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ANOMALY CHARTS AND FORECASTING

By R. W. JAMES, M.Sc.

Introduction.—It is normal to regard an instantaneous pressure pattern as consisting of an overall mean flow and one or more perturbations in that flow. It is therefore important to consider whether it is possible to disentangle perturbations from the mean flow, and present the pattern of each separately.

A chart of pressure meaned over any period, gives rigorously the pattern of mean geostrophic flow for that period, but careful thought must be devoted to whether a mean flow, so obtained, is physically significant. A chart of mean pressures over a 24-hr. period is certainly a mean chart, but such a mean would not be held to have any real relevance to atmospheric processes, for the period of meaning is shorter than the time during which a perturbation influences any one point.

In long-term forecasting the five-day mean chart is much used for "smoothing out" the perturbations, but here again the period of meaning is rather too short to give a physically significant mean flow. The pressure at a point may be unusually low for a period of three days or longer owing to its proximity to the path of a migrating low, and hence the 5-day mean pressure at that point will not be truly representative of what the pressure would have been in the absence of a perturbation. It is true that, in a five-day period, a given point might have been traversed by two perturbations of opposite sign. In this way the average may be "kept straight" but this presupposes a specific perturbation pattern, which is presupposing too much.

The only way to keep the average straight is to take a meaning period long compared with the time for which a single perturbation influences any one point. The longer the meaning period, of course, the slighter the disturbing influence of any one perturbation on the mean, but there is a limit to the length of period to be taken, for the mean flow itself changes seasonally, and in transitional periods it may change rapidly. Hence a suitable meaning period must be long compared with the life of a single perturbation, but must be short enough for changes in the mean flow to be inappreciable. In some circumstances both these conditions cannot be met simultaneously. We have been considering migratory perturbations, the effect of which is felt at a single point for only a day or so. However, it is possible to have a stationary perturbation in the mean flow dominating a region for a matter of weeks.

According to the principles enunciated above, it would be necessary to study such a perturbation with a mean chart extending over months, but then we could no longer neglect the seasonal variation in the mean flow. This difficulty is surmounted by taking as our mean flow some seasonal mean based on a number of years' observations. Three-monthly means might be considered adequate for the purpose, although a more refined elimination of seasonal trend would be obtained by using monthly mean charts.

An anomaly chart could be prepared by "gridding" a current synoptic chart with a seasonal mean field. This procedure is simple to apply as a synoptic routine, for no more is required than a set of mean seasonal overlays. It suffers, however, from the drawback that migrating and stationary perturbations both appear on the anomaly chart and are not separated. The short-lived migrating anomalies can be eliminated by meaning anomaly charts over a suitable period, say 10–30 days. This is entirely analogous to eliminating passing perturbations from current synoptic charts by meaning over five-day periods, or longer.

Once a chart of the "semi-permanent" anomalies is obtained, it is possible to produce a chart containing only the transient anomalies by gridding an anomaly chart against a "semi-permanent" anomaly map covering the relevant period. In general this double-gridding process is tedious, and takes a great deal of labour. In most circumstances it should be possible to separate the transient from the semi-permanent anomalies by examination of serial charts.

Normally the mean surface flow is weak compared with the surface flow in perturbations. The raw surface chart may be regarded as virtually an anomaly chart, the mean flow element in it being so weak as to occasion only a slight distortion of the perturbation pattern.

The same is not true of upper-level charts. Here gradients associated with the mean flow tend to be stronger than those due to perturbations. Perturbations are frequently so weak in relation to the general flow at 300 mb. that they are manifest only as trough or wedge distortions in the latter. The "true" structure of a weak perturbation can in this way be distorted almost out of recognition by a strong general flow, and in such cases the anomaly chart becomes of real value in disentangling the perturbation from the mean flow.

It might well be that forecasters are hampered in their interpretation of high-level charts by this swamping effect of the mean flow. The anomaly chart should therefore prove of value in interpreting the high-level structure of atmospheric vortices.

Anomaly Charts.—Fig. 1 shows the contour pattern over the United States at 0300 G.M.T. on April 19, 1949. Contours are drawn at 200-ft. intervals. The broken lines show the mean contours for March–May, derived from "Upper winds over the world"[1]. The conspicuous feature of this chart is a closed centre of low pressure over the Great-Lakes region. Gridding gives the anomaly pattern displayed in Fig. 2. It will be seen that the anomaly pattern is very much simpler than that of the contour chart from which it is derived. The normal north-south pressure gradient has been almost completely eliminated. Contour heights are close to normal everywhere except in the region of the cold low.

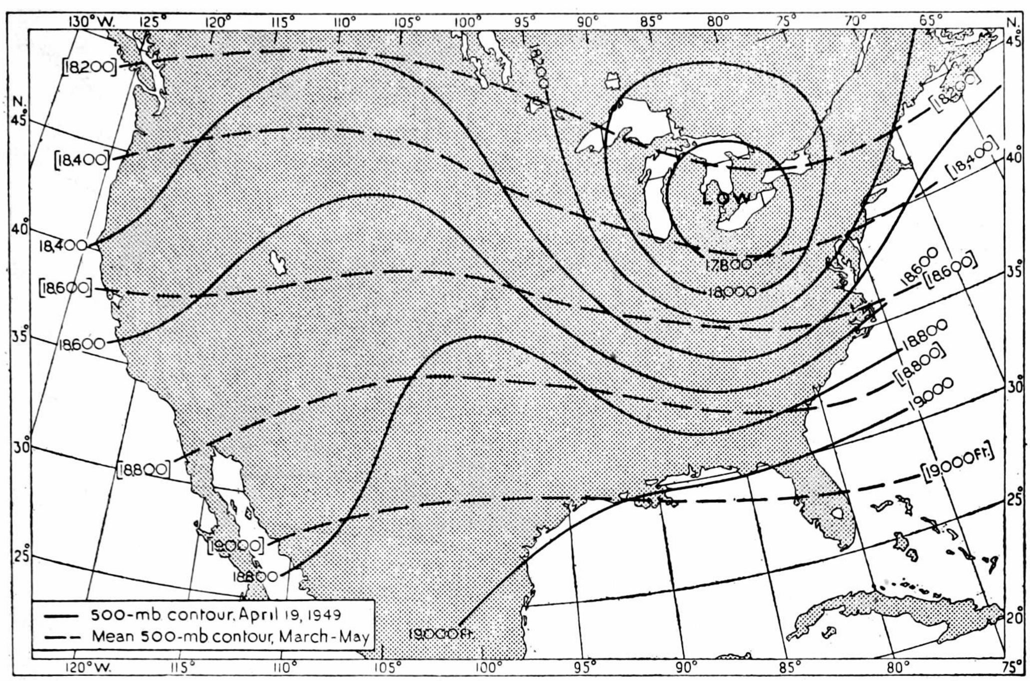

FIG. 1—500-MB. CONTOURS, 0300 G.M.T., APRIL 19, 1949

It seems reasonable, therefore, to take the anomaly pattern as representative of the structure of the cold low as such. The vortex covers something less than the eastern half of the United States, and is roughly circular. The outer limit of the vortex may be taken as the line of zero anomaly.

The central contour anomaly is —700 ft. indicating a pressure anomaly of —13 mb. approximately.

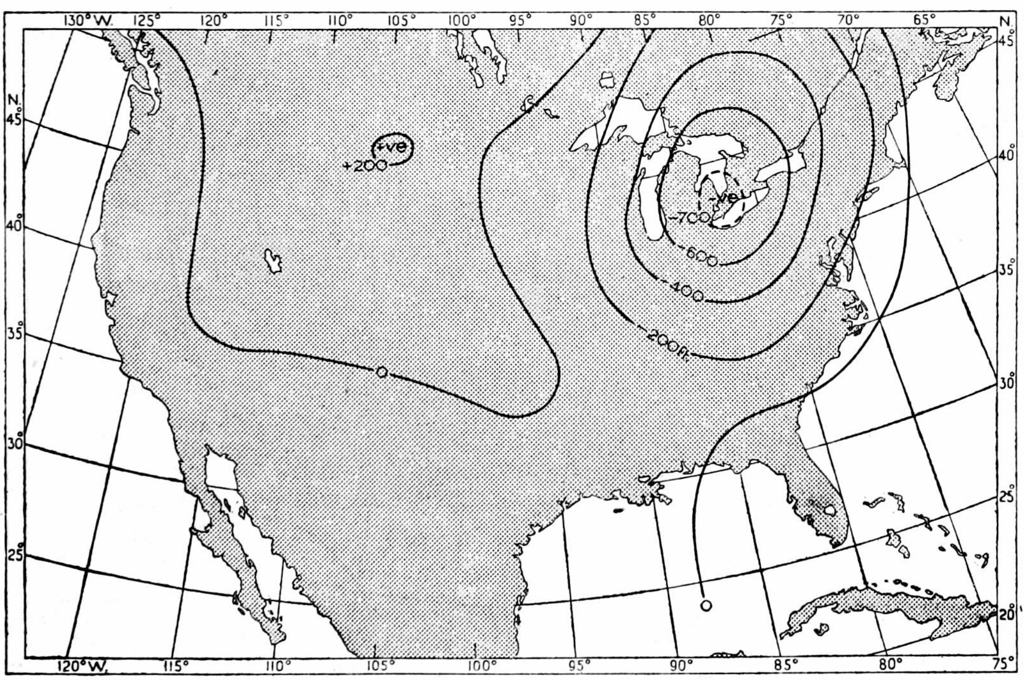

FIG. 2—500-MB. CONTOUR ANOMALY PATTERN, 0300 G.M.T., APRIL 19, 1949

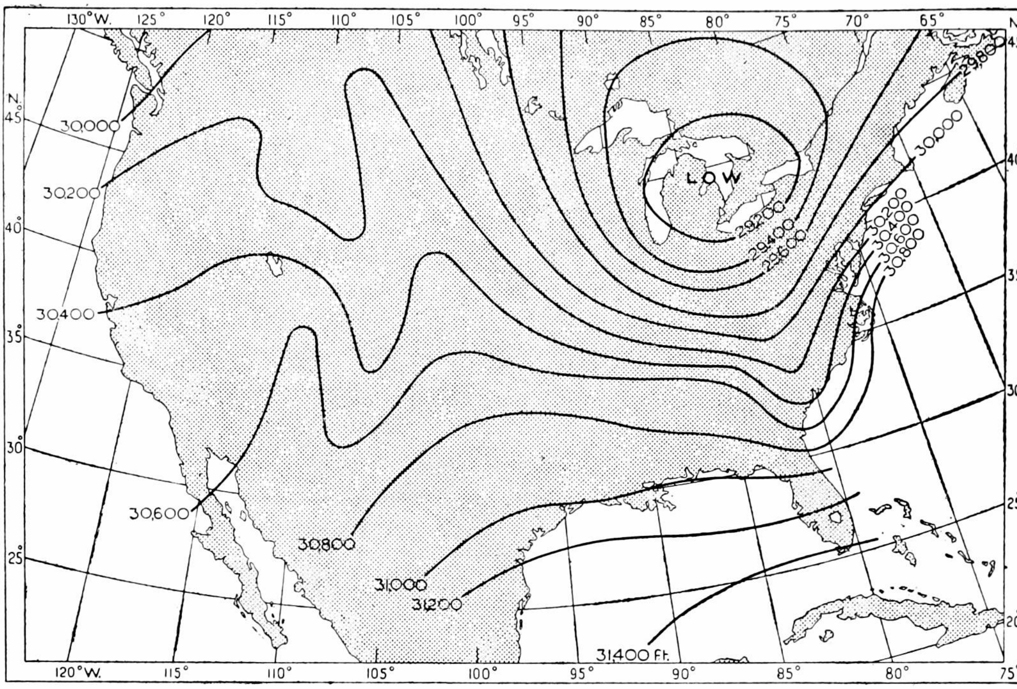

FIG. 3—300-MB. CONTOURS, 0300 G.M.T., APRIL 19, 1949

Fig. 3 shows the 300-mb. contours for the same time, and Fig. 4 the contour anomaly at 300 mb. Again a more clear-cut pattern is seen in the contour anomaly, dominated by the eastern vortex. The vortex at the 300-mb. level has a slightly greater extent along the north-south axis, and covers a slightly wider area, but its relation to the 500-mb. section is clear. The central anomaly is −900 ft., representing an intensity of −11 mb. There is a slight decrease in

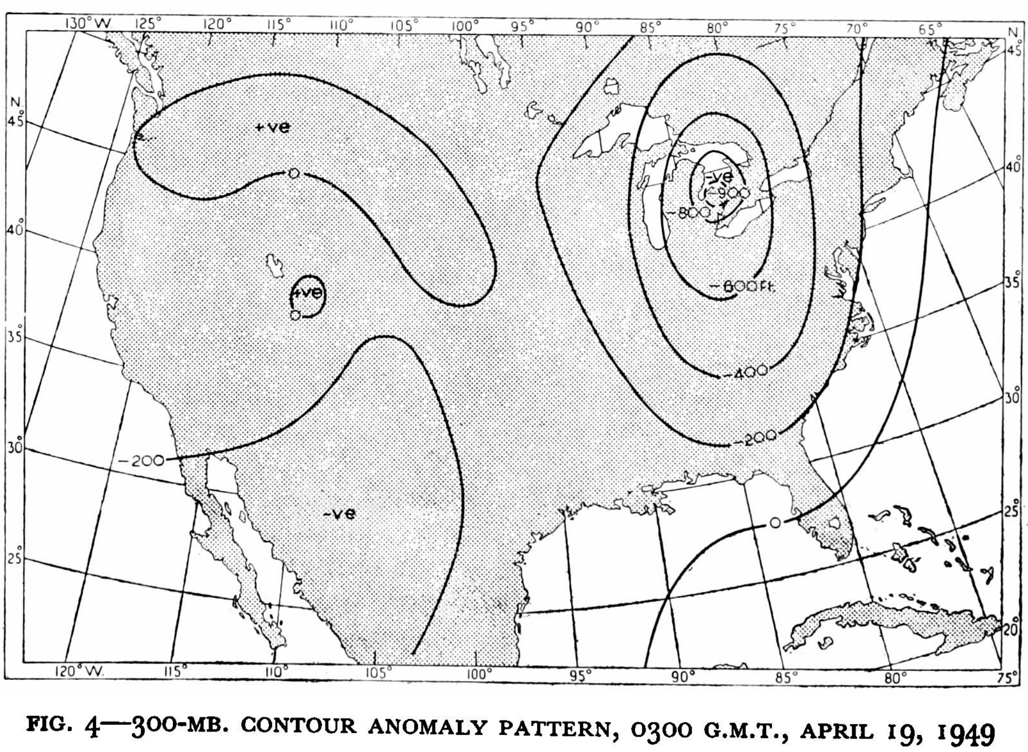

FIG. 4—300-MB. CONTOUR ANOMALY PATTERN, 0300 G.M.T., APRIL 19, 1949

intensity between the 500-mb. and 300-mb. levels, but the vortical geostrophic winds increase in this range proportionately to the increase in contour anomaly.

Similar patterns are found at other levels.

An examination of the situation illustrated, and others, convincingly demonstrates that it is possible to disentangle a perturbation field from a mean flow, and to analyse the horizontal and vertical structure of individual vortices. The anomaly chart purports to display the vortical structure as such, and, from this point of view, might be studied with profit so as to gain a clearer picture than is possible with the raw contour maps, which inevitably include the distortions associated with the mean flow.

The use of such charts puts emphasis on the high-level morphology of pressure patterns, and it seems likely that the structure of a vortex is related to its subsequent evolution.

The relation of horizontal pattern to stage of maturity and future development is well known in the case of frontal lows, and is an indispensable part of the forecaster's machinery. It may equally be possible to trace a characteristic evolutionary change in the vertical structure of pressure patterns, thereby making use of vertical structure as a guide to future development. That there is a characteristic evolution in the vertical structure of systems is, of course, widely known. Anticyclones characteristically first appear as cold wedges of little depth, and develop into warm highs of great vertical extent. On inception the frontal low is "warm" and shallow. There is a steady vertical extension with the occlusion process.

Goldie[2] has made these qualitative findings rather more explicit by presenting "characteristic" vertical structures corresponding to early and late stages of occlusion. He finds that in the natural occlusion momentum remains approximately constant with height up to about 8 Km. (Clayton-Egnell law) and falls off rapidly at higher levels. A similar structure of momentum is found to be characteristic of the developed warm high.

The author[3] has been able to confirm Goldie's broad findings by means of a parametric approach to the measurement of vertical structure. This parametric approach can be used to examine quantitatively such characteristic evolutionary developments as the occlusion process, and the transformation of a migrating cold high into a warm, stable system.

The bearing of these structural features on the evolution of pressure patterns is a question which must be left to future synoptic research. However, enough is known from a limited number of cases studied, to express the belief that high-level structure is an important element in the evolutionary process, and hence a key in the forecasting of development in the field of pressure. In an examination of vortical structure the anomaly chart may be expected to play an important role.

The anomaly-pattern technique can, of course, be applied to other meteorological elements, such as temperature, thickness pattern, etc.

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UNUSUAL AUGUST WEATHER OVER SOUTHERN SPAIN AND PORTUGAL

By A. WARD

The most marked feature of the weather over southern Spain and Portugal during the summer months is the almost complete lack of rain; over very large areas the average monthly rain in August is less than 0·2 in.[1] Much of the rain which does occur is in the nature of isolated upper-level thunderstorms, either produced *in situ* by the diurnal heating of the ground or carried over from north Africa by a southerly upper wind. The storms occur in the evening or during the early part of the night, and are generally quite local and of short duration. However, during the period August 27–29, 1952, inclusive, practically the whole area was affected by outbreaks of thundery rain or thunderstorms, and in places, particularly over an area to the north-east of Gibraltar, falls of over 1 in. were recorded.

Synoptic situation.—Throughout the period an anticyclone was centred north of the Azores with a ridge extending to the east-north-east over northern France and the Low Countries. Shallow and indefinite depressions persisted over Spain and Portugal until, on the morning of August 29 when a considerable fall in pressure occurred over south-western France and the southern Bay of Biscay, a more definite depression developed in the Bay, and a westerly gradient was established across the Iberian Peninsula. The synoptic chart for 0600 G.M.T. on August 28 is reproduced in Fig. 1.

Fair or fine weather was reported over most of the Iberian Peninsula on the 26th and during the night of the 26th–27th. Reports of thick medium cloud at Madeira and isolated cumulonimbus over French Morocco on the evening of the 26th indicated increasing instability to the south-west and south. During the morning of the 27th thick, unstable medium cloud, with outbreaks

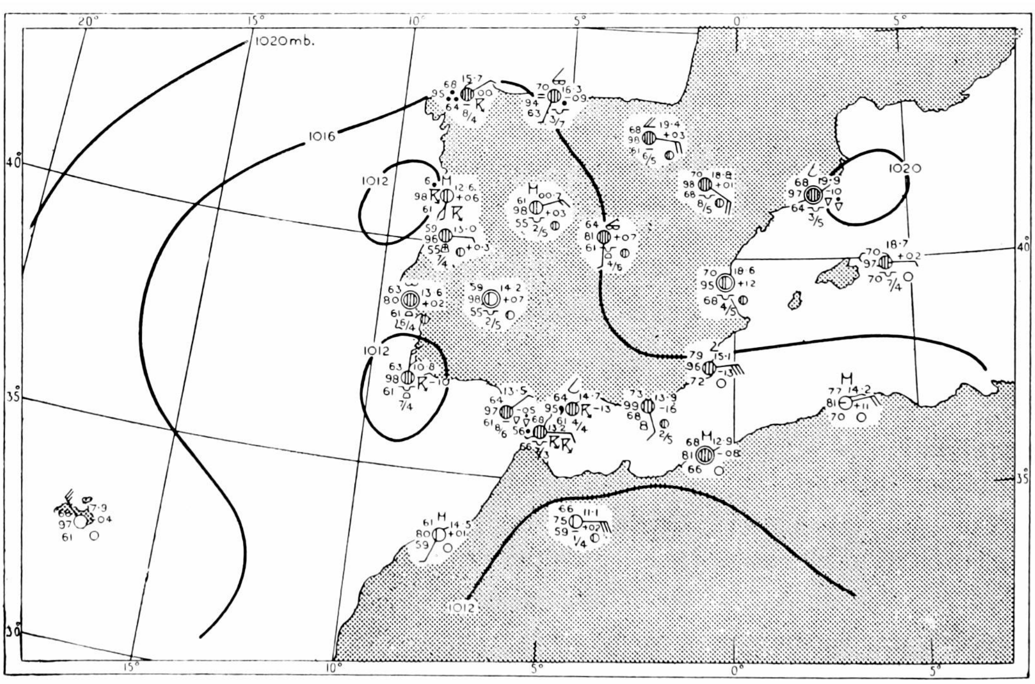


FIG. 1—SYNOPTIC CHART, 0600 G.M.T., AUGUST 28, 1952

of thundery rain, spread quickly north-east over southern Spain and by the evening had covered most of central, eastern and southern Spain. The area of thundery outbreaks continued to spread, and by midday on the 28th covered practically the whole of Spain and Portugal. During the 29th clearing conditions moved slowly north-east across the peninsula and the thundery outbreaks moved into southern France.

The lack of information precludes the construction of a detailed rain chart over the period, but it is evident that, over a very large area, the rainfall exceeded 0·5 in. The area of heaviest fall was to the north-east of Gibraltar where, in places mainly in the foot-hills and on the southern slopes of the Sierra Nevada, falls of over 1 in. in 24 hr. were recorded. The available climatological data for this area[1] indicate a mean August rainfall of about 0·2 in., with a maximum 24-hr. fall of 0·1 in. or less. The total rainfall at Gibraltar during the period was 0·3 in.

Upper air temperature and moisture content.—The unusual rainfall is mainly attributed to a cold pool, which developed in a pronounced cold trough off the Portuguese coast on August 26, moved eastwards to a position near Lisbon by 0300 G.M.T. on the 27th, and after remaining almost stationary for 24 hr. slowly increased in temperature and moved north-eastwards into the Bay by 0300 G.M.T. on the 30th. The 1000–500-mb. thickness chart for 0300 G.M.T. on August 28, with the approximate movement of the cold pool marked by crosses, is reproduced in Fig. 2. The exceptional depth of the cold air, indicated by a closed 18,200-ft. thickness line near Lisbon, was undoubtedly due to the marked southward penetration of cold air on the 25th and 26th

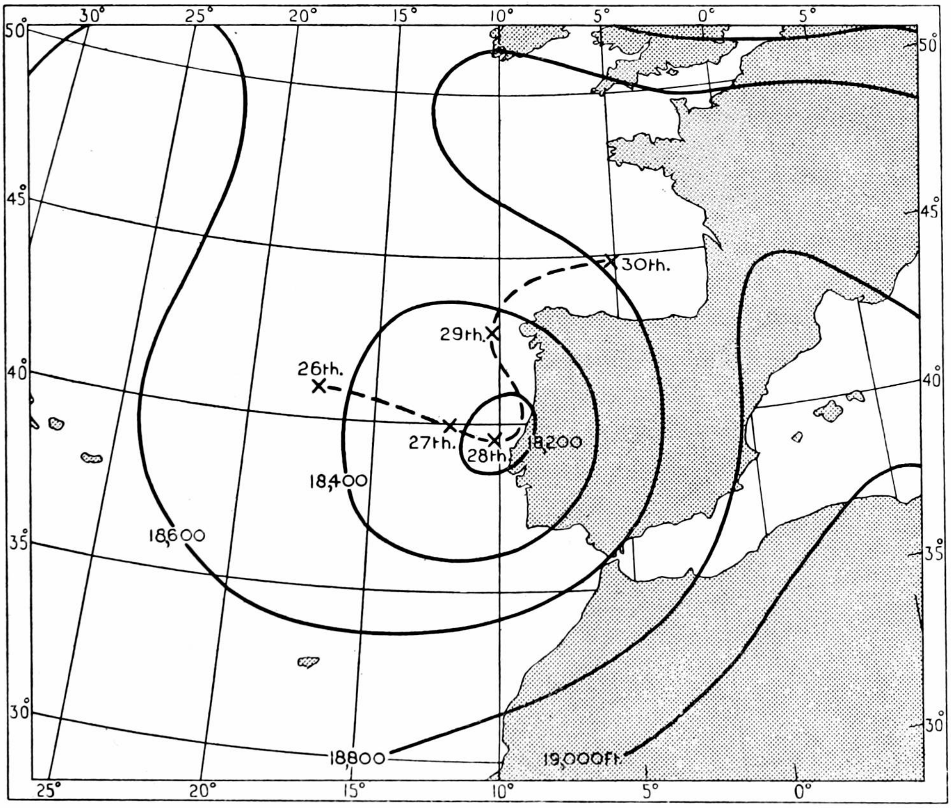
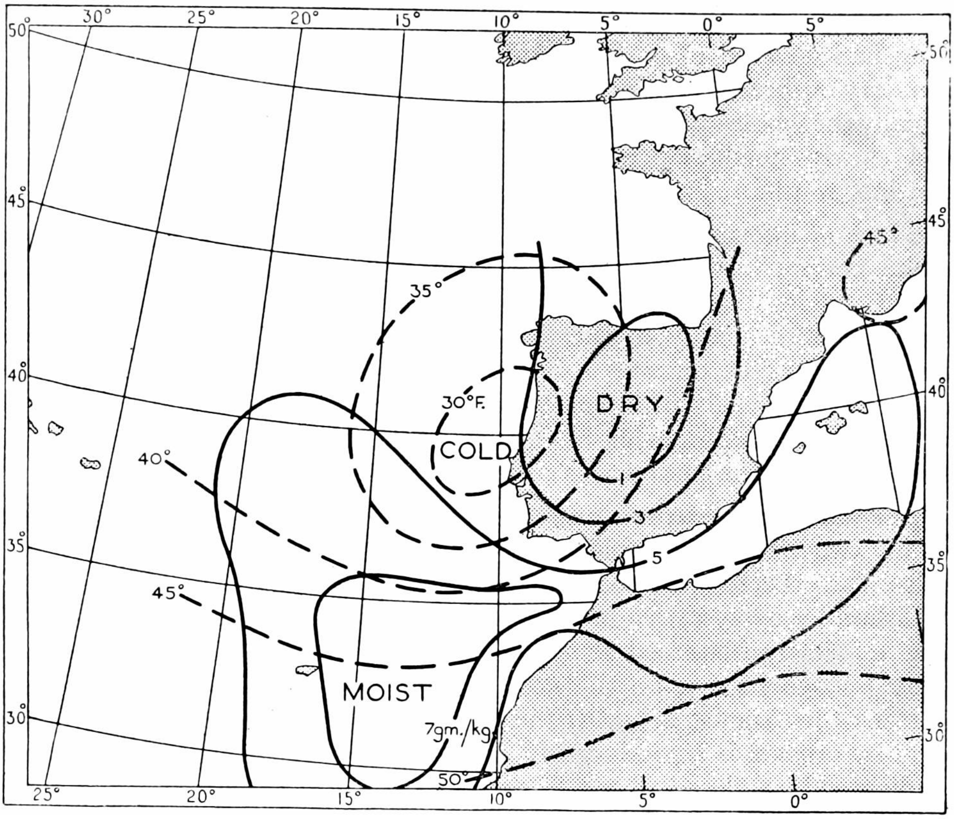


FIG. 2—1000–500-MB. THICKNESS CHART, 0300 G.M.T., AUGUST 28, 1952



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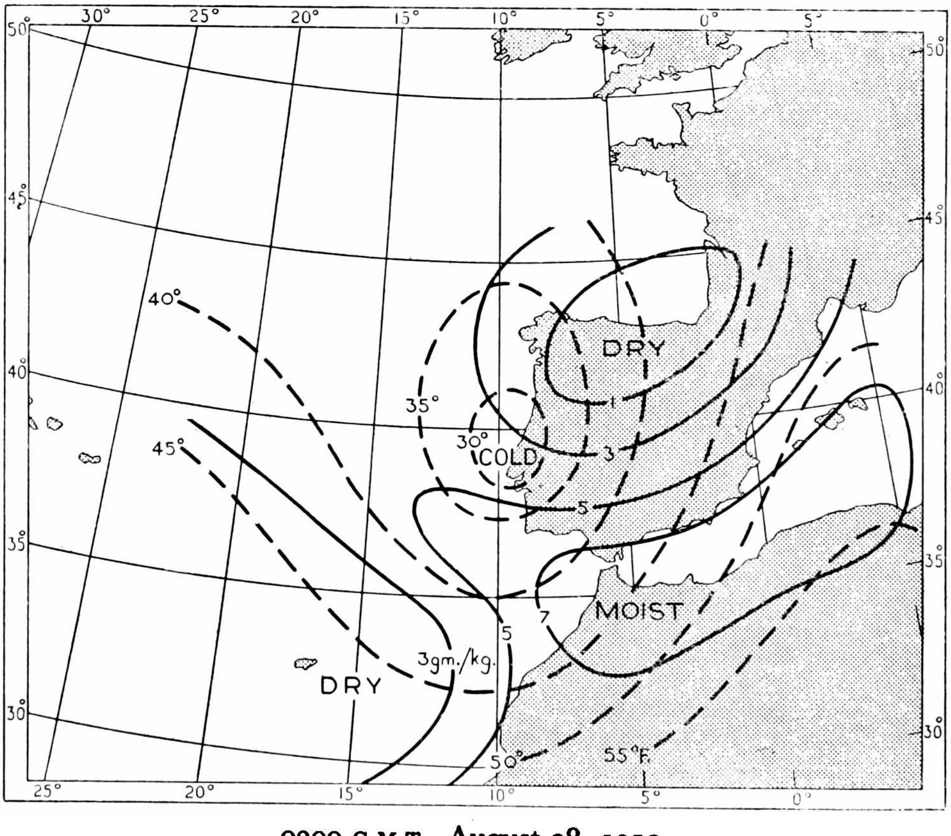

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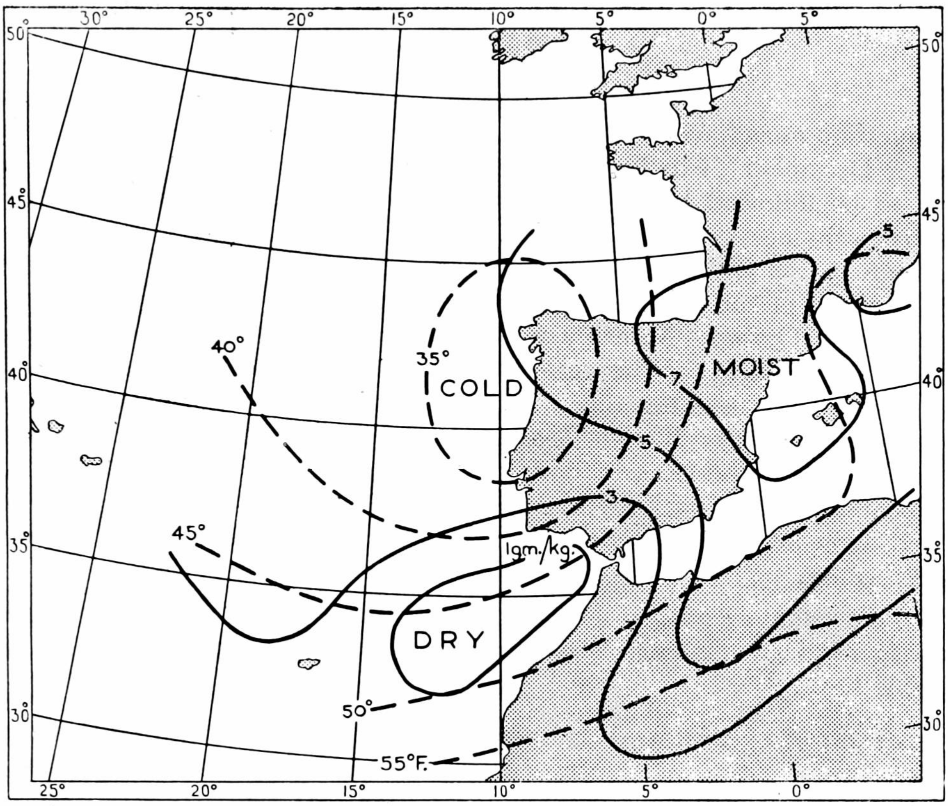

0300 G.M.T., August 29, 1952

FIG. 3—700-MB. TEMPERATURE AND MOISTURE-CONTENT CHARTS FOR AUGUST 27–29, 1952

- - - - - - - - - Isotherms. ———————— Isopleths of humidity mixing ratio.

Saturation humidity mixing ratio at 700 mb.

°F.	gm./Kg.	°F.	gm./Kg.	°F.	gm./Kg.
25	4	35	6	45	9
30	5	40	7·5		

behind a slow-moving depression over the Bay of Biscay. The 1000–500-mb. thickness at Lisbon was over 400 ft. below the mean value for August[2].

Cold pools of similar intensity have occasionally developed off the Portuguese coast in August in previous years, notably in 1947, but on these earlier occasions it appears that the air was too dry to give other than isolated thundery outbreaks.

During the period under discussion, however, the cold pool was associated with a pocket of very moist air aloft; the thundery outbreaks were closely related to the north-eastward movement of this moist air and the subsequent improvement to the incursion of drier air from the south-west. Selected 700-mb. temperature and moisture-content charts, based on all the upper air data available, are reproduced in Fig. 3.

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DOES A COLD AUTUMN HAVE ANY INFLUENCE ON THE WINTER FOLLOWING?

By R. F. M. HAY, M.A.

The question must have occurred to many people recently (this is being written in early December), whether a cold autumn such as we have just experienced tends to be followed by a cold winter or otherwise. A similar problem in seasonal sequences was recently investigated by Glasspoole.* For the south Midlands it was anticipated that some useful information might be obtained from a study of the long homogeneous temperature record of the Radcliffe Observatory, Oxford. Monthly values of mean temperature for this station have been published for the period 1815–1930. For the purpose of this note these values were used together with the series for the same station since published in the *Monthly Weather Report*, which were made directly comparable with the aid of monthly corrections kindly supplied by the Radcliffe Meteorological Station. The data used here refer to the period 1821–1950; autumn is defined as September, October and November, winter as December, January and February.

As the decadal means for autumn and winter for this period showed a range of up to 1·5°F., a first step was to obtain smoothed decadal means as given in Table I.

TABLE I—DECADAL MEAN TEMPERATURE DURING AUTUMN AND WINTER

Oxford — Period: 1821–1950

Decade	Autumn	Winter	Decade	Autumn	Winter
	°F.	°F.		°F.	°F.
1821–30	50·3	38·9	1881–90	49·2	38·9
1831–40	49·9	39·0	1891–1900	49·5	39·0
1841–50	49·5	39·0	1901–10	49·5	39·5
1851–60	49·4	39·2	1911–20	49·4	40·0
1861–70	49·4	39·5	1921–30	49·8	40·0
1871–80	49·2	39·2	1931–40	50·3	39·4
			1941–50	50·7	39·3

Smoothed values were obtained by the usual $(a + 2b + c)/4$ method, and the deviations of each autumn and the following winter from this long-period mean were corrected for each year for the difference of the appropriate smoothed decadal mean from the long-period mean. In practice a value of the smoothed decadal mean appropriate to each year was used by simple interpolation from the above table. In this way a large part of the effect of secular change was eliminated.

Frequency distributions of temperature deviations for autumn and winter at Oxford (related to smoothed decadal means as described) are shown in Fig. 1. The autumn curve has almost a "normal" distribution. The curve for winter on the other hand is distinctly "skew" and has two additional interesting maxima. These are taken to indicate a preference for a winter type of pressure distribution giving mild winters with a mode in the temperature deviations at +2·3°F. and for a less common type, though one which gives severe winters, with another mode at −5·3°F. These curves were drawn to assist in defining classes of autumn and winter temperature deviations, from

*GLASSPOOLE, J.; Seasonal weather sequences over England and Wales. *Met. Mag., London*, **78**, 1949, p. 193.

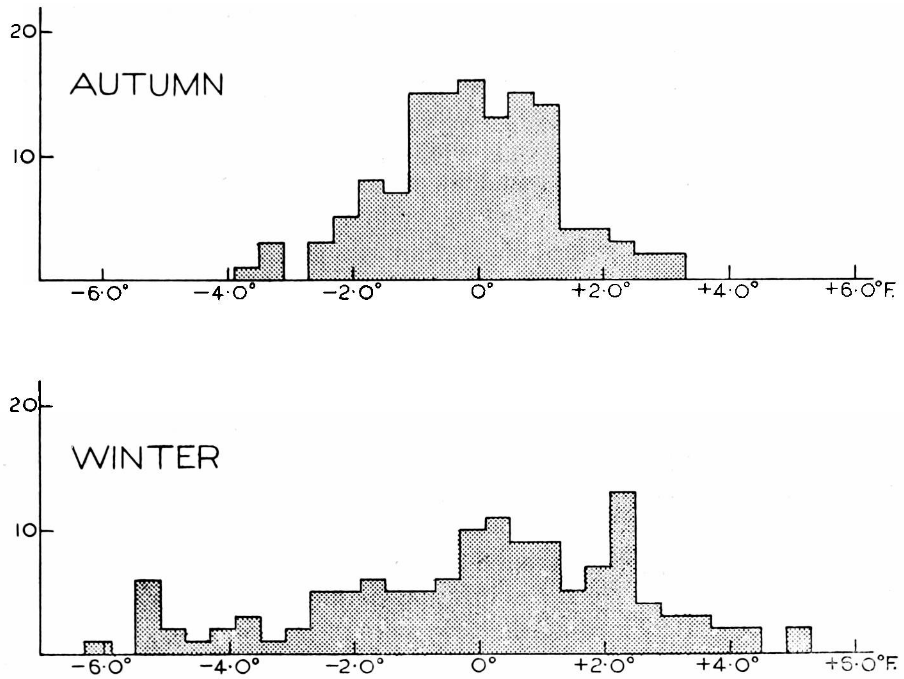

FIG. 1—FREQUENCY DISTRIBUTION OF DEVIATIONS OF MEAN DRY-BULB TEMPERATURE FROM SMOOTHED DECADAL MEANS, OXFORD 1821–1950

which the data given in Table II were obtained. The definitions adopted for both autumn and winter were: "average" not more than 0·9°F. from the mean, "above" or "below" more than 0·9°F. but not more than 2·9°F. from the mean, and "much above" or "much below" more than 2·9°F. from the mean.

TABLE II—CONTINGENCY TABLE BETWEEN ASSOCIATED TEMPERATURE DEVIATIONS DURING AUTUMN AND THE FOLLOWING WINTER

Oxford — Period: 1821–1950

AUTUMN	FOLLOWING WINTER Much below	Below	Average	Above	Much above	Totals
Much above	..	..	..	1	1	2
Above	2	3	8	11	3	27
Average	10	15	23	16	7	71
Below	2	5	9	9	1	26
Much below	2	1	..	1	..	4
Totals	16	24	40	38	12	130

It is at once obvious that the information here is of no direct value for long-range forecasting. Autumns classified as "below" and "much below" are almost equally likely to be followed by cold or warm winters. There does appear to be some evidence that autumns "above" and "much above" average are followed by winters "above" or "much above" more often than by winters "below" average. As there were not enough occasions in all classes for a χ^2 test to be applied to the table as it stands, the data for "much above" and "much below" were joined with their respective "above" and "below" classes for this purpose. Application of the test showed no statistically significant difference in the class frequencies from expected values, i.e. there is no significant association between characteristics of autumns and following winters when simply expressed as "above" and "below" normal. In preparing Table II the years which contributed to each class were noted. Most interest attached to the cell relating autumns above average with winters above average which included 11 out of 27 autumns in this class, namely those for the years 1824, 1834, 1847, 1865, 1866, 1921, 1929, 1938, 1945, 1947, and 1949. However, the influence of minor climatic change is evident here since no year between 1866 and 1921 contributed to this cell, while 4 years in the last 12 contributed.

The smoothed decadal means show that the period of mild winters in the first three decades of the present century has ended. The rate of fall of the decadal means has, however, become less and the fall seems unlikely to persist through another decade. At Oxford autumn decadal temperatures have increased by 1·3°F. in the last 30 years, though the recent autumn suggests this process may be ending. The autumn of 1952, relative to the appropriate smoothed decadal mean, was the coldest in the 130 years' series (deviation −3·9°F.), although in relation to the long-period mean the autumns of 1829, 1840, 1887 and 1919 were slightly colder.

In conclusion no reliable inference regarding the temperature of the winter of 1952–53 can be drawn from the unusual coldness of the past autumn. The most that can be stated is that the few cases of exceptionally cold and warm autumns in the past 130 years have been mostly followed by cold and warm winters respectively. Since sea temperature is very conservative and winter temperature in Great Britain is to some extent influenced by sea-surface temperature this result is not surprising; its violation is brought about by the incidence of easterly winds which, as was well seen in February 1947, can greatly reduce the warming influence of the narrow seas within a few weeks.

ACCURACY OF 100-MB. WINDS

By D. H. JOHNSON, M.Sc.

Summary.—The results of a statistical test applied directly to the wind reports show that for British land stations the standard vector errors in reported winds at the 100-mb. level are generally less than 6 kt.

Introduction.—A notable feature of the wind field at the 100-mb. level is its steadiness in space and time. This provides an opportunity to establish directly an upper limit to the observational error in the wind reports. Bannon[1] has already estimated from the performance of the radar equipment that high-level wind errors should be small. This is confirmed in the present paper.

Estimates of wind errors from instrumental performance.—Estimates of the errors in winds measured with the GL. Mk III radar equipment in use at British land stations have been made by Bannon[1]. These apply to measurements of wind over 1-min. intervals, and were deduced from the basic errors of the radar instrument as functions of height and of the mean wind speed up to the level in question. Bannon's estimates of the root-mean-square vector error in the measurement of winds at 50,000 ft. are reproduced in Table I. These values are expected to vary slightly with the skill of the operators and the state of efficiency of the instrument.

TABLE I—ROOT-MEAN-SQUARE VECTOR ERRORS IN WINDS AT 50,000 FT. TO THE NEAREST KNOT (DUE TO BANNON)

	Mean wind (kt.)						
	10	20	30	40	50	60	70
Root-mean-square error (kt.)	2	2	3	4	5	6	7

Errors at 100 mb.—The appropriate pressure level for each radar observation of wind is determined from a graph drawn to show the pressure level reached by the radio-sonde at any chosen time. Winds are calculated from radar observations made at 1-min. intervals, but it is the practice in the British Meteorological Office to ascribe to a given pressure level a wind averaged over a period of either 2 or 3 min. At 100 mb. the random errors in the measurement of pressure are known to be large. Harrison[2] has given the probable error at 200 mb. as 5 mb. It follows that winds at 100 mb. cannot be measured so accurately as winds at 50,000 ft. Additional errors may arise in the computation and transmission of the data.

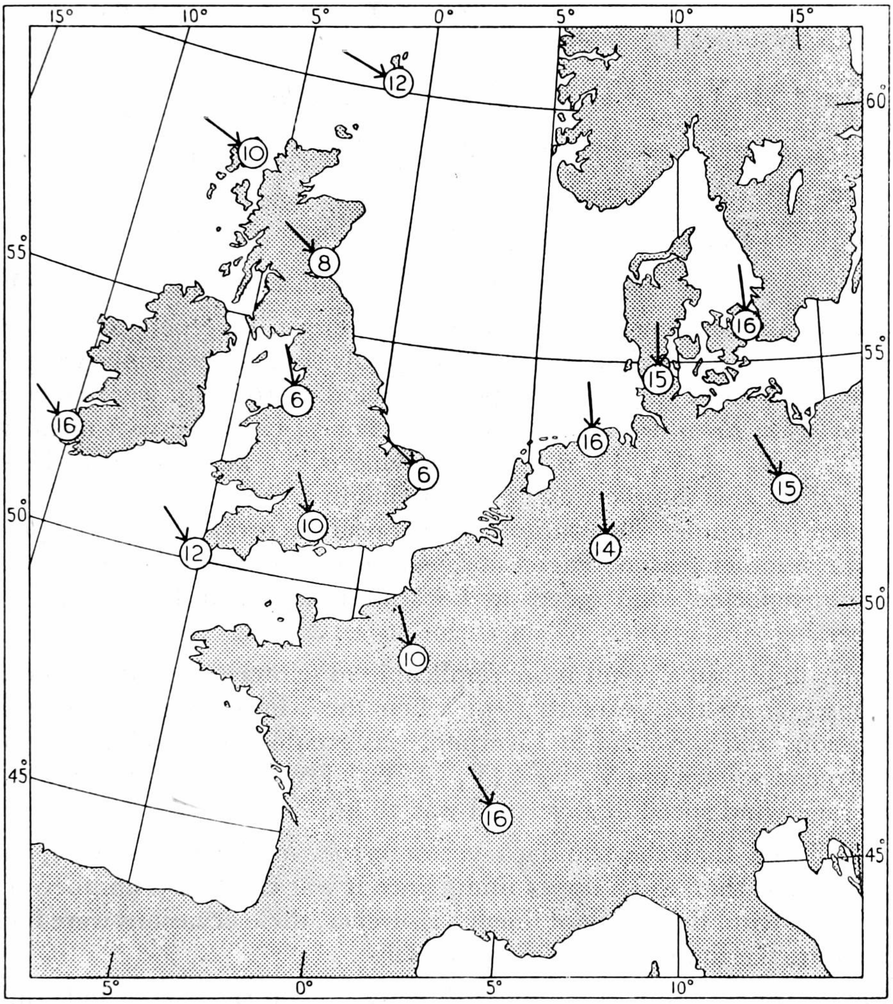

FIG. 1—WINDS (IN KNOTS) AT THE 100-MB. LEVEL, 1500 G.M.T., MARCH 17, 1952

A feature of the 100-mb. wind reports is the general coherence of the observations both in space and time with the suggestion of a steadiness in the wind exceeding that of lower levels. An example of the general coherence in space is shown in Fig. 1. Such smooth flow patterns are regularly to be seen on the working charts, which itself implies that the total effect of the vector errors discussed above must be small. It was decided to utilize this property of the flow to estimate statistically an upper limit to the total standard vector error of the reported winds rather than to attempt to estimate the magnitude of the component errors individually.

Statistical test.—Three stations A, B, C, are required, spaced at equal intervals along a line.

Let the true (vector) winds at A, B, C, be $\mathbf{V}_1$, $\mathbf{V}_2$, $\mathbf{V}_3$

Let the measured winds at A, B, C, be $\mathbf{V}_1'$, $\mathbf{V}_2'$, $\mathbf{V}_3'$

Let the (vector) errors in winds at A, B, C, be ε_1, ε_2, ε_3

Then the wind at B may be estimated from the winds at A and C by linear interpolation with an error η

Thus
$$\mathbf{V}_2 = \tfrac{1}{2}(\mathbf{V}_1 + \mathbf{V}_3) + \eta$$

or
$$\mathbf{V}_2' + \varepsilon_2 = \tfrac{1}{2}(\mathbf{V}_1' + \mathbf{V}_3') + \frac{\varepsilon_1}{2} + \frac{\varepsilon_2}{2} + \eta\,.$$

Thus $\left\{\mathbf{V}_2' - \tfrac{1}{2}(\mathbf{V}_1' + \mathbf{V}_3')\right\} = \dfrac{\varepsilon_1}{2} + \dfrac{\varepsilon_3}{2} - \varepsilon_2 + \eta.$

Now ε_1, ε_2, ε_3 and η are independent and $\overline{\varepsilon_1{}^2} = \overline{\varepsilon_2{}^2} = \overline{\varepsilon_3{}^2} = \sigma^2$ (say).

Therefore
$$\overline{\left\{\mathbf{V}_2' - \tfrac{1}{2}(\mathbf{V}_1' + \mathbf{V}_3')\right\}^2} = \tfrac{3}{2}\sigma^2 + \eta^2$$

and hence $\sigma\sqrt{(3/2)}$ is less than the root mean square of $\left\{\mathbf{V}_2' - \tfrac{1}{2}(\mathbf{V}_1' + \mathbf{V}_3')\right\}$.

The three British upper air stations at Aldergrove, Liverpool and Downham Market are approximately collinear and equally spaced; occasions were chosen from the first half of 1951 when reports of wind at 100 mb. were given in the *Daily Aerological Report* for all three stations. For 74 cases the root mean square of $\left\{\mathbf{V}_2' - \tfrac{1}{2}(\mathbf{V}_1' + \mathbf{V}_3')\right\}$ was 6 kt., implying $\sigma < 5$ kt. The mean Liverpool wind speed for this sample was 13 kt. As might be expected there was a preponderance of summer observations, so this result is probably more representative of the summer season; Part 1 of *Upper air data 1946–50*[3] gives the average of 100-mb. reported wind speeds at Larkhill as 13 kt. in June and 27 kt. in December.

In order to obtain a result more applicable to winter observations, occasions were chosen from the years 1950–51 when the winds were available for all three stations and the wind at Liverpool was greater than 19 kt. For 78 cases the root mean square of $\left\{\mathbf{V}_2' - \tfrac{1}{2}(\mathbf{V}_1' + \mathbf{V}_3')\right\}$ was 7 kt. implying $\sigma < 6$ kt. The average wind speed at Liverpool was 26 kt.

It is believed that the standard vector errors in the winds were, in fact, appreciably less than those upper limits since it was clear on a number of occasions that the wind field was not linear. However, these occasions were included in order to make the test completely objective.

Conclusions.—These tests, made directly on the reported winds, indicate that the standard vector error of 100-mb. wind reports from British land stations must be small both in summer and winter. They confirm the order of magnitude of the errors in winds at 50,000 ft. deduced by Bannon from the basic errors of radar.

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METEOROLOGICAL OFFICE DISCUSSION

Short-range weather forecasting

The discussion on Monday, November 17, 1952, held at The Royal Society of Arts, was opened by Mr. V. R. Coles who based his statement on two articles from the "Compendium of meteorology":—

DUNN, G. E.; Short range weather forecasting, p. 747.

BUNDGAARD, R. C.; A procedure of short-range weather forecasting, p. 766.

Mr. Coles said that both articles indicated that the problem of weather forecasting can be divided into three sections:—

(i) Analysis of current information

(ii) Construction of forecast charts

(iii) Forecasting the weather from the completed forecast charts.

Both Dunn and Bundgaard are mainly concerned with the construction of forecast charts, though they point out that on many occasions the problem of forecasting the weather is more difficult.

Although surface forecast charts—prebaratics—and upper air forecast charts —prontours—must obviously be closely integrated, the writers point out that there is some advantage in a semi-independent preparation of the prebaratic and prontour charts. This procedure ensures that well marked features on the upper charts are given full weight on the forecast charts and are not obliterated without good reasons.

After the prebaratic and prontour charts have been prepared more or less independently, they are adjusted to be mutually consistent.

The first step in the construction of all forecast charts is extrapolation of recent trends, and the prebaratic is considered first. Extrapolation from working charts over the last 24 hr. leads to the first approximation to the prebaratic and this approximation is then adjusted in the light of current tendencies. To this end isallobaric charts for 3 hr. and 12 hr. are maintained, the 12-hr. charts being adjusted for diurnal variation of pressure. New systems cannot, of course, be forecast by the extrapolation procedure, and the latest tendency field must be carefully watched for indications of the formation of wave disturbances on fronts and the development of new anticyclones.

Having located a wave disturbance the forecasting problem is to decide whether it is likely to develop into a large depression. At this stage in the preparation of the prebaratic chart the methods recommended by the two writers diverge, Dunn making use of the 700-mb. contour chart to decide how the surface systems can be expected to develop and move, whilst Bundgaard describes how Sutcliffe's expression for the divergence of the thermal wind enables the thickness chart for 1000–500 mb. to be used to determine areas of cyclonic and anticyclonic development and to forecast the movement of surface systems. Bundgaard points out that Sutcliffe's work calls for some modification of Scherhag's earlier rules for determining the development of surface systems from the topography of the 500-mb. contour chart. Several of these rules are quoted in Bundgaard's article.

Dunn then describes the semi-independent preparation of the 700-mb. forecast chart, other levels being constructed in a similar manner. The process is again one of extrapolation of recent trends, with adjustment in the light of the latest tendency field, followed by comparison with the independently prepared prebaratic.

Bundgaard describes the preparation of prontour charts by the building-up process, and is therefore concerned particularly with the forecasting of the thickness patterns. He describes in detail the preparation of the 1000–500-mb. forecast thickness, or pre-thickness chart. Again, extrapolation of recent trends is the first step followed by a correction for current tendencies, due weight being given to the motion of cold pools, warm ridges, etc. Bundgaard points out that though the thickness lines move, to the first approximation, with the gradient wind through the isobaric layer, care must be taken to make allowance for non-advective dynamical and thermodynamical effects. The completed pre-thickness chart is then compared with the prebaratic for consistency and the prontour chart obtained by the graphical addition of pre-thickness and prebaratic charts.

The problem of forecasting the weather from the completed forecast charts is not dealt with in great detail in either article, though Bundgaard devotes some time to the problem of objective forecasting, taking as an illustration the forecasting of rainfall amount.

The Director, before inviting general discussion, referred to the fact that forecast manuals were now being prepared in which the forecasting of pressure patterns and of the weather would be separately treated. In connexion with objective forecasting he asked what success the method had achieved.

Mr. Sharp said that the forecasting devices we had heard about were all empirical, and that the forward step made when fronts were recognized was of an entirely different nature, being the recognition of something factual, something real and fundamental. Mr. Sharp suggested the next big step forward would be similar, and would come from the appreciation of fundamental processes in the upper atmosphere above 500 mb.

Dr. Stagg asked if there was anything in practice we could learn from Dunn and Bundgaard's methods and whether sufficient attention was paid to cold pools. Mr. Coles replied that pre-thickness charts had been prepared independently of the prebaratics for some time at Dunstable as an experiment, but it was probably true to say that they were not so good as pre-thickness charts prepared after the completion of the prebaratic.

Mr. Sawyer said that a study of the extensive literature on methods of "objective" forecasting suggested that results achieved up to the present had been roughly of the same standard as those obtained by conventional methods. An attempt at Dunstable to estimate rainfall from prebaratic charts by computing Sutcliffe's expression for cyclonic development had given rainfall patterns which looked reasonable in relation to the chart. However, important features of the rainfall distribution obtained in this way were often dependent on minor details of the prebaratic chart which could not be relied upon. Perhaps the best way of improving rainfall forecasts was to apply statistical methods to specific recognizable synoptic types, rather than to such "objective" methods which are expected to apply with westerlies and easterlies alike.

Dr. Sutcliffe said that we could no longer blame all our forecasting troubles on our lack of a theoretical understanding of depressions and anticyclones. In fact we had now a tolerably good idea of how and why these systems developed,

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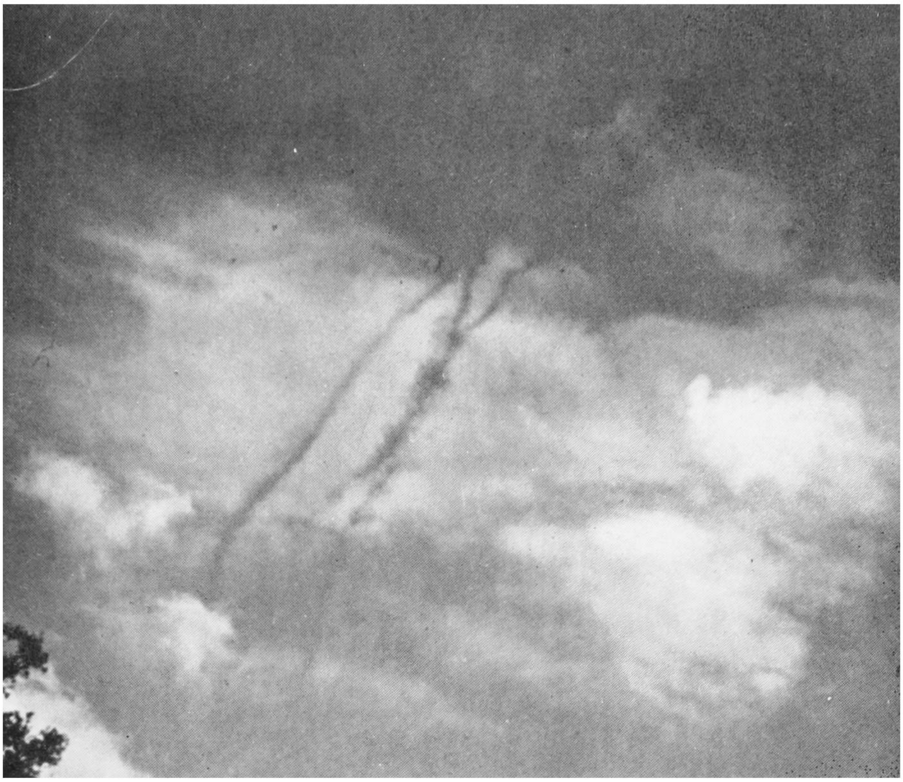
MAMMATUS CLOUD, ANDORRA, JULY 15, 1952

(see p. 57)

Reproduced by courtesy of Bath & Wilts. Chronicle & Herald

GLAZED FROST, LANSDOWN, BATH, SOMERSET, 11.15 a.m., NOVEMBER 30, 1952



Reproduced by courtesy of METPHOTO

CLOUD CLEARANCE LANES BY AIRCRAFT NEAR RYE, SUSSEX

The photograph was taken about 1730 on August 17, 1952, a few seconds after three piston-engined aircraft had passed through the cloud. The lanes slowly filled in and after five minutes had disappeared.

Reproduced by courtesy of METPHOTO

AIRCRAFT CONDENSATION CLOUD IN SHADOW

To face p. 49]

Reproduced by courtesy of J. W. Wilkins

TYPICAL FOG CONDITIONS, RICHMOND PARK, SURREY, 1500, DECEMBER 7, 1952

(see p. 57)

but the theory suggested that prediction had inherent limitations. It may be that the general standard of short-range forecasting had not improved very much, and so far as we could see at present there may be little prospect of a radical improvement, but there was a great difference, he said, between uncertainty based on ignorance, which led to guesswork, and uncertainty based on scientific understanding, which permitted the forecaster to give the maximum amount of useful advice appropriate to the problem in hand. It was very valuable to study methods used in other countries, but the conclusion was that at present there were no revolutionary ideas waiting to be picked up, little more than interesting variations in technique. Until something new was discovered the practical forecaster could justifiably regard his duty as that of extracting the extra few per cent. of efficiency by conscientious work in the light of available knowledge. Dr. Sutcliffe commented on numerical methods, and indicated that research was going well in the Office as well as in other countries but we had no right as yet to expect revolutionary improvements in forecasting by these methods.

Dr. Farquharson stressed the value of having trained scientists as forecasters, who could assess the relative value in the day-to-day problem of results achieved by research. It was better that a trained scientist should make an *ad hoc* selection of what was likely to be useful to him in the practical problem rather than that small pockets of staff should be employed on various lines suggested by research which might possibly be useful. The Forecast Division was at present engaged in two experiments: in one the upper air forecaster was attempting to work independently of the surface forecaster in the preparation of prebaratics; in the other the quantitative forecasting of rainfall in the London area was being attempted. The Forecast Division was very much alive to needs and did its best to meet outstation requirements; it would be interesting to hear what outstations had to say about this.

Mr. Robins criticized the prebaratics prepared by the Forecast Division, indicating that too little attention seemed to be paid to isallobaric, and too much to upper air, fields.

Mr. Douglas said that great weight was attached to tracks and barometric tendencies by the forecasters at the Central Forecasting Office, and three-dimensional analysis should not be regarded as a rival technique. Its function was rather to explain the changes in progress, and failing some miraculous advance in forecasting this was the criterion by which scientific ideas should be judged. A better understanding of the underlying physical processes leads to some improvement on pure extrapolation. The significant features of the tendency field can be picked up while the chart is being plotted. If isallobars are drawn this must be done on a separate chart before the prebaratic is made, at the same time as the isobaric chart is being drawn up and analysed. Hitherto the demand for the 3-hourly isallobaric chart has not been strong enough to justify it. Isallobaric charts for longer time intervals are difficult to interpret physically and are therefore more purely empirical. The factors which make progress in forecasting a slow process also limit the standard attainable by any forecaster. In view of the large element of chance in 24-hr. forecasting, an outstation forecaster will sometimes make a better guess than Dunstable. A reasonable measure of consistency in the forecasts issued must be maintained, but within these limits our outstations have always enjoyed considerable freedom.

Cmdr Frankcom asked if use were made of ships' barometric-tendency reports and whether the establishment of ocean weather ships had improved the accuracy of forecasts. Mr. Coles, in his reply, stated that he considered ships' observations to be vital and that tendency reports were necessary.

Dr. Scorer pleaded for greater attention to be paid in textbooks to the aspect of diurnal variation of the various weather elements.

Mr. Gold stressed that the step from forecast charts to weather forecasts was on occasions much more difficult than from analysis to forecast charts, and suggested that a special study of forecast errors associated with "wrong placing" on the forecast charts was needed.

Several following speakers protested about the mutilation of forecasts by the Press and B.B.C.

The Director, in summing up, said that post-mortems on forecasts were held daily at Dunstable and that major errors were investigated in an attempt to prevent their recurrence. He said that the forecasting monographs which were being prepared would give attention to all aspects of diurnal variation. He stated that considerable effort was spent in trying to ensure that the Press and B.B.C. did not mutilate the forecasts.

METEOROLOGICAL RESEARCH COMMITTEE

The 22nd meeting of the Synoptic and Dynamical Sub-Committee of the Meteorological Research Committee was held on October 3, 1952.

The papers discussed at this meeting included one by Mr. D. H. Johnson[1] on the accuracy of the measurement of the winds at 100 mb., and another by Mr. R. Murray[2] on jet streams over the British Isles during June 14–18, 1952. A paper by Mr. A. G. Matthewman[3] on cloud in relation to warm and quasi-stationary fronts near Bircham Newton in winter aroused much interest as it threw doubt on the idealized warm-front cross-section model which has adorned meteorological textbooks for the last 30 years.

The Sub-Committee also reviewed the progress made in research.

The 22nd meeting of the Physical Sub-Committee was held on October 9, 1952.

The Committee considered the results of work done during the previous winter on the measurement of visual range and of slant visibility and on the relation of these measurements to other conditions.

Interesting papers on turbulence in the lowest layers were discussed. They included one by Mr. Rider[4] dealing with the evaporation from a growing crop of oats in terms of the Richardson number at some low level and another by Mr. Lander and Dr. Robinson[5] describing some measurements of the small-scale fluctuations of wind and temperature near the ground.

The 14th meeting of the Instruments Sub-Committee of the Meteorological Research Committee was held on October 23, 1952.

The Committee reviewed the instrumental aspects of the investigation of visibility and visual range carried out last winter. Current methods of measuring liquid water content in cloud[6] were also considered.

Three reports dealing with the development of a technique for measuring atmospheric density at high altitudes by means of the scattering back of light from a pulsed searchlight beam were examined and a recommendation made regarding the next step in this work.

ABSTRACTS

1. JOHNSON, D. H.; A note on the accuracy of 100-mb. winds. *Met. Res. Pap., London,* No. 739, S.C. II/112, 1952.
Winds at 100 mb. are generally coherent in space and time, e.g. over west Europe on March 17, 1952. Hence winds at 3 collinear equally spaced stations can give the root-mean-square error at the middle one. For British stations it is appreciably below 6 kt.

2. MURRAY, R.; The jet streams over the British Isles during June 14–18, 1951. *Met. Res. Pap., London,* No. 743, S.C. II/114, 1952.
A long-wave trough with associated depression north of Scotland is shown by surface and 300-mb. charts. Vertical wind and temperature sections show a cold frontal zone and two jet streams. One moved rapidly south-east over Europe, dying out on June 16, the other moved south-east across the British Isles at about 5 kt., becoming dominant on June 15. Their average lateral speed, 7·9 kt., compares with a geostrophic component of 6·5 kt. Changes in wind maxima are related to changes of mean thermal gradient of troposphere. A model for tropopause structure and development during jet streams is put forward.

3. MATTHEWMAN, A. G.; On the three-dimensional structure of fronts: Part II—Cloud in relation to warm and quasi-stationary fronts near Bircham Newton in winter. *Met. Res. Pap., London,* No. 747, S.C. II/115, 1952.
Vertical cross-sections were drawn for 49 surface warm fronts or warm occlusions. Frontal cloud development is tabulated in relation to distance of surface front, height and thickness of frontal zone, shear of geostrophic and actual wind, relations between speeds of warm or cold air and of front, and ageostrophic motion of front. A definite relation was found only with forward wind component relative to front (correlation 0·5).

4. RIDER, N. E.; The evaporation from an oat field during the late spring and summer of 1951. *Met. Res. Pap., London,* No. 724, S.C. III/127, 1952.
The aerodynamic formula for evaporation from gradients of wind speed and specific humidity is extended to include zero displacement (height of effective surface above the ground, calculated from wind speeds at three heights) and Richardson number (for departure from adiabatic). The revised equation is applied to observations at various points in an oat field near Cambridge, recorded automatically at heights up to 160 cm. depending on the crop height. The apparatus is fully described and illustrated, specimen records shown, and a number of values of daily water loss computed (ranging from 0·05 to 5·65 mm.). Values are estimated as up to 15 per cent. too low.

5. LANDER, A. J. and ROBINSON, G. D.; Some observations of the small-scale fluctuations of wind and temperature near the ground. *Met. Res. Pap., London,* No. 740, S.C. III/138, 1952.
Records were made on cloudless days, wind 1–2 m./sec., 25 cm. over short grass, with small vertical and horizontal hot-wire anemometers and a resistance thermometer. Half-hourly profiles were taken of air and earth temperature, humidity and wind, with solar radiation and fluxes of atmospheric and terrestrial radiation. Theory and errors of flux of heat and linear momentum are discussed, and the estimated fluxes, eddy conductivity and eddy viscosity tabulated. The heat flux found is 30–50 per cent. of that calculated from radiation and soil temperature; the remainder is attributed to movements small compared with the instrument. The frequency distributions of the fluctuations are not normal and much of the heat flux is associated with large vertical currents. The turbulence is shown to be anisotropic.

6. MURGATROYD, R. J.; Methods of measuring liquid water content in cloud. *Met. Res. Pap., London,* No. 737, S.C. I/66, S.C. III/136, 1952.
The stringent instrumental requirements for use in aircraft are summarized. Existing methods discussed include: impaction, absorbent cylinders, capillary collector, resistence of absorbent paper, rotating cylinders, rotating disc, orifice-type icing-detectors, heated wires or cylinders, heated intake and hygrometer, transmitted or scattered light, etc.

HONOURS

The following awards were announced in the New Year Honours List, 1953:—

KNIGHT BACHELOR

Professor Harold Jeffreys, Cambridge University

O.B.E.

Mr. J. C. Cumming, Principal Scientific Officer, Meteorological Office

M.B.E.

Cmdr. J. Hennessy, R.D., R.N.R., Senior Nautical Assistant, Meteorological Office

OFFICIAL PUBLICATION

The following publication has recently been issued:—

METEOROLOGICAL REPORTS

No. 11—Duststorms of the Anglo-Egyptian Sudan. By M. H. Freeman, M. Sc.

Duststorms are the most important meteorological phenomena affecting the air routes over the Anglo-Egyptian Sudan. They are caused by an increase in the surface wind and occur in both winter and summer, but the two types are generated somewhat differently. In winter the gradient wind steadily increases and visibility is gradually reduced by blowing dust. In summer the duststorms are usually associated with thunderstorms and are known as haboobs; the wind increases in a sudden squall and visibility drops almost instantaneously from good to less than 1,100 yd.

The Report describes each type and discusses the physical processes involved. Statistics, based on the four-year period 1944–48, are given of frequency, duration, severity, time of onset and maximum wind speed. Methods of forecasting each type are considered. A particularly severe kind of haboob of long duration is discussed in detail in view of its importance to aviation. The Report was first written in 1948, and the principles outlined in it have been successfully used in the Anglo-Egyptian Sudan for some time.

ROYAL METEOROLOGICAL SOCIETY

At the meeting of the Society held on November 19, 1952, with the President Sir Charles Normand in the Chair, the following papers were read:—

*Ludlam, F. H.—Orographic cirrus cloud**

Mr. Ludlam said observations by aircraft pilots show that ridges or hills of 1,000 ft. in height can produce atmospheric waves disturbing the air flow up to 30,000 ft. leading to the air at these high levels being displaced vertically some 2,000 ft. at speeds of 1 m./sec. or more. At temperatures of about — 40°C. or less, if the humidity is sufficiently high, cloud droplets may form which subsequently freeze and form cirrus clouds which trail down wind. A number of observations made from Dunstable of cirrus trails forming over the Chilterns, Cotswolds and the Black Mountains were vividly described. The azimuths and elevations of the commencements of the trails were measured by theodolite. The rate of displacement of details observed by theodolite, supposing the clouds were at a height where temperature was about — 40°C., agreed with the Larkhill wind soundings. Orographic cirrus forms less readily in the middle of the day, as is to be expected from Dr. Scorer's theory of orographic wave formation which shows such waves form less readily when the air near the ground is made unstable by solar heating.

In the course of the discussion doubt was expressed about the orographic origin. Mr. Gold asked if these cirrus clouds had been seen at midday and how Mr. Ludlam knew the clouds were not at a higher level than where temperature was — 40°C. It was also pointed out by Dr. Farquharson and others that cirrus cloud has been observed at high levels from aircraft close to the cloud which could not be seen from the ground. Mr. Schove thought all cirrus was frontal in origin. Dr. Scorer said he had seen orographic cirrus

* *Quart. J.R. met. Soc., London,* **78**, 1952, p. 554.

at midday, and Prof. Sheppard described seeing cirrus form over the coastal mountains of south-west Ireland and spread inland. Mr. Ludlam said these clouds were observed at midday and when there were no obvious fronts. He pointed also to the mother-of-pearl clouds seen over southern Norway, which were at a much greater height than his orographic cirrus and were universally admitted to be of orographic origin. In thanking Mr. Ludlam, the President pointed out that the orographic theory of the formation of mother-of-pearl cloud was accepted by few meteorologists until the sail-plane observations in the Moazagotl wave of strong vertical currents at very great heights had been made.

*Sawyer, J. S.—A study of the rainfall of two synoptic situations**

Mr. Sawyer described the detailed analysis he had made of the rainfall associated with a small depression which moved eastwards across Northern Ireland and the English Midlands on March 14, 1949, the relation between the rainfall and the distribution of Dr. R. C. Sutcliffe's development function, and the effects of orographic lifting. A similar analysis for the rainfall connected with the warm front of February 14, 1950, is described in his published paper. Rates of rainfall were computed from the records of 50 autographic rain-gauges, and used to form a composite picture of the mean rate of rainfall in relation to the track and position of the centre of the depression. A chart of the distribution of the total rainfall was drawn using all the 24-hr. rainfall observations. The onset of the measurable rain was abrupt at most stations but no single moving line represented the onset of rainfall. The rain area had three discontinuous boundaries, one in the south, one in the centre, and one in the north, which overlapped at their ends and moved eastwards across the country. The main rain belt in front of the centre of the depression maintained a fairly constant position with respect to the depression but was not closely connected with the warm front. Most of the rain fell behind the warm front in the south-west and ahead of it in the south-east. The radar echoes observed from East Hill (near Dunstable) agreed well with the distribution of the rate of rainfall derived from the autographic records.

Sutcliffe's cyclonic development function was calculated at 6-hr. intervals and used to determine vertical velocities and so, on various assumptions, the rate of rainfall. The map of total rainfall computed in this way agreed well with the actual one except that its main features were displaced about 100 miles to the north.

Finally, the effects of orographic lifting were computed supposing that the air was saturated and lifted through a height equal to the height of the hills at the foot and decreasing proportionately to zero at 500 mb. This gave values of the right order of magnitude.

Mr. Sawyer's paper was greeted by the President, Dr. Stagg, and Prof. Sheppard as one of great, indeed historic, importance in meteorology. Dr. Stagg inquired about the possibilities of forecasting rainfall by the use of the development function, and commented that in this particular case the vorticity of the thermal wind appeared less important than the vorticity of the surface flow. Mr. Tucker described theoretical work on orographic rain tending to

* *Quart. J.R. met. Soc., London*, **78**, 1952, p. 231.

show that orographic effects would give drizzle and not rain on high ground when drizzle only was falling on lower ground. Dr. Sutcliffe asked Mr. Sawyer for his opinion on forecasting possibilities, and with Dr. Scorer commented on the difficulty of allowing for the degree of stability. Prof. Sheppard thought it was most important to be able to do such calculations at all and the time taken in them was secondary. Dr. Farquharson said he had calculated the development function for three thickness intervals and the values changed with the interval; he inquired which one should be used for calculating rainfall. Mr. Sawyer, in reply, stressed that the charts were approximate and to some extent subjective because of the necessity for interpolating between stations. The uncertainty of forecast charts restricts the possibility of forecasting rainfall amounts by his method. One important point was that in this case they knew there was rainfall but it was clearly possible to have occasions of upward motion without rainfall because the air did not reach saturation. His work on orographic rainfall was admittedly rather rough and assumed that all water condensed, fell to the ground.

LETTERS TO THE EDITOR

Unusual wet-bulb readings

In the March 1947 issue of the *Meteorological Magazine* I reported an occasion when my wet bulb read higher than the dry bulb. This morning at 9.15 a.m. the dry bulb read 30°F. and the wet bulb 31½°F. The muslin was frozen stiff; I had not been to the screen before, so the high reading was not due to wetting the bulb and allowing insufficient time for it to cool. There was no fog and only moderate hoar-frost. There seem to be two possible explanations:—

(i) The water in the muslin had only frozen just before; this does not appear very likely as it was an hour after sunrise on a bright sunny morning after a clear frosty night.

(ii) Water was moving along the wick and turning into ice only when it reached the frozen muslin. The water in the glass container was liquid except for a narrow strip of ice around the edge.

Whatever the explanation, the occurrence indicates another wet-bulb anomaly in the neighbourhood of freezing point about which the observer might be warned.

E. GOLD

8 Hurst Close, N.W.11, December 2, 1952

Postscript.—This morning at 9.10 a.m., the dense fog (visibility 8–10 yd.) having gone and visibility being above 100 yd., my dry bulb, from which a drop of water (melted rime) was hanging, read 33½°F. and the wet bulb, on which the muslin was wet, read 32°F. This low reading was due to the ice on the muslin not having all melted, as I verified; there was an appreciable amount in the folds at the top of the muslin cap. The true difference between the "dry" and the "wet" temperatures was 0·2° or 0·3°F. Two hours later they were 36·3° and 36·0°F. respectively.

This indicates another source of error of which warning might be given in observer's instructions.

E. GOLD

December 8, 1952

Unusual rainbow phenomenon

At 1555 G.M.T. on October 22, 1952, after a heavy shower a brilliant rainbow complex was observed from the Meteorological Office, Northolt. The secondary and some supernumerary bows were clearly seen as well as the primary.

The most remarkable phenomenon, however, was another very faint bow seen rising from the north base of the primary bow but with a definite curvature away from it as in Fig. 1. The length of this unusual arc, which was only visible at times, was 5°. It was coloured red on the side away from the primary

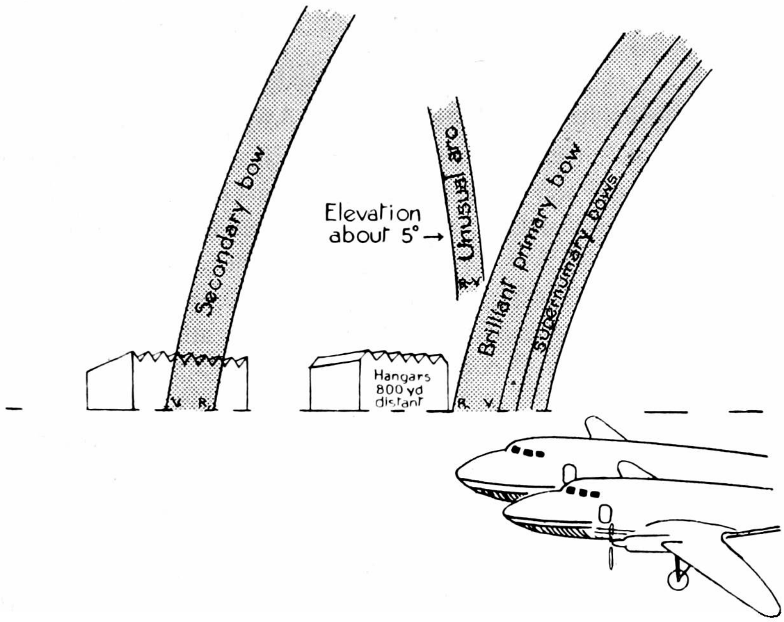


FIG. 1—UNUSUAL RAINBOW PHENOMENON

and violet on the nearer side. In the direction of this arc were an area of wet tarmac and the polished aluminium noses of two aircraft. No horizontal surface such as water in a reservoir could give an additional bow with axis at right angles to the normal but a vertical or spherical reflector could do so. Could it be that the unusual arc was the result of reflection from the aircraft noses? The arc was seen by at least four other members of the staff.

R. K. PILSBURY

Northolt Airport, October 24, 1952.

[An arc such as the one described by Mr. Pilsbury is very rare. An arc, exactly similar in position, curvature and colour order was seen at Wilhelmshaven, Germany, on November 9, 1926*; it was seen over a longer arc as it reached to the secondary bow. It is naturally not easy to determine the curvature of a short arc, but Mr. Pilsbury is certain the curvature of the one seen at Northolt was opposite to the curvature of the normal primary bow.

Pernter and Exner† consider arcs curved in the opposite sense to the primary to be produced by abnormal refraction but give no detailed explanation.

The colour sequence in the arc is opposite to the one which would be expected if the arc were part of a primary bow produced by a solar image displaced

* Wilhelmshaven, Marine-Observatorium. Anomaler Regenbogen. *Met. Z., Braunschweig*, 43, 1926, p. 508.

† PERNTER, J. M. and EXNER, F. M.; Meteorologische Optik. Wien and Leipzig, 1910, p. 599.

in azimuth by reflection as Mr. Pilsbury suggests. Further, it seems unlikely that reflection in a chance surface would produce a solar image at just the right distance in azimuth to give a bow intersecting the main primary at the ground. The order of colours and the intersection at the ground would be expected of a bow formed by reflection of the sun in a horizontal reflecting surface behind the observer. A "reflection" bow would however be curved in the same sense as the primary.

A brilliant rainbow with clearly defined secondary and supernumerary bows was seen from the Meteorological Office, Harrow, at about the same time but the unusual arc was not seen.—Ed., *M.M.*]

NOTES AND NEWS

Waterspout off Stromboli, August 8, 1952

We have received, through the courtesy of Miss D. G. Chambers, extracts from the meteorological log of the Charterhouse Geographical Expedition to Stromboli island in the Tyrrhenian Sea, in August 1952, kept by her nephew J. A. C. Cann.

The most interesting feature of the log is the description of a waterspout seen off Stromboli on August 8 which is very early after midsummer for the occurrence of such violent convective phenomena so far south in the Mediterranean.

The wind blew at force 7 from WSW. during the evening of the 7th with very black cloud to the west. Lightning was seen in the distance. About 0800 G.M.T. on the 8th the wind veered to NW. and died down, and it was calm on the sheltered side of the island at 1000 and 1300, though the smoke of the volcano showed the wind at 3,000 ft. was still NW. The waterspout was sighted at 1310 extending downwards from a cloud to the east-north-east of the island. As it drifted eastwards at an estimated speed of 5–10 m.p.h. the bottom became detached from the sea and by 1400 it had ceased to exist.

Mr. H. H. Lamb, Senior Meteorological Officer, Malta, writes: "A cold front crossed Spain from the Atlantic on the 6th and by 2000 G.M.T. was orientated from east-north-east to west-south-west and approaching Stromboli from the north. The WSW. winds reached gale force before the front passed Stromboli between midnight and 0100 on the 8th followed by a veer and decrease of wind.

"The waterspout seen several hours later does not appear to have been connected with any front. It was presumably chiefly an instability phenomenon though perhaps set off partly by some local influences on the surface winds.

"A curious and surprising feature is that subsidence was already active over a wide region covering the western part of Sicily and most of the the western Mediterranean, that is to say within about 150 miles of the scene of the waterspout.

"Such phenomena are not normally expected in this part of the Mediterranean so soon after midsummer. It is interesting to note, however, that 50 years' statistics of daily frequencies of rainfall in Rome show a small peak giving a frequency of one rain-day about once in 10 yr. for the 5-day period, August 4–8; this is more than double the frequency of rain in most other 5-day periods at that stage of the year though it is nearly equalled about July 26–30. Distinctly greater frequencies occur in the second half of August. These figures appear to be a faint reflection of well marked rainfall singularities affecting western and central Europe though much more rarely affecting the Mediterranean. Although we have no frequency figures for the regions nearest to Stromboli consideration of the statistics for Florence, Rome and Malta suggests that in most years the thunderstorms which bring the first rain should be expected about the middle of September. On the other hand in 1904 and 1933 there was no rainless month even so far south as Malta."

Mammatus

If air ascends in cumulus convection and spreads out at a level well above the condensation level it will contain large cloud droplets in contrast with the air above which it has spread. The base of a cumulus cloud, where the drops have just formed, is somewhat diffuse, unlike the sharply outlined base of stratocumulus formed by the spreading out of cumulus. Evening stratocumulus, which usually forms after the cumulus has all gone, looks different from the cumulogenitus type because their bases are respectively at and above the condensation level of the air of which they are composed.

Any descent of air at the base of a cumulogenitus cloud will lower the base of it simply because it is above the condensation level. The cloudy air will descend at the wet adiabatic lapse rate, and the dry air below at the dry adiabatic lapse rate, and generally an unstable discontinuity of temperature will quickly result. In such a case the base of the cloud assumes a mammatus structure. Though of ominous appearance and resulting from extreme instability there is no reason to suppose that it is a prognostic of precipitation, at any rate not from the region of mammatus itself, because there the air is descending. Mammatus is often produced on the lower outline of precipitation that is actually falling but it is then recognizable as of different origin. The effect of a redistribution of the liquid water within a cloud and just below it in producing mammatus in sinking air has been fully discussed by F. Wagner*, and the process is often important. But if spreading out has occurred no redistribution is required.

Because it is commonly associated with the edges of thunderstorms mammatus is often believed to be a bad omen, but it may be a sign that the precipitation is over, or at least that it is elsewhere. The photograph facing p. 48 shows a display of mammatus which occurred about two hours after the cessation of the rain of a thunderstorm. Mammatus had been visible almost continuously in one part of the sky or another ever since the storm moved away, and the sky cleared to the west as the sun set so that the cloud was illuminated from below, the pendulous parts being bright orange red, the background cloud almost black.

R. S. SCORER

Typical fog conditions

The photograph facing p. 49 was taken in Richmond Park (about 175 ft. above M.S.L.) at 1500 G.M.T. on December 7, 1952, during a period when London and its suburbs were enveloped by a severe fog. In the Park, visibility was 100 yd. while at lower levels transport was completely disrupted owing to visibilities ranging from zero to 50 yd. The depth of the fog, as indicated by the photograph, probably did not exceed 300 ft. while the sky above was partly covered by altocumulus-altostratus.

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* WAGNER, F.; Mammatusform als Anzeichen für Absinkbewegung in Wolkenluft. *Ann. Met., Hamburg*, **1**, 1948, p. 336.

REVIEWS

Atmospheric pollution, its origins and prevention. By A. R. Meetham. $8\frac{1}{2}$ in. × $5\frac{1}{2}$ in., pp. viii + 268, *Illus.*, Pergamon Press Ltd, London, 1952. Price: 35*s.* net.

This book contains a mass of interesting information vitally concerning us all. For the proper understanding of the problem of reducing atmospheric pollution some knowledge of the history, composition and use of fuels is necessary. Following a general account of the problem, seven chapters deal therefore with fuels: the chemistry of fuels, natural fuels, artificial fuels, industrial boilers, power and electricity, industrial furnaces, and domestic fires. The remaining seven chapters deal with atmospheric pollution: its measurement, distribution, changes with time, effects, prevention, and finally the law and its administration.

The chapters on fuels deal inevitably with engineering aspects, but there are many simple drawings which enable the layman to follow the general principles involved. The book contains 81 illustrations and 26 tables. The emphasis is always on the resultant pollution. Much of the pollution arises when fires are started or fuel added. In the early part of the war the Fuel Research Station devised a scheme for eliminating the smoke from the funnels of coal-burning ships, by allowing enough air to enter the fuel to consume all smoke. This principle has been applied on land with considerable success, both in the reduction of pollution and saving of fuel.

Since 1910 the total consumption of coal in Great Britain has decreased appreciably, but owing to improved efficiency the output of power has risen. The amount of coal used a year is now about 180 million tons; of which 65 are consumed for domestic purposes (45 in fires and 20 in the production of gas and electricity); 65 in industrial boilers, including railways; and 50 by other industrial users in furnaces. The railways, consuming some 15 million tons, are amongst the worst offenders in producing smoke pollution; next come the domestic fires. In districts where on the average one open fire is burning per house a group of 380 houses emits about a ton of smoke per week and nearly as much sulphur dioxide. In some districts smoke from special industries is a major problem and the methods necessary to eliminate pollution are outlined. The burning of 180 million tons of coal each year results in 9 million tons of atmospheric pollution, made up of 5·2 as sulphur dioxide, 2·4 smoke, 0·6 ash and 0·5 hydrogen chloride and other chlorides. The most destructive pollution is sulphur dioxide, the cost, apart from its effects on health, amounting to between 20 and 50 million pounds a year by its damage to metals, wool, cotton, leather, paint and building materials.

The book summarizes present knowledge on the subject, with special reference to the recent work of the Department of Scientific and Industrial Research, both at the Fuel Research Station and the Building Research Station. Information is naturally drawn from the report on "Atmospheric pollution in Leicester", published by the Department of Scientific and Industrial Research in 1945, since Dr. Meetham was in charge of the work there during 1937–39, especially to illustrate the effect of wind on smoke concentration and distribution, and on the variation of pollution with time. Meteorologists have an interest from many aspects. The Chairman of the Atmospheric Pollution Committee, 1934–50, was Dr. G. M. B. Dobson. Moreover, from 1915 to 1927 the Committee was under the control of Directors of the Meteorological Office, before being transferred to the Department of Scientific and

Industrial Research. The book should be read by everyone interested in using our fuel resources to the best advantage and in diminishing atmospheric pollution on health grounds or for the financial benefit to the community. It is claimed that the general problem of preventing smoke is not an insoluble one, either technically or economically, and this book explains how this may be accomplished.

J. GLASSPOOLE

Climate and the British scene. By Gordon Manley. *The new naturalist. A survey of British natural history.* 8¾ in. × 6¼ in., pp. x + 452, *Illus.*, Collins, London, 1952. Price: 25*s.* 0*d.*

In his preface Professor Manley says "This is not a meteorological text." This very positive statement might perhaps be construed as meaning that the book is not addressed to meteorologists but to that rather nebulous person, the "general reader". It would be a mistake to imagine however that this is a book from which meteorologists have nothing to learn. It is in fact a very substantial contribution to the climatology of Great Britain. The presentation is lively and unacademic, but it is in no sense a mere re-hash of routine climatological facts. As meteorologists we have all, no doubt, become very familiar with the essential facts about the British climate, and we are all familiar with the essential elements of the British scene. Few people can however have pondered so deeply as Professor Manley has done on the inter-relationship between the one and the other. It is a fascinating study and Professor Manley has handled it in masterly fashion.

The first impulse of any normally constituted reader on picking up this fine book would be to go right through it looking at the pictures. There are over eighty plates, and this fact is in itself a clear indication of the author's realistic method of approach. Pictures are of course essential to any portrayal of the British scene, with all its variations with place and with season, but Professor Manley has managed very cleverly to select pictures which portray the British climate just as clearly as they portray the British scene. The meteorology is often very unobtrusive, but it is there to see, with the aid of the carefully written legends. A good example of this dual role is furnished by Plate 17, a fine colour photograph of Princes Street, Edinburgh, by Cyril Newberry. This is the sort of picture which one might expect to find in any well illustrated book about Edinburgh, but in this context it illustrates not only the buildings, gardens and traffic of Princes Street, but also the characteristic features of springtime in the Scottish capital. The legend reads: "Princes Street, Edinburgh, early May. Springtime: almost calm, slight haze, very light air from S.E. Cautious retention of coats by older Scotsmen". In this sort of way a vivid realism is given to the climatological facts and their relationship to our environment of town and country, mountain, sea-shore and pasture.

About half the plates are in full colour, and this fact must have made the book costly to produce. It is to be hoped that Messrs. Collins's courage in publishing it at the very moderate price of 25*s.* will reap its just reward.

The text is divided into 14 chapters, followed by an appendix of climatological data for representative stations. After an introduction in which the general features of our climate are briefly surveyed, and a chapter on "The makers of the observations" which contains some interesting facts about sources of climatological data from mediaeval times to the present day, we reach Chapter 3 which is devoted to "Some elementary properties of our moist atmosphere". Here, if one may say so, the writing does not seem quite so carefree as in other chapters, and there is a rather bad slip on p. 38 where, in connexion with the condensation of moisture to form cloud, it is stated that "that part of the condensation which takes place below 32° will be directly as ice". Recent work on cloud physics has shown that things are by no means as simple as that. Again, on p. 45, after a perfectly clear description of the mode of formation of rime a reference is given to Plate 13; but Plate 13 is a picture of glazed frost, not of rime, and is in fact so described in the legend.

Chapter 4 gives a good account of the atmospheric circulation over the British Isles, and the author is to be commended for hanging the entire climatological discussion on an air-mass framework. It is to be hoped, however, that in a new edition Professor Manley will eliminate Fig. 10 on p. 60, which might easily lead the reader to imagine that at Parc St. Maur, Paris, and on the summit of the Eiffel Tower, the daily minimum temperature is 0°C. in January and July alike.

Chapters 5, 6 and 7, which are devoted to a survey of "Sky, temperature and season" from winter to high summer, are among the best in the book, displaying as they do Professor Manley's remarkable capacity for close observation and vivid description. This section is followed by two chapters on "Landscape features and their effect on weather". Here and elsewhere in the book the writing is leavened and adorned with a wealth of literary allusion, as in the following passage taken from a section on town smoke: "Smoke is indeed a gloomy subject: for while there are those who will rhapsodise over the hazy city sunsets across the Thames, there are many more who deplore the vanished glories of a sunny little Manchester from which the green and gold Pennine slopes were visible on many April mornings two centuries ago. It is possible that the whole country is affected more than we think. Early last century the Ordnance Survey sighted the Welsh Mountains from Bardon Hill in Leicestershire. Ralph Thoresby espied the shipping in the Thames as he rode over Harrow Hill in May 1702. Celia Fiennes saw the Isle of Man from near Chester; Defoe (1726) was informed that from the Cheviot the view extended to the Tyne, and George Smith saw the cliffs beside the North Sea from Crossfell in 1947. But Wordsworth noted the London smoke haze from Hampstead Heath."

Chapter 10, "Mountains and moorlands: the effect of altitude", contains some interesting facts about the repercussions of the climatological effects of altitude on agricultural practice. At the village of Nenthead in Cumberland, for example, at 1,500 ft. the growing season is about ten weeks shorter than in the lowlands, and it is consequently necessary to feed cattle, if any are kept, for six months of the year. Chapter 11, "Snowfall and snowcover", summarizes work to which Professor Manley has made noteworthy personal contributions. In the next chapter, on "Secular variations of the British climate", we have a useful survey of the facts, so far as they are known or surmised, regarding climatic variations since the last phase of the Ice Age, about 15,000 years ago.

Chapter 13, "Instrumental records: the ranges of climatic behaviour", is so to speak, a concession to conventional climatology, containing as it does data relating to extremes of temperature and other elements, "for the benefit of those whose curiosity is better satisfied by figures". The last chapter on

"Climate and man" attempts to assess the effects of climate on human activity, health and behaviour. There is, in particular, an interesting discussion on bracing and relaxing climates.

To summarize, this is a very noteworthy book and a valuable contribution to meteorological literature. Those of us who are professional meteorologists tend perhaps to drift into a narrowness of outlook through excessive concentration on those aspects of meteorology which relate to our daily tasks. Here is an excellent corrective.

E. G. BILHAM

OBITUARY

Edmund Gilbert Dymond, M.A., F.R.S.E.—The news of the sudden death on October 26, 1952, at the age of 52, of Mr. E. G. Dymond came as a shock to his friends in the Meteorological Office in which he served during the war.

Mr. Dymond had a distinguished academic career at Cambridge and after graduating in 1922 became a research worker at the Cavendish Laboratory. An International Education Board Fellowship enabled him to go to the Universities of Göttingen in 1924 and Princeton in 1925, when he was elected a Fellow of St. John's College, Cambridge, and appointed a University teacher. In 1932 he became lecturer and Carnegie Teaching Fellow in the Department of Natural Philosophy at Edinburgh University and in 1948 he was appointed Reader in Physics there.

From Edinburgh Mr. Dymond took part in the Wordie expedition to Baffin Bay in 1937, and, in collaboration with Dr. H. Carmichael, published the results of studies of cosmic rays and wind in the upper atmosphere near the north magnetic pole in two papers in the *Proceedings of the Royal Society* in 1939.

At the outbreak of the war Mr. Dymond immediately responded to the call to join the Meteorological Office, where it was realized that his experience of balloon-sounding technique was likely to be of great service. The Office had embarked on a programme for the development, by the National Physical Laboratory, of radio-sonde and radio-wind equipment. Trials of the earlier designs of radio-sonde had pointed the way to improvements, and it fell to Mr. Dymond, who was appointed to Kew Observatory, to develop and perfect what came to be known as the Kew radio-sonde. The thoroughness with which he undertook this work can be gauged by the fact that the design of the mass-production Mark II radio-sonde, now in use in very large numbers, is basically the same as that of the Kew radio-sonde. Having achieved a highly successful instrument Mr. Dymond was not content until he was able to assess its perfomance by an exhaustive series of trials and comparisons, the results of which he reported in a number of *Meteorological Research Papers* during the war. A full and excellent account of his work on the radio-sonde was published in the *Proceedings of the Physical Society* in 1947, and was followed by a more general description of radio-sonde technique in the journal *Research* in 1950.

On his return to Edinburgh after the war Mr. Dymond resumed his research on cosmic rays, one of his objects being to investigate meson production at very high altitudes. For this purpose he applied his war-time experience by using radio-sonde technique. His last published paper, in collaboration with J. D. Pullar on meson production in the atmosphere, appeared in the *Philosophical Magazine* in 1951, but at the time of his death he was engaged in writing up the main results of his post-war work on cosmic rays. He was recently elected to the office of Vice-President (for Scotland) of the Royal Meteorological Society.

Mr. Dymond's high ability as an experimental physicist combined with his special knowledge of radio-sonde design led to his being invited to become a member of the Instruments Sub-Committee of the Meteorological Research Committee in 1951. He travelled down from Edinburgh to attend its most recent meeting only three days before he died. It was a great loss to the Office when he left after the war and his valuable guidance on instrument development problems will now be sadly missed.

Mr. Dymond was quiet and modest in manner and he was generous in giving credit to colleagues working with him or under his direction for their assistance in his work. All those who were associated with him during his period in the Meteorological Office will sadly mourn his death. Our deepest sympathy goes to his widow and his family.

F. J. SCRASE

METEOROLOGICAL OFFICE NEWS

Ocean weather ships.—Things looked black for the ocean weather ship sailing schedule at 11 a.m. on Saturday, December 20, 1952, when it was discovered that two members of the meteorological staff of the o.w.s. *Weather Recorder*, due out of Greenock early on the following day, had fallen sick. However, an S.O.S. sent to all offices on the "first-channel" teleprinter broadcast brought in the names of two volunteers by 2 p.m. on the same day. Only one of these could be released from his post and he—an Assistant of 17—travelled from Plymouth to Greenock and was aboard the *Weather Recorder* by 9 a.m. on Monday, December 22, and the ship sailed forthwith.

WEATHER OF DECEMBER 1952

Mean pressure was below normal in Europe and the United States and above normal over the North Atlantic, north of 40°N.; at 55°N., 40°W. the mean pressure, 1010 mb., was 8 mb. above normal. The lowest mean pressure, 1004 mb., occurred just north of Scotland; this pressure is about normal for this region for December. The highest mean pressure, 1024 mb. between Portugal and the Azores, was 4 mb. above normal. Mean pressure in Europe was mainly between 1012 and 1016 mb. and varied from 2 to 5 mb. below normal.

Mean temperature varied between 30° and 40°F. over most of Europe, generally 2–4°F. below normal. In the Mediterranean region and extreme north of Africa mean temperature was between 50° and 60°F., rising to 70–80°F. in west Africa.

In the British Isles the weather was cold on the whole, with considerable snowfall around the middle of the month. Sunshine exceeded the average in most parts of Great Britain, the total at Oxford being the highest for December in a record going back to 1881. Other notable features of the weather were the long spell of dirty fog in the London area during the period 5th to 9th and the widespread, unusually severe gale on the 17th.

In the opening days of the month a ridge of high pressure associated with an anticyclone situated south of Iceland moved south over the British Isles. Frost and local fog occurred, the frost being severe in some places; air temperature fell to 13°F. at Renfrew on the 1st and to 18°F. at Manchester on the 2nd, while the maximum at Renfrew on the 1st was only 30°F., the low temperature being largely due to almost persistent fog. A trough of low pressure moving south-east immediately behind the ridge caused slight rain in the north and east. From the 3rd to the 5th the anticyclone off our north-west coasts moved south-east, being centred over south-east England and the nearby continent on the 6th. Cold mainly dry weather, with frost and local fog, persisted, though a trough of low pressure spreading east brought milder weather with occasional rain to some western districts on the 6th and 7th. These conditions did not reach the south-east, however, until the 9th. In the London area the fog was smoke laden and unusually persistent; at Kingsway, fog (visibility less than 1,100 yd.) lasted from 0000 on the 5th to 1800 on the 9th (114 hr.) while visibility was less than 220 yd. from 0900 on the 6th to 0900 on the 8th and only 40 yd. or less from 0600 on the 7th to 0300 on the 8th. On the 10th a depression off the west of Scotland moved north-east giving rain generally and a gale locally on our north-west coasts. On the 11th and 12th a depression off south-east Iceland moving south-south-east gave showery weather, and on the 12th another disturbance off our south-west coasts moved rapidly east causing further rain. Behind these depressions cold northerly winds prevailed over the British Isles with a gale locally in the north of Scotland and widespread snow which was heavy in places with deep drifts. For example snow was 12 in. deep at West Kirby on the 15th and 16 in. at Bwlchgwyn on the 16th; snow drifts were 5–7 ft. deep at Bwlchgwyn. Thunderstorms occurred at numerous places in north Wales and north-west England on the 15th. On the 16th a very deep depression off north-west Scotland moved east-south-east and later turned south-east giving considerable precipitation on the 16th and widespread, notably severe, north-westerly gales on the 17th. Gusts reached 80 kt. locally in the north-west, while Cranwell, Lincolnshire, recorded a gust of 96 kt., the highest ever registered at an inland station in this country. The depression filled quickly over the Low Countries and a spell of milder, unsettled south-westerly to westerly type of weather set in and persisted until the 25th. Rain fell frequently during this period but temperature rose to 50°F. locally at times and touched 55°F. at Hawarden and Wrexham on the 22nd. From the 25th to the 28th a depression moved south-south-east from the south of Iceland to south-west France; the weather became colder again, with rain or snow at times. Rather widespread fog occurred on the 27th, the fog being thick and persistent locally in south-east and east England and the Midlands. During the closing days a depression moved south-east from east of Iceland to the North Sea. More rain or sleet occurred and there was rather persistent fog in parts of south-east and east England on the 30th.

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 ...	56	15	−2·5	93	+2	132
Scotland	57	7	−1·8	94	+2	106
Northern Ireland ...	53	16	−2·5	111	+3	103

RAINFALL OF DECEMBER, 1952

Great Britain and Northern Ireland

County	Station	In.	Per cent. of Av.	County	Station	In.	Per cent. of Av.
London	Camden Square ...	2·38	100	*Glam.*	Cardiff, Penylan ...	3·34	67
Kent	Folkestone, Cherry Gdn.	4·32	135	*Pemb.*	Tenby	4·40	88
”	Edenbridge, Falconhurst	2·79	85	*Mer.*	Aberdovey	4·98	105
Sussex	Compton, Compton Ho.	3·83	91	*Radnor*	Tyrmynydd	6·34	77
”	Worthing, Beach Ho. Pk.	3·27	109	*Mont.*	Lake Vyrnwy	6·09	86
Hants.	Ventnor Cemetery ...	4·38	130	*Mer.*	Blaenau Festiniog ...	11·28	89
”	Southampton (East Pk.)	2·40	66	*Carn.*	Llandudno	3·21	111
”	Sherborne St. John ...	2·40	73	*Angl.*	Llanerchymedd ...	3·92	89
Herts.	Royston, Therfield Rec.	2·01	87	*I. Man*	Douglas, Borough Cem.	5·57	113
Bucks.	Slough, Upton... ...	2·30	91	*Wigtown*	Newton Stewart ...	4·40	81
Oxford	Oxford, Radcliffe ...	2·16	88	*Dumf.*	Dumfries, Crichton R.I.	3·61	84
N'hants.	Wellingboro' Swanspool	2·39	102	”	Eskdalemuir Obsy. ...	5·24	75
Essex	Shoeburyness	2·03	110	*Roxb.*	Kelso, Floors	..	..
”	Dovercourt	2·44	113	*Peebles*	Stobo Castle	4·16	109
Suffolk	Lowestoft Sec. School...	2·79	120	*Berwick*	Marchmont House ...	4·28	152
”	Bury St. Ed., Westley H.	2·14	89	*E. Loth.*	North Berwick Res. ...	1·90	88
Norfolk	Sandringham Ho. Gdns.	2·48	98	*Midl'n.*	Edinburgh, Blackf'd. H.	2·74	117
Wilts.	Aldbourne	3·43	106	*Lanark*	Hamilton W. W., T'nhill	3·12	72
Dorset	Creech Grange... ...	3·69	84	*Ayr*	Colmonell, Knockdolian	3·66	66
”	Beaminster, East St. ...	3·75	78	”	Glen Afton, Ayr San. ...	5·27	82
Devon	Teignmouth, Den Gdns.	3·33	79	*Renfrew.*	Greenock, Prospect Hill	7·59	102
”	Cullompton	4·10	93	*Bute*	Rothesay, Ardencraig...	7·18	132
”	Ilfracombe	4·29	89	*Argyll*	Morven (Drimnin) ...	7·24	92
”	Okehampton Uplands...	4·84	69	”	Poltalloch	6·43	101
Cornwall	Bude, School House ...	4·00	92	”	Inveraray Castle ...	9·60	97
”	Penzance, Morrab Gdns.	4·51	79	”	Islay, Eallabus... ...	5·83	98
”	St. Austell	5·31	87	”	Tiree	5·18	99
”	Scilly, Tresco Abbey ...	3·78	81	*Kinross*	Loch Leven Sluice ...	2·96	75
Glos.	Cirencester	2·88	86	*Fife*	Leuchars Airfield ...	1·79	72
Salop	Church Stretton ...	3·22	91	*Perth*	Loch Dhu	7·68	76
”	Shrewsbury, Monksmore	2·72	111	”	Crieff, Strathearn Hyd.	2·85	64
Worcs.	Malvern, Free Library...	2·26	82	”	Pitlochry, Fincastle ...	2·23	55
Warwick	Birmingham, Edgbaston	2·84	106	*Angus*	Montrose, Sunnyside ...	2·09	75
Leics.	Thornton Reservoir ...	2·65	99	*Aberd.*	Braemar	4·11	115
Lincs.	Boston, Skirbeck ...	1·61	75	”	Dyce, Craibstone ...	2·87	85
”	Skegness, Marine Gdns.	1·54	70	”	New Deer School House	3·28	96
Notts.	Mansfield, Carr Bank...	1·98	68	*Moray*	Gordon Castle	2·30	86
Derby	Buxton, Terrace Slopes	5·57	98	*Nairn*	Nairn, Achareidh ...	2·01	98
Ches.	Bidston Observatory ...	2·84	107	*Inverness*	Loch Ness, Garthbeg ...	4·25	92
”	Manchester, Ringway...	3·03	99	”	Glenquoich	12·34	84
Lancs.	Stonyhurst College ...	5·27	109	”	Fort William, Teviot ...	8·58	84
”	Squires Gate	3·75	120	”	Skye, Broadford ...	7·83	87
Yorks.	Wakefield, Clarence Pk.	1·72	71	”	Skye, Duntuilm ...	6·62	106
”	Hull, Pearson Park ...	1·81	75	*R. & C.*	Tain, Tarlogie House ...	2·18	77
”	Felixkirk, Mt. St. John...	1·57	65	”	Inverbroom, Glackour...	8·71	119
”	York Museum	1·64	73	”	Achnashellach	9·39	99
”	Scarborough	2·58	108	*Suth.*	Lochinver, Bank Ho. ...	5·75	103
”	Middlesbrough... ...	1·85	95	*Caith.*	Wick Airfield	3·62	118
”	Baldersdale, Hury Res.	2·92	76	*Shetland*	Lerwick Observatory ...	5·79	121
Norl'd.	Newcastle, Leazes Pk....	3·71	158	*Ferm.*	Crom Castle	3·42	83
”	Bellingham, High Green	3·53	97	*Armagh*	Armagh Observatory ...	3·47	111
”	Lilburn Tower Gdns. ...	4·40	167	*Down*	Seaforde	..	..
Cumb.	Geltsdale	3·51	92	*Antrim*	Aldergrove Airfield ...	3·54	103
”	Keswick, High Hill ...	5·10	76	”	Ballymena, Harryville...	4·66	105
”	Ravenglass, The Grove	4·58	100	*L'derry*	Garvagh, Moneydig ...	4·99	124
Mon.	Abergavenny, Larchfield	2·81	63	”	Londonderry, Creggan	5·78	132
Glam.	Ystalyfera, Wern House	5·99	72	*Tyrone*	Omagh, Edenfel ...	4·99	118

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