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## EFFECT OF ATMOSPHERIC INHOMOGENEITY ON THE INTERPRETATION OF VERTICAL TEMPERATURE SOUNDINGS

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The atmosphere is subject to oscillations and fluctuations ranging in period from a fraction of a second to several days and in scale from a few centimetres to a thousand kilometres or more. For the purpose of synoptic weather analysis and forecasting, attention is concentrated on weather systems with a minimum horizontal extent of 200 to 300 Km.; smaller-scale irregularities affect only one reporting station at a time and therefore cannot be incorporated in the analysis. Frith[1] has demonstrated the existence of temperature fluctuations of up to 2°F. over horizontal distances of 50 Km. These disturbances are too small to be incorporated in synoptic weather analysis, but nevertheless the temperature differences which arise in them are sufficient to be of interest to the synoptic analyst. The departures of the temperature from the true mean value for an area of the order of 100 Km. square must be regarded by the analyst as an error due to the unrepresentative nature of his sounding.

Relatively small-scale temperature fluctuations become of particular significance in the analysis of vertical soundings of temperature. The small-scale temperature variations may introduce changes in lapse rate, which are quite unrepresentative of the area around the sounding station but which may simulate frontal lapse-rate discontinuities or lead to false deductions regarding air-mass stability. It is the purpose of the present note to investigate the limitations imposed on the interpretation of vertical soundings by the existence of such temperature fluctuations.

A direct method of carrying out such an investigation would be to compare individual temperature soundings with the mean temperature sounding representative of an area of radius 50 Km. or so around the sounding station. Unfortunately there is no method of obtaining mean temperatures for a horizontal area of this extent in the free atmosphere at a large number of levels simultaneously without the use of a prohibitively large number of radio-sondes or aircraft. The problem must therefore be approached from a different point of view, and in the following paragraphs an estimate is made of the effect of the small-scale temperature fluctuations in modifying some tephigrams based on simple air-mass and frontal conditions. An examination of these reveals the magnitude of the spurious irregularities in lapse rate. For this purpose information is needed regarding the magnitude of the temperature fluctuations and the vertical scale of the disturbances. This has been taken from the original records of the Meteorological Research Flight which carried out a large number of flights during 1948 and 1949 for the purpose of studying these fluctuations. On each occasion the aircraft flew to and fro along a set of parallel horizontal tracks making temperature observations at points about 2½ Km. apart. A rectangular area with sides about 50 Km. long was thus covered by an observational grid.

**Standard deviation of temperature.**—From the records of the Meteorological Research Flight 34 cases were found in which a horizontal grid had been flown within an air mass (i.e. not within a frontal zone). In some cases more than one grid was flown on a particular occasion, usually at different levels. From each grid flight the standard deviation of temperature from the mean for the flight was calculated. Three of the flights were conducted in an inversion or markedly stable layer. These gave standard deviations of temperature of 0·79°, 0·77° and 0·78°F., values larger than obtained on the remaining flights. The average standard deviation for the remaining flights was 0·51° and the standard deviation of the individual standard deviations about this mean was 0·16°.

A reasonably representative value of the standard deviation of temperature over an area of some 50-Km. radius therefore seems to be about 0·5° in normal air masses and about 0·75° in inversion or other very stable layers.

**Vertical correlation of the temperature fluctuations.**—In order to discuss the effect of small-scale temperature fluctuations on the appearance of a temperature sounding curve, it is necessary to know not only the magnitude of the temperature fluctuations but also the vertical scale of the temperature variations. This is best examined by means of the correlation coefficients between the temperatures at pairs of levels with various vertical separations.

Flights have been made by Meteorological Research Flight aircraft to examine the vertical scale of the temperature fluctuations. In some of these two aircraft were used flying simultaneously along parallel tracks with vertical separation from zero to 2,000 ft. On other occasions one aircraft only was employed, and this returned along a track as nearly as possible vertically above the air through which it flew on the outward flight. Data are available from some 14 pairs of levels, and the correlation coefficients between the temperatures at each pair of levels have been calculated. The correlation coefficients are plotted against the vertical separation between the levels in Fig. 1.

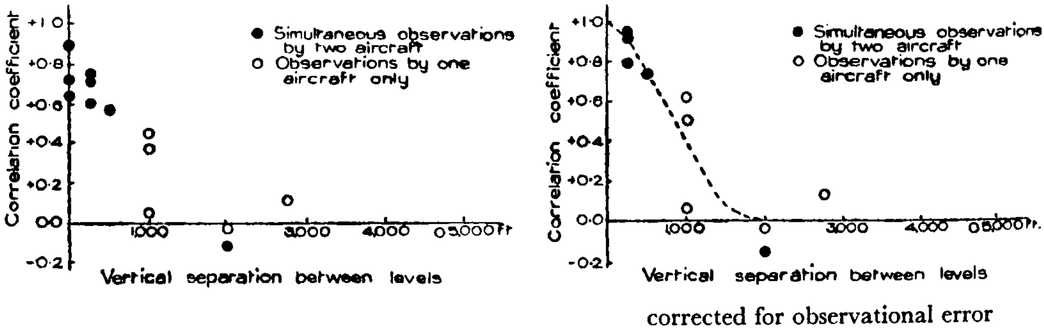


FIG. 1—CORRELATION COEFFICIENT BETWEEN TEMPERATURE AT TWO LEVELS OVER DISTANCES OF 100 TO 200 KM.

As would be expected the correlation coefficient decreases with increasing separation between the levels and becomes zero when the separation reaches about 2,000 ft. When two aircraft are employed flying as close together as possible the correlation coefficient does not reach unity. This may be attributed to errors of observation and to temperature variations on a still smaller scale. If this difference from unity is assumed to be due to random errors of observation the remaining correlation coefficients may be corrected, and this has been done in the right-hand half of Fig. 1 to give a better representation of the true correlation between the temperature fluctuations at two levels. Although, as would be expected, there is a good deal of scatter, nevertheless it seems that the variation of the correlation coefficient with separation between the levels can be adequately represented by the curve superimposed on the diagram, and such a variation has been assumed in assessing the effect of the temperature fluctuations on vertical soundings.

**Simulated temperature fluctuations.**—During the flight of a radiosonde, observations of temperature, pressure and humidity are made in sequence so that a set of discrete observations of temperature is obtained referring to a set of levels separated by about 400 ft. The observed temperatures will differ from the true mean temperature representative of the area by an amount, $\varepsilon$, due to the small-scale temperature fluctuations. The values of $\varepsilon$ at consecutive observations are correlated, and the correlation will decrease with increasing separation and become zero between observations separated by 2,000 ft., i.e. five observations apart.

The next step in the investigation was to construct sets of numbers which could represent possible sets of values of $\varepsilon$, i.e. sets of departures of observed temperature from representative mean temperature at a sequence of levels 400 ft. apart. The conditions which had to be satisfied were—

(i) The numbers should have a Gaussian distribution

(ii) Their standard deviation should be appropriate to the small-scale temperature fluctuations

(iii) The autocorrelation of the series should be appropriate to the curve corrected for observational error.

Such series were constructed by first preparing random sets of numbers with a Gaussian distribution. The standard deviation was then adjusted to be 0·5° or 0·75°F., appropriate to normal lapse or inversion condition respectively. From these sets a coherent series of numbers was prepared by forming running means of the form

$$\frac{2a_{n-2} + 3a_{n-1} + 5a_n + 3a_{n+1} + 2a_{n+2}}{\sqrt{51}}.$$

These coherent series should have autocorrelation coefficients, $r_1 = +0{\cdot}82$, $r_2 = +0{\cdot}57$, $r_3 = +0{\cdot}24$, $r_4 = +0{\cdot}08$, $r_5 = 0$, appropriate to levels separated by 400, 800, 1,200, 1,600, and 2,000 ft. respectively.

In order to study the effect of such temperature fluctuations on the appearance of the tephigram, various idealized tephigrams were drawn appropriate to frontal and non-frontal situations. The temperature was read off at 400-ft. intervals and a set of values of $\varepsilon$ taken from one of the coherent series and added term by term. The resulting temperatures were replotted on a tephigram and examined. The curves so obtained were more irregular than the usual temperature sounding used in upper air analysis. This difference is primarily a result of the smoothing introduced during the computation of the radio-sonde results and their transmission to a central office. It was desirable therefore to simulate these processes also, before considering the effect of small-scale temperature fluctuations on aerological analysis.

It is unnecessary to describe the procedure of radio-sonde computation in detail. It is sufficient to note that the radio-sonde observations are first plotted against time and the curve is simplified by joining selected plots by straight lines, subject to the requirement that no intervening omitted point should differ by more than 0·5°F. from the straight lines so drawn. The pressure and temperature are computed for the corner points, and these are transferred to a temperature-log pressure diagram and again joined by straight lines. Interpolation on this diagram gives values for the levels which are reported to the central office and plotted on the final tephigram. These levels are at 50-mb. intervals, but additional significant points are reported wherever the error of reporting would otherwise exceed 0·5°F. This procedure has been closely simulated in the present experiment using the ideal lapse rates to which the simulated temperature fluctuations have been added. The tephigrams produced in this way will be referred to as the soundings "as reported", and the results will be described in the following paragraphs.

**Simulated air mass soundings.**—Fig. 2 shows four idealized tephigrams representing smooth lapse rates in homogeneous air masses. Fig. 3 shows the result of modifying these soundings by the addition of a coherent series representing the effect of the small-scale temperature fluctuations. The standard deviations of the series used are indicated. Fig. 4 shows the same soundings as they would have been reported.

It is interesting to note that the curves in Fig. 4 are very similar in general form and in the nature of their irregularities to the curves actually plotted from radio-sonde reports. In three out of the four soundings spurious stable layers have been introduced. The standard deviation of the series used in forming curves B and D (namely 0·75°F.) is perhaps rather large for a homogeneous air mass, but a stable layer also appears in curve A for which the standard deviation of the simulated temperature fluctuation was only 0·5°F.

The irregularities of curves in Fig. 4 are not large, but they are sufficient to be misinterpreted by an analyst as minor air-mass boundaries if he were to regard them as real, or to lead him to erroneous conclusions on the development of convective cloud.

**Simulated frontal soundings.**—To illustrate the effect of small-scale temperature fluctuations on frontal soundings, an idealized frontal transition of moderate intensity has been studied. The same total air-mass temperature change has been considered, first as being linear over an interval of 100 mb. (Fig. 5, curve I), secondly as being somewhat smoother over about the same pressure range (curve II), and thirdly as spread smoothly over a range of about 250 mb. Temperature fluctuations have been added to these idealized curves, and the soundings replotted as they would have been reported. The results are presented in Fig. 6. The standard deviation of the series used is indicated beneath the sounding. The following points are of interest:—

(i) The sharp frontal transition of curve I has been little affected by the added fluctuation, but between 612 and 565 mb. another stable layer has been introduced which has an almost equally good claim to be treated as a frontal layer.

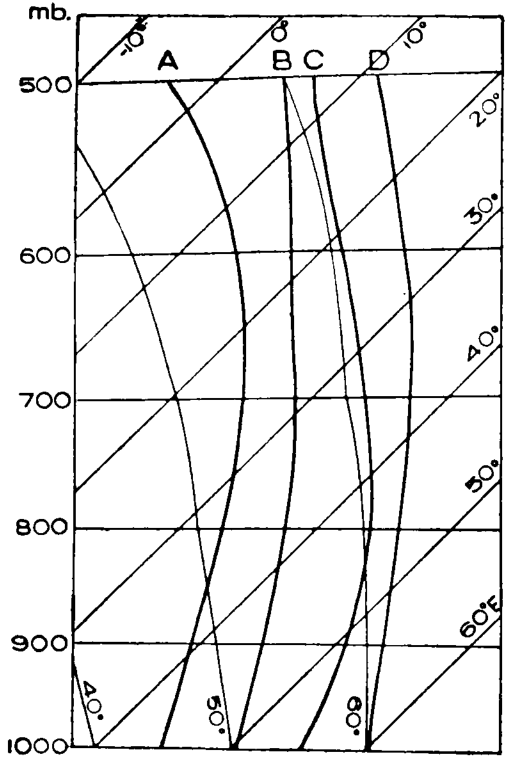


FIG. 2—IDEALIZED TEPHIGRAMS FOR HOMOGENEOUS AIR MASSES

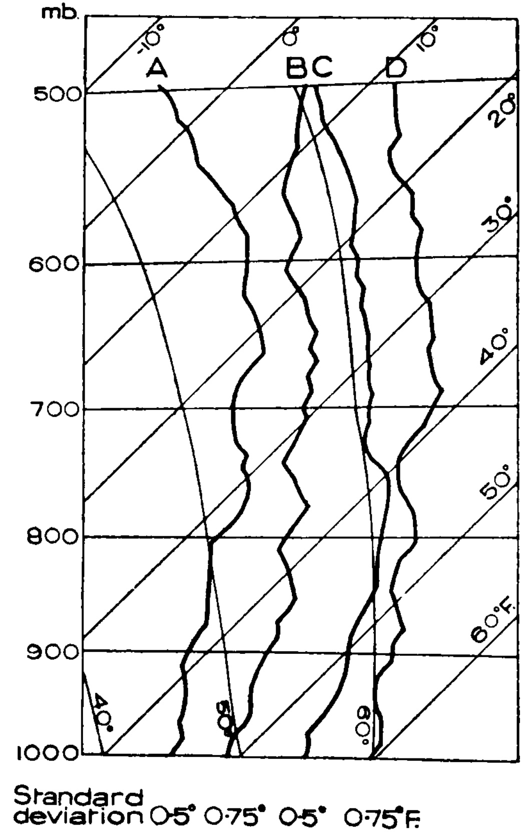


FIG. 3—IDEALIZED LAPSE RATES MODIFIED BY ADDITION OF COHERENT TEMPERATURE FLUCTUATIONS

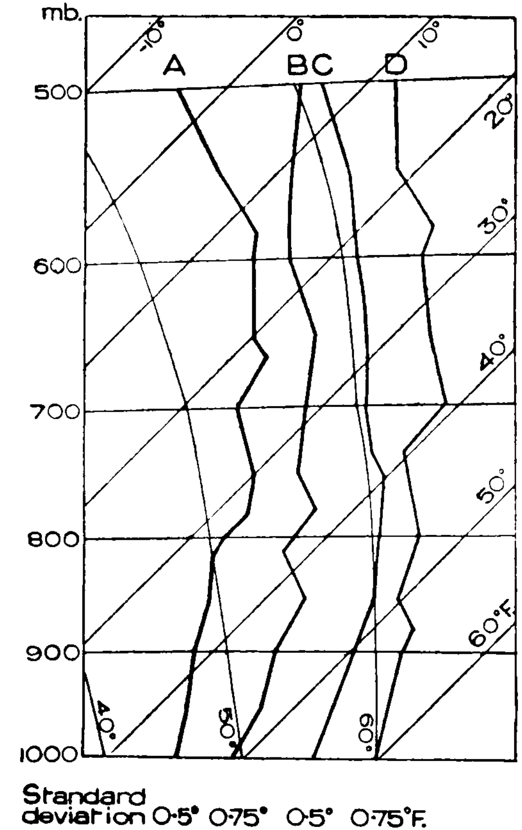


FIG. 4—SOUNDINGS OF FIG. 3 "AS REPORTED"

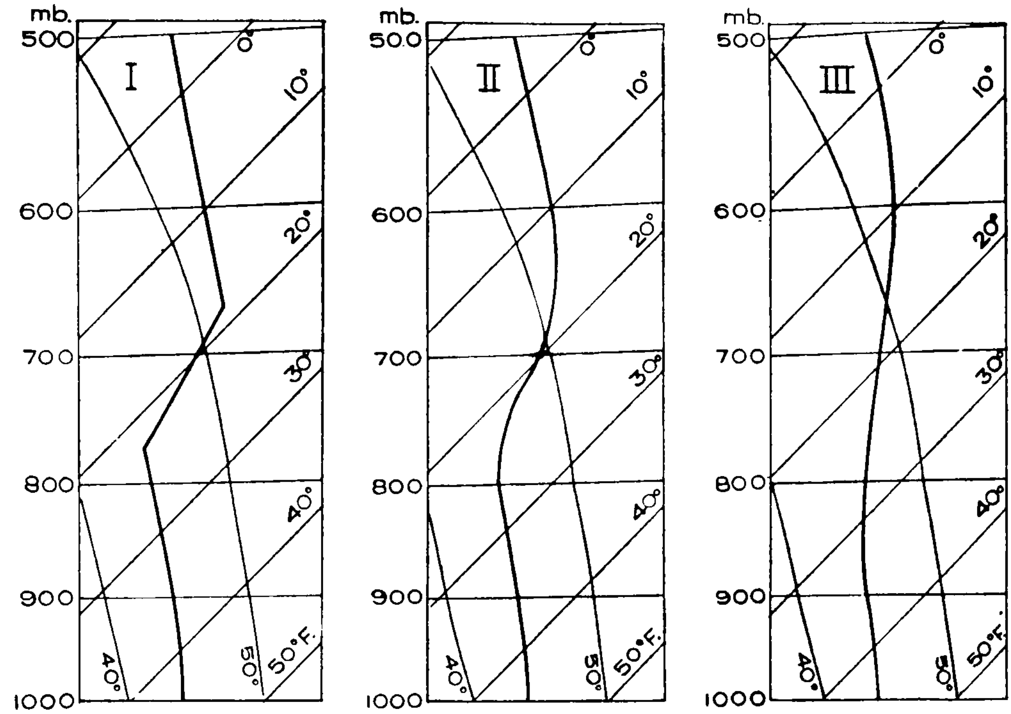


FIG. 5—IDEALIZED SOUNDINGS THROUGH FRONTS

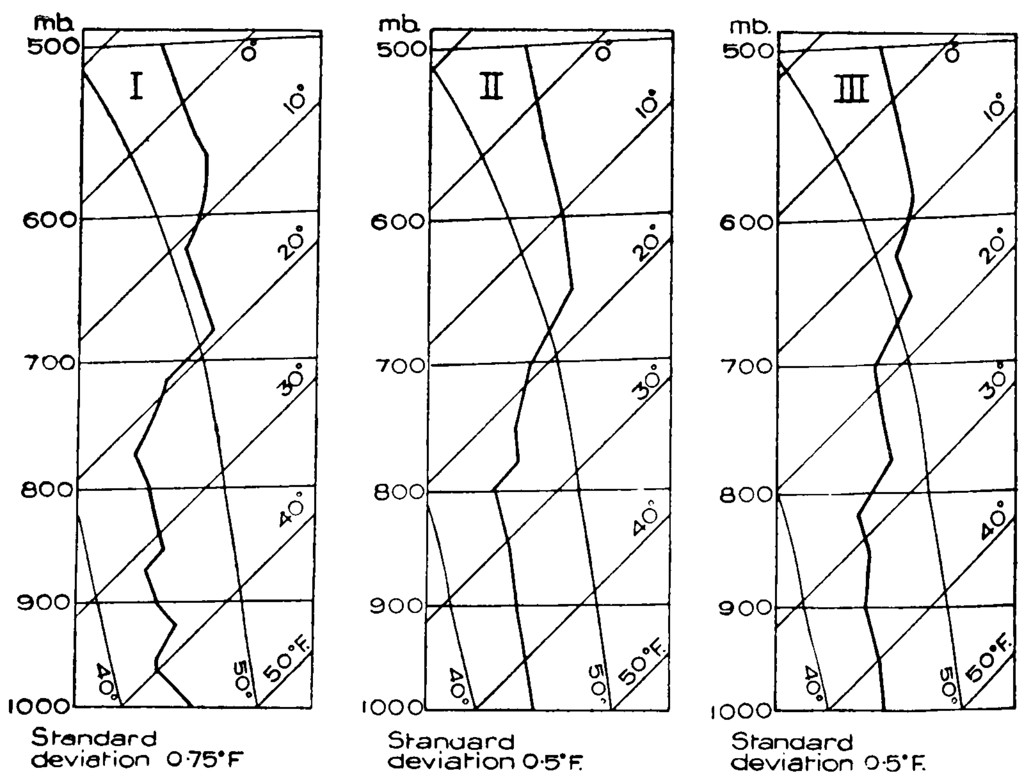


FIG. 6—SOUNDINGS THROUGH FRONTS "AS REPORTED"

(ii) The frontal transition is quite well defined in curve II "as reported". However, although in Fig. 5 the boundaries of the frontal zone were deliberately smoothed off, in Fig. 6 they appear to be quite sharp.

(iii) The very smooth transition of curve III Fig. 5 has been broken down into three distinct and rather sudden temperature changes. Similar transitions are not uncommon on observed soundings and there has been some uncertainty as to whether the individual steps should be regarded as real frontal subzones.

**Discussion of Results.**—So far no mention has been made of the errors of the radio-sonde itself. Sheppard[2] has estimated the probable error of reading as about 0·2°F. and the casual error of the temperature element itself as 0·6°F. (corresponding to standard deviations of 0·3° and 0·9°F.). A considerable part of the error of the element is probably systematic so far as a single sounding is concerned, and it seems probable that the effect of instrumental error on the sounding curves will be to add a random error with standard deviation about 0·4°F. to the individual readings. This will make the irregularity of the sounding curve somewhat greater than indicated in Figs. 4 and 6. It is evident that for synoptic purposes no advantage would be gained by further reducing the purely random errors of the individual radio-sonde readings, because the irregularities due to real local temperature irregularities in the atmosphere limit the accuracy of the values which can be obtained.

In the preceding sections it has been demonstrated that minor irregularities in temperature soundings may easily arise from the known small-scale temperature irregularities in the free atmosphere. These irregularities are large enough to be misinterpreted as real phenomena of importance in frontal analysis or in restricting convection. It is difficult to lay down any specific rules for the large-scale significance of irregularities on a sounding curve, but it is clear that one must treat with caution any irregularity which does not depart by more than 1·5°F. from a smoothed curve following the sounding.

It is also apparent that it is quite impossible to decide whether a frontal zone is best represented by a linear transition with discontinuities of lapse rate at the boundaries, or by a gradually changing lapse rate; also that division of a broad frontal zone into two or more subzones is of doubtful validity unless the subzones themselves are very well marked on the sounding (departing by 2°F. or more from the smooth curve).

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## RADIATION MINIMUM TEMPERATURE OVER A GRASS SURFACE AND OVER A BARE-SOIL SURFACE

By R. W. GLOYNE, B.Sc.

**Introduction.**—The minimum temperature recorded during a 24-hr. period by an unscreened radiation minimum ("grass" minimum) thermometer when placed with the bulb just touching the tips of short grass is a routine observation at most climatological stations. These data are frequently quoted and utilized by writers on scientific horticulture (e.g. Gardner, Bradford and Hooker[1]) and it is the purpose of the present note to examine the relationship between the minima over short turf and that just above bare soil as revealed by nearly two years' observations (namely from January 1, 1949–December 14, 1950) at the National Agricultural Advisory Service's Subcentre at Starcross, Devon.

There is a considerable amount of evidence, as given in papers by Cornford[2], Seeley[3], Cox[4], Young[5,6] and Rogers[7], that the night minimum over grass is lower than over bare soil, and lower over long grass than over short grass—results largely explicable in terms of the insulating property of the turf surface. An early paper by Glaisher[8] deserves special mention as a pioneer investigation to establish the effect of the characteristics of a surface on the minimum temperature recorded on or just above it. Of the many materials he used, a pad of raw wool placed on the ground gave rise to the lowest radiation minima. On one cold night in October 1843, for example, the air minimum was 28½°F., that on wool 16°F., over long grass 17°F., short grass 20½°F., on gravel 26½°F. and on loam 24½°F.

Clearly if the published figures of "grass minima" are used as estimates of the night minima over any surface other than short grass misleading conclusions will follow. In particular, if they are assumed to be close estimates of the minimum temperature just above a soil surface carrying seedlings, minimum temperature may be seriously under-estimated and the frequency of "ground frosts" seriously over-estimated.

**Site and technique.**—The investigation was carried out at the climatological station at Starcross which lies at 29 ft. above M.S.L. and is situated a few hundred yards from the west bank of the Exe estuary, some 4 miles north of Dawlish. The soil is a sandy loam of the Permian series with a good deal of alluvial silt. The water table is high and the drainage rather impeded during a wet period, but in summer the surface layers dry out quickly and the soil cracks and sets in hard lumps. The climatological station is well exposed in all directions.

On the soil plot the thermometer was set with its bulb between ¼ and ½ in. above the surface. Previous tests over five months had established that the point-to-point variation of two such instruments placed at random 2–3 ft. apart rarely exceeded ½°F., and only one instrument was in consequence used for this investigation. Every observation was carefully examined with reference to other observations at this and at neighbouring stations, and as a result it was found necessary to reject 21 observations and 6 observations respectively from the 1949 and 1950 records.

**Observations and analysis of results.**—It was clearly desirable to link the difference between "soil" and "grass" minima to the difference "screen minimum − grass minimum", and special note was taken of the former differences on "radiation" nights, i.e. nights on which the depression of the grass minimum reading was 7°F. or more below the screen minimum. This limit was found by Hogg[9] and Foley[10] to be a useful criterion for specifying those reasonably clear still nights when there is a rapid loss of heat from the surface. It has been consistently used by the Meteorological Office (Agricultural Branch) with satisfactory results.

*Means and extremes.*—The monthly means and monthly maxima are set out in Table I. Throughout this paper the value next to the absolute extreme will be given in brackets to indicate roughly the degree of dispersion.

In both tables the agreement between years is good for the months April–October (inclusive). In the winter months the thin, poor grass and frozen, flooded or snow-covered surfaces introduce complicating factors liable to differ widely

TABLE I—MONTHLY MEANS OF SCREEN MINIMUM — GRASS MINIMUM AND BARE-SOIL MINIMUM — GRASS MINIMUM AT STARCROSS, DEVON

| | Jan. | Feb. | Mar. | Apr. | May | June | July | Aug. | Sept. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | *degrees Fahrenheit* | | | | | | |
| | | | | | | Screen minimum — grass minimum | | | | | | |
| 1949 | 5·0 | 6·0 | 5·0 | 6·2 | 6·0 | 5·5 | 4·7 | 5·3 | 5·2 | 5·7 | 4·5 | 4·7 |
| 1950 | 3·4 | 5·0 | 4·8 | 6·6 | 5·5 | 5·9 | 5·8 | 7·0 | 5·8 | 6·3 | 8·3 | 8·2* |
| | | | | | | Bare-soil minimum — grass minimum | | | | | | |
| 1949 | 1·7 | 2·6 | 2·5 | 3·3 | 3·2 | 3·6 | 2·3 | 2·2 | 2·5 | 2·8 | 1·1 | 0·8 |
| 1950 | 0·6 | 0·9 | 1·3 | 2·7 | 2·7 | 3·6 | 2·7 | 3·7 | 2·3 | 3·0 | 3·1 | 3·2* |

*Dec. 1–14 inclusive

TABLE II—MONTHLY MAXIMA AND NEXT HIGHEST VALUE (IN BRACKETS) OF SCREEN MINIMUM — GRASS MINIMUM AND BARE-SOIL MINIMUM — GRASS MINIMUM AT STARCROSS, DEVON

| | Jan. | Feb. | Mar. | Apr. | May | June | July | Aug. | Sept. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | *degrees Fahrenheit* | | | | | | |
| | | | | | | Screen minimum — grass minimum | | | | | | |
| 1949 | 9·9 (9·1) | 10·5 (10·1) | 10·0 (9·1) | 12·5 (10·2) | 10·5 (9·3) | 9·1 (8·9) | 8·4 (7·7) | 10·5 (10·1) | 9·4 (9·0) | 10·4 (10·0) | 9·4 (9·2) | 9·7 (7·9) |
| 1950 | 6·8 (6·7) | 10·4 (9·5) | 9·6 (9·5) | 11·6 (10·9) | 11·1 (9·4) | 10·9 (10·7) | 8·3 (8·2) | 10·5 (10·1) | 10·8 (9·8) | 10·9 (10·9) | 12·6 (11·9) | 12·9* (11·5)* |
| | | | | | | Bare-soil minimum — grass minimum | | | | | | |
| 1949 | 4·1 (3·7) | 6·4 (6·4) | 6·0 (5·7) | 9·8 (6·2) | 5·6 (5·2) | 7·1 (5·6) | 6·9 (4·8) | 5·0 (4·3) | 7·6 (4·5) | 5·0 (4·6 | 3·5 (3·3) | 2·9 (2·5) |
| 1950 | 2·5 (2·2) | 2·7 (2·4) | 4·3 (2·7) | 5·9 (4·8) | 5·5 (5·5) | 7·5 (6·7) | 5·3 (4·9) | 7·2 (5·4) | 6·0 (5·2) | 6·2 (5·5) | 5·6 (5·4) | 12·0* (5·1)* |

*Dec. 1–14 inclusive

in their incidence from year to year and to override the effect of insulation which is our main concern.

On the average the contribution of the component "bare-soil minimum — grass minimum" to the total depression of "grass" below screen minimum is substantial, and in the warmer months of the year amounts to 50 per cent. or more.

Turning to monthly extremes, the approximate equality of the extreme value (about 10°F.) of "screen minimum — grass minimum" is worthy of note. The same result is implicit in the paper by Hogg and is explicitly mentioned by Glaisher. Foley's tables also show an extreme monthly depression of "grass" below "screen" minimum of about 10°F. independent of the actual month. In most months therefore, it appears that there will be at least one occasion when the night minimum over the bare soil will be 5°F. or more above that over neighbouring short turf.

*Daily variation.*—For each month dot diagrams were prepared, and the linear regression of "bare soil — grass minimum" upon "screen — grass minimum" computed; Fig. 1 relates to the observations for April 1949 and April 1950. In most months the regression line crossed the vertical axis within ±1°F., and hence the regression and correlation coefficients quoted in Table III fairly adequately represent the general results.

The standard errors of the parameters are not given owing to doubts as to how many statistically independent observations correspond to the thirty or so individual daily values per month.

TABLE III—SLOPE OF THE LINES OF LINEAR REGRESSION OF "BARE SOIL MINIMUM — GRASS MINIMUM" ON "SCREEN MINIMUM — GRASS MINIMUM" TOGETHER WITH CORRELATION COEFFICIENTS BETWEEN THE TWO VARIABLES

| | Jan. | Feb. | Mar. | Apr. | May | June | July | Aug. | Sept. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Slope of the lines of linear regression | | | | | | | | | | | |
| 1949 | 0·37 | 0·50 | 0·54 | 0·61 | 0·44 | 0·49 | 0·58 | 0·49 | 0·47 | 0·44 | 0·31 | 0·25 |
| 1950 | 0·21 | 0·24 | 0·09 | 0·51 | 0·41 | 0·39 | 0·66 | 0·42 | 0·41 | 0·50 | 0·33 | 0·46* |
| | Correlation coefficient | | | | | | | | | | | |
| 1949 | 0·64 | 0·64 | 0·88 | 0·86 | 0·74 | 0·66 | 0·82 | 0·87 | 0·77 | 0·81 | 0·67 | 0·66 |
| 1950 | 0·48 | 0·63 | 0·19 | 0·86 | 0·75 | 0·70 | 0·81 | 0·64 | 0·76 | 0·84 | 0·68 | 0·50* |

*Dec. 1–14 inclusive, value much influenced by one extreme observation.

As with the previous tables, Table III reveals an encouraging consistency between the values at least for the April–October period. The only serious anomalies occur in the winter months and in March 1950. On the vast majority of nights, screen minimum > bare-soil minimum > grass minimum. The "bare soil" minimum exceeded the screen minimum on 14 occasions in 1949 and 16 in 1950; and the grass minimum exceeded the bare-soil minimum on 14 and 12 occasions respectively, and of these 9 occurred in each year distributed between the four months January, February, November and December. Only in 3 of these 56 anomalous cases were any of the differences more than 2°F., and were generally much less.

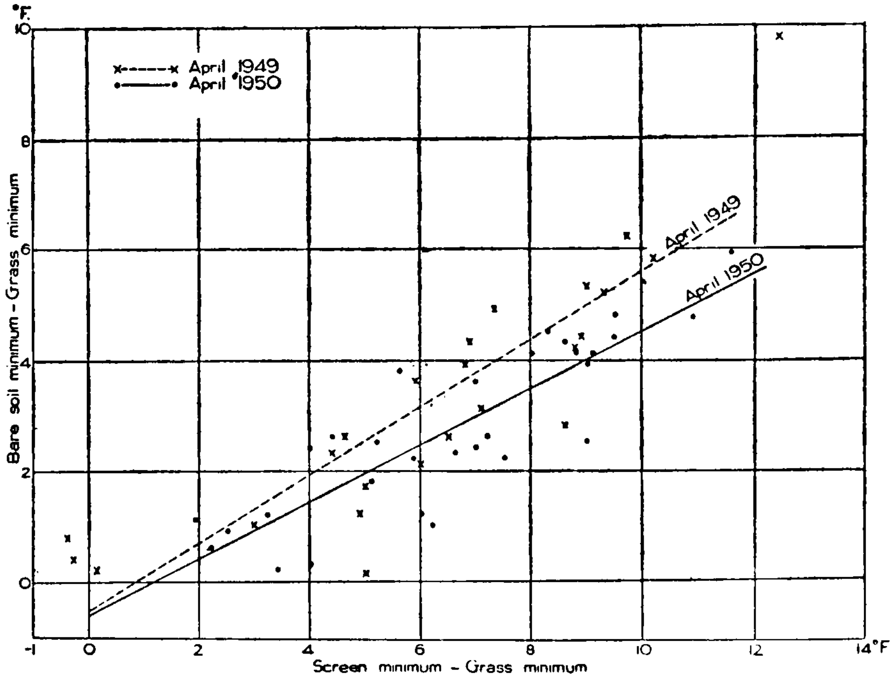


FIG. 1—LINEAR REGRESSION OF "BARE SOIL — GRASS MINIMUM" ON "SCREEN MINIMUM — GRASS MINIMUM" APRIL 1949 AND APRIL 1950

*Behaviour on "radiation" nights.*—Such nights are of particular interest in view of their close association with frost in certain months of the year.

In the period April to October on such nights, the temperature over short grass was on average some 4°F. or more above that over ~~short turf~~ bare soil and on individual nights the excess was rarely less than 2°F.

TABLE IV—VALUES ON "RADIATION" NIGHTS OF MEANS OF SCREEN MINIMUM—GRASS MINIMUM; MEANS OF BARE-SOIL MINIMUM — GRASS MINIMUM; AND LOWEST, AND NEXT LOWEST (IN BRACKETS), INDIVIDUAL VALUE OF "BARE-SOIL MINIMUM — GRASS MINIMUM" WHICH ACTUALLY OCCURRED

| | Jan. | Feb. | Mar. | Apr. | May | June | July | Aug. | Sept. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | *degrees Fahrenheit* | | | | | | |
| | | | | Means of screen minimum — grass minimum | | | | | | | | |
| 1949 | 8·2 | 8·3 | 8·3 | 9·1 | 8·3 | 7·8 | 7·6 | 8·2 | 8·5 | 8·5 | 8·4 | 8·1 |
| 1950 | .. | 8·7 | 8·4 | 8·7 | 8·7 | 9·1 | 7·8 | 8·6 | 8·5 | 9·2 | 9·7 | 9·5 |
| | | | | Means of bare-soil minimum — grass minimum | | | | | | | | |
| 1949 | 2·6 | 3·7 | 4·4 | 5·2 | 4·1 | 4·9 | 4·4 | 3·5 | 3·9 | 4·1 | 2·3 | 2·0 |
| 1950 | .. | 1·5 | 2·4 | 3·9 | 4·1 | 4·9 | 3·9 | 4·5 | 3·7 | 4·6 | 3·6 | 3·8 |
| | | | | Lowest, and next lowest (in brackets), individual value of "bare-soil minimum — grass minimum" which actually occurred | | | | | | | | |
| 1949 | 0·9 | 1·4 | 2·3 | 2·8 | 2·6 | 2·1 | 3·0 | 2·2 | 2·2 | 3·5 | 1·6 | 1·5 |
| | (1·8) | (1·9) | (3·1) | (3·1) | (3·3) | (4·3) | (3·2) | (2·6) | (2·7) | (3·8) | (1·7) | (1·8) |
| 1950 | .. | 0·9 | 0·7 | 2·2 | −0·3 | 3·2 | 0·7 | 0·8 | 1·9 | 2·8 | 0·9 | 1·0 |
| | .. | (1·2) | (2·1) | (2·4) | (2·8) | (4·3) | (3·2) | (3·5) | (2·3) | (3·5) | (2·5) | (1·5) |

*Ground frosts.*—When the minimum over grass is 30·4°F. or less a "ground frost" is said to have occurred. Accepting this convention as applying to the bare-soil surface also, the following monthly frequencies resulted:—

TABLE V—FREQUENCY OF "GROUND FROSTS" OVER A SURFACE OF SHORT TURF AND OVER BARE SOIL AT STARCROSS, DEVON

| | | Jan. | Feb. | Mar. | Apr. | May | June | July | Aug. | Sept. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Over grass ... | 1949 | 12 | 13 | 16 | 7 | 4 | 0 | 0 | 0 | 0 | 2 | 7 | 10 |
| | 1950 | 11 | 10 | 7 | 8 | 0 | 0 | 0 | 0 | 0 | 5 | 18 | 11* |
| Over bare soil | 1949 | 8 | 10 | 9 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 5 | 9 |
| | 1950 | 10 | 8 | 2 | 3 | 0 | 0 | 0 | 0 | 0 | 1 | 8 | 10* |

*Dec. 1–14 inclusive.

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## METHODS OF SYNCHRONIZING THE OBSERVATIONS OF A "SFERICS" NETWORK

By A. L. MAIDENS, B.Sc.

In the location of thunderstorms by the cathode-ray direction-finding method, three or more stations of a network each observe, or record, the direction of approach (the compass bearing) of the atmospheric generated by a single lightning flash. To complete the process of location these observations must then be made available to a control station, where the bearings can be transcribed on to a chart of suitable projection, and the source of the atmospheric thus determined.

Rapid communication between the controlling and observing stations is essential, not only for the purpose of transmitting the bearings but also for synchronizing the observations made at the individual stations, in order that the bearings relating to the same lightning flash can be identified.

As atmospherics often may occur in quick succession, and each persists for an extremely short period of time, the method of synchronization must be of a high order of accuracy and must be capable of distinguishing between successive discharges occurring within a fraction of a second of one another. The British "sferics" network is fortunate in that the network is connected by a private telephone system which permits a wide variation of method, and ensures a high degree of reliability and simplicity in operation. The system can be used for the transmission of two general categories of synchronizing signals—continuous or selective. In general, continuous synchronization is most suitable when automatic recording is adopted, and selective methods when visual observing is employed, but no hard and fast rule can be laid down, and the choice of method must depend upon the use to be made of the observations. The telephone system also provides a rapid means of passing the results to the controlling station.

The normal routine method for the operation of the network is designed primarily to meet synoptic requirements, necessitating rapid identification of storm centres. Suitable arrangements when the observations are required for statistical, research or climatological purposes are described later. Routine observational "runs" are made for ten minutes each hour, and for each run one station is made responsible for selecting the atmospherics to be located. Selection is made automatically by a device* which can be incorporated in a certain circuit of the cathode-ray direction-finding apparatus, and which generates a short audio-frequency pulse on the arrival of an atmospheric of signal strength of more than a pre-determined value. This pulse is then fed into the telephone network so that it is heard by all stations simultaneously, as far as the observers can detect, with the visual indication of the flash on the cathode-ray tube. Bearings are at once taken, aided by the afterglow which persists on the face of the cathode-ray tube and are called out by the operators over the telephone network for recording and plotting at the control station at Dunstable. To avoid the confusion which could arise from over-rapid selection, it is arranged that the device, having once operated, will not function again for a predetermined period of time. The time delay normally used for observing and transmitting the bearing is 7 sec., but this can be varied at will, and observational runs with selection at 4-sec. intervals have been made by experienced observers quite satisfactorily during periods of intense "sferic" activity.

Any one of the four observing stations or the control station itself can undertake the task of selection, the choice being made by the control station prior to each observational period in accordance with the synoptic situation. The employment of the selecting device does not interfere in any way with the

*Described briefly in the *Meteorological Magazine* for October 1951.

normal operation of the cathode-ray direction-finding apparatus, and flashes can be observed even during the quiescent period of the device. If, during this period, the observer at the selecting station observes a flash of particular interest, for example, from a source not previously explored, he may inject an oral call for bearings to be taken. The use of the device ensures a random sampling of the thunderstorms in progress at the time. This ability to combine random selection with a degree of discretion together with the speed with which location is determined, are the great merits of the system for synoptic purposes.

The provision and maintenance of a special telephone system adds greatly to the cost of a "sferics" network, and, in fact, could not be achieved in many parts of the world, particularly where long base lines exist between the individual observing stations. Very successful experiments have been made with a variation of the system, which retains all the advantages of the telephone apart from a somewhat greater delay in obtaining the results, in which one W/T transmitter is employed for short intervals in lieu of the telephone system. Although not in regular use such a method has given excellent results, both within the British Isles and to stations overseas. In this case the selecting device is connected, *via* a telephone link if necessary, to a convenient high-power radio transmitter. A simple additional piece of apparatus is incorporated in the system which automatically secures the transmission from the radio station of a signal equivalent to a morse "dot" virtually simultaneously with the selected lightning flash. It also provides for the lengthening of every fifth signal to a morse "dash" and of every twenty-fifth to the length of two "dashes". Thus, in the event of non-reception of an individual signal, there is no ambiguity in regard to subsequent bearings, and, although a group of five atmospherics may be lost, the run may be continued thereafter.

In these experiments no special W/T transmitter has been set up, the otherwise unused "break periods" in a broadcast normally used for meteorological messages being employed. Nor are the normal "sferics" observers specially trained in W/T operation, a few hours of practice being sufficient to instruct them in sending and receiving the simple call signs which are transmitted at the start and end of observational periods. When a "run" is concluded, the results are transmitted to the control station over normal meteorological channels in a code which gives the bearings in the order that they have been selected, with reference to the specially indicated fifth and twenty-fifth signals.

For research and climatological purposes the British "sferics" network can be adapted to a continuously recording system. Cameras are clamped over the face of the cathode-ray tubes and the "flashes" photographed on a slow-moving film. Each camera is provided with a small neon lamp which, when illuminated, projects a narrow pencil of light on to the margin of the film. By this means signals are recorded beside the record of the atmospheric. The neon lamp can be actuated, through suitable apparatus, quite conveniently by independent W/T receivers at the individual observing stations, each receiver being tuned to a certain radio transmission which, providing it is continuous for the period of observation, need be in no way under the control of the "sferic" organization. The recordings may be compared with reference to the morse symbols appearing on the margin of the film, when an analysis of the atmospherics is undertaken after the films have been developed and dispatched to a central laboratory.

This method is not so convenient when the individual observing stations themselves require to measure the bearings from the film, and in this case a simple form of synchronizing signal is transmitted from the control station by employing either the existing telephone network or a special W/T broadcast. In practice the synchronizing signal is produced by the aid of a teleprinter auto-transmitter actuated by a suitably perforated tape, which results in the transmission and recording on the film of a sequence of "dots" identified by morse symbols for the figures 0 to 99. By reference to these symbols and a suitable method of subdivision between "dots", the control station can obtain the bearings of every recorded flash which it is desired to examine.

A further modification of the system has been developed as a result of co-operation between the Meteorological Office and research workers engaged in the examination of the wave form of the atmospheric. To locate the source of the particular atmospheric which has actuated the wave-form recording apparatus the marking of the film can be actuated by the research authority. In such cases the marking can be achieved automatically by a signal operated by the wave-form recorder, or by simple hand keying.

The purpose of this paper is to indicate the great flexibility in the methods of communication on which a cathode-ray direction-finding "sferics" network may be based, and how the system most suited to the facilities available and the task in hand may be chosen.

## OBSERVATIONS ON LOCAL CLIMATIC CONDITIONS IN THE ABERYSTWYTH AREA

By G. MELVYN HOWE

The closer study of individual areas has shown that weather conditions vary, often quite surprisingly, within relatively small distances. Using average figures for the period 1929–48 for three climatological stations at different heights within a 7½ mile radius of Aberystwyth, Smith[1,2] has presented the differences in values of the monthly means of the various elements. The differences are appreciable, but mean figures and mean differences convey a quite inadequate picture of local climatic conditions.

Temperature conditions probably best lend themselves to detailed observation, and the significance of low-temperature contrasts which lead to frost pockets in low-lying ground has long been recognized. Hawke[3,4], Heywood[5], Manley[6] and Balchin and Pye[7] give details of English examples of these peculiar conditions taking place in association with valley bottoms and sheltered hollows during calm, clear-sky conditions.

Howe[8] has presented details of a minor Welsh example of a frost hollow within three miles of the sea at Aberystwyth, but apart from this little or no quantitative work has been done on these lines in the Principality. With a view to correcting this unfortunate omission, at least for the district around Aberystwyth, arrangements are in hand to conduct occasional investigations into local temperature conditions by means of group projects of an intensive, short-period character. One such investigation took place on the night of November 28–29, 1952, when, equipped with whirling psychrometers certified by the National Physical Laboratory, 22 student observers made ¼-hourly observations of temperature from 11 p.m. on November 28 to 5 a.m. November

29, 1952. A ridge of high pressure covered Scotland, Wales and the northern half of England. There was no cloud and little or no wind in the Aberystwyth district, and the meteorological station at Aberporth confirmed that conditions were favourable for radiation, and forecast a slight ground inversion.

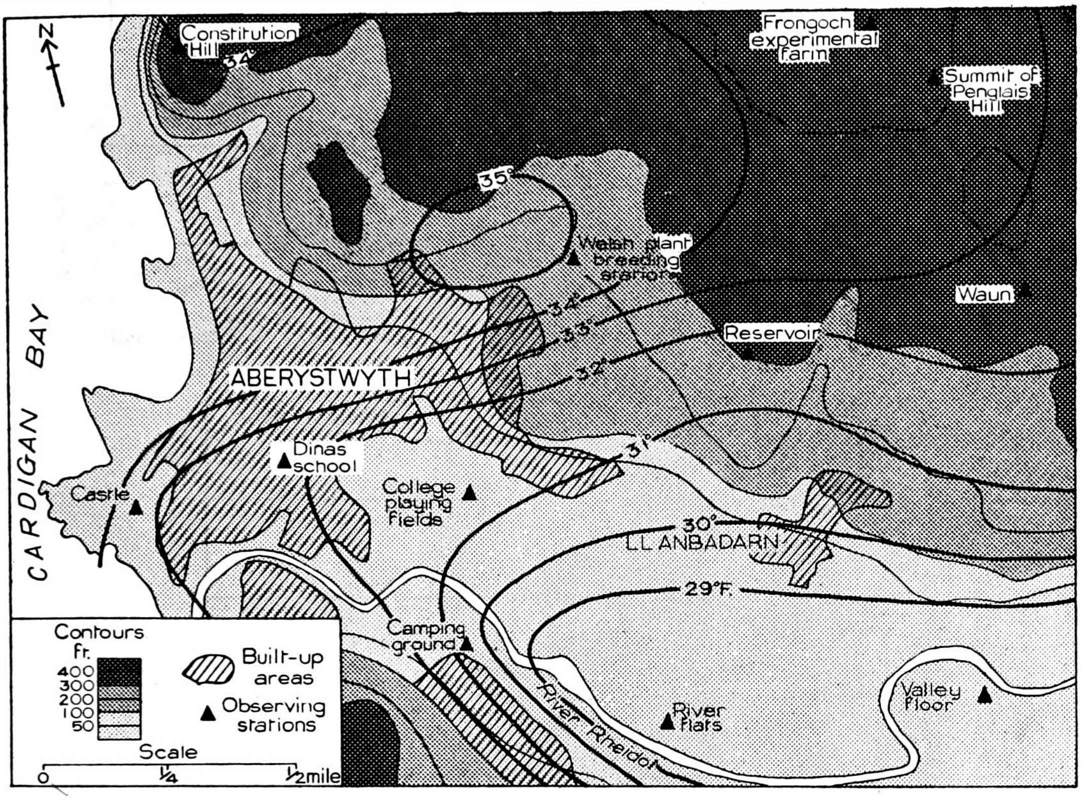



FIG. I—LOCAL TEMPERATURE CONDITIONS IN THE ABERYSTWYTH AREA, 11 P.M. NOVEMBER 28, 1952

Fig. 1 shows the local temperature conditions at the beginning of the investigation. Cold air had drained to and accumulated in the floor of the Rheidol Valley and temperatures there were 6°F. or more lower than at a point about half way up the weather slope of Penglais Hill at a height of 200 ft. above mean sea level. Here 35°F. was recorded. On the other hand, near the summit of Penglais Hill temperatures were more than 2°F. lower than on the hill side. A tongue of warm air appeared to extend up the weather slope of the hill from the sea to the hill summit while the floor of the valley was occupied by a "lake" of cold air. It is assumed that this "lake" extended well inland along the floor of the Rheidol Valley. Seaward and toward the town of Aberystwyth there was a notable rise in temperature, due probably to proximity to the sea and a minor heat island associated with the built-up area.

Fig. 2 shows in graphical form the temperature at two-hourly intervals at selected observing stations. To show relative heights, relief profiles have been drawn along lines connecting the stations concerned. The altitude scale is given on the right side of each graph; the horizontal scale is also shown. Temperatures for the particular times of observation have been plotted immediately above their respective stations according to the temperature scale on the

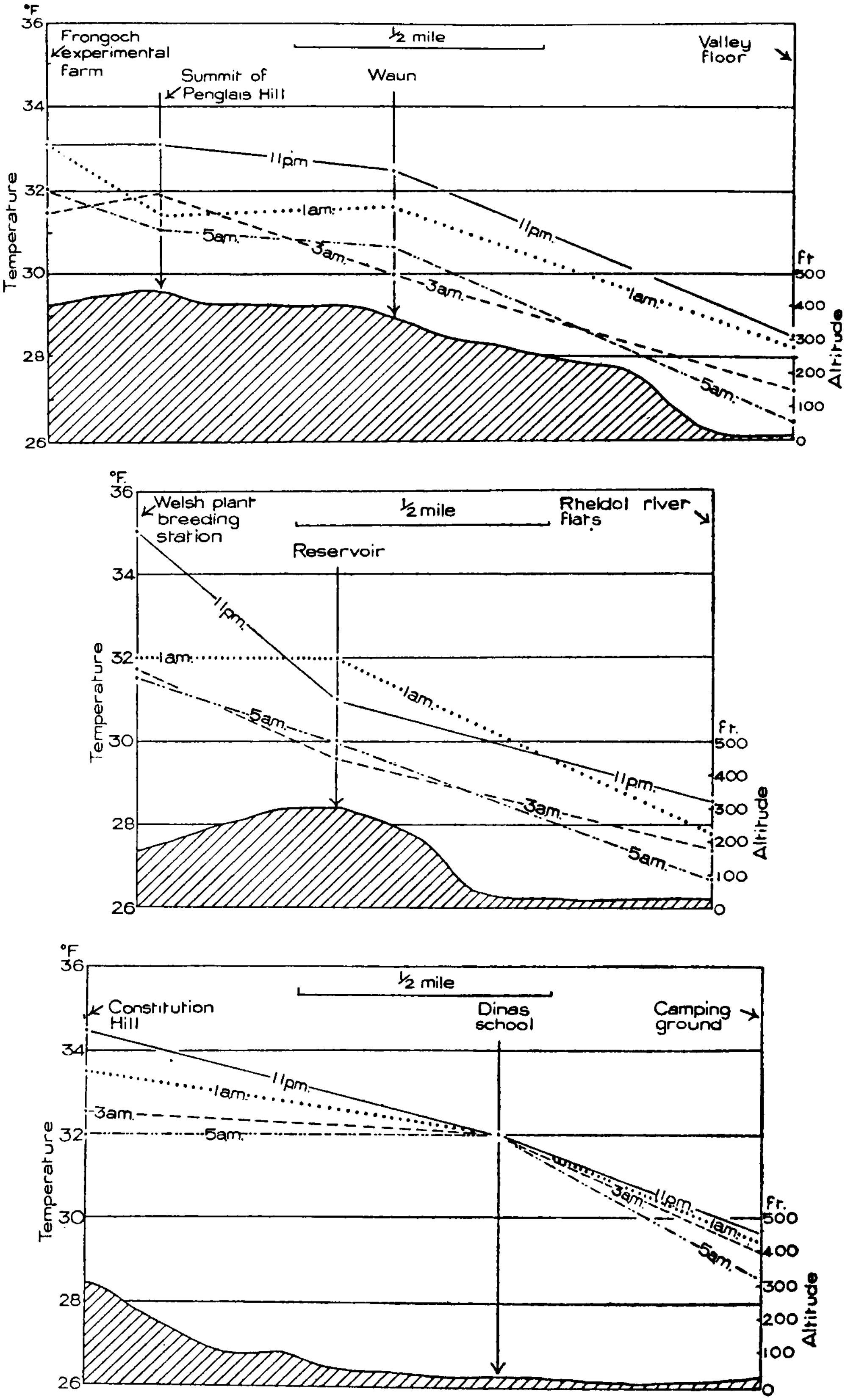



FIG. 2—LOCAL TEMPERATURE CONDITIONS AT SELECTED OBSERVING STATIONS

[To face p. 272

*Reproduced by permission of the Ministry of Agriculture and Fisheries*

WIND EFFECT ON TREES AT CAMBORNE

The photograph was taken facing south and shows the deformation of a hawthorn tree by the westerly winds. The smooth curve outlined by the branch ends against the sky will be noted.

*Reproduced by permission of the Ministry of Agriculture and Fisheries*

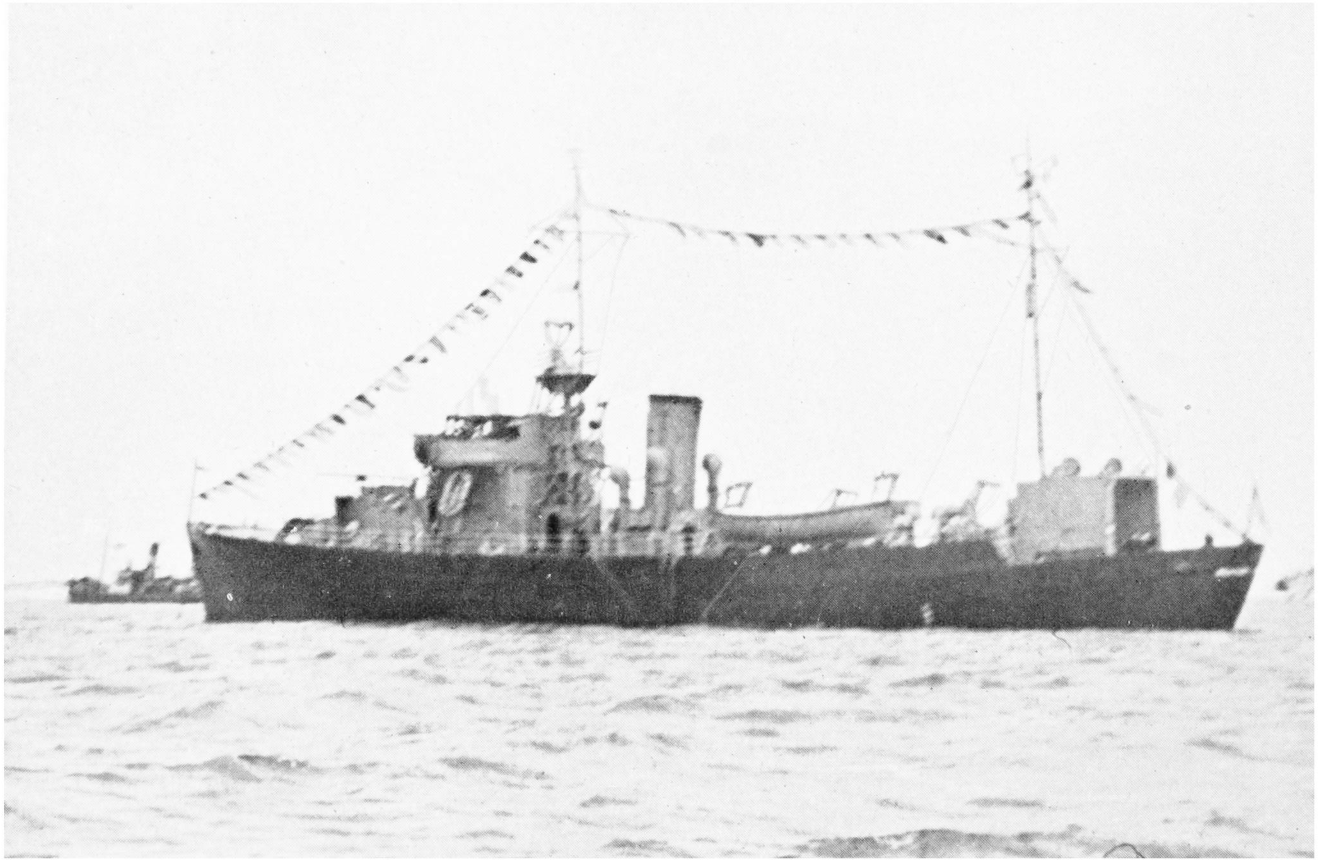
WIND EFFECT ON TREES AT CAMBORNE

This photograph was taken facing north. The Cornish elms on the west side of the road are unable to grow upright and symmetrically, whilst those on the east side are sheltered and grow normally. Note the deformation of the trees opposite the gap in the left foreground.

*Reproduced by permission of the Ministry of Agriculture and Fisheries*

WIND EFFECT ON TREES AT CAMBORNE

This photograph is also taken facing north and shows the suppression of growth by the wind on the west side of hawthorn, oak and ash.



*Reproduced by courtesy of R. McGill*

O.W.S. *Weather Explorer* AT THE ROYAL REVIEW OF THE FLEET

(see p. 279)

left side of each graph. A gradual fall of temperature, both in the valley floor and on the hill side and summit, is illustrated by the graphs. The valley floor, however, is constantly colder than either the hill side or summit. The katabatic inversion of temperature appears to have failed to influence the readings at Dinas school which remained fairly constant at 32°F. throughout the period of investigation. Yet a mobile observer within the town noted temperatures in places which would suggest that occasionally the fairly constant temperature of the minor heat island was being lowered by the inflowing of cold air. It was also observed that temperatures on the promenade were constantly above freezing level while those behind the houses which back the promenade were generally below freezing and surfaces were covered with hoar-frost.

Local temperature conditions at 5 a.m. November 29 at the termination of the investigation are shown in Fig. 3. The pattern is very like that for 11 p.m. the previous evening except that the pocket of warm air on the hill slope has disappeared and the temperatures are everywhere lower by more than 2°F. A slight valley mist had also formed.

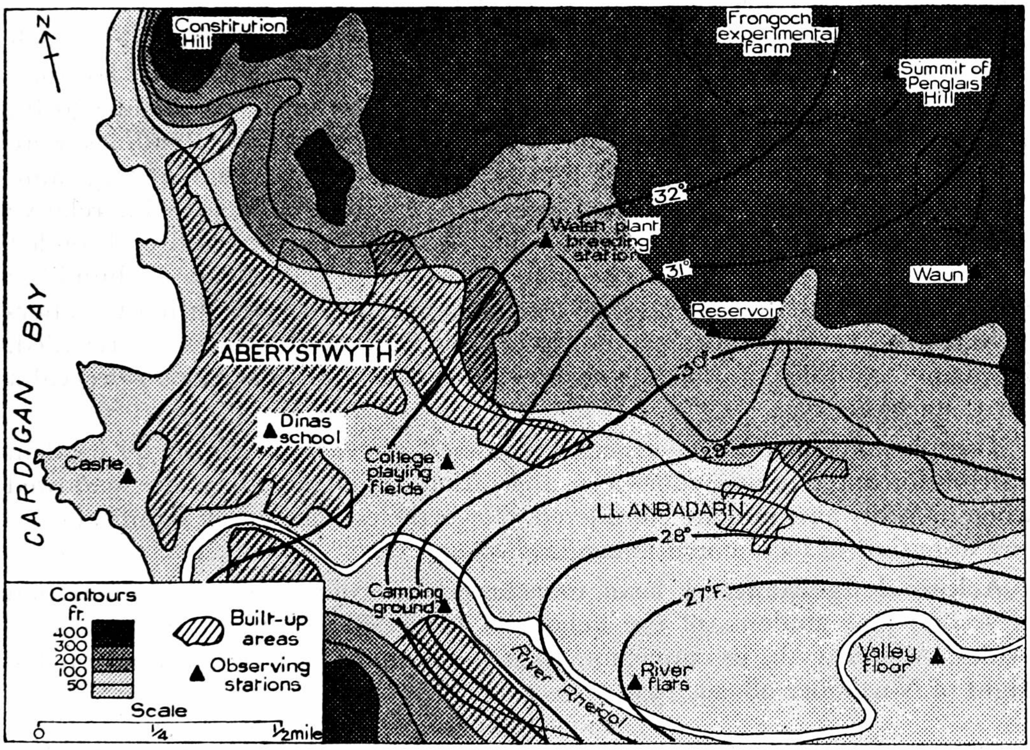



FIG. 3—LOCAL TEMPERATURE CONDITIONS IN THE ABERYSTWYTH AREA 5 A.M. NOVEMBER 29, 1952

Local temperature variations of another kind lead to mist and fog from the sea. Not infrequently during warm spells in the summer a line of fog develops and completely obscures the immediate coastline leaving places less than 100 yd. from the sea still bathed in sunshine. The fog usually forms about midday after a hot, calm morning during which vigorous evaporation has apparently taken place. A light cool wind from off the sea is then sufficient to cause the fog and mist. Such occurrences were noted on May 18, 1952, and again on

August 2, 1952, but quantitative observations were not made. Ruck[9] has drawn attention to a similar mist or fog forming over St. David's, Pembrokeshire. Such mist along the coast can also form in winter as the following example shows.

On February 27, 1953, Aberystwyth was bathed in brilliant sunshine until 11.15 a.m. There was no wind or cloud. Temperatures read at 9 a.m. in the Health Resort screen in the Castle were: dry bulb 40·2°F., wet bulb 39·3°F., relative humidity 92 per cent. Air temperatures taken with a whirling psychrometer at 11 a.m. were dry bulb 50·1°F., wet bulb 46·8°F., relative humidity 79 per cent. (Marvin's tables for relative humidity).

At 11.15 a.m. a thin layer of sea mist began to develop at about 200 ft. on the seaward side of Constitution Hill immediately to the north of Aberystwyth (see Fig. 1). By 11.30 a.m. the whole of the immediate coastline was obscured by the mist which then extended to sea level. Visibility was 120 yd. The mist advanced very slowly eastward over Aberystwyth. Air temperatures at 11.30 a.m. were dry bulb 39·9°F., wet bulb 39·9°F., relative humidity 100 per cent. Thus there was a drop of 10·2°F. in ¼ hr. The sea temperature was also taken at 11.30 a.m. and was 43·1°F.

For comparative purposes, temperatures were read at 11.30 a.m. at Frongoch experimental farm, which is situated at about 400 ft. above M.S.L. and less than 1 mile inland from Aberystwyth. The ceiling of the mist was about 350 ft., and so this station continued to enjoy brilliant sunshine. Readings were dry bulb 51·0°F., wet bulb 47·5°F., relative humidity 76 per cent. at 11.30 a.m. At 2 p.m. temperatures were dry bulb 54·5°F., wet bulb 50·0°F., relative humidity 71 per cent. at this farm, while Aberystwyth was still enshrouded in the mist and continued to show temperatures of 40°F. and relative humidity 100 per cent. Cars were obliged to use lights in Aberystwyth during the afternoon, while ½–1 mile eastward the clear sky and brilliant sunshine still prevailed. It was not until 8 p.m. that this extremely local sea mist dispersed to reveal a clear, starlight sky.

The phenomena that have been considered above are admittedly local in distribution and represent short-term aberrations which tend to be overshadowed when monthly averages are considered. Nevertheless they are of significance in any appraisal of local climatic conditions.

**Acknowledgement.**—I have to acknowledge the generous co-operation of second-year students of the School of Geography, University College of Wales, Aberystwyth, in connexion with the temperature observations on the night of November 28–29, 1952.

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## ROYAL METEOROLOGICAL SOCIETY

At the meeting of the Society held on May 20, 1953, the President, Sir Charles Normand in the chair, the following papers were read:—

*McIntosh, D. H.*—Annual recurrences in Edinburgh temperature*

Mean daily temperatures at Edinburgh were examined for different groups of years: for 1901–1950 at Blackford Hill, for previous periods of 50 and 100 yr. published by Mossman, and for the whole period of 150 yr. The magnitudes of the departures, in the various periods, of the daily temperatures from the corresponding seasonal values were compared with theoretical values based on no tendency for annual recurrences, the seasonal values being calculated from the monthly mean temperatures, using the first two harmonics. The following general conclusions were reached from this statistical analysis:—

(i) the non-seasonal temperature fluctuations are very largely random

(ii) there is strong evidence that any real anomalies are mainly negative in character

(iii) recurrences on the days of the cold and warm spells detailed by Buchan do not depart to a significant degree from chance expectations

(iv) it is unlikely that there are significant short-lived anomalies which are masked in long-period mean departures by changes of phase.

In the subsequent discussion it was appreciated that the paper represented a useful piece of statistical work. Dr. Weickmann was quoted as saying that some people believe in "singularities" and others do not. Dr. Sutcliffe thought "singularities" ought to be defined, i.e. can they be dated or are they only typical of some period? Prof. Manley regarded "singularities" as an event linked with the calendar, but emphasized that Buchan referred to cold and warm spells as irregular and subject to variation from year to year. Mr. Gold thought that the figures of the paper justified a stronger statement of the case for the existence of non-random temperatures and referred to the recent cold spell about May 11–13, the days of the "Ice saints". Other points made were that harmonic analysis might not be the best method of determining the seasonal values, since it involved too long a wave-length, and that minimum temperature rather than the mean temperature might have been used with advantage.

*Brown, P. R.—Climatic fluctuation in the Greenland and Norwegian Seas*†

Ship observations of air and sea temperature, as recorded on Hollerith cards, were summarized for the sea areas between 60°N. and 70°N., extending from Greenland to Norway with Iceland in the centre of the area, to give decadal means, from 1900–09 to 1940–49, for the year, for July, and for the period December to March. Over the 10 Marsden 5-degree squares involved there was a general increase of air temperature from 1900–09 to 1930–39. The rise was less marked in the neighbourhood of the Irminger current around Iceland. There was a marked decrease in the decadal annual means of sea temperature from 1930–39 to 1940–49 to the east of Iceland but an increase to the south of Iceland.

Cmdr Frankcom considered that the paper brought out the close relationship between meteorology and oceanography, and suggested further lines of research; the correlation of sea temperature observations of the previous year in the Gulf Stream area with air temperature up the Norwegian coast, and the relation

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*Quart. J. R. met. Soc., London, **79**, 1953, p. 262.
†Quart. J. R. met. Soc., London, **79**, 1953, p. 272.

of ice cover on the Grand Banks with temperature trends. Mr. Schove showed a slide to bring out the association between cold winters in Norway and warm winters in Greenland and *vice versa*, together with associated mean pressure and wind-flow maps.

*Manley, G.—The mean temperature of central England*, 1698–1952*

Serial values of the monthly mean temperature of central England are given for the period 1698–1952. The values are based on the mean of the Oxford and Lancashire record† back to 1815. For earlier years a number of records distributed over central England though extending as far as Edinburgh, London and Plymouth were used, but for 1707–22 the values had to be estimated from those at Utrecht. The extraction of these records from various libraries and their interpretation has involved a great deal of work. In the discussion Dr. Glasspoole emphasized some of the uncertainties involved in this method of piecing together records in different parts of the country. While temperature changes are broadly similar over a wide area there are distinct local variations, since the changes of temperature, year by year or decade by decade, over the country can be mapped. Moreover there is a greater variability in the annual values in the east than in the west of the country and a marked difference over the country in the seasonal variability.

## INSTITUTION OF ELECTRICAL ENGINEERS

### Utilization of solar energy

At the Institution of Electrical Engineers on May 20, 1953, Dr. E. C. Bullard, Director of the National Physical Laboratory delivered a lecture on the utilization of solar energy summarizing the work of a National Physical Laboratory Committee.

He opened by stating that the energy of solar radiation at the outside of the atmosphere was about 1·3 Kw./m.$^2$, and that under a clear sky an area at the earth's surface normal to the sun's rays could receive, at most, energy of about 1 Kw./m.$^2$ Averaged over the year the amount on a horizontal surface was 0·1 to 0·2 Kw./m.$^2$ Immediate difficulties were the intermittency of the supply and the fact that the energy received is least in winter when for many purposes it is most needed. It was better to use solar energy for direct warming of buildings or producing hot water than in the production of mechanical or electrical energy, because of the inevitable low efficiency of such production associated with the second law of thermodynamics.

Warming of houses or production of domestic hot water by heating water in tubes under glass by the sun was feasible, but not economical, because the cost of the heater and a large insulated storage tank was very high, and in any case normal heating apparatus could not be dispensed with. Cooking with a mirror of about 0·3 m.$^2$ area to concentrate the energy was possible in the tropics, but the cost might be too high for peasants to pay. The driving of a refrigerator for the cooling of buildings in the tropics was also possible using a collector covering about half the roof area. Orthodox steam or hot air engines for pumping water or generating electricity were very inefficient; a collector

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**Quart. J. R. met. Soc., London*, **79**, 1953, p. 242.

†MANLEY, G.; Temperature trend in Lancashire, 1753–1945. *Quart. J. R. met. Soc., London*, **72**, 1946, p. 1.

about 18 m.$^2$ in area would be needed to produce on the average 1 Kw. of useful power. Direct production of electric currents by the thermo-electric or photovoltaic effects was also very inefficient.

Growth of trees or plants to produce fuel for burning in a boiler has the advantage of overcoming the intermittency associated with direct use of insolation, but the disadvantage of requiring areas of ground so large as to affect food supply.

Continuous growth of algae in tanks so arranged that the plants could be filtered off, dried, and burnt to produce useful heat had been suggested. The proposal involved recovery of the mineral constituents of the plants and of the carbon dioxide which would be returned as carbonate to supply carbon for the next crop. To produce 10,000 Kw. an area of over 3 Km.$^2$ of algae tanks would be needed.

His general conclusion was that no way in which solar radiation can be made to supply a large amount of power can at present be envisaged, but that there were distinct possibilities in applications, such as air conditioning in the tropics, calling for a relatively small amount of energy.

Reference should be made to *Research, London,* **5**, 1952, p. 522 for the Committee's full report on the utilization of solar energy.

## LETTERS TO THE EDITOR

### Four simultaneous concentric halos

On April 10, 1953, the following observations were made at Alston, Cumberland:

0830–0930 G.M.T.

A 22° halo with both parhelia and a faint parhelic circle.

1040–1105 G.M.T.

A 46° halo almost complete and coloured and an upper arc of contact to a very bright 22° halo.

1105–1150 G.M.T.

An exceptionally bright 22° halo with a brilliant upper arc of contact.

A 9–11° halo clearly visible without smoked glasses and slightly red on the inner limb.

An 18–20° halo which was incomplete and in two parts, it affected about 240° of the circle altogether, the inner red limb was clear and a suggestion of green could be discerned on the outer.

The 46° halo recorded earlier, very faint and intermittent, but for most of the time, when present, almost complete.

Parhelia and parhelic circle, but only faintly visible dnring this period.

1150–1230 G.M.T.

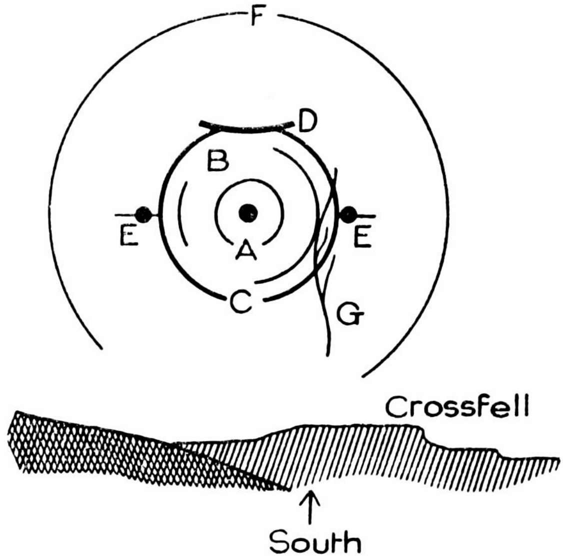
The 22° halo only with upper arc of contact.

1500–1830 G.M.T.

The 22° halo with distinct parhelia and upper arc of contact.

The phenomena seen between 1105 and 1150 is shown in Fig. 1.

At 1600 the 22° halo was measured along its vertical axis with a theodolite, and the figures 9–11° and 18–20° have been adopted as a result of deductions made by non-instrumental methods. Unfortunately the display with the four halos was seen whilst I was a long way from suitable equipment, but as a substitute rough measurements were made by extending the arm and using the knuckles to give a scale which could be converted into degress at a later time. The 22° halo having been established accurately the measurements 9–11° and 18–20° were adopted from the proportions suggested from the crude field work.




A = 9–11° halo
B = 18–20° halo in two parts
C = 22° halo
D = Upper arc of contact
E = Parhelia
F = 46° halo
G = Position of cirrus structure in cirrostratus veil

FIG. 1—HALO AT ALSTON, APRIL 10, 1953

The altitude of the sun was about 40° when the 9–11° and 18–20° halos were visible. The sky was well veiled with cirrostratus cloud which, in only a few places, produced a structure which could be called cirrus. One such patch was very near to the main part of the 18–20° halo.

W. E. RICHARDSON

*The Grove, Alston, Cumberland, April 10, 1953*

[The halos of radii between 9 and 11° and between 18 and 20° are very occasionally seen, but it is extremely rare for both to be seen together and with the 46° as well as the 22° halo. Mr. Richardson was fortunate to see such a spectacle.

The nearest approaches to it are, the observation by C. W. Hissink[1] at Zutphen, Holland, on May 19, 1899, of halos of radii 7·5°, 17·5°, 19·5° and 22°, and the observation by C. G. Andrus[2] at Sand Key, Florida, United States, on May 11, 1915, of halos of radii 8–9°, 17–18°, 18–19°, 22°, and 28°. Captain C. J. P. Cave[3] wrote that his observation of a halo of 18°30′ radius with the 22° one on May 16, 1926, was the most remarkable meteorological phenomenon he had ever seen. W. F. Watson and G. A. Clarke[4] observed a halo of radius 10–11° on May 1, 1938.

More instrumental measurements of the halos of radii less than 22° are needed.—Ed., *M.M.*]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## Condensation trails

On p. 125 of the *Meteorological Magazine* for April 1953, dynamic instability in large horizontal shear is tentatively suggested as a possible explanation of the shearing of the condensation trail shown in the photographs in the centre of that magazine. In the region of Stroud, where the trail was seen, there are many large hills, and with much smaller ones permanent distortions of marked lines of air have been shown to occur*. Such kinks as that shown in Mr. Tuke's photograph would, I think, be expected as the air passed over a hill whose size was about that of the kink. This is a very rough estimate, but the theory leaves no doubt about the order of magnitude of their size, and so this explanation seems possible.

R. S. SCORER

*Imperial College, London, S.W.7, May 12, 1953*

# NOTES AND NEWS

## Weather ship at Royal Review of the Fleet

The British O.W.S. *Weather Explorer* had the honour of being present at the Review of the Fleet by Her Majesty the Queen at Spithead on June 15, 1953. *Weather Explorer* was relieved at ocean station "Juliett" by the Netherlands vessel *Cirrus* on June 6, and instead of returning forthwith to Greenock as is customary she proceeded to Plymouth in order to refuel, give shore leave to her ship's company and to complete the painting of her hull for this royal occasion. The ship arrived at her appointed anchorage in line K of the Review area, situated about three-quarters of a mile to the east-north-east of Ryde Pier, early on Sunday, June 14, 1953.

The early morning of June 15, the day of the Review, provided a heavily overcast sky and gusty westerly winds of Beaufort force 5 to 6. One of the guests from the Meteorological Office Headquarters who, accompanied by their wives, travelled from London to be aboard the ship during the Review, telephoned Victory House at 0730 for a forecast and was informed that there would be fresh to strong W. to NW. winds during the day with overcast skies and perhaps quite a lot of rain but some sunshine. In the event, though the sky was generally overcast, some welcome sunshine did occur in the afternoon and there was no rain though "precipitation in sight" was recorded in the ship's deck log at 1600. The wind was fresh and squally during most of the day.

Those of us who were privileged to be aboard the ship, as guests of the Master and officers for this memorable occasion, witnessed a truly magnificent spectacle; every detail of which had been worked out with that meticulous attention to

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*SCORER, R. S.; Theory of airflow over mountains, II—The flow over a ridge. *Quart. J. R. met. Soc., London*, **79**, 1953, p. 70.

detail which one expects of the Navy and which went, so far as can be judged, exactly according to plan. The long lines of warships, not only of the Royal Navy but of visiting Navies as well, stretching as far as the eye could see, were bedecked on this royal occasion with bunting. It was noticed that no less than 12 of the Merchant ships present, similarly gaily festooned for the occasion, were "selected ships", whose officers voluntarily make observations at sea on behalf of the Meteorological Office. The surface visibility was at least seven miles, so that one could see the whole extent of the line of ships, and it was noteworthy how even in broad daylight the prominent "eternal flame" which burns at the Fawley Oil Refinery showed like a golden flag against the skyline. The fresh breeze was an advantage for it enhanced the effect of the flags with which every ship was dressed overall.

Those aboard *Weather Explorer* had a good view of the progress of the procession of vessels which accompanied Her Majesty aboard H.M.S. *Surprise* as she steamed down the lines of warships, and *Weather Explorer's* cheer joined those emanating from the Naval ships as Her Majesty passed.

The fly-past of about 300 Naval aircraft of various types reminded us of the amphibious nature of a modern Naval officer's job. By this time the cloud level had dropped to about 1,000 ft., but this did not interfere with the aircraft as they passed over the Fleet at a height of about 300 ft.

During the early evening the ship's motor boat did two short tours, for the benefit of the guests and the ship's company, around some of the assembled warships. The illumination of the warships and the firework display which followed were incredibly well synchronized and most efficiently executed and presented a fitting and colourful climax to this memorable occasion. The weather remained fine and clear throughout the evening and one B.B.C. announcer, during the course of the day, said he hoped that the presence of the weather ship at the Review was to some extent contributing to the fine weather which was experienced. *Weather Explorer* with her black hull and bright yellow upperworks—dressed overall with flags—looked very immaculate, and the 16 guests who were aboard her were impressed with her cleanliness, the admirable meals provided and the hospitality and kindness showed them by Captain Wilkinson and all the ship's company. The following morning *Weather Explorer*, having landed her guests at 0500, weighed anchor and returned to Greenock whence she sailed again for station "Juliett" on June 24, 1953.

C. E. N. FRANKCOM

## "Navigation to-day"

The exhibition "Navigation to-day", which opened at the Science Museum on April 22 and remains open until mid September, includes exhibits showing the application of meteorological information in both marine and aerial navigation.

The exhibit of the Meteorological Office in the marine section includes examples of the published charts of mean winds and currents and some synoptic charts drawn on merchant vessels at sea with notes on the use made in reducing passage time. The aerial section includes two beautifully constructed layer models showing wind roses at 10,000, 20,000, 30,000, 40,000, and 50,000 ft. over the British Isles and mean vector winds at the same levels over North America, the North Atlantic and much of Europe. Two composite upper air forecast charts for flight across the North Atlantic are shown with the tracks flown on them, which though longer in distance than the great circle track took less time because of the wind distribution. Some synoptic 500-mb. contour maps are also exhibited. Meteorologists will also be very interested in many other exhibits from the ship's bridge complete with the latest instruments for navigating and steering to the maps and spoken description of the control of civil aircraft.

## Smoke haze observed from an aircraft

The opportunity recently arose to undertake a flight over the central and southern Midlands to study the effect of smoke on visibility. One or two of the points observed were particularly striking, and it is for this reason that this note is written.

The flight was made on January 8, 1953, and the synoptic situation at 1500 G.M.T. showed a feeble ridge extending from the Scilly Islands towards Lincolnshire; this was moving south-eastwards, whilst a warm front west of Ireland was advancing slowly. Winds at 2,000 ft. were northerly at 0900 G.M.T. and west-north-westerly at 1500 G.M.T. over the Midlands as a whole, and about 10 kt. throughout; the back of the wind across the ridge was marked. There was no low cloud over the central Midlands, but stratocumulus was reported from the extreme south. The flight took place during the period 1420–1600 G.M.T.

It has frequently been noticed that the visibility at Benson in a north-westerly air stream is appreciably worse than that at Abingdon; the only apparent explanation is that smoke produced in the Oxford area affects Benson, 12 miles to the south-east, and not Abingdon, 5 miles to the south-west. However, Oxford is not primarily an industrial city, and one might not have expected pollution at such a distance. On the day concerned, the reported visibilities at Abingdon and Benson, at 1400 for example, were 5 miles and 3,000 yd. respectively. The flight to Abingdon and thence to Oxford confirmed the above explanation; appreciable smoke was being emitted both from the few (approximately six) major chimneys in Cowley and from Oxford itself (breweries, etc.), and visibility to the south-west of the city was many miles greater than to the south-east.

From Oxford north, the flight was made at heights up to 4,500 ft. The main, and perhaps surprising, impression was of the smoke generated by industrial sources being many times greater in pollution effect than that emitted by domestic sources. This was very striking over the Birmingham area, where the surface wind was almost due westerly. The western half of the city (the residential area) was relatively clear with visibility 5–10 miles, but at the edge of the industrial area to the east the visibility dropped very rapidly and dense fog could be seen in the streets, with roofs standing clear. The weather had been cold, and although domestic fires must have been in widespread use their lack of effect on the visibility was very apparent. Away from Birmingham, in the open country, it was noticed that isolated chimneys (e.g. cement works) produced spreading plumes of smoke several miles long, and that even roadmen's hedging fires constituted an appreciable source of pollution.

A point of real interest was that the smoke haze had a very clearly defined top at just over 2,000 ft., and the smoke from an individual chimney ascended in a gentle curve, finally drifting down wind at that level. Above 2,000 ft.

visibility everywhere was at least 30 miles, but below and to the east of Birmingham it was only about one mile. Neither the Larkhill nor Liverpool ascents showed any variation in, nor gave any indication of, this lapse rate at 2,000 ft.; there was no discontinuity below 4,000 ft. at either 0900 or 1500 G.M.T. Presumably the 2,000-ft. level marked the limit of convective turbulence. It was observed that the stratocumulus cloud in the vicinity of Reading also had a fairly flat upper surface at the same height.

A rather noteworthy feature was the manner in which high ground tended to stand clear of the haze although it did not by any means reach to the haze top. Travelling northwards from Oxford to Birmingham, it was observed that the ridges Edge Hill and Clent Hills, neither of them higher at any point than 1,100 ft. above sea level, stood out clearly from many miles away, whilst the lower ground disappeared beyond a distance of about 8 miles.

We are indebted to Sqd.-Ldr W. J. Kenyon, Commanding Officer of 540 Squadron, for arranging the flight, and to Flt-Lt J. P. Walker for piloting us on this flight.

G. W. HURST
P. G. F. CATON

## REVIEWS

*Weather inference for beginners made clear in a series of actual examples.* By D. J. Holland. 10 in. × $7\frac{3}{4}$ in., pp. xiii + 196, *illus.*, Cambridge University Press, Cambridge, 1953. Price: 30*s.* net.

This book is the outcome of a youthful enthusiasm for observing the weather. When the writer was a schoolboy he developed the habit of keeping a day-to-day record of weather, cloud, visibility, wind and often temperature. The observations were made whenever he could conveniently do so, sometimes two or three times a day, occasionally almost hourly. The book he has now written is built around a series of observations made in the London area during the last five months of 1936. Using these observations in chronological order, he introduces the reader to meteorological theory by relating what he saw to the probable synoptic situation and—in the later part of the book—to the analyses published in the *Daily Weather Report.* Whereas most books progress from theory to example, in general Mr. Holland takes the bold step of reversing this order.

A certain meteorological equipment is needed before anything at all can be learnt from a set of observations, so the first half-dozen pages are devoted to a very brief introduction to the ideas of air masses, fronts and circulations. Then Chapter II introduces the codes and gives a fairly detailed description of the standard cloud types (without illustrations) and the notation for present weather The reader is now regarded as ready to open the weather diary, and the next six chapters provide a reasoned interpretation of its contents. Every few days the writer finds a situation enabling him to introduce some new branch of the theory, and by the time he is midway through the book the reader has an acquaintance with the main weather types, the use of the tephigram, instability, radiation, pressure and wind, and even the circulation theorem.

The second half of the book follows the pattern of the first, but the approach is now synoptic. A good selection of *Daily Weather Reports* is reproduced, and the reader is shown how to associate the local observations with what is happening on charts. The "armchair talks" are now a thing of the past and it is as if the reader were invited into a forecast room. By Chapter X, if he is a conscientious reader, he will even find himself under the obligation to "grid" an upper air chart. Indeed, in the last few pages he receives such peremptory instructions on the art of forecasting for aviation as to be almost persuaded that he is on the staff of the Meteorological Office.

In a book written for specialists an author has considerable latitude in th matter of structure and tempo; he should present his subject scientifically, but has the right to expect a fair degree of industry on the part of his reader. On the other hand, a book written primarily for the general reader, as this is, calls for an accurate appreciation of his needs. It must be persuasive and inviting, and not so difficult as to discourage him, yet not so easy that the reader loses the sense of achievement. Scientific accuracy is something it cannot always attain, yet the half-truth must not be disguised.

The opening pages show that Mr. Holland set out to retain the interest of his reader. He adopts a friendly, conversational tone and is always ready with a simple analogy. His style, however, is somewhat staccato, and in places the flow is broken by the use of ugly abbreviations which hardly help the reader. Nevertheless something more than *bonhomie* is required to save the reader from mental indigestion after the fare that Mr. Holland provides. For example, within the space of a single page he is confronted with the low-level variation of wind with height, thermal winds, variation of wind with height as indicating temperature advection, and convergence through the drift of air across the isobars of a changing pressure system. There is not a single explanatory diagram, and in this respect the whole book is markedly deficient. The offence, in the opinion of the present writer, lies not only in the concentration of so much material into what are little more than lecture notes, but in missing such excellent opportunities to teach the reader to reason meteorologically. It is a peculiarity of forecasting that so many problems entail a close investigation of basic data and cannot be solved by a set of rules unless the reasoning behind those rules is ingrained in the mind of the forecaster. No better example of this can be found than the art of drawing thickness lines on an upper air chart, which involves much more than fitting lines to the observations. Nor is there any need for the general reader to avoid the theory, for such things as thermal winds and convergence can be presented in a simple, detailed and interesting way, and the understanding gained is invaluable in the study of charts.

Criticism of a book which can be applied equally to other books is perhaps no more than an expression of the idiosyncracies of a reviewer. However, the present writer holds the view that any introductory book should progress strictly from cause to effect, from solar radiation to air masses and later to fronts and circulations. If the reader cannot wait a few chapters to find out why it rains he is too impatient to profit from his studies. The desire to reach frontal examples as soon as possible results in the development of a parochial view of the structure of the atmosphere. A front should not be merely something that bobs up as bad weather in the vicinity of a weather ship, but should be expected because it is a boundary to a fully-charted air mass. Part of an organism such as the atmosphere cannot be studied without some knowledge of the whole of which it is part.

Mr. Holland touches on most of the subjects one expects to find in a book of this kind and his treatment is orthodox. Nevertheless, the emphasis is surprisingly uneven. The conception of potential instability, so difficult for a beginner, is described (albeit in three sentences) yet the reader is given no indication of what an ascent through a frontal surface looks like. In a practical book it is strange, too, to find no reference to ice accretion, or to the physics of rain. Again, despite the number of pages allotted to the actual work of the forecaster, we are not shown an aviation forecast or told what items are included. We may have hoped, too, that this would be the first book to explain in elementary fashion exactly why the wind blows (not simply how it fits the isobars). Further, the study of trajectories is, in the opinion of the reviewer, a major omission on the part of both Mr. Holland and earlier authors. The flow of air, so different in pattern from the isobars of moving systems, is the main cause of variations within an air mass, and so is the major factor in determining most of the weather we experience. The analogy between circulation round a depression and what happens near the bath plug is one that does more harm than good, and the presentation of isobars as though they were tram-lines rather than stream-lines does little to help to visualize the movements of the atmosphere. As Mr. Holland says, "there is indeed more in the beautiful patterns of air-flow than meets the eye," and it is a pity he went no further.

C. J. BOYDEN

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*Flying saucers.* By D. H. Menzel. 8 in. × 5½ in. pp. xii + 319, *Illus.*, Putnam and Co. Ltd., London. Price: 21*s.* net.

The author of this book is Professor of Astrophysics at Harvard University and his purpose in writing it was to answer the question "What are the flying saucers?" He describes a large number of alleged observations of these apparitions and easily provides in nearly all cases a simple natural explanation. Besides the recent "flying saucers" accounts of a number of apparently peculiar objects seen in past years, such as Maunder's "torpedo beam", are included and there is a chapter on false radar echoes. The book contains excellent elementary accounts of meteorological optics with some very good photographs, and of the aurora, radar and parts of astronomy. It is light in manner but very serious in purpose, for belief in "flying saucers" has caused much agitation and a number of deaths.

G. A. BULL

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*Report of the Hampstead Scientific Society*, 1947–8—1951–2. 8 in. × 6½ in., pp. 32. Typescript, London. Price: 1*s.* 6*d.* net.

This report covers the activities of the Society over the five years October 1947 to September 1952 and includes accounts of the work of its meteorological, astronomical and natural history sections. The main meteorological contribution is a comprehensive note by E. L. Hawke, M.A., on the "Climate of Hampstead Heath". Mr. Hawke has superintended the climatological station since it was established on the extreme summit of the heath (450 ft. above sea level) late in 1909. His note includes tables showing monthly and annual average and extreme values of temperature, of rainfall amount and duration and of sunshine, linked by an interesting commentary comparing the climate of the heath with that of other parts of the London area. The differences of snowfall and snow lying and of sunshine are specially worthy of note. Hampstead Heath receives on the average 167 hr. more sunshine a year than Regent's Park and 12 hr. more than Kew Observatory.

H. C. SHELLARD

## SPECIAL PROMOTION ON MERIT

One of the proposals of the Barlow Committee of 1945 on Government Scientific Staff (Cmd. 6679) was that provision should be made for the special promotion on merit of individual research workers of exceptional ability to posts outside normal departmental administrative complements.

It has now been announced that, on the recommendation of the Inter-departmental Scientific Panel, Dr. G. D. Robinson, Superintendent of Kew Observatory, has with effect from July 1, 1953, been awarded a special promotion on merit to the rank of Senior Principal Scientific Officer. Dr. Robinson is the first member of the staff of the Meteorological Office to be awarded such a promotion.

Dr. Robinson graduated at the University of Leeds with first class honours in Physics in 1933 and proceeded to the degree of Ph.D. in 1935. He joined the staff of the Meteorological Office at Kew Observatory in 1936, and became associated with the exploration of the electric field in thunderstorms by means of alti-electrographs carried by free balloons. He was joint author with Sir G. C. Simpson of a Royal Society paper on this subject.

During part of the 1939–45 war he was concerned, at H.Q., R.A.F. Balloon Command, with the meteorological-electrical problems of the kite-balloon barrage.

On returning to Kew Observatory in 1946 Dr. Robinson embarked on detailed studies in atmospheric radiation and the related subject of the transfer of heat and moisture between the ground and the air. The studies are basic to problems of energy exchange in the atmosphere—a subject which is receiving increasing attention. Dr. Robinson has applied his carefully controlled measurements of atmospheric radiation to an examination of the validity of the radiation chart devised by Elsasser about ten years ago for the purpose of computing the vertical flux of radiation from data on the vertical distribution of temperature and humidity, and has suggested a modified chart. Another outcome of the field work at Kew Observatory is the demonstration that, at least in the surface layers of the atmosphere, the radiational transfer of heat can be comparable in magnitude with convective tranfers. In these intricate investigations Dr. Robinson has shown marked experimental and observational acumen and a highly developed faculty of critical discussion and interpretation. His published papers on this work are widely recognized as important contributions. The investigations continue and have recently been extended to include the study (by specially designed equipment) of fine-scale fluctuations in air motion and temperature near the earth's surface.

Dr. Robinson, assisted by junior colleagues, has also been engaged in a critical examination of the technique used in continuous measurement of the solar radiation and daylight illumination received at the earth's surface. The results are to be incorporated in analyses and discussions, now in preparation, of five years' simultaneous recordings of components of solar radiation and daylight illumination at Kew Observatory.

Dr. Robinson was awarded the Buchan Prize of the Royal Meteorological Society for 1947 to 1951 in recognition of his contributions to atmospheric radiation and turbulent transfer published in papers in the *Quarterly Journal of the Royal Meteorological Society* during that period.

It is proposed that Dr. Robinson shall continue research on the basic problems of energy exchange in the atmosphere, extending the investigations to the flux of radiation at different heights above the ground, and secondarily that he shall carry further the investigations on solar radiation and daylight illumination.

## METEOROLOGICAL OFFICE NEWS

**Domestic help?**—The July 1953 number of *Air Clues* contains an excellent article on "Jet Streams" by Sqd.-Ldr L. G. Press, A.F.C. It describes, by way of illustration, the jet streams encountered by the Canberras of No. 12 Squadron R.A.F. (which Sqd.-Ldr Press commands) on their recent tour of South and Central America, and, though written mainly for pilots, contains much first-hand information about flying in jet streams which should be of interest to all who forecast for jet aircraft.

Sqd.-Ldr Press would have ready access to advice on meteorological problems, for Mrs. Press (formerly Miss Catherine Fielding) was for some years a forecaster. She joined the W.A.A.F. (Meteorological Section) in 1942, was later commissioned and promoted Section Officer in 1944. After demobilization she became successively an Assistant Experimental Officer and Experimental Officer. She resigned in 1952.

**Sport.**—Mrs. J. M. Sugden gained second place in the Civil Service Ladies' high jump championship at Chiswick on Saturday, July 18, 1953.

## WEATHER OF JULY 1953

Mean pressure was below normal (2 to 6 mb.) over Scandinavia and westwards to Iceland and Greenland. It was a little above normal (1 to 3 mb.) over south and west Europe and westwards to the Azores and over much of the United States. The lowest mean pressure, about 1006 mb., extended over the region between Scandinavia and Iceland; the highest mean pressure was 1028 mb. over the Azores.

Mean temperature was generally above normal over most of Europe, about 2°F. on the average. It varied from 60°F. in Scandinavia to 65–70°F. in central Europe and 75–80°F. in the Mediterranean region.

In the British Isles the weather after the first few days was unsettled and rather cool. Thunderstorms occurred on no fewer than 16 days and were widespread on the 9th, 16th–18th and 27th. There were some heavy falls of rain and rainfall was considerably above the average for the month in all areas except north-east England. Eskdalemuir with 9·60 in. had its highest July total since records began in 1910. More than the average sunshine was recorded in the west and south-west but most of Scotland and eastern England had a deficit.

During the opening days a ridge of high pressure moved very slowly south-eastwards across the country. Apart from considerable cloud in eastern districts and some local rain or drizzle in south-east England and northern Scotland up to the 4th, it was mainly fine and sunny. Temperature reached 80°F. locally in England on the 1st, 2nd and 5th and daily sunshine totals exceeding 14 hr. were recorded at places in the western half of the country. There was fog locally inland at night and early morning, and it occurred also in coastal areas, persisting after noon in places on the north-east coast on the 2nd. By the 5th the ridge had moved to England where it maintained warm sunny weather, but troughs of low pressure brought cloud and rain from the Atlantic to Scotland and Northern Ireland. These conditions reached Wales in the evening and spread over England during the night, rain being heavy locally in the west (2·05 in. at Blaenau Festiniog, Merionethshire on the 5th). A period of cloudy weather with occasional rain ensued with fog banks in the English Channel and on the south-west coasts on the 6th and 7th. From the 8th to the 10th a cool unstable west to north-west air stream gave showers and bright periods in most districts with widespread thunderstorms in east and south-east England on the 9th. The showers became more scattered on the 10th as a weakening ridge of high pressure moved across the country. For the remainder of the month the weather was dominated by four large slow-moving depressions whose centres passed north-eastwards over or near Ireland and Scotland, giving an unsettled south-west to westerly type of weather and frequent rain or showers. On the 11th rainfall was considerable in the west and south (2·02 in. at Compton, Sussex and 3·16 in. at Maesteg, Glamorgan on the 11th, and 2·20 in. at Shanklin in 24 hr. on the 11th and 12th). There were also heavy falls on the 12th to 14th in the Midlands and north of England and in Scotland, and flood damage was reported at a number of places (2·45 in. at Naseby Reservoir, Northamptonshire and 2·52 in. at Warrington, Lancashire on the 12th and 2·45 in. at Ballindalloch, Banffshire on the 13th). Widespread thunderstorms occurred on the 16th to 18th and were reported to have seriously affected crops in the west Midlands and central Scotland while there was local damage due both to lightning and flooding and some loss of life. In a severe storm in London on the 18th 0·63 in. of rain fell in 15 min. at Kensington Palace. During this period temperature in most areas was somewhat below the average and the sunniest places were in the south. During the 19th and 20th temperature rose appreciably, and although the unsettled weather continued with heavy rain at times in the west and north (2·76 in. at Blaenau Festiniog, Glamorgan, on the 20th and 2·33 in. at Thirlmere, Cumberland, on the 24th), there were some warm sunny days in the south-east on the 20th and 21st and on the 24th and 25th, temperature reaching 80°F. locally on the 25th. From the 26th to the 28th an unstable south-west to westerly air stream gave a renewal of cool showery weather, and on the 27th widespread thunderstorms occurred causing damage in many areas, particularly to crops in the eastern half of England and the Midlands. On the 29th a weak trough moved over the central districts of England giving duller weather and some rain, and on the 31st a shallow depression moved across southern England causing periods of continuous rain. Elsewhere the cool showery weather with bright intervals continued to the end of the month.

The general character of the weather is shown by the following provisional figures.

| | AIR TEMPERATURE | | | RAINFALL | | SUNSHINE |
|---|---|---|---|---|---|---|
| | Highest | Lowest | Difference from average daily mean | Percentage of average | No. of days difference from average | Percentage of average |
| | °F. | °F. | °F. | % | | % |
| England and Wales ... | 84 | 37 | −1·1 | 135 | +5 | 104 |
| Scotland ... ... | 84 | 36 | −0·6 | 147 | +7 | 76 |
| Northern Ireland ... | 75 | 45 | −0·9 | 146 | +5 | 97 |

# RAINFALL OF JULY 1953

## Great Britain and Northern Ireland

| County | Station | In. | Per cent. of Av. | County | Station | In. | Per cent. of Av. |
|---|---|---|---|---|---|---|---|
| *London* | Camden Square ... | 4·09 | 172 | *Glam.* | Cardiff, Penylan ... | 4·76 | 155 |
| *Kent* | Dover ... ... ... | 2·73 | 129 | *Pemb.* | Tenby ... ... ... | 5·40 | 183 |
| ,, | Edenbridge, Falconhurst | 3·41 | 148 | *Radnor* | Tyrmynydd ... ... | 5·56 | 135 |
| *Sussex* | Compton, Compton Ho. | 5·25 | 186 | *Mont.* | Lake Vyrnwy ... ... | 8·09 | 227 |
| ,, | Worthing, Beach Ho. Pk. | 2·47 | 121 | *Mer.* | Blaenau Festiniog ... | 15·32 | 180 |
| *Hants.* | Ventnor Park ... ... | 2·56 | 124 | ,, | Aberdovey ... ... | 3·86 | 110 |
| ,, | Southampton (East Pk.) | 4·38 | 192 | *Carn.* | Llandudno ... ... | 1·39 | 62 |
| ,, | South Farnborough ... | 2·81 | 138 | *Angl.* | Llanerchymedd ... | 2·99 | 105 |
| *Herts.* | Royston, Therfield Rec. | 3·10 | 123 | *I. Man* | Douglas, Borough Cem. | 5·03 | 164 |
| *Bucks.* | Slough, Upton ... ... | 3·14 | 164 | *Wigtown* | Newton Stewart ... | 5·44 | 173 |
| *Oxford* | Oxford, Radcliffe ... | 3·23 | 136 | *Dumf.* | Dumfries, Crichton R.I. | 5·94 | 182 |
| *N'hants.* | Wellingboro' Swanspool | 2·72 | 119 | ,, | Eskdalemuir Obsy. ... | 9·56 | 233 |
| *Essex* | Shoeburyness ... ... | 2·53 | 138 | *Roxb.* | Crailing... ... ... | 3·30 | 114 |
| ,, | Dovercourt ... ... | 2·92 | 146 | *Peebles* | Stobo Castle ... ... | 4·66 | 161 |
| *Suffolk* | Lowestoft Sec. School ... | 2·51 | 111 | *Berwick* | Marchmont House ... | 3·40 | 111 |
| ,, | Bury St. Ed., Westley H. | 3·72 | 149 | *E. Loth.* | North Berwick Res. ... | 4·12 | 160 |
| *Norfolk* | Sandringham Ho. Gdns. | 2·50 | 100 | *Midl'n.* | Edinburgh, Blackf'd. H. | 4·60 | 163 |
| *Wilts.* | Aldbourne ... ... | 2·96 | 124 | *Lanark* | Hamilton W. W., T'nhill | 3·79 | 132 |
| *Dorset* | Creech Grange... ... | 3·94 | 161 | *Ayr* | Colmonell, Knockdolian | 4·91 | 156 |
| ,, | Beaminster, East St. ... | 4·02 | 155 | ,, | Glen Afton, Ayr San. ... | 5·51 | 131 |
| *Devon* | Teignmouth, Den Gdns. | 2·12 | 91 | *Renfrew.* | Greenock, Prospect Hill | 6·70 | 181 |
| ,, | Cullompton ... ... | .. | .. | *Bute* | Rothesay, Ardencraig ... | 5·90 | 149 |
| ,, | Ilfracombe ... ... | 5·99 | 236 | *Argyll* | Morven (Drimnin) ... | 6·67 | 151 |
| ,, | Okehampton ... ... | 3·90 | 120 | ,, | Poltalloch ... ... | 5·58 | 135 |
| *Cornwall* | Bude, School House ... | 4·47 | 182 | ,, | Inveraray Castle ... | 8·33 | 177 |
| ,, | Penzance, Morrab Gdns. | 5·23 | 192 | ,, | Islay, Eallabus ... ... | 5·45 | 160 |
| ,, | St. Austell ... ... | 4·28 | 128 | ,, | Tiree ... ... ... | 4·52 | 125 |
| ,, | Scilly, Tresco Abbey ... | 4·57 | 206 | *Kinross* | Loch Leven Sluice ... | 4·45 | 155 |
| *Glos.* | Cirencester ... ... | 3·24 | 126 | *Fife* | Leuchars Airfield ... | 2·58 | 99 |
| *Salop* | Church Stretton ... | 2·95 | 112 | *Perth* | Loch Dhu ... ... | 7·13 | 148 |
| ,, | Shrewsbury, Monkmore | 2·58 | 123 | ,, | Crieff, Strathearn Hyd. | 3·81 | 128 |
| *Worcs.* | Malvern, Free Library... | 3·31 | 145 | ,, | Pitlochry, Fincastle ... | 2·93 | 109 |
| *Warwick* | Birmingham, Edgbaston | 3·57 | 154 | *Angus* | Montrose, Sunnyside ... | 3·25 | 124 |
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