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ATOMIC EXPLOSIONS AND CONDENSATION NUCLEI

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Recent speculations about a possible connexion between the explosion of atomic bombs and the weather lend an interest to a quantitative examination of the influence of an electric charge in enhancing the effectiveness of a nucleus of condensation.

The vapour pressure over a small droplet of water is reduced by the presence of an electric charge on the drop, the extent of the reduction being described by the equation[1]

$$R\theta \log_e \frac{p}{P} = \frac{M}{\sigma}\left[\frac{2T}{a} - \frac{n^2e^2}{8\pi a^4}\right] \qquad \text{............(1)}$$

where

R = universal gas constant (=8·315 × 10^7 c.g.s. units),
θ = absolute temperature,
p, P = vapour pressure over the drop and a plane surface,
M = molecular weight of water (= 18),
σ = density of drop,
T = surface tension constant (74 c.g.s. units for water),
e = unit electronic charge (4·77 × 10^{-10} e.s.u.),
n = number of electronic charges on drop,
a = drop radius (cm.).

Examination of this equation by the usual methods shows that as the droplet radius increases from near zero, the value of p/P rises steeply from a value much less than unity, reaches a maximum value which exceeds unity, and then decreases asymptotically to unity.

If the droplet is suspended in the atmosphere, condensation on or evaporation from the droplet will occur according as the ambient vapour pressure exceeds or is less than the value of p corresponding to the droplet radius and the electric charge. If a droplet initially in equilibrium with the ambient vapour pressure is brought into a region where the vapour pressure is greater the droplet will grow by condensation. Assuming that we start with an extremely small droplet, i.e. that the initial droplet radius corresponds to a point on the curve represented by equation (1) where the value of p/P increases with increasing radius, the droplet will grow by condensation until it is again in equilibrium with the new ambient vapour pressure. But if the new value of the ambient vapour pressure exceeds that represented by the maximum value of p/P equilibrium will never be attained and the droplet will grow indefinitely.

Let us now examine these considerations quantitatively. Inserting the numerical values given above and putting $\theta = 283°A.$, $\sigma = 1$, we find that the maximum value of p/P and the corresponding critical drop radius a_c are given by

$$\left.\begin{aligned} \log_{10}\left(\frac{p}{P}\right)_{max} &= \frac{0 \cdot 59}{n^{2/3}} \\ a_c &= 6 \cdot 2\, n^{2/3} \times 10^{-4} \text{ microns} \end{aligned}\right\} \qquad \ldots\ldots\ldots\ldots(2)$$

Equations (2) have been used to compute the relative humidity ($= 100\ p/P$) necessary to promote indefinite growth on droplets which initially have a radius less than a_c. The results were as follows:—

	n					
	1	2	5	10	50	100
			per cent.			
Relative humidity ...	389	235	159	134	111	107
			microns			
Critical drop radius...	$6 \cdot 2 \times 10^{-4}$	$9 \cdot 9 \times 10^{-4}$	$1 \cdot 8 \times 10^{-3}$	$2 \cdot 9 \times 10^{-3}$	$8 \cdot 4 \times 10^{-3}$	$1 \cdot 3 \times 10^{-2}$

Thus if the radius of a droplet carrying single electronic charge is to grow beyond $6 \cdot 2 \times 10^{-4}$ microns it must experience an ambient relative humidity exceeding 389 per cent. The molecular radius of oxygen and of nitrogen is about 2×10^{-4} microns, so that if condensation is to occur on singly charged ions, the relative humidity must reach about 400 per cent. This corresponds to condensation in a Wilson chamber, but such supersaturations do not occur in ordinary atmospheric processes. The writer has no knowledge of what charge may occur on ions resulting from an atomic explosion, but it seems unlikely that, at great distances (a few hundred miles or more) from the scene of the explosion, n will exceed 100. Even with a charge of this magnitude a relative humidity of 107 per cent. would be necessary to permit an ion to grow to cloud-droplet size. We shall return later to the question of the maximum relative humidity which can occur in, for example, strong convective currents, but for the present we may note that 7 per cent. supersaturation is very unlikely, and hence it is improbable that the ions resulting from an atomic explosion can be effective as condensation nuclei except perhaps in the immediate vicinity of the explosion.

There remains the possibility that solid charged particles resulting from the explosion and which are larger than the critical size may be charged so highly that the vapour pressure over the charged particle is significantly less than over the same particle uncharged. We are now dealing solely with difference between the vapour pressure over charged and uncharged particles of the same size and so use equation (1). Inserting numerical values in that equation we easily obtain

$$\log_{10}\frac{p}{P} = \frac{3 \cdot 02}{10^{14}}\left[\frac{1 \cdot 63 \times 10^{10}}{a} - \frac{n^2}{a^4}\right],$$

where a is now measured in microns. If now we denote the equilibrium vapour pressure over an uncharged particle by p_0 and the corresponding quantity for a particle carrying n electrons by p_n we have

$$\log_{10}\frac{p_0}{p_n} = \frac{3 \cdot 02\, n^2}{10^{14}\ a^4}.$$

Now the relative humidity likely to occur naturally is of the order 100 per cent. A difference between p_0 and p_n of less than 0·1 per cent. would certainly be insignificant in the present context, so that in order that the charge on the particle shall have a significant effect (and since $\log_{10} 1{\cdot}001 = 0{\cdot}00042$) we need,

$$\frac{3{\cdot}02\, n^2}{10^{14}\, a^4} > 0{\cdot}00042$$

or approximately,

$$n > 12 \times 10^4 a^2,$$

where a is measured in microns. Now there is both an upper and a lower limit to the values of the radius which need consideration. The lower limit is set by the fact that if the radius is too small the particle may be smaller than the critical size discussed above. The table of critical sizes given earlier suggests that the radius must certainly exceed $10^{-2}\mu$. The upper limit is set by the fact that the larger particles will not remain airborne for many hours. Probably 10^{-2} to 10 microns includes the range we need to consider, and we see that for the charge to have a significant effect on the equilibrium vapour pressure the corresponding value of n ranges from 12 to 12×10^6. Had we chosen 1 per cent. relative humidity as the minimum significant difference between p_0 and p_n these values of n would have been about three times greater. Unless the smallest solid particles resulting from an atomic explosion carry charges of the order of 50 electronic units then their effectiveness as condensation nuclei is not significantly affected by the electric charge.

So far we have assumed that supersaturation exceeding a few per cent. is unlikely to occur in the atmosphere in natural processes. Most meteorologists would accept this view, and indeed Johnson[1] (p. 206) suggests that relative humidities exceeding 100·1 per cent. are not to be expected. Howell[2] has computed the supersaturation likely to occur in convective cloud and suggests a maximum value of about 0·36 per cent. The reasoning behind the general belief that substantial supersaturations do not occur in nature is that no evidence has ever been found that nuclei of condensation are lacking in the atmosphere. As soon as saturation is reached (actually before that since the condensation nuclei are hygroscopic) cloud droplets are formed. As the air continues to rise in the convection current, the temperature falls and the relative humidity tends to rise. This leads to a more rapid rate of condensation on the cloud droplets, thus limiting the rise in relative humidity. The value of the latter is in fact determined by the two opposing processes. Naturally the stronger the vertical current is, the greater is likely to be the supersaturation achieved. We can obtain a reasonable approximation to the order of magnitude of the supersaturation from some computations in two earlier papers[3,4] by the present writer. In the first[3] of these two papers the liquid water contents at various heights in a convective cloud are computed. The figures in Table V of that paper show that the rate of release of water is unlikely to exceed 4 gm./m.^{3} for 5,000 ft. ascent even with a high cloud-base temperature. If the strength of the convection current is V ft./sec., the rate of release of water is $4V/5{,}000$ gm./m.^{3}/sec. In the other paper[4] the rate of growth of a drop of water upon a salt nucleus in various ambient conditions is discussed. The size of the nucleus is important only in the early stages of the life of the drop. Subsequently the rate of growth depends upon the size of the drop, the supersaturation and the temperature. From Table II of that paper it can be seen that the time required for a drop to grow from 10μ to 15μ radius is as follows:—

Temperature (°A.) ...	273	293	293
Relative humidity (%) ...	100·05	100·05	100·5
Time (sec.)	2,400	1,230	130

If there are r drops per cubic centimetre and they take t sec. to grow from radius 10μ to 15μ the average rate of increase of liquid water is approximately $r/100t$ gm./m.^{3}/sec. If the relative humidity indicated above is to be maintained, this must be equal to the rate of release of water, i.e.

$$\frac{r}{100t} = \frac{4V}{5000}.$$

In selecting a value for r we must have regard for the implied liquid water content. A value of 500 implies about 2 gm./m.^{3} of liquid water if the drops have a radius of 10μ and is in accord with observation. Substituting this value for r we get

$$V = \frac{6250}{t} \text{ ft./sec.}$$

Thus a relative humidity of 100·05 per cent. might be maintained by a vertical current of 2·6 ft./sec. at 273°A. and 5·1 ft./sec. at 293°A., but a vertical current of 48 ft./sec. would be necessary to maintain a relative humidity of 100·5 per cent. at 293°A. Despite the many approximations, both stated and implied, it is difficult to avoid the conclusion that the supersaturation is hardly ever likely to exceed 1 per cent. We may conclude that atomic explosions are not likely to have any significant effect upon the condensation of water vapour into cloud droplets at distances far removed from the scene of the explosion.

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PRESENT POSITION OF THEORIES OF CLIMATIC CHANGE

By C. E. P. BROOKS, D.Sc.

In 1947 in an article in the *Meteorological Magazine* on the "Unsolved problem of climatic change"[1], five groups of theories were examined—variations of solar radiation, changes in the elements of the earth's orbit, movements of the continents, changes in the constitution of the atmosphere, and changes of configuration—but the conclusion was that all the theories so far advanced remained unproved. The seven years which have elapsed have, if anything, made confusion even greater. It may be of interest to take a brief glance at some of the recently published work and to assess the present position.

Variations of solar radiation, either alone or combined with some other cause, are now first favourite. The theory which has been received with most interest is that of E. J. Öpik[2], first put forward in 1952 and completed in 1953, in which all changes of climate from major cycles of the order of 250 million years down to glacial and interglacial alternations are attributed solely to internal changes in the constitution of the sun. On the other hand, the theory of F. Hoyle and R. A. Lyttleton[3] that variations of solar radiation are due to the passage of the sun through concentrations of inter-stellar matter, is still actively maintained by Hoyle and was supported by M. Krook[4] in the volume on climatic change (reviewed in the *Meteorological Magazine* for November 1954) which also includes a discussion of Öpik's theory. Cycles of solar radiation with no ultimate cause assigned were also postulated by J. Wolbach in this volume[4]. B. M. Rubashev[5] combines cyclical variations of solar activity with variations in the speed of rotation of the earth. All these theories are at present almost entirely hypothetical, with little or no evidence to support them.

D. H. Menzel[4] finds the cause of ice ages in clouds of ions reaching the earth from the sun and providing sublimation nuclei in the upper atmosphere, but he remarks that volcanic dust could adequately fulfil the same role.

Most writers adopt the view, which will certainly commend itself to meteorologists, that changes of solar radiation, especially in the ultra-violet, take effect through changes in the atmospheric circulation, but two opposing points of view still prevail. Thus H. C. Willett[6] supports with modifications Sir George Simpson's view[7,8] that glaciation could be attributed to increased solar radiation in selected wave-lengths acting through changes of circulation. His idea is that an increase of solar radiation would raise temperature in low latitudes more than in high latitudes, increasing the poleward transport of heat and water vapour and so causing more snow in the subarctic regions. In a later paper[4] he summarizes a comprehensive review of the evidence as: quiet sun—interglacial; steady moderately disturbed sun (minor sun-spot maxima)—glacial; extreme solar disturbance (major sun-spot maxima)—chaotic climatic stress and deglaciation. On the other hand H. Flohn[9,10] from a study of the circulation during the cold winters of 1939–42 attributes glaciation to a marked decrease of solar radiation, especially in the ultra-violet, resulting in a strengthened meridional circulation and weakened W. winds (low-index type).

Orogenesis and changes of land and sea distribution do not now appear to be accepted as the major cause of climatic changes, but several authors express the view that both solar and geographical changes are required for ice ages. R. F. Flint[4] explains the glaciations of Alaska on these lines, with emphasis on the solar changes, while M. Schwarzbach[11] places the emphasis rather on orogenesis, and B. Bell[4] postulates high ground, a change of solar radiation and favourable topography, with possibly increased corpuscular radiation, to warm the polar stratosphere and so produce polar low-pressure areas.

Changes in the elements of the earth's orbit and the inclination of the axis are rather out of favour. They are still maintained by F. E. Zeuner[12] and G. Bacsák[13], while D. Brouwer[4] has produced a new solution, but they are rejected as insufficient by A. J. J. van Woerkom[4].

The third group, continental drift or pole shifts, also has a few adherents, among whom may be mentioned K. A. Pauly[14] who adopts Sir Arthur Eddington's theory of a sliding of the earth's crust over the interior due to tidal friction, and J. Goguel[15] who attributes displacements of the pole to winds, ocean currents and tides.

Changes in the constitution of the earth's atmosphere now reduce almost entirely to the effects of volcanic dust, H. Wexler[16] having revived W. J. Humphreys's theory of the cooling effect of a volcanic-dust veil, while volcanic dust plays a subordinate role in several other theories. In a recent one by C. A. Zapffe[17] volcanism in the Atlantic region plays a dual role, submarine eruptions causing a large supply of water vapour and aerial ones the necessary veil to lower temperatures generally, but Zapffe also brings in theosophy and the destruction of Atlantis to buttress his case.

From this rapid survey it will be seen that the problem of climatic change is really little nearer to a solution than it was seven years ago. The theories current in 1947 are still being argued; even some old ones have been revived. Thus in 1950 E. le Danois[18] brought back O. Pettersson's theory of climatic changes due to internal oceanic tides, and in 1952 H. Gerth[19] revived C. E. P. Brooks's geographical theory of the Permo-Carboniferous glaciation. Perhaps the most hopeful sign is that in 1954 palaeoclimatologists are not quite so tied to single causes to the exclusion of all others as they seemed to be in 1947; it is becoming accepted that combinations of two or more causes are necessary to explain the facts. The most urgent need now is for some credible method, direct or indirect, of reconstructing the variations of solar radiation during geological time; when that point has been cleared up the way may be open for the evaluation of other factors.

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SPEED AND DIRECTION OF MOTION OF SIMPLE WARM-SECTOR DEPRESSIONS

By H. D. HOYLE, B.Sc.

A considerable amount has been written on the subject of the movement of depressions and several empirical rules are in use, applied with varying degrees of confidence.

Results of empirical investigation of such rules have usually been somewhat unsatisfactory. In an unpublished work by Hollis[1] and an empirical study by

Austin[2] fair agreement was found with the direction of motion of depressions using the 1000–500-mb. thermal wind and the upper level winds respectively, angular deviations usually being within about 30°. Hollis, however, found no correlation between thermal wind speed and depression speed and no such attempt appears to have been made by Austin. Most previous work has considered all types of depressions together. The possibility of better results being obtained by considering separately different types of depression suggested the approach made here.

In measuring upper winds and thermal winds to investigate "steering" rules the mean flow over an area was measured rather than the "spot" geostrophic wind (measured at one place). This was not only in view of the theoretical concept of the barotropic advection of a vortex in a general stream, but also to lessen the effect of the subjective details of chart drawing.

In addition to steering values, other possible parameters were measured, for purposes of comparison and in the hope that they might be of use in finding empirical corrections to steering rules or in determining conditions under which such rules could be applied.

Selection of cases.—Depressions in the six months January to June 1951 were considered. To avoid complication by orographic and diurnal effects, depressions over the Atlantic alone were considered. Depressions which were occluded and depressions with very complex or doubtful analyses, or whose position was in doubt from lack of observations, were also omitted.

Great care was taken to see that the upper air flow was typical of unoccluded warm-sector depressions. Any cases with a closed cyclonic circulation at 500 mb. in association with the surface centre were excluded. The 1000–500-mb. thickness pattern had to be of conventional type also, cases being excluded if the thermal trough behind was unusually well marked or if there was marked diffluence or confluence in the neighbourhood of the depression. There were 16 satisfactory cases in the period considered.

Extraction of data.—The motion of the depression was measured by its west-to-east and south-to-north components over a 12-hr. period (H to $H + 12$). Preliminary work indicated that the original drawing of the charts was somewhat erratic. Consequently all the surface charts, including the ones for several 6-hr. intervals before and after the 12-hr. measured period, were completely redrawn, so as to satisfy fully all available observations and at the same time give a track for the depression which was as smooth as possible.

The upper flow over an area centred on the surface depression was estimated by measuring the difference in contour height (or thickness) at points a known distance due north and south, and again due east and west of the centre. This readily gave west-to-east and south-to-north speed components. The size of the area used was chosen in order to facilitate conversion into knots, a diameter of about 600 nautical miles being used. A scale was prepared for this purpose (Fig. 1) which incorporates a correction for map distortion. The line AB is placed over the depression centre with the lines perpendicular to AB in the required direction (due north, say) and such that the latitude figure on the scale conforms to the latitude immediately under it on the chart. The height (or thickness) is then read off on the line XY at the point appropriate to this latitude line on the scale. The height (or thickness) is similarly read in the opposite direction (due south, say). For the 1 : 10^7 charts used, the scale was so drawn that the speed component in knots was given by multiplying the diametrical height difference by 4. It is a simple matter to prepare such a device for use with charts of any scale. Values for the area mean geostrophic wind at 1000, 700, 500, 300 mb. and the 1000–500-mb. thermal wind were found in this way, there being two upper air charts (at $H + 3$ and $H + 9$) during the 12-hr. measured period. The values used in this investigation were means of the readings from these two consecutive charts.

Measurements were also made of the warm-sector geostrophic wind; the depression size (radius of outer closed isobar), change of size, and the change of central pressure were also noted. In addition, 6-hr. isallobars were drawn by gridding consecutive surface charts.

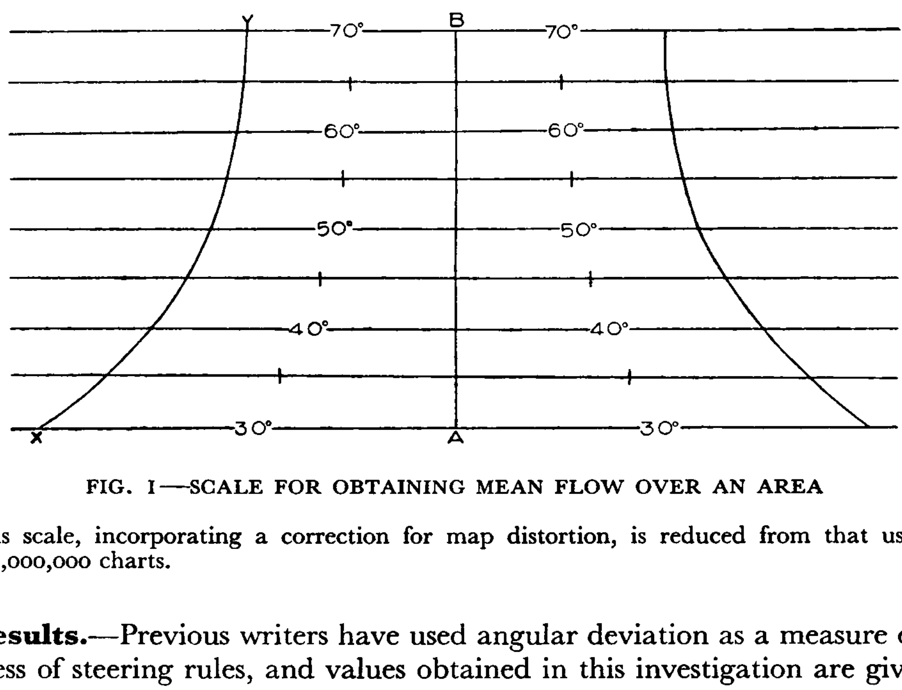

FIG. 1—SCALE FOR OBTAINING MEAN FLOW OVER AN AREA

This scale, incorporating a correction for map distortion, is reduced from that used for 1 : 10,000,000 charts.

Results.—Previous writers have used angular deviation as a measure of the success of steering rules, and values obtained in this investigation are given in Table I. The apparently smaller variability of the deviation from the 700-mb. direction is not thought to be significant, as this is based on only 15 cases. The case omitted is one in which lack of observations at 700 mb. made it impossible to give any reliable reading at this level—and it is by far the worst case of the 16 at the other levels, so that the 700-mb. level is doubtless favoured by its omission.

TABLE I—ANGULAR DEVIATIONS

Track of depression minus direction of:	Mean	Standard deviation	Mean ignoring signs
		angular degrees	
Area mean 300-mb. wind	−4·1	8·3	7·4
Area mean 500-mb. wind	−2·9	8·3	6·5
Area mean 700-mb. wind	−5·5	7·2	7·6
Area mean warm-sector wind	−6·1	11·9	10·2
Area mean 1000–500-mb. thermal wind ...	−0·6	9·8	6·3
Isallobaric gradient	−2·3	8·3	6·3

These results show that for this type of depression mean angular deviations for all the steering parameters shown are small, the smallest being that for the 1000–500-mb. thermal wind. It is noteworthy that the agreement between depression track and thermal wind direction during the measured period is as consistent as that between depression track and isallobaric gradient during the measured period.

Correlation coefficients were calculated between the component velocities of the depressions and the wind components for the various levels and these are given in Table II. There were 32 pairs of numbers (two components for each of the 16 cases) in the correlations. The correlation coefficient between the motion of the depression and the "spot" value of the 1000–500-mb. thermal wind, using a geostrophic scale in the usual manner, is also given.

TABLE II—CORRELATION COEFFICIENTS BETWEEN COMPONENTS OF DEPRESSION VELOCITY AND OTHER VELOCITIES

With area mean 300-mb. wind	0·89
With area mean 500-mb. wind	0·90
With area mean 700-mb. wind	0·86
With area mean 1000-mb. wind	0·47
With area mean warm-sector wind	0·81
With area mean 1000–500-mb. thermal wind ...	0·92
With spot value of 1000–500-mb. thermal wind	0·80

These values show that for depression speed the best correlation coefficient is that for the 1000–500-mb. thermal wind, but for this type of depression upper winds at all levels shown are quite strongly correlated with the speed of the depression. The improvement obtained by using an area mean is clearly shown, the spot value of the 1000–500-mb. thermal wind giving a correlation coefficient only comparable with that for the warm-sector wind.

The ratio of the depression speed c to the 1000–500-mb. thermal wind speed v' varied between 0·66 and 0·98 with a mean value of 0·80. The variations of c/v' were studied in relation to all the other parameters measured. No worthwhile correlation was evident. It was found impossible to formulate any empirical rule to improve upon the thermal steering results by using any of the other parameters. In view of the concept of the advection of a vortex in a general current it is particularly interesting that no success could be achieved in this way by using the 1000-mb. wind.

Errors.—A rough check of the magnitude of the errors involved in using thermal steering was thought to be worth while. Means and standard deviations were calculated and are given in Table III. Now (*a*) is a measure of the reliability of using $4v'/5$ as an estimate for c, whilst (*b*) is to some extent a measure of the reliability of the charts. As this latter includes only errors of inconsistency

TABLE III—MEANS AND STANDARD DEVIATIONS OF VARIOUS POSSIBLE ERRORS

	Mean kt.	Standard deviation kt.
(*a*) Difference between the 32 components of c and corresponding components of $4v'/5$	−0·5	1·5
(*b*) Difference between components of v' and the components found by subtracting the measured 1000-mb. components from the 500-mb. components	+0·5	2·4
(*c*) Difference between the components of c read off the charts before and after redrawing	+2·4	5·4

in gridding and measurement, whereas there are also other errors (consistent drawing errors, observational errors, errors due to the geostrophic assumption) likely to worsen the reliability of our measurement of upper winds, (*b*) is very probably an under estimate of the errors one might expect to find in the investigation by these methods of even a perfect steering law. Consequently the fact that (*a*) is less than (*b*) suggests that little improvement can be expected, using present charting technique, over the thermal steering result found.

The fact that (*c*) is more than twice as large as (*b*) and about four times as large as (*a*) suggests that considerably greater errors can exist in the placing of surface depressions on the Atlantic on the current surface chart than the errors involved in using thermal steering. Such errors in the position of the depression centre on the surface map affect the speed and direction which would be used in applying an extrapolation technique.

Further test cases.—A further 18 cases were found satisfying the conditions above during the six-month period July 1 to December 31, 1950. The following results were obtained for these depressions.

The correlation coefficient between area mean 1000–500-mb. thermal wind and the depression velocity components was 0·94; c/v' varied between 0·71 and 1·20 with a mean value of 0·97.

The standard deviations of possible errors found by an analysis similar to that above were somewhat larger than those quoted there, but still gave a probable error of less than 5 kt. in using $4v'/5$ as an estimate for c.

Conclusions.—(1) Simple warm-sector depressions on the Atlantic move with the direction of and slightly over four-fifths of the speed of the 1000–500-mb. thermal wind (meaned over an area) with a probable error of less than 5 kt. in speed and less than 10° in direction.

(2) Better results are obtained by measuring the mean thermal wind over an area than by reading a "spot" value of the thermal wind at the depression centre. Such a mean value may readily be obtained by using the type of scale shown in Fig. 1.

(3) The surface pressure distribution in the vicinity of the depression seems to have little effect, so that the barotropic advection of a surface vortex in the surface stream does not seem to be a very helpful theoretical concept in connexion with these depressions.

(4) Although cases of marked "development" in the thermal pattern were excluded from this investigation, during the course of the investigation several cases were noted where there was marked diffluence ahead of the surface centre. A cursory check suggested that in all such cases the speed of the depression was greater than would otherwise have been expected. The presence of marked development areas[3] in the thermal pattern in the vicinity of the depression may well have some considerable effect on the motion of the depression.

(5) Although the figures quoted throughout this investigation apply to measurements of the thermal wind simultaneous with the measured motion of the depression and not to the reliability of thermal steering at any instant as a guide to the motion of a depression over the subsequent 24 hr., the technique of preparing "pre-thickness" charts is already sufficiently well developed for them to be used with reasonable confidence for forecasting the subsequent 24-hr. motion of a depression if and when thermal steering is known to be the right

principle to employ. No such technique is available for forecasting the isallobars 24 hr. ahead (see comments on p. 209). The results thus suggest that for the limited class of depressions considered, thermal steering by the 1000–500-mb. thermal wind might well give better results than extrapolation of the past track or the use of isallobars, provided that the mean thermal wind is estimated over a substantial area centred on the depression.

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AN EXPLANATION OF THE BEHAVIOUR OF THE DEPRESSION OF OCTOBER 4–6, 1952, IN TERMS OF THERMAL-DEVELOPMENT THEORY

By F. E. LUMB, M.Sc.

C. A. S. Lowndes[1] has recently discussed the depression which formed near Greenland on October 4, 1952 and moved southwards then south-eastwards towards Denmark. He has described its thermal structure as unusual and complex and its movement as abnormal; nevertheless its behaviour can be explained in terms of Sutcliffe's thermal-development theory[2,3].

Growth of the thermal rear trough.—At 0300 G.M.T. on October 4 the incipient depression was at the crest of a markedly diffluent thermal ridge (Fig. 1). According to thermal-development theory the maximum of cyclogenesis would be situated just to the west of the ridge crest. Since thermal steering at the diffluence was weak the depression initially deepened with little movement. Deepening associated with slow movement resulted in the rapid growth of a thermal trough in the baroclinic zone immediately to the west of the centre of the depression. Also the thickness lines in the vicinity of the ridge

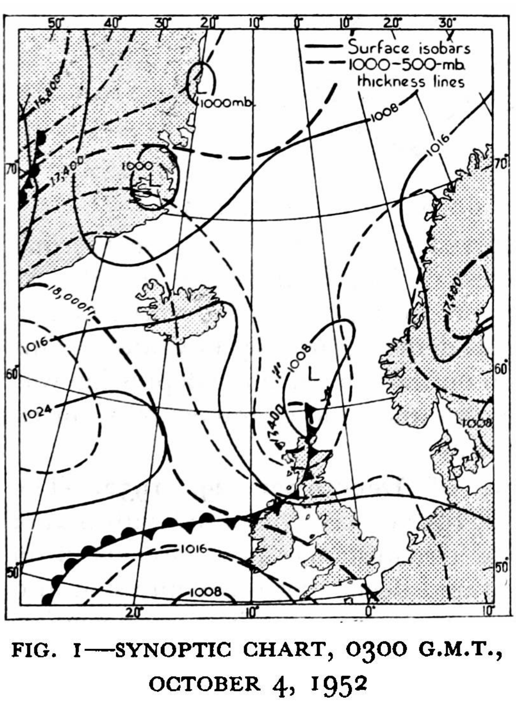

FIG. 1—SYNOPTIC CHART, 0300 G.M.T., OCTOBER 4, 1952

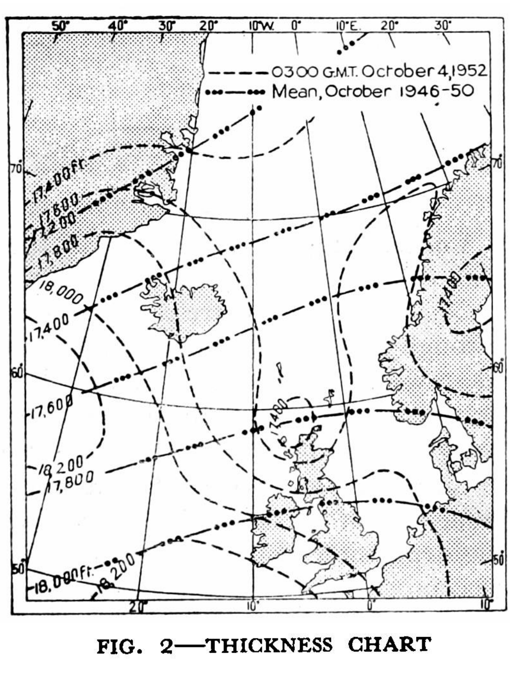

FIG. 2—THICKNESS CHART

crest were displaced well to the north of their mean geographical position for October (shown in Fig. 2) as given in *Meteorological Reports* No. 13[4]. Consequently the northerly winds to the west of the centre of the deepening depression strengthened in a thermal-geographic environment extremely favourable for the southward movement of the thickness lines by advection. The northward displacement of the thickness lines in the thermal ridge from their mean position was therefore also a factor favourable to rapid growth of the thermal rear trough.

Cyclogenetic transfer of the centre of the depression.—By thermal-development theory the maximum of cyclogenesis would be transferred to a position a little to the east of the tip of the developing thermal trough. Since thermal steering was weak, the centre of the depression was transferred southwards with the maximum of cyclogenesis. The position of the centre at 0300 on October 5 (Fig. 3) was in close agreement with theory, since it was situated very near to the point where Sutcliffe's cyclonic-development term (product of the thermal wind and the rate of decrease of cyclonic vorticity down the thermal wind) was a maximum.

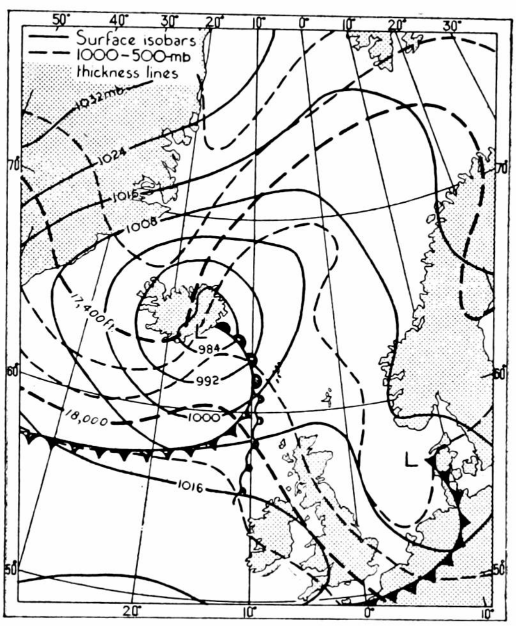

FIG. 3—SYNOPTIC CHART, 0300 G.M.T., OCTOBER 5, 1952

Vortex stage.—Deepening of the depression and growth of the thermal rear trough being interdependent processes, rapid growth of the trough was associated with a correspondingly rapid progress towards the vortex stage, through the agency of dynamical cooling as demonstrated by Lowndes[1]. This stage was reached approximately by 1500 on the 5th when the depression was between Iceland and the Faroes. It then assumed the character of a vortex travelling in the west-north-westerly current.

Comparison with the depression of December 29, 1952.—The behaviour of the depression of October 4–6, 1952 can be compared with that of the depression which formed under similar circumstances near Greenland on December 29, 1952. During the stage of rapid deepening this depression also moved south-eastwards, almost perpendicular to the thickness lines, in association with a rapidly developing thermal trough.

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METEOROLOGICAL OFFICE DISCUSSION

Recent investigations of fronts

The last discussion of the 1954–55 series, which was held on Monday, March 21, 1955, at the Royal Society of Arts, was opened by Mr. I. J. W. Pothecary who described recent research on fronts in the Forecasting Research Division at Dunstable.

The opener dealt briefly with frontal movement. The work of Matthewman[1] had shown that the "two-thirds geostrophic" rule for the speed of warm fronts over land was reliable in straightforward situations. Ageostrophic motion, which depended on the rate of change of the geostrophic wind component parallel to the front, was more difficult to forecast although the isobaric patterns associated with large ageostrophic movements could be recognized and taken into account. Recent work by Hinkel and Saunders had suggested that a "five-sixths geostrophic" rule was more appropriate for the speed of warm fronts over the Atlantic.

Warm-front rainfall had been correlated with 13 different synoptic parameters in an investigation by Corby into the possibility of forecasting rainfall amount or intensity. No single parameter was well enough correlated with rainfall to be of use in forecasting, but 60 per cent. of the variance of the average rainfall over England could be predicted by using pressure and frontal contrast in a multiple regression relation. Frontal contrast was defined in the investigation as the change in the mean 1000–500-mb. thickness over 250 miles ahead of the front. The results showed that even a completely successful forecast of the average rainfall over an area might be 100 per cent. in error for any one place, owing to the large spatial variability of warm-front rainfall.

The investigation of fronts by aircraft was described in some detail. From 1950 to 1952 23 fronts were flown through at various levels by the Meteorological Research Flight. The results of these flights, which had been analysed by Sawyer[2], were illustrated and amplified by flights from a second series which was still in progress.

The analysis of the first series showed a front to be a baroclinic zone extending upwards through a less baroclinic region. The total horizontal temperature contrast between air masses, which averaged about 15°F., took place through about 600 miles in the frontal region. An average change of 9°F. was concentrated in the frontal zone which had a horizontal width of about 130 miles. Half the air-mass contrast took place in the frontal zone which occupied only about a quarter of the frontal region. The observed slopes of the fronts varied from 1:30 to 1:250. Any one front varied in slope from level to level but the Margules relation between slope and temperature contrast was generally observed.

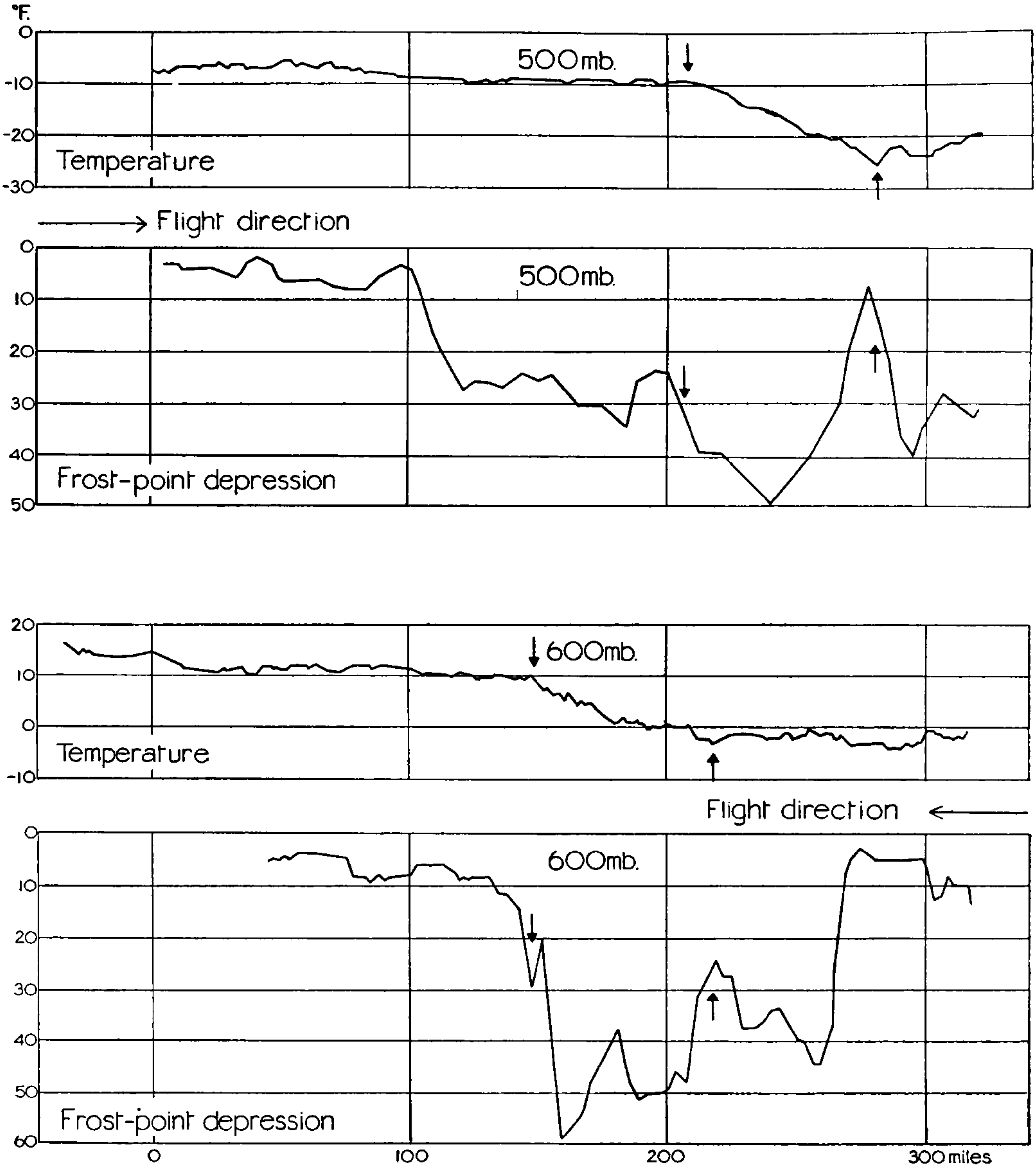

FIG. 1—AIRCRAFT OBSERVATIONS OF A WARM FRONT,
1200–1600 G.M.T., NOVEMBER 29, 1954
The boundaries of the frontal zone are shown by arrows

The flight discussed in detail took place on November 29, 1954, through the upper levels of a warm front associated with a deepening depression off south-west Ireland. Radio-sonde cross-sections along the line of flight were compared with cross-sections prepared from the flight observations (Fig. 1). The temperature cross-sections were almost exactly similar but the aircraft cross-section of frost-point depression showed that the humidity had a more complicated structure than the radio-sonde information suggested. The frost-point depression reached 60°F. in the frontal zone, indicating humidities of less than 5 per cent. Similar low humidities had been observed in association with other fronts.

In all the fronts investigated dry air was present as a more or less well developed tongue extending downwards in or near the frontal zone, and in about half the fronts of the first series the driest air was in the frontal zone.

The very dry air in the frontal zone of the warm front of November 29, 1954, was traced back westwards along an isentropic trajectory for 36 hr. from the time of observation. The air had been passing through a jet stream for the previous 24 hr. and had subsided only 15 mb. For 12 hr. before that this same air had been accelerating into the left entrance of the jet stream and had subsided 50 mb. as a result of the anticlockwise cross-axis circulation in the entrance region of the jet. Air that was probably already dry in the upper troposphere and lower stratosphere over mid Atlantic had been brought down to lower levels in the frontal zone and further dried by subsidence. Similar cases were noted in the first series.

An analysis of the position of cloud relative to the frontal zone showed that the main frontal cloud mass was often in the warm air away from the frontal zone. This was a fairly common feature. The presence of dry air on the cold side of the jet stream was proposed as the reason for the observed dissociation of the cloud system from the frontal zone.

The opener inferred from this that the humidity information from an individual radio-sonde ascent could not be regarded as a reliable indication of the activity of a front. The presence of dry air in or near the frontal zone did not necessarily indicate descending motion at the time, neither did the presence of dry air mean an inadequate supply of moisture for frontal rain.

The occurrence of clear-air turbulence at several places in the frontal zone of a cold front was illustrated, and it was suggested that, if the necessary wind shears are present, the cloud-free upper parts of frontal zones are preferred regions for turbulence.

Mr. Sawyer presented some recent theoretical work, supported by analyses of synoptic charts, which pointed to the process of confluence of two air streams in a region of strong horizontal thermal gradient as fundamental to the development and maintenance of recognizable frontal characteristics. The rain and cloud system of a front were due not only to the strong temperature contrast between adjacent air masses but also to the presence of a pattern of horizontal flow which tended to increase the temperature gradient.

Under these circumstances a vertical circulation is set up in which the warm air mass rises and the cold air mass sinks with ageostrophic flow towards the warm air at the ground and towards the cold air aloft. Theoretical calculation of the magnitude of the effect had given vertical velocities considerably less than those observed, unless the effect of saturation of the warm air on its stability was taken into account. Saturation of the air in a region of strong horizontal temperature gradient might lead to the condition for dynamical instability specified by Solberg[3], namely that the horizontal wind shear along a wet-bulb potential-temperature surface should be anticyclonic and exceed the Coriolis parameter. Calculation showed that when this state was approached the vertical circulation in the vicinity of fronts would be much larger, and the existence of such wind shears may well have an important influence on the activity of a front.

Mr. Matthewman pointed out that the boundaries of frontal zones as drawn in cross-sections by various authors showed several different interpretations of the structure of fronts in the upper part of the troposphere. From analogies with the mathematical properties of families of curves he argued that a structure in which the frontal-zone boundaries are continuous with the tropopause was the most satisfactory choice.

Dr. Sutcliffe remarked that the picture of frontal structure presented by the opener was a complicated one, far removed from the simple models presented in textbooks and training courses. The presence of dry air in or near frontal zones was a new and interesting feature of the picture. Instead of the single sloping surface separating warm and cold air evidence had been presented of two surfaces or rather narrow zones of discontinuity of temperature gradient. In the light of Sawyer's critical examination of upper air temperature observations, this complex picture might not be physically the best. Dr. Sutcliffe remarked that Matthewman's reasoning on the continuity of frontal and tropopause surfaces was based on geometrical continuity, but he wondered what it meant physically and whether it could really be argued that the tropopause and the stratospheric air came down to near the surface.

Mr. Durbin described the conditions on frontal flights of the Meteorological Research Flight, and said that out of about 40 flights there were only two occasions on which it had been necessary to discuss diverting the aircraft because of bad weather at base. On only two occasions had heavy icing been encountered. He felt that the present method of choosing fronts with a definite thermal contrast could be modified, together with the method of investigation, to give more information to the forecaster, and to make better use of the large amount of time at present spent flying through clear air in regions primarily of thermodynamic interest. Mr. Durbin added that a series of flights in bad-weather situations had been undertaken at Farnborough from which there was evidence that cloud above about 15,000 ft. was rarely extensive. Moderate to heavy rainfall sometimes occurred with cloud entirely below that level. Mr. Pothecary replied that it was important that the thermal structure which defined the front should be investigated even in clear air as this provided a frame of reference into which the weather might be fitted.

Mr. Bannon asked if Mr. Pothecary was satisfied that the temperature discontinuities in the upper troposphere above 500 mb., which were marked in the diagrams as boundaries of the frontal zone, were also the regions of change of air mass. The observations of frost point indicated that the air in the frontal zone had subsided through a considerable depth, and there was the possibility that the temperature discontinuity which was assumed to mark the cold boundary of the frontal zone might have been caused by subsidence and that the true frontal zone might be elsewhere. Mr. Pothecary replied that in the cases which he had analysed the distribution of wet-bulb potential temperature indicated that the boundary between the two air masses was coincident with the frontal zone as defined by temperature alone. Mr. Bannon also referred to the low correlation between rainfall and the Sutcliffe development term, and asked if this was due to the difficulty of measuring development.

Mr. Corby, in reply, said that somewhat higher correlations between development and rainfall had been obtained by Sawyer in the past. He thought that estimates of development from charts were liable to considerable uncertainties.

Dr. Stagg commented that so far the discussion had been concerned almost entirely with frontal structure, but the question of frontal movement was of

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GROUND FOG AT STEVENAGE, HERTFORDSHIRE

(see p. 226)

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METEOROLOGICAL OFFICE STAFF CENTENARY DINNER
March 11, 1955
(see p. 228)

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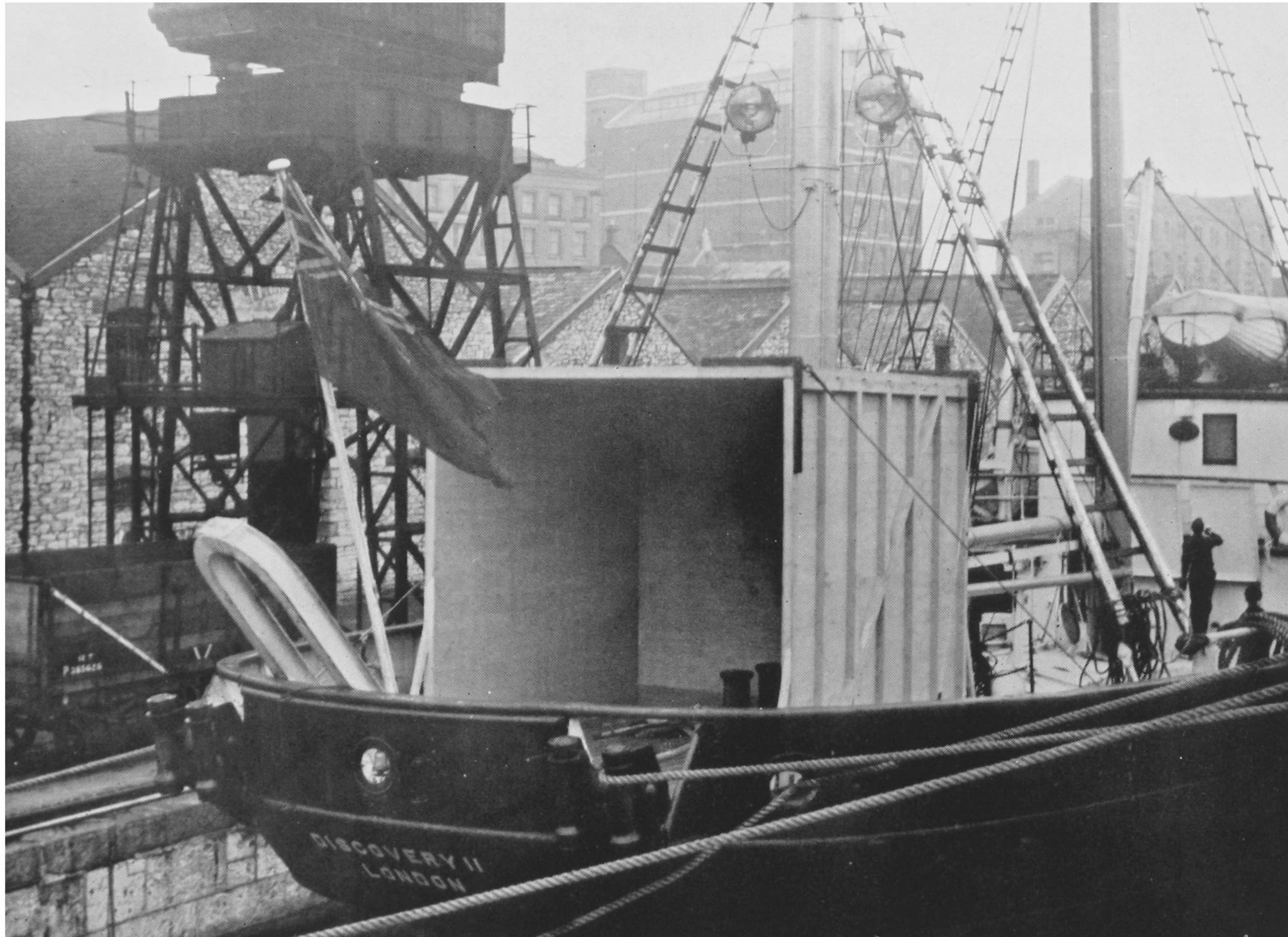
METEOROLOGICAL OFFICE STAFF CENTENARY DINNER
March 11, 1955
(see p. 228)



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R.R.S. *Discovery II* IN DOCK AT PLYMOUTH, SHOWING THE TEMPORARY BALLOON-FILLING SHELTER ERECTED ON THE AFTER DECK
(see p. 227)

great practical importance. He asked how the rules relating the speed of fronts to the geostrophic wind could be reconciled with the work of Goldie some 25 years previously. Goldie dealt not with the displacement of lines on synoptic charts but with the movement of rain areas, and found that in western Scotland the greater part of warm-front rain fell in the early morning and cold-front rainfall was greatest in the afternoon, suggesting preferred times of the day for the arrival of the fronts. The suggested explanation was the difference in diurnal heating over land and sea, and its effect on cloud. If frontal movements respond to temperature differences between land and sea might they not also be affected by the patchiness of sea temperature?

Mr. Sawyer replied that it was difficult to interpret statistics of precipitation amounts at fronts because of the uncertainty of frontal analyses. If frontal rain ceased the front was likely to be omitted from the analysis. Mr. Sawyer did not think that Goldie's figures of fewer frontal rain areas at one time of the day could be interpreted simply as meaning fewer fronts.

Dr. Robinson asked if any relation between the occurrence of cirrus and the position of the dry zone was apparent.

Mr. Bradbury asked if condensation trails were observed on flights through frontal zones, and whether trails were observed in the dry region. Mr. Pothecary replied that the investigating aircraft flew too low to make trails, but those made by other aircraft at higher altitudes were recorded as well as the occurrence and distribution of cirrus cloud. Uncertainty about the position or existence of the dry region at high levels precluded the establishment of any definite relation between the dry region associated with a front and the formation of condensation trails or cirrus cloud.

Mr. Absalom asked if dry air was associated with all the fronts that had been examined, and if there was any relation between the degree of dryness and the rainfall from the front. Mr. Pothecary replied that no noticeable dry region was flown through in the investigation of one or two very weak fronts, but the presence of dry air was definitely shown in all the other fronts that had been examined. Frost-point depressions of up to 70°F., corresponding to relative humidities well below 5 per cent., had been observed. No correlation between the dryness of the dry region and the rainfall from the front had so far been attempted.

Mr. Illsley remarked that few aircraft ascents were available and the deduction of cloud detail from radio-sonde ascents was difficult. He had found in practice that cloud might be present if the reported dew point was within 4°F. of the dry-bulb temperature. Mr. Illsley hoped that this problem might be given attention when the flights were fully analysed. Mr. Illsley also suggested that statistical investigations into the movement of fronts should be treated with caution. In his earlier work Matthewman had found that warm fronts over land moved on the average at about five-sixths of the geostrophic wind across them, but defining his warm fronts more rigorously he found that a ratio of two-thirds was more appropriate. Perhaps Hinkel and Saunders's investigation of the movement of warm fronts over the sea might give different results with a different selection of fronts. Practising forecasters relied more on extrapolation than on a statistical rule for short-term forecasts, and over longer periods a warm front had to be placed with due regard to numerous other factors. Mr. Pothecary replied that Hinkel and Saunders's data had been re-examined according to Matthewman's rigorous criteria so that the difference in the speed of warm fronts over land and sea appeared to be real.

Mr. Reed emphasized the importance of icing in fronts to the aviation forecaster. Aircraft had on occasions to be routed along a front and were likely to be subjected to icing over a considerable period. The forecaster was expected to provide an accurate assessment of the icing risk which necessarily varied with the direction in which the aircraft was flown. Mr. Reed also asked if any allowance was made for the lateral displacement of the radio-sondes when the cross-sections were drawn.

Dr. Pepper asked if the observed slopes of the fronts were checked against the Margules formula. Mr. Pothecary, in reply, said that no quantitative measurement had been made but both the radio-sonde and aircraft temperature cross-sections showed a qualitative agreement between frontal slopes and the Margules formula.

Mr. Wallington said that fronts were used to describe the weather pattern, to interpret the dynamical situation and to mark the progress of recognizable air masses. The first two requirements were met by analyses of the synoptic and thickness charts, but to give the third aspect the detailed attention it deserved it would be necessary to analyse the distribution of some conservative physical property of the atmosphere at about 800 mb.; such charts would, of course, be even more subjective than our more familiar analyses.

Dr. Stagg, in closing the meeting, remarked upon the clear presentation of Mr. Pothecary's opening statement, and said that this had been one of the best of recent discussions. Nevertheless there was still much to be learnt about the structure and movement of fronts.

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2. SAWYER, J. S.; The free atmosphere in the vicinity of fronts. *Geophys. Mem., London*, **12**, No. 96 (in the press).
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METEOROLOGICAL RESEARCH COMMITTEE

The 19th meeting of the Instruments Sub-Committee was held on February 17, 1955. Two papers[1,2], which had previously been discussed by the Synoptic and Dynamical Sub-Committee, regarding corrections which might be applied to radio-sonde temperatures were discussed and approved. The Sub-Committee then considered a paper[3] giving the results of humidity measurements from Meteorological Research Flight aircraft at heights up to 50,000 ft. On most of these ascents the frost point at 50,000 ft. was found to be between −110°F. and −120°F. Mr. Rider presented a paper[4] describing an instrument for the continuous recording of soil temperature. The Sub-Committee then went on to discuss the proposed amendments to Part I of the Research Programme for the coming financial year. The draft report of the Chairman to the Meteorological Research Committee was also approved.

The 34th meeting of the Synoptic and Dynamical Sub-Committee was held on February 24, 1955. A paper[5] by Mr. Sawyer on some characteristics of fronts and their relation to frontogenesis was presented by the author and evoked considerable interest. A report by a sub-committee which had been considering the problem of air flow over mountains was adopted and recommended to the Director for further consideration. The proposed amendments to Part II of the Research Programme and the draft report of the Chairman to the Meteorological Research Committee were then approved.

The 32nd meeting of the Physical Sub-Committee took place on March 3, 1955. A paper[6] by Mr. Blackwell was presented which dealt with five years' continuous recording of total and diffuse solar radiation at Kew Observatory. The Sub-Committee discussed and approved the draft programme for meteorological research at the Chemical Defence Experimental Establishment, Porton, and approved amendments to Part III of the Research Programme. The draft report of the Chairman to the Meteorological Research Committee was approved.

The 69th meeting of the Meteorological Research Committee was held on March 31, 1955. The reports of the Chairmen of the three Sub-Committees were received and the Research Programme for 1955–56 approved. The Annual Report to the Secretary of State for Air was agreed. Various changes in membership of the Committee and Sub-Committees were agreed, and the Chairman, Sir David Brunt, announced his retirement from the Chair and from the Committee. The Director expressed his appreciation of Sir David Brunt's advice and services as Chairman over the past three years and as a member of the Committee since its inception in 1941. Sir Charles Normand was elected as the new Chairman. Following the meeting there was a discussion of the work of the Meteorological Research Flight. Mr. H. W. L. Absalom opened the discussion and Mr. R. J. Murgatroyd answered questions regarding the work of the Flight. The Committee expressed their satisfaction with the progress being made and congratulated Mr. Murgatroyd on the work already done by the Flight.

ABSTRACTS

Abstracts Nos. 1–3 have been given in the May 1955 *Meteorological Magazine*, p. 154, Nos. 2, 3 and 5.

4. RIDER, N. E.; A note on an instrument for the continuous recording of soil temperatures. *Met. Res. Pap., London*, No. 883, S.C. I/93, 1954.

The instrument consists of a Tufnol tube in which thermo-couples are inserted at depths of 1, 5, 10, 20 and 40 cm. and connected to a six-colour recording galvanometer. Wiring is shown and a tracing of a record is reproduced. The instrument is simple, requires a minimum of attention and of soil disturbance.

5. SAWYER, J. S.; Some characteristics of fronts and their relation to frontogenesis. *Met. Res. Pap., London*, No. 896, S.C. II/183, 1954.

A front is regarded as an area into which active confluence of air currents at different temperatures is taking place. It is shown that frontogenesis must be accompanied by a vertical circulation. Air trajectories from the surface to 300 mb. are drawn and discussed. Temperature changes are consistent with a vertical circulation upwards in the warm air and downwards in the cold air. The field of frontogenesis near well defined precipitating fronts is examined, and the theory of confluence is applied to different fields of specific volume.

6. BLACKWELL, M. J.; Five years continuous recording of total and diffuse solar radiation at Kew Observatory. *Met. Res. Pap., London*, No. 895, S.C. III/179, 1954.

Records of Moll-Gorczynski solarimeters for total and diffuse radiation on a horizontal surface from 1947 to 1951 are described. Sources of error are exhaustively examined. Tables give corrected hourly means of total and diffuse radiation, computed extraterrestrial radiation on a horizontal surface, and hourly means of sunshine, all for 10-day periods. Values are shown in graphs, which also include diffuse and total radiation on cloudless days and correlation of total radiation with sunshine.

ROYAL METEOROLOGICAL SOCIETY

At a meeting of the Society held on March 16, 1955, the President, Sir Graham Sutton in the Chair, the following papers were read:—

*Lamb, H. H.—Two-way relationship between the snow or ice limit and 1000–500-mb. thicknesses in the overlying atmosphere**

The 1000–500-mb. thickness is closely associated with the temperature of the air at different levels, the largest variation being at the surface. Mr. Lamb showed in addition the relation with the freezing level and dwelt for some time on the relation between thickness and the occurrence of different types of precipitation. The change-over from frozen to unfrozen precipitation occurred at a thickness of 17,300 ft. at an inland station, and at 17,150 ft. at a coastal or oceanic station such as Lerwick. With snow on the ground this critical thickness would be increased to 17,500 ft., as shown by data from Stockholm, but the change-over was more gradual, the likelihood of unfrozen precipitation increasing from 30 to 70 per cent. as the thickness increased from 17,450 to 17,800 ft. Mr. Lamb thought that this was because slight snow would fall from stratus cloud lying beneath an inversion induced by the snow-cover, even when the higher atmosphere was warm.

It was also possible to correlate the thickness with the edge of the area with extensive snow lying. Mr. Lamb found a mean thickness of 17,297 ft. over the snow limit in north-west Europe and 17,260 ft. over the Dutch whaling ship *Willem Barendsz* near the edge of the antarctic pack-ice. An attempted correlation with the mean position of the 0°C. isobar over North America and Russia was not justified because of the difference between the periods of the data. Mr. Lamb also considered the incursion of various thickness lines across the ice or snow limit. Many of the incursions of warmer air to great distances occurred with high winds or anticyclonic inversions at low levels. The 17,400 ft. line could travel 2,500 miles across a snow surface with the help of subsidence but only 1,500 miles without. Warming of cold air over the sea gave similar limitations to the advance of lower thicknesses from the snow or ice margin.

In the discussion that followed, Mr. Murray drew attention to the slightly different critical thickness of 17,150 ft. that he had found† which was due solely to the difference in grouping of the various forms of precipitation. Mr. Lamb agreed with Mr. Murray, but stressed the higher critical thickness over a snow surface; he quoted Baur's criterion that if the mean temperature during the first half of December in Berlin was more than 2½°C. above normal then the winter would be mild. Mr. Craddock gave a brief résumé of an inconclusive investigation at Dunstable into Baur's criterion; among other conclusions they had found a greater loss of thickness due to radiational cooling at the top of the layer than from contact with a snow surface at the ground. Prof. Gordon Manley had been considering running means going back 200 yr. but could find no long persistence of cold weather; however, a cold February could be followed by a cold March because of extensive snow-cover. Dr. Sutcliffe thought the thickness criterion for type of precipitation would be very useful with modern numerical forecasting methods, but it would be better to associate the higher critical thickness in certain cases with stability rather than with snow-cover.

Moore, D. J. and Mason, B. J.—The concentration, size distribution and production rate of large salt nuclei over the oceans‡

This paper gives the observed distribution of salt nuclei from aboard ocean weather ships. Two types were observed. The first was particularly pronounced with strong winds, was possibly produced from the sea surface, and had a maximum concentration of nuclei heavier than 2×10^{-14} gm. of 10/cm.^{3}. A discontinuity in the distribution occurred at a critical size, depending on the wind speed, probably caused by sedimentation of the larger nuclei. The second type, which was only found on 5 occasions out of 30 when the wind speed was less than 7 m./sec., was shown to be very similar to the distribution found by Dessins at Haute Garonne in which only the largest droplets (1 per cent. of the total) were found to contain sodium-chloride crystals. It was concluded therefore that with light winds the nuclei were of land origin. Later Mr. Mason quoted Japanese research figures of nuclei proportions: 50 per cent. combustion nuclei, 20 per cent. sea salt, 20 per cent. soil nuclei, and 10 per cent. unidentified.

Using a wind tunnel with waves breaking inside it, Mr. Mason had found a production rate of 40/cm.^{2}/sec. for nuclei heavier than 10^{-13} gm. in a speed equivalent to 16 m./sec.; by consideration of observed size distribution he calculated a production rate of 43/cm.^{2}/sec. for nuclei heavier than 10^{-13} gm. in a wind speed of 15m./sec. or 86/cm.^{2}/sec. for nuclei heavier than 2×10^{-14} gm., the minimum size of nuclei captured. Laboratory studies by means of high-speed camera and collection in a confined space were made to show how the bursting of air bubbles could produce smaller nuclei. The smaller droplets were produced by disintegration of the

* *Quart. J.R. met. Soc., London*, **81**, 1955, p. 172.

† MURRAY, R.; Rain and snow in relation to the 1000–700-mb. and 1000–500-mb. thicknesses and the freezing level. *Met. Mag., London*, **81**, 1952, p. 5.

‡ *Quart. J.R. met. Soc., London*, **80**, 1954, p. 583.

bubble film; only two or three large droplets were produced by the breaking of the jet following the burst bubble. By converting the confined space into a Wilson cloud chamber he had, however, been able to show that, since a dense cloud was formed, many very small nuclei were produced by the bursting bubble.

Prof. Sheppard asked how the Japanese sorted out the types of nuclei; it was done by matching electron micrographs with those of known particles. There was also some discussion as to how the breaking of bubble films could produce such small droplets.

The Annual General Meeting of the Society was held on April 20 with Prof. P. A. Sheppard, Vice-President, in the Chair. After the passing of the Report of the Council for 1954, Prof. Sheppard presented the Symons Memorial Gold Medal for 1955 to Dr. R. C. Sutcliffe for outstanding work in the field of synoptic and dynamical meteorology. The Darton Prizes for original work of high quality in instrumental meteorology were also presented, the first prize jointly to Dr. J. T. Houghton and Dr. A. W. Brewer and the second prize to Dr. L. G. Smith. Special Canadian awards of Darton Prizes were also announced, the first jointly to Dr. D. P. McIntyre and Mr. R. Lee, and the second to Dr. J. S. Marshall.

Owing to the unavoidable absence of Sir Graham Sutton in Geneva instead of the customary Presidential Address there was an informal discussion on the weather of 1954.

The first speaker, Dr. J. Glasspoole, gave a brief outline of the weather in the British Isles. It was comparatively dry during the first four months of the year but was then wetter than the average for seven consecutive months in England and Wales and eight months in Scotland; this length of spell of wet weather has only been equalled six times, and exceeded twice, in the last 200 yr. in England and Wales. Taking the year as a whole there have been seven wetter years since 1869 in England and Wales and only three in Scotland. The number of rain-days in the year was also excessive; since 1919 in Scotland the number of rain-days in 1954 was only exceeded in 1923; during the last four months there were 102 rain-days out of a possible 122. Temperature during the summer was much below average, chiefly due to colder days, but this is only remarkable when compared with the warm summers prevailing since 1932; during 1902–31 there were 12 cooler summers. The daily mean sunshine for the year was 0·3–0·4 hr./day less than average throughout the country, but there was little change from the average general pattern. Mean annual pressure over the country was rather less than average in the south and 2·5 mb. less than average in the north showing an increased pressure gradient with more frequent winds with a westerly component; although it was windy on the whole the year was not the windiest on record nor a year of outstanding gusts.

Dr. A. G. Forsdyke referred to the weather over the world as a whole, and remarked that the year was not exceptional. Every year some part of the world experiences unusual weather; it so happened that in 1954 the British Isles seemed to get the worst of what was going. He divided the year into periods according to the weather over the British Isles, and showed charts, extending from the Rocky Mountains to the Urals, of monthly pressure anomaly and monthly 1000–500-mb. thickness anomaly for each of the periods. The January 1954 charts, representing January–March when the weather over the British Isles was changeable and cold with wintry spells, showed a large pressure anomaly near the British Isles and nearby a strong gradient in the mean thickness. The April charts, when it was dry and sunny in the British Isles, again showed a high pressure anomaly and thickness still below normal; the main feature of this thickness chart was a long trough over north-west Canada. The July charts in the middle of the dismal summer showed a substantial low pressure anomaly near the British Isles with a tendency for W.-NW. gradient winds; the thickness was also low just south-east of the British Isles but high over the United States and Russia. The September charts at the end of the summer showed an intensified westerly current over the British Isles and low thickness to the north. The stormy, mild, wet end of the year showed a low pressure anomaly stretching in December from Greenland to the coast of Norway with a high thickness anomaly over Iceland. Dr. Forsdyke also exhibited a diagram showing at a glance the types of monthly pressure anomaly in 11 different regions of the northern hemisphere; he could find no similarity of the anomalies in different parts with that over the British Isles except possibly that of the neighbouring region of Iceland. Also there was no obvious connexion between cyclonicity over the British Isles and over Newfoundland.

Dr. H. L. Penman discussed the effect of the weather on farming, confining his remarks to cereals, root crops and grass. After the cold dry start to the year and with droughts in some parts during April, crops were late starting and the dismal summer continually held them back throughout the year. The wetness encouraged weeds, fungus and virus diseases, and delayed and in some cases prohibited the harvest. In the end, thanks to modern harvesting methods, the harvest, although delayed, was up to 1947 and 1949 yields but well below the high yields of 1953. For instance, the largest crop, grass, yielded well above average, but difficulty was experienced in grazing or cutting it. The weather on the whole did good to the salt-damaged lands that suffered in the January 1953 floods.

In the general discussion, Mr. R. F. M. Hay showed that although sea temperatures over the eastern North Atlantic were above or near normal to a depth of at least 450 ft. in the first half of the year, they were much below in the summer when the positive anomalies would have been expected to continue if the overlying weather conditions had not been so exceptional. Mr. H. H. Lamb discussed the weather of the year in relation to the orientation and strength of the frontogenetic col in the western Atlantic. In a discussion on the effect of the melting of icebergs Mr. Hay showed that even the melting in an exceptionally heavy year would not lower the sea temperature over an appreciable area by as much as 1 °F. Dr. Rainey closed the discussion with a report of the appearance of desert locusts in 1954—the first in the British Isles since 1869. Mr. Corby had worked out the 500-ft. trajectory which brought them from north Africa to the Scilly Isles on October 17, 1954.

ROYAL ASTRONOMICAL SOCIETY

Hydrodynamical processes in meteorology and geophysics

A joint meeting of the Royal Astronomical and Royal Meteorological Societies was held at Burlington House on February 25, 1955, with Sir Graham Sutton in the Chair. In opening the meeting Sir Graham remarked that the present period, with the prospects of being able to apply mathematical methods and machines to test meteorological ideas, is as significant in meteorology as was the period in the early 1920's when the Norwegian theories of frontal analysis were being formulated.

The first paper, presented by Dr. R. Hide, dealt with magnetic effects in relation to internal motions of the earth's core. The earth is known to consist of a hard mantle surrounding a liquid core of about 3,500-Km. radius. It is not possible to observe the core directly, but since it is mainly iron, its motion can be inferred from changes in the earth's magnetic field. Three possible causes of motion in the core were suggested by Dr. Hide: precession in the mantle, iron sinking from the mantle into the core (Urey's proposal), and radioactivity in the core. Each of these causes can provide sufficient energy to meet the known dissipation of 2×10^{16} ergs/sec. After a demonstration of some of the mathematical arguments, Dr. Hide showed photographs of experiments designed to show the sort of motion that might occur with differential heating of a rotating fluid, such as the earth's core or atmosphere. The centre of a rotating fluid in a cylinder was maintained at one known temperature and the outside at another known temperature. Under certain conditions the motion, as shown by dye stains, consisted of a narrow stream flowing in waves round the cylinder, the wave pattern drifting slowly relative to the boundary. As the conditions varied the number of waves round the cylinder varied, but this wave number was limited by the relative dimensions of the inner and outer boundaries of the rotating fluid, being larger for smaller differences. As conditions changed with a tendency to increase the wave number beyond the limit the waves were disturbed violently.

Mr. J. S. Sawyer read a paper on the basis of numerical methods in dynamical meteorology. The most frequently used meteorological methods of solution were to solve idealized and simple problems and then apply the conclusions to the more complicated situations found in nature. After Richardson's pioneer attempt in 1922, the first numerical method, using electronic calculating machines, was that in the United States based on the barotropic model of Dr. Charney using only one independent parameter, the height of the 500-mb. surface. Further work in this country by Sawyer and Bushby used two independent parameters, the height of the 600-mb. surface and the 1000–600-mb. thickness. This method depended on the high correlation between temperature gradients at all levels. Mr. Sawyer illustrated this two-parameter method by comparing calculated forecast charts with actual charts of weather situations in western Europe. Mr. Sawyer also referred to work done in the United States by Dr. Charney using a three-parameter model which was claimed to have given a better indication than did a two-parameter model of the Thanksgiving Day storm of 1950. Mr. Sawyer thought, however, that the two-parameter model used by Dr. Charney might have given better results if lower-level data had been used instead of the 700-mb. and 300-mb. levels, which were rather too near the tropopause. Further increase in the number of parameters would take more machine time, but, in Mr. Sawyer's opinion, might not lead to greater accuracy because information errors would be more important.

Mr. Charnock showed a film of a rotating-disc model which simulated ocean currents. The stronger currents were induced on the western sides of the oceans. A pronounced circulation was evident in the Atlantic Ocean, but flow in the Pacific was more zonal with a tendency for a separate circulation in the west.

Dr. E. T. Eady read a paper on the mathematical aspects of "turbulent" hydrodynamical processes. Because turbulence was of so irregular a nature study had to be confined to its statistical properties which depended on the nature of the turbulence. Properties of the fluid could be transferred by turbulence either directly by the fluid (primary transfer) or indirectly (secondary transfer). Primary transfer would affect the turbulent motion and would tend to damp it out; secondary transfer might be in the form of momentum as well as heat and might be carried against the gradient as well as with the gradient. Applying these principles to the general circulation of the atmosphere Dr. Eady showed that the preferred direction of transfer had a smaller slope on the north-south vertical cross-section than the isentropic surfaces. If the Richardson number was large the form of break-down of the circulation led to active weather systems; if the Richardson number was less than 1 the systems were on a small scale; and for a Richardson number very much less than 1 the small-scale activities grew only very slowly.

Dr. Eady went on to consider possible motion in the core of the earth; the main difference, arising from the different nature of the heat source, was that the Richardson number was small and negative. Since there were small changes in the length of the day there must be free convection in the centre, not merely forced convection, although this convection is limited because the flow of heat is small. Considering the electro-magnetic effect it was possible for an electric flow to have more energy than a simple dipole, but Dr. Eady could not convince himself that there was a natural dynamo. From analogy with the atmosphere closed loops (eddies) may break away and flow with the normal convection, but with a tendency to set themselves in the same direction as the dipoles where the field was stronger.

The meeting ended with general discussion, mostly of a speculative nature regarding the motion in the earth's core.

LETTERS TO THE EDITOR

Distortion of condensation trails

Fig. 1 shows a series of condensation trails observed at Waterbeach between 1700 and 1800 G.M.T., on March 10, 1955. At the time of the observation a large slow-moving anticyclone was centred over north-east Ireland, and a 20-kt. north-easterly gradient wind covered East Anglia.

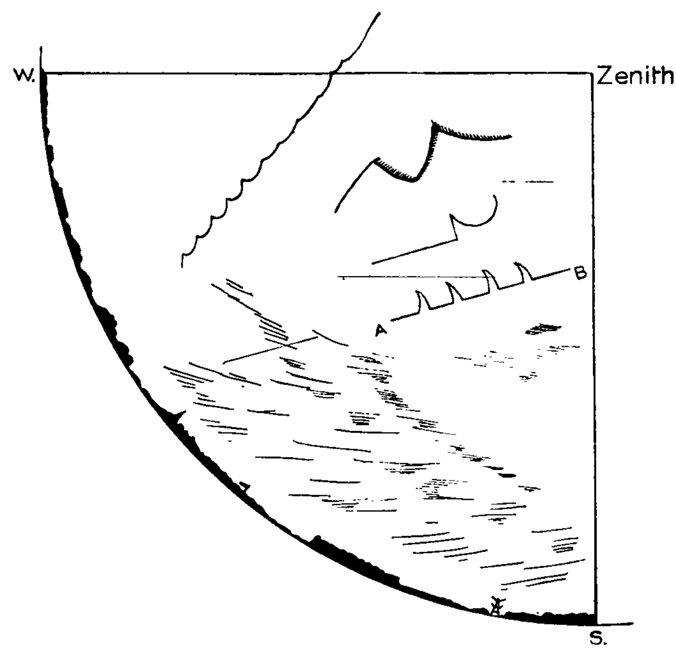


FIG. 1

Throughout the day, 5–7 oktas of variable thin cirrus and cirrostratus, the base of which according to an aircraft report at 1300 G.M.T. was 30,000 ft., had been present, and although trails had been forming previously they had exhibited no noticeable distortions. Aircraft flying over East Anglia at 1500 also reported dense persistent condensation trails of 3–4 miles in length between 29,500 and 39,500 ft.

The winds above Hemsby at 1400 were 50° 90 kt. at 300 mb. (29,760 ft.), 50° 95 kt. at 250 mb. (33,600 ft.), and 50° 63 kt. at 200 mb. (38,020 ft.). There was no change in the wind direction of 50° between 20,000 and 45,000 ft. The tropopause was at 36,000 ft., and the Mintra height* at 23,000 ft.

* Theoretical minimum height at which condensation trails can form.

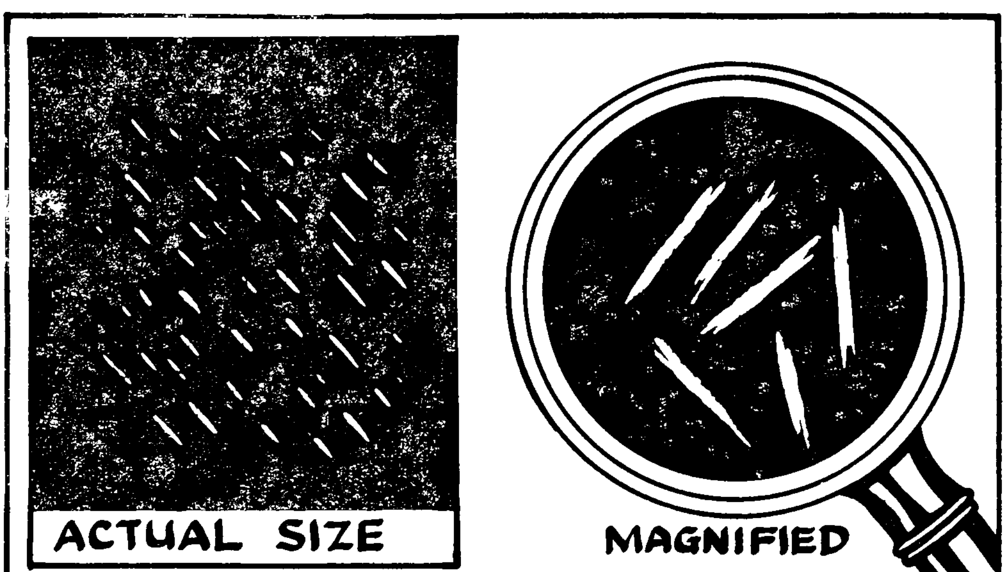
The trail AB, which unfortunately was not observed during its formation, appeared to be just above the cirrus, and probably at about 31,000–32,000 ft. It persisted from 1715 to 1800 and moved in the direction of the strong upper wind with no change of shape. The other trails shown, which were semi-persistent and well above AB, were probably between 35,000 and 40,000 ft. They formed as straight lines and then rapidly took on the configurations shown.

The distortions on AB were very similar to a previous case observed at Wick*. On that occasion a theory was put forward suggesting that the distortion was due to a vector wind change at a warm frontal surface. An examination of the upper air data for England on the present occasion has yielded no explanation of the phenomenon.

J. A. CLEMENTS

Ice needles at Ipswich

On February 24, 1955, an unusual type of continuous slight snowflakes fell in the Ipswich area between 1945 and 2050 G.M.T. Each particle of snow was in the form of a hard, opaque needle varying between 2 and 5 mm. in length. The needles were falling very thickly, reducing visibility to just under 300 yd., and were flying almost horizontally with the wind. Myself and a friend examined the needles closely as they stuck into a dark woollen pullover I was wearing at the time, completely covering it within 4 min.



During the snowfall the wind direction was about 120° true at a speed of between 18 and 25 kt. At 2100 the needles lay on the ground to a depth of almost ¾ in. causing glass-like surfaces on roads used by much traffic. At 2103 the continuous fall of needles changed to a normal fall of granular snow.

Was I correct in assuming that this phenomenon was a fall of ice needles? In the 1942 edition of the "Meteorological observer's handbook" it states that

* PHILLIPS, P. E.; Distortion of condensation trail at a frontal surface. *Met. Mag., London,* 83, 1954, p. 279.

ice needles usually occur in cold, clear weather and are distinct from an ordinary fall of snow. In the latest edition, however, it states "Another form of crystallization sometimes seen in light snowfalls consists of detached single rods about 2 mm. long. When these occur alone they are recorded as 'ice needles' ".

K. E. BLOWERS

10 Sherrington Road, Ipswich, Suffolk, March 10, 1955.

[There seems little doubt from Mr. Blowers's letter that the phenomenon he described was a fall of ice needles of unusual intensity.—Ed., *M.M.*]

Aircraft icing at very low temperature

Mr. J. B. Shaw* drew attention to the occurrence of water droplets in the free air at temperatures as low as −65°C. Mr. A. Campbell, Meteorological Officer at the R.A.F. Station, Binbrook, has obtained the following account of weather experienced by Flt-Lt Steele of 617 Squadron, R.A.F., on a flight from Juba to Nairobi on December 7, 1954, between 1200 and 1319 G.M.T. "Extensive cumulonimbus clouds encountered south-east of Juba, tops extending above 40,000 ft. Moderate, and very occasionally severe, turbulence in cloud at 48,000 ft. Aircraft in cloud for ten minutes. A coating of ice formed on the leading edges and swirl vanes."

The radio-sonde observations at Nairobi at 0600 G.M.T. on that day indicated a temperature of −70°C. at 48,000 ft. (127 mb.); the following day at the same time the temperature was −69°C. The average temperature at Nairobi at 127 mb. during the month of December was −70°C. over the years 1947–53. Allowing for the temperature within the tops of the cumulonimbus clouds to be perhaps a degree or two above the temperature in the air outside the clouds, there seems little doubt that Flt-Lt Steele's aircraft encountered water droplets at a temperature between −67° and −70°C.

J. K. BANNON

NOTES AND NEWS

Abnormal radio propagation December 3, 1954

The B.B.C. Research Department, using a receiver at Beddingham, near Lewes, frequently monitor a transmission on 180·4 Mc./sec. made from the B.B.C. station at Sutton Coldfield. Radio transmissions on these high frequencies normally have a range not much greater than that of the optical horizon from the transmitting aerial, but with certain meteorological conditions in the lowest few thousand feet of the atmosphere this range can be very greatly increased. Such conditions occur when there is an inversion of temperature or lapse of humidity of sufficient gradient and depth over the path of the radio waves. Thus, for example, in anticyclonic conditions when warm subsiding air lies above a colder and moister surface layer, or when warm dry air from the land travels over the colder sea, abnormal ranges of very high frequency radio transmissions are often reported.

Since Beddingham is 147 miles from Sutton Coldfield the normal field strength of the Sutton Coldfield transmission is very small but on the evening of December 3, 1954, the measured field strength increased considerably

* SHAW, J. B.; Aircraft icing at very low temperatures. *Met. Mag., London*, **83**, 1954, p. 281.

between 1400 and 2300 G.M.T. reaching a value 40 db. above the normal (i.e. an increase in field strength by a factor of 100). This increase was the highest ever measured and led to an inquiry in the Meteorological Office to explain its cause. A first glance at the charts for this period did not suggest abnormal conditions but examination of radio-sonde reports showed the presence of extraordinarily dry air at levels as low as 2,200 ft., as well as an inversion of temperature. Thus the 0200 G.M.T. ascent from Hemsby on December 4, 1954, showed an inversion of temperature of 9°F. between 570 ft. and 1,170 ft. above mean sea level and a dew-point change from 39°F. at 780 ft. to −14°F. at 2,200 ft. It seems quite likely that this dry air was present even at the top of the inversion at 1,170 ft. At Crawley at 0200 the inversion amounted to 4°F. and was at a greater height (2,190–2,670 ft.); the dew point decreased from 40°F. at 2,310 ft. to 3°F. at 3,730 ft.

Air as dry as these readings indicate must surely be extremely rare at such low levels in this country, and the accompanying large lapse of humidity with height was undoubtedly the cause of the unprecendented field strength at Beddingham.

I am indebted to Mr. L. F. Tagholm of the B.B.C. Research Department for the information of measured field strength.

R. F. JONES

Ground fog at Stevenage, Hertfordshire

The photograph facing p. 216 was taken by Hunting Aero Surveys Ltd between 9 and 9.30 a.m. on February 2, 1949, over Stevenage.

An intense anticyclone with a central pressure of 1043 mb. covered the British Isles. The centre of the high was situated over or near the Wash, but pressure over the whole of England was almost uniform, with calm or light winds over an extensive area. The previous evening the central region of the anticyclone had been situated near the Scottish border, with north-easterly winds and moderate or good visibility in eastern districts of England, but fog developed fairly extensively during the night as a result of the decrease of the pressure gradient.

Awards to civil airline personnel

Weather reports from civil aircraft on standard routes are of great assistance to the Meteorological Office. Such reports help the forecaster to compile forecasts for other aircraft and also facilitate the checking of forecasts made earlier. This is particularly true when the reports refer to areas (such as over the oceans) where there are comparatively few standard reporting stations. In recognition of the value of such reports the Air Ministry has decided to institute a system of awards to personnel of airline companies registered in the United Kingdom. The awards will be made annually and will be of two kinds. A number of awards of books, suitably inscribed, will be made to captains or navigators who have provided the best series of reports (in flight, post-flight or on debriefing) during the twelve months ending April 15. Up to two awards will also be made annually to captains of aircraft for long and meritorious service in the provision of weather reports.

The awards of both kinds will be made by the Director of the Meteorological Office who will be guided by weather reports received at offices maintained by the Meteorological Office.

The Royal Research Ship *Discovery II* on temporary duty as an ocean weather ship

In February 1955 the ocean weather ship *Weather Explorer* had to be "laid up" for fairly extensive repairs to one of her boilers. She was due to relieve the Netherlands ocean weather ship *Cumulus* on February 20 at ocean station K to the westward of the Bay of Biscay in 45°N. 16°W. It was most desirable that this British commitment should be fulfilled and, as the boiler repairs could not possibly be done during the ship's normal period in Greenock, it was decided that a ship should be chartered to take the *Weather Explorer's* place. Fortunately the R.R.S. *Discovery II* was available, and arrangements were made with the National Institute of Oceanography for her to be chartered for the voyage.

The *Discovery II*, Captain H. O. L'Estrange, D.S.C., R.D., R.N.R., was at Plymouth, and the necessary special stores and equipment had to be sent there from the ocean weather ship base at Greenock. A wooden balloon-filling shelter was designed, and was built on the ship's poop and secured by wire stays. Although somewhat small, it proved in practice to be quite adequate. Stowage racks had also to be fitted on deck for carrying about 100 hydrogen cylinders. In addition to the ship's own radio equipment an emergency V.H.F. transmitter/receiver was taken from the *Weather Explorer* and fitted in the *Discovery II*. Radio-sonde equipment was also installed. Her usual Captain and crew remained in the ship, and in addition the Meteorological Officer-in-charge from the *Weather Explorer* and five of his staff, together with the Radio Overseer of that ship and two radio operators, joined the ship for the voyage.

The *Discovery II* sailed from Plymouth on February 17, 1955, and relieved the Netherlands O.W.S. *Cumulus* on the 19th at station K. She remained on that station until March 15 when she was relieved by O.W.S. *Weather Watcher* and returned to Plymouth, arriving on March 18. At the beginning of the voyage the weather was unsettled with some snow showers. Later there was a long spell of NE. winds with cloudy skies and showers. While on station K hourly meteorological observations were made and recorded and the usual main synoptic observations were transmitted. The *Discovery II* does not carry radar equipment suitable for tracking balloons so the upper air observations were confined to TEMP soundings; 49 successful TEMP soundings were made. Wind soundings were attempted with the aid of a marine theodolite which had been obtained on loan from the Admiralty, but this instrument proved generally unsuccessful, due partly to the rapid motion of the ship. Difficulty was also experienced at times in getting azimuth bearings of the balloons by the compass mirror, and bearings were usually unobtainable when the balloons were over 6,000 ft. Attempts were made at pilot-balloon soundings using 500-gm. balloons suitably ballasted, but cloud conditions were almost wholly unfavourable. The radio-sonde gear worked well and reception was good throughout the voyage. Also the ship's radio equipment seems to have operated extremely well and communication with both Rennes, the French station, and Dunstable was excellent. The V.H.F. set from the *Weather Explorer* functioned well. The *Discovery's* deck officers soon accustomed themselves to its use and during the voyage they made contact with 134 aircraft. This work was a change from their normal oceanographical work and it seems they enjoyed it. On the night of March 3–4 a weather message from Prestwick was relayed by *Discovery II* to the aircraft *Canopus* which was flying H.R.H. Princess Margaret home from the

West Indies. Three mail drops by R.A.F. aircraft were made during the voyage; always a pleasant break in the routine and much appreciated. Two schools of whales were sighted and other sea life observed. Air/sea rescue drills were carried out, as is usual in ocean weather ships. Altogether a quite satisfactory voyage due to the ready and friendly co-operation of the National Institute of Oceanography and the Captain and ship's company of the "temporary acting" ocean weather ship *Discovery II.*

Meteorological Office Staff Centenary Dinner

This was held on the evening of March 11 at the Holborn Restaurant and was attended by no less than 218 members, or former members, of the staff with their guests. Sir Graham Sutton acted as President and the company were graciously received by him and Lady Sutton.

After an excellent meal, reminiscent of pre-war standards, and the loyal toast to Her Majesty the Queen, Mr. H. L. B. Tarrant proposed the toast of the Meteorological Office, reminding his audience of the days when the staff numbered less than 40. In his reply, Sir Graham reminded his audience of some of the great names of the past and expressed his delight in seeing so many old members of the staff. He also paid tribute to the present staff for the way in which they carried on the great tradition of service, and said that he hoped in his term of office to see them brought closer together by the provision of a national weather building worthy of the name.

Before the toast of the Ladies, proposed in characteristic maritime vein by Cmdr Frankcom, each lady was presented with a thermos jug. In her reply, Lady Sutton looked forward to the day, already envisaged by Sir Graham, when, with the Headquarters establishments housed under one roof, social functions and activities of various kinds would be much easier to arrange and to attend; and wives would get to know each other better.

In proposing the toast of the officers and members of the Social and Sports Committee, Dr. Stagg outlined its history, and referred to the successes achieved on the football field and in the athletic arena, the winning of the Air Ministry Challenge Cup and the Bishop Shield for 7 and 6 years in succession respectively. Mr. N. H. Smith, Chairman, replied, paying a tribute to the organizing genius of Mr. Ben. G. Brame (Treasurer) and Miss Joan Wordsworth (Secretary) which had done so much to ensure the success of the dinner. He also reminded his hearers of the sources of Committee funds, and that, but for support from those funds it would have been impossible to meet the expenses of those representative football and athletic teams which, under the enthusiastic guidance of Mr. H. A. Scotney, had proved so successful in departmental competitions. He also called attention to a Centenary Souvenir in the shape of an attractive perpetual calendar which was now available to purchasers on application to the Secretary.

Amongst former members of the staff present were Sir David Brunt, Sir George Simpson, Mr. E. Gold, Mr. R. G. K. Lempfert, Mr. R. Corless and Mr. W. Heinemann—a veteran of 90 years.

It was generally agreed that the occasion had proved a delightful and memorable one, although there was regret that time did not permit, as was intended, of the mingling together of old colleagues and friends in an after-dinner conversazione.

REVIEW

Seismology. By K. E. Bullen. *Methuens Monogr. phys. Subj.*, 6¼ in. × 4¼ in., pp. viii+132, *Illus.*, Methuen & Co. Ltd, London, 1954, Price: 8*s.* 6*d.*

This excellent little book is one of a series of monographs designed "to supply—at University level—a compact statement of the modern position". It can be recommended most strongly to all who wish to know what can be learned about the earth by the study of earthquakes and the elastic waves to which they give rise, and who are prepared to exert a little effort to acquire the knowledge. The emphasis is on general theory and geophysical applications rather than on instrumental seismology and the interpretation of seismograms, aspects of the subject which are well catered for in existing texts. The chapter on microseisms will be of most direct interest to meteorologists, and it provides a good example of the conciseness and relevance of the book as a whole. In six pages it lists the most recent and comprehensive descriptive studies, introduces the salient features of Longuet-Higgins's theory of microseism formation, and discusses the possibilities and difficulties of hurricane tracking by microseism recording.

G. D. ROBINSON

OBITUARY

Miss L. E. Weaver.—It is with deep regret that we learn of the death on March 13, 1955, of Miss Weaver at the age of 66 after a long and painful illness, cheerfully borne.

Miss Weaver came to the Meteorological Office about five years before the war as secretary-typist to Mr. E. Gold, then President of the International Commission for Synoptic Weather Information, a position which involved much international correspondence and intense work for Miss Weaver at meetings of the Commission at Warsaw in 1935 and Salzburg in 1937. Her service was beyond praise, and was commended with general applause at the closing session at Salzburg. In September 1940 her home in Mecklenburgh Square was bombed at night and she narrowly and miraculously escaped with her life from beneath the wreckage of the building. The shock was one which would have unnerved a less courageous woman, but Miss Weaver was back on duty immediately she could get re-clothed. In March 1945 Miss Weaver was lent by the Air Ministry for two years' service with U.N.R.R.A. A few months after her return in 1947 she resigned and went abroad again to serve in the Church of Scotland (Welfare) Canteens for nearly two years. She returned home in 1950 suffering from strain and overwork from which she never really recovered. Miss Weaver was a woman of untiring energy and enthusiasm for any work she undertook; she was restless in her efforts to render the best service to her fellows which it was in her power to give. Her many friends in the Meteorological Office, remembering her with affection and gratitude, mourn for her suffering and her death.

HONOUR

It was announced in the Birthday Honours List 1955 that Mr. R. A. Hamilton had been awarded the O.B.E. for his services as Chief Scientist of the British North Greenland Expedition, 1952–54.

METEOROLOGICAL OFFICE NEWS

Retirements.—*Mr. H. W. L. Absalom, O.B.E.*, Senior Principal Scientific Officer, retired on April 30, 1955. At a ceremony in the Conference Room in Victory House on May 6, Dr. R. C. Sutcliffe presented Mr. Absalom with a cheque subscribed by his colleagues. In expressing his thanks Mr. Absalom recounted some interesting recollections of his experiences in the Office and events with which he had been associated. Mr. Absalom has accepted a temporary appointment in the Meteorological Office.

Miss T. M. Hunt, Experimental Officer, retired on May 7, 1955, on grounds of ill health. Miss Hunt joined the Statistical Division of the Office in February 1918 and was transferred to the Library in 1920. In 1929 she became assistant to Dr. C. E. P. Brooks and helped to introduce the Universal Decimal Classification into Library practice. She also assisted with the introduction of the present set of bibliographies, classified by subject and geographically, which form the main source of information on meteorological literature in the Office. In 1937 Miss Hunt returned to the Library staff where she served, up to the time of her sudden illness about a year ago, as Assistant Librarian. Miss Hunt took an active part in various social activities of the Office, both at Stonehouse during the Second World War and at Harrow.

Sports activities.—The Meteorological Office defeated the Directorate General of Organization by 3 goals to 2 in the final of the competition for the Air Ministry Football Cup at Northolt on April 29. The Meteorological Office has won this cup on each of the last eight occasions on which the competition has been held.

At the 1955 Spring Regatta of the Royal Air Force Yacht Club, Habbaniya, the Snipe Class Challenge Cup was won by Mr. G. E. Parrey of the Meteorological Office.

This year's Air Ministry Contract Bridge Singles competition has been won by Mr. R. A. Ogden, who also won the Doubles competition with Mr. G. T. Smith.

ERRATA

APRIL 1955, PAGE 121; line 2, *for* "increased with height" *read* "decreased with height"; line 24, *for* "standing wave" *read* "standing lee eddy"; line 25, *for* "although the wave-lengths are increased" *read* "and the first lee wave is displaced down stream".

WEATHER OF MAY 1955

The circulation patterns over the Atlantic and Europe represented a notable break with the previous months, and were unusual for May, showing a prevalence of largely zonal movements with depressions passing eastwards across, or near, the British Isles. Mean pressure was lowest in mid Atlantic (1008 mb., anomaly −6 mb. near 50°N. 30°W.) and across central Scandinavia to north-west Russia (1006–1007 mb., anomaly −8 mb. over a wide area). Pressure was about normal in the high-pressure belt from the Azores across southern Europe (greatest anomaly +4 mb. in south France and Thrace) as well as in the Polar Basin anticyclone with its usual extension in May towards Iceland. In the general region of north-west Europe the usual northerly and southerly flow associated with blocking patterns returned to dominate the second half of the month.

The month as a whole was a little colder than normal over the northern Atlantic and Greenland, and over Europe, except Spain.

Precipitation ranged from 120 to 200 per cent. of the May normal in a broad belt across the British Isles and northern and central Europe. Rainfall was deficient over France, Spain, Italy and from north Scotland to Spitsbergen.

In the British Isles the weather was changeable with thundery rains during the first nine days as depressions moved quickly across the north of the country; it was unusually cold, with sleet and snow from the 10th to the 21st and brilliantly fine and warm during the last three days of the month.

On the 1st there were widespread thunderstorms in the path of a depression as it crossed Northern Ireland and southern Scotland and also heavy rainfall in central and southern England. The following day was sunny, although isolated thunderstorms persisted in south-east England, but there was further heavy rain in west Scotland on the 3rd associated with the eastward passage of a trough across the country. With a deep depression off the coast of Scotland, strong south-westerly winds were maintained over most of the country during the next two days, especially on the 5th when a gust of 60 kt. was recorded at Dishforth and local duststorms occurred in East Anglia, one of which reduced the visibility at Mildenhall to as little as 200–300 yd. for much of the afternoon; there were also heavy showers in the west and north which developed into local thunderstorms in west Scotland. Thunderstorms were also experienced in the south-west and widespread rain elsewhere in the south, as an active depression crossed southern England on the 6th, and during a severe thunderstorm the following day over 1 in. of rain fell at West Raynham. By the end of the week Eskdalemuir had recorded more than 3 in. of rain. An anticyclone developed near Greenland on the 6th, and after the passage of minor disturbances on the 8th and 9th, there was some particularly heavy rain in the west on the 9th (2·25 in. fell at Oakley Quarries, Blaenau Festiniog, Merionethshire), an inflow from the north of arctic air over the British Isles caused temperatures to fall sharply by about 10°F. on the 10th; rain turned to sleet and snow in the north and thunderstorms occurred in the south-east ahead of the cold air. The cold weather continued with only brief interruptions until the 21st. During this period rainfall in many districts was more than three times the average, there were outbreaks of sleet or snow most days and thunderstorms, which were widespread on the 14th and 15th, were fairly frequent. A depression which crossed southern England on the 16th and 17th and invaded the northerly air stream, was accompanied by gales and heavy rain. Many places in eastern England recorded more than 1 in. of rain on the 17th, and East Kirkby, Lincolnshire, 2·25 in.: the rain turned to snow later in many parts of England and Wales, even as far south as the London area and the Channel coast. The 17th was also the coldest May day on record at many places, temperature only reaching 39°F. at Harlech and Buxton while a lower maximum temperature in May had not been registered at Ross-on-Wye since records began 80 years ago. During the days which followed an anticyclone developed west of the British Isles and moved slowly across the country giving mostly bright weather but with showers and local thunderstorms or slight rain from time to time, until on the 26th the high-pressure system withdrew temporarily northward and a slow-moving frontal system brought substantial rainfall to some southern and midland districts; more than 1 in. of rain fell during the night of the 26th–27th at London Airport. By the 29th high pressure had spread south again to cover the country and the month ended with three days of warm, sunny weather, although it remained cool on the eastern seaboard and dull in some windward coastal areas. On each of the last three days over 15 hr. of sunshine were recorded in many districts, particularly in Scotland and northern England. In spite of the fact that much of southern and midland England had more than twice the average amount of rain for May, and several stations reported it as being the wettest May on record, many places recorded more than average sunshine.

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 ...	76	25	−2·6	179	+5	109
Scotland	77	21	−1·9	112	+2	125
Northern Ireland ...	68	32	−1·5	117	+4	113

RAINFALL OF MAY 1955

Great Britain and Northern Ireland

County	Station	In.	Per cent. of Av.	County	Station	In.	Per cent. of Av.
London	Camden Square ...	4·49	255	*Glam.*	Cardiff, Penylan ...	5·12	209
Kent	Dover	4·73	285	*Pemb.*	Tenby	3·06	133
,,	Edenbridge, Falconhurst	5·26	283	*Radnor*	Tyrmynydd	..	..
Sussex	Compton, Compton Ho.	4·66	210	*Mont.*	Lake Vyrnwy	7·93	246
,,	Worthing, Beach Ho. Pk.	3·65	221	*Mer.*	Blaenau Festiniog ...	9·02	160
Hants.	St. Catherine's L'thouse	3·12	190	,,	Aberdovey	4·80	191
,,	Southampton (East Pk.)	4·25	213	*Carn.*	Llandudno	1·91	107
,,	South Farnborough ...	3·50	200	*Angl.*	Llanerchymedd ...	3·35	143
Herts.	Harpenden, Rothamstead	4·56	234	*I. Man*	Douglas, Borough Cem.	2·65	106
Bucks.	Slough, Upton	3·39	237	*Wigtown*	Newton Stewart ...	3·26	123
Oxford	Oxford, Radcliffe ...	4·47	239	*Dumf.*	Dumfries, Crichton R.I.	2·57	93
N'hants.	Wellingboro' Swanspool	3·22	166	,,	Eskdalemuir Obsy. ...	4·10	124
Essex	Southend, W. W. ...	4·21	290	*Roxb.*	Crailing...	2·06	102
Suffolk	Felixstowe	2·19	166	*Peebles*	Stobo Castle	2·93	129
,,	Lowestoft Sec. School ...	1·61	100	*Berwick*	Marchmont House ...	1·85	75
,,	Bury St. Ed., Westley H.	2·26	124	*E. Loth.*	North Berwick Gas Wks.	1·91	97
Norfolk	Sandringham Ho. Gdns.	2·23	122	*Midl'n.*	Edinburgh, Blackf'd. H.	2·11	103
Wilts.	Aldbourne	5·37	258	*Lanark*	Hamilton W. W., T'nhill	3·38	141
Dorset	Creech Grange... ...	4·64	227	*Ayr*	Colmonell, Knockdolian	..	..
,,	Beaminster, East St. ...	4·48	217	,,	Glen Afton, Ayr San. ...	4·07	136
Devon	Teignmouth, Den Gdns.	3·61	197	*Renfrew*	Greenock, Prospect Hill	4·56	140
,,	Ilfracombe	3·81	185	*Bute*	Rothesay, Ardencraig ...	3·72	125
,,	Princetown	8·70	203	*Argyll*	Morven, Drimnin ...	2·88	89
Cornwall	Bude, School House ...	2·89	157	,,	Poltalloch	3·11	108
,,	Penzance	4·24	192	,,	Inveraray Castle ...	4·40	112
,,	St. Austell	4·40	182	,,	Islay, Eallabus	2·75	104
,,	Scilly, Tresco Abbey ...	3·87	229	,,	Tiree	1·97	79
Somerset	Taunton	3·47	203	*Kinross*	Loch Leven Sluice ...	2·70	111
Glos.	Cirencester	4·90	238	*Fife*	Leuchars Airfield ...	2·02	104
Salop	Church Stretton ...	5·30	209	*Perth*	Loch Dhu	5·27	117
,,	Shrewsbury, Monkmore	3·95	203	,,	Crieff, Strathearn Hyd.	2·54	102
Worcs.	Malvern, Free Library...	5·18	240	,,	Pitlochry, Fincastle ...	2·28	108
Warwick	Birmingham, Edgbaston	5·17	219	*Angus*	Montrose, Sunnyside ...	1·58	77
Leics.	Thornton Reservoir ...	4·40	219	*Aberd.*	Braemar	2·05	86
Lincs.	Boston, Skirbeck ...	2·55	145	,,	Dyce, Craibstone ...	3·07	120
,,	Skegness, Marine Gdns.	3·30	194	,,	New Deer School House	3·78	173
Notts.	Mansfield, Carr Bank ...	..	..	*Moray*	Gordon Castle	3·36	158
Derby	Buxton, Terrace Slopes	5·49	177	*Nairn*	Nairn, Achareidh ...	2·06	116
Ches.	Bidston Observatory ...	2·58	136	*Inverness*	Loch Ness, Garthbeg ...	3·55	143
,,	Manchester, Ringway...	2·64	125	,,	Glenquoich	5·49	100
Lancs.	Stonyhurst College ...	3·57	125	,,	Fort William, Teviot ...	3·42	87
,,	Squires Gate	1·83	88	,,	Skye, Broadford ...	2·78	66
Yorks.	Wakefield, Clarence Pk.	2·80	142	,,	Skye, Duntuilm ...	3·28	115
,,	Hull, Pearson Park ...	3·33	173	*R. & C.*	Tain, Mayfield... ...	2·41	117
,,	Felixkirk, Mt. St. John...	2·06	110	,,	Inverbroom, Glackour...	4·75	158
,,	York Museum	2·19	110	,,	Achnashellach	5·97	141
,,	Scarborough	3·27	171	*Suth.*	Lochinver, Bank Ho. ...	2·56	101
,,	Middlesbrough... ...	2·00	104	*Caith.*	Wick Airfield	2·55	123
,,	Baldersdale, Hury Res.	2·89	117	*Shetland*	Lerwick Observatory ...	2·00	96
Norl'd.	Newcastle, Leazes Pk....	1·78	90	*Ferm.*	Crom Castle	3·49	126
,,	Bellingham, High Green	2·33	97	*Armagh*	Armagh Observatory ...	2·76	116
,,	Lilburn Tower Gdns. ...	2·25	97	*Down*	Seaforde	2·90	110
Cumb.	Geltsdale	2·34	91	*Antrim*	Aldergrove Airfield ...	2·57	113
,,	Keswick, High Hill ...	6·08	191	,,	Ballymena, Harryville...	2·78	97
,,	Ravenglass, The Grove	2·00	71	*L'derry*	Garvagh, Moneydig ...	3·41	123
Mon.	A'gavenny, Plâs Derwen	6·61	223	,,	Londonderry, Creggan	3·42	131
Glam.	Ystalyfera, Wern House	6·68	191	*Tyrone*	Omagh, Edenfel ...	2·84	110

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