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Sand Mirages

By L. G. Vedy, B.A., B.Sc.

It has been found that a very good place for the observation of mirage phenomena in this country is a sea beach having a wide stretch of level sand. Simple experiments on the nature of the effect were contemplated, but these have only reached preliminary stages. The effect, however, is so striking that a brief description may be of interest to many observers.

To lie on the sand and to see, all around, what appears to be a pool of water, at apparently about 30 yards away is a very striking experience. Objects having an angular height of $\frac{1}{2}^\circ$ may be completely reflected, as in a mirror. The effect far surpasses, in magnitude and tranquillity, any road mirage that the author has ever seen. The best effects are produced over a long stretch of firm level sand, free both from small indentations and from slight inclines, on a warm or hot calm day. The effect is practically destroyed by a strong wind, and even a gentle breeze causes a shimmer; it is absent or very slight where rising air currents are apparent. I have often looked over a long regular bank of shingle, or over a smooth path of close turf, but have seen no mirage effects. It appears that slight irregularities in the surface aid convection currents, and thus the steady state of the layers of air near the ground is destroyed. Good effects can be seen looking up a gentle slope of firm sand, whereas in a direction at right angles, the effect is very small or entirely absent.

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In general, when the eye is very close to the sand (say about half an inch above it) no image can be seen. As the eye is gradually raised, an image of part of the sky appears, giving the "pool of water" effect, and distant objects appear to be reflected in this. An optimum height of the eye is reached, and after this the effect grows less and finally disappears. In cases where the temperature gradient is not great enough, or where the air is not still, distant upright objects appear to be elongated near the ground.

The investigations contemplated were :—

(1) To determine whether the deviated ray is bent symmetrically with respect to the ground. It is reasonable to suppose that, when the object and eye are at the same height, the ray is symmetrical, but it would be interesting to test this experimentally.

(2) To determine the curvature of the ray, to obtain the magnitude and extent of the temperature gradient.

(3) The difference of temperature between air at the level of the object, and air at ground level can also be found from the observed deviation of the ray (as calculated below).

The experimental procedure is very simple and the apparatus consists of merely a few scales.

(a) To plot the path of the deviated ray an object AM is chosen, and its image A'M observed from a distance by one observer whose eye, B, is at about the same height from the ground as A (see diagram). A second observer walks a known distance from N, towards M, and places a rule or stick horizontally at say C, so that it appears, to B, to coincide with A'. By repeating this process, at larger distances from N, the portion BD of the ray can be mapped. It has not yet been determined whether this process can be continued over the portion DA; in which case the images both of C and A would have to be brought into coincidence, as seen from B. A measurement of the heights AM, BN, and of the distance MN completes the observation.

(b) To find the total deviation of the ray at a given distance from the object, and hence the variation of deviation with distance, only one observer is required. An object AM is chosen as before. The observer walks a known distance from M, looks towards A', and notes the height of his eye above the sand. If AM is a solid object, *e.g.*, a rock whose top is A, care must be taken to look towards A' each time. If the effect is not very great, or if AM is too high, only a portion of MA' will be visible, say MA'', and the point A'' may be mistaken for A'. This error may be prevented to some extent by measuring the angles subtended by AM, MA' at the eye*, and making certain that

*Vertical distortion, which in suitable circumstances might cause the true image of A to be at A'', is assumed to be absent.—Ed. *M. M.*

these are nearly equal (MA′ not less than MA) before recording the position of the eye. In both (a) and (b) perfectly level sand must be used.

The results deducible from these observations are as follows. If the ray is deviated symmetrically with respect to the ground, then the point D (where the ray is nearest to, and parallel to the ground) found in (a) will be very near to the mid-point of MN. Further, the curvature of DB at any point will be a function of the velocity gradient at that point, and therefore of the temperature gradient. Thus, if the temperature varies throughout the height MA, the ray will be curved throughout, as (I) in the

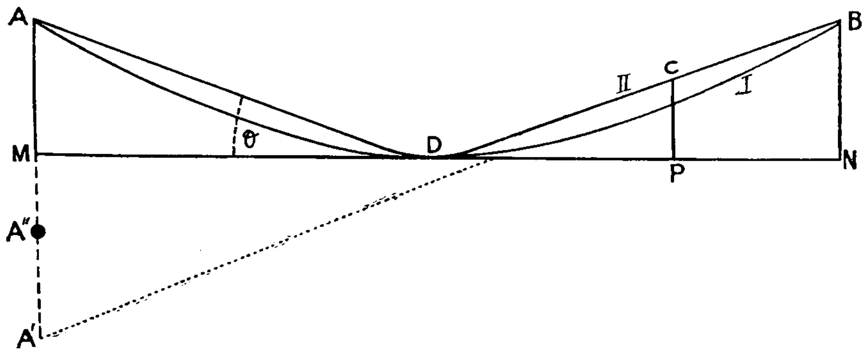

diagram. If, however, the temperature gradient exists only in the layers of air very near to the ground, then the ray will be curved in the neighbourhood of D, and straight at A and B, as (II) in the diagram.

In (II) the value of θ can be calculated for each reading of experiment (b), (except those near D, where the ray is curved) if we assume that the ray is symmetrical. For example, when the eye is at the point C we have

$$CP/DP = AM/MD = \theta = (AM + CP)/MP$$

Thus the variation of deviation (2θ) with distance can be found. In this case it is clear that the deviation must be independent of distance for points not too close to D, since the curvature is produced only near to D,

$$i.e.,\ (AM + CP)/MP = \text{constant}.$$

Hence if the results of experiment (b) give points (say, for example, from C to B) satisfying this equation, we may say that the temperature gradient can occur only in the air below the level of C. It may, of course, exist only in a very thin layer of air just above the surface of the sand.

It should be noted that the loci obtained in (a) and (b) are not the same. In (a), one particular ray ADB is plotted. In (b) rays leaving A in slightly different directions are used in turn. The loci plotted will differ widely near D, but gradually approach and finally touch as B is reached.

In case II the inclination of the ray at A is equal to θ, *i.e.*, the ray makes an angle of $(90° - \theta)$ with the vertical at A. At D the ray is horizontal, *i.e.*, it makes an angle of 90° with the vertical. If we call ${}_A\mu_M$ the refractive index of air at D with respect to air at A then clearly

$${}_A\mu_M = \sin(90° - \theta)/\sin 90° = \cos\theta.$$

Let the refractive index of air (with respect to a vacuum) be μ. The temperature at D is greater than at A, and this causes μ at D to be less than μ at A, the change in the value of μ between A and D being equal to $({}_A\mu_M - 1)$.

Now at normal temperature and pressure $\mu - 1 = 29 \times 10^{-5}$. If the pressure of the air is kept constant and the temperature increased by $\Delta t°$ C., $\mu - 1$ decreases to the value $29 \times 10^{-5}\left(1 - \frac{\Delta t}{273}\right)$.

Hence if the deviation of the rays is due entirely to this temperature change, we must have

$$\begin{aligned} ({}_A\mu_M - 1) &= \text{change in value of } (\mu - 1). \\ &= -\ 29 \times 10^{-5}.\ \Delta t/273. \\ \therefore \Delta t &= (1 - \cos\theta)\ 273/29 \times 10^{-5}. \end{aligned}$$

Since the angle θ is small and is equal to (AM + CP)/MP, this may be written

$$\Delta t = \frac{273}{29 \times 10^{-5}} \cdot \frac{1}{2}\frac{(\text{AM} + \text{CP})^2}{\text{MP}}$$

Hence Δt, the temperature difference between A and D can be calculated.

Three occasions on which the phenomenon was examined in a general way were as follows:—

(1) at Llanaber sands, near Barmouth (2nd September, 1927). Hot, calm day);

(2) at Giltar sands, near Tenby (17th August, 1928). Warm day, slight breeze;

(3) at Swanlake sands, near Tenby (1st September, 1928). Fairly hot and calm.

All these effects were seen at about noon and in sunshine, on firm level sand which had been exposed for about an hour (the tide was ebbing rapidly in each case). Observations of the type (a) and (b) (see above) were found to be possible, though extensive readings were not taken. The results obtained are summarised in the table below.

In (3) only 80 yards of level sand were available. The heights of the eye, observed as in experiment (b), at distances of 60, 70 and 80 yards from the object, were found to be 1·3, 1·7 and 2·6 inches respectively. Calculation shows that the deviation is approximately the same in the last two cases, and hence it appears that on this occasion the temperature gradient was confined to the air within about 1½ inches of the ground.

In the following table, the observed heights of the object and the eye, and the distance between these are shown. The fifth column shows the deviation ($= 2\,\theta$) produced, the next the calculated approximate value of ${}_A\mu_M - 1 (= \cos\theta - 1)$; and in the last column the temperature difference Δt, between A and M, calculated as shown above.

Mirage	Height of Object (inches)	Distance from Eye (yards)	Height of Eye (inches)	Deviation produced (2θ)	$\mu_M - 1$ ($= \cos\theta - 1$)	Temperature difference Δt
1.	12	40	3·5	about 1°	about −·00004	about 35°C.
2.	40	600	30	0·37°	−·0000054	5·0°C.
3.	6·5	80	2·6	0·36°	−·0000052	4·7°C.

Thus the magnitude of the deviation produced is very considerable, and involves large values of Δt. The deviation could never exceed 2·7° as this involves ${}_A\mu_M = \mu$, *i.e.*, a layer of air of refractive index unity at the surface of the sand. Even a deviation of 2·0° would require a temperature difference $\Delta t = 150°C$. Thus the observed deviations are not far below the maximum we could expect, even in desert phenomena. The magnitude of the temperature gradient is obtainable in (3), as here the 4·7°C. difference occurred in about one inch from ground level. Hence in this case the vertical temperature gradient is of the order of 1·5°C. per cm.

It may be thought possible that at the large angles of incidence used, sand has an appreciable reflecting power. It is, however, unlikely that the above effects are due to this cause, as they are entirely absent in calm dull weather. It would seem that the effect must be due entirely to the atmospheric temperature gradient; if light vapours were present, these would tend to rise and thus to produce a negative gradient of μ with height, thereby decreasing the effect caused by the temperature gradient.

It is hoped to continue these investigations at some future date. It would be interesting to determine the exact path of the rays and to compare this with the calculated curve for, say, rays in a medium with a constant temperature gradient; and also to compare the temperature gradient given by these results with that observed by direct measurement. Meanwhile it appears that, given a long enough stretch of level sand, we should see as fine effects as desert mirages on our very shores!

Experiments with Wet Bulb Thermometers

The articles on the renewal of the muslin and wick on wet bulb thermometers contributed to the *Meteorological Magazine* by Mr. Sutcliffe and Mr. Durward, may be supplemented by a short account of the experiments which have been conducted at Kew Observatory during the last two years.

The problem which was presented for consideration here was the explanation of the consistent difference between the humidities registered in the screen on the north wall of the observatory and the Stevenson screen on the lawn. The north wall screen contains mercury thermometers with large bulbs. Two of these thermometers are used for photographic recording and the other two are the control thermometers. The north wall screen is open at the bottom and differs in other ways from a Stevenson screen. The "psychrometric difference" between dry and wet bulb readings is consistently greater in the north wall screen. As the same tables are used for the reduction of all the observations, both the relative humidity and the absolute humidity deduced from the readings are lower for the north wall screen than for the Stevenson screen.

After numerous observations intended to throw light on the anomaly had been made, it occurred to me that the explanation might be found in the way in which water was supplied to the wet bulbs in the different screens. As has been mentioned, the thermometers used in the north wall screen have very large bulbs. The bulbs are nearly cylindrical, 4¼in. long and 0·35in. in diameter. The water supply is adjusted so that drips fall at long intervals from the bottom of the wet bulb. This has been the case from time immemorial.

In the Stevenson screen the normal practice is to use a thermometer with a spherical bulb 0·45in. in diameter. The water is drawn up to the wet bulb by capillary attraction from a bottle about 1½in. below.

During the summer of 1927 we tried the experiment of arranging the water supply of a number of wet bulb thermometers so that some had to draw up the water from below, others had the water dripping from them. As might have been expected it was found that when the water dripped freely the thermometer reading was comparatively high. With levels adjusted for slow drip we got low readings, but not much lower than those of the wet bulb arranged in the ordinary way. In the course of a few days larger differences began to develop, however, and we found that even though the ordinary wet bulb was still looking clean, its readings were higher than those of the well-watered thermometers. Evidently the water was not passing sufficiently freely through the pores of the muslin of the ordinary wet bulb. This effect occurred when boiled water was used, as is our general practice at Kew. With tap water the choking occurred much more quickly. Thus the result of this series of experiments was to show that a wet bulb thermometer becomes a less efficient evaporator as time goes on. If the muslin is only removed when it is obviously dirty, then the average reading of the thermometer will be considerably too high. During the summer the mean error on this account may amount to 0·2°C. or 0·4°F.

Thus we had found one of the causes of discrepancies between the humidities computed for different screens. That it was not the only cause was demonstrated by various comparisons, but most directly by setting up a dripping thermometer of the ordinary small bulb pattern alongside the big dripping wet bulb in the north wall screen. In warm weather there was a difference of about 0·2°C., the little thermometer having the higher readings. The only likely explanation was that whilst the long bulb was comparatively well insulated from its stem, sufficient heat could reach the little bulb by conduction and so keep the temperature high. To test this hypothesis muslin was wrapped round the stem of the little thermometer, and the water supply was arranged so that this muslin should be kept wet and cool whilst drips fell slowly from the bottom of the bulb. This arrangement proved highly satisfactory. The readings of the two thermometers came into exact agreement.

When a wet bulb thermometer has to drip continually it is necessary to arrange for the head of water to be constant. The free surface of the water should be a millimetre or so above the bottom of the bulb. One plan which we have adopted is to invert in the water bottle a test tube in which a hole has been made about 2cm. from the mouth. The test tube is filled with water, corked and then inverted in the bottle. A rubber collar round the tube keeps it upright but leaves room for the threads to the wet bulb. As an alternative arrangement, we are now using a bottle such as is shown in the illustration to Mr. Durward's article. The bottle stands on a block of wood so that the water surface is a little above the level of the bottom of the bulb. A bottle of this type is hardly suitable for a climate in which frosts are frequent. We are trying to reduce the risk of breakage by putting through the mouth of the bottle a rubber tube containing air. This rubber tube is closed at the end which is inside the bottle and open at the end which is outside. The water has frozen completely on more than one occasion without damage to the bottle. It is likely, however, that a water container of some other type will have to be substituted.

The question naturally arises whether the new mounting which gives us greater cooling power and greater consistency can be used to obtain true values of the vapour pressure. Another way of putting the question is to ask whether the formula adopted in our official tables is appropriate for the reduction of readings obtained in a Stevenson screen with the new mounting. As far as experiments have gone the answer is in the affirmative. The critical observations were made on July 18th and July 21st, 1928, in warm dry weather. On each occasion a long series of readings was obtained from an aspirated psychrometer near the Stevenson screen. It was found that the values of the vapour pressure computed from the readings of the aspirated psychrometer by the "Strong wind" formula agreed well with the values computed from the readings of the dry and wet bulb thermometers in the Stevenson screen by the "Moderate wind" formula, the wet bulb being the dripping one with the swathed stem.

It is clear that too little stress has been laid in the past on the importance of a free supply of water to the wet bulb thermometer. Our experiments show that the muslin is only kept thoroughly moist when the water is supplied from a reservoir at or above the level of the thermometer bulb. There is an obvious difference in appearance between the wet bulb which is glistening with moisture and one which is barely kept damp, and it is by no means surprising that the evaporation from the former is the more effective in producing the cooling effect.

There is a temptation to recommend the immediate and general adoption of the plan of keeping the wet bulb in good condition by having the reservoir in a raised position; of course, such a departure from established practice should only be made after the likely effects have been carefully analysed. It is to be hoped that experiments will be made in various localities so that information may be gleaned as to the extent to which routine observations would be affected by a change of practice.

F. J. W. WHIPPLE.

OFFICIAL PUBLICATIONS

The following publication has recently been issued:—

PROFESSIONAL NOTES—

No. 50. Some regions of formation of depressions in the North Atlantic. By L. Doris Sawyer, B.A. (M.O.273j).

If anyone were capable of swimming from the eastern end of Nova Scotia to Bermuda, he would probably find as he travelled southwards that, on a rough average, the temperature of the surface of the sea increased about five times as rapidly during the first half of the journey as during the second. This is because the warm waters of the Gulf Stream come in contact with the cold Labrador Current near Newfoundland, some of the cold water continuing to flow southwestwards along the American coast towards Carolina. Such marked differences in sea temperature favour large differences of temperature in neighbouring masses of air, so that conditions might well be expected to be particularly unsettled in these regions. This is shown to be the case in both winter and summer, though owing to the seasonal changes in America disturbances tend to develop rather further north in summer than in winter.

Among other regions where depressions are particularly apt to form or deepen may be mentioned the Davis Strait and the ocean southeastwards of Greenland. In both these parts there is a seasonal variation largely dependent on the drifting of ice.

Discussions at the Meteorological Office

The subject for discussion for the next meeting will be :—

January 21st.—*On the formation of ground inversions with a clear sky and a land breeze.* By R. Steiner (Abh. Rostocker Luftwarte) (in German). *Opener*—D. Brunt, M.A., B.Sc.

Royal Meteorological Society

The monthly meeting of this Society was held on Wednesday, November 21st, at 49, Cromwell Road, South Kensington, Sir Richard Gregory, LL.D., President, in the chair.

F. J. W. Whipple, D.Sc.—On the association of the diurnal variation of electric potential gradient in fine weather and the distribution of thunderstorms over the globe.

It is well known that in fine weather the ground bears a charge of negative electricity, and that this charge persists in spite of the continuous flow of positive electricity from the air to the ground. On the other hand, during thunderstorms the air-earth current is mostly of the opposite sign and is much stronger. It is probable that the two phenomena are complementary. It has been suggested by C. T. R. Wilson that the connexion between the upward currents produced by thunderstorms and the downward currents elsewhere is via the Heaviside layer. If this hypothesis is sound then the air-earth current will vary through the 24 hours with the number of thunderstorms in progress. Inland thunderstorms are most frequent in the afternoon and least frequent in the morning, so by utilising statistics as to the geographical distribution of thunderstorms it is possible to compare the area over which storms are likely to be in progress at different hours of universal time. It is found that storms are least frequent from 2h. to 4h. G.M.T. (when it is afternoon over the Pacific), and most frequent between 14h. and 20h. G.M.T. (afternoon hours for Africa and South America). Observations of potential gradient in polar regions and at sea, *i.e.*, in parts of the world where there is likely to be little systematic variation in the conductivity of the air, indicate that the gradient has its minimum and maximum values within these same hours. The results of the investigation are all consistent with the Wilson hypothesis.

N. K. Johnson, M.Sc.—Atmospheric oscillations shown by the microbarograph.

The microbarograph, which was invented by Sir Napier Shaw and the late Mr. W. H. Dines, frequently gives a regular wave-like record representing oscillations of atmospheric pressure. In the present paper, an analysis is made of the records of four observatories. The period of the oscillations is found to range from about 6 minutes to an hour, but there is a very marked maximum frequency of oscillations with a period of about ten minutes. The theory of the instrument is discussed, and it is shown that the distribution of frequencies observed is free from any appreciable errors due to instrumental causes.

Evidence is produced which indicates that the oscillations originate at the interface of two air currents possessing different densities and motions. The fact that oscillations with a period of about ten minutes occur most frequently is explained in terms of the natural period of vertical oscillation of the atmosphere. If the period of the oscillations agrees with that of the atmosphere, then the amplitude generated will be large and will be recorded at ground level. On the other hand, if the periods differ, the amplitude will generally be small and will not be felt at the ground. The natural period of vertical oscillation of the atmosphere is shown to be connected with the lapse rate of temperature, and it is further shown that the most frequent period of oscillation recorded corresponds with the most frequent lapse rate. Moreover, the distribution of these oscillations throughout the day also agrees with the above explanation.

H. Jameson, B.Sc.—On the mean maximum rain falling in a time t.

Correspondence

To the Editor, *The Meteorological Magazine*

Suggestions for Improvements in Details of Certain Instruments

In many years' use of instruments, one meets with various small annoyances arising from the design, or want of design, of these. I venture to offer, through the *Meteorological Magazine*, a few suggestions; both to observers, and to makers. Some of these are merely trouble savers. Others are observation savers, for they obviate the loss of observations, and prevent the inclusion in returns of the humiliating entry, "No record."

My first suggestion is that a one-day clock is an unmitigated nuisance. Human nature being what it is, it is certain, sooner or later, that the winding will be forgotten. Result, a lost record, if the clock is that of a self-recording instrument, or a lost rate, if it is a chronometer. Here at Armagh Observatory we have a chronometer which runs for the very inconvenient time of 30 hours. If the customary time of winding is in the evening, and the formality is forgotten once, the chronometer stops about 4 a.m. If wound in the morning, and once forgotten, it stops about 4 p.m. In either case no one is likely to be about. Had it been made to go for another 6 hours even, it would last till breakfast time, and there would be a likelihood of its condition being noticed in time to save its stopping. But a two-day movement would be better still.

Then there are the Robinson-Beckley anemograph, and the

Beckley rain-gauge, both of which have one-day clocks. The former was very easily remedied. I fitted a pulley block and double string, after the manner of grandfather clocks, and doubled the weight. The clock now goes for nearly three days, and is thus practically safe against accidental forgetfulness. The strange thing about this clock is that its drum is designed to carry three days' coil of line, but no provision was made, in installing it, for taking advantage of this long going capacity. In the Beckley rain-gauge clock, unfortunately, the weight descends in a concrete chamber, closed at the bottom, and a bare fit for the weight. There is therefore no room to fit a double purchase string, nor to increase the size of the weight, though here again there is ample room on the clock drum for two or three days' line. I have thought of substituting a lead weight for the existing cast-iron one, and so giving the clock a few inches longer run down.

On two or three occasions the line of the anemograph clock has broken. To replace a broken line is a simple job, if it does not entail taking the whole clock movement to pieces. This defect has been remedied by the simple expedient of drilling a second hole in the clock drum, diametrically opposite to that in which the line is knotted. The extra hole is large enough to pass a knot on the line. Therefore, in case a new line has to be fitted, all that is necessary is to pass the end of the line in at the smaller hole, and out at the larger,make a knot, and pull it in again. The clock need not even be taken off its seat.

When I first made the acquaintance of the Beckley rain-gauge, it was frequently liable to get out of order, when there was a heavy fall of rain, and to lose an important record through the siphon failing to act. This was especially the case when a gentle rain lasted for several hours, the small flow seeming to be unable to start the siphon. Then, one day, I got a small brush and scrubbed out the receiver. I obtained a marvellous collection of miscellaneous organic matter from it. Wings, legs, and the horny parts of flies, ants, earwigs, etc.; grass seeds, and other vegetable flotsam, bird droppings, were all represented. After a drastic clean out, there was no more trouble for a long time. But I found that various times of year produced their various seasonable *débris* to choke the siphon. It spring, bracts from the beech trees; in summer, grass seeds; in autumn, winged ants and earwigs; at all times of year bird droppings; found their way into the receiver. Finally I designed a strainer, to fit in the throat of the receiver. It is made of the copper wire gauze used for petrol filters, soldered into a very light ring turned off the end of a 1¼in. brass tube. The *modus operandi* was as follows. The gauze was cut with a pair of snips to a circle a little larger than the tube, and pushed through the latter to near the other end, becoming convex in the process. It was then soldered in position, and the end cut off the tube with a parting tool in the lathe. Before parting off, the outside was turned to a good fit for the throat of the receiving vessel. A light wire was soldered across the ring, for lifting off. Since introducing this little gadget to the Beckley gauge, there has been no more trouble with fouling of the siphon. The very slight extra weight is easily allowed for in fitting the chart to the drum. If preferred it could be compensated by adding a small quantity of mercury to the bath in which the receiver floats. At first it was found that, after a spell of dry weather, the strainer was liable to create an air lock, and prevent water entering the receiver. But this was remedied by drilling a very small hole in the neck of the vessel, just below the strainer, to act as an air release. Being only a sixteenth of an inch in diameter, the hole does not interfere with the emptying of the receiver with the breath in the usual manner.

The last of my criticisms is concerned with the soil thermometers. I have always thought that the readings of these are liable to be interfered with by convection currents. They are hung in iron pipes, 1ft. and 4ft. below the surface respectively. The pipes contain ample room, being 1½in. diameter. On a night when the grass temperature is far below freezing point, while the soil temperature is in the forties or fifties, the projecting ends of the pipes cool down to the temperature of the grass. Cold air cannot fail to flow down to the thermometers and reduce their reading below the true temperature of the soil. It seems to me that the recommendation in the *Observers' Handbook*, that water should not be allowed to collect in the bottom of the tube, is a mistake. If the thermometer bulb were immersed in water, the water would have the temperate of the surrounding soil, and would effectually protect the bulb from the influence of inflowing cold air. Or the lower end of the iron pipe could be closed, and contain a few inches of oil, glycerine, paraffin, or any other non-freezing liquid. In the meantime, I have adopted a plan which protects the thermometers from down draughts of cold air, while not interfering with regulation methods. On the suspension ring of each thermometer, I have fixed a disc of sheet rubber, which fits the bore of the pipe. The instruments are therefore in a closed chamber, and cold air is held up, and will probably assume the temperature of the soil before penetrating past the obstructing rubber disc.

Mr. J. Durward's communication in the *Meteorological Magazine* for October prompts me to add a word on the wet-bulb thermometer.

The constant-level water container figured by him would be ideal but for one fatal defect. It would never survive a winter in British latitudes. The first hard frost would infallibly burst it. I find that a vessel of considerable size answers admirably, provided it be covered with a lid which leaves just sufficient aperture to pass the wick without pressure. If this is placed a little to one side of the thermometer bulb, and at a slightly lower level, so that the wick slopes up, not too steeply, to the bulb, it is practically equivalent to a constant-level reservoir, for the portion of the wick within the lid is surrounded with a saturated atmosphere, and shielded from evaporation.

It is obviously undesirable to have a large area of uncovered water surface close to the bulb of the thermometer, for it will supply water vapour to the air in the neighbourhood of the bulb, and vitiate its reading, especially in still air.

The reservoir used at Armagh Observatory is a small glass mug, to which I have fitted a lead cover, cast to fit neatly, and having a notch to pass the wick, like that in the cover of a mustard pot. For some time I used a glass cover, but found it too light. It was often lifted in high winds, and sometimes blown clean out of the Stevenson screen.

WM. F. A. ELLISON.

The Observatory, Armagh. November 1st, 1928.

[Mr. Ellison's objection to clocks with an insufficient margin of safety is a very reasonable one. There is no real difficulty in providing clocks for "daily" drums which will run for several days on one winding, and such clocks are, in fact, fitted to many modern instruments, *e.g.*, the Dines anemograph.

Some form of removable filter, to prevent the ingress of rubbish, is essential in any self-recording rain-gauge employing a siphon. The best place for it is at the base of the funnel. Mr. Ellison's device is open to the objection that rubbish retained by it is represented on the record by an equivalent weight of rain. Could not the gauze be mounted on a fairly heavy ring turned to fit the funnel and placed in the bottom of the latter? The Casella natural siphon gauge has a very neat and efficient filter fitted to the inlet tube to the float chamber.

Water should be kept out of a Symons earth thermometer tube to minimize rust and deterioration of the thermometer mounts. A little mercury or oil at the bottom might improve the readings by ensuring better thermal contact, but experience shows that the Symons thermometer performs its function well enough without such additions. Mr. Ellison's steel tubes are much wider than the present pattern, which are only 1·25in. in diameter. Two rubber bands round the thermometer fit the tube fairly closely and give the same result as Mr. Ellison's discs of sheet rubber.

Letters such as Mr. Ellison's are of great interest and value. In many cases it may be found that defects existing in older instruments have been remedied in more recent patterns, but there is still need for improvement. Suggestions and criticisms from observers provide the best possible material on which to work.—E. G. BILHAM.]

Wet Bulb Thermometers

In the interesting note by Mr. Durward on Wet Bulb Temperatures, which appeared in the October issue, a sketch is given of a constant level container which has recently been brought into use at Air Ministry Meteorological stations in the Middle East. This apparatus, which was originally suggested by Mr. G. W. Grabham, Geologist to the Sudan Government, has been in use in the Egyptian Meteorological Service for many years—and, in fact, the experiments described were carried out with containers supplied by this Service. They are commonly known as " bird-fountains " and are obtainable from Baird & Tatlock. They have a capacity of about 150cc. and have proved satisfactory.

L. J. SUTTON.

Egyptian Meteorological Service, Cairo. November 4th, 1928.

Lunar Rainbow ; Artificial Halo

At 10.18 p.m. (G.M.T.) last night I observed a lunar rainbow which lasted two minutes. The bow was unbroken and was pure white in colour. A shower of moderate intensity had passed quickly overhead to between NE and N, the moon appeared from a break in the clouds to between S and SW. I have never observed one of these here before.

Also, during a heavy rainstorm about 8.15 p.m. (G.M.T.), I was walking along the Portsmouth Road towards Kingston (about 1 mile from it), when a car with bright headlights approached from behind. In front of me a large circle of white light appeared, resembling a lunar halo, and dispersed as the car drew near. This happened several times during the rain on the approach of further cars. The diameter of the ring appeared to stretch approximately from 1ft. above the ground to a few feet above the height of an ordinary gas lamp-post.

K. G. WILLIS.

Tadram, Effingham Road, Surbiton. November 22nd, 1928.

Weather Lore of the Polynesians

A recent book (" Myths and Legends of the Polynesians " by Johannes C. Anderson, Harrap and Co., 1928) gives much interesting information as to the weather lore, mythical and otherwise, of the South Sea Islanders.

As might be expected amongst a seafaring people, who, moreover knew of the fury of tropical cyclones, the winds played a great part in the cosmogony. They were the children of Raka, and each had a hole allotted to him at the edge of the horizon through which he blew at pleasure. Raka also possessed a basket in which to confine the winds, much in the same way as Homer represents Aeolus giving Ulysses the contrary winds tied up in a bag. The white clouds were regarded as due to the domestic labours of the goddess 'Ina who was forever preparing bark-cloth, and stretching it out to dry and bleach on the blue sky, securing it native fashion with huge stones. The bleaching finished, the stones were thrown on one side and the noise of their falling on the solid blue vault was thunder.

In the South Seas, as elsewhere, the rainbow was regarded as a bridge from heaven to earth.

But leaving myth on one side, the weather lore of the Polynesians was surprisingly accurate in the matter of prediction of wind and weather. Thirty-two winds were recognised, and the naming, as the following list shows, was elaborate and systematic :—

East.	Marangai.	
E. by N.	Marangai-anau.	" East giving birth " (to the new wind).
E.N.E.	Marangai-akavaine.	" East as gentle as a woman."
N.E. by E.	Marangai-maoake.	" East becoming North East."
N.E.	Maoake.	

The N.N.E. wind was called Maoake-ta—" The Terrible Northeast," in allusion to the extreme violence of this wind during a hurricane. Mr. Andersen says, " There was an unfailing natural indication of the approach of a cyclone expressed in the saying, ' Twisted is the core of the banana.' This twisting takes place some weeks before the coming of a hurricane, and at the same time there is an unusually luxuriant growth of food." One would like a little more definite information as to this; as it stands it seems rather obscure.

CICELY M. BOTLEY.

17, Holmesdale Gardens, Hastings. September 4th, 1928.

Change of Climate

There has been a popular belief that the climate of western Europe has become generally milder during the past 30 to 50 years or so. The discovery of the great heat reservoir in the Arctic by the U.S. Coast Guard ship *Marion* certainly lends colour to this idea.*

Take last winter in England also. After a severe cold spell in December instead of (as in former days) continuing into January and February, the cold disappeared suddenly for the rest of the winter, this being due to there being no mass of cold air over the Continent, even the snows of Switzerland melting from time to time. Evidence certainly goes towards showing a general amelioration in the winter climate of western Europe.

DONALD W. HORNER.

63, Canute Road, Clive Vale, Hastings. November 21st, 1928.

* See *Meteorological Magazine*, 63 (1928), p. 217.

NOTES AND QUERIES

Our More Equable Climate

Having occasion recently to examine some figures of the average winter and summer shade temperature at London and Edinburgh. I was impressed by the remarkable decrease in the annual range of temperature which they revealed. Ten-year means are shown in the following table, based on the data in D. Brunt's *Periodicities in European Weather*,* brought up to date by means of manuscript tables. Winter is December to February and Summer is June to August, the mean of two successive winters being subtracted from the intervening summer temperature to give the " seasonal range."

Ten years ending	*Seasonal Range*		*Ten years ending*	*Seasonal Range*	
	London °F	*Edinburgh* F		*London* °F	*Edinburgh* °F
1927	19·2	17·4	1847	22·7	19·2
1917	19·7	18·2	1837	22·6	18·5
1907	20·9	18·5	1827	23·1	21·0
1897	22·5	18·3	1817	22·3	20·6
1887	22·2	19·2	1807	23·5	21·4
1877	22·1	18·8	1797	23·3	19·5
1867	20·9	18·1	1787	24·1	21·4
1857	21·7	19·3	1777	23·1	19·7

The average for the whole period is 22·1° at London and 19·3° at Edinburgh, and at the former place the range during the ten years ending 1927 was no less than 2·9° F. below this long-period average.

By far the greater part of the decrease is due to the winter temperature. At both stations the average winter temperature for the ten years ending 1927 was higher than that for any other series of ten consecutive years since 1765.

This high average was not due to the inclusion of two or three extremely mild seasons, but rather to the persistent recurrence of winters characterised by a moderate degree of warmth. During the same period the summers have been distinctly cool in London, but at Edinburgh they have been about normal.

C. E. P. Brooks.

The Effects of Height on Screen Temperatures

In an article on this subject on p. 107 of the *Meteorological Magazine* for June, 1928, it was found that in Malta the diurnal range of temperature is appreciably smaller on a roof than near the ground. A similar result has been obtained in 'Iraq, where readings in a Stevenson Screen on the roof of Air Headquarters at Baghdad have been compared with those in a similar screen on the ground at the neighbouring station of Hinaidi. The maximum on the roof is usually 2°F. below that on the ground,

**London, Phil. Trans. R. Soc. A.* 225, 1925, pp. 247-302.

but the minimum on the roof averages 5°F. higher, and the difference has sometimes reached 13°F. The average readings during June, 1928, are as follows:—

	Hinaidi (ground).	*Baghdad* (roof).
	°F.	°F.
Mean daily max. ...	108.1	106.0
Mean daily min. ...	73.0	78.1
Mean daily range ...	35.1	27.9

Rain-Makers

My interest has been aroused more than once in a reference to "rain-making" which appears in the Eleventh Edition of *The Encyclopaedia Britannica* (Vol. XVII, p. 309) under "magic." The statement runs:—"Rain-making ceremonies are far from uncommon in Europe. Sometimes water is poured on a stone; a row of stepping-stones runs into one of the tarns on Snowdon, and it is said that water thrown upon the last one will cause rain to fall before night."

During a recent visit to North Wales I commented to my guide, a native of the district, on my inability to connect the legend with any of the lakes on Snowdon, and was intrigued to find that the very lake towards which we were then bent boasted that tradition. At Llyn Dulyn, in the Carnedd Llewelyn range, there was just discernible a row of stepping-stones leading to a submerged larger stone or "altar." Llyn Dulyn is just below and to the north-east of the gully where snow is said to lie later during the year than anywhere else in England and Wales. Of recent years the level of the lake had been raised by a low dam in order to meet the increasing demands for water by Llandudno, and it is not improbable that the storage capacity of this natural reservoir will again be increased and the stones themselves no longer dumbly speak of ancient times and magic sages.

The average rainfall at Llyn Dulyn is about 100 inches a year and the number of rain-days exceeds 225. The choice of such a locality for the demonstration of their powers suggests a regard of natural laws which seems to be an integral part of so many of the charms of mediæval times.

J. GLASSPOOLE.

Reshabar, Rushabar or Rrashaba?

One of the minor difficulties of meteorology is concerned with the transliteration of terms which are in use among peoples employing a different alphabet from our own. An example of this is a cold, gusty, north-easterly wind resembling the Bora in its origin, which blows down from the mountains of southern

Kurdistan when pressure is relatively higher there than to the southward over the plain of 'Iraq. The Kurdish name for this wind means "the black wind," a term which has not sufficient precision for scientific use. An attempt at a phonetic representation gave variously Rushabar and Reshabar; we are now informed that the correct transliteration is *Rrashaba*, which threatens difficulties of pronunciation. Incidentally one would wish to know why this particular wind should be described as "black."

Sunspots and Epidemics

On p. 47 of the present volume of the *Meteorological Magazine* we reviewed a paper by A. Tchijevsky in which it was claimed that historical events tend to occur more frequently near sunspot maximum than near sunspot minimum. He has now contributed a further study* in which the occurrence of epidemics of cholera and influenza is related to the sunspot cycle. The relationship is found most clearly with the cholera epidemics, for of fifteen which occurred between 1766 and 1900, no fewer than twelve coincided with a sunspot maximum. The relationship of influenza to sunspots is less clear, for though this malady shows indications of a periodicity of 11·3 years, its outbreaks come not exactly at sunspot maximum but at an average interval of 2·3 years before or after.

The way in which the variations of solar activity take effect is not yet clear, but the author considers that it is probably through their influence on atmospheric electricity and especially potential gradient, which may affect both the bacteria themselves and also the power of humanity to resist disease.

The Colours of Pilot Balloons

Those who make regular observations with pilot balloons are well aware of the fact that the visibility of a balloon at a given distance is largely dependent on its colour in relation to the background—of cloud or sky—against which it is viewed. Unless a balloon bursts, enters or passes behind a cloud, the termination of the observation is reached when the observer can no longer see the balloon through the telescope of the theodolite. By judiciously selecting a balloon of the best colour, it is possible to prolong the observation considerably beyond the point when an unsuitable balloon would have vanished from sight.

Experience has shown that a choice of three colours, white (undyed rubber), dark blue and cherry red, is sufficient to meet ordinary requirements both at home and in the tropics. It is

*Über die Wechselbeziehungen zwischen der periodischen Tätigkeit der Sonne und den Cholera—und Grippe-Epidemien. *Deutsch-Russische Medizinische Zs.*, no. 9, 1927, pp. 511-538.

possible, however, to obtain balloons made half of one colour and half of another, and it will be convenient to describe these as " bi-coloured " balloons. A balloon rotates during its ascent, and it seemed probable that a balloon, only half of which was, say, blue, would be just as serviceable as a balloon wholly blue when the circumstances necessitated a blue colour. It thus seemed possible to combine the advantages of the two different colours in the same balloon. Moreover, it was known that observers were not altogether unanimous in their opinions as to the best colour to use in given circumstances. There would be, for instance, many occasions when a blue and a red balloon were almost equally suitable. Some observers would select one and some another. It seemed quite possible, therefore, that a standard bi-coloured balloon of two suitable colours might prove as effective, in actual practice, as a selected balloon in one of the three standard colours.

At this point it may be desirable to explain what advantages were likely to accrue from the use of bi-coloured balloons, which would, at best, be no better than self-coloured balloons from the observer's point of view. The object aimed at was to avoid the necessity of maintaining, at stations and in store, stocks of three different balloons. These balloons deteriorate in store, and it sometimes happens that demands for one particular colour suddenly increase or suddenly fall off. On account of such fluctuations, the reserve stocks must be maintained at a higher level than would otherwise be the case and, consequently, the average duration of storage before use is increased. It was felt, therefore, to be worth while experimenting with bi-coloured balloons with a view to selecting a standard balloon for all occasions.

Supplies of balloons combining the colours " red-blue," " red-white " and " blue-white " were obtained, and trials were carried out at Upper Heyford in England and at Aboukir and Heliopolis in Egypt. At both the Egyptian stations, it was found that the combination " blue-white " gave best results, especially when viewed through an orange filter. At Upper Heyford, the observer found it impracticable to select a combination suitable for all occasions. He thought it possible to replace separate red and blue balloons by the single combination " red-blue," but found it essential to retain undyed balloons in addition. He also reported that the bi-coloured balloons required more care in filling than single-coloured balloons, because one half tended to expand before the other.

On the basis of the above reports, it would be necessary to obtain supplies of " blue-white," " red-blue " and undyed balloons. Since three types are involved, the one advantage claimed for bi-coloured balloons would be lost and the idea was accordingly dropped. Although the results of the experiments were negative, they demonstrated clearly that anyone undertaking pilot balloon work should have at his disposal balloons of the three colours already mentioned if the best results are to be obtained under all conditions.

E. G. BILHAM.

Memòires Patxot

To encourage research in Physics and Mathematics, principally in Catalonia, M. Raphaël Pàtxot i Jubert in 1922 and the following years has offered prizes for essays on certain scientific subjects connected with Catalonia. The winning essays, published by M. Patxot i Jubert are known as the *Memòires Patxot.* The subject chosen for the 1928 (the seventh) competion is a meteorological one, the title being "Météorologie de la Méditerranée Occidentale et plus spécialement de la côte Catalane, en donnant préférence à l'aspect dynamique du problème." This competition is international and the essays may be written in Catalonian, any one of the Latin languages or in English. The prize offered is 5,000 pesetas. The competition closes at 8 p.m. on December 31st, 1929. Further particulars can be obtained from M. R. Patxot i Jubert, Rue de la Cucurulla, 1 and 3, Barcelona.

Unusually Low Pressure

An unusually low barometer reading was obtained at Edinburgh at 3.25 p.m. on November 23rd. After correcting to mean sea level and normal gravity, the reading deduced from the barograph is 950·7mb. (28·08in.).

Major A. H. R. Goldie writes that "we have to go back to December, 1886, before we find anything so low. In December, 1886, a pressure of 27·651in. (uncorrected for gravity) was attained, and in January, 1884, one of 27·451in. [The gravity correction is about +·027in., making these readings respectively 27·678in. (937·3mb.) and 27·478in. (930·5mb.).] The last mentioned was the lowest since records commenced in Edinburgh in 1769, and occurred during the passage of the depression of January 26th, 1884, when a reading of 27·33in. was recorded at Ochtertyre in Perthshire. Isobars for this depression are given in Bartholomew's *Atlas.*"

Reviews

Eos; or the Wider Aspects of Cosmogony. By Sir J. H. Jeans, F.R.S. Size $6\frac{1}{2}$ by $4\frac{1}{2}$ in., pp. 88. *Illus.* London, Kegan Paul, Trench, Trubner & Co., Ltd., 1928, 2s. 6d. net.

In this little book Sir James Jeans gives a delightfully lucid account of the present position of our knowledge of the Universe, in a form suitable for reading by the educated layman. Modern conceptions of the universe deal in immensities of both space and time, while making use of the infinitesimal as represented by the detailed structure of the atom. In the space of a brief review it is not possible to do more than to refer to a few of the points raised by the author.

It is pointed out that while man has only existed on earth during a period of some 300,000 years, the age of the earth is of the order of 2,000 million years, and the sun has existed for a time to be measured in millions of millions of years, and can go on for an equally long interval. The immensity of space is exemplified by the statement that whereas light from the most distant objects visible in the 100-inch telescope at Mount Wilson takes about 140 million years to reach us, travelling at 186,000 miles per second. Hubble estimates that space extends 1,000 times as far as this. If we adopt this value, then light will take 100,000,000,000 years to travel round space, though wireless waves having the same velocity travel round the earth in one-seventh of a second.

Jeans draws attention to the fact that whereas stars show very considerable variability in size, brightness, and distance, they show a restful uniformity as to their masses. The energy which is radiated outward from the stars is regarded as having its source in the annihilation of matter, and so the stars are continually losing weight. The rate of loss is greatest for the more massive stars, and the uniformity of mass of the stars is regarded by Jeans as being due to the equalising effect of this. The final fate of the radiation is discussed, and it is stated that the radiation from thousands of dead universes could be contained in space without our being aware of its presence. Apparently the process of conversion of mass into radiation is not reversible, and the universe is comparable to a clock which is continually running down and cannot be wound up again. The clock appears to have been wound up some 5 to 8 million million years ago.

Some very beautiful pictures of nebulæ are given to illustrate the description of the evolution of star systems from spiral nebulæ. The birth of a solar system such as ours is described as a rare event, and we reach the conclusion that very few stars are likely to have planets in a condition adapted to the existence of life as we know it on the earth.

This little book can be recommended as well worth close study. It gives a very clear idea of the way in which modern cosmogony depends upon the very latest advances in atomic physics. In places the statements made appear perhaps more dogmatic than the observations seem to justify, but this is probably largely due to the necessity for compressing a whole science into so small a compass. The author has succeeded in producing a stimulating little book which should interest a wide circle of readers.

D. Brunt.

Les Hivers dans l'Europe Occidentale. Etude statistique et historique sur leur température : discussion des observations thermométriques 1852-1916 et 1757-1851 : tableaux comparatifs : classification des hivers 1205-1916 : notices historiques sur les hivers remarquables : bibliographie. By C. Easton. Size 9¾ x 6½ in., pp. 210. Librairie et Imprimerie ci-devant E. J. Brill, Leyden, 1928.

Of the various matters promised on the title page, the historical notices and the bibliography occupy three-quarters of the book, and they are a remarkable monument to the author's industry in research among ancient tomes, as well as to his linguistic accomplishments. Although they do not become sufficiently numerous for statistical treatment until the 13th century, the records actually begin with 396 B.C., and the collection will be welcomed by all meteorologists who are interested in historical studies.

As a preliminary to discussing this mass of historical material, the author investigates the severity of the winters from 1852 to 1916, for which complete instrumental observations are available for nine stations in western Europe between Greenwich and Strasburg, and also those of the period 1757 to 1851, for which less complete data are available. Considering that the impression of "severity" is given quite as much by short spells of intense cold as by a low mean temperature, he evolves a "coefficient of temperature" in which the mean winter temperature is combined with the number of days of frost, days without thaw, very cold days (below 14°F.) and the mean of the three lowest minima in different months from November to March, all expressed in terms of their standard deviation. A winter in which the coefficient of temperature is below the average value by more than four times the standard deviation of the coefficient is termed a "great winter," a deficit of three times the standard deviation characterises a "very rigorous winter," and so on. In the 160 years there was only one great winter, namely, 1829-30, when intense cold lasted from November 14th to February 22nd.

The winters from 1205 to 1756 are next arranged in estimated order of severity. Since 1757 to 1916 produced one "great winter," these 552 earlier winters should produce four; in the same way the theoretical numbers of "very rigorous," "very mild" winters, &c., can be calculated. Actually, the author selected five "great winters," ending in 1408, 1608, 1565, 1709 and 1435, four very mild winters, and 12 very rigorous. These are given the average coefficients of temperature of the same classes during the instrumental period, 4 for great winters, 10 for very rigorous winters and 90 for very mild winters, the theoretical range of the scale being from 0 to 100. In this way the verbal descriptions of the chroniclers are ingeniously converted into numerical estimates suitable for statistical computations, without making any attempt to estimate the actual mean temperatures of the different winters, which would be impossible to sustain. It was in these " coefficients " of temperature that the author found his well-known periodicity of 89 years.

Annali del R. Ufficio Centrale di Meteorologia e Geofisica Italiano. Serie terza. Osservazioni 1921. Size 13½ × 10in., pp. x + 222., Rome, 1928.

The publication of the official year-books of the Italian Meteorological Office has been interrupted for some years, and we welcome this issue of the observations for 1921, which contains monthly summaries for 120 second order and 158 third order stations. At the former complete observations are recorded at 9, 15 and 21h., the mean temperature for the day being taken as the mean of the 9h. and 21h. observations and the mean daily maxima and minima—a very useful combination. Days of rain are given separately for totals less than, and equal to or greater than 1 millimetre.

A proposed guide-book to the world's weather and climates. By Robert De C. Ward. Proc. Amer. Phil. Soc., 67, 1928, pp. 67-94.

Professor R. De C. Ward is a great advocate of " field work " in the study of climatology, and in this interesting paper he outlines a few trips to regions of climatic interest. From our point of view it is unfortunate that the standard pleasure trips are planned to avoid climatic vicissitudes as far as possible, and there are no excursions to north-eastern Siberia in January or to Cherrapunji in July. Even on the ordinary trips, however, the tourist could find a great deal to interest him in an account of the weather and climate of the places he will visit, and the outstanding meteorological phenomena he should look for, subjects about which he is generally left in ignorance. We hope that Professor Ward will find opportunity to publish the full text of his proposed guide-book.

The Weather of November, 1928

The weather of November was generally mild, unsettled and stormy except during the first ten days and the last few days, when it was mainly cold and misty. For the first three days light northeasterly winds prevailed, and heavy rain in the south-east of England on the night of the 1st to 2nd and on the 2nd was associated with a shallow depression over France: 2·87in. fell at Deal and 2·56in. at Dover. Much mist and fog occurred from the 4th to 7th in the south and Midlands, while in the north it was fair with slight showers. Anticyclonic conditions prevailed on the 8th and 9th, when many places experienced much sunshine, *e.g.*, 8·2hrs. at Southampton on the 9th, and severe frost occurred on the mornings of the 9th and 10th; the lowest reading for the month in the screen was 21°F. at Marlborough on the 10th, and on the ground 11°F. at Ford, Argyll, on the 9th. The change to mild unsettled conditions began in the north on the 9th, when 1·02in. of rain fell at Lerwick, and extended south on the 10th. Strong winds with local gales at times were frequently experienced until the 28th. The most notable gales were associated with the intense depressions which passed across England on the 16th, southern Scotland on the 23rd and northern Scotland on the 25th. These occasioned much destruction and some loss of life. Beaufort force 10 (59m.p.h.) was recorded at several places along the south coast of England on the 16th, and at one or two places in northwest England on the 23rd and 25th. The strongest gusts recorded were 93m.p.h. at Liverpool on the 23rd, 90m.p.h. at Cardington on the 16th (measured by the anemometer at 150ft.), and 87m.p.h. at Southport and South Shields on the 23rd. Rain fell on most days during this period with heavier falls locally on the 11th, 12th, 14th, 18th and 21st to 23rd. Amongst the heaviest falls were 2·47in. at Talyllyn (Merioneth) on the 11th, 2·58in. at Tynywaun (Glamorgan) on the 12th, 2·19in. at Sawrey (Lancashire) on the 14th, 2·00in. at Aasleagh (Mayo) on the 18th. At Rosthwaite (Cumberland) 4·80in. fell on two successive days, 2·44in. on the 22nd and 2·36in. on the 23rd. During the latter part of the month snow was reported on the hills in many parts of the north. Thunderstorms occurred at Waterford on the 14th and 15th, and in Yorkshire on the 23rd. In the rear of the depression on the 25th cold northerly winds flowed over the country and temperature fell considerably. On the 27th and 28th the temperature did not reach 40°F. at a few places, and at Aspatria the maximum value on the 28th was 37°F. Showers of rain, hail and snow occurred locally, while considerable periods of bright sunshine were enjoyed, especially on the 26th, when many places had over 6hrs. sunshine and Clacton as much as 7·1hrs. The distribution of bright sunshine for the month was as follows:—

	Total (hrs.)	Diff. from normal (hrs.)		Total (hrs.)	Diff. from normal (hrs.)
Stornoway	47	+4	Valentia	58	− 7
Aberdeen	63	+8	Liverpool	52	− 7
Dublin	70	—1	Falmouth	59	—17
Birr Castle	60	−·4	Kew	55	+ 3

Pressure was below normal over the whole of northwestern and central Europe and Italy, and from Spitsbergen to Newfoundland, the greatest deficit being 17·4mb. at Utsire. Pressure was above normal in a belt extending from Spain to Bermuda with the greatest excess, 5·2mb. at Horta. Temperature was above normal from Spitsbergen to Switzerland, but below normal in Portugal, while precipitation was in excess except in northern Norway northwest Lapland and Spitsbergen. In Kalmar (Sweden) precipitation was three times the normal.

Owing to the heavy rains in Switzerland and northern Italy at the end of October and during the first two days of November, the level of the lakes of Lugano, Maggiore, Como and Iseo rose considerably and there was serious flooding in the neighbouring districts. The situation had improved somewhat by the 4th. Heavy southerly gales were experienced in the Balearic Isles on the 8th. The storm of the 17th and 18th caused much damage, especially to shipping, in Germany and Holland, with some loss of life in Holland. Further gales on the 23rd to 26th caused material damage and loss of life in Denmark, Germany, Holland, Belgium, France and Switzerland. In Holland and Schleswig-Holstein the dykes burst in several places with consequent flooding. Gales occurred in southern Spain on the 26th. By the 28th the weather had much improved in Switzerland.

Heavy rain and strong winds occurred over Sumatra on the 7th, and a typhoon swept across the Philippines about the 20th; 200 people were killed, and it is estimated that 10,000 were rendered homeless in the island of Leyte.

A blizzard swept over the Rocky Mountain region and Upper Mississippi valley on the 1st and continued across Nebraska, Kansas, Iowa and Missouri on the 3rd. High winds about the middle of the month caused considerable damage to the banana crops of Jamaica. Forty-one people were killed and injured by a cyclone which swept across the province of Cordoba, Argentina, about the 12th. Fine weather favourable for harvesting operations was experienced in the Argentine after the 16th.

Many gales were experienced on the North Atlantic during the month.

The special message from Brazil states that the rainfall in the northern regions was variable with 0·16in. above normal, plentiful in the central regions with 1·26in. above normal and scanty in the southern regions with 2·91in. below normal. In the south the weather was unfavourable for the crops. Six anticyclones passed across the country and windstorms occurred in the south. At Rio de Janeiro pressure was normal and temperature 0·2F. below normal.

Rainfall, November, 1928—General Distribution

England and Wales ...	126	per cent. of the average 1881-1915.
Scotland	134	
Ireland	142	
... British Isles	132	

Rainfall: November, 1928: England and Wales

Co.	Station	In.	Per-cent of Av.	Co.	Station	In.	Per-cent of Av.
Lond .	Camden Square	2·15	91	*Leics* .	Thornton Reservoir ...	3·50	155
Sur .	Reigate, The Knowle...	2·85	98	,, .	Belvoir Castle............	2·37	106
Kent .	Tenterden, Ashenden...	3·79	125	*Rut* .	Ridlington	2·80	...
,, .	Folkestone, Boro. San.	6·04	...	*Linc* .	Boston, Skirbeck	2·72	136
,, .	Margate, Cliftonville...	3·50	145	,, .	Lincoln, Sessions House	2·55	136
,, .	Sevenoaks, Speldhurst	3·19	...	,, .	Skegness, Marine Gdns	2·66	123
Sus .	Patching Farm	4·10	115	,, .	Louth, Westgate	2·63	102
,, .	Brighton, Old Steyne	4·25	133	,, .	Brigg, Wrawby St. ...	2·78	...
,, .	Tottingworth Park ...	5·53	149	*Notts* .	Worksop, Hodsock ...	2.61	133
Hants.	Ventnor, Roy. Nat. Hos.	3·86	120	*Derby*.	Derby	3·31	153
,, .	Fordingbridge, Oaklnds	3·21	94	,, .	Buxton, Devon Hos....	8·29	177
,, .	Ovington Rectory	3·34	101	*Ches* .	Runcorn, Weston Pt.	3·84	139
,, .	Sherborne St. John ...	2·85	100	,, .	Nantwich, Dorfold Hall	4·74	...
Berks .	Wellington College ...	1·60	63	*Lancs* .	Manchester, Whit. Pk.	4·48	170
,, .	Newbury, Greenham...	3·24	116	,, .	Stonyhurst College ...	7·07	157
Herts .	Benington House	2·14	90	,, .	Southport, Hesketh Pk	5·72	182
Bucks.	High Wycombe	3·47	139	,, .	Lancaster, Strathspey	6·89	...
Oxf .	Oxford, Mag. College	2·61	118	*Yorks*.	Wath-upon-Dearne ...	2·18	107
Nor .	Pitsford, Sedgebrook...	3·23	147	,, .	Bradford, Lister Pk....	6·12	209
,, .	Oundle	1·83	...	,, .	Oughtershaw Hall......	11·54	...
Beds .	Woburn, Crawley Mill	2·35	105	,, .	Wetherby, Ribston H.	3·05	130
Cam .	Cambridge, Bot. Gdns.	1·26	65	,, .	Hull, Pearson Park ...	2·44	111
Essex .	Chelmsford, County Lab	2·13	95	,, .	Holme-on-Spalding ...	2·67	...
,, .	Lexden, Hill House ...	2·06	...	,, .	West Witton, Ivy Ho.	4·17	...
Suff .	Hawkedon Rectory ...	1·99	88	,, .	Felixkirk, Mt. St. John	2·38	97
,, .	Haughley House	1·76	...	,, .	Pickering, Hungate ...	3·20	...
Norf .	Beccles, Geldeston	...	...	,, .	Scarborough	2·35	95
,, .	Norwich	2·94	114	,, .	Middlesbrough	2·17	102
,, .	Blakeney..................	2·14	96	,, .	Baldersdale, Hury Res.	4·56	...
,, .	Little Dunham	2·74	106	*Durh* .	Ushaw College	3·09	122
Wilts.	Devizes, Highclere......	2·98	112	*Nor* .	Newcastle, Town Moor	2·50	103
,, .	Bishops Cannings	3·25	114	,, .	Bellingham, Highgreen	4·06	...
Dor .	Evershot, Melbury Ho.	5·61	132	,, .	Lilburn Tower Gdns....	3·77	...
,, .	Creech Grange	3·99	...	*Cumb* .	Geltsdale.................	5·43	...
,, .	Shaftesbury, Abbey Ho.	2·35	73	,, .	Carlisle, Scaleby Hall	4·34	145
Devon.	Plymouth, The Hoe ...	3·70	101	,, .	Borrowdale, Rosthwaite	21·09	...
,, .	Polapit Tamar	5·35	126	,, .	Keswick, High Hill ...	11·03	...
,, .	Ashburton, Druid Ho.	9·11	161	*Glam* .	Cardiff, Ely P. Stn. ...	4·98	120
,, .	Cullompton...............	4·38	127	,, .	Treherbert, Tynywaun	18·24	...
,, .	Sidmouth, Sidmount...	...	...	*Carm* .	Carmarthen Friary ...	8·78	176
,, .	Filleigh, Castle Hill ...	5·87	...	,, .	Llanwrda	11·04	187
,, .	Barnstaple N. Dev. Ath.	4·09	104	*Pemb* .	Haverfordwest, School	7·27	145
Corn .	Redruth, Trewirgie ...	4·71	97	*Card* .	Aberystwyth	6·96	...
,, .	Penzance, Morrab Gdn.	3·98	87	,, .	Cardigan, County Sch.	6·12	...
,, .	St. Austell, Trevarna...	4·72	96	*Brec* .	Crickhowell, Talymaes	7·50	...
Soms .	Chewton Mendip	4·60	107	*Rad* .	Birm W. W. Tyrmynydd	11·71	176
,, .	Long Ashton	3·76	...	*Mont* .	Lake Vyrnwy...........	13·83	249
,, .	Street, Hind Hayes ...	...	...	*Denb* .	Llangynhafal	4·88	...
Glos. .	Cirencester, Gwynfa ...	4·03	135	*Mer* .	Dolgelly, Bryntirion...	10·14	163
Here .	Ross, Birchlea............	2·81	111	*Carn* .	Llandudno	3·55	115
,, .	Ledbury, Underdown	2·36	97	,, .	Snowdon, L. Llydaw 9	26·80	...
Salop .	Church Stretton.........	4·85	165	*Ang* .	Holyhead, Salt Island	6·04	146
,, .	Shifnal, Hatton Grange	3·79	159	,, .	Lligwy.....................	5·94	...
Worc .	Ombersley, Holt Lock	2·35	103	*Isle of Man*			
,, .	Blockley	3·11	...		Douglas, Boro' Cem....	7·94	168
War .	Farnborough	4·30	157	*Guernsey*			
,, .	Birminghm, Edgbaston	3·69	155		St. Peter P't. Grange Rd.	4·57	109

Rainfall: November, 1928: Scotland and Ireland

Co.	Station	In.	Per-cent of Av.	Co.	Station	In.	Per-cent. of Av.
Wigt .	Stoneykirk, ArdwellHo	6·52	164	*Suth* .	Loch More, Achfary ...	13·01	152
,, .	Pt. William, Monreith	7·13	...	*Caith* .	Wick	4·58	145
Kirk .	Carsphairn, Shiel.	13·71	...	*Ork* .	Pomona, Deerness	4·28	109
,, .	Dumfries, Cargen	6·87	152	*Shet* .	Lerwick	5·33	125
Dumf.	Eskdalemuir Obs.	8·85	153	*Cork* .	Caheragh Rectory	8·24	...
Roxb .	Branxholm	4·59	139	,, .	Dunmanway Rectory...	8·10	131
Selk .	Ettrick Manse	8·15	...	,, .	Ballinacurra	4·58	114
Peeb .	West Linton	3·61	...	,, .	Glanmire, Lota Lo. ...	5·76	134
Berk .	Marchmont House......	3·42	114	*Kerry*.	Valentia Obsy.	7·33	134
Hadd.	North Berwick Res. ...	2·48	111	,, .	Gearahameen	15·80	...
Midl .	Edinburgh, Roy. Obs.	2·98	139	,, .	Killarney Asylum	...	...
Ayr .	Kilmarnock, Agric. C.	5·48	146	,, .	Darrynane Abbey	6·05	119
,, .	Girvan, Pinmore	8·02	151	*Wat* .	Waterford, Brook Lo...	5·77	153
Renf .	Glasgow, Queen's Pk. .	4·26	114	*Tip* .	Nenagh, Cas. Lough...	6·26	156
,, .	Greenock, Prospect H.	9·87	154	,, .	Roscrea, Timoney Park	4·54	...
Bute .	Rothesay, Ardencraig.	9·20	181	,, .	Cashel, Ballinamona...	4·42	126
,, .	Dougarie Lodge	7·82	...	*Lim* .	Foynes, Coolnanes......	5·96	147
Arg .	Ardgour House	15·03	...	,, .	Castleconnel Rec.	5·51	...
,, .	Manse of Glenorchy ...	11·24	...	*Clare* .	Inagh, Mount Callan...	9·81	...
,, .	Oban	9·56	...	,, .	Broadford, Hurdlest'n.	6·87	...
,, .	Poltalloch	9·37	166	*Wexf*.	Newtownbarry	...	...
,, .	Inveraray Castle...	15·10	179	,, .	Gorey, Courtown Ho ..	6·76	194
,, .	Islay, Eallabus	9·30	173	*Kilk* .	Kilkenny Castle.........	4·11	133
,, .	Mull Benmore	19·10	...	*Wic* .	Rathnew, Clonmannon	5·70	...
,, .	Tiree	6·28	...	*Carl* .	Hacketstown Rectory..	4·80	123
Kinr .	Loch Leven Sluice......	3·85	107	*QCo* .	Blandsfort House	4·30	129
Perth .	Loch Dhu	11·75	135	,, .	Mountmellick...........	5·90	...
,, .	Balquhidder, Stronvar	7·44	...	*KCo* .	Birr Castle	3·91	126
,, .	Crieff, Strathearn Hyd.	5·02	105	*Dubl* .	Dublin, FitzWm. Sq...	3·18	119
,, .	Blair Castle Gardens ...	5·03	143	,, .	Balbriggan, Ardgillan.	4·13	144
,, .	Dalnaspidal Lodge ...	9·02	136	*Me'th* .	Beauparc, St. Cloud...	3·81	...
Forf .	Kettins School	3·35	120	,, .	Kells, Headfort	5·49	161
,, .	Dundee, E. Necropolis	3·26	134	*W.M* .	Moate, Coolatore	3·92	...
,, .	Pearsie House...........	3·80	...	,, .	Mullingar, Belvedere..	5·29	155
,, .	Montrose, Sunnyside...	2·69	102	*Long* .	Castle Forbes Gdns......	5·56	154
Aber .	Braemar, Bank	3·49	91	*Gal* .	Ballynahinch Castle ...	9·48	158
,, .	Logie Coldstone Sch....	2·56	83	,, .	Galway, Grammar Sch.	8·11	...
,, .	Aberdeen, King's Coll.	3·93	133	*Mayo* .	Mallaranny...............	3·33	...
,, .	Fyvie Castle	4·55	...	,, .	Westport House.........	6·23	127
Mor .	Gordon Castle	3·87	134	,, .	Delphi Lodge	13·01	...
,, .	Grantown-on-Spey ...	3·54	118	*Sligo* .	Markree Obsy............	5·64	135
Na .	Nairn, Delnies	3·37	143	*Cav'n* .	Belturbet, Cloverhill...	4·57	147
Inv .	Kingussie, The Birches	4·59	...	*Ferm* .	Enniskillen, Portora...	5·48	...
,, .	Loch Quoich, Loan ...	14·40	...	*Arm* .	Armagh Obsy............	4·26	150
,, .	Glenquoich...............	17·22	142	*Down* .	Fofanny Reservoir......	9·98	...
,, .	Inverness, Culduthel R.	3·42	...	,, .	Seaforde	6·42	169
,, .	Arisaig, Faire-na-Squir	6·25	...	,, .	Donaghadee, C. Stn ...	4·96	163
,, .	Fort William	11·34	...	,, .	Banbridge, Milltown...	4·23	154
,, .	Skye, Dunvegan	9·97	...	*Antr* .	Belfast, Cavehill Rd ...	5·43	...
R & C.	Alness, Ardross Cas. ...	5·35	133	,, .	Glenarm Castle	8·98	...
,, .	Ullapool	6·40	...	,, .	Ballymena, Harryville	5·68	140
,, .	Torridon, Bendamph...	11·68	126	*Lon* .	Londonderry, Creggan	6·10	149
,, .	Achnashellach	10·69	...	*Tyr* .	Donaghmore	5·61	...
,, .	Stornoway	6·75	116	,, .	Omagh, Edenfel.........	5·38	142
Suth .	Lairg	4·70	...	*Don* .	Malin Head...............	4·89	149
,, .	Tongue	5·42	118	,, .	Dunfanaghy	5·53	...
,, .	Melvich	5·74	143	,, .	Killybegs, Rockmount.	7·09	112

Climatological Table for the British Empire, June, 1928.

STATIONS	PRESSURE		TEMPERATURE									PRECIPITATION			BRIGHT SUNSHINE	
			Absolute		Mean Values				Mean							
	Mean of Day M.S.L.	Diff. from Normal	Max.	Min.	Max.	Min.	½ max. and min.	Diff. from Normal	Wet Bulb	Relative Humidity.	Mean Cloud Am'nt	Am'nt	Diff. from Normal	Days	Hours per day	Percentage of possible
	mb.	mb.	° F.	° F.	° F.	° F.	° F.	° F.	° F.	%	0—10	in.	in.			
London, Kew Obsy.	1014·1	— 2·6	75	42	65·8	49·3	57·5	— 1·7	51·6	77	6·2	2·24	+ 0·09	18	7·0	43
Gibraltar	1016·0	— 1·4	85	60	76·5	64·2	70·3	— 0·2	62·9	82	4·6	0·13	— 0·35	1	..	..
Malta	1017·0	+ 1·4	88	62	78·6	66·9	72·7	0·0	66·2	70	1·0	0·00	— 0·09	0	12·5	87
St. Helena	1015·1	+ 2·2	66	53	64·1	56·6	60·3	— 0·7	58·4	97	8·7	1·02	— 3·05	9	..	..
Sierra Leone	1012·5	+ 0·5	89	69	85·3	72·8	79·1	— 1·2	75·9	81	8·8	11·10	— 8·94	22	..	..
Lagos, Nigeria	1010·2	— 2·7	87	70	84·0	74·4	79·2	— 0·1	76·0	85	7·2	21·05	+ 2·40	18	..	..
Kaduna, Nigeria	1015·2	+ 1·4	91	..	86·2	..	..	..	71·5	80	1·3	5·38	— 2·47	16	..	..
Zomba, Nyasaland	1016·9	— 0·6	81	49	73·6	55·5	64·5	+ 1·6	..	71	5·4	0·22	— 0·26	5	..	..
Salisbury, Rhodesia	1016·5	— 1·0	77	35	72·9	45·6	59·3	+ 2·4	51·6	56	1·8	0·00	— 0·05	0	9·5	86
Cape Town	1020·1	0·0	72	34	61·6	47·7	54·7	— 1·0	48·9	88	5·8	4·36	— 0·15	16	..	..
Johannesburg	1022·6	— 0·5	70	27	61·0	42·1	51·5	+ 0·8	39·3	40	1·3	0·10	— 0·04	1	9·6	91
Mauritius	1018·8	— 0·2	78	54	75·4	62·8	69·1	— 0·4	65·8	71	3·4	1.22	— 1·58	12	7·9	72
Bloemfontein	..	..	72	22	62·0	31·7	46·9	— 0·7	34·8	60	1·5	0·22	— 0·25	1	..	..
Calcutta, Alipore Obsy.	997·5	— 2·2	101	76	90·0	78·9	84·5	— 0·6	79·5	89	8·7	17·99	+ 6·09	22*	..	..
Bombay	1003·3	— 0·7	95	73	89·4	78·7	84·1	+ 0·2	78·3	81	7·1	27·71	+ 7·84	22*	..	..
Madras	1002·2	— 1·6	107	77	101·1	82·7	91·9	+ 1·8	74·7	51	5·5	0·24	— 1·65	10*	..	..
Colombo, Ceylon	1008·3	— 0·4	88	73	85·9	77·9	81·9	+ 0·2	78·1	78	8·2	8·92	+ 0·95	20	6·6	53
Hongkong	1004·4	— 1·7	89	72	84·3	76·5	80·4	— 1·0	76·0	80	7·9	15·13	— 0·96	22	5·9	44
Sandakan	..	..	92	72	88 2	74·6	81·4	— 0·3	77·1	82	..	4·61	— 2·59	12	..	..
Sydney	1017·0	— 0·8	72	41	62·2	48·7	55·5	+ 0·9	49·7	75	4·9	7·40	+ 2·63	15	4·7	47
Melbourne	1019·5	+ 1·0	66	32	56·3	43·0	49·7	— 0·7	46·5	86	7·4	1·44	— 0·65	16	3·5	37
Adelaide	1020·0	+ 1·0	67	39	60·5	46·2	53·3	— 0·2	49·0	81	6·7	3·52	+ 0·37	19	4·6	47
Perth, W. Australia	1019·5	+ 1.6	75	45	66·3	50·7	58·5	+ 1·7	52·9	70	5·4	5·50	— 1·42	16	5·1	51
Coolgardie	1021·3	+ 2·2	72	35	64·5	42·7	53·6	+ 0·9	47·3	69	3·8	0·29	— 0·94	5	..	..
Brisbane	1017·0	— 1·1	75	40	67·5	49·2	58·3	— 1·9	52·1	75	4·7	2·22	— 0·41	10	6·8	65
Hobart, Tasmania	1017·5	+ 3·2	59	34	52·9	41·1	47·0	+ 0·2	42·4	81	6·1	1·84	— 0·36	17	3·9	43
Wellington, N.Z.	1013·1	— 1·8	58	37	52·0	42·7	47·3	— 2·1	45·3	82	7·8	4·52	— 0·25	17	2·7	29
Suva, Fiji	1013·3	— 0·3	86	63	79·9	69·1	74·5	— 0·4	70·2	78	6·1	2·17	— 3·98	11	5·4	49
Apia, Samoa	1011·6	0·0	87	68	84·5	77·5	81·0	+ 3·2	74·7	75	4·2	1·24	— 3·92	4	7·1	63
Kingston, Jamaica	1013·2	— 0·6	94	71	89·6	74·2	81·9	+ 0·6	71·7	74	5·6	1·29	— 2.81	5	7·8	59
Grenada, W.I.	1009·8	3·3	90	71	87·0	73·7	80·3	+ 1·4	75·6	75	5·5	7·57	— 0·75	21	..	..
Toronto	1010·6	— 3·7	81	39	70·5	52·5	61·5	— 1·1	55·0	71	5·9	3·97	+ 1·21	14	7·4	48
Winnipeg	1010·6	— 1·9	84	34	69 6	49·3	59·5	— 2·7	52·0	84	6·0	3·58	+ 0·32	13	7·8	48
St. John, N.B.	1013·0	— 1·0	75	44	64·1	47·0	55·5	— 1·0	52·7	76	6·0	4·80	+ 1·53	16	6·9	44
Victoria, B.C.	1015·5	— 1·4	77	48	63·0	50·3	56·7	— 0·3	53·1	77	5·1	0·51	— 0·42	5	8·8	55

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