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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 ($7 x 10^{15}$), 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).

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* 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.

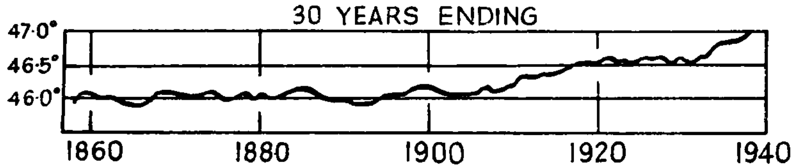

FIG. 1.—THE MARCH OF TEMPERATURE IN WEST EUROPE 1830–1938.

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.

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(2) Chamberlain, J. C. *Chicago, J. Geol.* 6, 1898.
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(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

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* 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?

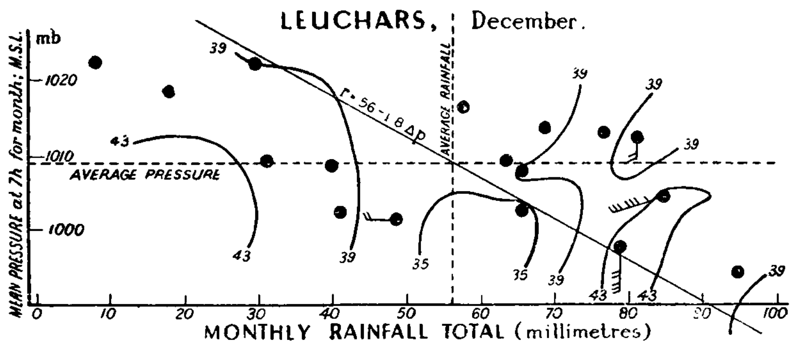

FIG. 1

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 $r = 49 - 3 \triangle p$, and " least square " methods give $r = 56 - 1{\cdot}8 \triangle p$. 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 ½ (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.	Absolute. Min. °F.	Mean Values. Max. °F.	Mean Values. Min. °F.	Mean Values. ½ Max. and Min. °F.	Mean Values. Diff. from Normal. °F.	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

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