that the lofty room was sometimes slightly warmer and sometimes slightly cooler than the thermograph screen, varying according to the time of year and strength of the wind. The exposure of the thermograph screen (Kew photographic thermograph) differs from the conventional exposure of the Stevenson screen owing to the presence of the neighbouring buildings; but the differences between the two screens are revealed by another comparison of simultaneous readings. The author says that while the maxima of temperature in the tropics are probably greater in a Stevenson screen than they would be in an ideal exposure the minima do not appear to be affected likewise. We may mention in this connection that Field decided in 1920, as a result of his experiments in India, that the temperature in the Stevenson screen was only affected appreciably if the air entered the screen on the side warmed by the sun.

A secular change is exhibited in the elements which have been examined at Mauritius, and it takes the form of a steady and prolonged decrease which begins about the year 1905 in the case of pressure, wind speed and temperature and some eight years earlier in rainfall.

J. WADSWORTH.

OBITUARY

M. T. REES. We regret to announce the death on November 17th, 1939, of Mr. M. T. Rees, B.Sc., Technical Officer in the Meteorological Office, from injuries received in a cycle accident.

Mr. Rees, who at the time of his death was only 24 years of age, joined the staff of the Meteorological Office in July, 1938. He was in charge of the station at Penrhos from February to the latter end of August, 1939, when he was transferred to the forecasting staff at Coastal Command Headquarters, Royal Air Force. Although his meteorological experience was comparatively brief it had, nevertheless, been sufficient to show in him qualities of initiative and resource which, added to his unquestionable scientific ability, gave every expectation of a highly successful career as a meteorologist. His unvarying good humour and engaging manner made him extremely popular with his professional colleagues and the personnel of the flying services alike, and his tragic death is a great loss to the department.

R. E. MONTGOMERY. Mr. Montgomery, who was born in May, 1908, was appointed to a post on the Geological Survey in 1934, upon passing the prescribed examinations. He joined the staff of the Edinburgh office and in 1937 he was transferred to the London office in Exhibition Road, South Kensington. He joined the Meteorological Section of the R.A.F.V.R. as an airman in August, 1939 and was called up on general mobilization. He was one of the unfortunate victims of the railway accident at Bletchley on 13th October, 1939.

G. F. REEVE. Mr. Reeve was born in November, 1899. He was educated at Manchester Grammar School and qualified as a Chartered Accountant. During the last war he saw active service in the Mercantile Marine as a navigating officer. He joined the Meteorological Section of the R.A.F.V.R. as an airman in August, 1939 and passed through the Training School in London. He was posted to a R.A.F. Station for further training and died there very suddenly on the 10th November, 1939.

CORRIGENDA

Mr. H. Arakawa forwards the following correction to his letter, "Height Calculation from the Emagram" in the issue for May, 1939, pp. 111–112.

Page 112, line 16, *for* "on the tephigram" *read* "on the emagram."

Mr. W. D. Flower forwards the following correction to his note, "A constant level water apparatus for wet bulb hygrometers" in the issue for Sept.–Oct., 1939, pp. 242–244.

Page 242, line 29, *for* "two" *read* "four."

Rainfall: December, 1939: England and Wales

Co.	Station.	In.	Per cent of Av.	Co.	Station.	In.	Per cent of Av.
Lond'n	Camden Square......	·93	39	*Warw*	Birminghm, Edgbaston	1·66	68
Surrey	Reigate, Wray Pk. Rd.	1·85	58	*Leics* .	Thornton Reservoir...	1·61	60
Kent .	Tenterden, Ashenden.	1·56	50	,, .	Belvoir Castle........	1·35	55
,, .	Folkestone, I. Hospital	1·32	..	*Rutl'd*	Ridlington	..	..
,, .	Margate, Cliftonville..	·83	36	*Lincs*.	Boston, Skirbeck.....	2·20	102
,, .	Edenb'dg.,Falconhurst	1·94	59	,, .	Cranwell Aerodrome..	1·64	74
Sussex	Compton, Compton Ho	2·91	69	,, .	Skegness, Marine Gdns	..	..
,, .	Patching Farm.......	2·20	65	,, .	Louth, Westgate.....	2·86	103
,, .	Eastbourne, Wil. Sq..	1·87	54	,, .	Brigg, Wrawby St....	2·25	...
Hants.	Ventnor, Roy.Nat.Hos.	1·70	52	*Notts* .	Mansfield, Carr Bank..	1·74	60
,, .	Southampton, East Pk	1·84	50	*Derby*.	Derby, The Arboretum	..	..
,, .	Ovington Rectory....	2·13	54	,, .	Buxton, Terrace Slopes	3·19	56
,, .	Sherborne St. John...	1·37	42	*Ches* .	Bidston Obsy........	2·31	87
Herts .	Royston, Therfield Rec	1·09	47	*Lancs*.	Manchester, Whit. Pk.	2·99	92
Bucks.	Slough, Upton.......	1·08	43	,, .	Stonyhurst College...	3·67	75
Oxford	Oxford, Radcliffe.....	1·42	58	,, .	Southport, Bedford Pk	3·09	96
N'hant	Wellingboro,Swanspool	2·16	92	,, .	Ulverston, Poaka Beck	2·68	49
,, .	Oundle	..	..	,, .	Morecambe..........	2·47	63
Beds .	Woburn, Exptl. Farm.	1·91	82	,, .	Blackpool...........	2·46	75
Cambs	Cambridge, Bot. Gdns.	1·09	56	*Yorks*.	Wath-upon-Dearne...	1·37	58
,, .	March	..	..	,, .	Wakefield,Clarence Pk.	1·54	63
Essex.	Chelmsford,CountyGns	1·00	45	,, .	Oughtershaw Hall....	4·47	..
,, .	Lexden Hill House....	1·17	..	,, .	Harrog'te,HarlowMoor	2·11	70
Suff .	Haughley House.....	·93	..	,, .	Hull, Pearson Park...	2·04	85
,, .	Campsea Ashe, HighHo	1·35	59	,, .	Holme-on-Spalding...	1·78	72
,, .	Lowestoft Sec. School.	2·22	95	,, .	Felixkirk, Mt. St. John	1·93	80
,, .	Bury St. Ed.,WestleyH	1·48	61	,, .	York, Museum.......	1·58	71
Norf..	Wells, Holkham Hall.	2·03	99	,, .	Pickering, Houndgate.	..	..
Wilts .	Porton, W.D. Exp'lStn	1·58	50	,, .	Scarborough.........	2·38	100
,, .	Bishops Cannings	2·23	68	,, .	Middlesbrough.......	1·10	57
Dorset	Weymouth, Westham.	..	..	,, .	Baldersdale, Hury Res.	1·38	37
,, .	Beaminster, East St ..	2·77	58	*Durhm*	Ushaw College.......	1·16	46
,, .	Shaftesbury	1·93	..	*Norl'd*	Newcastle, Leazes Pk.	1·47	63
Devon.	Plymouth, The Hoe...	3·05	61	,, .	Bellingham, Highgreen	1·28	35
,, .	Holne, Church Pk.Cott	5·19	61	,, .	Lilburn Tower Gdns..	1·86	71
,, .	Teignmouth, Den Gdns	1·57	37	*Cumb*.	Carlisle, Scaleby Hall.	1·21	38
,, .	Cullompton	2·55	58	,, .	Borrowdale,Seathwaite	5·00	32
,, .	Sidmouth, U.D.C.....	1·45	..	,, .	Thirlmere,DaleHeadH.	..	..
,, .	Barnstaple,N. Dev.Ath	2·59	58	,, .	Keswick, High Hill...	2·68	40
,, .	Dartm'r,Cranmere P'l	5·95	..	,, .	Ravenglass, The Grove	1·71	37
,, .	Okehampton, Uplands.	4·09	58	*West* .	Appleby, Castle Bank.	1·72	43
Cornw	Bude, School House ..	..	..	*Mon* .	Abergavenny, Larchf'd	1·84	41
,, .	Penzance,Morrab Gdns	3·03	53	*Glam* .	Ystalyfera, Wern Ho..	4·59	55
,, .	St. Austell, Trevarna..	3·72	61	,, .	Treherbert, Tynywaun	..	..
Soms .	Chewton Mendip.....	3·81	71	,, .	Cardiff, Penylan......	2·72	54
,, .	Long Ashton	2·34	61	*Carm* .	Carmarthen,M.&P.Sc.	4·19	70
,, .	Street, Millfield	1·78	54	*Card* .	Aberystwyth	3·61	..
Glostr.	Blockley	2·00	..	*Radn'r*	Bir. W. W. Tyrmynydd	..	..
,, .	Cirencester, Gwynfa ..	2·47	74	*Mont* .	Lake Vyrnwy........	..	..
Here .	Ross-on-Wye	1·44	48	*Flint* .	Sealand Aerodrome...	1·77	72
,, .	Kington, Lynhales....	1·80	48	*Mer* .	Blaenau Festiniog....	12·39	107
Salop.	Church Stretton......	2·29	..	,, .	Dolgelley, Bontddu...	5·68	83
,, .	Shifnal, Hatton Grange	..	..	*Carn* .	Llandudno	2·66	92
,, .	Cheswardine Hall	2·06	73	,, .	Snowdon, L. Llydaw 9	15·90	..
Worc .	Malvern, Free Library.	1·75	63	*Angl* .	Holyhead, Salt Island.	2·47	59
,, .	Ombersley, Holt Lock.	..	..	,, .	Lligwy.............	3·47	..
Warw	Alcester, Ragley Hall.	1·68	68	*I.Man*	Douglas, Boro' Cem...	4·72	96

Rainfall: December, 1939: Scotland and Ireland

Co.	Station.	In.	Per cent of Av.	Co.	Station.	In.	Per cent of Av.
Guern .	St.PeterP't.GrangeRd.	2·99	73	*R&C* .	Stornoway, C.G.Stn...	2·97	50
Wig .	Pt. William, Monreith.	2·43	53	*Suth* .	Lairg...............	3·11	77
,, .	New Luce School.....	4·65	84	,, .	Skerray Borgie.......	4·34	..
Kirk .	Dalry, Glendarroch...	2·91	41	,, .	Melvich.............	4·64	108
Dumf.	Eskdalemuir Obs.....	3·09	44	,, .	Loch More, Achfary..	6·21	67
Roxb .	Hawick, Wolfelee	1·40	33	*Caith* .	Wick...............	3·35	109
,, .	Kelso, Broomlands....	·89	38	*Orkney*	Deerness............	..	..
Peebs .	Stobo Castle.........	1·60	42	*Shet* .	Lerwick Observatory.	2·47	51
Berw .	Marchmont House....	1·06	38	*Cork* .	Cork, University Coll.	2·89	56
E.Lot.	North Berwick Res...	·78	36	,, .	Roches Point, C.G.Stn.	3·38	63
Midl .	Edinburgh, Blackfd. H	·88	38	,, .	Mallow, Hazlewood ..	2·83	..
Lanark	Auchtyfardle	1·98	..	*Kerry*.	Valentia Observatory.	4·43	67
Ayr .	Kilmarnock, Kay Park	2·92	..	,, .	Gearhameen.........	9·50	76
,, .	Girvan, Pinmore	3·45	41	,, .	Bally McElligott Rec.	3·24	..
,, .	Glen Afton, Ayr San..	3·38	53	,, .	Darrynane Abbey....	3·20	54
Renf .	Glasgow, Queen's Park	2·46	58	*Wat* .	Waterford, Gortmore.	2·75	60
,, .	Greenock, Prospect H.	3·06	41	*Tip* .	Nenagh, Castle Lough.	3·31	72
Bute .	Rothesay, Ardencraig.	3·46	63	,, .	Cashel, Ballinamona..	3·22	75
,,	Dougarie Lodge......	3·63	66	*Lim* .	Foynes, Coolnanes....	2·82	59
Argyll	Loch Sunart, G'dale..	5·62	65	,, .	Limerick, Mulgrave St.	..	..
,,	Ardgour House	5·10	..	*Clare* .	Inagh, Mount Callan..	4·86	..
,,	Glen Etive	3·05	25	*Wexf* .	Gorey, Courtown Ho..	2·81	74
,,	Oban...............	3·70	..	*Wick* .	Rathnew, Clonmannon	2·43	..
,,	Poltalloch..........	4·06	64	,, .	Blessington Rectory..	..	..
,,	Inveraray Castle	4·96	50	*Carlow*	Bagnalstown FenaghH	2·74	73
,,	Islay, Eallabus	5·30	89	,, .	Hacketstown Rectory.	2·85	69
,,	Mull, Benmore.......	..	..	*Leix* .	Blandsfort House	2·75	75
,,	Tiree	3·93	75	*Offaly*.	Birr Castle	2·22	67
Kinr .	Loch Leven Sluice....	1·51	38	*Dublin*	Dublin, Phoenix Park.	2·01	79
Fife .	Leuchars Aerodrome..	·82	33	*Meath*.	Kells, Headfort......	3·20	84
Perth .	Loch Dhu	5·30	53	*W.M* .	Moate, Coolatore.....	2·39	..
,, .	Crieff, Strathearn Hyd.	2·60	58	,, .	Mullingar, Belvedere..	3·12	85
,, .	Blair Castle Gardens..	1·97	52	*Long* .	Castle Forbes Gdns ..	3·09	78
Angus.	Kettins School.......	1·76	53	*Galway*	Galway, Grammar Sch.	3·01	66
,, .	Pearsie House	2·65	..	,, .	Ballynahinch Castle ..	5·11	68
,, .	Montrose, Sunnyside..	1·14	41	,, .	Ahascragh, Clonbrock.	2·87	61
Aberd.	Balmoral Castle Gdns.	1·56	46	*Rosc* .	Strokestown, C'node..	3·01	80
,, .	Logie Coldstone Sch ..	..	..	*Mayo*.	Blacksod Point	3·77	62
,, .	Aberdeen Observatory.	1·65	51	,, .	Mallaranny..........	6·31	..
,, .	New Deer SchoolHouse	2·58	75	,, .	Westport House......	3·83	67
Moray	Gordon Castle	2·92	109	,, .	Delphi Lodge........	7·34	60
,, .	Grantown-on-Spey ...	2·09	77	*Sligo* .	Markree Castle.......	4·57	97
Nairn.	Nairn..............	1·93	87	*Cavan*.	Crossdoney, Kevit Cas.	3·61	..
Inv's .	Ben Alder Lodge.....	..	..	*Ferm* .	Crom Castle	3·66	88
,, .	Kingussie, The Birches	1·75	..	*Arm'h*	Armagh Obsy........	2·35	75
,, .	Loch Ness, Foyers....	2·00	45	*Down*.	Fofanny Reservoir ...	5·79	..
,, .	Inverness, Culduthel R	1·91	71	,, .	Seaforde	2·13	52
,, .	Loch Quoich, Loan...	7·41	..	,, .	Donaghadee, C. G. Stn.	2·99	94
,, .	Glenquoich..........	8·15	56	*Antrim*	Belfast,Queen's Univ .	2·60	71
,, .	Arisaig House	3·94	54	,, .	Aldergrove Aerodrome	3·04	89
,, .	Glenleven, Corrour ...	4·50	49	,, .	Ballymena, Harryville.	3·67	83
,, .	Ft. William, Glasdrum	3·50	..	*Lon* .	Garvagh, Moneydig...	3·77	..
,, .	Skye, Dunvegan	4·19	..	,, .	Londonderry, Creggan.	3·94	90
,, .	Barra, Skallary	3·80	..	*Tyrone*	Omagh, Edenfel......	3·65	86
R&C.	Tain, Ardlarach......	2·62	84	*Don* .	Malin Head..........	2·97	72
,, .	Ullapool	2·72	43	,, .	Dunfanaghy	3·17	70
,, .	Achnashellach	3·70	37	,, .	Dunkineely..........	3·27	..

Climatological Table for the British Empire, June, 1939

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	1016·8	+ 0·1	85	44	66·6	51·6	59·1	+ 0·1	52·2	76	6·3	1·15	− 1·00	9	7·3	45
Gibraltar	1016·2	− 1·1	83	56	72·7	60·9	66·8	− 3·7	59·9	80	2·8	0·69	—	4	10·8	75
Malta	1014·2	− 1·0	91	58	77·1	65·1	71·1	− 1·6	63·6	69	2·0	0·00	− 0·09	0	12·4	86
St. Helena	1018·3	− 1·7	74	54	66·9	57·4	62·1	+ 2·3	59·0	81	6·4	1·38	− 1·44	11	—	—
Freetown, Sierra Leone	1012·9	+ 2·6	90	69	87·3	73·0	80·1	—	73·2	89	8·4	13·95	− 6·09	22	—	—
Lagos, Nigeria	1012·3	− 0·1	88	69	84·0	72·0	78·0	− 1·5	73·3	93	8·1	15·73	− 2·75	18	5·8	47
Kaduna, Nigeria	1011·5	—	91	61	85·0	66·8	75·9	− 0·8	69·8	89	5·7	8·98	+ 1·89	20	7·7	61
Zomba, Nyasaland	1018·8	+ 1·1	75	51	69·8	54·0	61·9	− 1·0	57·5	82	7·0	1·14	+ 0·66	8	—	—
Salisbury, Rhodesia	1022·5	+ 0·3	73	38	65·8	43·2	54·5	− 2·4	48·7	69	3·4	0·18	—	6	7·9	71
Cape Town	1021·2	+ 1·1	83	35	71·8	48·3	60·1	+ 4·4	50·9	82	4·6	1·94	− 2·56	8	—	—
Johannesburg	1023·9	+ 1·7	67	36	60·6	41·6	51·1	+ 0·4	41·6	53	0·8	0·00	− 0·14	0	9·0	86
Mauritius	1019·1	+ 0·3	79	56	75·9	62·1	69·0	− 0·4	66·0	71	5·1	3·58	+ 1·17	14	7·1	65
Calcutta, Alipore Obsy.	999·4	− 0·3	103	74	93·4	79·7	86·5	+ 1·4	81·0	85	8·6	15·20	+ 3·29	12*	—	—
Bombay	1004·6	+ 0·6	94	75	89·7	79·8	84·7	+ 0·7	78·5	79	6·5	4·67	−15·20	10*	—	—
Madras	1003·9	+ 0·1	110	77	100·1	81·9	91·0	+ 1·0	74·7	53	6·1	1·05	− 0·92	3*	—	—
Colombo, Ceylon	1010·0	+ 1·4	88	73	85·2	77·6	81·4	− 0·2	77·9	82	8·2	6·25	− 1·07	22	5·5	44
Singapore	1009·2	+ 0·3	89	72	85·8	76·3	81·1	− 0·4	77·4	77	6·8	5·67	− 1·20	15	5·8	48
Hongkong	1006·5	+ 0·7	89	71	85·7	78·2	81·9	+ 0·5	77·7	84	8·3	8·65	− 7·05	20	4·5	33
Sandakan	1009·2	—	90	75	87·6	77·1	82·3	+ 0·6	76·8	83	7·7	5·32	− 2·18	12	—	—
Sydney, N.S.W.	1013·6	− 4·3	70	42	64·4	48·7	56·5	+ 1·8	49·3	69	4·2	0·72	− 4·02	5	6·3	64
Melbourne	1012·9	− 5·6	62	38	58·0	44·4	51·2	+ 0·8	47·1	82	7·8	3·09	+ 1·03	15	2·5	26
Adelaide	1014·9	− 4·5	67	42	62·3	47·8	55·1	+ 1·5	51·1	83	7·3	4·25	+ 1·17	17	4·2	43
Perth, W. Australia	1015·1	− 2·9	71	44	64·7	49·1	56·9	+ 0·1	52·1	77	5·7	11·15	+ 4·21	18	5·2	52
Coolgardie	1017·1	− 2·8	73	34	62·4	42·5	52·5	− 0·3	48·0	81	4·3	1·32	+ 0·06	6	—	—
Brisbane			76	43	69·3	51·6	60·5	+ 0·3	54·2	71	3·6	2·44	− 0·35	5	7·0	67
Hobart, Tasmania	1008·4	− 5·9	61	35	54·2	42·9	48·5	+ 1·5	43·8	77	6·8	4·05	+ 1·82	16	3·9	43
Wellington, N.Z.	1010·2	− 4·7	63	38	56·1	45·5	50·8	+ 1·3	47·9	81	7·0	3·42	− 1·35	14	3·5	38
Suva, Fiji	1014·9	+ 1·3	86	64	79·6	68·8	74·2	− 0·5	68·6	80	5·1	2·07	− 4·64	17	5·2	47
Apia, Samoa	1011·6	0·0	89	67	84·6	72·5	78·5	+ 0·7	73·4	74	3·4	1·57	− 3·78	7	9·1	81
Kingston, Jamaica	1014·2	+ 0·4	93	71	88·1	73·6	80·9	− 0·4	72·6	76	3·6	1·61	− 2·49	9	7·4	56
Grenada, W.I.	1010·8	− 2·5	89	70	87·0	74·0	80·5	+ 1·5	74·0	79	7·0	10·13	+ 1·88	22	—	—
Toronto	1014·7	0·0	89	47	74·1	56·9	65·5	+ 1·7	56·8	76	6·1	1·91	− 0·75	10	8·4	56
Winnipeg	1011·6	− 0·2	86	37	69·7	48·4	59·1	− 3·2	50·7	85	6·3	2·49	− 0·62	12	7·4	45
St. John, N.B.	1014·7	+ 1·2	83	42	65·9	48·0	56·9	+ 0·4	51·3	76	5·1	3·89	+ 0·62	16	8·5	54
Victoria, B.C.	1017·2	+ 0·4	70	44	61·8	49·1	55·5	− 1·5	52·1	83	6·6	1·23	+ 0·39	11	7·3	46

(50384) Wt. 22/31 1,250 1/40 Hw. G. 377/6