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MAXIMUM CONCENTRATION AT GROUND LEVEL OF GAS FROM A HEATED ELEVATED SOURCE

By A. C. BEST, D.Sc.

Introduction.—Many industrial chimney stacks emit gases which, in sufficiently high concentrations, are harmful to health, and it is a matter of considerable importance to be able to assess the maximum concentration at ground level of these gases. The effect of a specified concentration of gas varies with the individual, and on this account great accuracy in predicting the concentration is not essential.

When the chimney stack is being designed the place where the maximum ground-level concentration will occur and the meteorological conditions leading to it (provided they are not unrealistic) are almost irrelevant. The design should be such that a harmful ground-level concentration never occurs anywhere.

If the effluent has the same density as the ambient air and is discharged without significant vertical speed, there is no real difficulty. Sutton[1] has given a formula which can be used to compute ground-level concentrations at various distances from the stack. But if the effluent experiences significant vertical movement after leaving the stack—either because the effluent is heated or because it is discharged with significant vertical speed—the problem is more difficult. Generally in such circumstances the gas plume will be vertical at the stack exit, but at any greater height it will bend over in the direction of the wind. At great distances from the stack the centre line of the plume will be practically horizontal and at some level above the top of the stack. An approximate method of computing ground-level concentration is thus to treat the source as a cold source emitting with zero vertical speed, but to assume that the source is raised by an amount z equal to the height of the plume above the source at a distance where the plume is practically horizontal. In order to use this method it is necessary to know how to compute the "height of rise" of the plume. The purpose of the present note is to compare the effects of three formulae for this height of rise on the maximum ground-level concentration.

Maximum ground-level concentration from an elevated source.—Sutton[1] has shown that if the effluent has the same density as the atmosphere and is emitted without significant vertical motion the concentration at ground level increases with increasing distance from the source up to a critical distance and then decreases again. The maximum concentration at ground level is given by

$$\chi = \frac{2Q}{e\pi u h^2}\left(\frac{C_z}{C_y}\right) \qquad \text{...........} \quad (1)$$

and occurs at a distance x given by

$$x = \left(\frac{h^2}{C_z^2}\right)^{1/(2-n)}, \qquad \text{.......... (2)}$$

where Q is the strength of source, u the wind speed, h the height of source above ground, C_y and C_z the usual turbulence coefficients in Sutton's diffusion theory, and n a parameter which depends upon the stability of the atmosphere.

Sutton suggests that, with $n = 0{\cdot}25$, equations (1) and (2) will give satisfactory results in conditions of small temperature gradient and moderate wind.

If the source is assumed to be raised to a height z above the top of the stack equation (1) should be replaced by

$$\chi = \frac{A}{u(h+z)^2}, \qquad \text{.......... (3)}$$

where A $[= (2Q/e\pi)(C_z/C_y)]$ is a parameter which is independent of stack design, u and h. It is intuitively obvious that z will decrease as u increases and it is convenient here to consider the effect of expressing z as a power of u. Suppose

$$z = \frac{B}{u^p}, \qquad \text{.......... (4)}$$

then χ, the maximum gas concentration at ground level at any distance from the stack, will be a function of u. It is easily verified that χ has a maximum value with respect to u given by

$$\chi_{\max} = \frac{A}{B^{1/p}} \frac{1}{h^{2-1/p}} \frac{(2p-1)^{2-1/p}}{4p^2} \qquad \text{.......... (5)}$$

$$u^p = \frac{B(2p-1)}{h} \qquad \text{.......... (6)}$$

$$z = \frac{h}{2p-1}. \qquad \text{.......... (7)}$$

For planning purposes it is the value of $\chi_{\max}$ which is of interest provided the corresponding value of u, given by equation (6), is within the range of values likely to be experienced. For these same purposes the distance at which this value of $\chi_{\max}$ occurs is unimportant in a densely populated country. The value of z is irrelevant except as an intermediate parameter introduced as a means of facilitating the computations.

Formulae for the height of rise of a heated plume.—There have been several formulae quoted for the value of z. Sutton[1] deduces a value based upon the heat output from the stack, the conservation of energy and the trajectory of a particle having a constant horizontal speed and a decaying vertical speed. Explicitly he takes z to be the height of the particle above the origin when the inclination of the trajectory to the horizontal is 10°. The formula thus obtained for z is of the form of equation (4) with p having the value 3 and B dependent upon various physical parameters, upon the air temperature and upon the heat output from the stack.

Bosanquet, Carey and Halton[2] have treated the motion of the heated plume as a problem in rate of dilution by the ambient air owing to the motion of the plume relative to the ambient air, both longitudinal and transverse, and to eddy motion. The formula finally reached for the height of rise is somewhat complicated and will not be repeated here explicitly. It should be noted, however, that the formula involves the gradient of potential temperature in the ambient air.

Another formula, having a purely empirical basis, has been suggested from America[3]. This third formula again has the same form as equation (4) with the value 1 for p.

Explicit comparison of the three formulae mentioned is far from straightforward since they do not contain the same parameters. In order to compare the three formulae indirectly, z was computed by each method for four different values of heat output from the stack and for three different wind speeds. The heat outputs chosen varied from $2 \cdot 5 \times 10^6$ to 5×10^7 cal./sec. If the stack is part of a power station it is believed that the corresponding power outputs would be, approximately, 50 and 1,000 MW. respectively. The selected wind speeds were 10, 15 and 20 ft./sec. In order to make the computations it was necessary to make assumptions concerning the characteristics of the stack, the effluent and the ambient air. The assumptions adopted were that the exit speed from the stack is 50 ft./sec., the effluent has the physical properties of air, the ambient and effluent temperatures are 288° and 423°A. respectively, and the atmospheric potential temperature increases upwards by 1 °C./1,000 ft. (This last assumption is needed only for the formula of Bosanquet, Carey and Halton.) The results were discordant by a factor which varied from 2 to 30 according to the circumstances. For our present purpose, however, it was notable that the disagreement between the three formulae was least when the height of rise z was least, i.e. when the ground concentration of gas would be greatest.

Although this comparison may be said to be appropriate to a scientific assessment of the three formulae we are here concerned with the more practical problem of how to assess the maximum gas concentration (irrespective of distance from stack and ambient conditions) which may occur at ground level. If the three formulae imply that the maximum ground-level concentration will be found at three different distances and in three different sets of ambient conditions those facts are irrelevant to the planning of the chimney stack provided the ambient conditions for maximum concentration are reasonably likely to occur.

Comparison of the formulae for maximum ground-level concentration.—It would obviously be convenient to use equation (5) in the comparison of maximum ground-level concentrations. This equation implies that the height of rise of the heated plume is given by an equation similar to equation (4). We have seen that this condition is satisfied by Sutton's formula and by the Oak Ridge formula. The formula by Bosanquet, Carey and Halton bears no resemblance, explicitly, to equation (4). Accordingly, z was computed, as a function of u, by Bosanquet's formula for the sets of conditions in Table I.

TABLE I

Rate of heat emission (cal./sec.)	10^5	10^5	10^8	10^5
Potential-temperature gradient (°C./1,000 ft.)	1	1	1	5
Speed of efflux from stack (m./sec.)	15	5	15	15

In each case it was assumed that the ambient temperature was 288°A. and the effluent temperature 423°A.

Plotting z against u logarithmically then demonstrated that equation (4) would give a very satisfactory relationship between u and z. The value of p

varied from 1·7 to 2·2 according to the conditions. The value of B was also obtained from the plotted points.

The maximum value of the ground-level concentration depends upon the height of the chimney stack. The ratio* of the maximum ground-level concentrations according to Sutton's formula and the formula of Bosanquet, Carey and Halton was computed for each of the sets of conditions described in Table I and for three chimney heights 50, 100 and 200 m. Of the 12 answers obtained only one exceeded 1·5—that one was 1·66. It is a matter of some surprise that two such dissimilar formulae should yield such similar results though it must be remembered that the wind speed necessary to produce the maximum concentration depends upon which formula is used.

A similar ratio* but using Sutton's formula and the Oak Ridge formula was next computed. The relevant parameters and the values adopted in this comparison were speed of efflux (5 and 15 m./sec.), stack diameter (5 and 10 m.), stack height (50, 100 and 200 m.), and heat output (10^5, 10^6, 10^7 and 10^8 cal./sec.). There were thus 48 values obtained for the ratio. Of these 48 values 25 were less than 2·0 and 38 less than 3·0. The three greatest values 4·3, 5·6 and 6·4, occurred with the greatest chimney height of 200 m.—a value which is probably unrealistic and would in any case lead to low values of the ground-level concentration. It was also notable that, in the conditions leading to high ground concentrations, i.e. low chimney height, low speed of efflux and low heat output, the Oak Ridge formula invariably predicted a higher concentration than did Sutton's formula.

In view of the uncertainty and variability of the effects of a specified concentration of gas on a human being, the discrepancies between the three formulae mentioned above are not important. Since safety is being considered, the formula predicting the largest concentration may be preferred, but convenience in use also deserves attention. Fortunately, these two considerations lead in the same direction and suggest the Oak Ridge formula. This formula, in the form in which it is quoted in the Report of the Committee on Air Pollution[4], is as follows:—

$$\chi = \frac{9.10^6.Q}{h(14vd + H)},$$

where χ is the maximum concentration (milligrammes per cubic meter), Q the strength of source (pounds per second), h the height of the stack (feet), v the speed of efflux (feet per second), and H the rate of heat output relative to air temperature (British thermal units per second).

It should be emphasized that this formula refers to occasions when the vertical temperature gradient is small. With a marked inversion above the top of the chimney stack the ground-level concentration may be increased markedly by an amount which will depend upon the height and intensity of the inversion.

REFERENCES

1. SUTTON, O. G.; Micrometeorology. London, New York and Toronto, 1953.
2. BOSANQUET, C.H., CAREY, W. F., and HALTON, E. M.; Dust deposition from chimney stacks. *Proc. Instn mech. Engrs, London,* **162,** 1950, p. 355.
3. Oak Ridge, Tenn., U.S. Weather Bureau. A meteorological survey of the Oak Ridge area. *Rep. U.S. Atomic Energy Comm., Oak Ridge, Tenn.,* No. ORO–99, 1953.
4. London, Committee on Air Pollution. Report. Cmd. 9322, London, 1954.

*These ratios were obtained by dividing the greater by the lesser concentration and so were all greater than unity.

NIGHT COOLING UNDER CLEAR SKIES AT HIGH-LEVEL STATIONS IN CUMBERLAND

By W. E. RICHARDSON, M.A.

Following work by W. E. Saunders[1-4] and others[5-7] an examination was made of the thermograph records covering a period of nearly two years at Alston, Cumberland. The records are for two stations, Nether Park and Riverside, especially selected to be representative of conditions on an east-facing slope and in an adjacent valley bottom. Details of the stations appear elsewhere[8,9]. Both stations were above grass supported by loamy soils.

Times of the evening temperature discontinuity were extracted from the thermograms of each station for clear evenings. The monthly mean times are given in Fig. 1. This shows that the same general pattern exists as at low-level stations. For much of the year the screen temperature of discontinuity T_r is much earlier at the valley station than at Nether Park, presumably owing to more rapid cooling at this lower level. The later discontinuity at Riverside in July and August may be fortuitous and due to the fact that observations began at Riverside in June 1952, and several late discontinuities which were recorded there in early July were not recorded at Nether Park, where the record began in late July.

A comparison of the values of T_r and T_{min} (night minimum temperature) at the two stations showed that, on the average, the discontinuity occurs at Riverside at a temperature 1·1°F. lower than at Nether Park and that the difference is slightly increased during the period of subsequent cooling, T_{min} at Riverside being 1·8°F. lower than at Nether Park.

The curve for Riverside (given in Fig. 1) shows spring and autumn discontinuities of the type commented on in some recent papers[1,4,5,7]. In spring it is

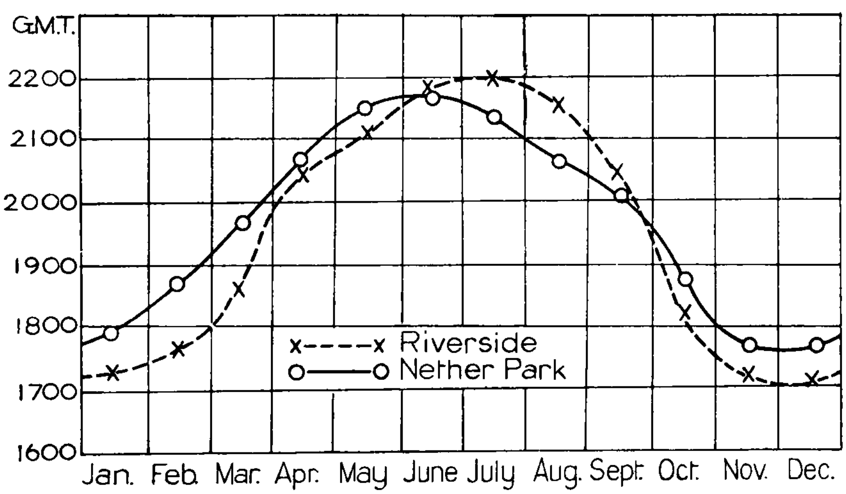


FIG. 1—ANNUAL VARIATION OF TIME OF EVENING TEMPERATURE DISCONTINUITY

Alston, June 1952–April 1954
Number of observations used

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
Riverside	4	10	24	18	8	12	14	9	4	9	2	5	119
Nether Park	3	9	30	18	11	9	11	9	8	8	0	4	120

suggested that the really significant change is that in March, when the time of discontinuity is later than would be expected from straighforward variation with time. W. J. Bruce[7] on the other hand lays stress on the subsequent further change towards a relatively earlier time in April. This feature may have been over-emphasized by Bruce, owing to his having drawn his smooth curve for June 1953 rather too late. Only three observations are plotted for May and June, and these all lie about one hour earlier than the times shown by the curve. If these suggestions are correct, the spring changes are due to drying-out as originally postulated by Saunders[1]. However this could be drying of the air as well as of the underlying surface in view of the low dew points which are markedly a feature of the spring months. These were especially prevalent in 1953[10], as is shown by the figures for relative humidity at Alston given in Table I.

TABLE I—AVERAGE MONTHLY RELATIVE HUMIDITY AT 0900 G.M.T. AT ALSTON CLIMATOLOGICAL STATION (1,070 FT.)

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
						per cent.						
1952	87	86	87	73	73	80	81	83	80	86	90	90
1953	91	91	74	76	75	80	83	78	85	85	88	91
1954	87	93	86	74	76	82	85	84	83	89	89	90
1955	88	92	80	75	...	...	...	...	...	...	...	...

The observed values of T_r and T_{min} taken from the thermographs at Nether Park and Riverside were plotted on graphs, separately for each station and for the summer and winter half years. The results are given in Fig. 2, occasions of snow-lying at 0900 G.M.T. being shown separately (XY). The mean deviation of individual cases from the curves drawn is of the order 2°F. Owing to lack of upper air information it was impossible to carry the analysis further, e.g. by classifying the cases according to gradient wind or according to whether or not there was an air-mass inversion as distinct from the surface-radiation inversion. Furthermore, some doubt must remain as to whether all the nights whose records were used were in fact completely clear nights within the definition "mean cloud amount not greater than one okta", since Alston is not a 24-hr. station. In view of all these circumstances the relationships between T_r and T_{min} seem to be remarkably close, and provide further confirmation of the idea upon which Saunders' work[1] on subsequent cooling is based, i.e. that the final temperature should be expressed as a function of the initial temperature.

The curves of Fig. 2 are similar for Nether Park and Riverside, and show the relation to be of the same type as at a low-level station, though the amount of subsequent cooling is less. However the inherent faults of curve-fitting, used in all work hitherto undertaken on this subject, are clearly demonstrated here, for the curves for Riverside and Nether Park being almost identical suggest that subsequent cooling at both stations is the same. It has been stated above that further cooling to the extent of 0·6°F. on the average takes place at Riverside in addition to that at Nether Park. The differences between T_r and T_{min} at Riverside and Nether Park are plotted on Fig. 3. It is interesting to note that a further analysis of the observations in relation to air-mass type at 0000 gives a very satisfactory curve for the non-anticyclonic groups. Assuming this curve to be linear, the following equation is found:

$$\Delta T_{min} \simeq 1\cdot 2 \Delta T_r - 0\cdot 9,$$

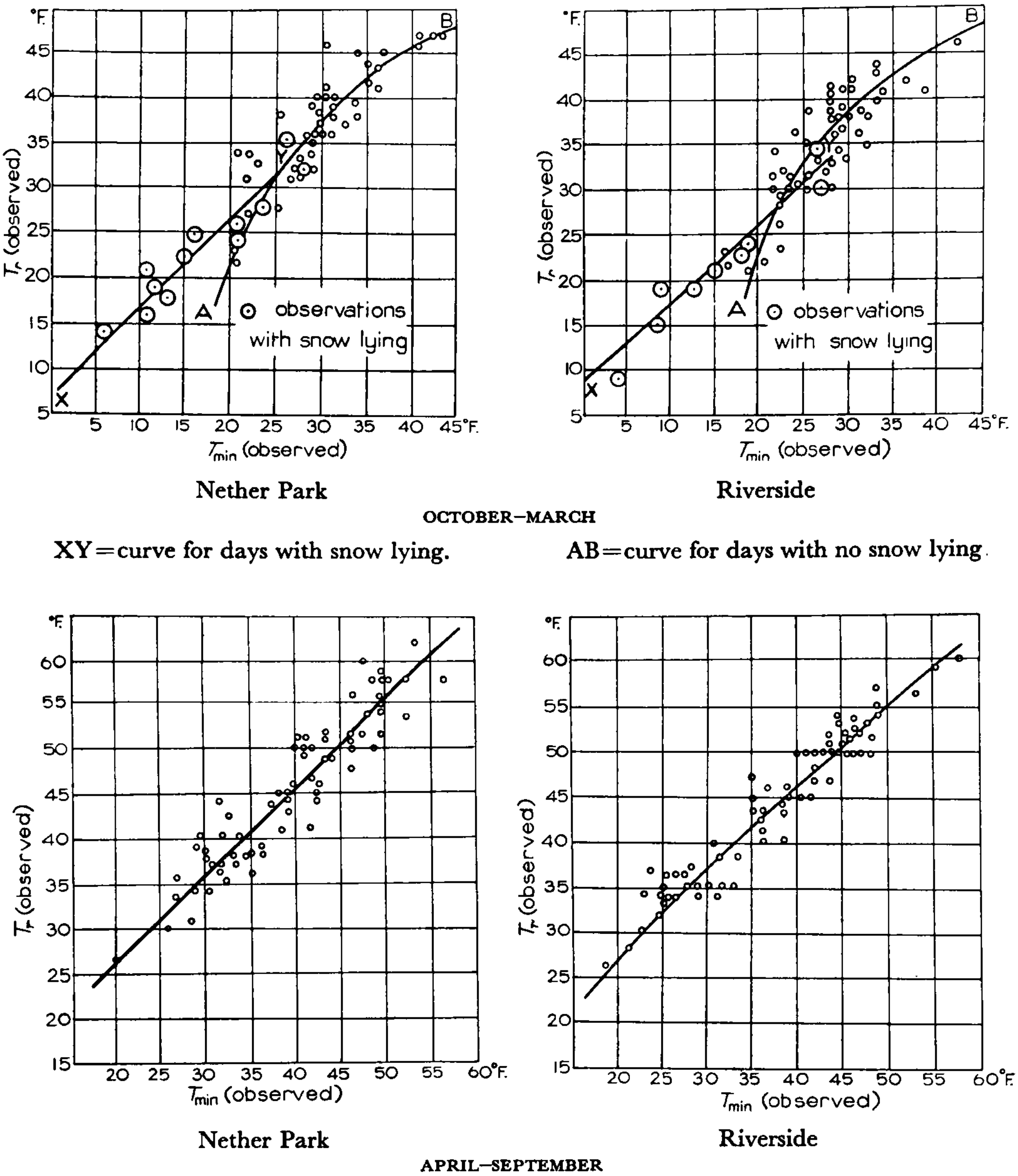


FIG. 2—RELATION BETWEEN NIGHT MINIMUM TEMPERATURE (T_{min}) AND TEMPERATURE AT THE TIME OF EVENING DISCONTINUITY (T_r)

where ΔT_{min} is the difference between the minimum temperatures at Riverside and Nether Park and ΔT_r is the difference between the temperatures at their discontinuities. For this work Belasco's classification[11] was used.

The main feature of Fig. 2 is the marked decrease in the amount of subsequent cooling with low values of T_r in winter in the absence of snow-cover. This suggests that under these conditions even the valley bottom is unlikely to produce a minimum below 15°F. With snow-cover, however, low values of T_r are followed by appreciably lower values of T_{min} than would be experienced in the absence of snow, a result which is of course to be expected having regard to the low thermal conductivity of snow.

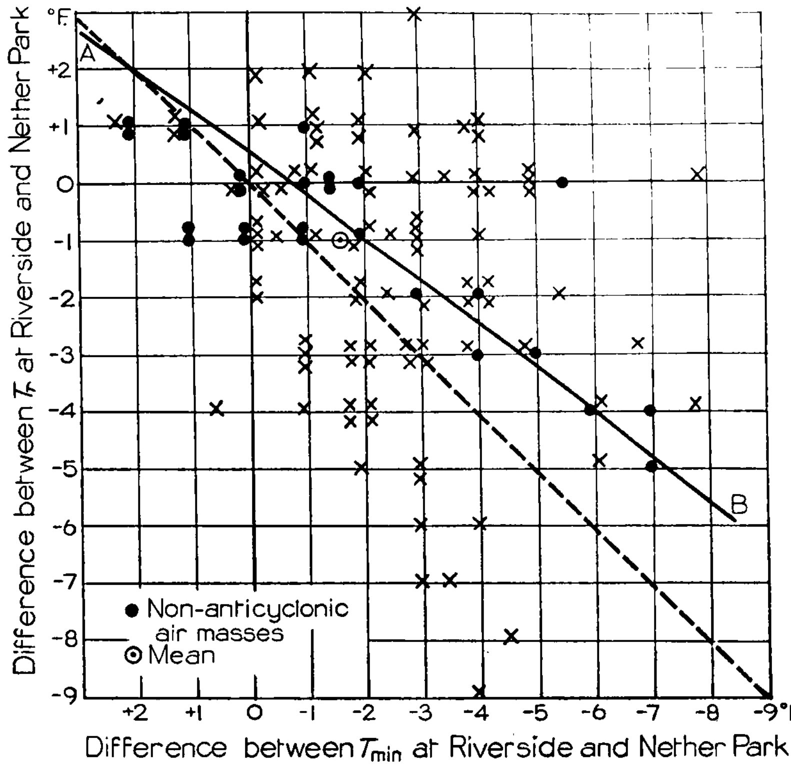


FIG. 3—DIFFERENCE IN TEMPERATURE BETWEEN RIVERSIDE AND NETHER PARK

AB = line fitted to observations with non-anticyclonic air masses
Broken line = line with equal subsequent cooling at Riverside and Nether Park

REFERENCES

1. SAUNDERS, W. E.; Some further aspects of night cooling under clear skies. *Quart. J. R. met. Soc., London*, **78**, 1952, p. 603.
2. SAUNDERS, W. E.; Night cooling under clear skies, Exeter Airport. *Met. Mag., London*, **83**, 1954, p. 9.
3. SAUNDERS, W. E.; Night cooling under clear skies. *Quart. J. R. met. Soc., London*, **80**, 1954, p. 458.
4. SAUNDERS, W. E.; Night cooling under clear skies at a coastal station. *Met. Mag., London*, **84**, 1955, p. 76.
5. PARRY, T. H.; Night cooling under clear skies at Shawbury. *Met. Mag., London*, **82**, 1953, p. 368.
6. ROBERTS, E. D.; Night cooling under clear skies at Mildenhall. *Met. Mag., London*, **84**, 1955, p. 48.
7. BRUCE, W. J.; Night cooling curves for Wahn, Germany. *Met. Mag., London*, **84**, 1955, p. 105.
8. RICHARDSON, W. E.; Temperature differences in the South Tyne Valley, near Alston, Cumberland. *Weather, London*, **9**, 1954, p. 82.
9. RICHARDSON, W. E.; "Remarkable" rises in temperature. *Met. Mag., London*, **82**, 1953, p. 374.
10. GREEN, F. H. W.; A remarkable low humidity. *Weather, London*, **8**, 1953, p. 182.
11. BELASCO, J. E.; Characteristics of air masses over the British Isles. *Geophys. Mem., London*, **11**, No. 87, 1952.

WIND EROSION IN THE FENS

By M. T. SPENCE, B.Sc.

A "blow" is the local name in the Fens for a storm which lifts the top soil, fills the air with grit and dust, and reduces visibility sometimes to a few yards. A "blow" causing widespread loss of soil occurs about once in five years. Such a "blow" was experienced on May 4–5, 1955. The essentials for a "blow" are:—

[*To face p. 304*

Reproduced by courtesy of N. J. Sneesby

DYKE FILLED BY BLOWN SOIL IN THE FENS
(see opposite)

To face p. 305]

Reproduced by courtesy of the Farmers Weekly

BLOWN SOIL COLLECTED IN THE LEE OF AN OBSTACLE

The blown soil collects in the lee of the gate and leaves the characteristic ripple of blown sand. The increased wind under the bars of the gate scoops out the soil leaving a hollow trough.

(i) soil particles small enough to be lifted and either kept aloft in the air (duststorm), or, having the size distribution of sand, simulate a sandstorm which is maintained by the grains never rising to great heights, but the bulk of them travelling in trajectories fairly near the ground, each grain gaining sufficient forward momentum from the wind to bounce again or to eject one or more other grains on hitting the ground and so keeping the sandstorm in motion.

(ii) a wind strong enough to raise the top soil of cultivated fields.

(iii) soil particles dry enough not to be cohesive.

A sample of "blown" soil taken from a typical deposit left by the storm of May 4–5 was composed almost entirely of grains corresponding in size to fine sand, i.e. some 0·02–0·2 mm. in diameter. This piece of evidence suggests that a "blow" in the Fens has more the characteristics of a sandstorm than a duststorm, basing the distinction on particle size. Further support for this view is obtained from the shape and location of the deposits. Dust particles move as part of the air stream in which they are being carried and therefore pass over or around ditches and obstacles. On the other hand sand grains fall through air and have an appreciable terminal velocity of fall. Therefore at any place in a sandstorm where the wind is systematically reduced a deposit of sand accumulates because the gravitational pull is given relatively more time to bring down the grains, and if on descent the falling grains do eject others the wind is too light to carry them away. Now on May 4–5, 1955 the "dykes" on the edge of eroded fields were filled with soil deposit (see photograph facing p. 304) and deposits were also formed near obstacles in the path of the wind, these deposits were in drifts, like snow drifts, a few of them showing the characteristic ripples of blown sand (see photograph facing this page). This photograph is of interest in another connexion too, because it shows both the sheltering effect of a barred gate extending to leeward a distance several times the height of the gate and the erosive effect of the increased wind caused by funnelling immediately underneath the gate.

Yet another piece of evidence that grains were "blowing" is that people who experienced the storm out of doors complained of the "stinging" felt on their hands and faces. Some dust was mixed with the grains, however, because a dust deposit was found on indoor furniture after the "blow" even when windows had been closed.

In a field in which potatoes had been ridged, the furrows were filled with soil deposit showing ripple structure. The ripples were particularly noticeable because the crest of each ripple was lighter in colour than the rest of the field; these crests were found to be composed of quartz grains. It is characteristic of sand ripples formed by wind that the coarsest material collects at the crests and the finest in the troughs[1].

With regard to wind, Bagnold[1] shows that when the wind increases beyond the threshold speed at which sand begins to move, the quantity of sand blown increases as the cube of the excess wind. On the morning of May 4 "blowing" began in a small way with a wind averaging about 20 kt. at Mildenhall, measured by an anemometer with its vane at an "effective height" of 60 ft. On the 4th and the night of the 4th–5th "blowing" was intermittent, but the wind increased on the 5th and reached a mean speed of 39 kt. at 1400 continuing over 30 kt. all afternoon when the "blow" reached its height. On the 4th a gust reached 41 kt., and on the afternoon of the 5th, 56 kt.; and many gusts over 45 kt. were recorded on the latter day. The strength of the wind undoubtedly goes a long way to explain the magnitude of the "blow" on this occasion.

It is difficult to know which drying factors are the most important in preparing the soil for a "blow". Sand on a beach has been known to dry sufficiently between two high tides to be set in motion by the wind. This suggests that only recent rains may have significance where "blows" in the Fens are concerned provided there has been good drying since the last rain. Nevertheless, in the particular case under review, April and the first three days of May were all comparatively dry (0·64 in. in April, 0·25 in. in the period May 1–3). In the week before the "blow" drying was very good on at least two days with relative humidity of the order of 40 per cent. in the afternoon and wind moderate in force. On the afternoons of May 4 and 5 relative humidity was 40–50 per cent. which, combined with strong wind, meant that the air had exceptionally good drying properties at the time of the "blow".

The state of cultivation of the soil is another important factor. In spring most of the land has been prepared as seed beds and therefore brought to a fine tilth; it is no mere coincidence that the worst cases of "blowing" occur between mid March and early May. The soil eroded in May 1955 was in fact the top inch or two to which the farmers had devoted so much attention in preparation for seed sowing—soil, which a correspondent to *The Times*, writing about the events of May 4–5, described as "the black sand formed by the breaking down of the peat".

The fields which suffered most erosion were those prepared for seed but still bare and those recently sown with sugar beet, carrots and other root crops in which the plants had only just emerged. Fields of barley an inch or two above ground were generally intact, except for abrasive damage to the leaves from blowing soil, though one case was reported of a patch of soil in a field of barley having been lost. Fields of winter wheat with upper surface some five inches or more above ground were quite immune from "blowing" but much abrasive damage was done to the leaves.

A farmer who anticipated the "blow" hurriedly ridged up a bare field with ridges at right angles to a SW. wind; he not only prevented loss of soil but acquired soil in his furrows from other fields. In another field, in which potatoes had been ridged several days before the storm, erosion occurred—the soil from the top of each ridge was lost; presumably the material difference between this and the previous case is the interval of time between ridging and the storm which allowed the surface of the potato field to dry out.

An instructive lesson in protection from erosion is to be learnt from one farmer's experience. He had a field, which was cropped with rye in 1954, and strips, aligned at right angles to a SW. wind, had been left to a width of about 13 yd., alternating with 34 yd. of bare land, scheduled to be drilled with sugar beet. Little or no erosion occurred in this field though fields round about, but without the strips of rye, were badly eroded.

Hedges and belts formed by trees on the windward side of fields gave complete protection to leeward for a distance of 6–10 times the height of the hedge or belt. This is disappointingly poor protection when it is considered that, in the lee of a shelter-belt, at a distance of some 20 times the height of the belt, wind may be reduced to a speed 60 per cent. of the free wind. However, the favourable conditions to be satisfied for this result are (i) a wind at right angles to the sheltering belt and (ii) a belt with about 50 per cent. permeability, the openings distributed evenly over the obstruction. The comparatively poor results in May 1955 were no doubt due to the strength of the wind which was probably much in excess of the "threshold" speed for sand blowing, and therefore recovered to the "threshold" speed in the lee of the shelter-belt before the speed of the "free" wind was reached. Other factors are that the few belts of trees which exist in the Fens are of varying and irregular permeability, and no belt was at right angles to the wind all the time of the "blow" because wind direction varied between SSE. and SW. It is worthy of note, however, that some of the worst erosion occurred round Manea, an area of the Fens in which virtually no hedges or trees are to be seen except on a far horizon.

The general estimate of the height of the top of the cloud formed by blowing soil was 50–60 ft., but staff at the meteorological office, Mildenhall, estimated the top to be 150 ft. at the worst period of the "blow". Visibility at Mildenhall was reduced to 300 yd. for 4 hr. at the height of the "blow" on the afternoon of the 5th.

I am indebted to Mr. N. J. Sneesby of the Agricultural Land Service, Eastern Province, for information concerning the extent of erosion in "sheltered" fields.

REFERENCE

1. BAGNOLD, R. A.; The physics of blown sand and desert dunes. London, 1954.

UNUSUAL BEHAVIOUR OF A DEPRESSION, APRIL 17–23, 1954

By H. D. HOYLE, B.Sc.

Development and movement of the surface depression.—The depression referred to as low A in the *Daily Weather Report* first appeared on the charts at 1800 G.M.T. on April 17, 1954, at the southern tip of Greenland; 12 hr. previously there was a shallow non-frontal low Y 250 nautical miles to the west-south-west and an old occluded depression N 800 nautical miles to the south (see Fig. 1). From 1800 on the 17th to 1800 on the 18th, the depression A moved east-north-east at an average speed of 17 kt. The depression then began to turn to the right and from 0000 on the 19th to 0000 on the 20th moved steadily south-south-east at an average speed of 22 kt. The depression then turned further to the right and for the 24 hr., 0000 on the 20th to 0000 on the 21st, moved fairly steadily south-west at an average speed of 20 kt. After this the depression was slow moving, describing roughly a small half-circle, in a cyclonic sense, during the next 48 hr., and it finally filled completely by 1800 on the 23rd.

There were thus five main stages: Stage I formation, Stage II east-north-east movement, Stage III south-south-east movement, Stage IV south-west movement, Stage V slow movement.

Upper air charts.—*Stage I: Formation* (up to 1800 on the 17th).—Although a shallow depression at mean sea level, low Y had an associated closed cyclonic circulation at all levels up to and including 300 mb., whilst low N had an associated closed cyclonic circulation up to the 200-mb. level. These two features gave, together, a large-amplitude upper trough at about 49° W. At 500 mb. the distances to the next up-stream and down-stream troughs were appreciably shorter than the equilibrium stationary wave-length, which is consistent with the eastward progression which actually took place[1]. In particular the motion of the upper low from its position in association with low Y to a position near that given for low A at 1800 on the 17th was to be expected.

The 1000–500-mb. thickness showed a well marked trough to the west of low Y terminating in the south in a closed cold pool south-west of low N (see Fig. 2). The pattern is favourable[2,3] for the formation, to the north of low N, of a new centre, which could be expected to move north-north-east to the position given for low A at 1800 on the 17th. Thus low A may have been historically the same depression as low Y or it may have been a development associated with low N.

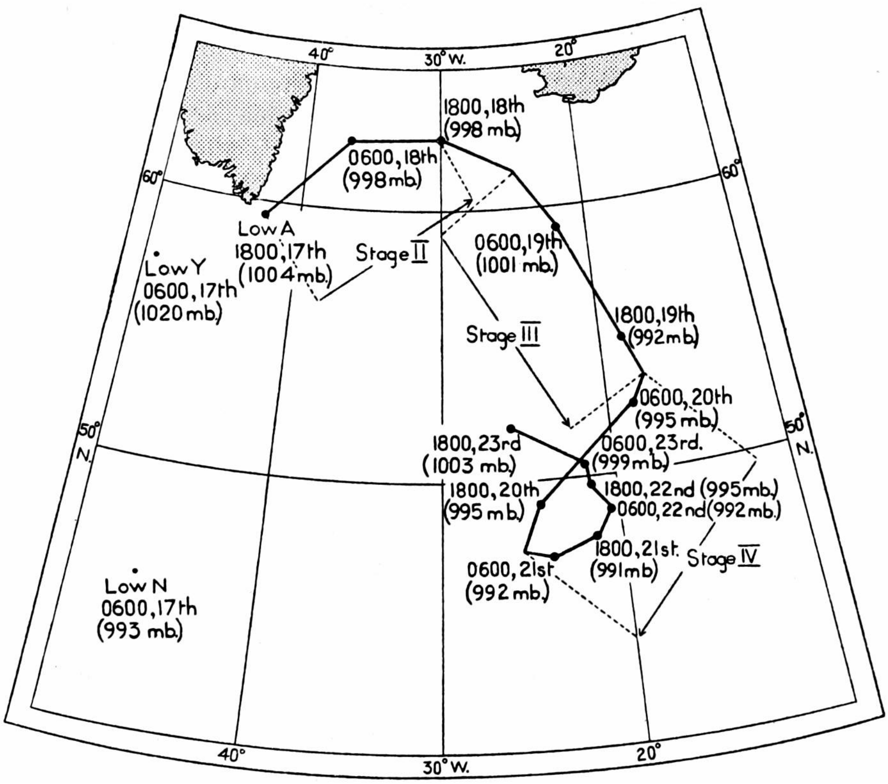


FIG. 1—TRACK OF THE DEPRESSION A, APRIL 17–23, 1954

Stage II: East-north-east movement (1800 on the 17th to 1800 on the 18th).—Associated with low A was an intense closed cyclonic circulation up to 300 mb., which extended later to 200 mb. also. The 1000–500-mb. thickness pattern over low A was a fairly conventional sinusoidal type, but became very distorted later. Towards the end of this period a closed cold pool was beginning to be apparent. The 500–300-mb. layer, however, showed the coldest air to the east of the surface centre with warmer air from the west encroaching. The 300–200-mb. layer showed a warm centre just west of the position of low A.

Stage III: South-south-east movement (0000 on the 19th to 0000 on the 20th).—The closed circulation at all contour levels up to and including 200 mb. remained intense and at all levels, was almost concentric with low A. The 1000–500-mb. thickness also showed a cold pool almost concentric with low A. In the 500–300-mb. layer the coldest air was still east of low A with encroachment of the warm ridge from the west (see Fig. 3). In the 300–200-mb. layer the warm centre associated with low A persisted and was nearly concentric with low A.

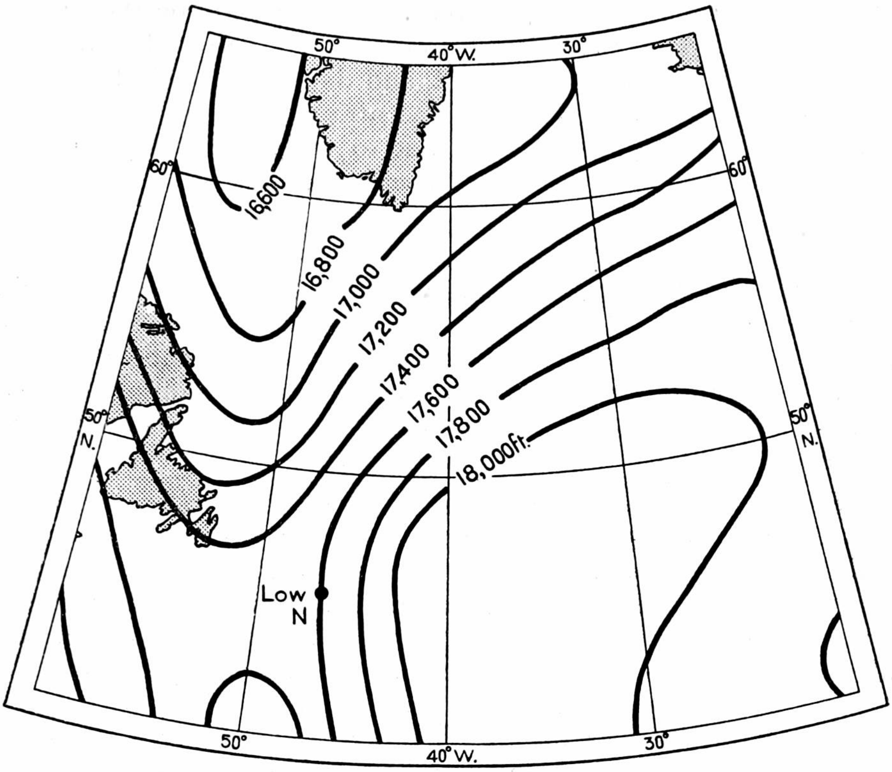


FIG. 2—1000–500-MB. THICKNESS, 0300 G.M.T., APRIL 17, 1954

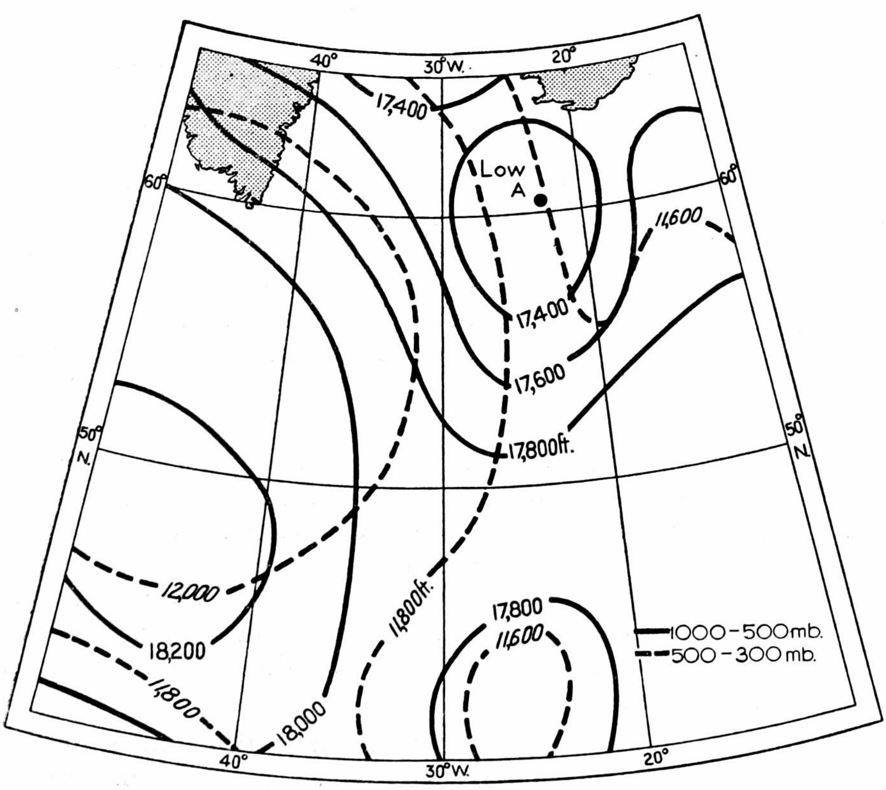


FIG. 3—1000–500-MB. AND 500–300-MB. THICKNESS, 0300 G.M.T., APRIL 19, 1954

Stage IV: South-west movement (0000 on the 20th to 0000 on the 21st).—The closed circulation at all contour levels up to 200 mb. persisted. The cold pool in the 1000–500-mb. thickness remained, and the 500–300-mb. layer now also showed a closed cold pool, again almost concentric with low A. The 300–200-mb. layer showed the warm centre somewhat to the north-west of the surface centre, and this layer was thus the one with the best defined thermal-wind direction over low A.

Stage V: Slow movement (after 0000 on the 21st).—A large closed circulation was still apparent in the contours at all levels up to 200 mb. The thermal winds were weak for all layers, but a more conventional thickness pattern was established in the lower layers with slight ridge formation ahead and with the coldest air moving round the western and then the southern side of low A. Conventional ideas of steering by the 1000–500-mb. thermal wind would thus suggest the slow circular track of low A during this final period.

Direction of motion.—Stages II, III and IV are the more interesting ones with regard to the direction of motion. Measurements were made, for the standard thickness layers, of the mean thermal wind over an area centred on the depression, by a method similar to that used by the author elsewhere[4]. The measurements were made over an area of radius about 300 miles and over one twice as great. The mean of the two values so obtained is shown in Table I. It will be seen that the direction of motion of the depression was in agreement with the thermal-wind direction for successively higher layers during stages II–IV. The directions in agreement are shown in italics in the table.

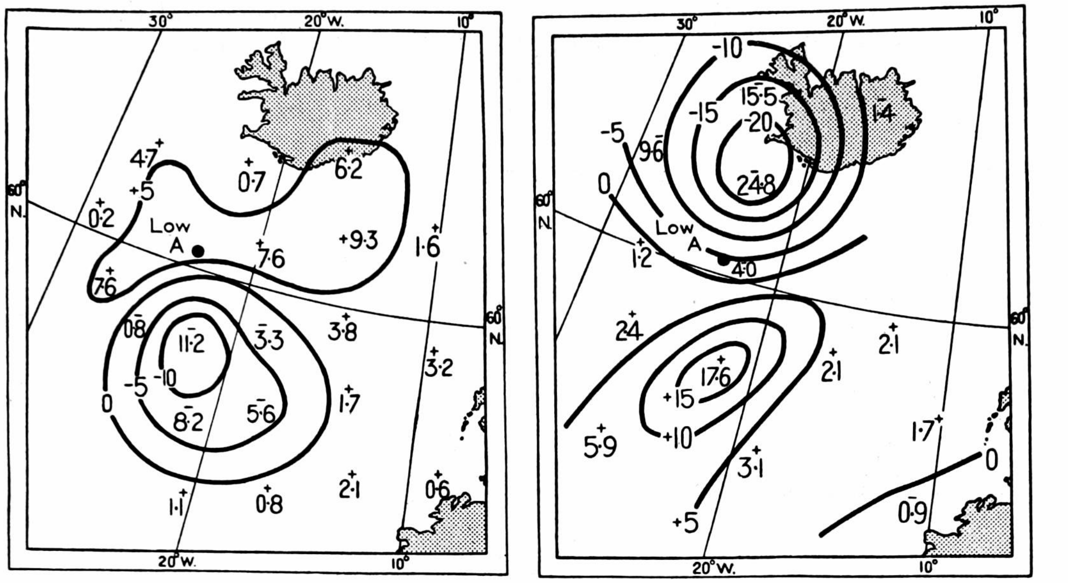
TABLE I—MEAN THERMAL-WIND DIRECTIONS

	Stage II	Stage III	Stage IV
		degrees true	
Track of low	*245*	*335*	*40*
300–200-mb. thermal-wind direction ...	25	43	*33*
500–300-mb. thermal-wind direction ...	301	*337*	339
1000–500-mb. thermal-wind direction ...	*244*	265	260

Comparison with an earlier case.—A depression of October 4, 1952 described by Lowndes[5] had several points of close similarity. In both cases there was a closed cyclonic circulation extending up to 300 mb. Both cases were noteworthy for the manner in which the coldest air in the 500–300-mb. layer was ahead of the surface depression. Both depressions moved south-east at variance with 1000–500-mb. thermal steering, but in good agreement with the 500–300-mb. thermal wind.

Relative divergence during stage III.—A "development chart" was drawn for the 1000–500-mb. layer, using the Sawyer-Matthewman scale[6]. The values found (see Fig. 4(*a*)) were not very large, indicating no great relative divergence through this layer, and they failed to explain the south-south-east movement in that they indicated cyclonic development towards the east-north-east of the centre. The same principle was applied to the 500–300-mb. layer (see Fig. 4 (*b*)). This layer gave much larger values of relative divergence and shows cyclonic development towards the south-south-east, in agreement with actual developments.

Speed of motion.—It is possible to obtain a theoretical estimate of the speed of motion by assuming the form of the curve of divergence against pressure and using equations obtained by Sutcliffe[3].



(*a*) 1000–500 mb. (*b*) 500–300 mb.

FIG. 4—DEVELOPMENT CHARTS, 0300 G.M.T., APRIL 19, 1954

Values are given in units of 10^{-2} hr.$^{-2}$, positive for cyclonic development and negative for anticyclonic development.

The essential features of the case considered, during stage III, are a negligible 1000–500-mb. thermal wind, and hence an almost identical flow pattern at all levels up to 500 mb., but appreciable relative divergence through some layers above 500 mb. We thus consider the steering of the 500-mb. low by the thermal wind in the layer above, and infer the motion of the surface low by virtue of the identical pattern through the lower layers.

An approximation to the type of flow found is made by simply assuming no relative divergence from 1000 to 500 mb., divergence increasing linearly with pressure from 500 to 200 mb. and no divergence above 200 mb. (see Fig. 5).

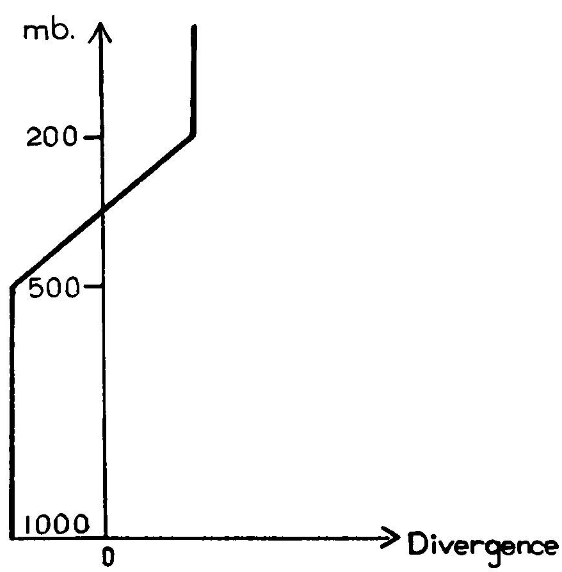


FIG. 5—ASSUMED FORM OF DIVERGENCE PROFILE

As a rough approximation we may assume that convergence and divergence balance, in a vertical column. That is, if p_0 is the surface pressure,

$$\frac{dp_0}{dt} = -\int_0^{p_0} \operatorname{div}_p \mathbf{V} dp = 0 \quad \text{approximately.}$$

The assumed form of the divergence curve (Fig. 5) then gives

$$13 \operatorname{div} \mathbf{V}_5 + 7 \operatorname{div} \mathbf{V}_2 = 0, \qquad \text{(1)}$$

where $\mathbf{V}_5$ and $\mathbf{V}_2$ are the winds at 500 mb. and 200 mb. But if we consider "steering" effects only and apply Sutcliffe's equation for the relative divergence to the 500–200-mb. layer then

$$l(\operatorname{div} \mathbf{V}_2 - \operatorname{div} \mathbf{V}_5) = -2V' \frac{\partial \zeta_5}{\partial s}, \qquad \text{(2)}$$

where ζ_5 is the vorticity of the 500-mb. flow, and $\mathbf{V}'$ is the 500–200-mb. thermal wind. Eliminating $\mathbf{V}_2$ from equations (1) and (2) we obtain

$$l \operatorname{div} \mathbf{V}_5 = \frac{7}{10} V' \frac{\partial \zeta_5}{\partial s}. \qquad \text{(3)}$$

Now we may use the equation

$$\frac{d\zeta}{dt} = -l \operatorname{div} \mathbf{V}$$

and obtain

$$\frac{d\zeta_5}{dt} = -\frac{7}{10} \mathbf{V}'.\nabla \zeta_5. \qquad \text{(4)}$$

But $d\zeta_5/dt = \partial\zeta_5/\partial t + \mathbf{V}_5.\nabla \zeta_5$, and since we are dealing with a closed circulation (approximately circular) at 500 mb. the second term on the right will make little contribution. Equation (4) thus gives an approximation for the local change of vorticity ($\partial\zeta_5/\partial t$) and shows this to be equivalent to advection of the 500-mb. vorticity at a speed roughly 70 per cent. of the 500–200-mb. thermal wind. Considering the very simple form assumed for the divergence-pressure curve, the values shown in Table II are in reasonable agreement.

TABLE II—RELATION OF SPEED OF DEPRESSION TO 500–200-MB. THERMAL WIND SPEED

	Stage III	Stage IV
	knots	
Average speed of depression	22	20
500–200-mb. thermal-wind speed ...	19	19

Conclusions.—Steering by the thermal wind at levels above 500 mb. would seem to be operative during stages III and IV in the movement of this depression. It is suggested that whenever the thermal wind becomes weak, or of ill defined direction through the lower layer so that there is almost identical flow at all levels through that layer, then thermal steering by the layer above may become operative

This is similar to the view put forward by Scherhag[7] but refers to "thermal" steering rather than "contour" steering. For example, during stage III of the motion of the depression considered in this note the 500–300-mb. thermal wind had a well defined direction but the contours showed closed circulations to 200 mb.

The formation of a closed cold pool in the 1000–500-mb. thickness is a fairly frequent feature of the later stages of the life-cycle of a depression. Although we cannot draw conclusions of general application from this isolated example, it is possible that thermal steering at levels above 500 mb. is sometimes operative in other cases. The abnormal feature of the present case was probably the strength and direction of the thermal wind at the higher levels.

REFERENCES

1. ROSSBY, C.-G.; Planetary flow patterns in the atmosphere. *Quart. J. R. met. Soc., London,* **66,** Suppl., 1940, p. 68.
2. SAWYER, J. S.; Secondary depressions on warm fronts and warm occlusions—the associated thickness pattern and other characteristic features. *Met. Res. Pap., London,* No. 476, 1949.
3. SUTCLIFFE, R. C.; A contribution to the problem of development. *Quart. J. R. met. Soc., London,* **73,** 1947, p. 370.
4. HOYLE, H. D.; Speed and direction of motion of simple warm-sector depressions. *Met. Mag., London,* **84,** 1955, p. 206.
5. LOWNDES, C. A. S.; Mobile depression with an unusual thermal structure. *Met. Mag., London,* **83,** 1954, p. 40.
6. SAWYER, J. S. and MATTHEWMAN, A. G.; Note on the evaluation of terms of a type arising in Sutcliffe's treatment of cyclonic development. *Quart. J. R. met. Soc., London,* **77,** 1951, p. 667.
7. SCHERHAG, R.; Neue Methoden der Wetteranalyse und Wetterprognose. Berlin, 1948.

[A search was made through the *Daily Aerological Record* and the working charts for 1949–54 to see whether any cases similar to that described by H. D. Hoyle have occurred in the post-war years. The field of investigation was limited to the area covered as a routine by the *Daily Aerological Record*; this extends roughly from Iceland to Gibraltar and from 25°W. to 25°E. All cases were noted where the surface depression was concentric, or nearly so, with a cold pool in the 1000–500-mb. thickness pattern and where the thermal wind in the 500–300-mb. layer across the centre was 15 kt. or more.

In six out of the ten examples satisfying these criteria it was not possible to observe the effect of the upper thermal wind upon the lower vortex; either the surface depression filled quickly and disappeared or further development took place in the baroclinic zones ahead of the 1000–500-mb. trough. There was some evidence of steering in the remaining four which occurred during the following periods:—

0300 G.M.T. January 14, 1950 to 0300 G.M.T. January 15, 1950
2100 G.M.T. January 22, 1951 to 0900 G.M.T. January 23, 1951
1500 G.M.T. October 30, 1951 to 1500 G.M.T. October 31, 1951
1500 G.M.T. February 10, 1954 to 1500 G.M.T. February 11, 1954.

The depressions in none of these sequences approached the depth of that of April 17–23, 1954 nor did they retain their identity for so long a period.—F. E. DINSDALE]

PRELIMINARY ANALYSIS OF STANDING-WAVE REPORTS RECEIVED AT NORTHOLT DURING THE WINTER OF 1953–54

By R. K. PILSBURY

Introduction.—The forecasters at Northolt Airport and the pilots of British European Airways and Aer Lingus have for some years shown a great interest in standing waves. During the winter of 1953–54, pilots operating from Northolt were told by the forecaster at briefing, on the basis of previous experience, when waves were considered to be likely and the pilots were invited to make observations of any wave effects encountered. An attempt was then made to deduce the upper air conditions prevailing in the area concerned at the time of each report and to analyse these conditions to ascertain whether any features were common to all reports. This note gives the result of the analysis.

Data and their limitations.—During the period October 1953 to April 1954, 95 reports were received from pilots: 66 were concerned with lee waves found over the British Isles, 8 with waves over the nearby Continent and the remaining 21 reported no waves found. The investigation was most intense during November and December 1953 and January 1954; thereafter interest in the scheme was spasmodic.

Civil aircraft, based at Northolt, operated along well defined flight paths within a layer usually extending from 4,500 to 10,500 ft. above sea level. Flights were made irregularly from 8 a.m. to 10 p.m. Thus it was not possible to investigate closely the changes in wave structure with time, distance or height. Furthermore, the determination of the upper air conditions, representative of the undisturbed air stream up wind of the hilly terrain, involved interpolation from upper air data and was sometimes unreliable. This was particularly true of the waves which occurred over the nearby Continent, and such reports were therefore excluded from the analysis. Although forecasters suggested to pilots the occasions on which they might, with advantage, be on the watch for wave effects, it is not considered that the analysis was prejudiced by this, especially as similar meteorological conditions were also common to many spontaneous reports which were received.

Method of analysis.—For each reported case of waves over the British Isles, an attempt was made to deduce the upper air temperature and wind structure representative of the undisturbed air stream, up wind of the incident. As most reports were received from areas not far removed from the sea, i.e. north Wales, the Lake District and south-west Scotland, and as upper winds were generally from a westerly direction, diurnal modification of the air stream during its passage from sea to land was not considered. Synoptic surface and upper contour charts were studied to aid in the selection of upper air data, and to indicate their likely modification due to time and space changes in the weather situation.

Each representative ascent was then examined and the layers having markedly different stability were noted; in addition the vertical profile of the parameter l^2, discussed by Scorer[1], was calculated, using the scale devised by Wallington[2]. Attempts were then made to see whether any particular conditions of stability or wind structure were common to all cases of waves. Data were also examined to ascertain if there were any connexions between the strength of vertical currents reported and the wave-length, the wind at 2,000 ft., the increase of wind with height, the aircraft height in relation to the stable layers, or variations in Scorer's parameter l^2.

Further analyses were made into cases of no waves and of waves associated with strong vertical currents.

Analysis of 66 reports of waves over the United Kingdom.—*General upper air conditions.*—Certain upper air conditions were found to be common to these reports of lee waves, namely:—

(i) A layer of steep lapse rate from surface to at least 2,000 ft.; there were several cases where this layer was 7,000 ft. deep.

(ii) A second layer above (i) with marked stability. This layer was often isothermal and sometimes contained steep temperature inversions. The thickness of this stable layer varied from 800 ft. to over 10,000 ft.

(iii) In 62 cases, there was a layer above (ii) but below 18,000 ft., where the lapse rate once again became steeper.

(iv) The wind at 950 mb. (approx. 2,000 ft.) was at least 15 kt. and in all but five cases it was over 20 kt.

(v) Wind direction was almost constant with height throughout the first and second layers.

(vi) In every case but one, the wind increased with height to at least the top of the stable layer (thus there was a reinforcing thermal wind).

Synoptic situations.—The analysis indicated that waves were found in a wide variety of synoptic situations, all satisfying the upper air conditions given above. Waves were reported in advance of warm fronts, in warm sectors, to the rear of cold fronts, along stationary fronts and in cold air. An examination of the nine days when widespread waves were reported revealed that on six of these warm-sector conditions prevailed, whilst on two days reports referred to positions just to the rear of a cold front. On the ninth day a stationary front lay across the area from which the reports were received.

Height, location and frequency of occurrence.—Civil aircraft operating from Northolt flew at certain fixed height levels between 4,500 and 10,500 ft. with an occasional flight over Wales between 14,000 and 18,000 ft. Waves were reported at all levels within these ranges. On one occasion, when over the English Channel in a northerly air stream, a pilot stated that he experienced waves having vertical currents of 100 to 200 ft./min. when flying at 6,000 ft. He then ascended to just above the haze top at 8,000 ft. and the waves ceased. From the Crawley radio-sonde ascent it appears that, when at 6,000 ft., the pilot was flying in a stable layer between two inversions; on ascending to 8,000 ft. he was just above the second inversion. This is consistent with the variation of lee-wave amplitude through inversions, as deduced theoretically by Scorer[3]; he found that the amplitude decreased very rapidly above an inversion. Approximately 90 per cent. of reports were received from pilots operating from Northolt and flying along the following three British air corridors:—

(i) Northolt–Daventry–Lichfield–Ringway–Dean Cross–Renfrew–Edinburgh.

(ii) Northolt–Daventry–Lichfield–Wallasey–Belfast.

(iii) Northolt–Daventry–Nevin–Dublin.

Thus an examination of the geographical distribution of the occurrence of waves would reveal little of material significance. The strongest vertical currents were reported near the highest mountains of north Wales, the Lake District and southern Scotland, i.e. where the mountains rise to 2,000 ft. or more in the vicinity of the above corridors. On some occasions, however, waves were widespread, and were experienced from soon after take-off from Northolt to destinations in Scotland and Ireland. One pilot found them practically all the way across the Irish Sea from Wallasey to Belfast. It is noted however that in many cases, wave trains of sufficient intensity to affect powered aircraft did not persist over long distances to the lee of the high ground causing them. On many occasions pilots flying the Dublin route reported waves over Wales, but other pilots flying along the other two routes at about the same time and height but some 30–60 miles further to the leeward of the Welsh mountains did not find them, although later they were experienced when the Lake District was crossed.

Reports of waves were most frequent from November 1953 to January 1954. During this period they were found on an average of one day in three in November and January and one day in seven in December, over some parts of the British Isles. On six days in these three months they were widespread. A further period of widespread waves worthy of special note was on April 13, 14 and 15, 1954. Occasionally some pilots reported waves but other pilots, flying at about the same time at or near the same height on the same route, failed to detect them. A further note on these cases will be found later.

Wave-length of lee waves.—As the orientation of the aircraft course to the wave train was not known, it was not possible to calculate accurately the wave-lengths of the lee waves in these reports. It is significant, however, that the shortest reported distance from crest to crest was 2 miles, whilst many lay in the range 3–8 miles. Of the six occasions when vertical currents were 1,000 ft./min. or more, five gave an apparent wave-length of 5–6 miles. A British European Airways pilot, when flying over south-west Scotland at 6,000–8,000 ft. reported that he was experiencing waves of length 3–4 miles whilst above him he observed bands of lenticular cloud at about 12,000–15,000 ft. spaced at intervals of about 20 miles.

Strength of vertical currents with special mention of cases reported in excess of 800 ft./min.—An analysis was made of the vertical currents reported and their relationship to the three layers mentioned on p. 314. Pilots who happened to be flying in the upper part of the stable layer reported stronger currents than those in other positions within the layer. Aircraft flying near the bottom of the stable layer or below it found vertical currents were slight. In the six cases where pilots were flying above this stable layer but still experiencing currents of 500 ft./min. or more there was always a second stable layer above the flight level.

In four cases, the strength of both upward and downward currents was given. In three of these the upward current was much the stronger.

The speeds of the majority of vertical currents lay within the range of 300–500 ft./min., but some were as low as 100–200 ft./min. The most violent case in this series was over the sea to the north of Great Orme's Head, when an Aer Lingus pilot, flying at 4,500 ft. at 2030 G.M.T. on March 22, 1954, experienced an uplift of 2,200 ft./min. He did not find any corresponding downward current, but with upper winds from the south it is probable that his east–west course lay parallel to the wave crests. The second strongest vertical current was found by a British European Airways pilot on April 15, 1954, at 0800 G.M.T. near Dollar Law, south of Edinburgh where he measured an uplift at the rate of 1,900 ft./min.; the corresponding downward flow was only of the order of 500 ft./min.

When vertical currents of 800 ft./min. or greater were reported, an examination of the position of the aircraft, relative to the surface analysis of synoptic conditions prevailing, revealed that in 8 cases out of 10, the pilot was flying just to the rear of the surface cold front. The remaining 2 cases occurred within a warm sector. In every case there was an inversion present whilst in 6 cases there was a double inversion. It is worthy of note that, in relation to the wind structure, in 8 cases the wind increased rapidly with height above the base of the inversion and at 18,000 ft. it was double and sometimes treble the speed at 2,000 ft. The wind speed at 2,000 ft. in the undisturbed air stream, before reaching the high ground which caused the waves, was in 8 cases 25 kt. or more and in 4 cases over 30 kt.

These strong vertical currents were found both in daylight and at night, at various heights from 4,500 to 8,500 ft., and in several mountainous regions.

Turbulence and variations in the wave train.—Of the 66 cases examined 20 found some turbulence, although all but 2 stated that it was only slight. Several pilots found this slight turbulence to be of the "cobblestone" variety, and one commented that vibrations were of the order of 60 times a minute.

The two cases where turbulence was classified as moderate were examined further:—

> November 11, 1953, 0930 G.M.T.—An Aer Lingus pilot flying over Wales at 7,500 ft. found several ill defined waves giving up and down currents of only 100–200 ft./min. with moderate turbulence. A second pilot, on the same route at 6,500 ft., one hour later experienced several waves with currents of 300 ft./min. and only slight turbulence. That evening two other pilots again found waves but no turbulence. No reports of waves were received the day before this series but there were several cases on the following day.
>
> December 28, 1953, 2200 G.M.T.—A British European Airways pilot, flying over south-west Scotland at 5,000 ft. experienced two distinct waves with moderate turbulence. At midday another pilot found isolated waves over south-west Scotland and numerous well defined wave trains over north-west England giving much greater vertical currents; the first pilot had also found numerous waves over the Irish Sea at 1300–1400 G.M.T. that day. No reports of waves were received on the following day.

An examination of the position of all cases of turbulence in relation to the wave train showed that three occurred near the troughs of the wave, two near the crests and two each in the ascending and descending currents.

Analysis of 21 cases of no waves.—The reports do not comprise a random statistical sample and conclusions about the relative frequency of waves and no waves cannot, therefore, be drawn.

Of the 21 cases, 6 referred to occasions when some of the upper air conditions enumerated on p. 314 were not present and thus waves were not expected. In each of the remaining cases, waves were not found by one pilot but were found on nearby routes by other pilots some time during that day. In 3 cases the aircraft probably did not pass near enough to the lee of high ground likely to cause waves, whilst on 8 occasions changing conditions of upper air temperature or wind profile could account for no waves being found. Thus two cases were left without explanation and both are interesting as they occurred over north Wales when reports of waves from other pilots were numerous at about the same time on each occasion.

Some tentative conclusions on lee-wave formation.—The upper air conditions which appear to be present, when waves strong enough to affect powered aircraft occur, are as follows:—

(i) A layer of steep lapse rate from the surface to at least 2,000 ft.

(ii) A stable layer or, even better, an inversion above (i)

(iii) Wind speed of 20 kt. or more at 2,000 ft.

(iv) An increase of wind speed with height, but with wind direction approximately constant, to above the top of the stable layer (ii).

As one would expect, these conditions imply the variations of l^2 with height found theoretically by Scorer to be necessary for lee waves to be possible. The conclusions are thus consistent with theory[4].

There is little evidence to indicate what happens at heights greater than 10,000 ft., but the few reports received show that if the upper air temperatures indicate several inversions or stable layers with shallow unstable layers between, wave formations are propagated to great heights, provided the wind direction still remains reasonably constant and the wind speed does not decrease with height.

It is significant that nearly all the strongest vertical currents were reported from positions to the rear of slow-moving cold fronts, in regions where there was a good inversion and a strong reinforcing thermal wind. Furthermore the currents were strongest near the top of the inversion.

Lee-wave reports were much more numerous in winter than in summer, both in this series and in the earlier reports mentioned by Turner[5]. It seems that the requisite upper air conditions obtain more often in winter than in summer, as would be expected.

REFERENCES

1. SCORER, R. S.; Forecasting the occurrence of lee waves. *Weather, London,* **6,** 1951, p. 99.
2. WALLINGTON, C. E.; A lee-wave scale. *Quart. J. R. met. Soc., London,* **79,** 1953, p. 545.
3. SCORER, R. S.; Theory of airflow over mountains: III—Airstream characteristics. *Quart. J. R. met. Soc., London,* **80,** 1954, p. 417.
4. CORBY, G. A.; The airflow over mountains: a review of the state of current knowledge. *Quart. J. R. met. Soc., London,* **80,** 1954, p. 491.
5. TURNER, H. S.; Air flow to the lee of hills—a study of pilots' reports. Typescript, Meteorological Office, London, 1954.

METEOROLOGICAL RESEARCH COMMITTEE

The 35th meeting of the Synoptic and Dynamical Sub-Committee was held on June 16, 1955, under the Chairmanship of Professor P. A. Sheppard who has succeeded Sir Charles Normand. Discussion of the paper by Dr. D. G. James[1] on the nocturnal dissipation of stratocumulus cloud led to the conclusion that the problem of growth and dispersal of this form of cloud merited further synoptic-dynamical study in addition to any detailed physical study which might be practicable within and near the cloud. The two related papers by Mr. J. M. Craddock[2,3] on the representation of the annual variation of temperature in the northern hemisphere were received with much interest, and represent an item in the preparatory stage of the investigation of variations of weather over the British Isles during intervals of about a month. After discussion of the significance of certain temperature anomalies in Europe, it was agreed that the general procedure which had been adopted for temperature should be applied to other weather elements as far as practicable. Mr. H. Heastie presented an interim report[4] on the method of preparation of circumpolar charts of standard isobaric surfaces (700–100 mb.) for the revised edition of *Geophysical Memoirs* No. 85 "Upper winds over the world". The various devices and adjustments necessitated by scarcity of direct observations in some regions were described.

The 33rd meeting of the Physical Sub-Committee was held on June 23, 1955, There was considerable discussion on Dr. K. H. Stewart's highly instructive report[5] on the experimental investigation of radiation fog at Cardington. The complexities of the processes in operation were noted. Suggestions for further work, including the study of radiation effects, were generally approved, and recommendations made for the study of the variation in humidity between day and night at different heights, the fall-out of droplets from fog, the frequency of visibilities at short-range intervals between 200 and 1,000 yd., and the possibility of obtaining temperature, wind and humidity observations on masts up to about 1,000 ft., or by use of low-level radio-sonde apparatus. The Sub-Committee then discussed the paper by Dr. James[1] already considered by the Synoptic and Dynamical Sub-Committee, and recommended that the Meteorological Research Flight should make suitable observations in and near stratocumulus cloud according to a programme to be agreed with the Forecasting Research Division. The other main item before the meeting was atmospheric turbulence in relation to aviation. After discussion of Mr. G. A. Corby's paper[6] and certain recommendations of the Gust Research Committee of the Aeronautical Research Council, it was agreed that the Meteorological Research Flight with suitable instrumentation of the Canberra should be able to assist in providing data for investigation of the structure of atmospheric turbulence, and that, in seeking a method independent of the use of aircraft, the use of the latest techniques in the radar tracking of a free balloon should be further explored.

ABSTRACTS

1. JAMES, D. G.; The nocturnal dissipation of stratocumulus cloud. *Met. Res. Pap., London*, No. 913, S.C. II/187 and S.C. III/184, 1955.

Typical cases of dissipating and non-dissipating stratocumulus were examined statistically for advection and vertical motion, radiation from cloud top, turbulent mixing with air above or below, and cloud thickness. A parameter $\xi = x - 9 \cdot 15y - 0 \cdot 77z$ is devised, where x = maximum depression in degrees Fahrenheit of dew point below temperature up to 50 mb. above cloud top, y = average hydrolapse in 10^{-2}gm./Kg./mb. over 50 mb. below cloud base, and z = cloud thickness in millibars. The majority (74 per cent.) of "no breaks" had $\xi < -20$, 76 per cent. of "breaks" had $\xi > -20$. Exceptions are discussed.

2. CRADDOCK, J. M.; The representation of the annual temperature variation over central and northern Europe by a two-term harmonic form: *Met. Res. Pap., London*, No. 915, S.C. II/188, 1955.

In this paper the long-period annual variation of temperature at 42 stations in central and northern Europe is analysed from 5-day means for the first four harmonics. The first two represented nearly all the annual variation, except for about 10 5-day periods which had the same anomaly at all or nearly all stations. These singularities persist when independent periods are examined; the most obvious is a positive anomaly in late May and early June. Charts show amplitudes and phases of first two harmonics.

3. CRADDOCK, J. M.; The variation of the normal air temperature over the northern hemisphere during the year. *Met. Res. Pap., London*, No. 917, S.C. II/189, 1955.

This paper gives and charts the amplitude, phase and date of maximum of the first two harmonics of 12 monthly values (1921–40) for 305 stations in the northern hemisphere. The best method of allowing for the different lengths of the months is discussed.

4. HEASTIE, H.; Average height of the standard isobaric surfaces over the area from the North Pole to 55°N. in January. *Met. Res. Pap., London*, No. 918, S.C. II/190, 1955.

A revision of "Upper winds over the world" was begun by constructing circumpolar charts for standard pressure levels for January 1949–53. The sources of data are given and method of construction described. Charts give contour heights (in geopotential decametres) for 700, 500, 300, 200, 150 and 100 mb. and intervening thicknesses.

5. STEWART, K. H.; Radiation fog. Investigations at Cardington, 1951–54. *Met. Res. Pap., London*, No. 912, S.C. III/183, 1955.

Numerous meteorological elements were observed at Cardington, at 4, 20 and 55 ft. on a tower, up to 4,000 ft. by captive balloon, and in the ground to 40 cm., whenever fog was forecast. The site and instruments are described by R. H. Pedlow. Six typical cases are discussed: two (most frequent types) with steep inversion below 50 ft. in early evening, sharpening and deepen, ing; two with cooling spread through lowest few hundred feet; and two when fog did not form- Mean wind profiles show a decrease in speed with increasing height above 750 ft. on foggy nights. probably a thermal-wind effect. In section 3 the heat balance, heat exchange with cooling layer, and flow of water vapour are discussed quantitatively. At the earth's surface the heat losses by radiation, conduction and convection are roughly equal. Section 4 takes up empirical fog forecasting and produces a diagram based on screen temperature and dew point at time of dew formation, and the forecast grass minimum. Future lines of research are suggested. Appendices discuss various physical problems.

6. CORBY, G. A.; Atmospheric turbulence in aviation. *Met. Res. Pap., London,* No. 919, S.C. III/186, 1955.

The problem of forecasting turbulence at high levels is discussed. Turbulence is important in planning operations, flight forecasting and design of aircraft, but little research is being done. Proposals include full reports by civil pilots and research with accelerometers and hot-wire anemometers.

OFFICIAL PUBLICATION

The following publication has recently been issued:—

PROFESSIONAL NOTES

No. 115—Cloud in relation to active warm fronts, Bircham Newton, 1942–46. By J. S. Sawyer, M.A., and F. E. Dinsdale, B.Sc.

The cloud structures of 76 active warm fronts are examined in relation to a number of parameters available to the operational forecaster. The only significant correlation (about 0·4) is between the extent of frontal cloud and the component of wind relative to the surface front taken normal to the front at its upper boundary. An examination of the vertical distribution of cloud in relation to the frontal zone reveals a tendency for the slope of the edge of the cloud to be steeper than the slope of the front.

NOTES AND NEWS

West London tornado, December 8, 1954

A tornado swept across west and north-west London soon after 1700 G.M.T. on December 8, 1954 in a north-east to north direction leaving a trail of destruction some 100–400 yd. wide. The boroughs of Brentford and Chiswick, Acton and Willesden seem to have suffered most severely.

The tornado struck Gunnersbury station, Chiswick at 1708 G.M.T. unroofing station buildings, blocking and short-circuiting the track. Six people on the platform were injured. Rush-hour traffic was dislocated. In the borough of Acton alone five houses had their end walls blown out or were unroofed and many other houses suffered less serious damage. Over twelve people were injured. Railway buildings at Willesden were damaged. A lorry was overturned near Golders Green at 1720 showing that the tornado travelled at about 40 m.p.h. Buildings were also damaged at Golders Green and at Hampstead Garden Suburb. A factory was damaged at Southgate.

The damage is comparable with that caused by the Linslade and Leighton Buzzard tornado of May 21, 1950, and probably with most tornadoes in the United States.

Mr. H. H. Lamb of the Meteorological Office reports that the main trunks of several full-grown trees in the Acton area were twisted off at 5–10 ft. above the ground by the great shear of wind across their width. This is one of the most characteristic sights left by a tornado. The tree tops are finally left lying on the north-east side of the trunk in those instances where the track is from south-west to north-east.

[To face p. 320

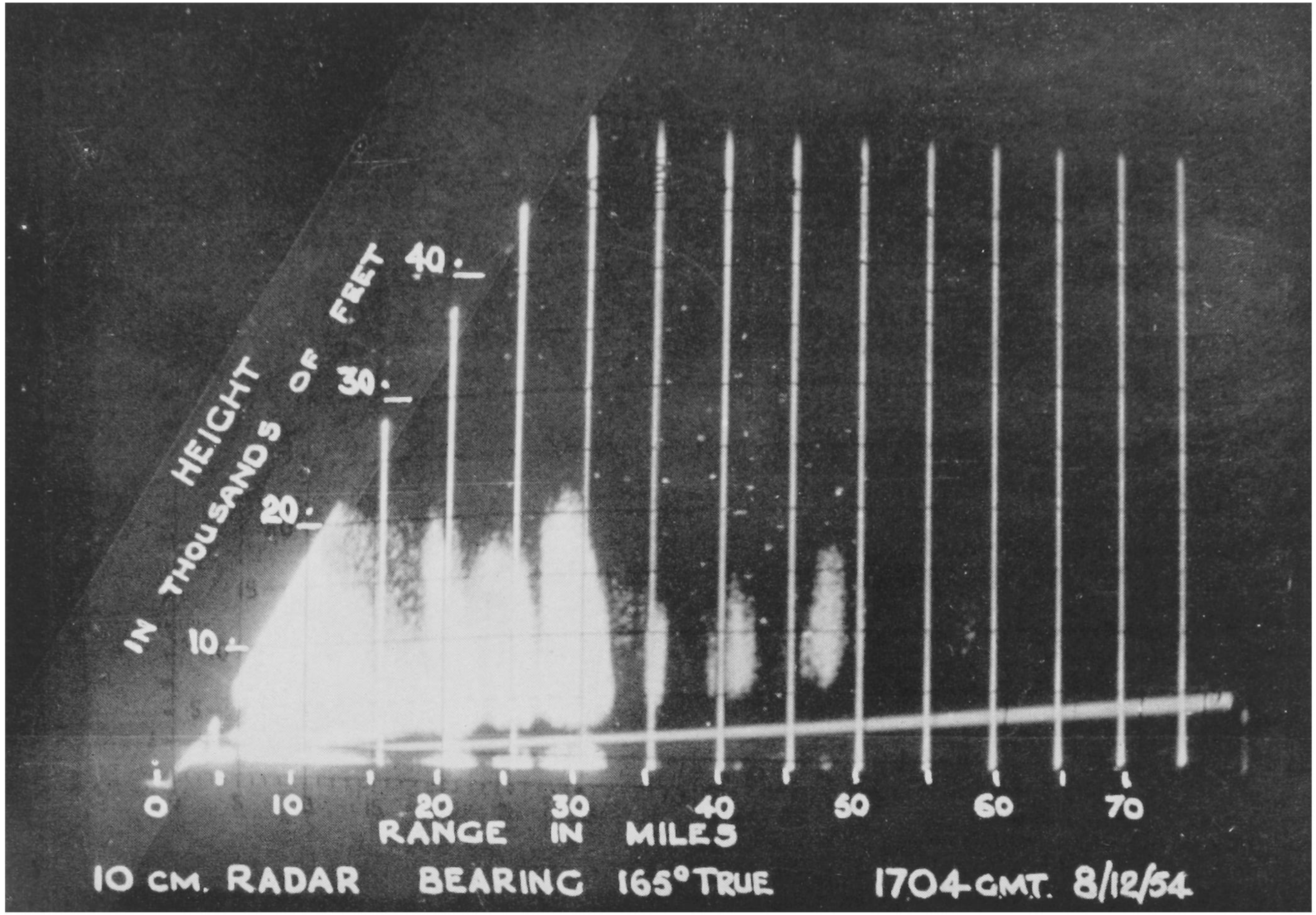


FIG. 1—HEIGHT-RANGE RADAR PHOTOGRAPH ON A BEARING OF 165° FROM EAST HILL, BEDFORDSHIRE AT 1704 G.M.T., DECEBMER 8, 1954

The large intense echo centred on 29½ miles was given by the comulonimbus which produced a tornado, which a few minutes later caused much damage at Gunnersbury Station (see p. 321).

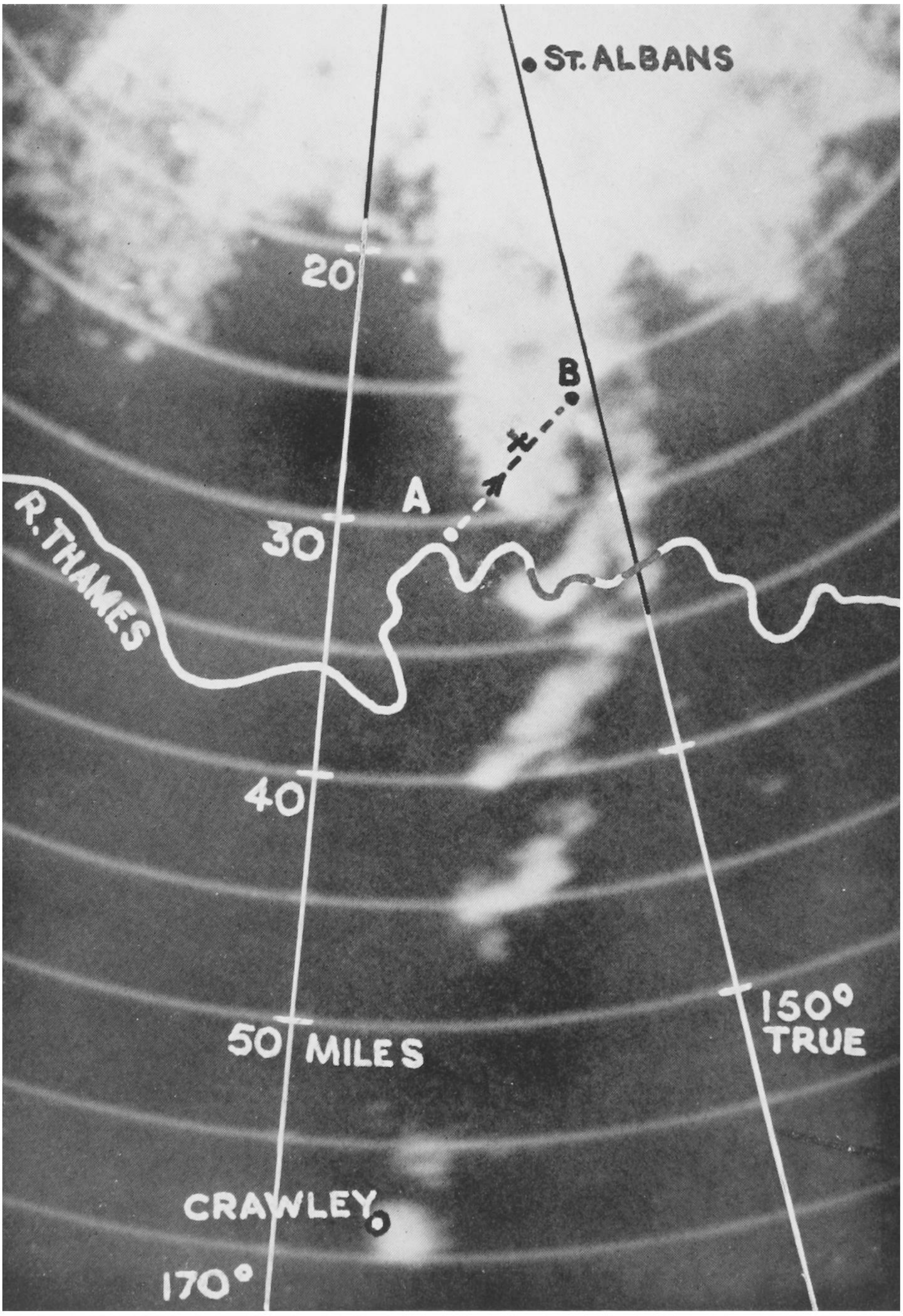


FIG. 2—PLAN-POSITION RADAR PHOTOGRAPH AT
$1708\frac{1}{2}$ G.M.T., DECEMBER 8, 1954

The intense echo marked with a cross was given by the cumulonimbus which produced a tornado. The track of the tornado is indicated by the line AB (see opposite).

The instruments at Kew Observatory showed no record of the tornado. At 1800 G.M.T. the surface winds at Kew and London Airport were respectively 22 and 23 kt. from 190°.

The tornado occurred during a thunderstorm accompanied by very heavy rain and hail of unusual violence for southern England in the winter. A very deep depression, central pressure below 956 mb., was centred over the mouth of the Bristol Channel at 1800 G.M.T. on December 8. The depression developed over the Atlantic about 55°N., 30°W. on the 6th and moved south-eastwards and deepened rapidly. The occlusion of the depression passed north-eastwards over the London area soon after midday on the 8th.

G. A. BULL

Radar equipment at the Meteorological Office at East Hill, 32 miles north-north-west of London, was in use on December 8, 1954, and it is of some interest that two of the radar photographs (facing pp. 320 and 321) clearly define the storm which struck west London in the late afternoon.

Fig. 1 is a height-range radar photograph taken at 1704 G.M.T., 3–4 min. before the tornado reached Gunnersbury Station. It was taken at a reduced gain setting in order to show the intense cores of cumulonimbus imbedded in the prevailing cloud mass, adjusted for maximum intensity on the very intense cumulonimbus echo at 29½ miles, bearing 165°. This cumulonimbus was larger and taller than any neighbouring cumulonimbus. The echo is 5 miles in diameter, which is large for a winter thunderstorm, and is very sharp-edged, indicating an active stage of development. The echo top shows as 22,000 ft., but a full-gain photograph taken a few seconds earlier recorded its echo top as 24,000 ft.

Fig. 2 is a plan-position radar photograph taken at 1708½ G.M.T., coinciding with the passage of the tornado across the Uxbridge Road at Acton Vale. This was also taken at a reduced gain setting. The 5-mile diameter cumulonimbus is marked with a cross (range circles are at 5-mile intervals) and the whirlwind track AB from Gunnersbury to Golders Green is shown by a broken line. The agreement in time and position makes it certain that the tornado was associated with this storm. It can be seen to be part of a north-south line of cumulonimbus clouds extending from Crawley to St. Albans, where the line merges into a much more extensive area of precipitation.

The whirlwind track has an azimuth of 205° while the echo movement measured from other radar photographs taken about this time was 210° 46 kt. The 2,000-ft. wind found at Crawley at 2000 G.M.T. was 208° 49 kt. If the echo over Acton is traced back it is found to coincide exactly with an isolated cumulonimbus echo 3 miles north-west of Midhurst, Sussex, on a radar photograph taken at 1622 G.M.T. The echo was then about 3 miles in diameter. A further extrapolation takes us to within 1 mile of the Langstone Toll Bridge to Hayling Island at 1605 G.M.T. It was at Langstone that a waterspout did damage that same afternoon, wrecking a boat-builder's shed close to the bridge. A police officer at Leigh Park near Havant reported, "a conical-shaped cloud travelling in the direction of Leigh Park, and when it was near Emsworth the point of the cloud curled upwards and disappeared into the cloud above". This is typical of the later stages in the life of a waterspout. The Hampshire Constabulary report that the clock in the toll collector's office at the Langstone Toll Bridge stopped at 1610 G.M.T. when the whirlwind passed. This agreement between calculated and reported times is sufficiently close to make it certain that the waterspout at Langstone and the tornado over London were associated with the same cumulonimbus.

Stout and Huff* state that unusually large and strong radar precipitation echoes are almost always present when tornadoes occur in America, masking any tornado structure which might otherwise be visible on radar. This is seen to be the case with the west London tornado.

W. G. HARPER

REVIEWS

Selected meteorological papers of Sir Napier Shaw, F.R.S. Selected and arranged by R. G. Lempfert and E. E. Austin. $11\frac{1}{4}$ in. × $8\frac{1}{2}$ in., pp. 276, *Illus.*, Macdonald & Co. Ltd., London, 1955. Price 50*s*.

This handsome and well bound volume is a credit to the editors, the printers, and publishers. It is printed on beautiful paper in clear type and the numerous diagrams are well executed. The price is surely modest as prices go today, and any serious student of meteorology will be glad to possess a copy.

Sir Napier Shaw, of whom an excellent portrait, dated 1922, appears as frontispiece to the volume, was born on March 4, 1854 and died on March 23, 1945, more than ten years ago. Before his death he expressed a wish that the trustees of his estate, who are the editors of the volume, should publish a collective edition of a selection from his meteorological lectures, addresses, essays and contributions to scientific journals. The editors compiled and printed at the end a bibliography of Shaw's works. They number no less than 381 and are dated from 1878 (an article on electrolysis for the 9th edition of the "Encyclopaedia Britannica") to four short papers in 1937. They include considerable works like the "Manual of meteorology" in four volumes, "Forecasting weather", "The air and its ways", "The drama of weather", as well as original papers on various aspects of meteorology, smoke abatement, reform of the calendar, daylight saving, units of measurement, meteorology in schools and colleges, fog and its dispersion, thermodynamics, and earlier, hygrometry, ventilation, "Practical physics" (with R. T. Glazebrook), and a number of other subjects, as well as numerous reviews and obituary notices.

The task before the editors was therefore bewildering—there was a mass of material, and the difficulty was to decide what to include in the volume and what to omit. Nor was the task mitigated by the fact that so long an interval had to elapse, owing to printing and publishing difficulties consequent on the Second World War, before a final selection could be made. The editors are to be heartily congratulated on their actual selection and also on the fact that the volume is published in 1955, the centenary year of the Meteorological Office. Shaw was Secretary of the Meteorological Council from 1899 to 1905 and Director of the Office from 1905 to 1920, and I feel that he would have been immensely pleased by the coincidence.

One of the main reasons which led Sir Napier to lay the charge of publishing a volume of his collected works upon his trustees was no doubt the fact that he himself was greatly disappointed that his first major excursion into dynamical meteorology, "The life history of surface air currents", which appeared in an

*STOUT, G. E., and HUFF, F. A.; Radar records Illinois tornado-genesis. *Bull. Amer. met. Soc., Lancaster Pa.*, **34**, 1953, p. 281.

edition of only 350 copies as an official publication in 1906, passed practically unnoticed by the meteorological world. Efforts to produce a reprint remained unsuccessful, and the reviewer knows that it was Shaw's wish that this work, at any rate, should be reproduced. Mr. Lempfert and Miss Austin have placed it first in the volume. Such is the modesty of some meteorologists that there is hardly an inkling in the book under review that the paper was the joint work of Shaw and Lempfert. It is believed that Lempfert drew all the charts, traced the "trajectories" of air and wrote the discussion of individual cases which forms Parts II and III of the Work, while Shaw no doubt supervised the work and wrote Part I.

At this point we might with advantage pause to consider the state of dynamical meteorology in this country in 1906. It is no exaggeration to say that it was then in process of being born, for apart from Scott's "Elementary meteorology", Abercromby's early edition of "Weather", a little but excellent pamphlet by Clement Ley entitled "Aids to the study and forecast of weather" (which incidentally was out of print) and a few papers in the journals of the Royal Meteorological Society and Scottish Meteorological Society, there was practically nothing available to the student except the regular issues of the *Daily Weather Report.* But in none of these works was there any suggestion that the track of a particle of surface air in a moving depression was otherwise than spirally towards the centre of the depression, and perhaps the greatest contribution made by the "Life history" was to demonstrate beyond question that this idea was incorrect, and that in fact surface air in a depression could travel thousands of miles almost along a great circle across the Atlantic. Incidentally present-day forecasters would be aghast if they could picture the material available to their predecessor of half-a-century ago—no information from Iceland, none from the Azores, nothing from the Atlantic, no upper air data, only a very few simple observations from western Europe and the western Mediterranean shores. Wireless telegraphy had not been developed and brought into use, while broadcasting and teleprinters were of course unknown. Shaw was indeed a pioneer in the field of dynamical meteorology, and he personally superintended the work of the Forecast Division until 1910.

The reprint of the "Life history" occupies 131 of the 275 pages of the book. The next paper is "The law of sequence in the yield of wheat for eastern England, 1885–1905" in which Shaw traced a connexion (remarkably exact for the years considered) between the yield of wheat in the eastern counties of England and the rainfall of the previous autumn, a dry autumn being followed by a good wheat yield. Like so many such relationships this one proved to be unreliable.

The next paper is the preface to an official publication entitled "Barometric gradient and wind force" by E. Gold. This initiated the Office practice, still current, of using "gradient" winds (now more properly called "geostrophic" winds) to obtain estimates from an isobaric chart of wind speed and direction at 1,500 ft. above sea level.

There are 10 other papers, memoranda, letters or notes in the Volume, of which probably the two most important are "The convective energy of saturated air in a natural environment", and "Note on the graphic representation of pressure and temperature obtained from observations of balloons, aeroplanes or kites". In these two papers the advantages of the well known T-ϕ diagram or tephigram as it is now called, for plotting upper air observations of temperature and pressure, and the properties of this method of representation were demonstrated for the first time. The method is still in official use in this country, and it has proved to be of very great value in considering questions of vertical stability and in the forecasting of thunderstorms.

From 1918 to 1920 Shaw became very interested in the part which "revolving fluid" might play in the atmosphere, following on a paper by the late Lord Rayleigh, which suggested that the conception of travelling columns of revolving air was very important in meteorology.

In two papers "The travel of circular depressions and tornadoes and the relation of pressure to wind for circular isobars" and "The birth and death of cyclones" which together occupy 35 pages of the Volume, Shaw endeavoured to prove that revolving fluid exists in the atmosphere not only in the obvious cases of tropical revolving storms, but in certain instances in parts of depressions in temperate latitudes where the wind is usually very strong.

Shaw's interest in agricultural meteorology was considerable, and this is represented in a short paper, "The book of the grower's year", in which the calendar comes under review.

The subject of units for meteorological measurements was always to the fore in Shaw's mind. He changed the unit of barometric pressure from the inch of mercury, which as he pointed out was not a scientific unit of pressure at all, to the millibar, which is 1000 dynes/cm.^{2} The reviewer well remembers a Monday morning in about 1913 when Shaw arrived at the Office with a bulky mass of manuscript. It transpired that he had spent the week-end compiling a logical scheme of meteorological units based on the C.G.S. system which subsequently formed part of "The computer's handbook". A paper entitled "Units for meteorological measurements" contains this material and much more, while a paper with the rather grandiloquent title of "Principia atmospherica: a study of the circulation of the atmosphere", sets out a scheme for the orderly study of atmospheric laws, lemmas and postulates.

The last reprint in the Volume, "The march of meteorology: Random recollections", was published in a special number of the *Quarterly Journal of the Royal Meteorological Society* for April 1934, issued to celebrate Shaw's 80th birthday. It is a very interesting review of Shaw's own career, and fittingly brings this remarkable volume to a close, except for the bibliography and a complete index.

R. CORLESS

Radio astronomy. By J. L. Pawsey and R. N. Bracewell. *Int. Monogr. Radio.* 9½ in. × 6¼ in., pp. vi + 374, *Illus.*, Oxford University Press, London: Geoffrey Cumberlege, 1955, Price: 55*s.*

This book, one of the series *International monographs on radio*, is written by two workers in the Radiophysics Laboratory, Sydney, Australia, where notable contributions to the science of radio astronomy have been made. This science can be said to date effectively from the end of the last war, and its subsequent world-wide development along various lines of research has been most striking. The book performs the very useful functions of describing the basic principles involved, and of summarizing and discussing the results obtained by many different research workers; in general, work published up to about mid 1952 has been considered though there are a few references to results published in 1953.

The aim of the authors has been to cater for radio physicists with little knowledge of astronomy and also for astronomers with little knowledge of radio, the result being a book which may be understood without specialized knowledge of either science. Two of the early chapters are concerned entirely with the radio aspect and describe the principles of the various methods of measurement of extraterrestrial radio emissions and the theory of the passage of radio waves through ionized gases. Of particular interest to a meteorologist are the two following chapters which are concerned exclusively with the sun. In the first of these a straightforward account is given of various aspects of solar physics, including a discussion of sun-spots and other visible features of changes in the sun's state; this chapter also includes useful diagrams illustrating the geometry of sun-earth relationships. In the second chapter dealing with the sun, attention is confined to the sun's radio emissions which have been continuously recorded since about 1947 at a number of stations by various developing techniques. Five types of solar radio waves are tentatively classified: a basic thermal component, a slowly varying part, and three types of shorter-period variation termed respectively noise storms, outbursts, and isolated bursts; the complex relationships between these various types of emission on the one hand and known features of the sun and of solar-produced earth phenomena on the other are discussed at length. Symptomatic of the power of the radio tool and of the speed with which it is being put to use is the recent attainment of important results by this means in two old problems of geomagnetism; these results, which are foreshadowed in this book, are connected with the detection of the expulsion of solar particles and with the mysteries of the sun-spot–geomagnetic disturbance relationship.

The various lines along which radio astronomy has developed are dealt with in turn. A chapter is devoted to cosmic radio waves (historically the first of the basic discoveries of the science) with a preceding chapter in which relevant aspects of astrophysics are discussed. Separate sections describe the reception of thermal radio waves from the moon and the use of the echo method for obtaining information about extraterrestrial bodies. The echo method has been most fruitfully employed in observations of meteors and a separate section describes this development. As has been shown in recent years these meteor observations are capable of yielding apparently reliable information about winds in high levels of the atmosphere, but meteorologists will be disappointed to find that this aspect of the meteor observations is not considered by the authors. There is further disappointment for meteorologists in the penultimate chapter of the book in which the effects of the lower atmosphere and ionosphere on the reception of extraterrestrial radio waves—a potentially useful method of revealing the nature of atmospheric irregularities—are considered only very briefly. The opening chapter of the book contains an account of the basic discoveries which led to the birth of the science and gives an outline of its scope. In a short concluding chapter the authors speculate on the probable future mode of development of the science.

It is hardly a valid criticism of this book that the authors have not pursued matters of meteorological interest as far as they might. Writing in the capacity of radio astronomers they have produced a book which must be invaluable to the specialist but which also contains much of interest to workers in all branches of physics.

D. H. MCINTOSH

Man and the winds. By E. Aubert de la Rue. Translated by Madge E. Thompson. $8\frac{3}{4}$ in. × $5\frac{1}{2}$ in., pp. 206, *Illus.*, Hutchinson & Co. Ltd., London, 1955, Price: 18*s.*

The pattern of life on this planet—perhaps even its very presence—much depends upon adequate air movement, and this book—a study of "human geography"—is a semi-popular development of this basic theme.

The first five chapters describe the main general and regional wind systems. Attention is then turned to the physiological effect of wind, its influence on architecture, and, in the next four chapters, its activity as a transporter of sand and soil. The final 80 pages deal mainly with the wind as a source of energy in relation to agriculture, industry, and aviation.

A number of inaccuracies and half-truths occur, particularly in the early part of the book where the author is dealing with the physical mechanism of the wind, but this over, the reader is treated to a vigorous, readable, but not necessarily complete or up-to-date account of wind in its more violent moods. The text is illustrated by a number of appropriate and attractive photographs. There will be few interested in the weather, who will not find something novel in these pages, but the last sentence, "The wind appears sometimes as a friend of man, sometimes as an enemy, but more often in the latter role." may be questioned.

There is a useful bibliography, mainly from French sources; the book is well produced and the translation smooth and efficient.

R. W. GLOYNE

METEOROLOGICAL OFFICE NEWS

Academic successes.—Information has reached us that the following members of the staff have been successful in recent examinations; we offer them our congratulations.

B.Sc.(General) : pure and applied mathematics and physics, L. Dent.

B.Sc.(Special) : second class honours in physics, J. B. Andrews.

Intermediate B.Sc.: pure and applied mathematics and physics, B. Entwistle, P. J. Rollins, P. J. Wiggett; pure and applied mathematics, physics and chemistry, R. J. Thorne.

General Certificate of Education (Advanced Level) : pure and applied mathematics and physics, J. M. C. Burton, G. A. Dent, D. Oseman, D. S. Reed; pure and applied mathematics, J. M. Bayliss, A. Stemmler; pure mathematics, V. A. Winslow; applied mathematics, A. R. Belton, Miss C. Bulgin, B. G. Ellis; physics, D. H. A. Gamble, P. B. Gildersleeves, B. Stapleton; physics and applied mathematics, F. Burns, J. P. T. Randles.

City and Guilds Intermediate and Final Certificate in Telecommunications Engineering: A. F. Hope.

Sports activities.—*Netball.*—The Meteorological Office Ladies' Netball team won the Air Ministry championship on August 20 for the seventh consecutive year. A cup has now been awarded for this competition by the Ariel Club.

WEATHER OF AUGUST 1955

In the Atlantic and European sector the weather during August continued to show the same broad features as those which characterized July. Pressure and temperature were again below normal in the Greenland area. The north-eastward extension of the Azores anticyclone across Scotland to Scandinavia was a very frequent feature of the daily maps resulting in a very large anomaly of + 10 mb. in the mean monthly pressure in this region and a corresponding temperature anomaly of 2–3°C. above the normal for the month.

Elsewhere the main features of note in the mean pressure and temperature distribution were below normal pressures in the Florida region of the United States in association with hurricanes experienced there, and pressures also below normal over Russia and over north-west Canada. Temperatures were above normal over most of southern Canada and the northern United States but below normal over much of the Mediterranean and south-east Europe.

Less than half the normal August rainfall fell over most of Britain and much of Scandinavia and north France, but rainfall was above normal in Czechoslovakia and most of the Mediterranean region including the southern half of France. Slightly over the normal rainfall for August was experiened in the extreme north of Norway, Iceland and Faeroes. Rainfall was below normal over much of the central United States but was a little above normal in north Canada; rainfall was also much above normal in the eastern United States as a result of the hurricanes.

In the British Isles weather was anticyclonic for the major part of the month but conditions were rather unsettled from the 14th to the 19th.

During the first week depressions moved across the Atlantic in high latitudes and frontal systems crossing the country were mostly weak except for the one moving southwards on the 2nd and 3rd which gave ½ in. of rain at Aldergrove and Mildenhall and similar amounts in north-east England. Weather was sunny and warm generally. Reports of 11 and 12 hr. sunshine were common during this period and on the 4th some stations in the north-west had more than 14 hr. Temperature rose to 80°F. at London Airport on the 1st and 2nd and to 83°F. at Leuchars on the 1st. A depression from Iceland became established over Scandinavia on the 6th, and although the British Isles remained chiefly under the influence of anticyclones to the west and south-west, the more northerly air stream produced somewhat lower temperature than of late. There was some ground frost in Scotland; grass temperature at Dyce fell to 29°F. early on the 9th and 10th. The 9th was dull with occasional rain as a weak trough moved into western districts, but the following day a general rise of pressure took place and from the 10th to the 13th an anticyclonic belt extended from the Azores across the British Isles to Scandinavia. Temperature rose slowly in most places to the middle seventies. Thunderstorms developed in many areas from the 10th with outbreaks of heavy rain locally; storms were particularly widespread on the night of the 12th–13th when more than ½ in. of rain fell in parts of London and south-east England and 3·44 in. fell in 1 hr. 20 min. during a heavy storm at Annaghanoon, Co. Down. A general increase in cyclonic activity occurred over the Atlantic from the 14th to the 19th. A south-westerly air stream covered the British Isles, and with this moister air widespread fog formed early but cleared quickly during the morning. There were outbreaks of thundery rain and scattered thunderstorms in most areas on the 17th and 18th as troughs moved across the country. For the remainder of the month, apart from the last day or two anticyclonic conditions were re-established over the British Isles. Temperature rose steadily and exceeded 85°F. at many places on the 22nd, 23rd and 24th and reached 90°F. at Chivenor on the 23rd; in some places during these three days temperature did not fall below 65°F. at night. Fog was again widespread during the early morning and persisted throughout the day in some coastal areas, but weather was generally dry and sunny apart from the last two days of the month when troughs from the Atlantic brought fairly general rain to the north-west. Rainfall was below the average everywhere, and monthly amounts only exceeded 50 per cent. of the average in south-east England and locally in Wales, north-west England and southern Scotland. There was less than 25 per cent. of the average over the Midlands and south-west England.

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 ...	90	32	+3·5	34	−8	116
Scotland	89	32	+3·5	30	−10	123
Northern Ireland ...	83	39	+4·1	24	−12	111

RAINFALL OF AUGUST 1955

Great Britain and Northern Ireland

County	Station	In.	Per cent. of Av.	County	Station	In.	Per cent. of Av.
London	Camden Square ...	0·95	43	*Glam.*	Cardiff, Penylan ...	1·54	36
Kent	Dover	1·79	77	*Pemb.*	Tenby	0·46	12
"	Edenbridge, Falconhurst	0·79	30	*Radnor*	Tyrmynydd	1·51	28
Sussex	Compton, Compton Ho.	1·50	49	*Mont.*	Lake Vyrnwy	2·12	40
"	Worthing, Beach Ho. Pk.	1·48	65	*Mer.*	Blaenau Festiniog ...	3·14	28
Hants.	St. Catherine's L'thouse	1·58	82	"	Aberdovey	1·69	38
"	Southampton (East Pk.)	0·96	37	*Carn.*	Llandudno	1·13	40
"	South Farnborough ...	0·97	44	*Angl.* •	Llanerchymedd ...	0·88	24
Herts.	Harpenden, Rothamsted	0·75	30	*I. Man*	Douglas, Borough Cem.	2·44	64
Bucks.	Slough, Upton	0·97	45	*Wigtown*	Newton Stewart ...	1·66	40
Oxford	Oxford, Radcliffe ...	0·45	20	*Dumf.*	Dumfries, Crichton R.I.	1·71	42
N'hants.	Wellingboro' Swanspool	0·58	24	"	Eskdalemuir Obsy. ...	1·54	30
Essex	Southend, W. W. ...	1·70	92	*Roxb.*	Crailing...	0·71	24
Suffolk	Felixstowe	1·75	100	*Peebles*	Stobo Castle	1·88	53
"	Lowestoft Sec. School ...	1·51	69	*Berwick*	Marchmont House ...	0·57	17
"	Bury St. Ed., Westley H.	1·71	66	*E. Loth.*	North Berwick Gas Wks.	0·57	18
Norfolk	Sandringham Ho. Gdns.	0·75	28	*Midl'n.*	Edinburgh, Blackf'd. H.	1·05	33
Wilts.	Aldbourne	0·48	17	*Lanark*	Hamilton W. W., T'nhill	1·46	43
Dorset	Creech Grange... ...	0·97	34	*Ayr*	Prestwick	1·62	51
"	Beaminster, East St. ...	0·67	21	"	Glen Afton, Ayr San. ...	1·55	29
Devon	Teignmouth, Den Gdns.	0·46	20	*Renfrew*	Greenock, Prospect Hill	1·24	24
"	Ilfracombe	0·37	10	*Bute*	Rothesay, Ardencraig ...	1·48	30
"	Princetown	1·06	16	*Argyll*	Morven, Drimnin ...	1·73	33
Cornwall	Bude, School House ...	0·34	12	"	Poltalloch	1·87	38
"	Penzance	0·48	15	"	Inveraray Castle ...	3·73	57
"	St. Austell	0·22	6	"	Islay, Eallabus	1·15	26
"	Scilly, Tresco Abbey ...	0·36	13	"	Tiree	1·31	31
Somerset	Taunton	0·72	30	*Kinross*	Loch Leven Sluice ...	0·99	26
Glos.	Cirencester	0·98	32	*Fife*	Leuchars Airfield ...	0·27	9
Salop	Church Stretton ...	1·09	33	*Perth*	Loch Dhu	1·37	20
"	Shrewsbury, Monkmore	1·46	53	"	Crieff, Strathearn Hyd.	1·22	29
Worcs.	Malvern, Free Library...	0·67	23	"	Pitlochry, Fincastle ...	1·17	33
Warwick	Birmingham, Edgbaston	0·58	19	*Angus*	Montrose, Sunnyside ...	0·53	19
Leics.	Thornton Reservoir ...	0·61	22	*Aberd.*	Braemar	0·88	26
Lincs.	Boston, Skirbeck ...	0·68	28	"	Dyce, Craibstone ...	0·35	12
"	Skegness, Marine Gdns.	0·98	40	"	New Deer School House	0·50	17
Notts.	Mansfield, Carr Bank ...	0·82	29	*Moray*	Gordon Castle	2·28	72
Derby	Buxton, Terrace Slopes	0·89	20	*Nairn*	Nairn, Achareidh ...	0·40	16
Ches.	Bidston Observatory ...	1·53	50	*Inverness*	Loch Ness, Garthbeg ...	0·57	18
"	Manchester, Ringway...	1·00	30	"	Glenquoich	..	..
Lancs.	Stonyhurst College ...	1·03	20	"	Fort William, Teviot ...	1·17	27
"	Squires Gate	1·11	32	"	Skye, Broadford ...	1·70	26
Yorks.	Wakefield, Clarence Pk.	0·29	11	"	Skye, Duntuilm ...	1·31	29
"	Hull, Pearson Park ...	0·77	26	*R. & C.*	Tain, Mayfield... ...	0·56	21
"	Felixkirk, Mt. St. John...	0·77	27	"	Inverbroom, Glackour...	0·93	22
"	York Museum	0·59	23	"	Achnashellach	2·89	46
"	Scarborough	0·72	26	*Suth.*	Lochinver, Bank Ho. ...	1·26	38
"	Middlesbrough... ...	0·81	30	*Caith.*	Wick Airfield	0·57	21
"	Baldersdale, Hury Res.	1·45	44	*Shetland*	Lerwick Observatory ...	0·89	30
Norl'd.	Newcastle, Leazes Pk....	1·14	40	*Ferm.*	Crom Castle	0·73	18
"	Bellingham, High Green	1·19	34	*Armagh*	Armagh Observatory ...	1·10	30
"	Lilburn Tower Gdns. ...	0·61	22	*Down*	Seaforde	1·21	32
Cumb.	Geltsdale	1·94	47	*Antrim*	Aldergrove Airfield ...	1·60	44
"	Keswick, High Hill ...	4·36	84	"	Ballymena, Harryville...	0·97	23
"	Ravenglass, The Grove	3·10	68	*L'derry*	Garvagh, Moneydig ...	0·63	16
Mon.	A'gavenny, Plâs Derwen	0·74	22	"	Londonderry, Creggan	1·31	28
Glam.	Ystalyfera, Wern House	3·48	56	*Tyrone*	Omagh, Edenfel ...	0·91	21

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