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The Unequal Heating of Land and Water

Dr. E. Kidson, Director of the Meteorological Service of New Zealand, in a letter to the *Meteorological Magazine* quotes the common assumption that the greater heating effect of solar radiation on land surfaces than on the sea is caused mainly by the smaller specific heat of the soil, and asks for a discussion of this point. The problem might be discussed on the basis of either the diurnal or annual variation of temperature. The general principles are more or less the same in each case, but the annual variation is complicated by the transport of heat in ocean currents, seasonal variations in rainfall and cloudiness, etc., and it seems best to confine the discussion to the diurnal variation.

From various sources the mean daily range of the sea surface is estimated as about 0·7° F. The mean daily range of the land surfaces of the globe is much more difficult to estimate, as direct measurements are rare, but a rough figure can be obtained indirectly. From some figures for 131 well distributed stations between latitudes 40° N. and 40° S., I estimated the average difference between mean daily maximum and mean daily minimum over land areas as 19° F., the figures being :—small islands 11° F., coast 14° F., inland 22° F. No systematic observations of the daily range of temperature at the surface of the ground are available for a variety of places, but from various scattered data it appears to average between two and three times the daily range of screen temperature on open ground in clear weather. In cloudy weather and also under trees the ground temperature probably differs little from the screen temperature. We can assume a mean of 30° F. as a conservative estimate between 40° N. and 40° S. The daily range at the surface of the ground is thus of the order of forty or fifty times as great as that at the surface of the sea.

The surface of the ground and the uppermost layers of the sea gain heat during the day mainly by absorbing radiation from the sun and sky, and lose heat at night mainly by radiation outwards to the sky. Let us consider first the absorption of radiation during the day. The processes involved are quite different for land and water surfaces. The thermal conductivity of sea water is very small, and the amount of heat which passes downwards by molecular conduction is negligible. On the other hand water transmits solar radiation fairly well, and the short-wave radiation reaching a water surface from above penetrates and warms the upper layers. Only a small fraction of the radiation reaches a depth of 25 metres however, and the greater part of the warming effect is confined to the upper third of this depth. The uppermost layers of the water are also affected by vertical circulation caused by convection, eddies and breaking waves, which tends to equalise the temperature. At times this equalisation may extend to a depth of 20 or 30 metres, but at other times a thin surface layer of highly warmed water may be formed. As a rough approximation we may assume that the radiation received by the ocean is uniformly distributed through a layer 10 metres deep.

The ground is opaque and immobile, and the whole of the radiation is absorbed at the surface, where the temperature rises rapidly. Heat can only penetrate below the surface by conduction, with perhaps a small effect by percolation of rain-water or circulation of air. The thermal conductivity of soil or rock is low, and the diurnal range of temperature decreases very rapidly with depth. Hourly observations of earth temperature are rare, but some figures obtained by L. Herr* at Leipzig show that the range decreases to less than a tenth of the surface value at a depth of only 35 cm. If alongside a patch of undisturbed soil we placed a thermally insulated pan of soil which could be kept at a uniform temperature throughout by constant stirring, the depth of the pan could be only 10 cm. or less if its temperature were to be always the same as that of the undisturbed surface. The actual thickness of the layer in this hypothetical pan would vary greatly according to the nature of the ground. Loose dry soil or sand containing a great deal of air is almost a non-conductor, and the heat penetrates only a very short distance; a surface of this nature warms or cools very rapidly. A temperature of 172° F. has been recorded at the surface of dry

*Bodentemperaturen unter besonderer Berücksichtigung der äusseren meteorologischen Faktoren. Berlin, 1936.

dune sand in the Sahara. Solid rock is a better conductor and heat penetrates into it to a greater depth than into sand, hence it warms more slowly and retains its heat for a longer period, but even in such material the process of conduction is slow and the daily variation of temperature is small below about 10 cm. Thus the solar heat, which in the oceans is spread through a layer some 10 metres thick, is confined on the land to a layer of only about one hundredth of that thickness.

At night the surfaces of both sea and land begin to cool, but here also cooling operates in a different way in each. As the surface layer of the sea cools by radiation, its density increases and it becomes heavier than the underlying layers. A vertical circulation is set up, which keeps the upper layers well mixed and at the same temperature. Thus the cooling by night, like the heating by day, is uniformly distributed through a layer of the order of 10 metres deep. On the other hand the loss of heat from the surface of the ground can only be made good by the slow process of conduction from the underlying layers, and the cooling by night extends only to the same small depth as the warming by day. This great difference in the depths to which diurnal heating and nocturnal cooling extend in land and sea is ample explanation of the contrast in the daily ranges of temperature on the ground and at the sea surface.

A point is often made of the cooling effect of evaporation. According to G. Wüst* the average evaporation from the oceans is 93 cm. a year, from the land only 42 cm. As however evaporation from the land is largely confined to the day, while that from the sea is probably more continuous, the net effect on the difference of the daily range appears to be negligible.

We can now consider the effect of the accumulated heat on temperature. The specific heat of sea water is between 1 and 0·99, that of rock about 0·2. The specific heat of loose sand or dry soil may be even less, but that of wet soil would be greater. The same amount of heat would therefore raise the temperature of a gramme of rock about five times as much as it would raise the temperature of a gramme of water. Rock is about 2·5 times as heavy as sea water, but soil, sand and many rocks are porous and contain much air or water. The effective density of the ground surface may be about twice that of the sea. Thus if the same amount of heat were applied to layers of ground and of sea of the same thickness, the rise of temperature of the ground would be about two and a half times that of the sea. While the small specific heat of rock is one factor in the great range of temperature of the ground, it is a very small one, being only about one fortieth as effective as the difference in the depth to which the daily heating and cooling penetrate in land and water.

It would appear from the rough calculations given above that the

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*_Länderk. Forsch., Stuttgart, Festschr. Krebs,_ 1936, p. 353.

daily range of the ground surface should be about 250 times that of the sea instead of only forty or fifty times, as it actually is. The difference is of course due mainly to the fact that outward radiation is proportional to the fourth power of the absolute temperature. The radiation from the sea varies little, but the land radiates far more by day than by night. This enormously decreases the daily range of temperature of the ground surface without greatly affecting that over the sea.

C. E. P. Brooks.

Wave Motion in the Upper Air

Many examples of periodic wave motion in the atmosphere recorded on anemograms and barograms have been examined and described by various writers* but no upper air data have usually been available at the actual time and place of the occurrence.

An occurrence of definite and regular wave motion on the anemometer record was noticed at Abbotsinch on the morning of November 16th, 1936, and several pilot balloon ascents were made to note what changes, if any, occurred in the upper air. Balloons with tails attached, and with a normal lift of 500 ft. per minute were released at frequent intervals and, as far as possible at the crests and troughs of waves as recorded by the anemometer. The oscillations were also well marked on the record of the anemometer at Coats Observatory, Paisley, which is situated about two miles due south of the anemometer at Abbotsinch aerodrome. The times of occurrence of the oscillations were almost identical at the two stations as shown in Table I.

The wave motion became apparent at 1h. 30m. and continued until the early afternoon. At first the time gap between wave crests was approximately one hour but this period decreased progressively to 40, 30 and finally about 20 minutes, gradually damping out and finally disappearing about 14h. The oscillations appeared on both the direction and velocity records at Abbotsinch but are well marked on the direction trace only, at Coats Observatory. Generally speaking the crests and troughs of the waves correspond on both the velocity and direction records.

Wave motion was also apparent on both the barogram and hygrogram, although on the former the oscillations were small. Those on the hygrogram were well marked and coincided with those on the anemogram on most occasions. No fluctuations in temperature were apparent on the thermogram which is in agreement with the

*Shaw, Sir Napier; Manual of Meteorology, Vol. III, pp. 28–31 (Fig. 12). Gold, E.; Wind in Britain (Fig. 26). *London Quart. J. R. met. Soc.* 62, 1936, p. 167. Goldie, A. H. R.; *London Quart. J. R. met. Soc.* 51, 1925, p. 239. Ley, C. H.; *London Quart. J. R. met. Soc.* 37, 1911, p. 33.

opinion expressed by Shaw in the "Manual of Meteorology," Vol. III, p. 28.

A photograph of the anemogram for the day in question is shown in Fig. 1 which forms the frontispiece to this number of the magazine. Table I gives the time of occurrence of the crests of the waves as shown by the two anemometers and the hygrogram.

TABLE I.—TIMES OF WAVE CRESTS

Abbotsinch.			Coats Observatory, Paisley.
Anemometer.		Hygrogram.	Anemometer.
Velocity. h. m.	Direction. h. m.	h. m.	Direction. h. m.
1 30	...	1 15	1 30
2 45	2 45	1 50	1 50
3 50	3 30	2 45	2 45
4 50	4 00	3 50	3 30
5 50	6 10	...	4 50
6 55	...	6 50	—
7 30 (small)	7 20	7 20	7 10
8 00	8 05	7 50	7 55
8 45	8 45	8 40	8 40
9 25	9 25	9 20	9 15
...	10 00	10 10	9 50
10 30	10 30	10 30	10 25
11 05	11 00	11 00	10 55
11 35	11 35	11 35	11 25
12 00	11 55	12 10	11 50
...	12 35	...	12 15
...	12 55	...	12 35
13 00	13 10	13 10	12 50
...	...	...	13 10
13 30	13 30	13 35	13 20
13 45	13 45	...	13 55
14 05	...	...	...

The balloons were released as detailed below :—

No. 1 released at 11h. 7m. at crest of wave on anemometer.
No. 2 „ 11h. 22m. at trough „ „ „
No. 3 „ 11h. 39m. at crest „ „ „
No. 4 „ 11h. 47m. at trough „ „ „
No. 5 „ 11h. 58m. at crest „ „ „
No. 6 „ 12h. 47m. at crest „ „ „
No. 7 „ 13h. 45m. at crest „ „ „

The chief feature found in the results of the pilot balloon ascents is the variation in the rate of ascent, see Table II. Each ascent shows the existence of alternating phases of upward and downward vertical currents. In No. 1 ascent a mean up current of 135 ft./min. existed to a height of 3,200 ft. followed by a down current of 235 ft./min. between 3,200 ft. and 3,800 ft. and then between 3,800 ft. and 4,300 ft. an up current of 100 ft./min. Each of the ascents showed similar characteristics but in successive ascents the upward and

TABLE II.—VERTICAL VELOCITY OF THE BALLOONS

Time	No. 1, Crest		No. 2, Trough		No. 3, Crest		No. 4, Trough		No. 5, Crest		No. 6, Crest		No. 7, Crest	
	Height	Vertical Velocity	Height	Vertical Velocity	Height	Vertical Velocity	Height	Vertical Velocity	Height	Vertical Velocity	Height	Vertical Velocity	Height	Vertical Velocity
min.	ft.	ft./min.	ft.	ft./min.	ft.	ft./min.	ft.	ft./min.	ft.	ft./min.	ft.	ft./min.	ft.	ft./min.
1	485	− 15	425	− 75	565	+ 65	450	− 50	595	+ 95	620	+ 120	560	+ 60
2	1,100	+ 115	850	− 75	1,270	+ 205	910	− 40	1,210	+ 115	1,230	+ 110	1,080	+ 20
3	1,670	+ 70	1,300	− 50	1,830	+ 60	1,050	− 360	1,860	+ 150	1,740	+ 10	1,620	+ 40
4	2,400	+ 230	1,750	− 50	2,400	+ 70	1,270	− 280	2,670	+ 310	2,150	− 90	2,230	+ 110
5	3,170	+ 270	...		2,700	− 200	1,500	− 270	3,600	+ 430	2,510	− 140	2,750	+ 20
6	3,460	− 210	...		2,920	− 280	1,830	− 170	4,300	+ 200	3,300	+ 290	3,250	0
7	3,700	− 260	...		3,000	− 420	2,500	+ 170	4,450	− 350	3,500	− 300	3,500	− 250
8	4,300	+ 100	...		...		3,300	+ 300	4,050	− 900	4,000	0	3,800	− 200
9	...		...		...		4,100	+ 300	4,040	− 500	4,300	− 200	4,500	+ 200
10	...		...		...		4,700	+ 100	4,650	+ 110	5,200	+ 400	5,100	+ 100
11	...		...		...		5,100	− 100	5,500	+ 350	6,100	+ 400	5,750	+ 150
12	...		...		...		5,320	− 280	6,200	+ 200	6,800	+ 200	6,450	+ 300
13	...		...		...		5,380	− 440	6,800	+ 100	7,800	+ 500	7,100	+ 150
14	...		...		...		5,500	− 380	7,650	+ 350	8,200	− 100	7,700	+ 100
15	...		...		...		6,100	+ 100	8,500	+ 350	8,300	− 400	8,350	+ 150
16	...		...		...		6,400	− 200	9,100	+ 100	8,500	− 300	8,900	+ 50
17	...		...		...		7,100	+ 200	9,450	− 150	8,800	− 200	9,400	0
18	...		...		...		8,000	+ 400	9,500	− 350	9,700	+ 400	9,800	− 100
19	...		...		...		8,700	+ 200	...		10,300	+ 100	10,200	− 100
20	...		...		...		9,000	− 200	...		...		10,600	− 100
21	...		...		...		...		...		...		11,000	− 100
22	...		...		...		...		...		...		11,500	0
23	...		...		...		...		...		...		12,100	+ 100

downward currents were interchanged. Ascent No. 4 consisted of up and down currents in layers as shown in the following table :—

Surface to 1,800 ft.	down	current	195 ft./min.
1,800 ft. —4,700 ,,	up	,,	220 ,,
4,700 ,, —5,500 ,,	down	,,	300 ,,
5,500 ,, —6,100 ,,	up	,,	100 ,,
6,100 ,, —6,500 ,,	down	,,	200 ,,
6,500 ,, —8,800 ,,	up	,,	270 ,,

From further examination of the results it will be seen that the balloons released at the crests of the waves, as shown on the anemogram, at 11h. 7m. and 11h. 39m. (Ascents Nos. 1 and 3) had an upward vertical motion of about 100 ft./min. (in excess of the normal lift), for the first four minutes, followed by a period in a downward current of 200 to 300 ft./min. (see Table II) whereas those balloons released in troughs of waves, Ascents Nos. 2 and 4, showed the existence of a downward current of about 60 ft./min. for the first four minutes, and 195 ft./min. for the first six minutes respectively. In the latter ascent a descending current of 300 ft./min. was encountered for the 3rd, 4th and 5th minutes followed in the next four minutes by a mean up current of 220 ft./min. These up and down currents were found to exist in the later ascents in layers of varying thickness to heights of between 9,000 ft. and 12,000 ft. at which heights the balloons were either lost or abandoned owing to the tails being indistinguishable.

It is therefore evident that the balloons, instead of proceeding upwards along a straight track equal to a lift of 500 ft./min., followed an undulating path.

From the foregoing remarks we may therefore say that :—

(1) the atmosphere exhibited a periodic wave motion at least up to heights of between 9,000 ft. and 12,000 ft., and

(2) the occurrence of wave crests, as shown by the autographic records at the surface, coincided with an upward current of air in the layers below approximately 2,000 ft., and the wave troughs when down currents existed in the lowest layers.

Table II shows the vertical motion of the balloons for each minute throughout the ascents and discloses the abnormal behaviour of the balloons and the magnitude of the vertical currents. In most cases these currents, up and down, are of the order of 200 to 300 ft./min. but in ascent No. 5 the balloon actually was forced down when at about 4,000 ft., in spite of the 500 ft./min. free lift, showing a descent of 400 ft., in the 8th minute, representing a downward current of 900 ft./min. In four minutes the balloon only ascended 200 ft. instead of 2,000 ft.

The direction of the upper winds (at 2,000 ft.) was very nearly the same in all the results so that the balloons released in the trough of waves, when the surface wind was about 200°, (at 11h. 22m. and 11h. 47m.) veered 90° to 100° between the surface and 2,000 ft.

while those balloons released at crests of waves veered only 20° to 30° in the same period. The results of each balloon ascent are given in Table III.

TABLE III.—PILOT BALLOON RESULTS SHOWING WIND DIRECTION AND VELOCITY FOR THE ASCENTS NOS. 1 TO 7.

Height.	No. 1 Crest.		No. 2 Trough.		No. 3 Crest.		No. 4 Trough.		No. 5 Crest.		No. 6 Crest.		No. 7 Crest.	
ft.	°	m.p.h.	°	m.p.h.	°	m.p.h.	°	m.p.h.	°	m.p.h.	°	m.p.h.	°	m.p.h.
Surface	258	12	193	3	247	6	204	4	265	11	275	6	235	8
1,000	280	19	255	10	263	12	270	15	280	17	250	10	260	13
2,000	290	21	...		273	14	293	26	290	17	285	10	278	11
3,000	291	22	...		287	25	303	23	290	21	290	25	278	17
4,000	294	33	...		...		295	18	292	24	265	13	300	20
5,000	...		...		...		275	21	283	19	250	15	263	11
6,000	...		...		...		290	13	280	17	257	12	250	12
7,000	...		...		...		300	13	300	17	265	13	250	12
8,000	...		...		...		290	17	298	19	270	11	250	16
9,000	...		...		...		...		273	20	280	25	280	20
10,000	...		...		...		...		293	23	285	27	280	20
11,000	...		...		...		...		...		290	33	290	32
12,000	...		...		...		...		...		295	35	287	38
13,000	...		...		...		...		...		290	33	290	31
14,000	...		...		...		...		...		287	37	290	32
15,000	...		...		...		...		...		293	37	285	40
16,000	...		...		...		...		...		...		285	45
17,000	...		...		...		...		...		...		288	54

On the day in question a feeble ridge of high pressure which had formed behind an occlusion, covered Scotland. The sky in the morning was almost clear but gradually became covered with cirrus and cirrostratus. No low cloud existed during the time in which balloon ascents were made. In the early afternoon altocumulus and altostratus began to spread from the west. Nephoscope observations of cirrus cloud showed a general current from west at between 70 and 80 m.p.h.

The occlusion which passed Abbotsinch on the day before, November 15th, at about 10h. was accompanied by a very sudden pressure rise of over 2 mb. and a sharp veer of wind. After the passage of the occlusion squalls occurred at approximately 2-hourly intervals. The period became obliterated temporarily on the anemogram during the night but oscillations continued on the barogram, being superimposed on the fall and subsequent rise. It may be considered that the wave motion really commenced at 10h. on the 15th, with a two-hourly period gradually damping down to a period of one hour early on the 16th. On the 16th, a warm front was advancing northwards over Ireland which accounted for the cirrus cloud and the cirrostratus cloud gradually degenerating, and indicating a lowering of the surface of discontinuity.

R. T. ANDREWS.

OFFICIAL PUBLICATION

The following publication has recently been issued :—

PROFESSIONAL NOTES

No. 76. *The effects of obstacles on sunshine records.* By E. G. Bilham, B.Sc., D.I.C. (M.O. 336p.).

At certain meteorological stations some sunshine is cut off near sunrise and sunset by obstacles such as hills, buildings or trees. The duration of sunshine cut off in this way on a day of uninterrupted sunshine may be calculated from astronomical considerations but information has not hitherto been available in regard to the effect of such a cut-off on the monthly and annual averages. The hourly averages for certain stations with unobstructed horizons have now been employed to evaluate the cut-off due to obstacles of altitudes up to 12 degrees in different latitudes and in the several months of the year. The results show that the loss is small, when reckoned as a percentage of the mean daily duration, for obstacles of the kinds met with in practice. In general, the loss due to an obstacle of stated altitude is smaller in summer than in winter, and is smaller at a southern station such as Falmouth than at a northern station such as Aberdeen.

Correspondence

To the Editor, *Meteorological Magazine*

A "Remarkable" Fall of Rain

I am writing to let you know that in a thunderstorm here at 8·45 p.m. lasting 12½ minutes, we had 1·03 in. of rain. As I left the house to take the measure of the storm a flash of lightning struck and scored a tall Cupressus Lawsonia from top to bottom less than 30 ft. from me. Altogether a very exciting quarter of an hour, on the evening of July 18th.

R. G. W. BUSH

Lingfield House, Lingfield, Surrey, August 7th, 1937.

Thunderstorms at Street, Somerset, July 15th, 1937

At 9 a.m. B.S.T. here on July 15th, a distant rumbling became intermittent in the north and west. A faint flash in the north at 9.30 was followed by others never very bright nor was the thunder loud. Rain began about 9.20 growing torrential by 9.25 and continuing so to about 9.48. Then quickly growing lighter from the south-west, the rain ceased by 9.50 and only a normal cloudiness remained. Some fairly large hailstones fell from 9.40 to 9.43. The total fall was 1·21 in. in the 25 minutes falling almost vertically from about north, a slight wind only blowing; none before. The first downfall quickly flooded the roads but rarely to reach door steps. The aneroidograph had fallen to 29·90 in. (1012·5 mb.) at midnight. Then a very slight "cup" associated with a few heavy drops (only a "trace" to measure) preluded a slightly wavy fall to 29·85 in. (1010·8 mb.) at 8 a.m., when to 8.30 a.m. and again 10.30 to 11.15 a.m. it gave two "cups" of 0·005 in. (0·2 mb.) At 11.20 thunder began again to the west. This soon passed to the north. The more frequent vivid lightning and louder thunder were accompanied by heavy rain though less so than before ten. The thunder ceased about 12.30 and the rain moderated by 12.35 ; 0·82 in. more were measured at 12·45. Later the rate rose again so that the total at 4.15 was 3·20 in. in nearly three hours. The ensuing drizzle brought the 24 hours total 9 a.m. to 9 a.m. to 3·23 in.

The records at seven other stations within about 1 mile radius of Portway confirm this total as they varied from 3·14 in. at Hindhayes, Street, to 3·42 in. at High Street, Street, for the 15th.

J. E. CLARK.

Portway, Street, Somerset, July 22nd, 1937.

Damage by Lightning

The photograph on the opposite page shows the damage caused by lightning to the concrete base of the hatch (flood-gate) on the River Piddle here at Wareham during a storm on the night of May 25th–26th, 1937.

It seems probable that the flash which caused the damage shown in the photograph travelled down the railway metal forming the end of the fence, came in contact with a piece of re-enforcing in the concrete parapet of the aquaduct, and so blew out the concrete. There is no sign of scorch on the fence at this point, and none on the metal of the hatch.

Since taking the photograph we have found that 100 yds. away on the right hand side of the photograph, the top strand of fence wire was cut through for some 10 ft. and that the galvanising of the wire is scorched. An ash tree close to the fence at that point was apparently struck at the same time, as a few of the leaves are burnt and a piece of bark low down on the base of the trunk has been blown out.

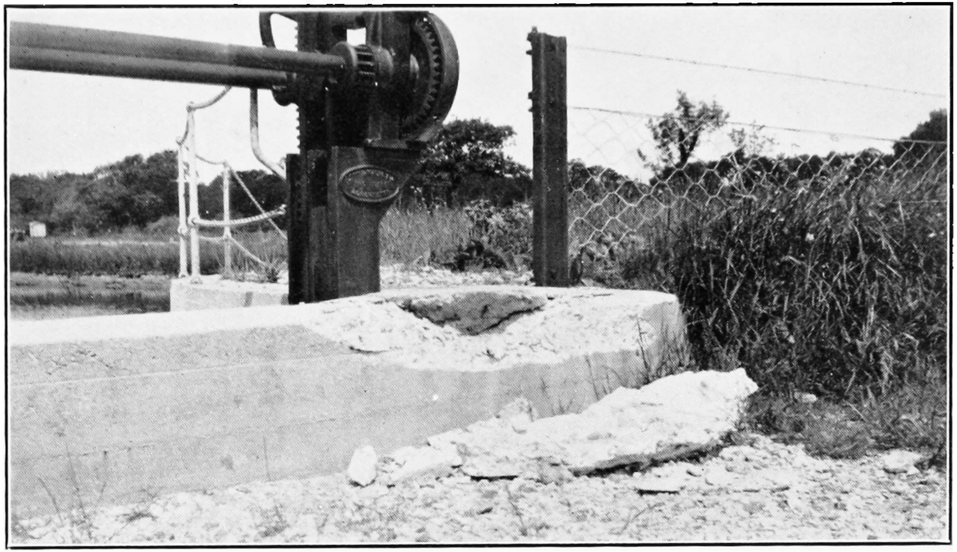
NINA STURDY.

Trigon, Wareham, Dorset, June 8th, 1937.

A Brilliant Fragment of Halo

About 8 p.m., B.S.T., on July 2nd, after a warm sunny day with cumulus, a rapid development of cirrus occurred with patches of cirrostratus. One of the latter as seen from Hampstead was over the sun, and showed a striking development of lines and streaks. Every few minutes a small but very brilliant arc of a halo with prismatic colours appeared in this comparatively dense patch of cirrostratus, and one of these could be seen through the streaks

[facing p. 162



FLOOD-GATE ON THE RIVER PIDDLE, WAREHAM, DAMAGED BY LIGHTNING, MAY 25TH—26TH, 1937.

and fibres. I did not note whether these coloured arcs belonged to the 46° or 22° halo but I can say that the colours showed the halo sequence with red inside, and that they appeared at intervals sometimes on one side of the sun sometimes on the other. Once when this coloured arc appeared it was crossed by the lines in question, but this does not mean that they were causing the colours because on the other occasions the arc was clear.

Later near the edge of the same cloud I noticed a patch of iridescence further complicating the whole set of phenomena.

L. C. W. BONACINA.
15, Christchurch Road, London, N.W.7, July 4th, 1937.

Rain from Altocumulus Clouds

During the four days February 18th to 20th, 1937, showers were experienced at many places in central Sudan. While the occurrence of slight rain over this area during February is not unknown the associated cloud types on the present occasion are a matter of interest.

A cold front orientated roughly north-north-east and south-south-west passed Khartoum during the evening of February 16th. Some cirrostratus cloud had preceded the passage of the front and this persisted with the addition of altocumulus during the night; altocumulus castellatus developed during the early hours of the 17th at Khartoum, but the total amount of cloud did not exceed 6 tenths until the evening of the 17th, when the sky became almost covered with a single layer of dense altocumulus, or high stratocumulus, at about 12,000 ft. This cloud persisted throughout the night and rain, composed of very large drops and having the characteristics of a thunder shower, fell at intervals between 2 a.m. and 4.30 a.m. The intensity of rainfall varied considerably and even though locally in Khartoum the roads became very wet, there was nothing measurable in the rain-gauge.

The sky was three-quarters to almost completely covered with altocumulus, but only a single layer, throughout the rest of the 18th and also for the next three days at an average height of 12,000 ft. During the 18th portions of the cloud exhibited extremely well-defined mammillations.

Observations by aircraft on the 18th confirm that the base of the cloud was at 12,000 ft.; the upper and lower limits of the cloud layer were well-defined and the average thickness of the cloud sheet was 800 ft. It was particularly noted that there were no cumulus heads rising out of the cloud sheet. At the time that the above observations were made precipitation was taking place. Showers were also experienced on each of the three following nights and although a full moon permitted excellent conditions for observing the cloud types no case of altocumulus castellatus was noticed.

It is difficult to understand why there should have been rain from the cloud sheet described since the large drops which fell on all occasions would appear to indicate fairly strong vertical currents.

The upper winds throughout the period were N. to NNE. near the ground and gradually backed to SSW. or S. at about 10,000 ft. with a gradual decrease in speed with height so that the showers may have been connected with the wind distribution in the vertical; on the 21st when no rain occurred the upper winds were very light at all heights and at 10,000 ft. only backed to about WSW.

WILLIAM D. FLOWER.

Meteorological Service, Khartoum, A.E. Sudan, March 20th, 1937.

A Peculiar Cloud Formation

At 10h. 38m. G.M.T. on July 20th, my attention was drawn to a large cumulus cloud about five miles away to west-south-west. Depending from a point on the base of the cloud was a thin sharply defined streak tapering down to a point. The height of the cloud was estimated at between 2,000 and 3,000 ft., and the length of the streak at about 300 ft. The duty pilot reported having watched it for about 20 minutes. We ourselves watched it for four minutes, during which time it did not appear to alter in any way. At 10h. 42m. however, it commenced to disappear from the bottom end, and vanished within two seconds. It did not appear to disperse, but rather to shorten rapidly.

A. ERIC MAYERS.

Meteorological Station, R.A.F., Driffield, Yorkshire, July 28th, 1937.

NOTES AND QUERIES

Agricultural Meteorology in India

The close dependence of plant growth on climate has long been recognised. In recent years attention has been directed towards the details of this relation. The so-called microclimate—the meteorological conditions within and immediately around a growing crop—has been investigated; statistical relationships between weather and crop yield have been sought in connexion with crop forecasts; and some study has been made of radiation and moisture exchange between soil and atmosphere.

For the past five years the Agricultural Meteorological Branch of the India Meteorological Department, under the Director-General, Dr. C. W. B. Normand, has vigorously developed these lines of work, both independently and in collaboration with the Agricultural Departments. The results have been published in the Departmental Reports, in the *Proceedings of the Indian Academy of Science*, in *Current Science* and elsewhere. They range from a preliminary statistical study of the influence of weather and prices on the area sown to cotton in the Bombay Presidency, to the moisture relationships between the soil and the adjacent air. Considerable attention is being given to the border-line between meteorology and soil physics : heat convection from the ground to the air ; short-period variations in nocturnal radiation from the sky ; the factors controlling soil temperature and moisture content ; all of these are the subject of published papers.

Among the interesting points brought out is the small depth of soil that is affected by the diurnal evaporation and condensation of moisture. Samples taken under field conditions at Poona showed no diurnal variation in moisture content even 1 inch below the surface. This result is, of course, in harmony with recent physical work on the movement of soil moisture, which shows that the soil water is relatively static. Water in excess of a certain moisture content (whose value is fairly characteristic of each soil type) percolates to lower levels ; while loss of moisture occurs primarily by evaporation *in situ* into the pore-spaces and thence by diffusion into the atmosphere, and there is little or no movement towards the depleted area of water from the adjacent areas to replace the loss.

Soil temperature, on the other hand, seems to be more responsive to soil type. A preliminary report is given of an experiment in which marked changes of temperature were caused by covering the local Poona soil with very thin layers of other soils and substances so as to obtain white, black and coloured surfaces.

Although much of the work of the Branch is necessarily of a preliminary nature, definite progress has been made in applying the methods to agricultural problems which, in India, are intimately connected with the date of the monsoon and its intensity.

B. A. KEEN.

Construction of Thermometer Screens

For the benefit of meteorological observers who wish to make their thermometer screens themselves, or have them made by a local carpenter, the Meteorological Office, Air Ministry, has revised an illustrated pamphlet that contains the necessary information. It retains the number of a former pamphlet (Form 63) of a similar character now out of print, but the title has been changed to " Instructions for making Thermometer Screens of the Stevenson type". The types of screen dealt with are the standard, which takes maximum, minimum, dry- and wet-bulb thermometers, the modified form of this to take a thermograph and hygrograph instead of the thermometer, the large type designed to hold the four thermometers as well as the thermograph and hygrograph, and lastly the small screen for housing four thermometers of the sheathed type only, in a horizontal position as described by Mr. E. G. Bilham in the *Quarterly Journal of the Royal Meteorological Society* for July, 1937, p. 309. Screens for use at sea are not included in this pamphlet. Constructional details are also given of both wooden and steel stands for the various screens. A new feature is the inclusion of a list of materials required for each item. The price is 6*d*., and the pamphlet can be obtained through any bookseller or from H.M. Stationery Office, Adastral House, Kingsway, London, W.C.2.

Frosts in Spring, Summer and early Autumn

The table below shows the average number of days with a minimum temperature of 32° F. or lower, in the screen, for each month from April to October at representative stations. The table was prepared in order to comply with a Resolution of the International Meteorological Committee, and acknowledgments are due to the local observers who were good enough to extract the data from their own past records.

AVERAGE NUMBER OF DAYS WITH MINIMUM TEMPERATURE 0° C. (32° F.) OR BELOW AT REPRESENTATIVE STATIONS.
April–October, 1901–25

	Latitude. (North)	Longitude.	Height above M.S.L.	April	May	June	July	Aug.	Sept	Oct.
			ft.							
Aberdeen ...	57° 10′	2° 6′W	37	4·0	0·5	0	0	0	0	1·5
Eskdalemuir*	55° 19′	3° 12′W	794	13·8	5·0	0·5	0	0·3	2·1	6·1
Durham ...	54° 46′	1° 35′W	336	7·0	1·4	0·2	0	0	0·2	2·6
Rothamsted	51° 48′	0° 22′W	420	6·8	1·0	0	0	0	0·3	2·5
Oxford (Radcliffe Observatory) ...	51° 46′	1° 16′W	208	4·0	0·3	0	0	0	0	1·8
Birmingham (Edgbaston)	52° 29′	1° 56′W	535	3·4	0	0	0	0	0	0·3
Greenwich (Royal Observatory)	51° 29′	0° 00	149	3·1	0·2	0	0	0	0	1·1
Kew Observatory ...	51° 28′	0° 19′W	18	2·6	0	0	0	0	0·1	1·0
Eastbourne...	50° 46′	0° 14′E	35	1·6	0	0	0	0	0	0·2
Totland Bay	50° 41′	1° 33′W	140	1·1	0	0	0	0	0	0·2
Stonyhurst...	53° 51′	2° 28′W	377	3·8	0·7	0	0	0	0	1·2
Liverpool (Bidston)	53° 24′	3° 4′W	198	1·0	0	0	0	0	0	0
Southport ...	53° 37′	3° 0′W	35	2·8	0·3	0	0	0	0	0·8
Newquay ...	50° 25′	5° 4′W	190	0·8	0	0	0	0	0	0
Armagh ...	54° 21′	6° 39′W	204	4·7	0·5	0	0	0	0	1·8
Valentia Observatory...	51° 56′	10° 15′W	30	0·3	0	0	0	0	0	0·2

* 1911–1925.

In considering the data it is necessary to remember (*a*) that the figures refer to the period 1901–25, specified in the Resolution, and (*b*) that the averages are expressed only to the nearest 0·1 of a day.

The occurrence of one reading of 32° F. or lower in a particular month during the 25-year period would give an average of ·04, which would be rounded off to "0" in the table. During the period considered one frost was registered at Oxford in September, at Edgbaston in May, at Kew in May, at Stonyhurst in June and at Bidston in October. The only station where no frost occurred in any month from May to October was Newquay, Cornwall.

REVIEWS

Forests and Floods in New Hampshire by Dr. Henry I. Baldwin and Dr. Charles F. Brooks. Publication No. 47, New England Regional Planning Commission, Boston, Mass., December, 1936.

New Hampshire, sloping down from hills in the west to the Atlantic coast, is liable to disastrous floods, especially in spring, when heavy rain combines with the rapid melting of the winter snow to pour great quantities of water into the rivers. For example on March 9th–21st, 1936, in the Mount Washington region a rainfall of 14 to 22 inches and 6 to 10 inches of melted snow combined to make totals up to 30 inches of water, giving the greatest flood of the century.

It has long been known that forests have the property of holding up water and so making the flow of rivers more even, but Dr. Baldwin and Dr. C. F. Brooks in this detailed investigation add precision to the qualitative statement. Forests intercept both snow and rain, and some of the intercepted precipitation is evaporated without reaching the ground. More important is their effect in preserving the snow cover by sheltering it from wind and sun, for a layer of snow can hold up almost its own volume of rain-water. The more absorbent soil of the forest and the layer of litter also help to hold water. Evergreens, especially spruce and fir, are naturally more effective than deciduous trees, but they are also the most valuable lumber and the first to be cut. Thus there is a tendency for the protective effects of the forests to diminish and the authors advise a programme of conservation or re-afforestation of critical areas, which though costly would be much less so than the construction of flood-control reservoirs.

C. E. P. BROOKS.

The Physical State of the Upper Atmosphere. By B. Haurwitz. Reprinted from the Journal of the Royal Astronomical Society of Canada, October, 1936–February, 1937.

By the use of aircraft, sounding balloons and pilot balloons we have obtained a fairly comprehensive knowledge of the mean state of the atmosphere up to a height of about 30 kilometres. Of conditions above this height we know comparatively little and of that little much is still rather speculative. Although we are, at present, unable to send instruments to these greater heights there is a variety of phenomena which provide data for inferences and deductions concerning some of the characteristics of that part of the atmosphere beyond our reach. Observations of this type are being made almost daily in one form or another to augment our knowledge. Probably owing to the rapid way in which our knowledge of the higher levels is changing the ordinary textbook of meteorology has comparatively little to say about these inaccessible regions and most of the information is to be found only in the publications of scientific societies and the like. Thus the author of this little book has performed a very useful service in rendering this knowledge more accessible.

The book is based upon a series of eight public lectures delivered in April, 1936, and which formed a survey of the then extant knowledge of the upper atmosphere. The first nine chapters deal with the Troposphere and Stratosphere, Mother-of-Pearl and Noctilucent Clouds, Meteors, the Light of the Night Sky, Propagation of Electric Waves and Ionization, the Diurnal Variations of Terrestrial Magnetism, the Aurora, Ozone, and Anomalous Propagation of Sound. The tenth and last chapter suggests the probable composition and structure of the atmosphere up to about 200 Km. in the light of the evidence available.

In dealing with each of the subjects mentioned above the author gives a brief survey of the present knowledge on the subject and also shows what deductions may be made therefrom about the physical state of the upper atmosphere. For example in the chapter on the "Diurnal Variations of Terrestrial Magnetism" we are told that these variations must be considered as magnetic effects of current systems above the earth. The "dynamo" theory of Schuster and Chapman which purports to explain these currents is outlined, some supporting evidence is given and some of the difficulties are mentioned. The drift-current theory is also briefly described and the author concludes that the evidence is as yet insufficient to decide between the two theories.

The specialist in his own subject will, perhaps, find little of interest but the scientific inquirer who is venturing into more or less unfamiliar regions will find an admirable digest, not sufficiently detailed to discourage but containing nevertheless most of the essential facts as we know them to-day. Finally, for the reader who is sufficiently attracted to wish to delve deeper into the subject and examine the evidence for himself there is an excellent bibliography of nearly 130 articles, papers or books.

A. C. Best.

British Health Resorts, Spa, Seaside, Inland, including Australia, Canada, Cyprus, New Zealand, South Africa and British West Indies. Official Handbook of the British Health Resorts Association. Size $9\frac{3}{4}$ in. × $6\frac{1}{4}$ in., pp. 288. *Illus.* London, 1937, 2*s.* 6*d.* net.

While keeping the plan of the book essentially the same, the fifth edition of this Handbook has been enlarged by the addition of one or two new features. Amongst them may be noted a valuable chapter on climatology by L. C. W. Bonacina. On p. 148 will be found a synopsis of the " attractions " offered by British Resorts during the invalids' winter. New information is given in a condensed form as regards the sunshine and rainfall in many resorts; the latter is divided into the fall during the day and during the night—an important factor from the visitors' point of view. Cyprus is included as a health resort for the first time; its role as a summer hill station in the near East and as a winter resort for English travellers should give it a double qualification as a place of recovery.

The whole of the material has again been carefully revised by a sub-committee of the Association with the object of making the book indispensable for the doctor advising his patients where best to seek the change of air they need and for the intelligent layman seeking a suitable place for temporary or permanent residence.

Unfortunately the price of the handbook this year is more than double last year's being now 2*s*. 6*d*. A more attractive cover might increase its popularity.

BOOKS RECEIVED

Royal Alfred Observatory, Mauritius. Annual Report, 1935. Results of magnetical and meteorological observations for March to December, 1935, and January to May, 1936. Port Louis, 1936 and 1937.

Boletin de Agricultura Suplements de Meteorologia. Bogota, 1934.

Liquid-propellant rocket development. By R. H. Goddard. Smithson, Misc. Coll. Vol. 95, No. 3, Washington, D.C., 1936.

OBITUARY

Mungo McCallum Fairgrieve, M.A., F.R.S.E.—The death took place in Edinburgh on August 4th of Mr. M. McC. Fairgrieve, who was formerly the head of the Science Department of Edinburgh Academy. He collaborated with his colleague, the late J. Tudor Cundall, in the writing of scientific text-books which were in use at the Academy. In 1915, he set up a rainfall station at the Academy and for 20 years sent copies of the observations for inclusion in the annual volumes of *British Rainfall.* He was elected a Fellow of the Scottish Meteorological Society in 1909 and of the Royal Society of Edinburgh in 1910, and contributed papers to both. After the amalgamation of the Scottish Meteorological Society with the Royal Meteorological Society he continued his Fellowship and served as Secretary in the years 1934–6. A few years ago Mr. Fairgrieve was involved in a motor accident resulting in the loss of a leg. He made a remarkable recovery but the injury had a weakening effect on his health and two years ago he had a breakdown from which he never fully recovered.

NEWS IN BRIEF

We learn that the honorary degree of doctor of science has been conferred upon Sir Napier Shaw by the University of Athens in connexion with the University's centenary celebrations.

The Senate of the University of London has conferred the degree of B.Sc. (Engineering) on Mr. W. M. James, Technical Assistant III of the Marine Division.

ERRATUM

JULY 1937, p. 147, line 19, *for* "4th" *read* "5th".

The Weather of July, 1937

An area of low pressure extended from Greenland across northern and central Europe to western Asia with a centre below 1010 mb. over Iceland and another centre below 1000 mb. over Iraq, while an area of high pressure above 1020 mb. extended over the southern North Atlantic and a second high pressure area (above 1015 mb.) lay over Spitsbergen and north-west Siberia. Pressure was slightly below normal over the North Atlantic and southern and eastern Europe and above normal over most of north-west Europe and Bear Island where the excess amounted to 6 mb.

Mean temperature was below 40° F. in north Greenland, Franz Josef Land and the north of Novaya Zemlya and between 40° and 50° F. from south Greenland across Spitsbergen to the Arctic coasts of Russia. The 60° F. isotherm passed south of Ireland across north England and then followed the Norwegian coast until just south of Tromso, where it turned eastwards and extended across the White Sea. Most of southern Europe, south Russia and the western Mediterranean was between 70° and 80° F. and from the Black Sea temperature increased south-eastwards to the Persian Gulf where 100° F. was exceeded. Temperature was above normal over Europe, south-west Asia and the Nile Valley with the exception of a narrow belt below normal extending from Italy across Czecho-Slovakia to Lithuania and central Russia and an area over the southern British Isles and eastern Scotland. Temperature was as much as 5° F. above normal in northern Scandinavia and the Persian Gulf.

Rainfall was between 1 and 2 in. over north and south Russia, Scandinavia, France and west Germany increasing to 3–4 in. over east Germany, Czecho-Slovakia and to 4–5 in. over central Russia, while no rain fell generally over the Mediterranean and Iraq. Rainfall was mainly below normal in Europe and Iraq except in parts of Sweden, Germany, Czecho-Slovakia and Estonia. At Båstad, Skåne (Sweden) 6·26 in. of rain fell on the 27th, the greatest amount ever measured in 24 hours in Sweden.

The main characteristics of the weather of July over the British Isles were the deficiency of sunshine, the heavy rain accompanying some of the thunderstorms, maximum temperatures often below normal and the frequency of fog off the south-west coasts. A new low July record for sunshine was set up at Cranwell where the month's total was 93 hours less than the average and the previous low record was equalled at Lympne for observations subsequent to 1920 at both stations. Rainfall totals were variable except in southern Ireland where Valentia recorded the wettest July since 1866. Light to moderate westerly winds backing SW. to S. prevailed generally on the 1st and 2nd with considerable sun in the south and east but rain generally in the west and north, becoming heavy in Ireland—2·20 in. at Valentia and 1·83 in. at Omagh (Co. Tyrone)—on the 2nd, and in south Scotland on the 3rd. Thunderstorms were reported locally in northern England on the 3rd and in south Scotland on the 4th. Thick morning mist or fog occurred off the south-west coasts on the 1st and 2nd. In the south and east temperature rose above 70° F. on the 2nd and above 80° F. with over 10 hrs. bright sunshine on the 3rd ; 87° F. was recorded in London and 86° F. at Deal, and 14·1 hrs. sunshine at Gorleston on that day. With the change to northerly winds in the rear of the depression centred over north England maximum temperatures in the south and east were about 20° F. lower on the 4th than on the previous day, Deal 65° F. From then to the 13th depressions moving north-east from the Atlantic brought generally cool unsettled weather with frequent rain and not much sun except on odd days, while morning mist or fog was experienced off the south-west coasts. A thunderstorm occurred at Edinburgh on the 7th; Scotland, east England and the Midlands had further storms on the 9th and the eastern counties again on the 10th. From the 13th to 15th, while a complex depression passed across the country from the Atlantic, another depression moved north from France. Temperature rose generally in England and east Scotland on the 13th and exceeded 80° in the south and east on the 14th and 15th. A severe and extensive series of thunderstorms developed in south and central Ireland on the 14th ; the storms crossed England during the 15th reaching the east coast during the night. Exceptionally heavy rain accompanied these storms and caused flooding in several places, the heaviest falls being chiefly in Lincolnshire and Somerset ; 5·46 in. at Boston (Lincolnshire) ; 4·19 in. at Pensford (Somerset) ; 3·94 in. at Angersleigh (Somerset) in 10¼ hrs. from 6.45 a.m. to 5 p.m. ; 3·70 in. at Glentham (Lincolnshire) ; and at Lincoln 1·70 in. of the total of 2·65 in. fell in ½ hr. from 6 to 6.30 p.m.* A ridge of high pressure following these depressions brought sunny but somewhat cooler weather to Scotland and Ireland on the 15th, to the whole country on the 16th and to the east on the 17th ; 15·0 hrs. bright sunshine were recorded at Bath on the 16th and 14·9 hrs. at Margate and Aberdeen on the 17th. On the 18th and

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* See also p. 161.

19th temperature was again high, reaching 79° F. at Tunbridge Wells on the 18th and Norwich on the 19th. Thunderstorms were experienced in south and east England and the Midlands on both these days. At Edenbridge (Kent) during the thunderstorm 1·40 in. of rain fell in 25 minutes from 8.45 to 9.10 p.m. on the 19th.* Morning mist or fog occurred off the south-west coasts from the 13th to 21st and occasionally locally on other coasts. From the 19th to 25th a complex area of low pressure passed across the country giving cool unsettled weather with rain most days but some sun. The 20th and 24th, however, were dry sunny days in the south. On the 25th an anticyclone over the Atlantic was spreading eastwards over the British Isles and from then to the 30th pressure was high over the country. Slight rain occurred over Scotland and Ireland on the 27th, but generally until the 30th the weather was dry and cool with little sun except in isolated districts, mainly in Scotland and later also in Wales. The 30th was a sunnier day generally, and the 31st was dry, warm and sunny with, however, much morning mist or fog. Thunderstorms occurred in east England on the 24th and in south Scotland on the 27th. The distribution of bright sunshine for the month was as follows:—

	Total (hrs.)	Diff. from normal (hrs.)		Total (hrs.)	Diff. from normal (hrs.)
Stornoway ...	103	−42	Chester ...	140	−33
Aberdeen ...	127	−25	Ross-on-Wye ...	126	−66
Dublin	130	−40	Falmouth ...	180	−37
Birr Castle ...	101	−48	Gorleston ...	153	−58
Valentia... ...	97	—60	Kew	135	−59

Kew, Temperature, Mean 63·7° F., Diff. from normal — 0·8° F.

Miscellaneous notes on weather abroad culled from various sources.

A storm did much damage north of Valenciennes (Nord) on the 10th, and several people were injured. A violent hailstorm over Ferrara (Emilia) and the surrounding district on the 26th caused much damage to crops, etc., and injured 6 people. Dense fog occurred near Catalan Bay about the 23rd. Severe thunderstorms were experienced in northern Italy and the Riviera on the 31st and August 1st, with a subsequent fall of temperature; many cellars were flooded (*The Times*, July 7th–August 2nd).

A violent storm lasting two days occurred on Lake Molro on the eastern border of the Belgian Congo about the middle of the month—several waterspouts were observed (*The Times*, July 27th).

During a gale off the north-west coasts of Australia early in the month the mother ship of the Japanese pearling fleet sank off the mouth of Liverpool River. The total rainfall for the month in Australia was below normal except in parts of Queensland and Tasmania (Cable and *The Times*, July 10th).

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* See also p. 161.

In the United States temperature was generally above normal, except in the eastern and central States at the beginning of the month and in the south-eastern States at the end of the month; rainfall was mainly below normal. A heat-wave crossed Canada about the 6th to 12th, and about the 14th the long-continued drought in Canada was broken when heavy rain fell generally (*The Times*, July 7th–16th and *Washington D.C., U.S. Dept. Agric., Weekly Weather and Crop Bulletin*).

Daily Readings at Kew Observatory, July, 1937

Date	Pressure, M.S.L. 13h.	Wind, Dir., Force 13h.	Temp. Min.	Temp. Max.	Rel. Hum. 13h.	Rain.	Sun.	REMARKS. (see vol. 69, 1934, p. 1).
	mb.		°F.	°F.	%	in.	hrs.	
1	1018·8	W.3	60	73	65	—	6·1	pr_0 12h.–13h.
2	1019·0	SSW.2	62	77	62	—	2·5	
3	1012·0	SSE.4	63	82	54	—	9·8	
4	1018·2	SW.4	60	64	66	—	0·0	
5	1021·0	SW.3	51	70	58	—	3·4	
6	1014·6	S.3	55	67	77	0·10	0·1	r_0 4h.–7h., 20h.–21h.
7	1013·9	WNW.3	59	68	63	—	4·4	
8	1021·4	SW.2	53	69	47	—	11·3	
9	1015·2	SSW.4	55	64	75	0·04	0·9	r 12h.–14h.
10	1014·1	WNW.4	54	65	56	0·04	2·7	pr morning.
11	1018·6	SW.3	52	69	59	0·02	6·3	d 20h.–23h.
12	1016·0	SSW.1	59	69	81	0·02	0·0	r_0–r 9h.–10h.
13	1017·1	W.3	64	76	66	—	7·4	
14	1014·7	S.3	59	79	56	—	10·8	
15	1004·7	S.2	61	81	66	0·10	3·7	tlr 15h., r_0 18h.–22h.
16	1015·7	W.4	57	73	47	0·03	12·6	r–r_0 2h.–5h.
17	1023·5	SSW.3	54	72	65	—	1·9	w early.
18	1023·1	SW.2	60	78	62	—	2·0	
19	1019·8	WSW.2	60	75	70	0·50	0·8	TLR 18h.–19h., R [20h.
20	1019·9	NNW.2	55	73	55	—	9·4	
21	1012·0	SW,4	59	71	58	0·06	2·5	r_0–r 14h.–15h.
22	1011·8	W.4	55	65	51	—	4·6	
23	1006·8	SSW.4	55	70	88	0·04	3·3	d_0 5h.–8h., id_0 to 13h.
24	1008·3	WSW.3	52	69	52	—	8·3	
25	1012·1	W.3	56	66	65	—	2·2	
26	1018·2	WNW.2	57	66	63	—	0·7	
27	1019·1	WSW.2	57	64	59	—	0·0	
28	1017·2	NNE.3	55	67	57	—	5·3	
29	1015·8	NNE·2	54	70	55	—	6·4	
30	1016·5	ENE.3	51	66	70	—	0·2	
31	1019·2	NE.3	56	67	70	—	5·6	
*	1016·1	—	57	70	63	0·95	4·4	* Means or Totals.

General Rainfall for July, 1937

England and Wales ...	84	per cent of the average 1881–1915.
Scotland	126	
Ireland	141	
British Isles	109	

Rainfall : July, 1937 : England and Wales

Co.	Station.	In.	Per cent of Av.	Co.	Station.	In.	Per cent of Av.
Lond .	Camden Square..........	·53	22	*War* .	Birminghm, Edgbaston	2·74	118
Sur .	Reigate, Wray Pk. Rd..	1·37	61	*Leics* .	Thornton Reservoir ...	3·26	131
Kent .	Tenterden, Ashenden...	·84	40	,, .	Belvoir Castle............	5·59	230
,, .	Folkestone, Boro. San.	1·77	...	*Rut* .	Ridlington	1·98	79
,, .	Margate, Cliftonville....	·77	39	*Lincs* .	Boston, Skirbeck.........	7.37	335
,, .	Eden'bdg., Falconhurst	2·20	96	,, .	Cranwell Aerodrome...	2·89	124
Sus .	Compton, Compton Ho.	1·73	61	,, .	Skegness, Marine Gdns.	1·71	78
,, .	Patching Farm..........	1·62	67	,, .	Louth, Westgate.........	1·72	69
,, .	Eastbourne, Wil. Sq....	1·42	65	,, .	Brigg, Wrawby St.......	2·88	...
Hants.	Ventnor, Roy.Nat.Hos.	1·57	78	*Notts* .	Worksop, Hodsock......	2·27	100
,, .	Fordingbridge, Oaklnds	1·86	93	*Derby*.	Derby, The Arboretum	2·83	115
,, .	Ovington Rectory.......	1·02	40	,, .	Buxton, Terrace Slopes	3·66	93
,, .	Sherborne St. John......	·98	44	*Ches* .	Bidston Obsy.............	1·56	60
Herts .	Royston, Therfield Rec.	3·62	144	*Lancs*.	Manchester, Whit. Pk.	2·19	66
Bucks.	Slough, Upton............	1·22	64	,, .	Stonyhurst College......	2·15	56
,, .	H. Wycombe, Flackwell	1·83	91	,, .	Southport, Bedford Pk.	1·89	66
Oxf .	Oxford, Radcliffe.........	1·38	58	,, .	Ulverston, Poaka Beck	3·32	73
N'hant	Wellingboro, Swanspool	1·71	75	,, .	Lancaster, Greg Obsy.	2·30	66
,, .	Oundle	1·60	...	,, .	Blackpool	1·97	67
Beds .	Woburn, Exptl. Farm...	1·21	54	*Yorks*.	Wath-upon-Dearne......	2·69	107
Cam .	Cambridge, Bot. Gdns.	1·98	92	,, .	Wakefield, Clarence Pk.	2·59	102
,, .	March.......................	1·98	83	,, .	Oughtershaw Hall.......	3·17	...
Essex.	Chelmsford, County Gdns	1·73	81	,, .	Wetherby, Ribston H..	...	...
,, .	Lexden Hill House......	·91	...	,, .	Hull, Pearson Park......	2·64	113
Suff .	Haughley House.........	1·11	...	,, .	Holme-on-Spalding......	1·61	62
,, .	Rendlesham Hall........	1·30	56	,, .	West Witton, Ivy Ho.	1·91	73
,, .	Lowestoft Sec. School...	1·67	74	,, .	Felixkirk, Mt. St. John.	1·26	46
,, .	Bury St. Ed., WestleyH.	1·81	72	,, .	York, Museum Gdns....	1·75	69
Norf. .	Wells, Holkham Hall...	2·80	121	,, .	Pickering, Hungate......	1·56	58
Wilts .	Porton, W.D. Exp'l. Stn	1·08	55	,, .	Scarborough..............	2·06	85
,, .	Bishops Cannings........	1·78	71	,, .	Middlesbrough...........	1·04	41
Dor .	Weymouth, Westham.	4·47	248	,, .	Baldersdale, Hury Res.	1·74	54
,, .	Beaminster, East St....	3·39	130	*Durh* .	Ushaw College............	2·59	93
,, .	Shaftesbury, Abbey Ho.	2·71	105	*Nor* .	Newcastle, Leazes Pk...	2·64	103
Devon.	Plymouth, The Hoe....	1·78	65	,, .	Bellingham, Highgreen	2·64	80
,, .	Holne, Church Pk. Cott.	1·54	43	,, .	Lilburn Tower Gdns....	2·55	103
,, .	Teignmouth, Den Gdns.	1·32	57	*Cumb*.	Carlisle, Scaleby Hall...	2·63	80
,, .	Cullompton	2·53	94	,, .	Borrowdale, Seathwaite	7·75	98
,, .	Sidmouth, U.D.C........	2·64	...	,, .	Thirlmere, Dale Head H.	4·12	71
,, .	Barnstaple, N. Dev.Ath	3·07	114	,, .	Keswick, High Hill......	2·95	77
,, .	Dartm'r, Cranmere Pool	4·40	...	*West* .	Appleby, Castle Bank...	2·89	91
,, .	Okehampton, Uplands.	2·19	68	*Mon* .	Abergavenny, Larchf'd	3·93	158
Corn .	Redruth, Trewirgie......	1·87	61	*Glam* .	Ystalyfera, Wern Ho....	3·69	80
,, .	Penzance, Morrab Gdns.	1·61	59	,, .	Treherbert, Tynywaun.	4·05	...
,, .	St. Austell, Trevarna...	2·15	64	,, .	Cardiff, Penylan..........	3·12	101
Soms .	Chewton Mendip.........	3·89	111	*Carm* .	Carmarthen, M. & P. Sch.	...	...
,, .	Long Ashton............	3·99	141	*Pemb* .	St. Ann's Hd, C. Gd. Stn.	3·12	126
,, .	Street, Millfield..........	5·27	...	*Card* .	Aberystwyth	3·13	...
Glos .	Blockley	2·67	...	*Rad* .	BirmW.W.Tyrmynydd	2·86	70
,, .	Cirencester, Gwynfa....	2·39	93	*Mont* .	Lake Vyrnwy	3·37	98
Here .	Ross-on-Wye.............	3·41	150	*Flint* .	Sealand Aerodrome......	1·42	...
Salop.	Church Stretton.........	2·63	107	*Mer* .	Blaenau Festiniog	5·16	66
,, .	Shifnal, Hatton Grange	3·45	153	,, .	Dolgelley, Bontddu......	3·25	76
,, .	Cheswardine Hall........	3·44	127	*Carn* .	Llandudno	·94	42
Worc .	Malvern, Free Library...	2·78	122	,, .	Snowdon, L. Llydaw 9..	9·95	...
,, .	Ombersley, Holt Lock.	2·52	118	*Ang* .	Holyhead, Salt Island...	2·18	84
War .	Alcester, Ragley Hall...	3·55	149	,, .	Lligwy	1·94	...

Rainfall : July, 1937 : Scotland and Ireland

Co.	Station.	In.	Per cent of Av.	Co.	Station.	In.	Per cent of Av.
I. Man	Douglas, Boro' Cem....	4·20	137	*R&C* .	Achnashellach	3·81	74
Guern.	St.Peter P't.Grange Rd.	1·78	88	„ .	Stornoway,C.GuardStn.	1·60	...
Wig .	Pt. William, Monreith.	5·56	198	*Suth* .	Lairg......................	3·37	108
„ .	New Luce School.........	4·67	137	„ .	Tongue	...	...
Kirk .	Dalry, Glendarroch......	5·26	147	„ .	Melvich....................	3·36	120
Dumf.	Dumfries, Crichton R.I.	3·18	103	„ .	Loch More, Achfary....	3·83	72
„ .	Eskdalemuir Obs........	4·48	109	*Caith* .	Wick.......................	1·96	75
Roxb .	Hawick, Wolfelee........	3·80	123	*Ork* .	Deerness	1·65	64
Peeb .	Stobo Castle..............	4·25	147	*Shet* .	Lerwick	1·46	69
Berw .	Marchmont House......	2·65	87	*Cork* .	Dunmanway Rectory...	...	...
E.Lot.	North Berwick Res.....	3·19	124	„ .	Cork, University Coll...	3·21	118
Midl .	Edinburgh, Blackfd. H.	5·37	190	„ .	Mallow, Longueville....	4·19	167
Lan .	Auchtyfardle	3·87	...	*Kerry*.	Valentia Observatory...	8·77	232
Ayr .	Kilmarnock, Kay Park	5·03	...	„ .	Gearhameen...............	9·80	171
„ .	Girvan, Pinmore.........	3·74	102	„ .	Bally McElligott Rec...	6·48	...
„ .	Glen Afton, Ayr San....	6·01	143	„ .	Darrynane Abbey.......	8·11	213
Renf .	Glasgow, Queen's Park	3·60	123	*Wat* .	Waterford, Gortmore...	4·34	136
„ .	Greenock, Prospect H..	4·15	106	*Tip* .	Nenagh, Castle Lough.	...	...
Bute .	Rothesay, Ardencraig...	4·94	125	„ .	Roscrea, Timoney Park	...	...
„ .	Dougarie Lodge..........	5·85	185	„ .	Cashel, Ballinamona....	5·14	180
Arg .	Loch Sunart, G'dale....	5·06	109	*Lim* .	Foynes, Coolnanes......	5·30	171
„ .	Ardgour House..........	9·22	...	*Clare* .	Inagh, Mount Callan....	10·85	...
„ .	Glen Etive................	...	...	*Wexf* .	Gorey, Courtown Ho...	2·52	86
„ .	Oban.......................	7·15	...	*Wick* .	Rathnew, Clonmannon.	2·06	...
„ .	Poltalloch.................	7·38	179	*Carl* .	Bagnalstown,Fenagh H.	3·65	116
„ .	Inveraray Castle.........	9·50	191	„ .	Hacketstown Rectory...	3·19	92
„ .	Islay, Eallabus............	5·86	172	*Leix* .	Blandsfort House.......	3·71	118
„ .	Mull, Benmore............	10·20	101	*Offaly*.	Birr Castle................	3·85	130
„ .	Tiree	3·38	93	*Kild* .	Straffan House...........	3·59	127
Kinr .	Loch Leven Sluice.......	...	...	*Dublin*	Dublin, Phoenix Park..	1·74	65
Fife .	Leuchars Aerodrome...	3·64	140	*Meath*.	Kells, Headfort..........	3·90	123
Perth .	Loch Dhu..................	6·65	138	*W.M* .	Moate, Coolatore........	...	...
„ .	Crieff, Strathearn Hyd.	4·39	148	„ .	Mullingar, Belvedere...	4·08	128
„ .	Blair Castle Gardens....	4·24	166	*Long* .	Castle Forbes Gdns......	...	...
Angus.	Kettins School............	4·68	181	*Gal* .	Galway, Grammar Sch.	...	...
„ .	Pearsie House............	4·70	...	„ .	Ballynahinch Castle....	9·27	224
„ .	Montrose, Sunnyside...	3·90	148	„ .	Ahascragh, Clonbrock.	5·74	165
Aber .	Balmoral Castle Gdns..	3·32	130	*Rosc* .	Strokestown, C'node.....	...	...
„ .	Logie Coldstone Sch....	...	...	*Mayo*.	Blacksod Point..........	...	...
„ .	Aberdeen Observatory.	3·93	140	„ .	Mallaranny	...	...
„ .	New Deer School House	...	...	„ .	Westport House.........	3·95	127
Moray	Gordon Castle...........	3·07	96	„ .	Delphi Lodge.............	11·59	175
„ .	Grantown-on-Spey	...	...	*Sligo* .	Markree Castle..........	6·39	186
Nairn.	Nairn	3·15	118	*Cavan*.	Crossdoney, Kevit Cas..	4·14	...
Inv's .	Ben Alder Lodge.........	5·09	...	*Ferm* .	Crom Castle..............	4·13	119
„ .	Kingussie, The Birches.	2·68	...	*Arm* .	Armagh Obsy............	3·28	113
„ .	Loch Ness, Foyers	3·15	104	*Down*.	Fofanny Reservoir......	5·26	...
„ .	Inverness, Culduthel R.	2·58	99	„ .	Seaforde	3·90	122
„ .	Loch Quoich, Loan......	6·36	...	„ .	Donaghadee, C. G. Stn.	2·59	93
„ .	Glenquoich................	6·31	98	*Antr* .	Belfast,Queen's Univ....	...	...
„ .	Arisaig House............	5·38	108	„ .	Aldergrove Aerodrome.	4·36	156
„ .	Glenleven, Corrour......	...	...	„ .	Ballymena, Harryville.	4·99	145
„ .	Fort William, Glasdrum	...	...	*Lon* .	Garvagh, Moneydig....	5·38	...
„ .	Skye, Dunvegan.........	4·61	...	„ .	Londonderry, Creggan.	5·17	141
„ .	Barra, Skallary..........	2·04	...	*Tyr* .	Omagh, Edenfel.........	5·84	172
R&C .	Alness, Ardross Castle.	...	...	*Don* .	Malin Head..............	4·80	...
„ .	Ullapool	2·69	85	„ .	Dunkineely...............	...	...

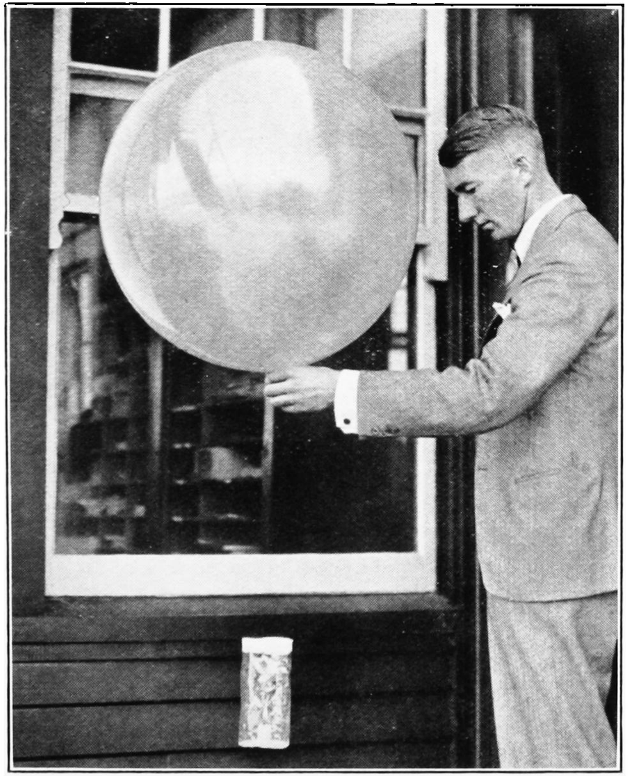
Climatological Table for the British Empire, February, 1937

STATIONS.	PRESSURE. Mean of Day M.S.L. mb.	PRESSURE. Diff. from Normal. mb.	TEMPERATURE. Absolute. Max. °F.	TEMPERATURE. Absolute. Min. °F.	TEMPERATURE. Mean Values. Max. °F.	TEMPERATURE. Mean Values. Min. °F.	TEMPERATURE. Mean Values. ½ Max. and Min. °F.	TEMPERATURE. Mean Values. Diff. from Normal °F.	TEMPERATURE. Mean. Wet Bulb. °F.	Relative Humidity. %	Mean Cloud Am'nt 0–10	PRECIPITATION. Am'nt. in.	PRECIPITATION. Diff. from Normal. in.	PRECIPITATION. Days.	BRIGHT SUNSHINE. Hours per day.	BRIGHT SUNSHINE. Percentage of possible.
London, Kew Obsy....	1002·8	−13·2	55	31	48·0	39·0	43·5	+ 2·8	40·4	89	7·6	4·05	+ 2·51	22	2·2	23
Gibraltar	1020·6	+ 0·6	67	46	61·0	52·4	56·7	+ 0·9	52·1	83	4·8	0·19	...	3	...	...
Malta........	1013·2	− 2·9	67	43	59·8	51·8	55·8	+ 0·5	51·2	77	5·9	2·67	+ 0·47	8	6·5	60
St. Helena	1011·9	− 0·3	75	60	71·4	62·3	66·9	+ 1·7	63·1	93	9·1	2·00	− 0·68	13	...	...
Freetown, Sierra Leone	1010·5	+ 1·4	91	75	88·3	77·4	82·9	...	76·6	78	4·7	0·01	− 0·29	1	...	...
Lagos, Nigeria	1009·9	+ 0·2	90	72	88·2	76·9	82·5	0·0	76·6	89	6·7	2·77	+ 0·87	8	6·8	57
Kaduna, Nigeria	1012·4	...	96	56	91·3	59·7	75·5	− 1·4	55·3	46	2·9	0·00	− 0·02	0	8·6	73
Zomba, Nyasaland	1007·6	− 0·5	86	50	80·3	64·9	72·6	+ 0·6	69·5	81	8·0	7·11	− 3·54	17	...	...
Salisbury, Rhodesia....	1009·1	− 1·0	83	55	78·0	61·0	69·5	+ 0·7	63·3	82	8·5	8·13	...	18	4·4	35
Cape Town	1013·1	− 0·3	98	51	82·9	61·7	72·3	+ 2·0	64·4	64	2·3	0·28	− 0·30	4	...	...
Johannesburg	1010·3	− 0·3	80	51	75·1	57·0	66·1	+ 0·5	60·1	79	6·2	5·85	+ 0·63	14	7·4	52
Mauritius	1009·7	− 1·3	90	71	86·0	74·7	80·3	+ 1·0	77·2	83	6·1	5·09	− 3·31	20	7·6	59
Calcutta, Alipore Obsy.	1013·3	0·0	88	57	80·3	62·9	71·6	+ 0·4	64·1	89	5·4	5·43	+ 4·44	7*	...	...
Bombay	1012·1	− 0·6	85	64	81·9	68·9	75·4	− 0·3	67·7	78	1·6	0·55	+ 0·52	1*	...	...
Madras	1012·0	− 0·9	88	66	86·0	71·9	78·9	+ 1·2	73·6	82	5·2	0·00	− 0·30	0*	...	...
Colombo, Ceylon	1011·0	+ 0·2	90	71	86·6	73·6	80·1	− 0·3	76·4	77	4·6	7·09	+ 5·15	8	9·3	78
Singapore........	1010·4	+ 0·2	90	71	86·1	74·8	80·5	+ 0·3	76·4	81	6·5	7·54	+ 0·92	13	6·1	51
Hongkong........	1018·4	− 0·2	79	46	66·2	57·5	61·9	+ 2·8	57·2	78	7·5	0·31	− 1·52	6	3·7	32
Sandakan	1011·1	...	88	73	86·9	75·4	81·1	+ 0·9	77·1	85	7·8	4·58	− 5·39	13	...	...
Sydney, N.S.W........	1015·6	+ 1·7	91	59	77·1	65·5	71·3	0·0	65·4	67	5·8	1·30	− 2·90	11	7·0	52
Melbourne	1015·8	+ 1·3	95	49	79·8	57·3	68·5	+ 0·9	60·8	63	5·9	1·63	− 0·08	7	7·7	57
Adelaide	1015·2	+ 0·9	99	54	85·0	62·7	73·9	− 0·1	63·1	51	5·0	0·79	+ 0·07	5	9·1	69
Perth, W. Australia ...	1013·3	+ 0·3	108	55	86·8	64·9	75·9	+ 1·8	62·0	45	4·8	0·41	− 0·04	2	9·9	75
Coolgardie	1012·8	+ 0·4	105	52	90·5	63·8	77·1	+ 0·9	62·5	52	2·3	0·38	− 0·47	2	...	...
Brisbane........	1012·6	+ 0·1	97	63	82·5	67·8	75·1	− 1·4	68·3	65	6·6	5·25	− 1·09	12	5·5	41
Hobart, Tasmania......	1018·2	+ 5·0	79	48	67·8	54·4	61·1	− 1·2	55·1	67	7·5	1·03	− 0·45	7	6·0	44
Wellington, N.Z.	1013·4	− 2·4	73	44	64·1	51·3	57·7	− 4·9	54·3	73	6·6	4·22	+ 1·08	11	7·1	52
Suva, Fiji	1007·2	− 0·6	93	74	87·9	76·8	82·3	+ 2·0	77·7	83	6·8	8·29	− 2·43	22	6·5	51
Apia, Samoa	1008·4	0·0	89	73	85·3	75·5	80·4	+ 1·4	77·4	81	7·1	15·85	+ 0·56	19	5·4	43
Kingston, Jamaica	1014·8	− 0·5	88	65	84·5	67·6	76·1	− 0·4	65·6	85	1·3	0·10	− 0·50	2	7·6	66
Grenada, W.I.	1011·2	− 2·3	89	71	87	73	80	+ 2·9	73	74	4	1·83	− 0·95	17	...	...
Toronto........	1014·8	− 3·2	50	5	33·8	22·0	27·9	+ 6·8	...	...	7·4	2·21	− 0·17	11	3·7	35
Winnipeg	1015·6	− 6·2	34	−33	12·1	− 6·5	2·8	+ 2·7	...	...	5·2	1·18	+ 0·44	13	4·1	41
St. John, N.B.	1012·2	− 1·7	48	3	32·9	18·5	25·7	+ 5·8	20·8	77	7·3	2·16	− 1·74	11	4·3	41
Victoria, B.C........	1011·7	− 4·9	53	26	42·8	34·4	38·6	− 1·9	36·1	86	8·3	5·23	− 1·97	19	2·5	25

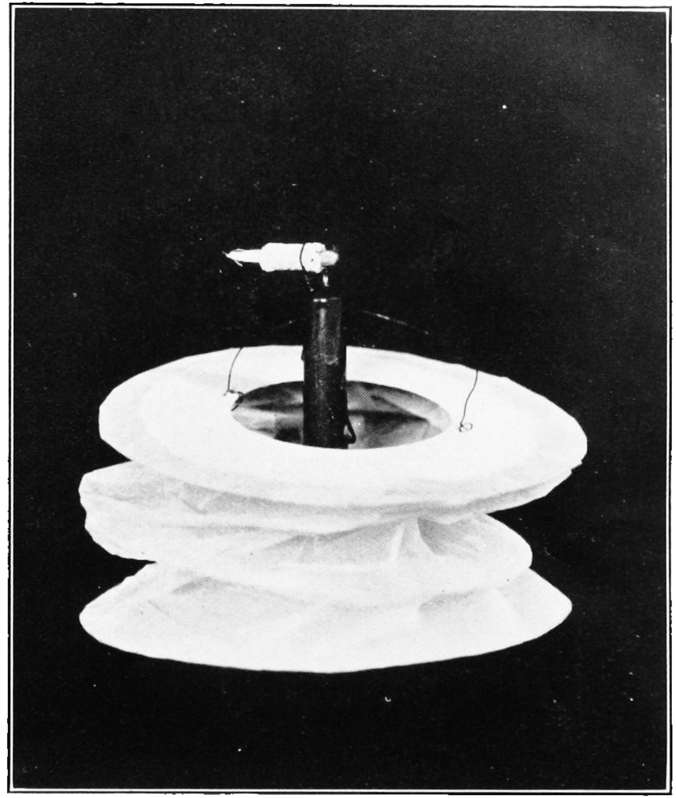
* For Indian stations a rain day is a day on which 0·1 in. or more rain has fallen.

(38363) Wt. 20/31 1125 8/37 Hw. G. 377/6

facing p. 177.]



Cellophane lantern for night ascents with pilot balloons (*see* p. 178).



The use of a fuse to light a candle.