M.O. 313.

The Meteorological Magazine

Air Ministry :: Meteorological Office

Vol. 64

April 1929

No. 759

LONDON: PUBLISHED BY HIS MAJESTY'S STATIONERY OFFICE

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The maximum Heights which it is possible to reach by Sounding or Pilot Balloons

By L. H. G. Dines, M.A.

Very few authentic records of the temperature of the upper air claim to penetrate to heights much over 22 kilometres, and in view of the great interest which attaches to the conditions at still higher levels the question is sometimes asked why this limit exists. The height to which a free balloon can rise is limited by definite physical conditions, and the main elements of the problem are all known reasonably accurately. The aim of this note is to set them out in such a manner that the probable maximum height attainable under given conditions can be readily determined.

The following table is based on the average conditions of temperature and pressure over the British Isles. As we do not know the mean temperature at heights above 22km. it is necessary to make some assumptions. Accordingly, a constant temperature has been assumed between 20 and 30km., a steadily rising temperature between 30 and 40km., and a constant temperature of 280a. above 40km.

Balloons may be of two kinds; (1) Those made with a thin inextensible envelope, either from which the gas escapes as it expands, or which is sealed up with just sufficient gas enclosed to give the requisite vertical velocity. (2) Those made of sheet rubber, which is capable of very considerable extension before

(83756) P. S. 1602/81. 1,000 4/29 M. & S. Gp. 303.

it ruptures. In the latter case the balloon is always sealed up, and apart from leakage the mass of contained gas remains constant.

Height above Mean Sea Level	Mean pressure in millibars P.	Mean temperature, absolute T.	Mean ratio P/T.	Relative diameter of spherical balloon	Lift of the hydrogen contained in the balloon	
					Lbs. per cu. ft.	Grammes per cu. metre
km.						
0	1014	283	3·58	1·00	·072	1160
10	261	222	1·18	1·45	·024	383
20	55	220	0·250	2·43	·0051	81
25	25	220	0·114	3·15	·0023	37
30	11·6	220	0·0527	4·08	·00107	17
35	5·61	250	0·0224	5·42	·00045	7·2
40	2·95	280	0·0105	6·99	·000212	3·40
45	1·60	280	0·00571	8·56	·000115	1·85
50	0·87	280	0·00311	10·47	·000063	1·01

In the case of inextensible balloons from which surplus gas can escape the limiting height is determined by the condition that the weight of the envelope and attached apparatus shall be equal to the lift of the included gas. Suppose, for example, that a balloon of 1,000cu. ft. capacity weighs 4lbs., it is seen by interpolation from column 6 of the table that it would just float at a height of about 22km., and under average conditions could rise no higher. In practice it is essential that the balloon be made to burst, and therefore it must be sealed up. Suppose then that it be sealed up with enough hydrogen enclosed to give a free lift of 1lb., the total lift of the gas is then 5lbs., and from column 6 it will be seen that at 20km. the balloon will reach its full capacity of 1,000cu. ft. and will burst. Suppose, again, that a balloon be made of the same material but twice the diameter. Its capacity will be 8,000cu. ft., and weight 16lbs. By interpolation from column 6 it is seen that 8,000cu. ft. of hydrogen will lift 16lbs. at a height of about 26km., and this represents the absolute limit under average conditions. It is clear that only by employing very large balloons made of very light material can heights appreciably greater than 20km. be reached by this means.

In the second case of rubber balloons the limiting factor is the extent to which the rubber envelope will stretch before rupture. The writer has tested many small samples cut from rubber balloons, and has found that the best specimens will stretch before rupture until their superficial area is about 55 times as

Extract from letter received from
Mr. L.H.G.Dines by Dr. Scrase,
19.7.40.

.... In the last paragraph of p.59 I have clearly erred as you suggest. I make the correct figures to be as follows.

Diameter at surface 2.12 m instead of 2.38.
Initial stretch 1.165 " 1.31.
Height at which stretch is 5....
30.9Km. instead of 28½.

great as it was originally. In the case of a spherical balloon of uniform quality this means that if its unstretched diameter is 1 metre it will expand to 7½ metres before bursting. A great deal of information is available from the data of balloon soundings, in which the density of the surrounding air at the instant of bursting was known, and though many different makes of balloon have been used none have been found capable of expanding to more than about 5½ diameters in actual flight. The majority burst much sooner, at about 4 diameters more or less.

The specific gravity of rubber is about 0·92, and from the known densities of air and hydrogen the following equations are readily deduced :—

Weight of balloon in grammes $= 2890.\ d^2.\ t.$ ... ... (1)

Lift of enclosed hydrogen at the surface in grammes $= 607.\ d^3$ (2)

where d is the diameter of the balloon in metres and t is the thickness of the envelope in millimetres. It follows immediately that under surface conditions a rubber balloon will just support itself when the relation between d and t is given by the equation

$$d = 4{\cdot}76\ t \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (3)$$

also that if another balloon be made from rubber sheet of the same thickness but of twice the diameter it will just support itself at the surface when half filled with hydrogen.

In England the weight of the recording meteorograph used with sounding balloons is so small that in the present case when we are considering only the larger types of sounding balloons it may be neglected entirely. It must, however, be remembered that to ensure a sufficiently high rising velocity a balloon must be filled initially to a diameter at least 10 per cent. greater than is required for it just to support itself.

To work out a definite example, it is generally found that balloons in which t is less than 0·5mm. do not stretch so well as thicker ones. Suppose then a case in which $t = 0{\cdot}5$mm. and $d = 2$m. From equation (2) this balloon will support itself when its diameter at the surface is 2·38m. Multiplying by 1·10 to give the requisite vertical velocity we have a diameter of 2·62m. at the start, that is an initial stretch of 1·31. If the rubber be of very good quality it will endure a stretch of 5 before the balloon bursts. To find the height at which this will take place we have to interpolate in column 5 for the ratio 5/1·31, or 3·82; this is seen to be at about 28½km. From equation (1) the weight of this balloon will be 5·8 kilogrammes, which is about six times as heavy as the balloons commonly employed in England at the present time. If the thickness were 0·4mm. and the endurable stretch be taken as low as 4 a similar process shows that the height will again be about 28½km. As these values of the stretch are comparable with those actually obtained in the case of smaller balloons there is good ground for asserting that with balloons of 2m. diameter it is in general impossible to exceed heights of about 28½km.

It will be seen from the table that the density of the atmosphere roughly halves itself with every increase in height of 5km., and it readily follows from equations (1) and (2) that doubling d and keeping t constant can only result in a gain of about 5km. in the maximum height attainable.* At the same time the weight of the balloon is increased four times, and the cost in at least the same proportion.

In the above investigation several factors have been omitted in order to simplify the calculations, *e.g.*, the effect of the tension of the rubber envelope on the density of the included gas, the heating of the envelope and gas by solar radiation, the casual variations of the density of the air from its mean value and the possibility of a small and fortunate leakage reducing the strain on the rubber near the upper limit of the sounding. The last two are the only significant factors from the present point of view, and under special circumstances they are capable of adding perhaps 2 or 3km. to the maximum heights previously determined. There is also the element of uncertainty in the value of the temperature above 25km. to be considered; if, however, the table be recomputed to suit any other distribution of temperature which may be conceived of as possible, it will be found that the effect on the density at 30km. is comparatively very small, and that the order of magnitude of the results just obtained is unaffected by such changes.

It is evident that definite practical limitations exist which make the attainment of heights appreciably greater than 30km. almost prohibitive, but there is no reason why a good maker should not supply balloons which would sometimes reach about 30km.

As a further example of the use of the table the case is worked out below of the type of balloon commonly employed at Kew Observatory:—

Weight of balloon = 800 grammes.
Diameter unstretched = 70 cm.

From equation (1) we find that t = 0·58mm.

To obtain an adequate vertical velocity this balloon would be given a free lift of 680 grammes, and hence from (2) its diameter at the start would be $\frac{800 + 680}{607}$ m., that is 1·35m.

The balloon will therefore start with an initial stretch of $\frac{1 \cdot 35}{0 \cdot 70}$ or 1·93. If it endure a stretch of 5 before bursting the height reached will be from column 5 about 21km., or if it burst at a stretch of 4 it will reach about 18½km. Such heights are approximately those which good balloons of this size attain.

*In this case the balloon would be only partially inflated at the start.

Unusual Ranges of Temperature

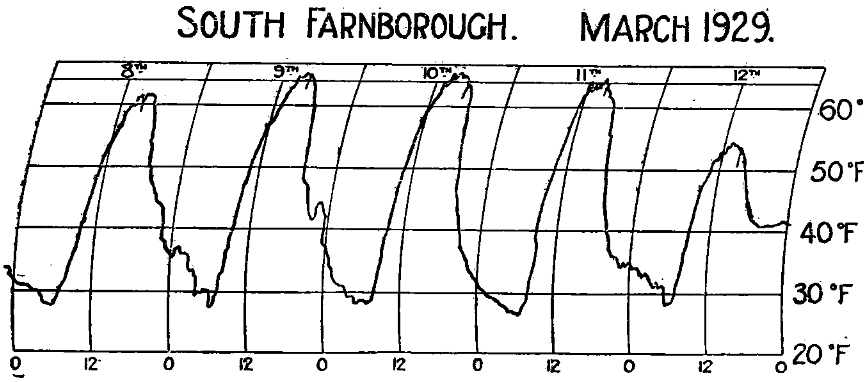
By S. T. A. MIRRLEES, M.A.

On the " average day " in March air temperature at inland stations in southeast England varies from about 36°F. near sunrise to about 49°F. in the afternoon. (These figures refer to temperatures measured under standard conditions.)

During this month both the sun's declination and the time during which the sun is above the horizon are increasing most rapidly, and when clear skies and absence of wind permit radiation effects to have free play it may happen that temperature after falling a few degrees below freezing point during the night rises rapidly after sunrise and reaches a maximum of 60° or over. The conditions in which a large temperature range occurs represent a nice balance of tendencies—if temperature falls low enough, a thick fog forms, and unless the fog clears quickly the rise of temperature will be restricted. The conditions are of course not confined to southeast England, but their effect is best seen where the climate is normally most extreme. If stable anticyclonic weather prevails a sequence of days with warm afternoons and cold nights may be experienced, and when conditions are favourable the daily range of temperature becomes exaggerated, and reaches 30° or more. Such a sequence was experienced over a large part of the country on March 8th—11th, when at several stations ranges in excess of 35° were recorded on each of the four days. The average daily ranges for this period at various stations as reported in the *Daily Weather Report* have been calculated, and are as follows :—Birr Castle 27°, Chester (Sealand) 32°, Shoeburyness 33°, Kew Observatory 34°, Ross-on-Wye 37°, Eskdalemuir 37°, South Farnborough 41°. During these days anticyclonic conditions prevailed over the British Isles, and at most of the stations mentioned cloud amounts were very small. Fog generally developed during the night, but cleared rather quickly, and relative humidity fell to low values during the afternoon hours, several stations reporting 30 per cent. or less at 13h.

A tracing of the South Farnborough thermograms for March 8th—12th is reproduced in the figure and shows the very rapid rise and fall of temperature before and after the hottest period of the day, approaching 10°F. per hour at times. The ranges shown by the thermograph are somewhat restricted, as compared with the ranges given by the maximum and minimum thermometers. By applying suitable corrections, however, it becomes possible to tabulate the curves for the four days. The resulting average curve shows a close resemblance to the actual curve for March 10th : the amplitudes of the coefficients of the first and second harmonic terms are 19·1° and 5·3° respectively, which may be compared with the average values for March of

4·4° and 1·1° at Kew Observatory. The irregular parts of the thermograms in the late evening hours are presumably the effects of local conditions, and cancel out in the average curve. The greatest daily range in the period was 43° on March 9th; on the same day the range of 41° experienced at Eskdalemuir (Dumfriesshire) is noteworthy.



From the results of temperature soundings by aeroplane published in the *Upper Air Supplement* to the *Daily Weather Report*, it appears that during a considerable part of the month temperatures in the upper air over southern England up to at least 20,000 feet were some 15° above normal. A temporary drop to the normal March level on the 23rd was followed by a return to warmer conditions again by the 27th. Considering the seven days on which the range reached or exceeded 40° at South Farnborough, one finds the following figures:—average surface temperature 49°, average temperature at 5,000 feet 44°, at 10,000 feet 28°. If convection had been sufficient to set up a dry adiabatic lapse rate of temperature between the ground and 5,000 feet in the warmest part of the day, the maximum temperature at the surface would have been about 71°; actually the average maximum for the seven days was 69°. The aeroplane ascents were carried out after 10h., by which time the surface temperature was rising above the mean for the day, and there is no direct measurement of the extent of the temperature inversion due to nocturnal cooling, but it was probably insignificant above the first two thousand feet.

Since the absolute daily range of shade temperature is not usually dealt with in meteorological statistics it would be a matter of considerable difficulty to find the actual highest daily range recorded in the British Isles. A few examples of large ranges may be cited without in any way attempting to define the record. Ranges of 40° were experienced on March 20th at South Farnborough and Croydon, and on March 28th at Eskdalemuir. At South Farnborough the range was 41° on 28th and 30th and 42° on 29th. At the same station on March 22nd—24th, 1918, the average range was 41°, the greatest range being 43° on 24th. On March 29th, 1893, a range of 44° was experienced at Cambridge.

Discussions at the Meteorological Office

March 11th.—*Contributions on the mechanism of waterspouts and tornadoes.* By A. Wegener (Met. Zs., Bd. 45, H.6, 1928) (in German). *Opener*—Mr. M. A. Giblett, M.Sc.

Dr. Wegener considers that a waterspout or tornado consists of a horizontal mother-whirl in the cloud, one end of which is bent downwards towards the ground, while the other end usually ends in the cloud. Various lines of evidence are adduced in support of this view, the strongest being the distribution of objects transported by the whirl. In the whirlwind of August 19th, 1890, at St. Claude for example, washing identified by the marks of the owners was carried from the right hand side of the track and dropped about 20km. to the left of the track, some distance forward. In another example the objects carried from the right of the track to the left were found to be encrusted with ice, showing that they must have passed through the cloud at a considerable height.

The rotation of the horizontal mother-whirl is clockwise when viewed from the right hand side. The hypothesis of the origin of these whirls assumes that initially a current of air moves horizontally across a layer of heated air with small horizontal motion, forming a discontinuity at a height of about three kilometres, along which a row of small whirls is developed, rotating clockwise when seen from the right. Where the lower air breaks through the upper layer, as shown by the formation of cumulonimbus clouds, two vertical discontinuities are formed, with similar rows of horizontal whirls, the forward whirls rotating in the same sense as the horizontal whirls. At the junction of this vertical row with the horizontal row a larger whirl is formed which, as it advances, absorbs the minor whirls. Instead of advancing directly forward, however, it tends to move obliquely towards the right, owing to the change of wind direction with height, so that the right hand end emerges from the cloud and is sometimes bent downwards to the ground.

There are several difficulties involved in this hypothesis, especially the difficulty of accounting for the intensity of the whirl and of the manner in which the one end becomes bent down to the ground. It also fails to account for the occurrence of three or more whirls along the same line-squall front as sometimes observed, though the author gives an explanation of the formation of multiple spouts. Mr. Giblett set out an alternative hypothesis, according to which waterspouts or tornadoes are developed at the front of an advancing wedge of cold air either at a long cold front associated with a depression or at the local cold front which often develops under a thunderstorm. The cold air at a height of a few hundred metres, but higher at times, over-runs the cold air at the surface, owing, for example, to friction with the ground, though sometimes also to other reasons, and some warm air is trapped beneath this advancing nose. It is the uprush of this warm air which forms the line of cloud in a line squall, as shown for example in the squall of October 14th, 1912, at Aberdeen. In this example three elementary waterspouts were seen to develop along this line. The strong horizontal convergence in such cases is adequate to produce a violent whirl about an axis leading upwards from the surface, by conservation of angular momentum, wherever the vertical uprush becomes at all localised. This alternative was suggested and illustrated in a paper on "Line Squalls" published in the *Journal of the Royal Aeronautical Society*, June, 1927.

Whatever may be the ultimately accepted theory, Wegener's paper will always be outstanding for the observational facts co-ordinated in it, and especially for the demonstration that, at least in a number of important cases in Europe, the tornado track lay on the right hand side of the track of the main cumulo-nimbus cloud and of the associated belt of heavy rain or hail, and also that there is evidence that such right-side tornadoes are cyclonic in rotation. The paper thus gives an important lead to future investigators, and, in particular, suggests that this characteristic should be examined specially for the case of American tornadoes.

Royal Meteorological Society

The meeting of the Society on Wednesday, March 20th, at 7.30 p.m. (Sir Richard Gregory, LL.D., President, in the chair) was devoted to the Symons Memorial Lecture. Mr. R. A. Watson Watt gave an account of "Weather and Wireless," of which the following is a summary.

Wireless as a means of communication is essential in modern meteorology because it alone is capable of giving sufficiently rapid interchange of data over wide areas. It is of special importance in British meteorology because it carries data from ships in the Atlantic giving the first indications of impending changes. In aerial navigation it provides the only means of carrying forecasts and the data necessary for the intelligent use of the forecasts. The broadcasting of weather reports and forecasts is educating a public opinion which will lead to greater attention to meteorology in education, and consequently to improvements in meteorological methods. The results of observations made all over Great Britain are in the hands of the central forecaster within an hour, the majority of the data for Europe are received within an hour and a half, and that for the whole Northern Hemisphere within six hours.

The demonstrations given showed the reception of the weather map for 1 p.m. transmitted on the Fultograph system across the room to show the complete process, and of the map for 6 p.m., together with a written forecast based on the latter prepared at the Meteorological Office at Royal Airship Works at Cardington, and transmitted by wireless from Cardington.

Wireless has a climate and a weather of its own. The weakening of signals over different kinds of country, according to time of day and season, and the dependence of atmospheric disturbance on latitude, place and time, are climatological in scope. The quick-period changes and the erratic phenomena of fading, are part of the weather of wireless; atmospherics are its rainfall. The history of civilisation is in the main the story of man's progress towards independence of the weather; the history of wireless is that of progress towards the mitigation of these disturbing factors. The nature of the broadcast service area, of the zone of severe fading and the reduced fading at greater distances, were discussed. Among the phenomena described was the reception of short-wave signals after they had travelled several times round the world, and also of "echoes" of this kind which would appear to have been reflected back to earth after being out beyond the moon. Atmospherics may be counted arriving at the rate of three or four thousand per second in a tropical night. The average atmospheric is a hundred thousand times as strong as a readable signal. Atmospherics have been known to disturb broadcast reception up to four thousand miles from their place of origin.

Atmospherics are found to originate in thunderstorms, and the predominate source of the world's supply of atmospherics at any moment usually lies in a land where it is summer afternoon. A map showing the travel across the world of these sources was exhibited. The average atmospheric received in England is of such strength as would be sent out by a thunderstorm 2,000 miles away. Visual direction finders of the type demonstrated in operation have accurately located thunderstorms in progress at places one or two thousand miles away.

Dr. Johnson has immortalised a brief chapter "concerning snakes," whose full text is, "There are no snakes to be met with throughout the whole island." Thus it is with the alleged effects of wireless on weather. The average rainfall of England requires for its production the expenditure of energy at the rate of a third of a million horsepower per square mile, night and day throughout the year. This is the rating of the largest electricity generating station in Great Britain. The total rate of emission of energy from all the broadcasting stations of Great Britain and northern Ireland, in the limited periods during which they work, is under 55 horsepower, the corresponding figure for Europe being about 400 horsepower. Any effect of broadcasting on weather would therefore be due to "sub-homeopathic doses" of less than one in a thousand million. Applying the same kind of arithmetic to the suburban home, one finds that to produce a year's rain for the tennis court by means of an electric kettle would cost £800 or more, while the home's contribution to the power bill of the local broadcasting transmitter is an eighth of a penny a year.

Extensions of the application of wireless telegraphy in meteorological communications may well include the transmission of three-colour weather charts. The detection and location of thunderstorms by wireless direction finding on atmospherics will probably become part of day-to-day meteorological practice. It is possible that some of the other measurements, and of the effects of weather on wireless described, may be used as aids to forecasting.

The lecture was illustrated by lantern slides and by the reception of current weather maps and written forecasts on the Fultograph system, and by demonstrations of the Cathode Ray Direction Finder, a visual direct-reading instrument used for locating wireless transmitters and thunderstorms.

Correspondence

To the Editor, *The Meteorological Magazine*

Drifting Ice on the Sea near Chester

During the severe frost of mid-February the unusual phenomenon of drifting ice was observed on the River Dee at Queensferry.

The river at this part has been banked up to form a canal about 300 feet wide and is subject to heavy tidal influence—on this particular date the range of tide was about 17 feet, with high water about 14h. 30m. The photograph forming the frontispiece of this number of the magazine was taken between 13h. 30m. and 14h., February 14th, 1929.

It was noticed on several days that the river became covered, as shown in the photograph, during the flow of the tide, and that most of the ice was deposited along the banks on the ebb. No doubt the bore, which is particularly evident in this estuary, prevented the river here from being completely frozen over. This is the opinion of a local river pilot of 20 years' experience. He referred to the phenomenon as "pack" ice. Does not this rather resemble what is known as "pancake" ice?

The grass minimum temperatures at Sealand from February 11th to 20th inclusive, were 24°, 18°, 13°, 8°, 9°, 24°, and 23°F. respectively.

The river at Chester was completely frozen over and skating was general.

The photograph was obtained by the Station photographer through the courtesy of Group Captain A. D. Cunningham, C.B.E., Commanding No. 5 Flying Training School, Royal Air Force.

F. DAVIES.

Sealand. March 18th, 1929.

Low February Temperatures

The following notable records of low temperature which Mr. R. Gray obtained at Oaklands, Dorstone, Herefordshire, were received too late for inclusion in " Notes on the Frost " in the March number of the *Meteorological Magazine.*

Screen temperatures

Feb.	Max.	Min.	"Grass" Min.	Feb.	Max.	Min.	"Grass" Min.
12th	24.5	18.0	16.0	16th	32.0	16.0	17.5
13th	25.5	—1.5	—4.5	17th	31.0	3.5	0.5
14th	26.0	—3.0	—7.0	18th	35.5	4.5	0.0
15th	22.0	—0.5	—4.5				

He also stated that " holly and ivy have been badly damaged by the frost and to-day present a scorched and brown appearance."

Sun Pillar

On March 9th at 17h. 55m. G.M.T. I observed a strange phenomenon of which I can find no record.

The sun was setting and appeared, when almost on the horizon, as a well-defined light-red ball with a sun pillar ascending from it. In the path of the pillar there was an image alike in all respects to the sun, the distance between the two balls being equal to the diameter of either. It was quite impossible at that time to say which was the object and which the image but this was decided when, two minutes later, the upper " sun " quite suddenly faded. Five minutes later the sun had set and only the pillar remained. There was very high and hazy cirrus in the vicinity of the phenomenon and no low cloud was present. The high cloud was travelling from southeast while the surface wind was east.

Mr. W. L. Andrew observed an excellent example of a sun pillar on February 22nd, but there were no other attendant phenomena.

T. H. APPLEGATE.

Cattewater, Plymouth, Devon. March 15th, 1929.

[Mr. Applegate's experience recalls a picture in Pernter and Exner's *Meteorologische Optik* (2nd Edn. p. 252). This picture represents observations made by Hevel as long ago as 1682. The significance of the duplication of the sun is not discussed by Pernter and Exner.

The accepted explanation of a sun pillar is the reflection of light from snow crystals fluttering down in the air with their flat surfaces nearly horizontal. Such reflection would not produce a sharp round image above the sun. From mountains or balloons a sharp reflection (as in the surface of calm water) is sometimes seen but this reflection is naturally below the sun.

If we try to explain the duplication of the sun in Applegate's observations by refraction of the light on account of a temperature inversion, we are met with the difficulty that there seems to have been no distortion. It is not at all unusual for the setting sun to assume bizarre shapes and to divide into two segments before it disappears but no one would describe such segments as well-defined balls. The cause of the Hevel-Applegate phenomenon must remain a mystery.

It may, however, be relevant to mention that on March 9th, the evening of Mr. Applegate's observations, a sun pillar was to be seen from Holmbury Hill in Surrey. The pillar was brightest where it intersected a belt of cloud (apparently cirro-stratus). The setting sun as seen from Holmbury Hill was distorted considerably.—F. J. W. WHIPPLE.]

Sun Pillar, March 29th

An exceptionally bright sun pillar, red in colour, was seen at 18h. 20m. on the above date . The base of the pillar was about 5° above the horizon rising to an altitude of about 25°, 1° in width. At 18h. 35m., nine minutes after sunset at an altitude of 10° in the pillar, the disc of the sun appeared indistinctly, radial arms developing extending 4° on either side. The complete phenomenon remained visible to 18h. 42m., the pillar alone being continued to 19h. The sun, deep red in colour, had disappeared in thick haze at 18h. 15m., no visible cloud being apparent to the west, cirrus, estimated at three-tenths, was present towards the east.

In its entirety the phenomenon must be assigned to that of a halo cross, uncommon with the sun above the horizon, more particularly so after sunset.

SPENCER RUSSELL.

Worcester Park, Surrey. April 2nd, 1929.

I observed a very vivid "sun pillar" this evening (Good Friday), here at Camberley. The sky in the west was clear except for some very fine cirrus cloud, which was only visible owing to the red rays of the set sun falling on it. There were also two streaks of more pronounced cirrus running at an apparent angle with the "pillar." Where the higher of these streaks crossed the pillar, it was somewhat brighter. From approx. 10° elevation to the horizon, the sky was dark with fog, whilst the ground was covered with ground fog in wreaths. Above 10°, the sky was reddish, and above this line, up to about 25°, the pillar was brilliant red, fading out just about 25° up. At about 10°, the pillar had a bright patch—doubtless a mock-sun, below which it faded into the fog. The sun had already set below the horizon, and I first noticed the pillar about 6.45 p.m. It had gone by 7.15 p.m. I did not look before, but there must have been some strong halo effects before sunset. I thought it worth while recording, owing to the extraordinary sharpness and brilliance of the pillar, especially during the absence of the sun itself.

E. W. Goodman.

Old Dean Hall, Camberley, Surrey. March 29th, 1929.

A sun pillar was observed here on Good Friday, March 29th, at 17h. 55m., extending about 20 degrees above the sun, rainbow-hued at first, then slowly turning a fiery red and finally fading away at 19h.

F. Claude Banks.

Market Gardens, Horndon-on-the Hill, Essex. April 3rd, 1929.

A remarkable phenomenon was seen here on Friday evening, March 29th, just after sunset, a sun pillar which took the form of a perfect luminous red cross which remained visible for some time.

G. E. Dacey.

6, *Clarendon Road, London, S.E.*13. *April 2nd*, 1929.

Ice Crystals

May I make some comments on the correspondence on ice crystals in the March number of the *Meteorological Magazine*?

The deposit which Mr. Weller observed on the Hog's Back on February 9th, 1929, must have been rime blown from the trees. There were great quantities of rime of similar character in Arundel Park on February 12th, 1927. On that occasion (as was reported in *Nature*, February 26th, 1927, p. 328) "the rime was heavy enough to bend the branches. In the light breeze the fragments of rime . . . . pelted the passer-by in no pleasant fashion. In places the fallen rime lay on the ground to the depth of one inch." The rime had formed on the twigs in plates such as Mr. Weller describes.

Ice crystals, of the type which Mr. Bigg observed, I saw on three occasions this winter. On January 26th on the Chiltern

Hills the crystals were falling whilst there was blue sky overhead but they might have come from clouds which had passed before the crystals reached the ground. On February 13th crystals were falling at Chiswick as well as at Richmond. At Richmond the crystals were of various patterns; in addition to the simple crystals such as Mr. Bigg mentions, the hub and six spokes, there were numerous crystals with hexagonal symmetry in lace-like designs. Most remarkable were two crystals in each of which there was a hub and twelve spokes. It is important to place the occurrence of this form on record as there is a note in Pernter and Exner's *Meteorologische Optik* (2nd Edn., 1922, p. 318) "Vom sternförmigen Dodekagon ist nun schon gar keine Rede; man findet dafür in den Mikrophotographien nicht einmal eine leise Andeutung." Almost simultaneously with my own observations, my son, who was examining ice crystals at Chiswick, also found a twelve-rayed specimen. One point which is not usually stated explicitly in descriptions of such crystals is that they are quite flat; they might have been cut from a very thin sheet of mica. Has anyone ever measured the thickness?

On February 13th, when the crystals were falling near Kew Observatory, the temperature was 21°F. The relative humidity was 83 per cent. with respect to vapour over water and therefore 88 per cent. with respect to vapour over ice. It is clear that the crystals must have come from a level where the relative humidity was greater. It is remarkable that such frail structures had not evaporated in their slow descent.

May I refer also to a very curious ice formation which occurred in a wood on the Chiltern Hills on January 26th? This formation was only found on two fallen trees a considerable distance apart. The ice was in threads and formed masses which looked like asbestos. The threads melted at a touch but they were so strong that a piece of wood covered with them could be carried in the hand for miles. In some cases, if not in all, the asbestos-like threads were between the wood of the tree and the bark. The fibres may possibly have been formed like the ice structure in Mr. Langley's bowl, each fibre being forced out of a pore in the saturated wood. I should be glad to learn of any published description of this phenomenon.

F. J. W. WHIPPLE.

Kew Observatory, Richmond.

[With reference to the last paragraph I have observed a very similar formation of fibrous ice on the surface of saturated lumps of chalk and formed the same explanation, namely, that the ice was forced out of the pores of the chalk during the process of freezing. It resembled a layer of fibrous calcite, but melted on being handled.—C. E. P. BROOKS.]

Smoke Cloud

On March 9th I was on Leith Hill when a great fire, which I ascertained afterwards must have been the one which destroyed the woods on the Fire Hills, near Hastings, was raging. The smoke cloud had a cumulus-like top. The elevation of the top was estimated as one-twentieth of the distance, *i.e.*, about 12,000 feet. The cloud stretched towards the northwest and the smoke from Hastings was being carried apparently beyond London to the Chiltern Hills.

It would be interesting to know whether these observations could be confirmed by the experience of aviators.

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NOTES AND QUERIES

The Dry Period, January to March, 1929

The dry weather of January to March 1929 falls naturally into three phases, the main characteristics of which are shown by the monthly rainfall maps. During January the more prevalent west winds were replaced by drier northerly winds. Over Scotland as a whole the month was the driest January since that of 1881. Falls in excess of the average occurred along the east coast from the Cheviots to east Anglia, while there was less than half the average over the western half of Scotland, the north-west of England, most of Wales and the western half of Ireland. During the greater part of February south-easterly winds prevailed over Great Britain, while Ireland came under the influence of south-westerly winds. The rainfall exceeded the average for the month practically everywhere in Ireland and reached twice the average in the south-east. Over most of England there was only 30 to 50 per cent. of the average, while the northern half of Scotland was again very dry having large areas with less than 25 per cent. The weather of March was dominated by high-pressure systems centred over the British Isles, and the drought was intensified. The total for the month was everywhere less than half the usual amount and over a broad strip along the east coast from the Grampians to Margate and over much of south-eastern England there was less than 10 per cent. Over the country as a whole March 1929 was the driest March since before 1870 and ranks with February 1891 and June 1925 as the driest months in 60 years.

The general values for the rainfall of each month and for the whole period are set out below as percentages of the average amounts.

	January	February	March	Jan.-March
	%	%	%	%
England and Wales	71	49	13	45
Scotland	49	54	24	43
Ireland	57	129	24	70
British Isles	63	67	18	50

January to March 1929 was drier than any similar period in the last 60 years, the next driest being that of 1891 with 60 per cent. of the average. The rainfall of January to March 1929 reached half the average over practically the whole of Ireland as well as along parts of the east and south coasts of Great Britain. Over most of England and Wales and Scotland the totals were between 30 and 45 per cent. of the average, while in the neighbourhood of London, in the English Lake District and in Ross-shire there was less than 30 per cent. The falls at representative stations in these regions are given below:—

	Rainfall, Jan.-Mar., 1929.	
	in.	*% of average.*
London (Camden Square) ...	1·55	29
Borrowdale (Seathwaite) ...	9·75	27
Alness (Ardross Castle) ...	2·25	22

At Ardross Castle the period included both the driest January and the driest March of the last 60 years of comparable data, and the total rainfall was less than that of any other three consecutive months. The driest three consecutive months at these stations were:—

London, March-May, 1893, with 1·36in.,
Seathwaite, April-June, 1921, with 9·51in., and
Ardross Castle, April-June, 1887, with 3·42in.

At a number of stations near London, March was rainless and over most of the south-eastern half of England and to the east of the Pennines the fall was trifling, being about one-tenth of an inch. At Gloucester the total for January to March was only 1·27in. and at Shoeburyness only 1·18in., but conditions do not seem to have been as severe (up to the end of March) as during the famous spring drought of 1893 when in the south-east of England there was no rain for a period of 50 days and only about 1·1in. during 110 days. J. GLASSPOOLE.

The Alabama and the Mississippi Floods

Two years after the great disaster of the Mississippi floods in 1927 floods are again reported from the Mississippi area and from Alabama in March, 1929, though not to the same extent.

According to the *Weekly Weather and Crop Bulletin* of the United States Department of Agriculture extremely cold weather with unusually heavy snow was experienced in the States northwards of the Ohio and Missouri valleys during January, the heavy snow in the western Lake region and upper Mississippi valley constituting a record there for this month. Further south the precipitation varied little from the normal. In February the mean temperature was below normal generally over the United States, but for the eastern states the area of coldest weather was further south than in January. The precipitation was also differently distributed, being generally below normal in a belt from Lake Erie to Texas and above normal to the southeast of this. Alabama, Georgia and southern Mississippi lay well within the most notable wet region, where the amounts at some places were about twice the normal fall. Two periods of excessive rainfall occurred at the end of February and beginning of March, viz., February 26th-27th and March 3rd-4th, making the total rainfall for the week ending March 5th considerably in excess of the normal in Alabama, Georgia and southern Mississippi; the total at Macon being 12·5in. or 11·4in above normal and at Montgomery 12·0in. or 10·7in. above normal. Both these periods of excessive rainfall succeeded sharp rises in temperature and were associated with severe thunderstorms. Reports that flood stages had been reached in the rivers of the eastern cotton States followed quickly, as the rising temperatures had also caused the snow to melt on the upper reaches of the rivers. For the next few days there was scarcely any rain as a large anticyclone moved eastwards across the States accompanied by a rapid fall of temperature. By the 12th, however, this was replaced by a series of depressions which brought wet weather with southerly winds and rising temperatures again to the Gulf States. Heavy falls of rain were reported on the 12th, 13th and 14th, as much as 8·92in. falling at Mobile on the 14th, making the total there for the week ending March 19th, 15·5in. or 14·0in above normal. Floods were first reported on the early morning of the 14th, when Elba, Alabama, at the confluence of the Pea River with the Big and Whitewater Creeks was isolated from the surrounding country. During the next few days the town became completely submerged except for the upper storeys of some houses. The floods continued until about the 17th when the flooded area extended from Chattahoochee River on the Georgia border of Alabama to Tombigbee at the other side of the State, and from Montgomery southward to below the Florida border. Twenty thousand people were driven from their homes. On the 18th these rivers started to fall.

Owing to further heavy rains on the 21st and 22nd the Mississippi river, which was still in flood, burst the levee twice, at Point Pleasant, six miles north of Quincy, Illinois on the 21st, and at Quincy on the 22nd flooding rich farm land in the Indian Grave district. Fortunately these breaks had been anticipated and much of the livestock and personal belongings of the residents had been moved previously to higher ground. The Iowa River inundated 1,500 acres of land near Wapello, Iowa, on the 21st.

Torrential rains and tornadoes caused much loss of life and material damage in the States of Tennessee, Kentucky, Mississippi, Alabama and Georgia on the 23rd. No subsequent information is available but this absence of news suggests that conditions in the flooded areas have gradually improved.

The Adjustment of a Sunshine Recorder

It is customary, when examining sunshine cards from a recorder which has recently been installed or from a recorder which has not been securely fixed to its support, to see whether the burns which constitute the records run parallel to the central lines of the cards, and to assume that the recorder is correctly adjusted if that condition is satisfied.

It may therefore be useful to state that although this condition is necessary for the correct adjustment of a sunshine recorder, it does not form a sufficient guarantee that the recorder is correctly adjusted. It is possible to arrange that the level adjustment (in an east-west direction) and the azimuth adjustment are both incorrect (though related to one another) and still secure parallelism of burns to the central lines of the cards. When this occurs the recorder does not indicate local apparent time (L.A.T.) as it should, but L.A.T. increased or decreased by a constant interval of time.

A simple way of looking at the matter is to remember that parallelism of burns implies that the axis of the bowl of the recorder is parallel to the polar axis and that the sphere is in the centre of the bowl. Hence a rotation of the bowl about its axis will not disturb the parallelism of the burns. In practice, such rotation would correspond with mutually related errors of time, azimuth and east-west level.

If α is the angle in degrees through which the bowl is rotated beyond its correct position about its axis, the error in time is $\frac{\alpha}{15}$ hours. It can be shown that if θ is the latitude, the corresponding error in level in the east-west direction is $\alpha \cos \theta$, and the error in azimuth is $\alpha \sin \theta$.

Thus, suppose the error in time is a quarter of an hour, then

$$\frac{\alpha}{15} = \frac{1}{4}$$

$$\text{and} \quad \alpha = 3\tfrac{3}{4}^\circ$$

The necessary tilt of the instrument in an east-west direction to secure parallelism of burns in latitude 55° is 3.75 × .57 = 2.1°, and the necessary error in azimuth is 3.75 × .82 = 3.1°.

This combination of errors will not occur if care is taken to ensure that any one of the three adjustments of time level and azimuth is correct. Probably the best course to follow is to verify that the instrument records local apparent time at noon. The other adjustments may, however, be tested instead.

Obituary

We regret to learn of the death on March 21st, in his 90th year, of Prof. Dr. August von Schmidt, formerly Head of the Meteorological Geophysical section of the Wurttembergisches Statistisches Landesamt, Stuttgart.

The Weather of March, 1929

Quiet, dry, sunny weather with a large diurnal range of temperature and much morning mist prevailed generally over the British Isles during March. On the 1st the northwestern districts were under the influence of a depression centred near Iceland and strong to high southerly winds were experienced there, but by the 3rd the anticyclonic conditions in the eastern districts extended over the country generally. During the first five or six days, day temperatures, though higher than those experienced at the end of February, were yet below the normal for the beginning of March except at a few places on odd days notably in southern Scotland. On the 7th and 8th there was a change to southeasterly winds in the west and the days became sunny and warm over the whole country. From the 8th to 11th 60°F. was exceeded in many places while 70°F. was reached at Norwich and Hull on the 9th, and the hours of bright sunshine exceeded 10 at many places in the south and 9 in the north of England, *e.g.*, Brighton had 10·7hrs. on the 9th and Durham 9·9hrs. on the 8th. Severe night frosts were experienced during all this time and indeed almost throughout the month though by far the lowest readings were at the beginning when 10°F. in the screen and 2°F. on the ground were recorded at Rhayader on the 1st. The diurnal range of temperature was greatest on the 8th-11th, 20th and 28th-30th when it exceeded 40°F. at a few places.* After the 11th light north to northeasterly winds brought cooler weather generally and the morning mist or fog persisted during the greater part of the day at several places. On the 16th the anticyclone moved away eastwards so that the British Isles again had southeasterly winds backing south. Temperature, however, only rose gradually, 65°F. not occurring

*See p. 31.

until the 19th and 20th when the winds had become southwest and Ireland and Scotland were under the influence of a depression near Iceland. Over 9hrs. sunshine occurred generally in the Midlands and southeastern England but along the East Anglian coast fog persisted occasionally throughout the day, preventing the temperature from rising, *e.g.*, the maximum was 34°F. at Gorleston on the 19th and 20th and 35°F. at Clacton on the 19th. On the 20th and 21st a shallow secondary passed across Ireland, Wales and Scotland and heavy rain fell locally, 1·35in. at Treherbert, Glamorgan, on the 21st and 0·91in. at Kilmacthomas, Waterford, on the 20th. For the next four or five days there were southwesterly winds, with slight to moderate rain in the west and north, and varying amounts of sunshine, the most occurring in southern England. On the 25th the anticyclone centred near the Azores spread over the British Isles and fine sunny weather with a gradually rising temperature was experienced until the 31st when the retreat of the anticyclone towards the southwest brought northwesterly winds and cooler weather. During the warm spell record temperatures were obtained, 70° and above being recorded at many stations over the whole of England and Ireland on all four days, the highest was 75°F. at Ilkley on the 28th and at Collumpton on the 30th. The total rainfall for the month over the whole country was very scanty, several places having less than 0·1in.* Sunshine totals for the month were far above normal, the distribution being as follows :—

	Total (hrs.)	Diff. from normal (hrs.)		Total (hrs.)	Diff. from normal (hrs.)
Stornoway	131	+26	Valentia	197	+74
Aberdeen	145	+28	Liverpool	180	+72
Dublin	201	+78	Falmouth	171	+33
Birr Castle	192	+82	Kew	146	+41

Pressure was above normal over the whole of western Europe, Iceland and Bermuda, the greatest excess being 16·5mb. at Malin Head; and below normal over northern Scandinavia, Spitsbergen and the North Atlantic from Madeira to Newfoundland, the greatest deficit being 6·6mb. at Horta. Except for central Europe, temperature was above normal especially in northern Sweden and Spitsbergen. At the latter place it was as much as 16°F. above normal. Precipitation was scanty in southern and central Europe and below normal even as far north as Vardo, except in western Norrland where it was abundant. At Spitsbergen it was slightly above normal. For the first time since 1893 ice floes were seen floating down the Bosporus during the first days of the month. Propelled by the current and a strong north wind they reached the Sea of Marmora. On the 3rd the weather in the neighbourhood again

* See p. 71.

became very cold with heavy snowfalls which interrupted the railway communications. On the 2nd and 3rd severe gales occurred in northern Italy, the northern Adriatic and Austria, and from the 1st—4th cold snowy weather was experienced in Berlin. For several days at the beginning of the month the ferry services connecting Denmark, Germany and Sweden had to be suspended on account of the ice; they were resumed generally about the 8th. Owing to the prolonged dry weather large stretches of forest were destroyed by fire in the Cher and Touraine regions of France on the 11th and in parts of Switzerland between the 12th and 17th. By the 12th the greater part of the Rhine had become free of ice, and on the 14th it was reported that the ice in the Yugoslav section of the Danube and in the Save was breaking up. Slight rain fell in all parts of Switzerland on the 23rd and 24th, thus bringing to an end the drought which had lasted there for 24 days. Cool weather with strong winds and much rain at times occurred in Germany during the last days of the month.

After an unusually long drought, rain fell in torrents in Madeira causing floods and a landslip on the northern coast of the island on the morning of the 6th. About 40 people were killed. Gales were experienced on the North Atlantic early in the month.

Heavy rains in the Otago Province of New Zealand caused extensive floods there, especially in Dunedin, about the 20th. Serious damage was done to the crops and property and the railway lines were breached.

Owing to heavy rains floods were experienced in Mississippi, Alabama, Georgia and Iowa.* A severe thunderstorm followed by heavy rain occurred at Ottawa on the 25th.

The special message from Brazil states that in the north and south rainfall was 3·66in. and 1·54in. respectively above normal, but in the centre it was 1·11in. below normal. Seven anticyclones passed over the country; during the last ten days the weather was abnormally cold and windy in the centre and south and very early frosts occurred in Parana. Coffee crops continued in exceptionally good condition. At Rio de Janeiro pressure was 0·2mb. below normal and temperature 0·2°F. below normal.

Rainfall, March, 1929.—General Distribution

England and Wales	13	per cent. of the average 1881-1915.
Scotland...	24	
Ireland	24	
British Isles	18	

*See p. 72.

Rainfall: March, 1929: England and Wales

Co.	Station	In.	Per-cent of Av.	Co.	Station	In.	Per-cent. of Av.
Lond .	Camden. Square.........	·01	0	*Leics* .	Belvoir Castle............	·07	4
Sur .	Reigate, The Knowle...	·02	1	*Rut* :	Ridlington	·08	...
Kent .	Tenterden, Ashenden...	·04	2	*Linc* .	Boston, Skirbeck	·28	18
,, .	Folkestone, Boro. San.	·18	...	,, .	Lincoln, Sessions House	·32	21
,, .	Margate, Cliftonville...	·16	10	,, .	Skegness, Marine Gdns	·16	10
,, .	Sevenoaks, Speldhurst	·03	...	,, .	Louth, Westgate	·31	15
Sus .	Patching Farm	·12	6	,, .	Brigg, Wrawby St. ...	·16	...
,, .	Brighton, Old Steyne	·08	4	*Notts* .	Worksop, Hodsock ...	·06	4
,, .	Tottingworth Park ...	·15	6	*Derby*.	Derby, L. M. & S. Rly.	·21	12
Hants.	Ventnor, Roy. Nat. Hos.	·25	12	,, .	Buxton, Devon Hos....	·87	21
,, .	Fordingbridge, Oaklnds	·20	9	*Ches* .	Runcorn, Weston Pt.	·57	28
,, .	Ovington Rectory	·10	4	,, .	Nantwich, Dorfold Hall	·47	...
,, .	Sherborne St. John ...	·07	3	*Lancs*.	Manchester, Whit. Pk.	1·01	45
Berks.	Wellington College ...	·01	0	,, .	Stonyhurst College ...	1·67	45
,, .	Newbury, Greenham...	·12	5	,, .	Southport, Hesketh Pk	·84	38
Herts.	Benington House	·04	2	,, .	Lancaster, Strathspey	·98	...
Bucks.	High Wycombe.........	·06	3	*Yorks*.	Wath-upon-Dearne ...	·05	3
Oxf. .	Oxford, Mag. College	·08	5	,, .	Bradford, Lister Pk....	·28	12
Nor .	Pitsford, Sedgebrook...	·19	10	,, .	Oughtershaw Hall......	1·75	...
,, .	Oundle	·07	...	,, .	Wetherby, Ribston H.	·51	26
Beds .	Woburn, Crawley Mill	·10	6	,, .	Hull, Pearson Park ...	·12	7
Cam .	Cambridge, Bot. Gdns.	·03	2	,, .	Holme-on-Spalding ...	·15	...
Essex.	Chelmsford, CountyLab	·06	3	,, .	West Witton, Ivy Ho.	·14	...
,, .	Lexden Hill House ...	·02	...	,, .	Felixkirk, Mt. St. John	·23	12
Suff .	Hawkedon Rectory ...	·03	2	,, .	Pickering, Hungate ...	·20	...
,, .	Haughley House	·04	...	,, .	Scarborough	·13	7
Norf .	Norwich Eaton	·07	4	,, .	Middlesbrough	·11	7
,, .	Wells, Holkham Hall	·16	10	,, .	Baldersdale, Hury Res.	·32	...
,, .	Little Dunham	·27	14	*Durh* .	Ushaw College	·13	6
Wilts.	Devizes, Highclere......	·16	8	*Nor* .	Newcastle, Town Moor	·51	24
,, .	Bishops Cannings	·38	17	,, .	Bellingham. Highgreen	·26	...
Dor .	Evershot, MelburyHo.	·43	14	,, .	Lilburn Tower Gdns....	·19	...
,, .	Creech Grange	·08	...	*Cumb*.	Geltsdale..................	·60	...
,, .	Shaftesbury, Abbey Ho.	·18	8	,, .	Carlisle, Scaleby Hall	·61	25
Devon.	Plymouth The Hoe ..	·75	26	,, .	Borrowdale, Seathwaite	2·15	20
,, .	Polapit Tamar	·40	13	,, .	Borrowdale, Rosthwaite	1·73	...
,, .	Ashburton, Druid Ho.	·46	10	,, .	Keswick, High Hill ...	·80	...
,, .	Cullompton.......	·25	9	*Glam* .	Cardiff, Ely P. Stn. ...	·59	18
,, .	Sidmouth, Sidmount...	·23	9	,, .	Treherbert. Tynywaun	1·97	...
,, .	Filleigh, Castle Hill ...	·48	...	*Carm*.	Carmarthen Friary ...	2·03	53
,, .	Barnstaple.N.Dev.Ath.	·49	19	,, .	Llanwrda	1·28	28
Corn .	Redruth, Trewirgie ...	·72	20	*Pemb* .	Haverfordwest, School	1·55	...
,, .	Penzance. Morrab Gdn.	·54	17	*Card* .	Aberystwyth	·84	...
,, .	St. Austell, Trevarna...	·45	13	,, .	Cardigan, County Sch.	·34	...
Soms .	Chewton Mendip	·23	6	*Brec* .	Crickhowell. Talymaes	·50	...
,, .	Long Ashton	·55	...	*Rad* .	BirmW.W.Tyrmynydd	·53	10
,, .	Street, Millfield ...	·20	...	*Mont* .	Lake Vyrnwy...........	1·24	29
Glos. .	Cirencester, Gwynfa ...	·24	10	*Denb* .	Llangynhafal	·08	...
Here .	Ross, Birchlea...........	·17	8	*Mer* .	Dolgelly, Bryntirion...	1·76	36
,, .	Ledbury, Underdown	·11	6	*Carn* .	Llandudno	·17	8
Salop.	Church Stretton.........	·33	14	,, .	Snowdon, L. Llydaw 9	...	...
,, .	Shifnal, Hatton Grange	·22	12	*Ang* .	Holyhead, Salt Island	·55	21
Worc.	Ombersley, Holt Lock	·12	7	,, .	Lligwy....................	·81	...
,, .	Blockley	·07	...	*Isle of Man*			
War .	Farnborough	·08	4		Douglas, Boro' Cem....	1·29	44
,, .	**Birminghm, Edgbaston**	**·16**	**8**	***Guernsey***			
Leics .	**Thornton Reservoir ...**	**·13**	**7**		**St. PeterP't. GrangeRd.**	**·06**	**24**

Rainfall: March, 1929: Scotland and Ireland

Co.	Station	In.	Per-cent of Av.	Co.	Station	In.	Per-cent. of Av.
Wigt .	Stoneykirk, Ardwell Ho	·73	28	*Suth* .	Loch More, Achfary ...	1·97	31
,, .	Pt. William, Monreith	1·14	...	*Caith* .	Wick	·88	39
Kirk .	Carsphairn, Shiel.	1·46	...	*Ork* .	Pomona, Deerness	·89	32
,, .	Dumfries, Cargen	·77	21	*Shet* .	Lerwick	1·20	38
Dumf.	Eskdalemuir Obs.	1·10	22	*Cork* .	Caheragh Rectory	1·61	...
Roxb .	Branxholm	·46	16	,, .	Dunmanway Rectory...	2·05	42
Selk .	Ettrick Manse	...	...	,, .	Ballinacurra	·87	31
Peeb .	West Linton	·65	...	,, .	Glanmire, Lota Lo. ...	1·06	34
Berk .	Marchmont House	·17	6	*Kerry*.	Valentia Obsy.	1·37	30
Hadd.	North Berwick Res. ...	·34	18	,, .	Gearahameen	2·90	...
Midl .	Edinburgh, Roy. Obs.	·20	11	,, .	Killarney Asylum	·78	17
Ayr .	Kilmarnock, Agric. C.	1·22	44	,, .	Darrynane Abbey	1·18	29
,, .	Girvan, Pinmore	1·13	30	*Wat* .	Waterford, Brook Lo...	1·01	37
Renf .	Glasgow, Queen's Pk. .	·90	35	*Tip* .	Nenagh, Cas. Lough...	1·04	34
,, .	Greenock, Prospect H.	1·47	30	,, .	Roscrea, Timoney Park	·95	...
Bute .	Rothesay, Ardencraig.	1·67	47	,, .	Cashel, Ballinamona...	·69	25
,, .	Dougarie Lodge	1·33	...	*Lim* .	Foynes, Coolnanes	·81	27
Arg .	Ardgour House	1·90	...	,, .	Castleconnel Rec.	1·19	...
,, .	Manse of Glenorchy ...	1·73	...	*Clare* .	Inagh, Mount Callan...	1·54	...
,, .	Oban	1·62	...	,, .	Broadford, Hurdlest'n.	·11	...
,, .	Poltalloch	1·26	33	*Wexf*.	Newtownbarry	...	...
,, .	Inveraray Castle	2·36	37	,, .	Gorey, Courtown Ho ..	·59	26
,, .	Islay, Eallabus	1·04	27	*Kilk* .	Kilkenny Castle	·81	35
,, .	Mull Benmore	8·10	...	*Wic* .	Rathnew, Clonmannon	·52	...
,, .	Tiree	·69	...	*Carl* .	Hacketstown Rectory..	1·10	39
Kinr .	Loch Leven Sluice	·53	18	*QCo* .	Blandsfort House	·89	34
Perth .	Loch Dhu	1·65	25	,, .	Mountmellick	1·01	...
,, .	Balquhidder, Stronvar	·72	...	*KCo* .	Birr Castle	·53	22
,, .	Crieff, Strathearn Hyd.	·57	18	*Dubl* .	Dublin, FitzWm. Sq...	·22	11
,, .	Blair Castle Gardens ...	·66	25	,, .	Balbriggan, Ardgillan.	·42	...
,, .	Dalnaspidal Lodge ...	1·23	25	*Me'th* .	Beauparc, St. Cloud...	·51	...
Forf .	Kettins School	·56	25	,, .	Kells, Headfort	·71	26
,, .	Dundee, E. Necropolis	·42	20	*W.M* .	Moate, Coolatore	·52	...
,, .	Pearsie House	1·05	...	,, .	Mullingar, Belvedere..	·61	23
,, .	Montrose, Sunnyside...	·17	8	*Long* .	Castle Forbes Gdns	·52	18
Aber .	Braemar, Bank	·31	10	*Gal* .	Ballynahinch Castle ...	·93	18
,, .	Logie Coldstone Sch....	·19	7	,, .	Galway, Grammar Sch.	1·15	...
,, .	Aberdeen, King's Coll.	·22	9	*Mayo* .	Mallaranny	·97	...
,, .	Fyvie Castle	·39	...	,, .	Westport House	·30	8
Mor .	Gordon Castle	·25	11	,, .	Delphi Lodge	1·52	...
,, .	Grantown-on-Spey ...	·24	9	*Sligo* .	Markree Obsy	·51	15
Na .	Nairn, Delnies	·33	18	*Cav'n* .	Belturbet, Cloverhill...	·55	20
Inv .	Kingussie, The Birches	·46	...	*Ferm* .	Enniskillen, Portora...	·20	...
,, .	Loch Quoich, Loan ...	4·30	...	*Arm* .	Armagh Obsy	·34	14
,, .	Glenquoich	3·96	41	*Down* .	Fofanny Reservoir	·93	...
,, .	Inverness, Culduthel R.	·25	...	,, .	Seaforde	·62	21
,, .	Arisaig, Faire-na-Squir	1·01	...	,, .	Donaghadee, C. Stn ...	·56	25
,, .	Fort William	1·83	...	,, .	Banbridge, Milltown...	·29	...
,, .	Skye, Dunvegan	2·05	...	*Antr* .	Belfast, Cavehill Rd ...	·81	...
R & C.	Alness, Ardross Cas. ...	·61	19	,, .	Glenarm Castle	·66	...
,, .	Ullapool	1·96	...	,, .	Ballymena, Harryville	·51	16
,, .	Torridon, Bendamph...	1·94	26	*Lon* .	Londonderry, Creggan	·85	27
,, .	Achnashellach	3·20	...	*Tyr* .	Donaghmore	·43	...
,, .	Stornoway	1·23	30	,, .	Omagh, Edenfel	·48	15
Suth .	Lairg	1·59	...	*Don* .	Malin Head	·32	...
,, .	Tongue	·58	17	,, .	Dunfanaghy	25	...
,, .	Melvich	1·05	37	,, .	Killybegs, Rockmount.	·90	18

Climatological Table for the British Empire, October, 1928.

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	PRECIPITATION: Diff. from Normal	PRECIPITATION: Days	BRIGHT SUNSHINE: Hours per day	BRIGHT SUNSHINE: Percentage of possible
London, Kew Obsy.	1011·3	— 2·7	66	31	58·3	44·4	51·3	+ 1·4	46·5	91	7·0	3·61	+ 0·91	21	3·6	34
Gibraltar	1017·9	+ 0·7	81	52	72·8	60·5	66·7	+ 0·6	59·4	82	4·5	0·71	— 2·60	5	..	..
Malta	1017·5	+ 0·9	90	61	76·3	67·7	72·0	+ 1·1	66·9	78	5·6	1·28	— 1·59	7	7·7	68
St. Helena	1014·8	+ 2·6	65	52	61·4	54·0	57·7	— 1·1	55·1	93	9·6	0·98	— 0·93	14	..	..
Sierra Leone	1014·3	+ 2·7	88	68	84·1	71·6	77·9	— 2·2	75·3	85	5·0	16·41	+ 3·79	21	..	..
Lagos, Nigeria	1010·2	— 1·5	86	69	83·9	73·9	78·9	— 0·6	75·7	86	6·5	12·67	+ 4·91	20	..	..
Kaduna, Nigeria	1014·7	+ 2·4	93	..	88·2	..	..	..	72·1	74	..	3·03	+ 0·85	8	..	..
Zomba, Nyasaland	1009·7	— 1·2	92	57	87·2	64·8	76·0	+ 1·9	..	55	2·0	0·08	— 1·44	2	..	..
Salisbury, Rhodesia	1007·4	— 1·0	95	49	88·6	59·0	73·8	+ 3·1	58·1	29	1·0	0·35	— 0·79	2	10·7	86
Cape Town	1018·3	+ 0·9	88	46	70·2	52·9	61·5	+ 0·3	56·1	78	5·6	0·87	— 0·77	8	..	..
Johannesburg	1012·8	— 0·5	87	35	75·5	54·2	64·9	+ 2·2	53·4	53	3·1	2·35	— 0·21	9	9·3	73
Mauritius	1017·9	— 0·3	84	56	79·3	62·8	71·1	— 1·6	65·7	57	5·7	0·60	— 0·78	7	9·5	76
Bloemfontein	..	..	91	33	78·9	49·1	64·0	— 0·6	52·8	48	3·0	1·43	— 0·25	7	..	..
Calcutta, Alipore Obsy.	1009·5	+ 0·1	92	74	88·6	77·1	82·9	+ 2·2	78·1	91	6·3	2·83	— 1·36	6*	..	..
Bombay	1008·8	— 1·0	95	73	88·4	76·4	82·4	+ 0·1	76·5	85	4·0	0·43	— 1·24	2*	..	..
Madras	1007·9	— 1·0	94	74	88·5	76·3	82·4	+ 0·1	77·7	86	5·5	20·81	+ 9·09	14*	..	..
Colombo, Ceylon	1010·6	+ 0·3	88	72	84·0	75·5	79·7	— 0·6	76·3	79	8·7	24·70	+ 11·58	28	4·7	39
Hongkong	1015·2	+ 1·6	83	67	80·1	71·1	75·6	— 1·3	67·1	61	3·3	0·43	— 4·42	4	8·5	73
Sandakan	..	..	91	73	88·0	74·2	81·1	— 0·4	76·7	79	..	8·55	— 1·45	11	..	..
Sydney	1009·0	— 5·9	98	50	74·6	56·8	65·7	+ 2·2	56·5	47	4·1	1·65	— 1·56	10	7·9	63
Melbourne	1007·9	— 6·8	77	38	65·5	47·7	56·6	— 1·0	51·3	60	7·5	2·17	— 0·42	21	5·8	44
Adelaide	1010·5	— 5·5	91	43	69·1	51·0	60·1	— 1·8	52·3	53	6·2	2·43	+ 0·69	17	6·6	51
Perth, W. Australia	1015·2	— 1·6	75	42	66·7	49·9	58·3	— 2·7	54·1	60	5·7	1·78	— 0·40	16	8·1	63
Coolgardie	1011·8	— 3·4	92	35	76·6	47·8	62·2	— 1·4	51·6	39	2·8	0·88	+ 0·14	3	..	..
Brisbane	1012·1	— 4·1	93	52	81·7	63·0	72·3	+ 2·5	65·2	60	3·7	1·29	— 1·28	7	7·8	61
Hobart, Tasmania	1001·0	— 9·6	70	35	58·5	43·7	51·1	— 2.9	46·5	65	6·7	4·20	+ 1·94	25	6·3	48
Wellington, N.Z.	1006·3	— 6·8	68	38	58·8	48·7	53·7	— 0·6	51·0	78	7·6	5·32	+ 1·24	16	5·6	42
Suva, Fiji	1012·8	— 0·4	92	67	83·0	71·3	77·1	+ 1·1	72·0	71	5·8	1·57	— 6·23	13	7·0	56
Apia, Samoa	1011·0	— 0·5	87	70	85·5	74·1	79·8	+ 1·4	77·1	76	3·5	7·62	+ 1·56	14	8·3	67
Kingston, Jamaica	1012·0	+ 0·5	91	69	87·7	72·1	79·9	— 0·6	71·5	88	5·3	5·57	— 1·89	8	6·8	58
Grenada, W.I.	1008·6	— 2·0	90	71	87·5	74·4	80·9	+ 0·8	77·3	81	4·6	4·16	— 3·49	21	..	..
Toronto	1018·0	0·0	84	23	58·8	42·8	50·8	+ 3·9	44·4	80	5·2	2·94	+ 0·48	13	4·8	43
Winnipeg	1016·6	+ 1·3	68	16	50·0	32·5	41·3	+ 0·5	..	..	6·5	0·42	— 1·01	5	3·9	36
St. John, N.B.	1017·3	+ 0·8	67	22	53·8	39·9	46·9	+ 1·6	43·2	81	6·0	4·18	— 0·36	15	4·8	44
Victoria, B.C.	1017·8	+ 0·2	63	41	53·7	46·0	49·9	— 0·5	48·4	88	8·0	3·58	+ 1·03	17	2·7	25

* For Indian stations a rain day is a day on which 0.1 in. or more rain has fallen.