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AIR WAVES FROM A VOLCANIC EXPLOSION

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On reading in *The Times* of 23 April 1957 that the explosion of the volcano Bezyymyannaya Sopka in Kamchatka (55°57′N., 160°32′E.) at 0611 G.M.T. on 30 March 1956 was reported by Prof. Gorshkor, Head of the Kamchatka Vulcanological Station to have "exceeded several dozen times the strength of explosion of an ordinary atom bomb", it was realized that the explosion might well have produced air waves of the types recorded after the explosion of Krakatoa[1] and of nuclear weapons.[2] The microbarograph record from Kew Observatory for the day in question was examined and a fairly prominent disturbance was found at about the expected time of arrival of the air wave (see Figure 1). Similar pulses, occurring at the same time, are just visible on the float-barograph and photo-barograph traces, but are too small for reproduction.

Microbarograph movements of this size are quite common as a result of local meteorological disturbances, but some confirmation that Figure 1 indeed shows an effect of the volcanic explosion was found from the records of Eskdalemuir and Lerwick Observatories. The microbarogram from Eskdalemuir, also reproduced in Figure 1 has less background disturbance than Kew's and shows a clear pulse about 20 minutes earlier than the one at Kew. The Lerwick microbarograph was adjusted to a low sensitivity at the time, but the float-barogram has a small clear pulse of the same form as at Kew but nearly an hour earlier.

On all the records the clearest feature is the rapid fall of pressure, amounting to about 0·2 millibars towards the end of the pulse. From the Kew micro-barogram the start of the disturbance appears to be 12 minutes earlier than this fall. The records were therefore measured to find the times of rapid fall, clock corrections were applied as necessary, and 12 minutes was subtracted from each time to obtain the times of arrival given in the following table.

Place	Time of arrival	Travel time from 0611 G.M.T.	Distance from volcano	Average speed
	G.M.T.	min.	Km.	m/sec.
Lerwick	1208	357	7050	329
Eskdalemuir	1240	389	7630	326
Kew	1300	409	8000	326

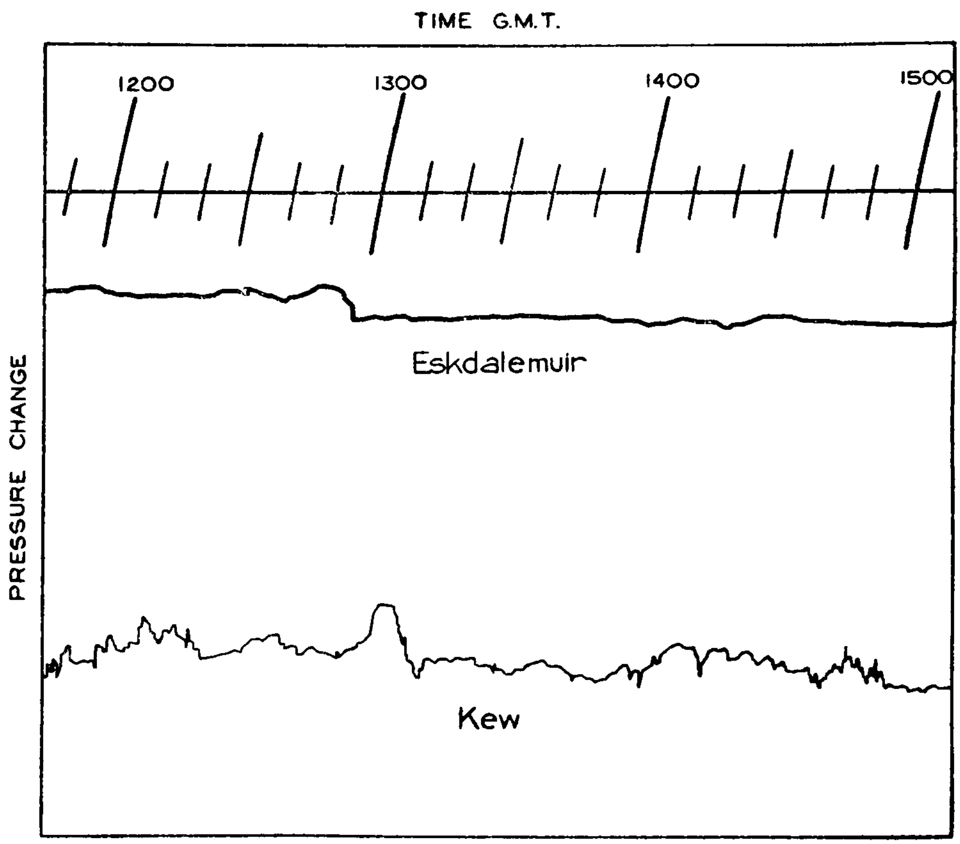

FIGURE I—MICROBAROGRAMS FOR KEW AND ESKDALEMUIR FOR 30 MARCH 1956
Vertical scale: 1 cm. represents 0·26 mb. on the Kew trace and 0·33 mb. on the Eskdalemuir trace.

A careful examination of the Kew seismograms for the relevant time was made but no clear signs of waves from the volcanic explosion could be seen; very small movements between 0650 and 0700 may represent the arrival of "surface" waves, but the identification is quite uncertain.

The Kew microbarograms have also been examined for signs of air waves from the various thermonuclear test explosions that have been reported.[2] Unfortunately there was a considerable background of local disturbances at all the expected times of arrival and there is only one occasion, at 0532 on 5 May 1954, when a pulse on the record (actually a rapid fall in pressure of about 0·2 millibars, followed by an irregular train of waves) can be ascribed with any confidence to one of the reported explosions.

The theory of travelling air waves of long wavelength has been extensively studied.[3, 4, 5] The ordinary theory of sound waves can only be used so long as the restoring force per unit displacement does not vary appreciably in one wavelength. In the atmosphere the restoring force for vertical displacements contains a gravity component which depends on the temperature gradient and must be taken into account for waves longer than a few kilometres (that is with periods greater than about 10 seconds). The difference between sound waves and "long" waves is important in considering transmission to great distances because the waves are affected differently by changes in temperature with height. The stratosphere, for instance, presents no barrier to sound waves (though they may be reflected from higher levels) but it effectively prevents the escape of sufficiently long waves, which can be "trapped" in the troposphere and travel long distances without great loss of energy. The transmission can be thought of as a pattern of reflections between ground and tropopause, somewhat analogous to the transmission of electromagnetic waves in a waveguide, and can occur in a number of patterns or "modes", each with a characteristic velocity of propagation and "cut-off frequency", above which the waves are not transmitted.

Calculations of the velocity and the form of the waves that would be transmitted in atmospheres with various types of temperature structure have been made in the papers quoted. For the more realistic atmospheres and the most important mode of propagation the result is that long waves should travel at a speed intermediate between the velocity of sound at ground level (about 330 metres per second) and at the tropopause (about 300 metres per second); the effects of wind are usually neglected in the theory. The form of the pressure wave received at any point depends partly on the cause of the wave—whether it is a sudden explosion or a relatively prolonged outrush of hot gases—and partly on the properties of the atmosphere, which is more readily excited at some frequencies than others and which transmits high frequencies rather more slowly than low ones. In most records of long waves attributable to explosions the period of the main waves is several minutes and is probably associated with the natural period of vertical oscillation of the atmosphere whose existence was pointed out by Brunt.[6]

The energy in the air waves can readily be calculated from the observed pressure waves at the ground provided some assumption is made about the way in which the energy varies with height. Making the same assumption as Pekeris,[1] the energy in the waves shown in Figure 1 is found to be about 1×10^{21} ergs, considerably less than the energy in the Krakatoa air wave but of the same order as in the waves from the Great Siberian Meteor and from thermonuclear explosions.[2] Scorer[5] has shown that the energy in the travelling air waves may represent only a small fraction of the total energy of an explosion.

The dust flung high into the atmosphere by the eruption appears, as described in this Magazine by Bull and James,[7] to have reached the stratosphere over the British Isles.

Note added, October 1958. Two recent Kew records, for 28 June and 12 July 1958, show characteristic wave trains of the type described by Yamamoto[2], presumably caused by the reported test explosions in the Pacific on these dates.

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THE PREPARATION AND USE OF CHARTS OF THE DISTRIBUTION OF RELATIVE VORTICITY

By B. G. WALES-SMITH

Summary.—The distribution of vorticity (by which latter is here meant the vertical component of the geostrophic vorticity relative to the earth) in a given 1000-millibar surface is determined by means of a graphical technique.[1,2] This distribution is compared with that published for the same set of contours in a paper by Sawyer[3] and it is shown that the two versions are very similar. Certain apparent practical advantages of the graphical method are discussed.

The graphical methods of producing actual and prognostic patterns of vorticity are described. An analysis of 24-hour forecasts of the distribution of vorticity at 500 millibars is made. A reasonably satisfactory degree of success is shown to have been attained in these forecasts.

A brief appendix deals with the relationship between vorticity and the shear and curvature properties of contour charts.

1. **The production of vorticity charts by Fjørtoft's graphical technique.**—The vorticity of fluid motion specifies the local rotation of a fluid element and may be defined as twice the local average angular velocity of such a small element of the fluid.

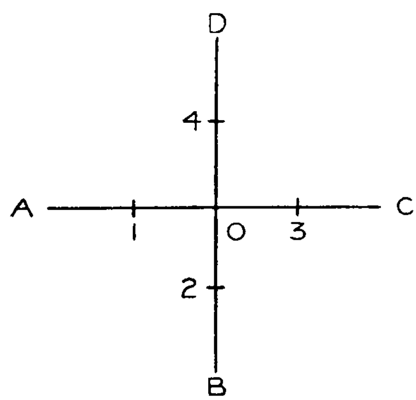


FIGURE 1—GRID POINTS

Let O, A, B, C, D (Figure 1) be points on a constant pressure surface such that OA = OB = OC = OD = d, AC and BD are at right angles and points 1, 2, 3, 4 are mid points of OA etc. The vertical component ζ of the relative vorticity at O is given by $\partial v/\partial x - \partial u/\partial y$ which can be expressed in finite differences as

$$\zeta = \frac{V_3 - V_1}{d} - \frac{U_4 - U_2}{d},$$

where U is the wind component in the x direction AO and V is in the y direction BO.

Since the geostrophic value of U_2 may be expressed as

$$\frac{g}{f}\,\frac{Z_B - Z_O}{d},$$

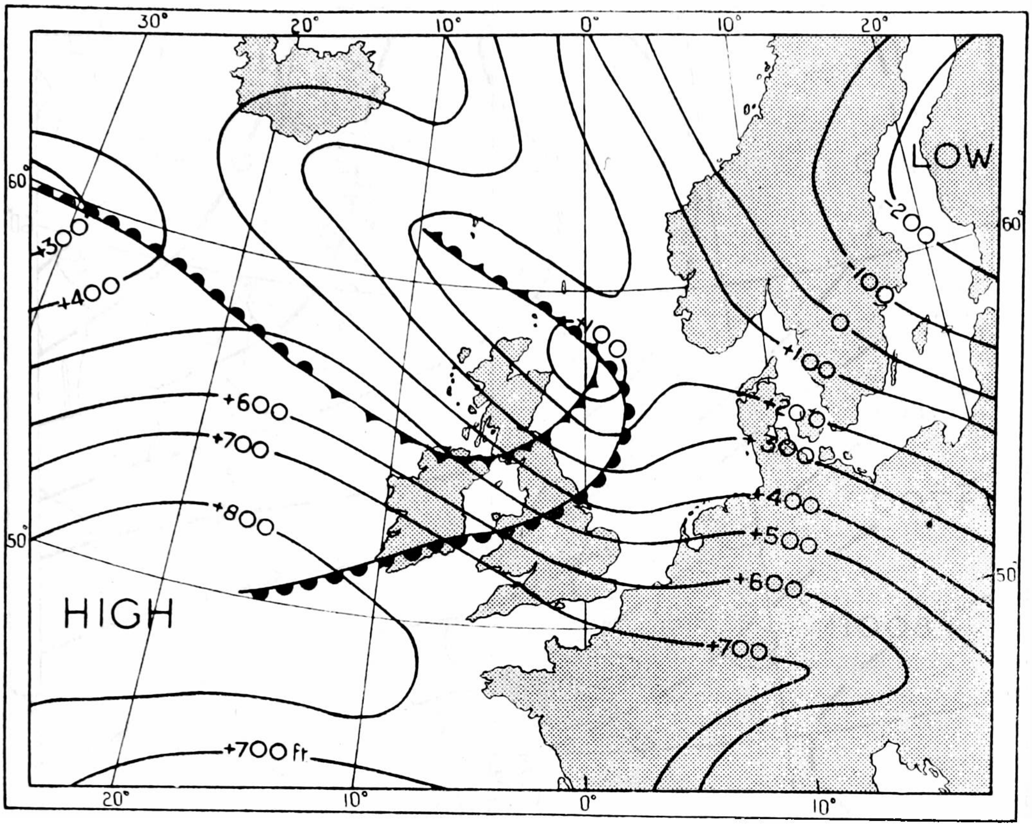


FIGURE 2—1000-MB. CONTOURS, 0300 G.M.T., 16 MARCH, 1949

where f is the Coriolis parameter and z_B the height of the isobaric surface at B, and so on: then the vorticity at O may be expressed in terms of heights as

$$\zeta = \frac{g}{fd^2}\,(z_A+z_B+z_C+z_D-4z_o)$$

$$= \frac{4g}{fd^2}\,(\tfrac{1}{4}\overline{z_A+z_B+z_C+z_D}-z_o). \qquad \ldots . (1)$$

If we treat the quantity $4g/fd^2$ as constant (that is we neglect the variation of f with latitude) we can represent the vorticity field of a height field by the distribution of $\bar{z}-z$; where

$$\bar{z} = \tfrac{1}{4}[z(x-d, y) + z(x+d, y) + z(x, y-d) + z(x, y+d)].$$

Using formula (1), arithmetical computations may be made for any desired number of points O, separately. This is the method used by Sawyer.[3] However, applying this method to a large area is a lengthy task and, in particular, great care has to be exercised in the selection of regions of the contour map requiring a specially detailed network of vorticity measurements. Fjørtoft[1] has given a much more economical graphical method of obtaining the vorticity field over a whole chart by the field of $z-\bar{z}$. The method requires two identical versions of the original z (contour height) chart. (Note it is convenient to use three sheets of transparent material; if these are not of chart size they must have position indicators for registering with the chart.) The method proceeds thus:

(i) Displace the two copies of the contour chart a distance $2d$ apart in the x direction (a choice of $2d = 12°$ of longitude in 60° latitude or approxi-

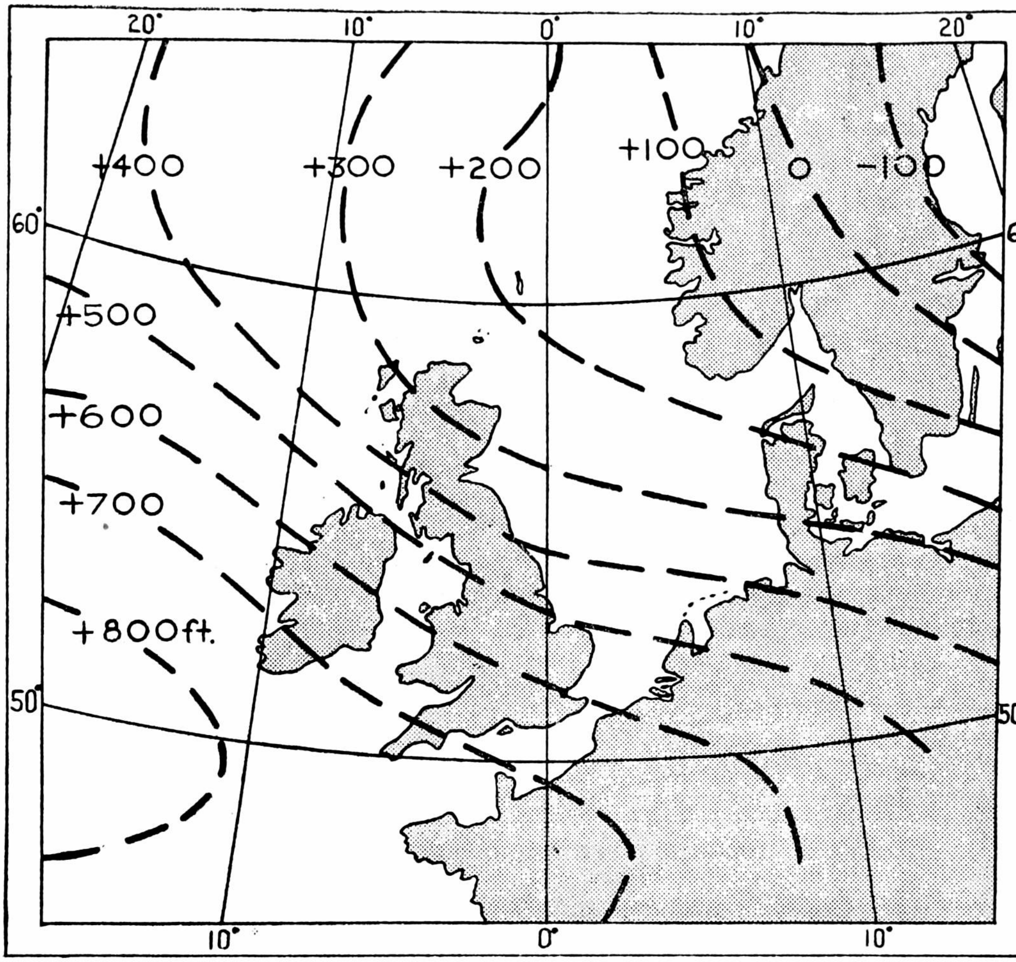


FIGURE 3—"SPACE MEAN" VERSION OF THE 1000-MB. CONTOUR FIELD, 0300 G.M.T., 16 MARCH 1949

mately 360 nautical miles is recommended) and form the mean of the two height fields on a sheet placed centrally between them by graphical addition of alternate lines (i.e. 18,200-foot mean contour crosses intersections 186/178, 184/180, 182/182 etc.). This gives $\frac{1}{2}[z(x-d, y)+z(x+d, y)]$.

(ii) Displace the two copies by $2d$ in the y direction and mean graphically to obtain $\frac{1}{2}[z(x, y-d)+z(x, y+d)]$.

(iii) Form the mean of the resulting charts. This gives the field of $\bar{z}$. (This is a horizontal space average of the heights, often called the "space mean". The small-scale perturbations have been removed leaving a smoothed flow.)

(iv) Graphically subtract the $\bar{z}$ chart from the original z (contour height) chart.

The resulting chart shows the field of Kx (vorticity) where K is the factor $-4g/fd^2$ regarded as constant over the chart. Vorticity has dimensions 1/T but it is convenient to represent it by the chart produced by process (iv) with isopleths in feet. Since K is a negative factor the sign of the vorticity is opposite to that of the plotted isopleths.

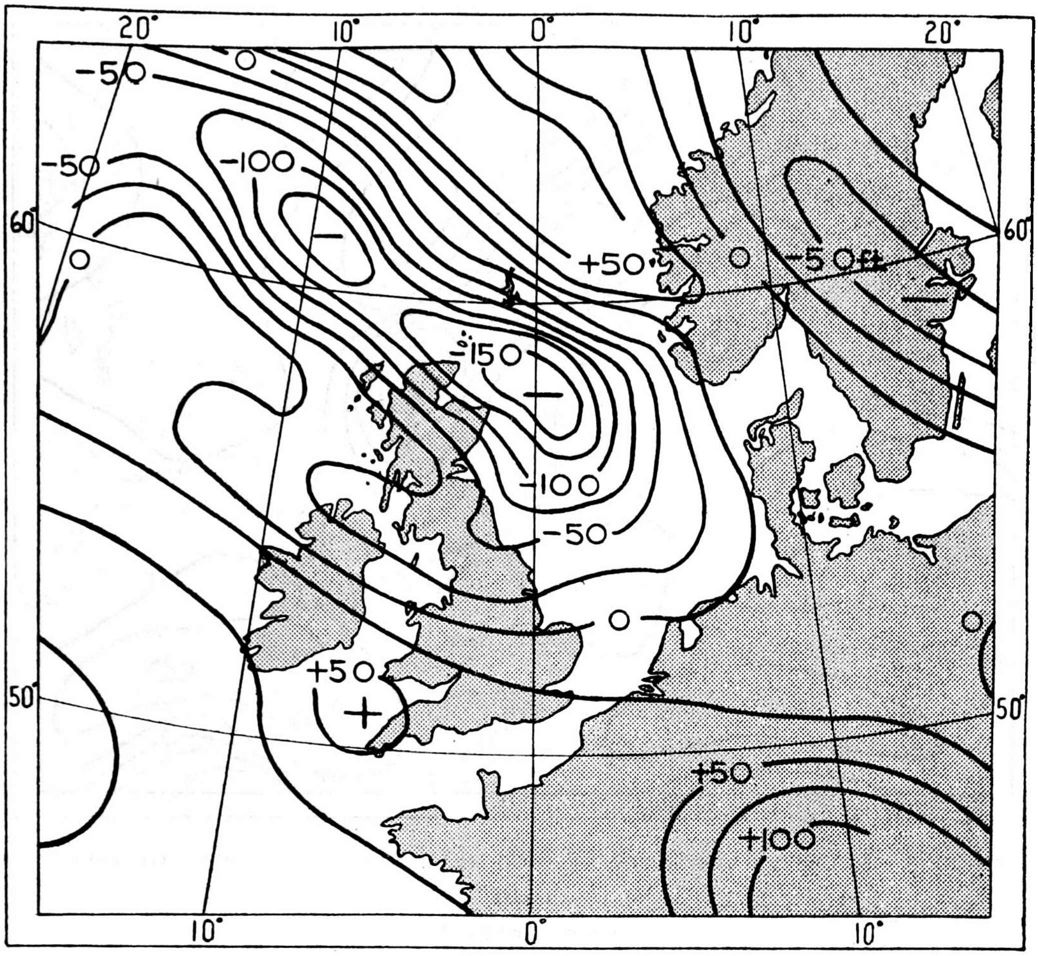


FIGURE 4—RELATIVE VORTICITY AT 1000-MB. LEVEL, 0300 G.M.T., 16 MARCH 1949
Units: feet

2. **Arithmetical and graphical methods compared.**—Figure 2 shows the 1000-millibar contour analysis at 0300 G.M.T. on 16 March 1949. The graphical process detailed above was carried out to produce Figure 3, the $\bar{z}$ chart, and Figure 4, the vorticity or $z-\bar{z}$ chart.

Figure 5 shows the distribution of vorticity in the same contour field as produced by the arithmetical method.[3] It will be seen that there is little significant difference between the two vorticity charts. The values of Figure 5 are numerically larger than those of Figure 4 and generally of opposite sign. The reason for sign reversal has been seen at the end of the last section. Both methods use a grid length of about 200 nautical miles. It will be seen, however, that the likeness between Figures 4 and 5 decreases near the edges of the pictures. This is because the contour field available for graphical treatment covered only the same chart area as the arithmetically produced vorticity isopleths and thus it was impossible to apply the graphical method with confidence over the whole area.

These techniques are, of course, applicable to any level in the atmosphere.

3. **Prognostic applications.—Theory.**—Only a reminder of the essentials of the theory will be given here—for a complete treatment the reader is referred to the original papers or for example Petterssen.[4]

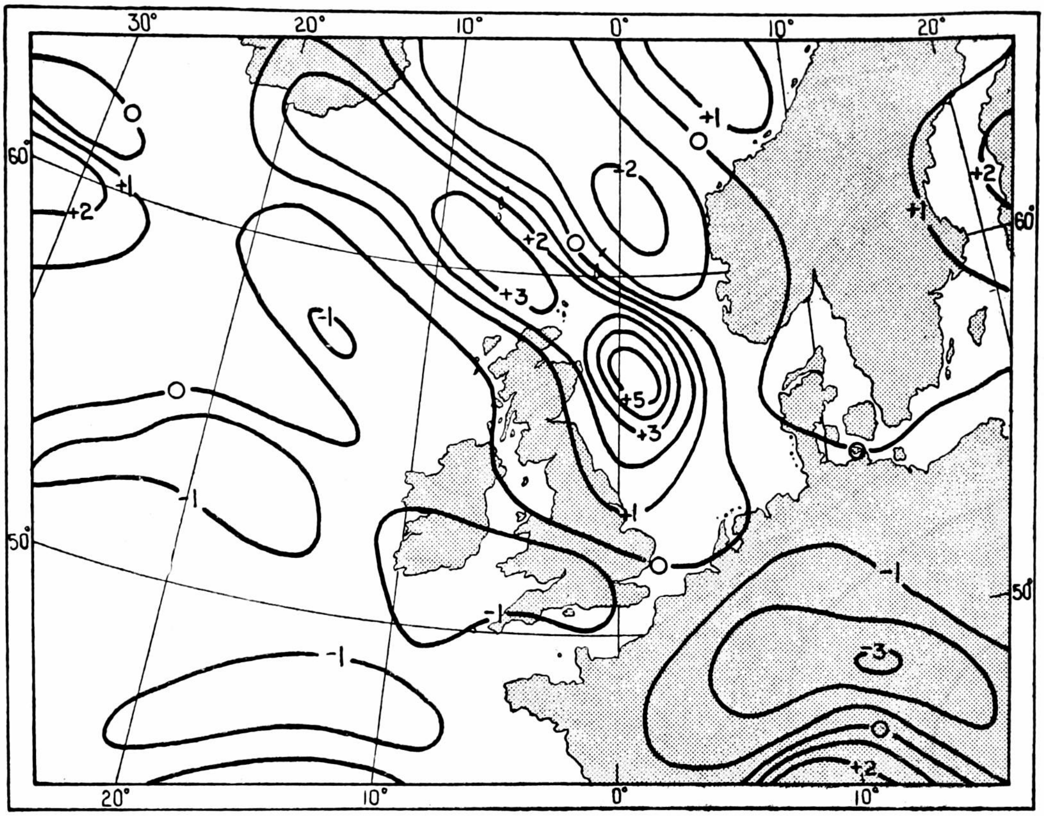


FIGURE 5—RELATIVE VORTICITY AT 1000-MB. LEVEL, 0300 G.M.T., 16 MARCH 1949

Units: 10^{-1} hr.$^{-1}$

The vertical component of the absolute vorticity of a moving parcel of air is given by $\zeta + f$, where ζ is the vorticity relative to the earth and f (the Coriolis parameter) is the "local vorticity of the earth". The vorticity equation, which is believed to be a good approximation for large-scale atmospheric motions, states that the rate of change with time of the absolute vorticity of a parcel of air is equal to the product of the absolute vorticity and the divergence, that is

$$\frac{d}{dt}(\zeta+f) = -\,(\zeta+f)\,)\text{ div } V, \qquad \ldots . (2)$$

where V is the horizontal wind velocity. (This means that increasing cyclonic vorticity of a parcel must be accompanied by convergence and so on.)

If now we consider flow at a given pressure level, that is, we neglect vertical transfer, and we restrict ourselves further to a level where the flow is non-divergent (i.e. div $V = 0$)—this level is usually assumed to be near 500 millibars —then (2) becomes

$$\frac{d}{dt}(\zeta+f) = 0, \qquad \ldots . (3)$$

that is with these assumptions parcels moving in the 500-millibar surface conserve their absolute vorticity; or, in other words the vorticity pattern can be considered to be instantaneously moving with the wind.

Equation (3) can be written in finite differences as

$$\frac{d}{dt}\,(z-\bar{z}-G) = 0, \qquad \ldots\ldots (4)$$

for we have already seen that the field of geostrophic relative vorticity can be represented by the field of $z-\bar{z}$. The term G is the contribution due to the earth's rotation

$$G = \int_0^{\varphi} \frac{f^2 d^2}{4gm^2} \cot \phi d\phi,$$

where m is the chart magnification factor and ϕ is the latitude. The G field is a height field with a weak gradient from north to south corresponding to an easterly geostrophic wind of about 6 knots.

We can now forecast a future field of $z-\bar{z}-G$ by advecting the present field with the geostrophic wind given by the z contours. But we can do this only for a short time ahead (say one hour) because the z field is itself changing, slowly or rapidly according to the situation. To proceed in steps of only one hour or less, integrating at each step from a forecast vorticity field to a forecast height field at 500 millibars and then repeating the process over, say, 24 hours would involve calculations so numerous that these could be handled sufficiently expeditiously only by an electronic computer. In order to get around this difficulty Fjørtoft suggests that if we can replace the advecting field z by an equivalent advecting field which is much more slowly varying with time than the z field, then we may be justified in using a much longer time step (24 hours in one step is the aim). Such an equivalent advecting field could be the field of $z-(z-\bar{z}-G)$ that is $\bar{z}+G$, because advecting the field of $z-\bar{z}-G$ with the geostrophic wind given by the $z-\bar{z}-G$ contours produces no additional change. Thus we might expect to obtain a reasonable approximation to the absolute vorticity field at 500 millibars in 24 hours time by advecting the present vorticity field with the wind given by the present $\bar{z}+G$ field for 24 hours in one step.

4. **24-hour forecasts of relative vorticity fields at 500 millibars.**—The adaptation of the theory used by the present writer is that given in the *Strategic Air Command Forecasting Manual.*[2] This makes no direct use of the G field, variations in f being catered for as indicated below:

(i) The relative vorticity field as represented by $z-\bar{z}$, is advected with only 80 per cent of the wind normal to it as given by the "space mean" $\bar{z}$ field. The 80 per cent is advocated because experience has shown this to give better results—presumably this is because of neglect of the G field (easterly component of 6 knots) and the fact that 500 millibars is rather above the level at which the motion is normally considered to be non-divergent. In the trial, the results of which are given later, it was considered that some allowance should be made in cases where the $\bar{z}$ contours were strongly curved. Curvature corrections to the "space mean wind" were made in such cases, employing conventional methods.

(ii) In cases of zonal advection of vorticity patterns the values are not modified.

(iii) In poleward advection, centres of anticyclonic vorticity are increased and centres of cyclonic vorticity are decreased in central value; and vice-versa for equatorward advection.

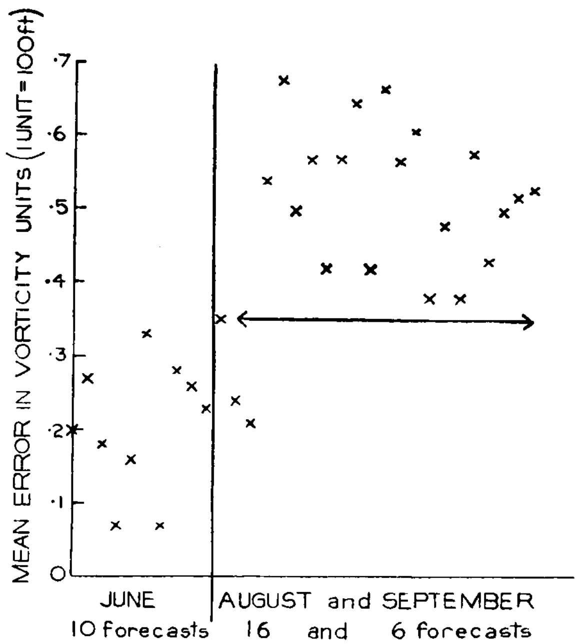


FIGURE 6—ERRORS IN FORECASTS

Note. The words "increase" and "decrease" refer to absolute magnitude, that is, decreases are toward zero and vice-versa.

The modifications called for in (ii) and (iii) are, of course, direct consequences of the condition of non-divergence,

$$\frac{d}{dt}(\zeta+f) = 0, \text{ or } \zeta+f = \text{constant},$$

following the motion (f increases polewards). In the trial the modifications were applied subjectively but were normally quite small, rarely amounting to a change of more than 30 per cent of the initial value at a centre. Speed and angular departure from zonal motion were the quantitative guides to modification.

5. **Analysis of 24-hour forecasts of the distribution of relative vorticity at 500 millibars.**—A short trial was carried out to determine the accuracy with which 24-hour vorticity forecasts could be made using the simple technique outlined above and to gain experience in both the evaluation and prognosis techniques.

Ten forecasts were made in June, sixteen in August and six in September 1955. A larger number of forecasts would have been desirable but staffing limitations prevented this. However, it is thought that the material available justifies a preliminary survey.

The first ten forecasts were made from 500-millibar contour patterns for 0200 G.M.T. broadcast from Dunstable. The vorticity patterns obtained from these reproduced charts did not show strongly marked features and it was thought that smoothing by the original analysts, the effects of coding, decoding and plotting might be the cause of this. The August and September forecasts were made from locally analysed 500-millibar charts which extended much further eastwards than the broadcast analyses. The *S.A.C. Manual* advocates a very detailed analysis of the basic contour chart and every attempt was made to

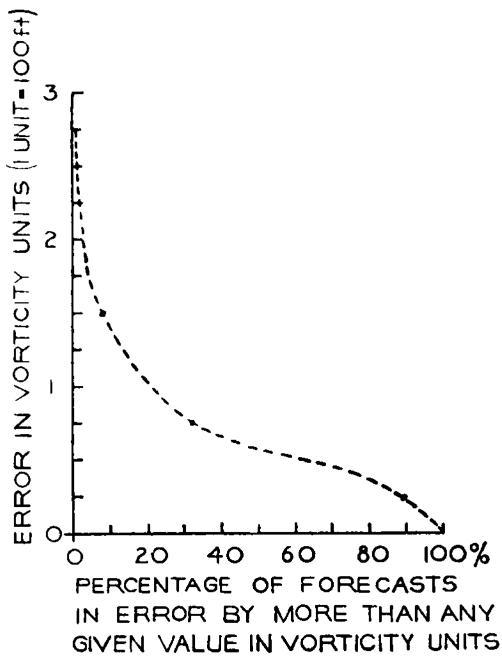


FIGURE 7—PERCENTAGES OF ERRORS IN VORTICITY UNITS FOR 2,043 "SPOT" FORECASTS

follow this advice. The change in method produced immediate results in the form of quite definite and strongly featured vorticity patterns.

Actual vorticity fields were traced on to the corresponding contour charts (in broken red lines) as also were the forecast vorticity fields (in broken blue lines). Thus direct daily comparisons could be made between "Actual" and "Forecast".

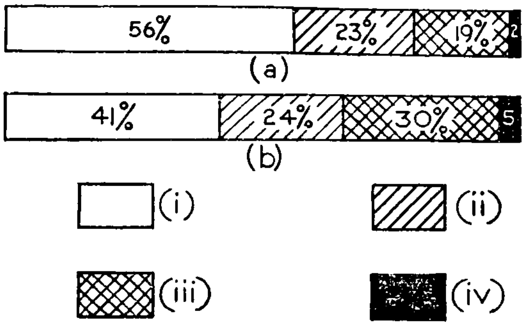
(*a*) *Evaluation of errors in forecasts.*—A "100-point" overlay (using intersections of convenient meridians and parallels) was constructed from transparent material. Differences between actual and forecast values of vorticity were read off at all points and tabulated as actual differences (for example forecasts $+2$; actual -1; error 3). The errors for each day were totalled and divided by the number of points used (on some days the full 100-point grid could not be used). The results are shown in Figure 6. It will be seen that error values rose sharply when the larger charts and more specialized analyses were introduced. The basic analyses, vorticity measurements and vorticity forecasts were made by three forecasters (including the writer) on different days. None of us was able to claim any systematic improvement in his forecasts.

Figure 7 uses point comparisons from August and September charts only, which provided a total of 2,043 "spot" forecasts. It will be seen that really large errors represent less than 10 per cent.

(*b*) *Movement and development of individual vorticity centres.*—106 (70 cyclonic and 36 anticyclonic) cases were examined. The comparison between occurrences and forecasts is made in Figures 8, 9, 10, 11.

(i) Movement—Average speed over 24 hours. (Figure 8). The average speed of anticyclonic vorticity centres was forecast more accurately than that of cyclonic centres. There does not seem to be any real bias towards over- or under-forecasting average speeds.

(ii) Movement—Direction—Bearing of position at end of 24 hours taken from position at beginning of period (Figure 9). As with forecasts of average



(a) Anticyclonic centres (36 cases).
(b) Cyclonic centres (70 cases).
Forecast speed (i) within 10 per cent, (ii) less than 60 per cent, (iii) greater than 130 per cent of actual speed. Cases (iv) where direction was badly in error, or where no movement was forecast and occurred or where movement was forecast but failed to occur.

FIGURE 8—FORECASTS OF AVERAGE SPEED OF VORTICITY CENTRES OVER 24 HOURS

speeds better results were obtained in forecasting directions for anticyclonic centres than for cyclonic centres.

(iii) Development—Forecast actual changes in central values of individual vorticity centres (Figure 10). Regarding bad forecasts as those giving increase for decrease or vice-versa we can say that the development forecasts were tolerably successful.

(iv) Development—Forecast and actual central values of individual vorticity centres (Figure 11). Here, again, forecasts for anticyclonic centres were more successful than for cyclonic centres.

6. **Relation between change of latitude and development.**—In paragraph 4 we saw that, on the assumption that the flow at 500 millibars is non-divergent, motion with a meridional component (changing Coriolis parameter) should be accompanied by a change in relative vorticity. Table 1 below shows the result of an examination of the movement and behaviour of the 106 vorticity centres considered. (The very few cases where no motion occurred are included in the West/East bracket.)

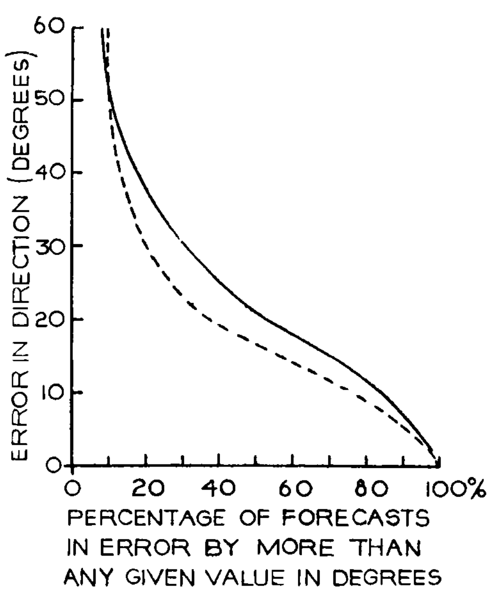


FIGURE 9—PERCENTAGES OF ERRORS IN FORECASTS OF DIRECTION OF MOVEMENT OF 70 CYCLONIC AND 36 ANTICYCLONIC VORTICITY CENTRES

———— Cyclonic centres — — — — — Anticyclonic centres

NOTE: The very few cases in which movement was forecast and failed to occur or vice-versa are included under "direction in error by more than 60°".

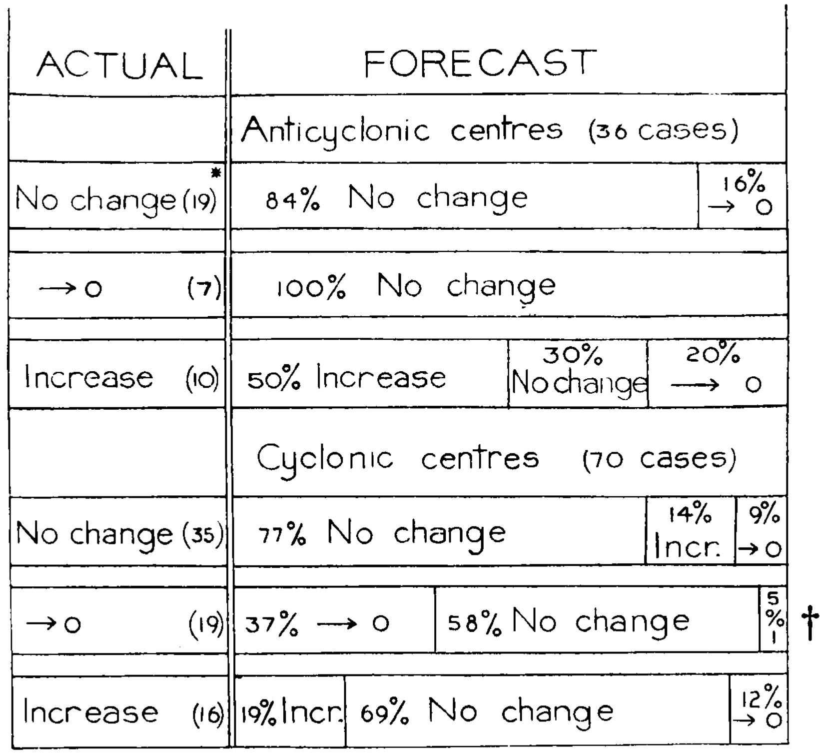


FIGURE 10—FORECASTS OF DEVELOPMENT OF VORTICITY CENTRES

* Number of cases.

†This value should read 5% increase.

TABLE I—BEHAVIOUR OF VORTICITY CENTRES (ACTUAL)

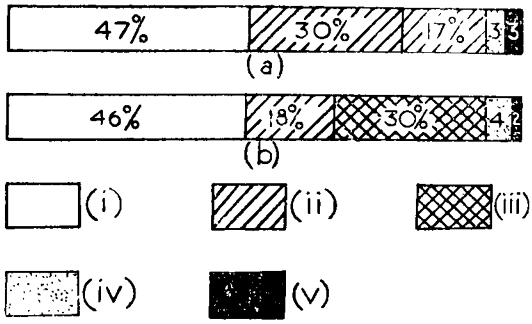
No. of cases	Direction of movement	Increase %	No change %	Decrease %
		Cyclonic Centres		
28	North	21	(43)	36
27	West/East	7	(63)	30
15	South	(53)	40	7
		Anticyclonic Centres		
8	North	(62)	25	13
17	West/East	18	(53)	29
11	South	18	(73)	9

The percentage in any line which should have been the greatest has been underlined and the actually greatest percentage bracketed.

7. **Forecasting of 500-millibar contour patterns.**—The work described above was not continued to the stage of obtaining forecast 500-millibar contour patterns. This aspect will be dealt with in a forthcoming article by D. G. James and R. C. Smith.

8. **Conclusions.**

(*a*) Forecasts of the distribution of relative vorticity.—On the basis of the very restricted trial described above relatively little can usefully be added to the statements of results. The forecasts were more successful as regards direction and average speed than in development. It should be remembered that the rules of paragraph 4 were followed in all forecasts and that the Table in paragraph 6 shows that the rules failed in some cases (that is the 500-millibar surface was not non-divergent for those cases).



(a) Anticyclonic centres (36 cases).
(b) Cyclonic centres (70 cases).
Forecast value (i) correct (ii) within 25–50 feet (iii) within 75–100 feet (iv) within 125–150 feet (v) within 175–200 feet.

FIGURE 11—FORECASTS OF CENTRAL VALUE OF VORTICITY CENTRES

(*b*) Comparison of the two techniques for plotting the vorticity field.—It has been shown that there is no essential difference between the two methods of obtaining vorticity values, so far as theory is concerned. In practice, however, the graphical (Fjørtoft) method is quicker, easier to operate and almost entirely mechanical, whereas the arithmetical method depends on personal selection of areas of the chart where close networks of measurements are needed, and on the accuracy of numerous interpolations and (simple) computations.

(*c*) The use of relative vorticity charts in practice.—An increasing number of papers dealing with forecasting problems involve techniques which require the evaluation of the relative vorticity at some level in the atmosphere. We may require to know for example whether relative vorticity increases or decreases downstream in a particular area on a contour chart or the location of the line of zero vorticity. Difficulties in subjective estimation of vorticity often arise where shear and curvature are opposed in sense. In using the graphical techniques described it is emphasized that in the final operation of subtracting the $\bar{z}$ chart from the z (contour height) chart, care must be taken to note differences of even less than 25 feet if the zero line is to be placed accurately.

9. **Acknowledgements.**—The writer acknowledges with grateful appreciation much valuable advice and useful criticism from Mr. R. F. Zobel, on whose instructions the trial was carried out and from Mr. R. H. Clements, who suggested the final form in which the material should be published and also several important additions to and changes in the early sections. Thanks are also due to Dr. G. B. Tucker and Mr. W. D. Hyde who drew some of the analyses and carried out the forecasting "drill" on some occasions.

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Appendix

Relationship between vorticity and the shear and curvature properties of a contour chart.

If vorticity is thought of as "spin" it follows that a particle (of air) taking part in curved motion possesses vorticity and that a particle in a field of wind shear similarly possesses vorticity (Figure A).

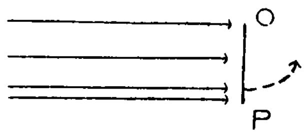

FIGURE A—CYCLONIC SHEAR

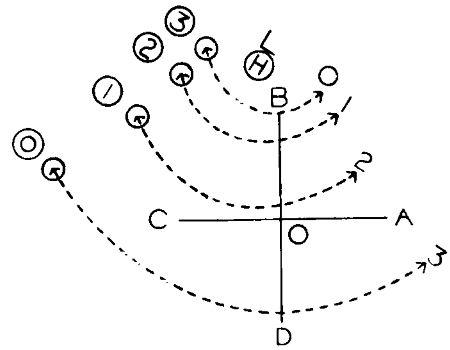

FIGURE B—CONTOURS

OP is regarded as a bar of material hinged at O and placed in air flow having cyclonic shear. The dotted arrow suggests its instantaneous motion.

Thus we may write $$\zeta = \frac{v}{r} + \frac{\partial v}{\partial n},$$

where v is the velocity of the flow, r is the radius of curvature of the flow trajectory and $\partial v/\partial n$ is the gradient of velocity normal to the trajectory.

We are now able to decide, at sight, the sign of the vorticity in all but two of the possible contour forms which appear on working charts and to identify, fairly accurately, the position of vorticity maxima and the location of areas of zero or small vorticity values.

TABLE A.—THE SIGN OF THE VORTICITY BY INSPECTION

Case	Contour Form: Curvature	Contour Form: Shear	Sign of Vorticity
(*a*)	Nil	Nil	Zero
(*b*)	Nil	Cyclonic	+ (*Cyclonic*)
(*c*)	Nil	Anticyclonic	— (*Anticyclonic*)
(*d*)	Depression centre	——	+
(*e*)	Anticyclone centre	——	—
(*f*)	Cyclonic	Nil	+
(*g*)	Anticyclonic	Nil	—
(*h*)	Cyclonic	Cyclonic	+
(*i*)	Anticyclonic	Anticyclonic	—
(*j*)	Cyclonic	Anticyclonic	?
(*k*)	Anticyclonic	Cyclonic	?

The results given for cases (*a*) to (*i*) may be checked by the finite difference method in the manner shown below to examine cases (*j*) and (*k*). Cases involving either convergent or divergent flow may be examined in the same way when it will be found that the results given above depend only on shear and curvature.

Figure B shows a set of contours (numbered arbitrarily) which possess cyclonic curvature and anticyclonic shear using the "open" numbers and symbols, and anticyclonic curvature and cyclonic shear using the ringed numbers and symbols. It will be seen that in this particular example shear is the stronger component of vorticity.

$$\zeta = +(h_A + h_B + h_C + h_D - 4h_O)$$

"Open" symbols $+\ (2\tfrac{1}{2} + 0 + 2\tfrac{1}{2} + 3 - 4 \times 2\tfrac{1}{4}) = -1$ Anticyclonic

"Ringed" symbols $+\ ((\tfrac{1}{2}) + (3) + (\tfrac{1}{2}) + (0) - 4 \times (\tfrac{3}{4})) = +(1)$ Cyclonic

RECORD LOW TEMPERATURE AT SHAWBURY

By J. G. GALLAGHER

The lowest temperature ever recorded at Shawbury (height 245 feet), namely −3·3°F., occurred at 0600 G.M.T. on 24 January 1958. A fairly reliable thermometer in a local frost hollow which is approximately 50 feet lower than the airfield and towards the bed of the River Tern recorded − 5°F., equal to the lowest temperature ever recorded at a low-level station in England.[1] The minimum ground temperature recorded was − 9°F.

The sequence of three-hourly observations commencing at 1200 G.M.T. on 23 January was as follows:

Time (G.M.T.)	1200	1500	1800	2100	2400	0300	0600	0900	1200
Temperature (°F.)	27	23	11	09	01	−01	−03	−01	16

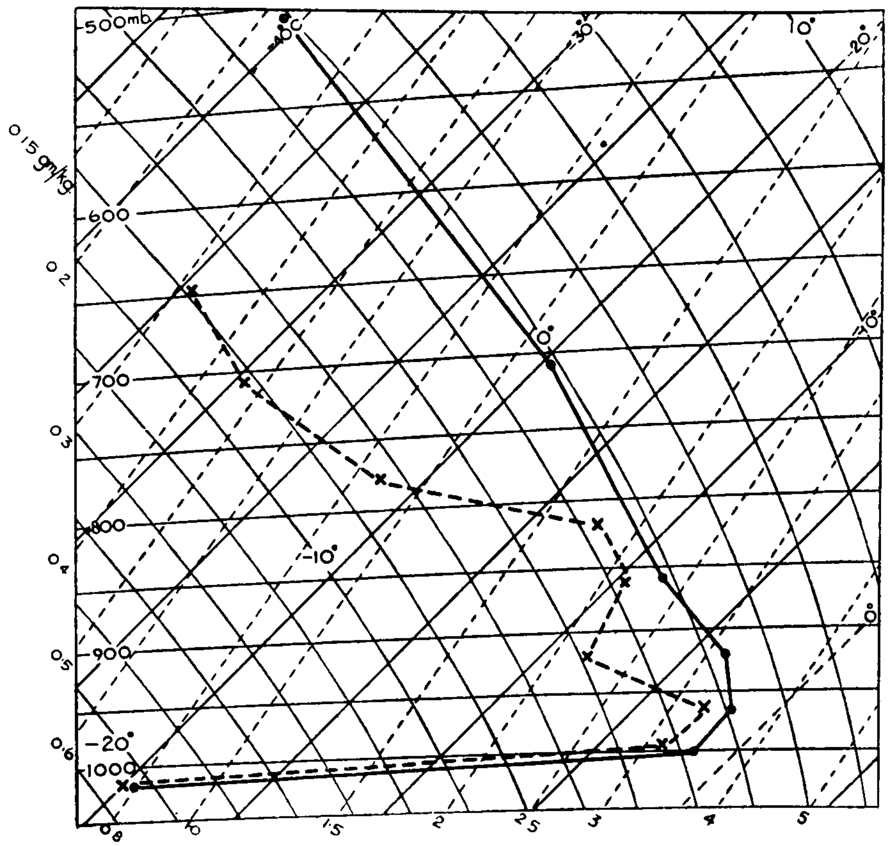

FIGURE 1—TEPHIGRAM FOR LIVERPOOL, 2300 G.M.T. ON 23 JANUARY 1958

In the same period other lowest recorded minimum temperatures occurred at Driffield on the night of 20 January, and Dyce on the night of 24 January. In both cases the minimum air temperature was – 2°F.

Synoptic situation.—A northerly polar maritime airstream persisted for several days before 24 January. At times it was temporarily distorted by polar depressions, one of which was responsible for a fall of 10 centimetres of snow at Shawbury on 22 January.

On the 24th, a weak ridge from an anticyclone over Spain was moving eastward across the country in the rear of a similar polar disturbance moving up the English Channel, and in these conditions with clear skies discernible through radiation fog, no surface wind, and over 10 centimetres of lying snow, this extreme low temperature was recorded.

Upper air.—The Liverpool ascent for 2300 G.M.T. 23 January 1958 is considered representative of the Arctic nature of the air mass (Figure 1). On this has been superimposed the surface temperature of – 20°C. (– 3·3°F.) demonstrating the magnitude of the surface inversion.

The upper air temperatures indicate that the air was of fairly recent Arctic origin (1000—500-millibar thickness, 5136 metres) and so extremely unstable that temperature in the lower layers was barely increased by sea surface heating.

Effect on visibility.—Ice-crystal and water fog patches formed suddenly in "bright sunshine" as the temperature increased to 20°F. at 0907 G.M.T. on the 23rd, and reformed when the temperature fell to 20°F. at 1535 G.M.T. Both

The Herts. Advertiser

BLOWING SNOW ON THE ST. ALBANS TO HATFIELD ROAD AT OAKLANDS AT 2 P.M. ON 25 FEBRUARY 1958

Photograph by R. K. Pilsbury.

PLATE I

1640 local time.—The wave clouds are to the north-west; also visible on the horizon at the bottom left corner is a belt of altocumulus moving towards the camera.

Photograph by R. K. Pilsbury.

PLATE II

1642 local time.—The wave cloud is to the south; the wind is blowing across the photograph from left to right.

OROGRAPHIC WAVES OVER MALTA 15 MARCH 1958

(see p. 17)

Photograph by R. K. Pilsbury.

PLATE III

1650 local time.—There is a wave cloud to the south and a second belt to the south-east. The cloud near the tree is still in the same position as in Plate II but it has increased in size.

Photograph by R. K. Pilsbury.

PLATE IV

1705 local time.—A wave cloud is to the south-east with further bands to the east-south-east. The cloud over the church has not moved since Plate III but has increased considerably in size.

OROGRAPHIC WAVES OVER MALTA 15 MARCH 1958

(see p. 17)

Photograph by R. K. Pilsbury.

PLATE V

1745 local time.—The wave clouds are to the east and the belt of altocumulus mentioned in Plate I is shown passing through the waves.

OROGRAPHIC WAVES OVER MALTA 15 MARCH 1958

(see p. 17)

deteriorations caused some concern to pilots because the fog, though only 20–30 feet thick, was most dense at cockpit level.

Petterssen[2] quotes a figure of − 15°C. (+ 05°F.) for Oslo for the lowest temperature at which fog will persist over a snow-covered surface and states that few water fogs can survive below −15°C. At Shawbury the visibility fluctuated from 50 to 1000 yards throughout the night of the 23rd and improved at 1000 G.M.T. on the 24th with a temperature of −16°C. (+ 03°F.). Petterssen's figures indicate that the contents of the fog were mainly ice crystals and the silvery appearance of the fog appeared to support his opinion.

REFERENCES

1. London, Meteorological Office; Climatological atlas of the British Isles. London, 1952, plate XIV, p. 47.
2. PETTERSSEN, S.; Weather analysis and forecasting. Vol. II. New York, 1956, p. 125.

OROGRAPHIC WAVES OVER MALTA

By R. K. PILSBURY

On 15 March 1958 at about 1600 local time it was noticed that lenticular clouds were forming over the south-east of Malta and photographs were taken at intervals from 1630 to 1745 local time from the position shown on the map (Figure 1). It was interesting to confirm that although the upper winds were north-westerly at about 40 knots, one belt of cloud remained directly overhead

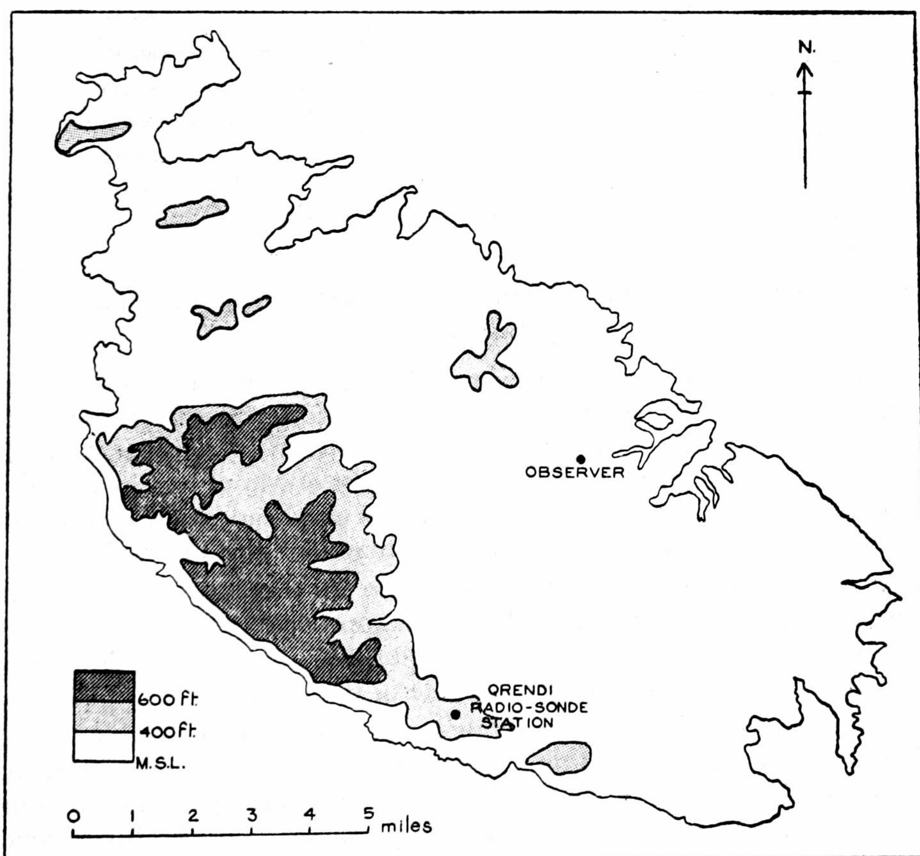

FIGURE 1—MAP OF MALTA

The photographs, Plates I–V, were taken from the position marked as "observer".

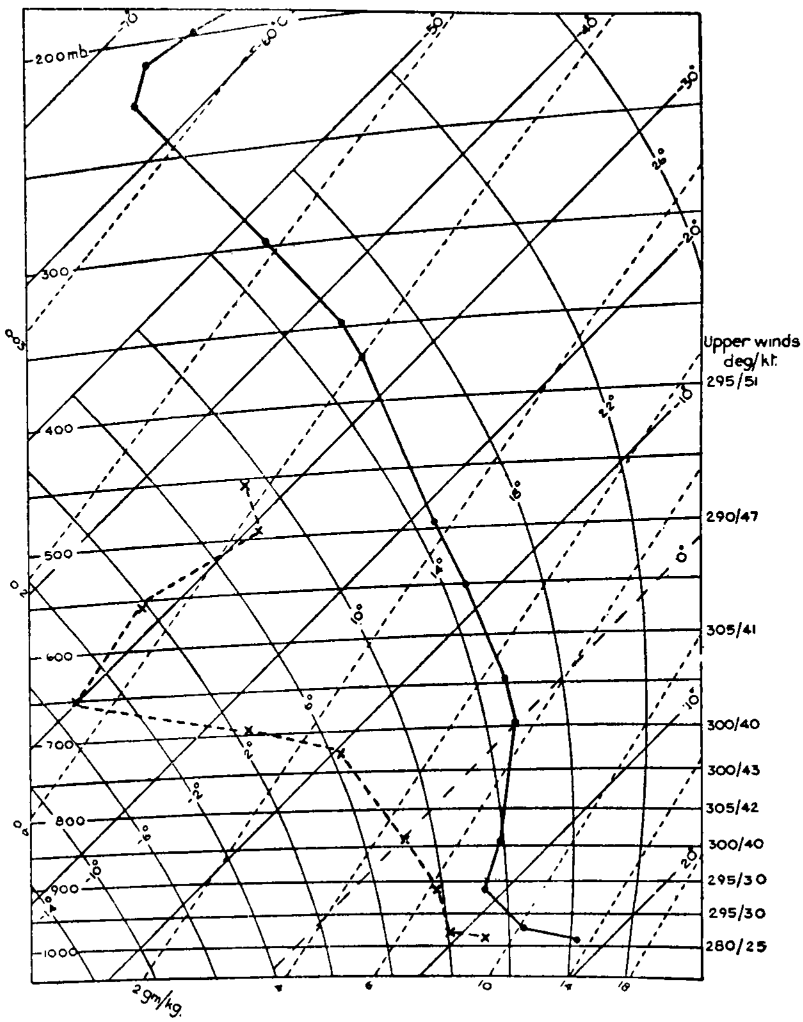

FIGURE 2—RADIO-SONDE ASCENT FOR QRENDI, MALTA FOR 1200 LOCAL TIME 15 MARCH 1958

for at least two hours, merely growing and diminishing from time to time. Several bands of cloud (at least five) were visible and it was estimated that these bands were spaced at about two-mile intervals. By dusk (1800 local time) the display of lenticular cloud over the sea to the east of Malta had increased considerably but by about 1900 local time the cloud overhead had dispersed and as the moonlight strengthened it was apparent that all the cloud had gone.

An interesting feature of the display was the effect of the orographic waves on a sheet of broken altocumulus which was approaching from the north-west at 1640 local time. This cloud was transferred across the wave bands from wave peak to wave peak but disappeared entirely in the troughs.

An analysis of the midday radio-sonde ascent from Qrendi, Malta (Figure 2) following the method described by Corby[1] showed vertical currents of the order of 300–600 feet per minute over Qrendi, with a maximum upward current in the lower layers occurring at about 11,000 feet (Figure 3). There is also evidence of further waves at 29,000 feet and 38,000 feet. The wavelength shown by the ascent at the cloud level is about 8–9 miles and between 30,000 and 40,000 feet about 6–7 miles calculated from the radar slant range. From the map of

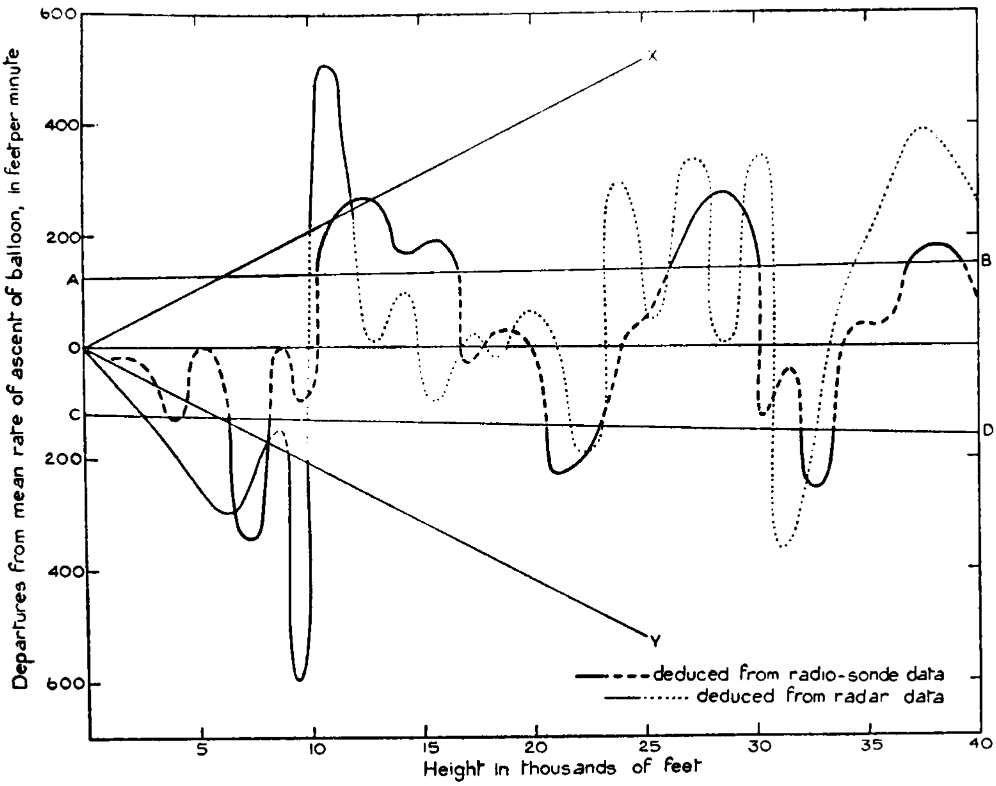

FIGURE 3—ANALYSIS OF RADIO-SONDE ASCENT, QRENDI, FOR 1200 LOCAL TIME 15 MARCH 1958, SHOWING DEVIATIONS FROM MEAN RATE OF ASCENT OF BALLOON USING RADAR MEASUREMENTS AND RATE OF ASCENT CALCULATED FROM PRESSURE VALUES OF RADIO-SONDE

The dashed portions of these curves, within ABCD for radio-sonde data and OX, OY for radar data, are not significant.

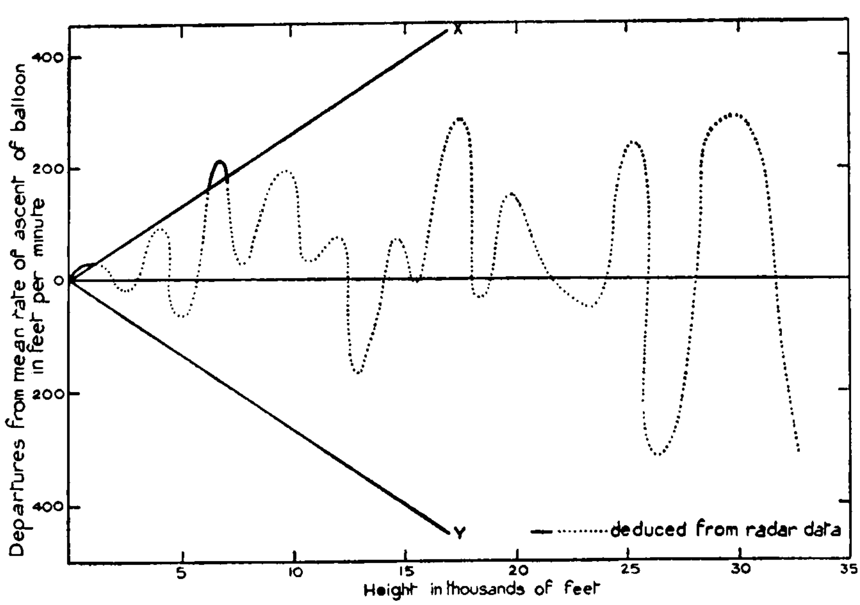

FIGURE 4—ANALYSIS OF RADIO-SONDE ASCENT, QRENDI, FOR 2359 LOCAL TIME 15 MARCH 1958 USING RADAR DATA

Malta (Figure 1) it will be seen that air moving from 300 degrees across the Island towards the photographer would pass over a series of ridges spaced at intervals of 2–3 miles. It would appear that the cloud belts to the lee of the high ground were related to the ridge distances and not to the wave structure as calculated from the radio-sonde ascent. Analysis of the later radio-sonde ascent at midnight (Figure 4) indicated that the orographic waves, if any, were on a much smaller scale than earlier in the day.

A more comprehensive analysis of Qrendi radio-sonde ascents is at present being carried out to collate evidence of orographic waves over Malta.

REFERENCE

1. CORBY, G. A.; A preliminary study of atmospheric waves using radiosonde data. *Quart. J. R. met. Soc., London,* **83,** 1957, p. 49.

CONVECTION AS AN INDIRECT CAUSE OF DETERIORATION AT TERNHILL ON 29 APRIL 1958

By F. M. KARGOL

At 0600 G.M.T. an anticyclone of 1028 millibars was centred just west of Brest. A ridge extending northwards was intensifying and maintaining west-north-westerly flow over England and Wales. There was a gradient of 15 knots over the area.

The 2300 G.M.T. Liverpool ascent showed conditional instability below 850 millibars. A temperature of between 58 and 59°F. was required for convection, which was triggered off about 0830 G.M.T.

Orographic stratus with drizzle covered the Cheshire Plain, the southern edge of this cooler air lying along the line Chester to just south of Crewe (Ringway weather at 0800 G.M.T. was: visibility 2,900 yards; continuous slight

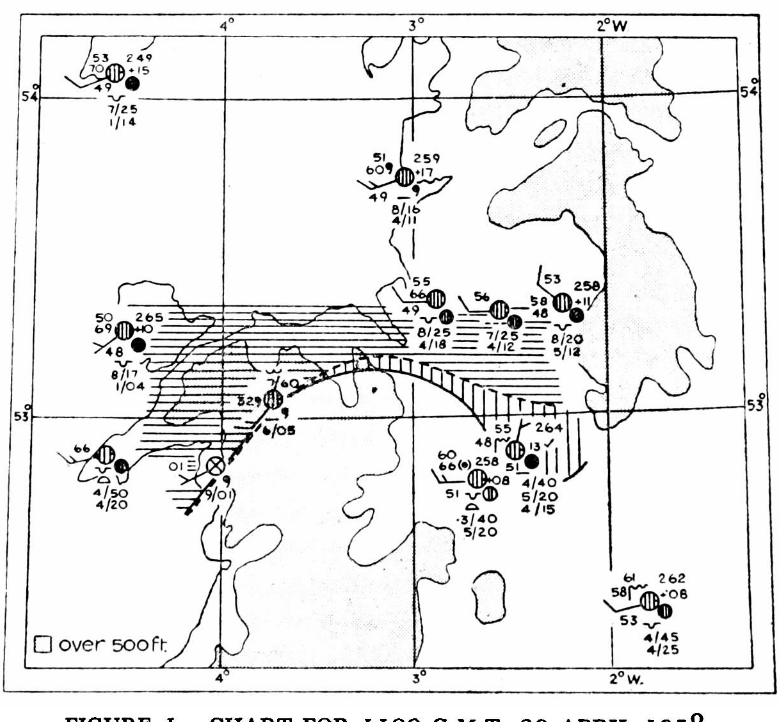

FIGURE 1—CHART FOR 1100 G.M.T. 29 APRIL 1958

The boundary of the cooler air at 0900 G.M.T. is shown by a broken line and at 1100 G.M.T. by a continuous line.

drizzle; 4 eighths at 300 feet, 7 eighths at 400 feet, 8 eighths at 800 feet. At 0900 G.M.T. conditions were similar). Ternhill, sheltered by Welsh hills, was free from the general stratus affecting the coastal areas of Wales and Cheshire. Conditions were consequently good, and improved further when convection began (see Table 1).

TABLE I—DETAILS OF WEATHER CONDITIONS AT TERNHILL AND SHAWBURY ON 29 APRIL 1958

	TERNHILL						SHAWBURY					
Time G.M.T.	Surface Wind deg.	kt.	Vis. N M	Temp. °F.	Cloud amount eighths	Cloud height ft.	Surface wind deg.	kt.	Vis. N M	Temp. °F.	Cloud amount eighths	Cloud height ft.
0800	270	05	6	55·3	1	1,200	—	—	—	—	—	—
					3	3,000						
0900	280	14	20	58·8	2	1,700	270	12	16	58·1	3	2,000
					3	4,000						
1000	250	13	25	59·2	3	1,800	260	14	16	60·8	2	1,700
					6	4,000						
1035	350	13	3·5	—	6	2,200*						
1100	010	07	2·4	55·1	4	1,500	270	15	8	60·0	5	2,000
					5	2,000					3	4,000
1200	020	03	4	56·0	4	1,600	250	13	16	61·9	4	2,500
					4	2,000						
1300	250	06	10	60·0	2	2,500	—	—	—	62·6	—	—
					5	4,000						
1400	230	09	25	62·2	3	1,800	250	14	22	63·5	6	3,000
					5	4,000						
1500	020	12	4	57·9	1	2,000	270	16	13	63·5	1	1,500
					5	2,500					3	5,000
1600	010	06	3·5	57·3	2	2,500	340	11	4	59·2	2	300
					6	4,000					8	3,200

* To the north-north-east of the airfield aircraft reported stratus at 900 feet and patches did appear for a time over the north-east part of the airfield.

Therefore there was little apparent reason why the surface wind should suddenly veer to between north and north-east at 1035 G.M.T., followed by a deterioration in visibility, with low stratus appearing to the north-east of the airfield at a base of about 900 feet. Also at that time the pilot of a Provost aircraft flying from the direction of Shawbury towards Ternhill encountered considerable turbulence at about 1,300 feet, some 5 miles south of the airfield, which then would be the southern boundary of the cooler air. Shawbury, 8 miles to the south-south-west, was not affected the first time, though it will be seen from the 1100 G.M.T. observation that the cooler air was very close to Shawbury—visibility dropped from 16 to 8 miles (presumably in the north-easterly direction) and temperature fell 0·8°F.—but the second influx of cooler air penetrated there, as the 1600 G.M.T. observation shows.

The first deterioration lasted for two hours. Conditions then became normal again until 1450 G.M.T., when the temperature reached 62°F. and a recurrence of deterioration followed. Each time the temperature fell by 4°F.

Similar changes in temperature and in surface wind were recorded at the University College of North Staffordshire at Keele, 15 miles to the north-east of Ternhill, (See Figure 2). The weather diary from Keele reads as follows: "Cloudy at first, becoming overcast with mist after 09 hours, as light air veered from west-south-west to north-west, remaining overcast until late afternoon. Light air backed to south between 11 hours and 13 hours, veering north-north-

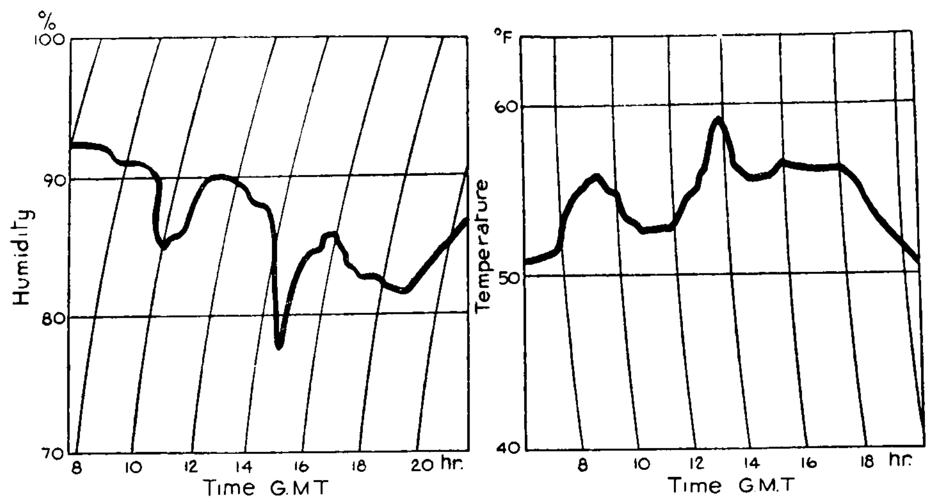

FIGURE 2—HYGROGRAM AND THERMOGRAM FOR KEELE, STAFFS., 29 APRIL 1958

west by 15 hours. Sky cleared in evening and wind dropped to calm by 22 hours." The reading of temperature and description of conditions at Alsager (Teachers' Training College, 5 miles east of Crewe) confirm that the southern edge of cooler air was just south of Crewe at 0900 G.M.T. (dry bulb 53°F., visibility ¼ mile, 8 eighths stratus. Day maximum 56·2°F.).

The possible effect of a sea-breeze was considered, but was discarded for three reasons: (1) The sea-breeze direction is 320–340 degrees and the breeze does not normally set in before noon. (2) Once it has set in, it is reasonably expected to continue. (3) The conditions were more favourable the following day, yet a sea-breeze did not set in.

It seems reasonable to conclude that the cooler air from the Cheshire Plain (cooled in the first instance by passage over the Irish Sea and then orographically) was sucked into the Ternhill area to replace the air lifted up by convection.

METEOROLOGICAL RESEARCH COMMITTEE

At the meetings held in February 1958 each subcommittee considered the terms of the annual report for the year ending 31 March 1958 and the programme of research for 1958–59. Note was taken of the requirement for improved techniques and equipment to ensure that upper air soundings shall be extended to appreciably greater heights than at present, and for increased attention to the problems of local forecasting (for example, cloud base, visibility and wind), changes and persistence of weather types (for example, dry, wet and cold spells) and the automatic processing of synoptic data. Other subjects discussed are mentioned below.

Instruments Subcommittee

At the meeting on 5 February the subcommittee noted the possibility of further development of an American phosphorus pentoxide hygrometer (M.R.P.1084) to render the instrument suitable for use in aircraft or on sounding balloons. Proposals for improvement of the promising optical methods for investigating droplet-size distribution in fog (M.R.P.1074) were endorsed, as were the proposed extended trials on aneroid barometers (M.R.P.1077). It was considered that the basic design of the floating equipment (M.R.P. 1079) for measurement of temperature and humidity above the sea surface (near to an ocean weather station) was satisfactory, though maintenance troubles are to be expected in the circumstances of the use of the equipment at sea.

ABSTRACTS

BREWER, A. W.; The phosphorus pentoxide electrolytic hygrometer, *Met. Res. Pap., London*, No. 1084, 1958.

A brief account of the Keidel hygrometer and its application to meteorological problems is given. In the hygrometer a controlled flow of air of 100–200 cubic centimetres per minute is passed over a film of partially hydrated P_2O_5 in which are platinum electrodes. The water from the air is absorbed and electrolysed into hydrogen and oxygen by a d.c. potential applied between the electrodes. No humidity calibration is required and the hygrometer is claimed to be suitable for frost-points of −20° C. to −80° C., with an exponential response time of 1–2 minutes. For upper air ascents this may be inadequate, and also the resistance to flow of air through the element is unsuitably large.

STEWART, K. H.; Some observations on the composition of fogs. *Met. Res. Pap., London*, No. 1074, 1957. (Abstract published in *Met. Mag., London*, **87**, p. 315.)

FRITH, R.; The development of precision aneroids—interim report. *Met. Res. Pap., London*, No. 1077, 1957.

Five aneroids made to Meteorological Office specifications, and one commercial "precision aneroid", were compared with a Kew pattern barometer over a period of six months. The readings suggested that most of the aneroids had a slow drift of "zero", amounting to not more than 0·5 millibar in the six-month period. Such a drift, if it persisted, would make it necessary to adjust the aneroids periodically. It is shown that if the aneroids had been adjusted, on the basis of a single spot check, once every two months, then more than 80 per cent of the readings would have been correct to 0·3 millibar and more than 95 per cent to within 0·5 millibar. If the adjustment were based on the mean of five readings (instead of a single reading) then more than 90 per cent of the readings would have been accurate to within 0·3 millibar and almost no readings would have been in error by more than 0·5 millibar. There was little to choose between the commercial aneroid and the specially made aneroids.

SHELLARD, H. C.; Some measurements of temperature and humidity near the sea surface. *Met. Res. Pap., London*, No. 1079, 1957.

The paper describes equipment developed to measure temperature and humidity profiles within 10 feet of the sea surface and in air undisturbed by the presence of a ship. Two sets of profiles measured at Ocean Weather Station I are presented and discussed. They are shown to be of logarithmic form and lend some support to the suggestion that profiles of temperature and humidity are similar under near-neutral conditions. It is concluded that the apparatus is satisfactory for use in measuring profiles up-wind of a weather ship in winds of up to at least force 4.

Physical Subcommittee

The main part of the meeting on 12 February was devoted to a review of information relating to controlled field experiments, based on Salisbury Plain, undertaken to examine if silver iodide smoke released at ground level and assumed to diffuse upwards into supercooled cloud in selected weather situations does result in increased rainfall over the south-eastern half of England. The number of experiments which satisfied certain prescribed conditions, and other relevant data, are insufficient as yet to enable clear conclusions to be reached on the efficacy of this method of cloud seeding in augmenting rainfall in the south-eastern half of England.

Synoptic, Dynamical and Climatological Subcommittee

The papers M.R.P. 1075, 1078 and 1080 were discussed at the meeting on 26 February. It was noted that charts of the average water content of the atmosphere above selected heights over much of the world (M.R.P. 1075) will be of assistance in studies of the transport of water vapour and computations of the absorption of radiation. The results reported in M.R.P. 1078 are pertinent to the procedure for the forecasting of wind at the 100-millibar level. The close relation between mean monthly anomalies of surface air temperature and of the 1000–500-millibar thickness, demonstrated in M.R.P. 1080, enables the weather of past years to be interpreted in terms of the anomalies of the upper air circulation and will help in the preparation of experimental long-range forecasts.

ABSTRACTS

BANNON, J. K. and STEELE, L. P.; Average water-vapour content of the air. *Met. Res. Pap., London*, No. 1075, 1957.

Charts are presented of the average total water-vapour content above one square centimetre at the earth's surface and the levels 850, 700 and 500 millibars for each of the months January, April, July and October based mainly on data for 1951–55. The area covered by the charts is approximately 70°N. to 52°S. There is a discussion of the accuracy of the data and the charts.

PROBERT-JONES, J. R.; Conservation of vorticity at 100 mb. *Met. Res. Pap., London*, No. 1078, 1957.

Five sequences of 100-millibar charts, each sequence covering three to five days, were redrawn so that the change in each 12-hour period implied a divergence of less than 2×10^{-6} sec.$^{-1}$, which is negligible on the synoptic scale. The redrawn sequences were smoother in time with respect to height and significantly smoother with respect to wind than the original set. The observed winds were fitted better by the redrawn sequences, and although the heights were fitted better by the original sequences, it is indicated that the fit of the original sequences was too good. It is concluded that the evidence supported the hypothesis of approximate non-divergent flow at the 100-millibar level.

LOWNDES, C. A. S.; The relation between anomalies of surface air temperature and of 1000–500-millibar thickness over the Atlantic sector of the Northern Hemisphere. *Met. Res. Pap., London*, No. 1080, 1957.

The preparation is described of two series of charts covering the Atlantic sector of the Northern Hemisphere, one giving the monthly mean surface temperature anomaly and the other the monthly mean 1000–500-millibar thickness anomaly for each month of the year 1956.

From a comparison of the charts month by month, it is evident that the main features of the thickness anomaly patterns are reflected in the surface temperature anomaly patterns. The importance of this relationship to a long-range forecasting method is discussed. In the appendix, charts are produced to show how the temperature anomaly patterns are affected by the choice of the period used to obtain the normal from which the anomalies are measured.

OFFICIAL PUBLICATIONS

The following publications have recently been issued:—

No. 19—*The summer sea-breeze at Ismailia.* By D. E. Pedgley, B.Sc.

A survey of the summer sea-breeze at Ismailia has been made, based on statistical data, and detailed observations on about 25 chosen days, including both surface conditions and upper winds found by means of pilot balloons. Two features were discovered, extending the classical ideas on the sea-breeze which previously had been based largely on observations made in the immediate vicinity of the coast.

With an on-shore gradient wind, the sea-breeze develops distinct frontal characteristics as it extends inland. This contrasts with previous knowledge that the sea-breeze has a frontal nature only when the gradient wind is off-shore.

The rate of advance inland of the front differs from that of the sea-breeze, and varies in a regular manner during the day. This controls the time of arrival and the accompanying convergence not only maintains the front, but determines both the vertical wind structure and the cloud development.

No. 20—*Equivalent headwinds at heights of* 30,000 *and* 40,000 *feet along air routes.* (*Supplemented and revised*). By P. Graystone, B.A.

An earlier publication, *Meteorological Reports* No. 7, gave tabulations of equivalent headwinds at 10,000, 20,000, 30,000 and 40,000 feet over some of the world's principal air routes. As foreshadowed in that publication these values have been found to be in need of revision, mainly at the higher levels, in the light of more recent upper wind information.

The present publication gives values of equivalent headwinds at 30,000 and 40,000 feet over an extended network of routes, based on the most up-to-date information available.

The tables in this publication give for each height and mid-season month, the average equivalent headwind in knots from one terminal airport to another, the average values for the return route, and a figure which gives a measure of the variability of the equivalent headwind from these mean values.

The report should be of considerable use for long-term planning by air-route operators, to aircraft designers, and by anyone planning to fly an aircraft overseas.

Averages of rainfall for Great Britain and Northern Ireland 1916–1950.

This contains monthly and annual averages of rainfall for 719 stations, an introduction with a brief discussion of the relationships between the averages for the old period (1881–1915) and the new, and an index giving the position of each station, both by latitude and longitude to the nearest minute, and by the 100-metre grid reference appropriate for use with Ordnance Survey one inch to the mile maps.

It is expected that this will remain a standard publication, with only minor amendments and additions, for two decades or more.

OBITUARY

Miss V. M. Huckle, B.Sc.—It is with great regret that we record the death of Miss Vera M. Huckle on 19 May 1958 at the early age of 27 years. She had been in poor health for some time and had spent long periods in hospital.

Miss Huckle took her degree in mathematics at Bedford College, London and joined the Meteorological Office in October 1952 as an Assistant Experimental Officer. She was assigned to research work in M.O.21 at the Napier Shaw Laboratory, Dunstable and became one of a small group who were investigating the possibility of forecasting the pressure field through numerical integration of the equations of motion. She quickly mastered the art of writing programmes for an electronic computer and became a very valued member of the group; in addition, she showed her meteorological ability by her co-authorship of papers on numerical forecasting in the *Quarterly Journal of the Royal Meteorological Society.* Her talent was rewarded by promotion to Experimental Officer at the early age of 26 years; the news of her promotion reached her while she was in hospital. All who knew Miss Huckle appreciated her quiet ability and her willingness to help, either at work or in the everyday things of life.

E. KNIGHTING

AWARDS

L. G. Groves Memorial Prize and Award

The following awards have been made for the year ended 30 June 1958. The L. G. Groves Memorial Prize for Meteorology was awarded to *Dr. R. J. Murgatroyd*, Senior Principal Scientific Officer, Meteorological Office, with the following citation:

"After brief service in Her Majesty's Patent Office, Dr. Murgatroyd entered the meteorological service in 1939, in the Royal Air Force Volunteer Reserve, and joined the scientific staff of the Meteorological Office in 1946. For the last seven years he has been the leader of the Meteorological Research Flight at Farnborough, being promoted to Senior Principal Scientific Officer in 1957. Many important contributions to research, especially in cloud physics, have been made by Dr. Murgatroyd and his collaborators in the Meteorological Research Flight and at the same time he has been engaged personally in the study of the high atmosphere. His recent paper "Winds and temperatures between 20 km. and 100 km", published in the *Quarterly Journal of the Royal Meteorological Society*, is a very valuable survey based on a research thesis which recently gained him the degree of Doctor of Philosophy in the University of London."

The L. G. Groves Memorial Award for Air Meteorological Observers was awarded to *Flight Lieutenant R. E. Parsons*, A.F.C., Royal Air Force, Coastal Command with the following citation:

"This General Duties Branch officer, who had previously served as an Air Meteorological Observer, volunteered for duties at Christmas Island during the periods 15 October to 14 November 1957 and 10 February to 6 May 1958. As Air Meteorological Observer leader on these detachments, he flew 215 hours on meteorological reconnaissance and was responsible both for the preparation and dissemination of meteorological information and the instruction of other observers. His fostering of a high degree of co-operation between air-crew and meteorological staff and his qualities of skill, combined with enthusiasm, contributed greatly to the success of the meteorological task."

METEOROLOGICAL OFFICE NEWS

Retirements.—*Mr. W. L. Andrew*, Senior Experimental Officer, retired on 30 November 1958. He joined the Office in June 1919 after service in the Royal Flying Corps and Royal Air Force during the First World War. After short periods at Kew Observatory and West Lavington he was posted to Cattewater in September 1920, where he remained until 1931 when he was transferred to the Climatological Branch at Headquarters. In January 1935 he was posted to the Middle East and returned to the United Kingdom a year later for forecasting training. After a short spell at Headquarters in the Forecast Division he was transferred in 1937 to an aviation outstation and he has since worked at outstations including further tours in the Middle East and the Far East. From 1948 until his retirement he served at Abingdon.

Mr. E. W. Barlow relinquished his temporary appointment as Experimental Officer on 30 November 1958. He had previously retired from the grade of Senior Experimental Officer in 1949. He joined the Office as a Senior Professional Assistant in January 1920 after service in the Royal Naval Volunteer Reserve and the Royal Air Force from 1916 until the end of 1919. He first worked in the Climatology Division, being transferred to the Marine Division in 1927 where he served until his retirement. His work in the Marine Division has been mainly concerned with ocean currents and sea ice, the preparation of atlases of ocean currents, and information about currents and ice in the *Admiralty Pilots*. He is a keen amateur astronomer and a Fellow of the Royal Astronomical Society. He made a special study of atmospheric phenomena of various types and of oceanographical phenomena, such as bioluminescence for which he prepared a unique classification. In the preparation of the International Ice Nomenclature he assisted Mr. (now Sir James) Wordie, who was the British representative on the working group appointed for this purpose by the Commission for Maritime Meteorology in 1947.

Mr. P. I. Mulholland, Senior Experimental Officer, retired on 30 November 1958. He joined the Office in August 1918 as a Senior Professional Assistant at Valentia Observatory. In 1921 he was transferred to the Climatological Branch at Headquarters where he remained until 1932 when he was posted to the Forecast Division. Since 1936 he has worked at aviation outstations including two tours of duty overseas. From 1953 until his retirement he served at Upavon.

Mr. R. M. Rudlin, Senior Assistant (Scientific), retired on 15 November 1958. During the First World War he served in the Somerset Light Infantry and was severely wounded at Arras in 1917 and was invalided out in 1918, when he joined the Naval Meteorological Section. He was transferred to the Office in August 1920 and apart from short periods of detached duty he has served continuously at Headquarters in the Forecast and Observations and Communications Divisions. Throughout his career he has been closely associated with the sporting and social activities of the Office. Mr. Rudlin has accepted a temporary appointment in the Meteorological Office.

Mr. H. A. Scotney, Senior Experimental Officer, retired on 30 November 1958. He joined the Office in May 1925 as a Grade III Clerk and was posted to the Airship Division. After a spell in the General Services Division from 1926 to 1928 he returned to the Airship Division and remained there until it was disbanded in 1931. He was then posted to the Forecast Division and has since served at Headquarters in various branches dealing with aviation services.

From 1946 until his retirement he served in the Civil Aviation Division. Over the past 10 years he was sports representative on the Meteorological Office Social and Sports Committee and it was largely due to his activities behind the scenes that the Meteorological Office gained prominence in Air Ministry sporting competitions. During the First World War he served in the Royal Army Ordnance Corps.

REVIEW

A pair of colour film strips on clouds; and notes to accompany film strips. By F. H. Ludlam and R. S. Scorer. Film strip A: haze, convection clouds, ice clouds. 24 photographs. Film strip B: layer clouds, wave clouds, billow clouds. 22 photographs, 3 diagrams. Notes, 8 in. × 5 in., pp. 20. Produced by Diana Wyllie Ltd., London. Price: single frames (24 × 18 mm.), 27*s.* 6*d.* each; double frames (35 × 24 mm.), 37*s.* 6*d.* each.

In the past much effort has been made to devise systems for classifying clouds according to their appearance. Whilst these are important and necessary for such tasks as describing the state of the sky and then reporting the results in terms of international codes for synoptic purposes, mere classification does not arouse much interest. An understanding of the processes involved in cloud formation and decay is far more satisfying.

These two film strips approach the study of clouds in this more scientific way. The emphasis is on processes of formation, in particular the varying types of vertical motion which occur in the atmosphere and which are important factors in controlling the shapes of clouds. Accompanying the strips are lecture notes explaining in a clear and readable way many ideas, both old and new, on the physics of clouds. They are perhaps deceptively simple since a very wide range of ideas is introduced and some need more explanation than is given.

The first strip deals with atmospheric aerosols and their roles in droplet and crystal formation, then with convection in the atmosphere and the production of showers, and lastly, ice clouds. Although most of the well-established ideas on convective clouds are admirably illustrated, there is an undue emphasis on mamma since five out of 24 pictures contain this feature. More space could have been given to describe such processes as entrainment and vertical wind-shear, which are much more common and which are most important in deciding how large a cumulus will grow and whether it will give a shower. The omission of a "textbook" anvil cumulonimbus is a good feature since such clouds are rarely seen. It was good, also, to see more attention paid to ice clouds which have often been poorly treated in the past.

The second strip is concerned with layered clouds of various types. Those due to turbulence are adequately treated, but those resulting from slow widespread uplift of air are passed by rather superficially. This is a pity since such clouds form an important part of those experienced in this country, and they also exhibit a wide variety of forms most of which are easily illustrated. More detail might also have been given explaining cellular convection. The major part of this strip (18 pictures out of 25) deals with wave and billow clouds. Whilst these are fascinating, such a large fraction of the available space taken up by them is too much, especially when one considers that good examples in this country are rare and usually localized. Some of the points illustrated are subtle and too specialized for strips which are designed to cover the whole range of cloud forms.

One or two diagrams inserted between the photographs are very useful, but why use them only for wave clouds? They would be equally helpful in illustrating, for example, the transition from cumulus to cumulonimbus, or the development of cellular convection in layer clouds.

Considered as a whole, this collection of photographs forms an excellent aid for instructional purposes. Most of the pictures have been carefully selected to illustrate separate points, and in some cases this has been helped, in a very pleasant way, by the increase in contrast which results partly from the reproduction process. In teaching, it is essential that an indication of the correct scale be included in each picture; this is best arranged by always having a little foreground. It is hoped that in future editions the few examples which have no foreground in them will be replaced.

For the cloud watcher there are many ideas shown here which will make it easier for him to interpret an interesting sky. D. E. PEDGLEY

BOOKS RECEIVED

Indian journal of meteorology and geophysics (quarterly). **9,** No. 3. Issued by Indian Meteorological Department, 9½ in. × 7 in., pp. 94. July 1958.

Works of the Academy of Athens. **24,** *No.* 1 *The areas of sunspots in the two sun hemispheres.* By. Prof. J. Xanthakis. 11½ in. × 8½ in., pp. 54. Publications Bureau of the Academy of Athens, 1958.

LATE RAINFALL REPORTS—1958
Great Britain and Northern Ireland

Month	County	Station	Inches	Per cent of average
May	*Worcs.*	Worcester, Red Hill ...	2·32	101
May	*Aberd.*	Braemar	no record	
May	*R. and C.*	Fearn, Geanies	3·08	153
June	*Bute*	Rothesay, Ardencraig ...	3·69	106
June	*Argyll*	Morven, Drimnin	2·03	55

WEATHER OF SEPTEMBER 1958
Northern Hemisphere

The Iceland low was centred near its normal position but it was 5 millibars deeper than usual. A pronounced trough extended south-eastwards from the centre towards the Bay of Biscay causing negative pressure anomalies over and to the west of the British Isles; these anomalies reached −10 millibars at 50°N. 20°W. Although the southward displacement of the depression track during the previous months was maintained, the advance of depressions from the Atlantic into western Europe was hindered by blocking anticyclones which occurred over Europe on a number of occasions. In all parts of Europe, except the British Isles, mean pressures were above normal.

Mean pressures were below normal in the polar basin and also over Siberia, where a low pressure centre north-east of the Urals gave negative anomalies of up to − 7 millibars. While the flow was rather more meridional than zonal over much of Europe and Asia, in the North Pacific and American sector it was almost zonal, the synoptic features having a correspondingly greater mobility. Pressure anomalies were small over the whole region, the largest being − 4 millibars to the west of Hudson Bay associated with depressions moving across Canada from the extreme north of the Pacific.

Mean temperatures were above average over Europe west of 20°E. on account of the predominantly southerly flow. The largest anomalies reported were

+ 3°C. but these occurred in many areas including parts of Norway, Scotland, Iceland, southern France and eastern Spain. Negative anomalies of up to − 5°C. over Siberia were a direct consequence of the advection around the low centre mentioned previously. Slight positive anomalies predominated over North America, but mean temperatures were a little below normal over Quebec and Labrador. The largest reported anomalies were + 2°C. in the Canadian Arctic and + 3°C. in coastal regions of California. Anomalies in the tropical regions of the hemisphere were all small and variable in sign.

Much of western Europe had more rain than usual in September. Totals were less than normal over Scandinavia and eastern Europe, while the rainfall distribution over central Europe was very irregular. Precipitation amounts were above normal over Siberia where pressures were below normal.

Excesses of rainfall were reported in many southern and eastern districts of the United States of America and in Mexico. A vigorous hurricane moved north along the coast of Carolina during the last week of the month and gave very heavy rainfall at coastal stations. Further unusually large rainfall totals were reported in north-west India and Pakistan, where some places had more than five times the monthly average. Two typhoons affected Japan during the month. The second was the more severe and exceptionally heavy rainfall and strong winds caused much damage in and around Tokyo.

WEATHER OF OCTOBER 1958
Great Britain and Northern Ireland

Weather was generally unsettled during the first half of October as a succession of depressions and troughs from the Atlantic moved eastwards across the British Isles. The second half of the month was mainly anticyclonic with dry, though mainly dull, weather.

During the first four days active depressions from the Atlantic moved east-south-east towards our south-west approaches subsequently turning northwards over the British Isles. There was widespread rain, heavy locally, especially in southern and central England where scattered thunderstorms also occurred. On the 3rd, the wettest day of the month, most western districts from Renfrew to Cornwall had falls of more than one inch in 24 hours. Until the 5th, temperature was somewhat above average, especially at night when at many places it failed to fall below 50°F., but, with the arrival of a north-westerly airstream, the night of the 4th–5th was distinctly colder; 27°F. was recorded at Eskdalemuir which was 20°F. below the previous night's temperature and the second air frost of the autumn there. The following day was sunny although there were scattered showers which were heavy locally with hail and thunder. A depression began to move east across the British Isles on the 7th, and on that and the next day several troughs, associated with a deepening depression on the Atlantic, crossed the country giving cloudy, mild and rather windy weather with rain or drizzle which was mainly slight but heavier locally in southern England. Three or four brighter days, with scattered thundery showers, followed. On the 12th, which was sunny and dry over much of the country, rain from the Atlantic reached north-west Scotland during the afternoon and spread to the remainder of the country during the evening and night; 1·06 inches fell at Eskdalemuir in 12 hours. The following day was dull in the south and Midlands with widespread rain, but there were fair periods in the north with scattered showers. In the rear of a further trough, which gave some slight rain in most districts, fresh north-westerly winds spread across the whole country on the 14th, and pressure rose rapidly as an anticyclone situated near the Azores increased in intensity and moved north-eastwards. These fresh winds, with generally fair weather, apart from scattered showers in the north-west, persisted for a couple of days until on the 17th, when the anticyclone became centred over Ireland, they veered towards the north and moderated. The next day the anticyclone retreated south-westward and cloudy weather with occasional rain spread round its northern side, first to Scotland and Ireland and subsequently to the whole country. Generally dull weather persisted for most of the remainder of the month. Pressure reached its peak on the 23rd with the anticyclone centred over the southern part of the British Isles, and it was on this date that the mean sea level pressure at Kew rose to 1040·6 millibars, the highest recorded there in October since records began in 1869. Subsequently the anticyclone declined slowly and by the 26th had moved south-east to the continent. On the night of the 28th–29th a frontal rain belt, the first to affect the British Isles for about 8 days, reached north-western districts, subsequently moving slowly south-east across the country and clearing south-east England early on the 31st.

Mean temperatures were generally above the average, in some places by as much as 4°F. From the 20th to the 23rd night temperatures were only a little below the maximum to be expected at that time of year. Sunshine was above the average in eastern districts of Scotland, in north-east England and locally in south-west England, elsewhere it was mainly below the average. Rainfall was 86 per cent of the 1916–50 average in England and Wales and 77 and 75 per cent in Scotland and Northern Ireland respectively. Less than half the average occurred along much of the east coast from Tynemouth to the Moray Firth. More than the average occurred in a narrow strip from north Devon to Hereford, over Kent, east Surrey, London and Essex.

Rain during the first half of the month continued to hold up apple picking and the potato harvest. The ensuing dry spell, however, allowed good progress to be made with these and other operations which had been delayed. There were heavy pickings of apples and pears; potato yields, though below average, were not as low in some areas as was previously feared after the serious blight infection. Glass-houses were largely cleared of tomatoes and the mild weather had reduced heating costs.

WEATHER OF NOVEMBER 1958

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 ...	63	20	+0·1	58	−4	81
Scotland	61	15	+1·4	39	−6	88
Northern Ireland ...	60	30	+2·3	55	−7	75

*1916–1950 †1921–1950

RAINFALL OF NOVEMBER 1958

Great Britain and Northern Ireland

County	Station	In.	*Per cent of Av.	County	Station	In.	*Per cent of Av.
London	Camden Square Gdns.	2·00	77	*Carm.*	Pontcrynfe	3·68	56
Kent	Dover	1·91	52	*Pemb.*	Maenclochog, Ddolwen B.	4·56	65
"	Edenbridge, Falconhurst	1·91	51	*Radnor*	Llandrindod Wells	3·08	70
Sussex	Compton, Compton Ho.	3·32	76	*Mont.*	Lake Vyrnwy	2·69	39
"	Worthing, Beach Ho. Pk.	2·06	60	*Mer.*	Blaenau Festiniog	5·43	46
Hants.	St. Catherine's L'thouse	2·64	73	"	Aberdovey	4·69	106
"	Southampton, East Pk.	2·42	67	*Carn.*	Llandudno	1·97	69
"	South Farnborough	2·61	91	*Angl.*	Llanerchymedd	2·89	66
Herts.	Harpenden, Rothamsted	2·37	78	*I. Man*	Douglas, Borough Cem.	3·78	80
Bucks.	Slough, Upton	2·03	75	*Wigtown*	Newton Stewart	2·92	57
Oxford	Oxford, Radcliffe	3·03	117	*Dumf.*	Dumfries, Crichton R.I.	1·63	39
N'hants.	Wellingboro' Swanspool	1·91	79	"	Eskdalemuir Obsy.	2·13	36
Essex	Southend W.W.	1·24	52	*Roxb.*	Crailing	·80	33
Suffolk	Ipswich, Belstead Hall	1·14	46	*Peebles*	Stobo Castle	1·21	32
"	Lowestoft Sec. School	1·07	39	*Berwick*	Marchmont House	1·12	38
"	Bury St. Ed., Westley H.	1·60	61	*E. Loth.*	N. Berwick	1·04	44
Norfolk	Sandringham Ho. Gdns.	1·26	46	*Midl'n.*	Edinburgh, Blackf'd H.	1·08	45
Dorset	Creech Grange	4·00	90	*Lanark*	Hamilton W.W., T'nhill	1·27	33
"	Beaminster, East St.	3·18	66	*Ayr*	Prestwick	1·53	45
Devon	Teignmouth, Den Gdns.	2·46	63	"	Glen Afton, Ayr San.	2·27	47
"	Ilfracombe	4·03	94	*Renfrew*	Greenock, Prospect Hill	2·53	38
"	Princetown	7·68	75	*Bute*	Rothesay, Ardencraig	2·27	47
Cornwall	Bude	4·02	102	*Argyll*	Morven, Drimnin	2·61	42
"	Penzance	3·28	67	"	Ardrishaig, Canal Office	3·24	43
"	St. Austell	3·64	65	"	Inveraray Castle	3·41	38
"	Scilly, St. Mary	1·77	49	"	Islay, Eallabus	3·32	57
Somerset	Bath	2·33	74	"	Tiree	2·67	57
"	Taunton	2·27	70	*Kinross*	Loch Leven Sluice	1·29	35
Glos.	Cirencester	3·13	93	*Fife*	Leuchars Airfield	·63	25
Salop	Church Stretton	2·37	65	*Perth*	Loch Dhu	2·77	34
"	Shrewsbury, Monkmore	1·79	72	"	Crieff, Strathearn Hyd.	1·41	36
Worcs.	Worcester, Red Hill	2·27	94	"	Pitlochry, Fincastle	1·10	31
Warwick	Birmingham, Edgbaston	1·97	62	*Angus*	Montrose Hospital	·70	25
Leics.	Thornton Reservoir	2·19	79	*Aberd.*	Braemar	·62	16
Lincs.	Cranwell Airfield	1·09	47	"	Dyce, Craibstone	·76	21
"	Skegness, Marine Gdns.	·85	37	"	New Deer School House	1·31	34
Notts.	Mansfield, Carr Bank	·81	29	*Moray*	Gordon Castle	1·07	37
Derby	Buxton, Terrace Slopes	1·79	36	*Inverness*	Loch Ness, Garthbeg	1·19	29
Ches.	Bidston Observatory	1·71	62	"	Fort William	2·44	31
"	Manchester, Airport	1·20	40	"	Skye, Duntulm	3·01	53
Lancs.	Stonyhurst College	1·86	39	"	Benbecula	3·31	66
"	Squires Gate	1·49	44	R. & C.	Fearn, Geanies	1·12	55
Yorks.	Wakefield, Clarence Pk.	·77	30	"	Inverbroom, Glackour	1·93	36
"	Hull, Pearson Park	·58	23	"	Loch Duich, Ratagan	3·74	39
"	Felixkirk, Mt. St. John	·91	33	"	Achnashellach	3·06	38
"	York Museum	·70	30	"	Stornoway	2·26	50
"	Scarborough	·62	24	*Caith.*	Wick Airfield	1·35	43
"	Middlesbrough	·79	33	*Shetland*	Lerwick Observatory	2·70	58
"	Baldersdale, Hury Res.	·85	23	*Ferm.*	Belleek	3·67	75
Nor'l'd	Newcastle, Leazes Pk.	·48	18	*Armagh*	Armagh Observatory	1·66	57
"	Bellingham, High Green	·95	29	*Down*	Seaforde	2·14	53
"	Lilburn Tower Gdns.	·57	18	*Antrim*	Aldergrove Airfield	1·62	51
Cumb.	Geltsdale	1·84	53	"	Ballymena, Harryville	2·04	51
"	Keswick, High Hill	1·21	20	*L'derry*	Garvagh, Moneydig	1·73	41
"	Ravenglass, The Grove	2·67	59	"	Londonderry, Creggan	2·82	65
Mon.	A'gavenney, Plâs Derwen	2·14	43	*Tyrone*	Omagh, Edenfel	2·53	61
Glam.	Cardiff, Penylan	2·46	56				

* 1916–1950

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