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FACTORS LEADING TO THE MERIDIONAL EXTENSION OF THERMAL TROUGHS AND SOME FORECASTING CRITERIA DERIVED FROM THEM

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Summary.—This phenomenon is defined, and all occurrences between 20°W. and 20°E. during the period 1953–56 are studied to elucidate the factors associated with the process. Forecasting criteria are proposed and tested on data for the year 1957.

Introduction.—Meridional extension (abbreviated to M.E. henceforth) is defined as the southward displacement of thickness lines. In this study a thermal trough was said to have undergone M.E. if at least two thickness lines (1000–500 millibars) moved southwards through five degrees latitude or more in a 24-hour period. All subsequent measurements were made on the more southerly of the two, which will be referred to as the defining thickness line of the trough.

M.E. of a thermal trough was found to be nearly always accompanied by a substantial fall of surface pressure to the south-east of it. This may be reflected either in the south-east movement of a surface depression or in the formation of a new low-pressure centre to the south-east of the parent depression. The latter development is illustrated in Figures 1 and 2, from which it can be seen that falls of over 10 millibars occurred in the twenty-four hours over an extensive area of north France, north Germany and the Low Countries, and that several thickness lines moved south over a longitude band of about 15° centred just east of the Greenwich meridian.

If the cold front has moved well to the east before the thermal trough begins to extend, the pressure falls will produce a trough in the polar air. In all cases M.E. leads to the onset of colder weather over a zone some 15° to 20° longitude wide.

Observational material.—The results described are based on a study of all thermal troughs which underwent M.E. (as defined above) between longitudes 20°W. and 20°E. during the four years 1953–56. There were 102 such cases, and about three-quarters of them underwent a further extension in the following twenty-four hours (42 of them a further 5° latitude or more).

Measurements were made of the latitude changes of the defining thickness line both in the trough and in the upwind thermal ridge. The longitude of this ridge and of the anticyclone immediately upwind were also noted for

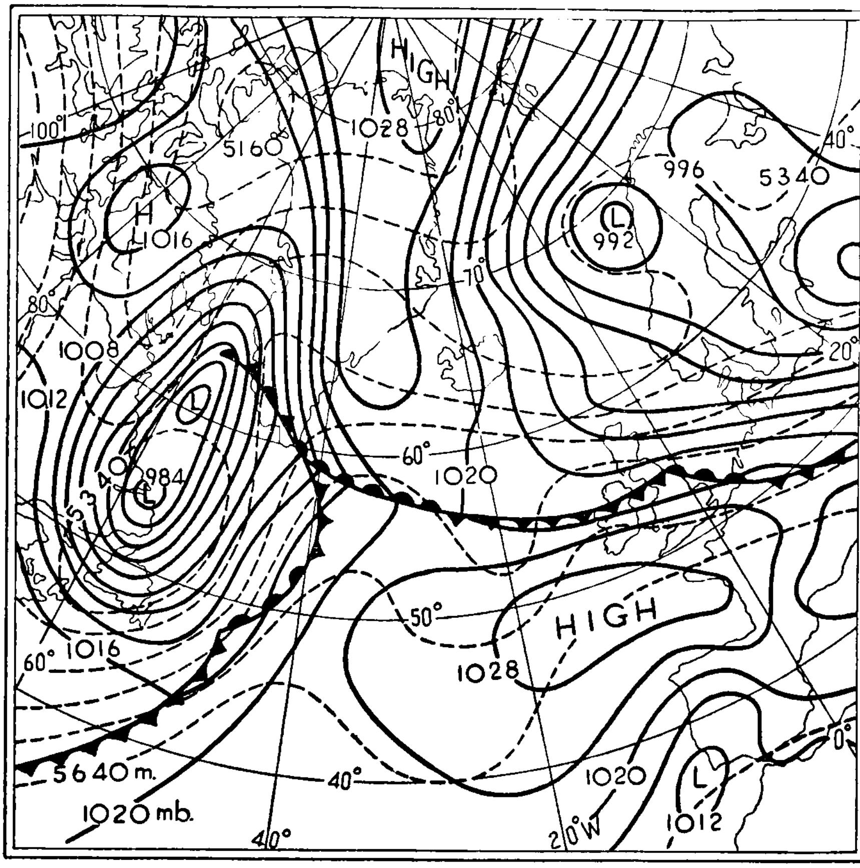


FIGURE 1—SEA-LEVEL ISOBARS AND TOTAL THICKNESS, 1200 G.M.T., 28 SEPTEMBER 1957

The broken lines are 500–1000-mb. thickness lines.

the time t when the M.E. began. When there was an inflexion point in the 500-millibar contours upwind of the M.E. its location was noted and the wind speed and direction there measured at time t. The time of its first appearance in the contour pattern was also noted if this was earlier than t.

Deceleration of thermal troughs during meridional extension.—The data in Table I show that there was usually a marked slowing down in the eastward progress of a thermal trough during and after the extension.

TABLE I—RATE OF MOVEMENT OF THERMAL TROUGHS

	Movement in degrees longitude per day								
	Westward		Eastward						
	6–10	1–5	0–4	5–9	10–14	15–19	20–24	25–29	>30
	percentage frequency of cases								
Day before	0	6	6	16	18	16	14	18	6
1st day of M.E.	0	2	15	25	22	11	10	5	8
Day after	3	9	36	25	18	5	4	1	0

The mean displacements were 16° longitude for the day before t, 12½° longitude between t and $(t+24)$ hours, and 6° longitude between $(t+24)$ and $(t+48)$ hours. There were a few cases of acceleration between $(t+24)$ and $(t+48)$ hours, and these were mainly when relaxation (that is, negative M.E.) occurred during this period.

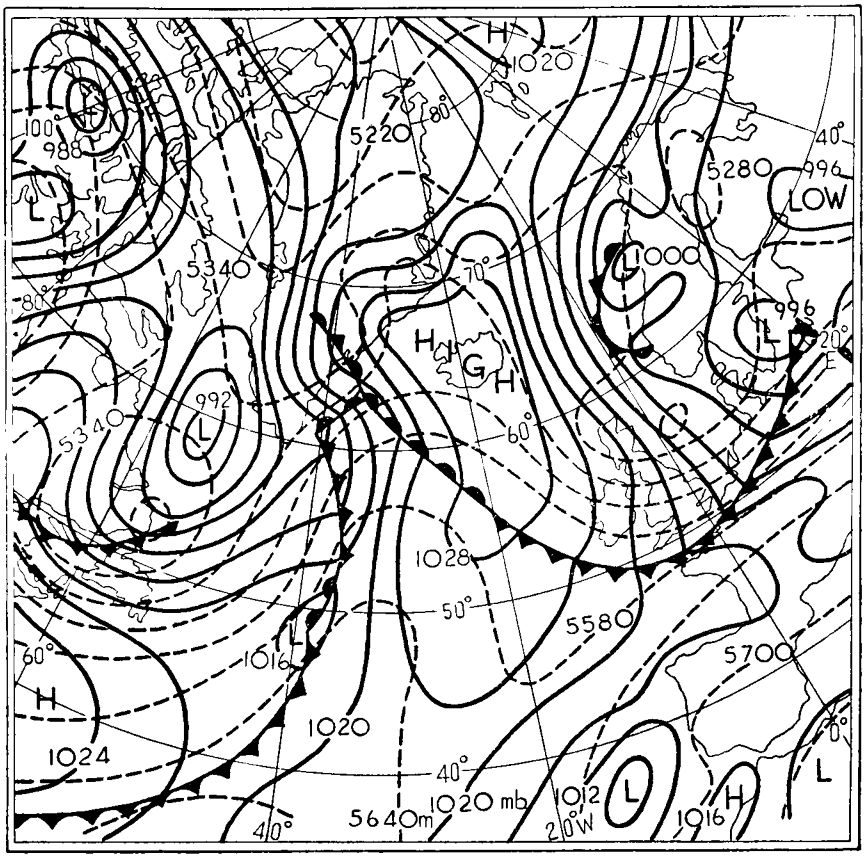


FIGURE 2—SEA-LEVEL ISOBARS AND TOTAL THICKNESS,
1200 G.M.T., 29 SEPTEMBER 1957
The broken lines are 500–1000-mb. thickness lines.

A defining longitude for meridional extension.—In view of the tendency of many of the thermal troughs to come to near-stagnation within 48 hours of the onset of M.E. it seems useful to define the longitude of the thermal trough at $(t+48)$ as the location of the M.E. This will be described as l_{t+48} and, for the sample studied, over 70 per cent of the troughs were within 10° longitude of this position at the end of the first day of M.E., that is, at $(t+24)$ hours. The 500-millibar contour trough at $(t+48)$ hours was usually a few degrees east of l_{t+48} (5° longitude or less in 90 per cent of all the cases).

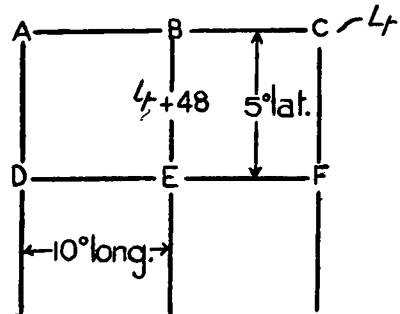


FIGURE 3—NETWORK OVER WHICH SURFACE PRESSURE CHANGES WERE MEASURED

Surface pressure changes.—These have been referred to l_{t+48} by measuring the twenty-four hour changes at the lettered points of the network shown in Figure 3, where L_t is the latitude of the defining thickness line at time t. Figure 4 shows the mean 24-hour isallobars for the period t to $(t+24)$. The largest falls occur in the region of l_{t+48} and to the south-east of the thermal trough which on average was just over 10° longitude west of l_{t+48} in the middle of this period. In the following twenty-four hours, as Figure 4 shows, the falls occurred farther south-east and rises were occurring over the northern part of the thermal trough.

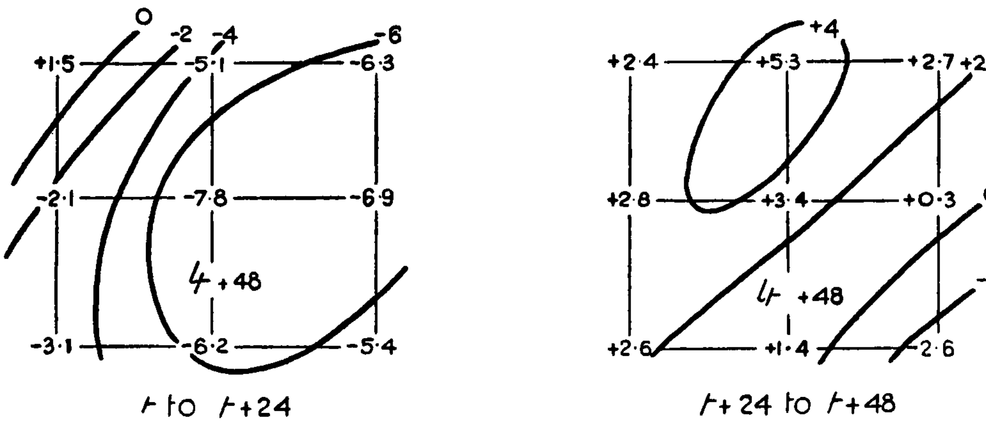


FIGURE 4—24-HOUR PRESSURE CHANGES

These pressure changes, especially the falls, could not as a rule be attributed to the simple displacement of the existing pressure pattern, and would be difficult to predict from existing trends. This pattern of average pressure changes means that M.E. of the thermal trough is usually accompanied by M.E. of the contour trough.

Weather associated with meridional extension.—There is a good deal of variety in the intensity of the weather associated with M.E., but the distribution shown schematically in Figure 5 applies fairly generally. The area of rain (or snow) to the south-east of the thickness trough usually moves south-east as the process goes on. This rain may be associated with the cold front, but if this has already moved away to the east, the rain may occur ahead of a post-frontal trough. In these cases it sometimes appears to result from an amalgamation of shower clouds into a continuous belt of cloud and may be of a rather intermittent nature.

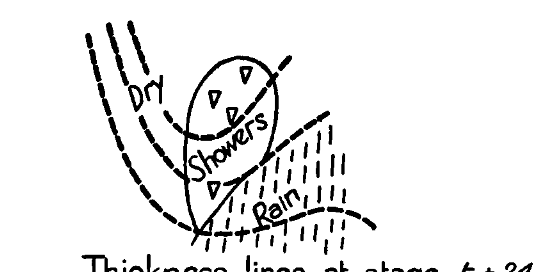


FIGURE 5—IDEALIZED WEATHER DISTRIBUTION WITH EXTENDING TROUGHS

In the northerly current, showers are usually restricted to an area near the axis of the thermal trough, and stabilization comes in quite quickly as a rule from the north-west.

Association of meridional extension with an amplifying upwind ridge.—About 90 per cent of the occurrences of M.E. were preceded by an increase in amplitude of a 500-millibar contour ridge upwind. On average the M.E. began twenty-four hours after the beginning of the growth of the ridge as found by Austin.[1] It is noteworthy that during the first twenty-four hours while the ridge was extending northwards (mean amount 6° latitude) the contour troughs were usually relaxing (mean negative extension 3° latitude). In the following twenty-four hours while the ridges extended north another 3½° latitude on average, the troughs underwent a mean extension of 6° latitude with a further 6° in the next twenty-four hours.

The growth of the contour ridge was nearly always accompanied by an approximately equal growth of the thermal ridge some 10° longitude farther west.

During the study it became apparent that the southerly component in the flow upwind of this growing contour ridge played an important part in its growth. Figure 6 shows the amount of growth, Δh, over a 24-hour period plotted against the southerly component, V_s, at the beginning of the period. The correlation coefficient of 0·44 between the 52 pairs of values though rather small probably indicates a physical connexion in view of the large random errors in the data.

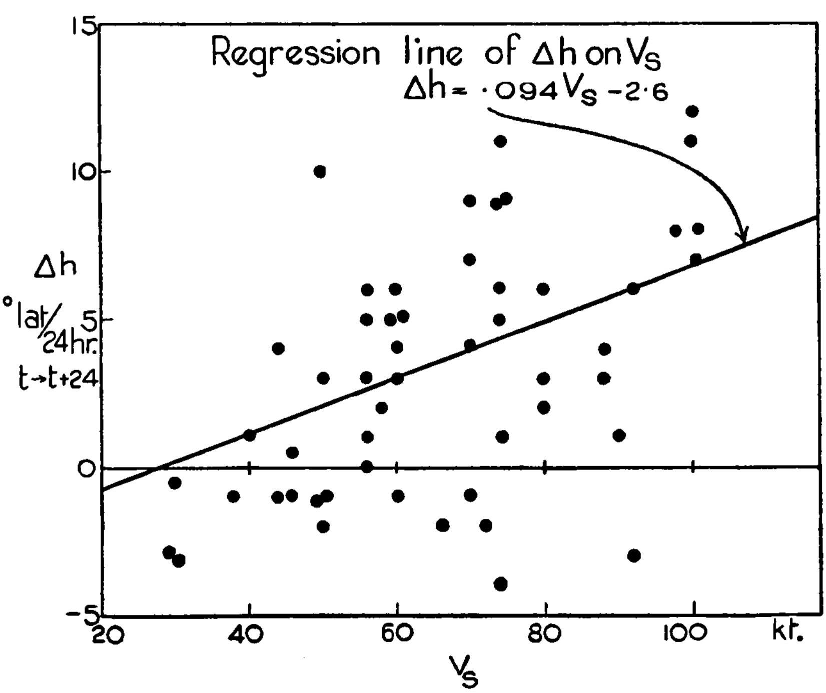


FIGURE 6—GROWTH OF 500-MILLIBAR RIDGE AND SOUTHERLY COMPONENT, V_s, AT INFLEXION POINT AT TIME t

Significance of the upwind inflexion point in the 500-millibar flow.—The maximum southerly component is likely to occur at an inflexion point in the flow. A well-marked inflexion point (I.P. henceforth) could be readily recognized in the 500-millibar contours for 71 of the M.E.s. In eleven other cases there were double I.P.s due to wave trains at different latitudes, and in the remaining 20 cases no I.P. could be readily recognized. These were mostly made up of anticyclonic southerlies and cases where the air moved into a confluence from a wide area.

The spacing of l_{t+48} from the longitude of the upwind I.P. at time t was measured and in Figure 7 is the frequency polygon for the 71 single I.P.s.

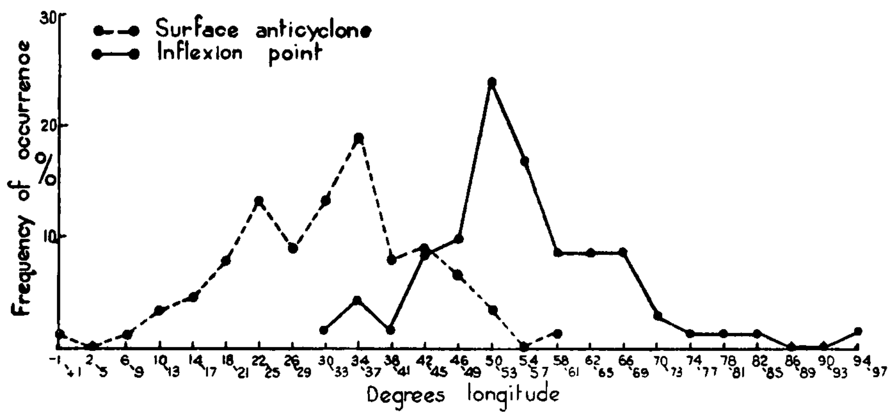


FIGURE 7—FREQUENCY POLYGON OF SPACING TO l_{t+48}

There is a fairly well-marked mode in the range 50–53° longitude. The mean spacing is 55° longitude with a standard deviation of 11° longitude. The mean spacing is 63° longitude for the eleven double I.P.s and this is principally due to the northern member of the pair. This tendency for spacing to increase with latitude can be seen with the single I.P.s. For the seven single I.P.s north of 57°N. the mean spacing is 66° longitude. 80 per cent of the I.P.s occurred between 47°N. and 57°N. and for these there is little relation between latitude and spacing.

The importance of the southerly component is again shown in the wind directions at the I.P.s as given in Table II.

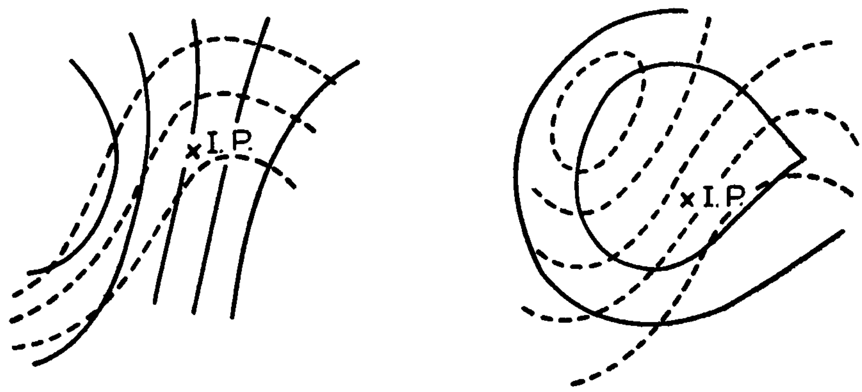
TABLE II—DISTRIBUTION OF WIND DIRECTION AT INFLEXION POINTS

	Wind direction (in degrees) at I.P.							
	140–159	160–179	180–199	200–219	220–239	240–259	>260	Total
				number of cases				
Single I.P.s	–	6	23	27	11*	4	–	71
Double I.P.s	1	6	7	5	2	1	–	11 (2 values for each)

* 9 of these are 220 degrees

There are only six of the single I.P.s for which the angle exceeds 220°, and even for these the mean southerly component amounts to 42 knots.

The I.P.s are most often located just to the west of the axis of the thermal ridge as shown in Figure 8(*a*). In these cases much of the southerly component is present in the airstream near the surface. In a smaller number of cases the I.P. is located as in Figure 8(*b*) and the southerly component arises from the thermal wind.



(*a*) (*b*)

FIGURE 8—PATTERNS ASSOCIATED WITH INFLEXION POINTS
The continuous and broken lines are respectively surface isobars and thickness lines.

These characteristic inflexions appear on the forward sides of upper troughs usually in association with cyclogenesis as indicated in Figure 9. At first the amplitude of the new ridge–trough pattern may be little more than 5° latitude, and the I.P. about 15° longitude from the trough. In the following 24 to 48 hours the amplitude increases at an average rate of 5° latitude per day and the separation from the upwind trough at an average rate of about 5° longitude per day often with further backing of the wind at the I.P.

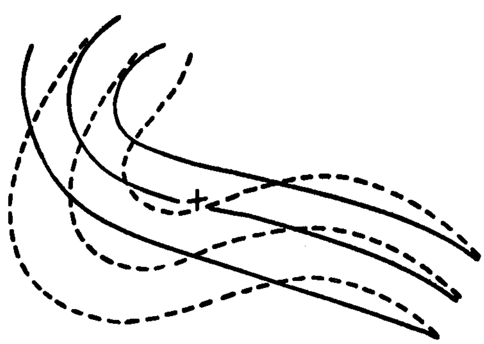


FIGURE 9—FORMATION OF AN INFLEXION POINT
The continuous and broken lines are respectively initial contours and contours 12–24 hours later.
X Surface cyclogenesis

Association of the upwind anticyclone with meridional extension.— As the frequency polygon in Figure 7 shows, there is evidence of a preferred spacing of the M.E. from the position of the upwind anticyclone at time *t*. Though the peak is not quite as sharp as that for the I.P.s the standard deviation (11° longitude) is no greater.

The anticyclones were usually centred farther north than the average high pressure cell in the east Atlantic. 90 per cent of them were north of latitude 40°N. at time *t* compared with a latitude between 30 to 35°N. for the average high pressure cell. It was quite usual for the axis of the upwind anticyclone to change from west–east to north–south as M.E. progressed, that is, there was development northwards ahead of the growing upper ridge.

Relation of constant absolute vorticity trough and l_{t+48}.—The longitude of a constant absolute vorticity trough at 500 millibars was worked out from the wind speed and direction at the I.P. using tables due to H. B. Wobus.[2] The results of the comparison are shown in Table III, where positive values mean that l_{t+48} is to the west of the C.A.V. trough.

TABLE III—DISPLACEMENT OF CONSTANT ABSOLUTE VORTICITY TROUGH FROM l_{t+48}

Negative values, degrees longitude			Positive values, degrees longitude						
<20	11–20	1–10	0–9	10–19	20–29	30–39	40–49	50–59	≥60
				number of cases					
2	3	6	5	12	8	15	11	6	3
				Total 71 cases					

It is quite evident that even allowing for the fact that the 500-millibar trough may be some 5° longitude farther east than l_{t+48}, the extension usually occurred substantially to the west of that indicated by a C.A.V. trajectory.

Synoptic situations in which meridional extension occurred.—About half of the cases occurred in a zonal type of situation. They appear to have been initiated either by vigorous cyclogenesis (about 60° longitude upwind) ahead of a moderate or large-amplitude contour trough or by a fairly sudden increase in the amplitude of this trough. These developments were followed by the growth of a downwind ridge and then by M.E. of the existing downwind trough or the formation of a new trough from the existing zonal flow. When the amplitude of an existing trough exceeded 5° latitude before M.E. it was nearly always at least 30° longitude downwind of the I.P. at time t. Troughs of this amplitude usually suffered negative extension or led to cut-off cold pools in low latitude if nearer than about 30° longitude to the I.P.

About a third of the cases occurred in already meridional situations as a relaxing trough followed by a new amplifying ridge from the west moved through the existing long-wave ridge. M.E. of this trough then occurred after it had led to the partial (or in some cases the complete) collapse of the old ridge and the new one had taken its place. A few occurred downwind of "blocks", in a region of strong westerly flow aloft, and a few slightly upwind of "blocks", that is, they were associated with the southern part of the splitting upper flow. Two summer cases appeared to be due to the propagation south-eastwards of a marked north-north-westerly flow over Greenland at 500 millibars.

There were three interesting occurrences of M.E. following anticyclonic disruption of a fairly large-amplitude thermal trough. The northern part of this trough moving east faster than the southern part underwent a little negative extension at first but began to extend positively when about 40° longitude away from the southern part. On a number of occasions M.E. occurred a day or two earlier in an area occupied by a quasi-stationary warm anticyclone.

Mechanism of the meridional extension process.—It appears probable that the effect of the growing contour ridge on the contour pattern downwind is the essence of the process. The ridges were usually quite mobile (mean speed near the crest 17° longitude per day) and preceded by considerable rises of

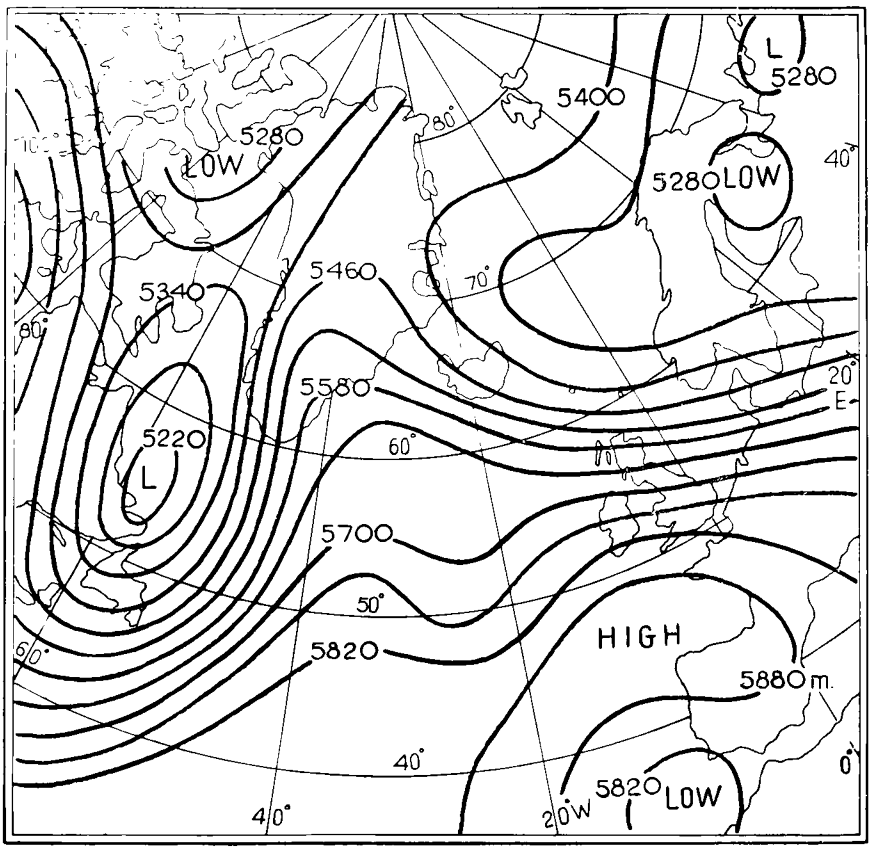


FIGURE 10—500-MILLIBAR CONTOURS FOR 1200 G.M.T., 28 SEPTEMBER 1957

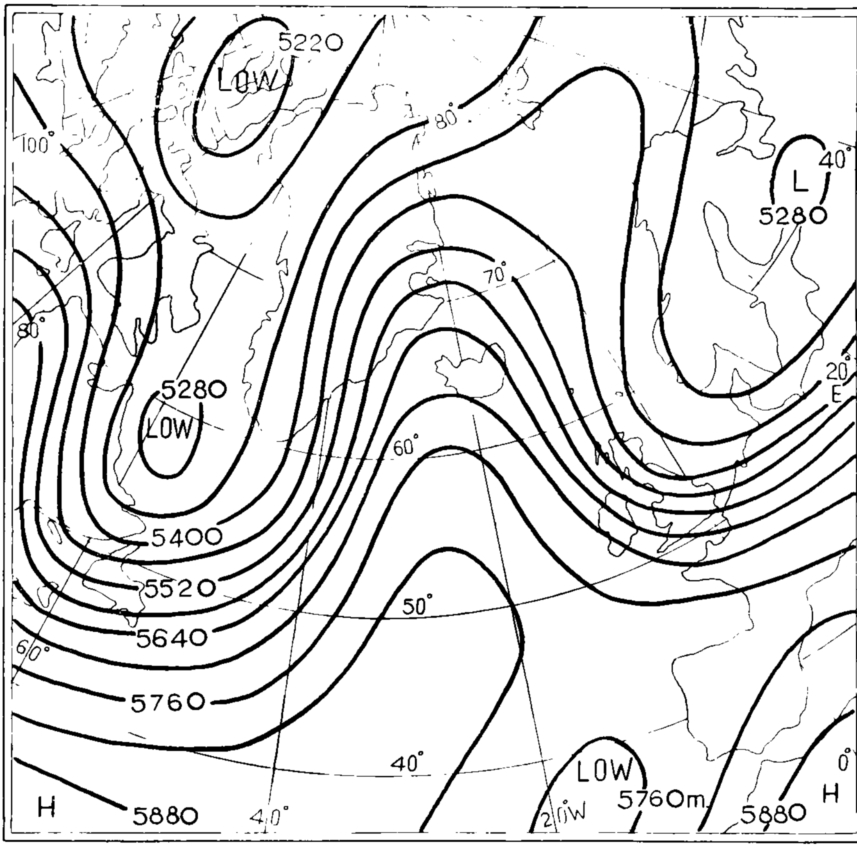


FIGURE 11—500-MILLIBAR CONTOURS FOR 1200 G.M.T., 29 SEPTEMBER 1957

contour height at all levels, which have their maximum near the latitude of the crest. The first effect of the veering contour gradient which this implies would be to increase the cyclonic curvature on the west side of the downwind trough assuming for the moment no change in the contour pattern in the trough. For the veered flow to attain the vorticity appropriate to this sharpened bend an additional convergence of the order 10^{-5}sec.$^{-1}$ would be required throughout almost the entire troposphere. The resulting changes of surface pressure would be an order of magnitude greater than those which can be sustained with this scale of flow. This suggests that the veered flow must continue with nearly constant absolute vorticity and, from a selection of measurements made, this requires that the cyclonic bend be transferred southwards. The surface pressure and contour height falls presumably represent the small mass adjustment necessary to balance this flow pattern.

Figures 10 and 11 show the growth of the 500-millibar contour ridge and the fall of contour height to the south-east of the veered flow during the M.E. of 29 September, 1957. Continued southward extension of the north-northwesterly flow occurred in the next 24 hours accompanied by further falls of contour height. This particular M.E. is an example of one occurring in a zone previously occupied by a quasi-stationary anticyclone. During the M.E. the anticyclone weakens greatly and mainly shifts westwards as this one did.

Forecasting the occurrence and location of meridional extension.— (*a*) *Occurrence:* The growth of a ridge upwind would appear to give the most reliable advance indication of the onset of M.E., but it seems likely that an I.P. with wind direction less than 225° commonly appears in the early stages of the ridge growth, and may sometimes give an earlier indication. There is a rather variable interval between the first appearance of such an I.P. and the onset of M.E. It is most often between 12 and 24 hours, with 15 per cent of these intervals less than 12 hours and about 20 per cent 36 hours or more. This interval appears not to be closely associated with either the latitude or the strength of the southerly component at the I.P., or the rate of movement of the growing ridge at time *t*.

This matter of the precise timing of the onset of M.E. is important because there are often no other signs of its happening right up to the moment of onset.

(*b*) *Location:* The best forecast of location when there is a single upwind I.P. is probably 55° longitude downwind of it. If *t* can be correctly determined such a forecast could be expected to have a root-mean-square error of 11° longitude. When the main concentration of thickness lines is initially north of 55°N. there is evidence that spacings greater than 60° longitude are nearly as likely as those below this value, though in the five months April to August only once was a spacing greater than 60° longitude measured. All spacings show a tendency to be some 5° longitude shorter in the summer months.

When there is a strong anticyclone north of 40°N. and other indications of M.E. then a forecast that it will occur 30° longitude downwind from the position of the centre at time *t* may also be expected to have a root-mean-square error of 11° longitude. In the absence of an I.P. and a strong anticyclone, a location 45° longitude downwind from a growing thermal ridge is probably a useful forecast.

Forecasting test.—To establish the value of the I.P. as an indicator of M.E. and the time of onset, a forecasting test was carried out on the data for 1957.

(*a*) *Occurrence:* Every I.P. at the 500-millibar level with wind direction between 150° and 225° occurring between 80°W. and 20°W. was noted. The geostrophic wind at the I.P. was measured and the longitude and amplitude of the nearest downwind thermal trough. (A trough was classified as of moderate amplitude if the crest-to-trough difference in the latitude of the thickness lines exceeded 5° latitude and large if it exceeded 15° latitude.) The amount of M.E. of the thickness lines of this trough was then noted at successive 12-hour intervals so that, for each I.P., *t* the time of onset of M.E. could be stated if it occurred. An extension of 5° latitude or more was noted as a strong M.E. and 3 or 4° latitude as moderate. These were regarded as successful forecasts provided *t* was within 48 hours of the first appearance of the I.P. (It was quite evident during this test that the original criterion of 5° latitude was too severe. Quite significant effects followed moderate M.E.s, especially in summer-time.)

It was found that 68 per cent of the I.P.s were followed by M.E. excluding all cases with an existing large-amplitude thermal trough between 35° and 60° longitude downwind from the I.P. at the time of its first appearance. 81 per cent of all the M.E.s during the year were forecast. The fact that the proportion (81 per cent) of M.E.s which had been previously forecast exceeded the proportion (68 per cent) of forecasts of M.E. subsequently verified by occurrence implies that M.E. is, not surprisingly, being forecast too often, which in general forecasting practice is an unsatisfactory state of affairs.

The application of two further criteria, namely that the wind speed at the I.P. shall equal or exceed 40 knots and the nearest downwind thermal trough be at least 25° longitude from the I.P. if it is of moderate or large amplitude, eliminates more incorrect than correct forecasts and brings both success ratings to the same level at 77 per cent. It is noteworthy that the spacing criterion produces a greater improvement than one based on the growth of the upwind contour ridge, implying that the inflexion point direction and speed give all the necessary information about the growth of this ridge.

The fourteen M.E.s in 1957 not preceded by an I.P. within 48 hours were all associated with a growth of the upwind contour ridge in the 24 hours before *t*, though in only one case did the growth exceed 5° latitude. 65 per cent of the M.E.s began within 12 to 24 hours of the first appearance of the I.P., 4 per cent later than this and 31 per cent earlier. The rather greater number beginning within 12 hours can probably be attributed to allowing an extension of 3° latitude in 24 hours to count, for the purpose of determining *t*.

(*b*) *Location:* The spacing data confirmed the results obtained earlier. The mean spacing from the I.P. at *t* was 53° longitude with a standard deviation of 12° longitude, and from the anticyclone 32° longitude with a standard deviation of 10° longitude. Owing to the difficulty of forecasting *t* precisely, the spacings from the first appearance of the I.P. have been examined. The mean spacing from the I.P. was 60° longitude and from the anticyclone 35° longitude. The root-mean-square error of a forecast using a mean of these two indications would have been 15° longitude. This combination of the two values provides the best forecast of location if the time of onset is not known, but can only be used when there is a single anticyclone centre upwind, that is, on about 85 per cent of occasions.

Conclusions.—From this study of a large sample of meridional extensions the following conclusions may be drawn.

1. M.E. of thermal troughs occurs during an evolution involving the whole troposphere which extends over a period of 48 to 72 hours.

2. Thermal troughs which undergo M.E. decelerate on average about 6° longitude per day during the evolution.

3. Over 90 per cent of M.E.s are preceded by the growth of a thermal and contour ridge upwind.

4. An isallobaric minimum occurs to the south-east of extending troughs and moves south-eastwards, and an isallobaric maximum occurs to the north-west.

5. Surface anticyclones centred north of about 40°N. appear to play an important part in determining the location of M.E.

6. Troughs which have undergone M.E. tend to stagnate (or be cut off) on average about 20° longitude further west than would be expected from a constant absolute vorticity trajectory.

7. An inflexion point (wind direction 150–225° and speed $\geqslant$40 knots) in the 500-millibar flow ahead of an upwind trough occurs with about 75 per cent of all M.E.s and precedes the onset by some 12 to 24 hours.

8. A test made on the data for 1957 shows:
   (i) that a forecast of M.E. whenever an I.P. occurred would have been correct on about 70 per cent of occasions, and
   (ii) that the longitude of the trough 48 to 72 hours later would have been forecast with a root-mean-square error of 15° longitude from considerations of the longitude of this I.P. and that of the anticyclone just downwind of it.

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THIRD CONGRESS OF THE WORLD METEOROLOGICAL ORGANIZATION

By C. W. G. DAKING, B.Sc.

The Third Congress of the World Meteorological Organization was held in Geneva at the Palais des Nations from 1–28 April 1959. It was attended by representatives of eighty-eight Member States or Territories, by observers from two non-member countries, and by representatives of fifteen other international organizations. The Congress was presided over by M. André Viaut, Director-General of the French Meteorological Service, who was re-elected as President of the Organization for the Third Financial Period. The United Kingdom delegation was led by Sir Graham Sutton, Director-General of the Meteorological Office.

The very large agenda was dealt with by means of three working committees namely, the Legal and General Committee; the Administration and Finance Committee; and the Technical Programme Committee. It would be impossible to deal adequately with all the matters discussed by these three committees within the compass of a short article, and attention will therefore be directed to those items likely to be of most interest to the readers of this magazine.

General questions.—The Convention of the World Meteorological Organization, which was drawn up in Washington in 1947, had not hitherto been amended, but for Third Congress, Member States had tabled amendments to Articles 10 and 13, dealing with voting procedures and the composition of the Executive Committee respectively. For some time past it had been considered by several Member States that, having regard to the large increase of membership of the Organization, the time had arrived when consideration should be given to an increase in the size of the Executive Committee which, up to the present, had consisted of the President and Vice-Presidents of the Organization; the six Presidents of the Regional Associations; and six elected members. It was decided to increase the Executive Committee to eighteen members by substituting nine elected members for the six elected previously.

There was considerable discussion on whether the Executive Committee, as the body responsible for guiding the activities of the Organization during the interval between meetings of Congress, should be authorized to propose amendments to the Convention, a right hitherto reserved for Member States. It was agreed that the Executive Committee should keep the Convention under review between meetings of Congress and submit to Congress the text of any proposed amendment which appeared to the Executive Committee to be necessary.

During the deliberations on the Convention, it became clear that Article 28(*c*) of the Convention, which covers amendments not involving new obligations for Members and provides that such amendments shall come into force upon approval by two-thirds of the Members which are States, was open to several interpretations and it was decided that the Executive Committee should study the text and its application and report to Fourth Congress. Nevertheless, it was under the terms of this Article that Congress approved the increase in size of the Executive Committee by 56 votes in favour, none against, with three States abstaining. Unless this had been done, the increase in size of the Executive Committee, clearly desired by the vast majority of Members, would have had to be postponed for four years.

The amendments to the General Regulations which prescribe the constitution and functions of the various bodies of the Organization, occupied a great deal of time. Substantial revisions were made to those sections dealing with elections during sessions and between sessions, to the conduct of business in meetings of constituent bodies, committees and working groups, and to some of the general regulations pertaining to the Executive Committee. Supplementary instructions and procedures to the General Regulations in the form of annexes were prepared to assist constituent bodies in the preparation of resolutions and recommendations, and in the procedures to be followed in voting by correspondence and in elections by correspondence.

Although there was some support for a W.M.O. technical assistance programme, it was decided to continue on an increased scale the Operational and Technical Development Fund which was created by Second Congress. An amount of $60,000 was allocated for the purpose of furthering scientific projects of international significance with the proviso that the employment of the Fund for any one project should be for a limited period only.

Technical questions.—Congress reviewed the broad aspects of the technical programme for the Third Financial Period (1960–63). Disappointment was expressed by delegates that existing serious gaps in the world network of meteorological stations had not been filled and that many important problems such as the general circulation, could not be fully understood until this deficiency was rectified. The Executive Committee is to study ways and means whereby more effective action can be taken in this field and, in addition, machinery for the operation of joint support schemes was set up by Congress since such schemes may play a major role in reducing deficiencies in meteorological facilities, especially in observation networks.

Much attention was devoted to the structure and terms of reference of the Technical Commissions. It was decided to dissolve the Commission for Bibliography and Publications and to establish a Commission for Hydrological Meteorology. The number of Technical Commissions, therefore, remains at eight.

W.M.O.'s responsibility in the field of hydrology gave rise to much vigorous discussion, since there was a substantial body of opinion in favour of adopting hydrology on a large scale. On the other hand, there were those who wished W.M.O. to have as little as possible to do with that science, beyond providing the meteorological data required by hydrologists and water engineers. Some delegations opposed the setting up of a Commission for Hydrology—hence the compromise which had to be adopted for the name of the new Commission.

There was a lively discussion on the meteorological aspects of atomic energy. Congress considered that the use of radioactive isotopes in meteorology could help the development of the science and that W.M.O. could play a very important role in informing and advising Members on meteorological problems connected with various activities related to the peaceful uses of atomic energy.

With regard to artificial satellites, Congress realized that while it was too early to foresee all the possible meteorological applications, they would provide many valuable data not only for research work but possibly also for synoptic purposes. Examples of such applications specifically mentioned during Congress were the early detection of tropical cyclones and the accurate determination of variations in the solar constant. The Executive Committee was requested to arrange for a continuing review to be made of the uses of artificial satellites for meteorological purposes and to keep Members informed of developments in this field.

The Technical Programme Committee carried out a thorough review of the Technical Regulations (Volume I, Chapters 1–11) which deal with observations, synoptic and forecasting practices, climatological practices, publications, and services for shipping and agriculture. Many changes of substance were made and ambiguities in other regulations were removed. The revised Technical Regulations will come into force on 1 January 1961.

Administrative and financial questions. — Congress authorized the Executive Committee to incur expenditure of $2,694,484 during the Third Financial Period—this represents an increase of some $900,000 over the sum approved for the Second Financial Period. The increase is largely accounted for by extra costs of meetings of the constituent bodies, especially the Executive Committee, and by a re-organization of the Secretariat which resulted in the creation of a new Division to deal with Conferences, Documents and Publications, with a consequent increase in the size of the Secretariat.

As at Second Congress, there was a protracted debate on the assessment of proportional contributions. Several delegations pressed for a scale closer to that of the United Nations and, as in 1955, a compromise was ultimately found between the existing scale and the current United Nations scale. This results in a reduction of units contribution by the United Kingdom from 64 to 62.

Congress decided that the W.M.O. celebrations to commemorate its tenth anniversary should take place jointly with the ceremonies on the occasion of the opening of the new permanent building of the W.M.O. It further decided that the Secretary-General should publish a special illustrated booklet in the four official languages of W.M.O. dealing with the activities and achievements of the Organization during its first ten years and that one of the regular issues of the *W.M.O. Bulletin* should be devoted to the tenth anniversary of the Organization.

Elections.—M. André Viaut (France) was re-elected as President of the Organization. Messrs. Luiz de Azcárraga (Spain) and M. F. Taha (United Arab Republic) were elected First and Second Vice-Presidents respectively. The following were elected to fill the nine seats on the Executive Committee allocated to Directors of Meteorological Services: Dr. M. F. Barnett (New Zealand); Mr. F. L. Fernandez (Argentina); Mr. F. Giansanti (Italy); Mr. J. Lambor (Poland); Dr. A. A. Solotoukhine (U.S.S.R.); Sir Graham Sutton (United Kingdom); Dr. A. Thomson (Canada); Dr. K. Wadati (Japan); Mr. A. A. Wahab (Sudan).

Appointment of the Secretary-General.—There were no nominations for Secretary-General other than Mr. D. A. Davies, who held this appointment during the Second Financial Period. Mr. Davies was re-appointed unanimously by Congress for the Third Financial Period.

The arrangements made for the Congress by the Secretary-General and his staff were of the highest order; everything was done to make the work of the Committees flow quickly and easily, and working papers were available usually within 24 hours of having been agreed at Committee level. Copies of the Abridged Report of Congress were ready on the last day, containing all the resolutions passed in plenary sessions, except those agreed on that day.

Delegates to Third Congress cannot fail to have been impressed by the energy and enthusiasm of the Secretariat of the W.M.O., who are clearly dedicated to the task of furthering the purposes of the World Meteorological Organization as laid down in Article 2 of its Convention.

METEOROLOGICAL OFFICE DISCUSSION

Objective Methods of Local Forecasting

The Meteorological Office discussion at the Royal Society of Arts on Monday, 16 March 1959 was on "Objective methods of local forecasting", and was opened by Mr. M. H. Freeman.

An objective method of forecasting can be defined as one which depends only on the initial data and will produce the same answer whoever prepares it; the method will not call for any judgement on the part of the forecaster. Most objective techniques achieve this by the use of formulae or graphical diagrams, which may be worked out from physical or dynamical principles or derived empirically. Purely empirical formulae need to be used with caution; unless the relation is at least plausible on physical grounds there is a risk that the sample data used may not be sufficiently typical to produce a useful forecasting tool.

Objective forecasting has been the subject of a lot of work in America, but has received less attention in this country. Durst[1] developed a completely objective method of forecasting upper winds, which was tested by Johnson.[2] Swinbank,[3] Saunders[4] and Craddock[5] all devised methods of fog forecasting which were partly objective but which also required one or more parameters to be forecast subjectively. An investigation was therefore started, aimed at producing a purely objective method of forecasting visibility which would give the answer in yards or miles rather than the fog/no fog type of forecast previously attempted. The specific problem was posed as follows: using 0600 G.M.T. data to forecast the visibility at London Airport at 0900 and 1200 G.M.T., and using 1500 G.M.T. data to forecast the 1800 and 2100 G.M.T. visibilities. The investigation was restricted to the winter period November–January and the operational requirement was for a forecast of visibility to the nearest 100 yards up to 1,000 yards and then in 200-yard steps up to 2,000 yards.

TABLE I—VISIBILITY SCALE USED IN THE INVESTIGATION

Visibility	Code	Visibility	Code
Less than 50 yd.	0	2,500 yd.	16
100 yd.	1	3,000 yd.	17
200 yd.	2	3,500 yd.	18
300 yd.	3	4,000 yd.	19
400 yd.	4	2½ miles	20
500 yd.	5	3 miles	21
600 yd.	6	3½ miles	22
700 yd.	7	4 miles	23
800 yd.	8	5 miles	24
900 yd.	9	6 miles	25
1,000 yd.	10	8 miles	26
1,200 yd.	11	10 miles	27
1,400 yd.	12	12 miles	28
1,600 yd.	13	16 miles	29
1,800 yd.	14	20 miles	30
2,000 yd.	15	Over 22 miles	31

Visibility scale.—The first problem was the choice of a suitable visibility scale. A linear scale was rejected since it would not give sufficient emphasis to low visibilities. Initial work was done with the logarithm of the visibility in miles, but this gave too open a scale below 500 yards, so the arbitrary scale shown in Table I was adopted. Half the scale, code figures 0 to 15, covers the range up to 2,000 yards as specified in the operational requirement. The remainder of the visibility range is covered by another sixteen code figures and is approximately logarithmic.

Parameters used.—The selection of the parameters to be tried was one of the most important parts of the investigation. Anything which physical principles suggested might be relevant was included, and the advice of experienced forecasters at London Airport was sought. The list of parameters tested was as follows:

(i) Visibility at the beginning of the forecast period
(ii) Change in visibility during the previous three hours
(iii) Dry-bulb temperature
(iv) Dew-point
(v) Depression of dew-point
(vi) Relative humidity
(vii) Hydrolapse through lowest 50 mb. (surface dew-point at London Airport minus dew-point 50 mb. above the surface at Crawley or Larkhill)
(viii) Hydrolapse through lowest 25 mb.
(ix) Lapse rate through lowest 50 mb. (surface dry-bulb temperature at London Airport minus temperature 50 mb. above the surface at Crawley or Larkhill)
(x) Lapse rate through the lowest 25 mb.
(xi) Total amount of low and medium cloud
(xii) Total amount of all cloud
(xiii) Surface wind speed and direction
(xiv) Change in surface wind in three or six hours
(xv) Geostrophic wind speed and direction at London Airport measured from Central Forecasting Office charts
(xvi) Shear of the wind: ratio of surface to geostrophic wind speeds
(xvii) State of the ground
(xviii) Past weather (three hours at 1500 G.M.T., six hours at 0600 G.M.T.)
(xix) Excess of soil temperature over air temperature

Since no soil temperature data were available for London Airport, the 0900 G.M.T. readings for Kew were used although the characteristics of the soils at the two places are not necessarily similar. It was assumed that changes in soil temperatures between 0600 and 0900 G.M.T. would not be sufficiently great to significantly alter its value as a forecasting parameter. Of the various soil temperature readings available from Kew, that at eight inches was used, though four inches might have been better.

All this information was recorded on Paramount edge-punched cards which were specially printed for the investigation, a separate card being used for each day. Data for the eleven winters November 1946 to January 1957, 1,012 days in all, were entered on the cards and used in developing the objective forecasting technique. The winters 1957–8 and 1958–9 were used to obtain an independent check on the efficacy of the system.

Method of graphical correlation. — D. H. Johnson, who started this investigation, used a technique of graphical correlation described by Brier[6] to produce an objective forecasting technique using eleven parameters. Figure 1

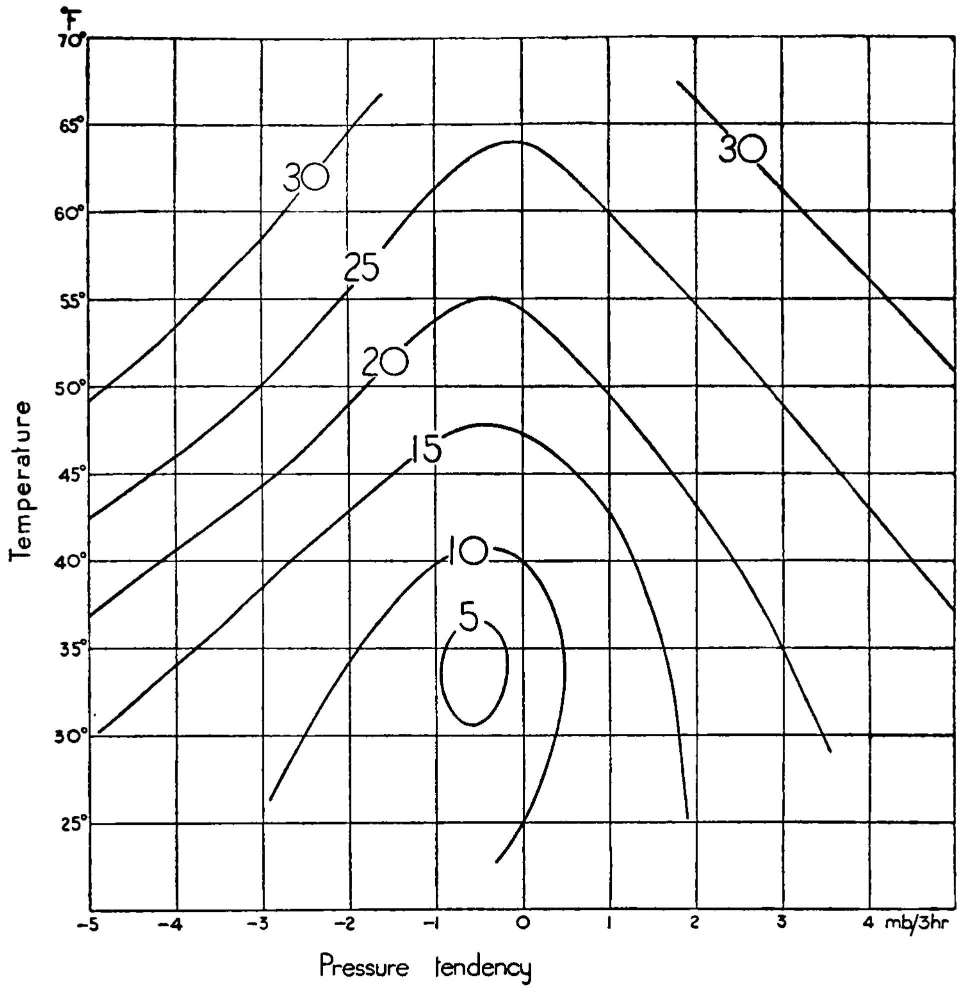

FIGURE 1—FIRST DIAGRAM IN JOHNSON'S ELEVEN-PARAMETER SERIES, SHOWING ISOPLETHS OF Q_1, THE FIRST ESTIMATE OF THE 2100 G.M.T. VISIBILITY AT LONDON AIRPORT

shows the first chart in Johnson's series. In this diagram two parameters, pressure tendency and air temperature at 1500 G.M.T., are graphically correlated with the predictand, the 2100 G.M.T. visibility. The diagram was constructed in the following way. Using the first observation, a point was plotted with the observed 1500 G.M.T. pressure tendency as abscissa and temperature as ordinate and at this point the value of the visibility which occurred at 2100 G.M.T. was recorded. Similarly, all the remaining 1,011 observations were plotted, covering the chart with numbers which, it was hoped, would show some sort of pattern; and in fact there was a tendency for low values of visibility to be associated with low temperatures and small pressure tendencies. In order to make the pattern clearer the chart was divided into a number of areas each containing 20 or more observations; the mean visibility for each area was then calculated and plotted near the centre of gravity of the group. These mean values were used to construct the series of isopleths of 2100 G.M.T. visibility shown in Figure 1, a good deal of smoothing being necessary in order to obtain a reasonable set of lines. These isopleths were then used to read off for each day of the eleven winters the value of a new parameter, Q_1 (which may be considered as a first estimate of the visibility to be predicted). In exactly the same way another graph was drawn to combine two more parameters, wind speed and direction, to produce a second predictor Q_2. The process was repeated to correlate Q_1 and Q_2 giving yet another parameter, R_1. Obviously this method of graphical correlation can be repeated as many times as is required. Table II shows how the eleven parameters used by Johnson were combined to produce a final forecast of the visibility.

TABLE II—COMBINATION OF PARAMETERS IN JOHNSON'S OBJECTIVE FORECAST

Surface temperature	Q_1	R_1	Z	Forecast visibility
Pressure tendency	Q_1	R_1	Z	Forecast visibility
Geostrophic wind speed	Q_2	R_1	Z	Forecast visibility
Geostrophic wind direction	Q_2	R_1	Z	Forecast visibility
Surface dew-point depression	P_1	Q_3	R_2	Z → Forecast visibility
Hydrolapse through lowest 25 mb.	P_1	Q_3	R_2	Z → Forecast visibility
Ratio of surface to geostrophic wind speeds	P_2	Q_3	R_2	Z → Forecast visibility
Temperature lapse through lowest 25 mb.	P_2	Q_3	R_2	Z → Forecast visibility
Amount of low and medium cloud	Q_4	R_2	Z	Forecast visibility
Past weather	Q_4	R_2	Z	Forecast visibility
Actual visibility				Forecast visibility

Freeman's five-parameter objective forecast.—With the completion of the eleven-parameter model the investigation was carried on by M. H. Freeman, one aim being some simplification of Johnson's rather cumbersome scheme. Since a good deal of inter-correlation existed between the various parameters it seemed likely that a smaller number might produce almost as good a result, and a more compact form of diagram was desirable. Figure 2 shows the form taken by Freeman's five-parameter model, which used wind direction, wind speed, pressure tendency, dew-point depression and actual visibility. The pecked line on the diagram illustrates its method of use. The top right-hand section is entered with the 0600 G.M.T. geostrophic wind direction (90°) and a line followed vertically until the isopleth representing the 0600 G.M.T. geostrophic wind speed (18 kt.) is reached. A horizontal line is now followed into the next diagram until the 0600 G.M.T. pressure tendency (+2 mb./3 hr.) is reached, successive turns being made at the appropriate isopletsh for dew-point depression (2°F.) and the 0600 G.M.T. visibility (2,000 yards), the final prediction of the 1200 G.M.T. visibility (2,500 yards) being read off from the bottom right-hand side of the diagram. The method of construction of the individual graphs was essentially similar to that of Johnson's, but instead of plotting all the values on a large sheet the mean values were found by sorting the edge-punched cards. For instance, to obtain the first diagram, all cards with 0600 G.M.T. wind direction 10°–30° were sorted out and these further divided into piles in which the 1200 G.M.T. visibility was 0–4, 5–9, 10–14, etc. For each small pile the mean 0600 G.M.T. wind speed was calculated and this value plotted using the mean of the direction, 20°, as abscissa and the mean visibility 2, 7, 12, etc., as ordinate. (The ordinate visibility scale has not been marked on Figure 2 as it is not required in the final diagram.) Using this array of plots a series of isopleths of wind speed were drawn as shown—a good deal of smoothing again being required.

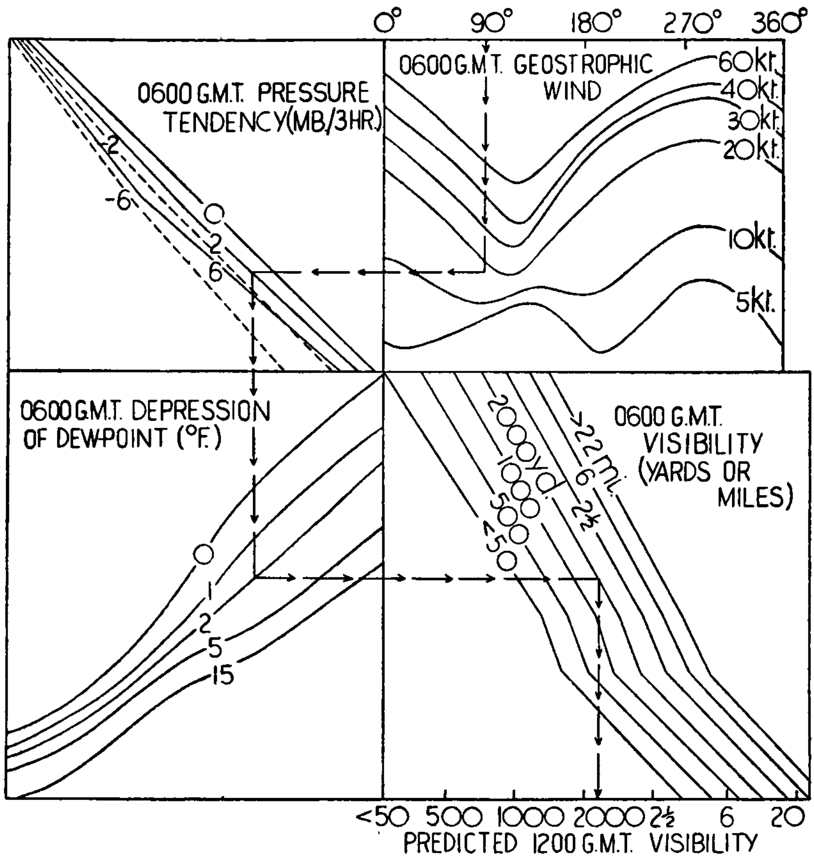

FIGURE 2—FREEMAN'S FIVE-PARAMETER VISIBILITY PREDICTION DIAGRAM FOR 1200 G.M.T. AT LONDON AIRPORT

This diagram was then used to read off first estimates of the forecast (Z_1) which were entered and punched on the cards. The second diagram was drawn after sorting according to Z_1 and the 1200 G.M.T. visibility, and meaning the pressure tendencies, and so on for the remaining graphs, the process being repeated as many times as required.

A test on independent data showed that the Freeman five-parameter, or *F*, forecast was almost as good as Johnson's eleven-parameter *J* forecast. Ease of use, therefore, showed that the *F* system was a more practical forecasting tool than the *J* system. Both, however, suffered two subjective weaknesses in their construction—namely the selection of the parameters and the smoothing of the isopleths. The advent of the "Meteor" electronic computer made it possible to consider overcoming both these weaknesses by rigorous statistical methods.

Modification of the Freeman system using "Meteor".—The method of "least squares" used in simple regression equations can readily be extended to more complicated relations. A linear relation of the form $z=ax+by+c$ can be fitted to a series of three variables by summing the squares of the errors and differentiating with respect to a, b and c to give three simultaneous equations which must be solved to find a, b and c (see, for example, Brooks and Carruthers[7]). Something much more refined than a linear relation was needed and in fact all the powers up to five were evaluated and the best selected. The quintic $z=ax^5+bx^4y+$etc. requires the formation of 86 sums of the type $\Sigma x^7 y^3$ (each sum comprising 1,012 terms) and the solution of 21 simultaneous equations. "Meteor" was programmed to do this arithmetic, print out a table giving values from which the isopleths could be drawn, print out the graphs themselves and finally compute the root-mean-square error of the predicted visibility.

Various combinations of parameters were tried and those giving the lowest standard error selected. In order to restrict the number of combinations to be tried a preliminary series of computations was done on the machine to find out which single parameters were most highly correlated with the visibility to be forecast. Table III shows these in order for 0900 and 2100 G.M.T.

TABLE III—CORRELATION OF INDIVIDUAL PARAMETERS WITH VISIBILITY TO BE FORECAST

0900 G.M.T.	r	S.E.	2100 G.M.T.	r	S.E.
Visibility	0·83	4·5	Surface wind speed	0·70	5·3
Surface wind speed	0·73	5·6	Geostrophic wind speed	0·69	5·4
Geostrophic wind speed	0·71	5·8	Visibility	0·66	5·6
Surface wind direction	0·66	6·1	Surface wind direction	0·51	6·4
Relative humidity	0·62	6·4	Lapse rate	0·43	6·7
Lapse rate	0·61	6·5	Wind shear	0·42	6·7
Dew-point depression	0·59	6·6	Geostrophic wind direction	0·42	6·7
Wind shear	0·59	6·6	Past weather	0·37	6·9
Excess soil temperature	0·52	7·0	Temperature	0·34	7·0
Temperature	0·51	7·0	Relative humidity	0·30	7·1
Past weather	0·49	7·1	Dew-point depression	0·29	7·1
Geostrophic wind direction	0·45	7·3	Excess soil temperature	0·26	7·2
Hydrolapse	0·39	7·5	Pressure tendency	0·19	7·3
Dew-point	0·36	7·6	Dew-point	0·18	7·3
Total cloud	0·26	7·9	Low and medium cloud	0·15	7·3
Low and medium cloud	0·25	7·9	Hydrolapse	0·12	7·4
Pressure tendency	0·25	7·9	Total cloud	0·11	7·4
State of ground	0·25	7·9	State of ground	0·09	7·4
S.D. of 0900 G.M.T. visibility		8·2	S.D. of 2100 G.M.T. visibility		7·4

Note.—S.E. is the root-mean-square error of the predicted visibility (z) obtained after a regression relation of the form $z=ax^5+bx^4+cx^3+dx^2+ex+f$ had been fitted to the data, where x was the parameter being tested. S.D. is the standard deviation of the visibility to be forecast. Both S.E. and S.D. are measured in units of the visibility code given in Table I. The correlation coefficient (r) was calculated from the formula $r^2=1-(\text{S.E./S.D.})^2$.

Wind direction, wind speed and visibility all came out high on the list, and these three are the first parameters used in all four forecasts (for 0900, 1200, 1800 and 2100 G.M.T.). Interesting features of these tables are the poor showing of hydrolapse, cloud amount and pressure tendency. Lapse rate and wind shear both come high up. But since many of these parameters are highly inter-correlated, items from low down the list may yet prove useful predictors.

After the first two parameters had been chosen the machine was made to punch out a tape giving the values obtained from the graphical correlation of these two parameters, and this formed one of the data tapes which were fed in for the second stage. The process was repeated as many times as necessary, all the unused parameters being tried in turn and the best combination selected. After four or five parameters had been chosen it was found that there was no significant lowering of the standard error on adding more. This confirms the rightness of using only five variables in the F forecast, but it is evident that the most useful parameters were not chosen for the F system.

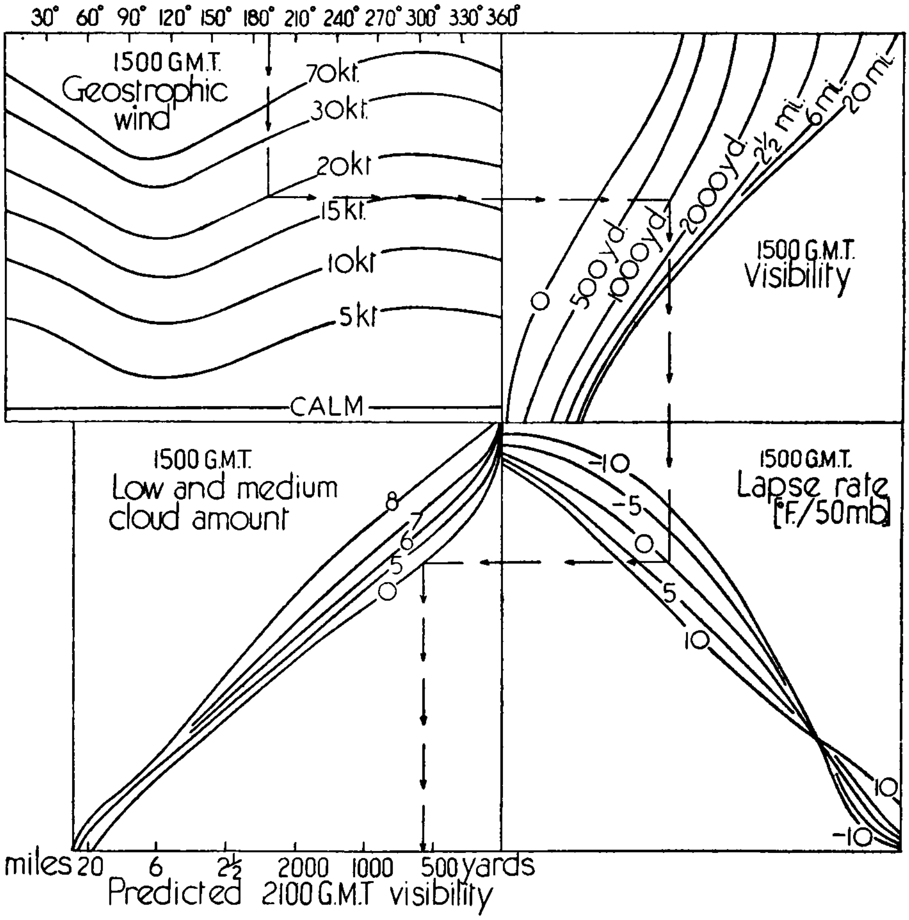

FIGURE 3—MODIFIED FREEMAN VISIBILITY PREDICTION DIAGRAM FOR 2100 G.M.T., CONSTRUCTED USING THE "METEOR" ELECTRONIC COMPUTER

TABLE IV—PARAMETERS USED IN "METEOR" FORECASTS

	Residual standard error
Forecast of 0900 G.M.T. *visibility*	
0600 G.M.T. surface wind	5·1
0600 G.M.T. visibility	3·9
0900 G.M.T. Kew excess soil temperature ...	3·7
Forecast of 1200 G.M.T. *visibility*	
0600 G.M.T. surface wind	4·9
0600 G.M.T. visibility	4·6
0600 G.M.T. temperature	4·5
0600 G.M.T. amount of low and medium cloud	4·4
Forecast of 1800 G.M.T. *visibility*	
1500 G.M.T. surface wind	4·0
1500 G.M.T. visibility	3·5
1500 G.M.T. amount of low and medium cloud	3·4
Forecast of 2100 G.M.T. *visibility*	
1500 G.M.T. geostrophic wind	4·9
1500 G.M.T. visibility	4·6
1500 G.M.T. lapse rate in lowest 50 mb. ...	4·5
1500 G.M.T. amount of low and medium cloud	4·3

Figure 3 shows the modified Freeman diagram for 2100 G.M.T. produced using "Meteor". Its method of use is exactly similar to that described for Figure 2, but it will be noted that the parameters used are different. In fact, the choice of parameters for the forecasts at 0900, 1200, 1800 and 2100 G.M.T. were all different, both the three-hour forecasts requiring only four parameters. The parameters used in each forecast and the standard error after each stage are shown in Table IV.

Comparison of results.—In order to assess the degree of success of the *J*, *F* and "Meteor" or *M* systems, a comparison was carried out during the winter November 1958–January 1959 of all the objective forecasting methods with subjective forecasts prepared at London Airport in the ordinary way. These three check months provide a very stringent test of any visibility forecasting procedure. The frequency of poor visibilities was greater than average, but there were no long periods of persistent dense fog; variations in visibility were frequent and often large. The standard errors of the various forecasts made during the test period are shown in Table V; simple regression and persistence forecasts have been included for comparison.

TABLE V—STANDARD ERRORS OF VARIOUS FORECASTS MADE DURING THE TEST IN THE WINTER, NOVEMBER 1958 TO JANUARY 1959

	G.M.T. 0900	1200	1800	2100	All hours
	standard error				
London Airport subjective	3·4	5·4	4·3	6·3	5·0
"Meteor" objective	3·7	4·9	3·6	5·0	4·4
Freeman objective	4·0	5·0	3·7	5·5	4·6
Johnson objective	3·8	5·2	3·9	5·1	4·6
Simple regression	4·6	5·8	4·4	6·7	5·5
Persistence	5·2	6·3	5·4	7·6	6·2

On the whole, the three objective forecasts are better than the subjective forecasts, the "Meteor" system being the best and with little to choose between the *J* and *F* methods. At individual hours success varied; London Airport's three-hour forecast for 0900 G.M.T. was clearly better than any of the others.

The criterion of least square errors penalizes large errors heavily. Since the *M* system was specifically designed to minimize the standard error, whereas the subjective forecast was not, it is worth considering the sizes of the average error regardless of sign. These are shown in Table VI, which confirms the superiority of the objective system.

TABLE VI—AVERAGE ERRORS REGARDLESS OF SIGN

	G.M.T. 0900	1200	1800	2100	All hours
	average error				
London Airport subjective	2·7	4·1	3·6	4·7	3·8
"Meteor" objective	2·6	3·9	2·9	3·9	3·3

Conclusion.—Among the advantages of a good objective forecasting technique is the fact that a forecaster who has just arrived at a station, even though he is inexperienced, can issue forecasts straight away with confidence. Similarly, a forecaster newly come on duty can answer an enquiry at once. Again, the method is speedy and easy to use. However, if extensive use is made of objective forecasts the number of diagrams needed will be large, and the sheer multiplicity of forecasting sheets may become cumbersome. Any statistical method tends to fail to forecast big changes when they occur, though the *M* system has gone a long way towards eliminating this feature. The largest change forecast during the 1958–9 winter was a drop of 15, from 3,500 to 300 yards (visibility actually fell to less than 50 yards); a technique which, starting from a value less than the mean, can forecast a decrease of twice the standard deviation has advanced a long way from a simple regression equation. Nevertheless, a number of the larger changes were not adequately forecast, and there is plenty of scope for further investigation.

One line which it is hoped to follow is some combination of subjective and objective methods. Cloud amount during the period of the forecast is obviously of great importance, but it is not very highly correlated with cloud amount at the beginning of the period, and so this parameter did not prove very powerful. A system which used a subjectively forecast cloud amount during the period of the forecast as a parameter could easily be devised and might be an improvement. But a lot of care is needed in modifying an objective forecast, or the errors may be increased as often as they are decreased.

Another line of development which might help to cope with air-mass changes is to determine three- and six-hour trajectories and use as parameters the nearest observations to these points. If the method is to be used operationally work will have to be done to reduce the total number of diagrams by suitable grouping of times and seasons. A very obvious extension is to see how a 12- or 24-hour forecast works out. Yet another development is to give the answer as a probability forecast; the objective forecast is particularly well adapted for such presentation.

The objective forecast system described was developed to predict visibility but the method is a powerful one which could be used on a great variety of problems. Work has already started on the collection of data needed for forecasting the 24-hour deepening of Atlantic depressions.

Mr. V. R. Coles said that it would appear to be possible to improve on the statistical forecast by combining objective and subjective techniques. However, he reiterated the warning given by Mr. Freeman that such a procedure must be used with caution as it may do more harm than good. In order to illustrate such a combination of methods, Mr. Coles said that in making an objective forecast of visibility for 2100 G.M.T. based on 1500 G.M.T. data there must be, inherent in the statistical manipulations, an allowance for a certain amount of outgoing radiation during the evening period. If the skies are clear and the winds light during this period, there will be more than this average amount of outgoing radiation and under conditions of strong winds and full cloud cover there will be less. Mr. Coles produced diagrams showing the range of actual visibility at 2100 G.M.T. associated with each value of the statistical forecast and demonstrated how the objective forecast could be modified to enable the most probable visibility and the range of possible visibilities at 2100 G.M.T. to be predicted assuming various cloud and surface wind conditions at that time.

Finally, Mr. Coles stressed again the inadvisability of amending the statistical forecast unless the forecaster felt a very high degree of confidence in his forecast of the wind strength and cloud amount for 2100 G.M.T.

Mr. N. E. Davis explained that London Airport was most interested in visibilities (i) less than 200 yards, when all flying stopped, (ii) in the range

200 to 800 yards, which included the landing limits for most aircraft, and (iii) 800 to 2,000 yards, when additional fuel would be necessary in case of diversion. The method should be modified to give more weight to visibilities less than 2,000 yards.

Mr. J. C. Cumming said that there was no ideal way of checking accuracy of visibility forecasts. Using data on the objective forecasts received from the Synoptic Research Division, Dunstable (the Freeman unmodified forecasts), he had assessed the relative accuracy of the subjective and objective methods from the point of view of the civil aviation user, that is, the correctness or otherwise of the forecast when the visibility was below certain limits in the range 200 to 2,000 yards. The result showed very little difference between the two methods except that the objective method failed more often at the lowest visibilities. For example, at 2100 G.M.T., the objective method was correct only twice when visibility was below 300 yards and the subjective method was correct five times; for visibility below 200 yards the objective method showed no successes while the subjective method scored four times. Large changes, that is, when the visibility was halved or doubled during the period, showed that the subjective forecast proved better over three hours (twenty as against nine cases) while the objective proved better over six hours (twenty-six cases against twenty-one). A further rough analysis of the results had been made when visibility was below 1,000 yards, to compare the accuracy of the two methods and of persistence over a three-hour period, that is, using the current values as a three-hour forecast, the comparative successes resulting:

0900 G.M.T.:	subjective 8½	objective 5½	persistence 2
1800 G.M.T.:	subjective 9	objective 5	persistence 2

success in this case being accredited to whichever of the three values was the nearest to the actual visibility. Mr. Cumming concluded that objective forecasts could be a useful guide to the forecaster but must be used with caution.

Mr. W. D. May suggested that cloud height might be an important parameter, especially at coastal and hill stations.

Mr. J. M. Craddock pointed out that the objective method is based on all the relevant experience during eleven years, that is, far more than that of even the most experienced synoptic forecaster. The synoptic forecaster cannot with his more limited experience hope to do better than the objective method by using the same parameters. He can, however, try to estimate the effect of parameters which are not explicitly allowed for in the objective forecast. The objective forecast effectively gives on every occasion the average effect of such parameters and as far as the synoptic forecaster can make a better than average estimate of the actual effect of such parameters he can hope to improve on the objective forecast.

Mr. S. P. Peters thought snow cover would be a significant parameter, of importance at any rate in Scotland. In an investigation at Waterbeach a soil temperature at a depth of two inches was to be used. The *Director-General* agreed that eight inches was too great a depth for the temperature to have much effect and stressed the importance of whether the soil was wet or dry.

Mr. F. E. Lumb emphasized the importance of being able to forecast whether the visibility would be greater or less than 200 yards. In view of the difficulty of explaining variations in the visibility he thought the forecast should be given as a probability.

[*To face p.* 216

Photograph by G. J. Jefferson

STRIATED CIRRUS CLOUD, ZERMATT, SWITZERLAND, 1500 G.M.T., 24 FEBRUARY 1959

(see p. 218)

To face p. 217]

Photograph by I. M. Laurie

TELEGRAPH WIRES BROKEN BY RIME ICE

(see p. 218)

Mr. S. J. Netrval spoke of the importance in correctly timing changes in visibility, 800 to 1,000 yards being the important limits at an R.A.F. station.

Mr. E. Gold mentioned the clearance of fogs by the lowering of the inversion and suggested that the height of the inversion should be used as a parameter. He also thought that a subjectively forecast cloud amount should be used rather than the actual cloud at the beginning of the forecast period. He agreed that soil temperatures should be measured much nearer the surface than eight inches.

Mr. D. C. Evans pointed out the different diurnal visibility pattern over weekends compared with weekdays and thought these occasions ought to be separated.

Dr. J. M. Stagg thought some factors in fog formation operated on a synoptic scale over considerable areas with more localized factors superposed, and suggested that it might be possible to prepare a series of curves which would apply to a region to be supplemented by other curves applicable to individual stations.

Mr. R. G. Veryard queried whether smoke did affect the visibility at London Airport on occasions of thick radiation fog. *Dr. K. H. Stewart* and others confirmed that smoke was undoubtedly an important factor.

Mr. S. G. Crawford referred to the considerable variation of visibility over short distances. The changing micrometeorology of an area, for example, increasing urbanization, would necessitate objective forecasting diagrams being recomputed periodically. The method could not be used for a new station with no past data to work on.

Mr. J. S. Sawyer stressed the importance of keeping an objective aid truly objective so that the synoptic forecaster using it can appreciate exactly what has been included in the method. He thought there was a need for an investigation to determine the lower limit of forecasting accuracy obtainable.

Mr. W. J. Bruce pointed out that 1200 and 2100 G.M.T. were times of rapid changes in visibility, and it was therefore difficult to forecast spot values at these times.

Mr. C. V. Ockenden wanted to know if an instrument could be made to measure the height of the top of the fog, as this might be a useful parameter.

Mr. C. E. Wallington sounded a warning against imposing on the forecaster the problem of making subjective modifications to an objective method in which the relative significance of the parameters used is not clear.

Mr. G. R. R. Benwell wanted to know what success the Freeman objective method would achieve on forecasts for longer periods up to 24 hours.

Mr. Freeman, replying to various speakers, welcomed their suggestions concerning other parameters and ways of extending the investigation. Work already planned included the trial of soil temperatures at four inches, the combination of subjective and objective methods and the development of probability forecasts. The use of weighting factors to improve the method for the lowest visibilities was well worth trying, and the possibility of extending the method to cover regions as well as individual stations would be investigated.

The *Director-General* said that an objective forecasting system will give the most probable answer, and the forecaster should use this in the light of his other experience in preparing his final forecast.

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NOTES AND NEWS

Photograph of striated cirrus

The photograph facing p. 216 was taken towards the south-east at Zermatt, Switzerland, at 1520 G.M.T. on 24 February 1959 and shows cirrus cloud which appears to have striations in two directions at right-angles to one another. During the previous few hours the whole sky had become covered with this cloud which had appeared to move fairly quickly from about 340 or 350 degrees. It was dense in patches with other areas almost clear of cloud between. No exact estimate of height could be made but it was thought to be not lower than 25,000 feet. The synoptic charts at this time show an anticyclone centred over Austria and extending over France, Spain, Italy, the Balkans and the central Mediterranean. At 1200 G.M.T. an occlusion lying north to south across Finland was linked by a cold front along the Baltic coast of Germany to the warm front of a depression north-west of Iceland while another warm front extended from near Leningrad to eastern Poland.

At 500 millibars, westerlies over Britain, northern France and the Low Countries gave way eastward to a northerly jet stream over eastern Europe. The cloud was probably just on the eastern side of this upper ridge.

G. J. JEFFERSON

Telegraph wires broken by rime ice

The photograph facing p. 217 shows telegraph wires broken by the weight of rime ice deposited on them in the spell of frost and fog in the first half of February. It was taken at 3 p.m. on Sunday, 8 February 1959, at Wirksworth near Derby at a point 900 feet above sea level. The rime grew to a thickness of 2½ inches in places on the wires. We are indebted to Mr. Ian M. Laurie, 24 Queen Victoria Road, Totley Rise, Sheffield, for this photograph.

CORRIGENDA

Meteorology of the Antarctic was published by the Weather Bureau, Department of Transport, Pretoria, South Africa, in 1957, price £3 10*s*, and not by the Falkland Islands Dependencies Survey, Stanley, price 15*s*, as stated in the May 1959 *Meteorological Magazine.*

OBITUARY

Mr. William Ralph Hanson, M.B.E., B.Sc.—The news that Mr. W. R. Hanson had died on 3 May 1959 caused deep regret throughout the Meteorological Office, for he was very widely known and a large number of people were glad to count him among their friends. To his widow and four children we offer our deepest sympathy.

Mr. Hanson—or "Bill" as he was invariably called—was born on 3 November 1904. After taking his B.Sc. in geography at London University and then a period of teaching, he entered the Office as a Technical Assistant II in May 1937 and during the next four years gained experience in forecasting at such stations as Boscombe Down, Uxbridge, Biggin Hill and Hendon.

In 1941 he was mobilized in the Royal Air Force Volunteer Reserve and was posted to General Headquarters Home Forces. For the remainder of the war he was to be engaged in forecasting for the Army and for the Air Forces acting in tactical support of the Army. When Operation TORCH, the invasion of French North Africa, was mounted, Flight Lieutenant Hanson was posted to the meteorological contingent and arrived at Algiers a few days after the initial landings which took place on 8 November 1942. In the following year, when the Mediterranean Allied Tactical Air Forces were formed, he was posted to the Headquarters as Senior Meteorological Officer and in due course was promoted to Squadron Leader. In this appointment his responsibilities were heavy and varied—he was in charge of a major forecasting office, in control of a number of mobile forecasting and observing units attached to Royal Air Force and Army formations, and had also to help in the integration of Allied meteorological sections—American, South African, Canadian, New Zealand, French, Polish and so on—into a co-ordinated organization for the exchange of basic data. With M.A.T.A.F. he saw the completion of the African campaign, the invasion and capture of Sicily and the lengthy but crucial operations through Italy. In all his work he earned great esteem and was twice mentioned in despatches. Apart from the high technical efficiency which he fostered, a noteworthy feature was his popularity among the many nationalities represented in the Mediterranean theatre of war.

After demobilization, Mr. Hanson became a Senior Experimental Officer and served for nearly three years with the examinations section of the Ministry of Civil Aviation and then, following a period of forecasting at Northolt he, transferred temporarily to the New Zealand Meteorological Service. On his return to this country in September 1950 he was posted to Uxbridge and shortly afterwards went to Habbaniya for an overseas tour of duty. He returned in May 1953 and from then until his death he was in charge of the London Forecast Office. In the New Year Honours List of 1958 he was made a Member of the Order of the British Empire.

His war service in the Mediterranean and his work in the London Forecast Office were the highlights of his professional career. In both phases his talents received full scope. His six years in the London Forecast Office saw much development in the forecasting and advisory services provided for the general public. It fell to him to implement many of the new ideas that were introduced such as the automatic telephone weather service and the presentation of forecasts on television. In these activities, which he pursued with enthusiasm, he made a host of friends among journalists and at the British Broadcasting Corporation.

When a man dies it is appropriate that his colleagues should have available a bare recital of the main features of his career. Many who read these facts will care less for the details than for the reminder which they provide of the man. For there are many who will not soon forget Bill Hanson. They will recall his geniality, the friendship which he gave unsparingly, his tremendous pride in his job and his devotion to his family. He had a full life. All he did another might have spread over a greater span of years. Yet there was still much to come to fruition—his children about to launch on their careers and more developments in the London Office. He was 54 when he died. It is very sad that a few more years of fulfilment were denied him.

P.J.M.

METEOROLOGICAL OFFICE NEWS

Sports Activities.—The Annual Sports Meeting organized by the Harrow Social and Sports Committee was held on the evening of 3 June at the Headstone Manor Ground. Events were open to all members of the Meteorological Office and there were many entries. Two new records were established for these sports. They were:

Men's High Jump: 5ft 3in
Men's Long Jump: 18ft 2½in

Both records were set up by R. M. Hearld (Stanmore).

Four cups donated by the Dunstable Social and Sports Committee were awarded to the winners of the Tug-of-war (won by Dunstable), Men's and Ladies' 4×110 yd relays (won by Harrow and London Airport respectively) and to the office with most first places in all events. The latter cup was won by Harrow.

Four events were Meteorological Office Championships for which medals were awarded by the Meteorological Office Social and Sports Committee. They were the 100 yd (won by A. Davies, Harrow), 880 yd (won by R. Stratton, Harrow), one mile (won by R. Stratton, Harrow) and Ladies' 100 yds (won by Mrs. A. Brown, Harrow).

The meeting was favoured with fine warm weather and there were many visitors from Dunstable, London Airport, Victory House and other nearby offices, who enjoyed a pleasant evening's sporting entertainment. The prizes were presented by Mrs. A. L. Maidens.

REVIEW

British weather in maps. By J. A. Taylor and R. A. Yates. 8½ in. × 5½ in., pp. xiv + 256, *illus.*, Macmillan & Co. Ltd., St. Martin's Street, London, W.C.2, 1958. Price: 21*s*.

This book has been written by two lecturers in geography and is based on part of a first year university course in practical climatology. After an introductory chapter which includes an elementary account of stability and instability the authors proceed to the task in hand, an appreciation of the format and function of the British *Daily Weather Report*. Some twenty synoptic examples have been chosen illustrating different air masses, fronts and pressure pattern features. Each synoptic example is illustrated by an almost full page map of the British Isles containing a complete set of fully plotted synoptic observations. These main illustrations are nicely plotted, with the observations, which are not analysed, plotted in two colours. The observations are not crowded and can be easily read. Each main illustration is succeeded on the two following pages by a number of smaller figures consisting of maps of isopleths of barometric tendency, temperature, dew-point, visibility and others showing a demarcation of wind and weather. Small inset maps beside the main map illustrate the isobars and frontal analysis for a short sequence leading up to the main chart. Each example chosen is then discussed in some detail.

The approach is entirely that of the geographer, that is, it is descriptive and the text contains no mathematics and no (or hardly any) physics. For that reason it will make little appeal to the professional meteorologist (except for school-leavers) who will find the long and detailed descriptions of the various charts (insufficiently scientific to constitute a true meso-analysis) a little tedious.

There is some confusion about humidity. Thus on page 63 (also pages 55 and 77) it is implied that the relative humidity of air at low temperatures is low. It is, of course, the absolute humidity of the air which is usually less at low temperature due to the fact that the saturation mixing ratio of water vapour decreases as the temperature decreases.

The book is well produced and will be found of value to school-leavers undergoing a first course of training in meteorology and also for those for whom meteorology is a hobby rather than a profession.

A. H. GORDON

BOOK RECEIVED

Annual Meteorological Tables 1957. *Falkland Islands and Dependencies Meteorological Service.* 13 in. × 8½ in., pp. iv. + 168, Falkland Islands Dependencies Survey, Stanley, 1958. Price: 20*s*.

WEATHER OF MARCH 1959

Northern Hemisphere

As in February, cyclonic activity across the North Atlantic from eastern Canada to the Siberian Arctic was unusually intense. On the mean pressure chart there was a low pressure centre just east of Cape Farewell where pressure was 16 millibars below normal, and another near Novaya Zemlya in association with anomalies which reached −18 millibars at approximately 85°N., 80°E. Mean pressure was below normal over the entire Arctic basin, northern Siberia, and the Atlantic north of 40°N. A secondary centre of the Siberian high was situated north of the Black Sea and over all except western districts of Europe pressure was a few millibars above average. Anomalies were largest over the Baltic where they reached +9 millibars.

The centre of the Aleutian low was displaced from its normal position east of the Kamchatka peninsula to a position south of Alaska, but the value of the central pressure was close to average. Thus positive anomalies occurred near Kamchatka and negative ones over western Canada, both of which reached 8 millibars. Like the Azores high, the North Pacific high was slightly more intense than usual but near its usual position.

It was a warmer month than average everywhere in Europe, mainly because of an increased southerly component in the mean flow. The largest temperature anomalies occurred in northern Scandinavia where +6°C. was reported at a number of stations. Anomalous warmth also occurred in north-west and central Russia and in Mongolia, anomalies of +7°C. being reported from the latter region. The strong northerly flow over the Davis Strait and eastern Canada maintained the unusually cool conditions which prevailed there in February and mean temperatures were 7°C. lower than usual in Baffin Land. Similar anomalies occurred in Alaska and north-west Canada in association with the eastward displacement of the Aleutian low centre. A stronger westerly wind than usual across the Rockies was also associated with this displacement; the combination of relatively warm air from the Pacific and the Föhn effect over the mountains produced temperatures up to 6°C. above normal in central Canada. In the United States of America mean temperatures were close to average.

The rainfall distribution over Europe was very irregular but amounts were generally between 50 and 150 per cent of average. The area of vigorous cyclonic activity in the region of Novaya Zemlya was marked by precipitation totals well above the average (five times average in places) and there was more precipitation than usual over much of Russia east of the Urals. It was a wet month at all stations along the east coast of North America from Labrador to Florida. The largest amounts (up to four times average) were reported from Georgia and South Carolina. Apart from some stations in central states of the United States of America which received twice their average amount, other parts of North America had totals near or below normal.

WEATHER OF APRIL 1959

Great Britain and Northern Ireland

With pressure relatively high over the British Isles during the first few days of April, weather was fine and warm in most districts. An unsettled spell began on the 6th as depressions approached the country first from the north-west, then from the west and finally from the south-west. An anticyclone from the Azores brought a spell of dry settled weather from about the 19th to the 24th but thereafter the situation was more or less cyclonic and the weather changeable until the end of the month.

The first four days were fine and warm over most of the country although weak fronts gave some rain in the north and west and fog was prevalent on the east coast. Ground frost occurred chiefly in central and eastern districts and there was a good deal of sunshine. On the 4th the afternoon temperature rose into the upper sixties in parts of southern England and reached 72°F. in the Channel Islands. A vigorous depression moved south-east from Iceland on the 6th and squally north-westerly winds spread over the British Isles bringing changeable and cooler weather with periods of rain or showers alternating with sunny intervals. Gusts of 60 knots were recorded in west Scotland on the 6th, but on the 8th the wind moderated considerably. The showery weather, with hail and local thunder continued, however, until the 10th, and with gradually falling temperatures the showers turned to sleet and snow in some northern districts.

The approach of a depression from the west on the 11th brought widespread rain and a change to milder conditions with south-westerly winds. Temperature remained above 50°F. in many places throughout the night of the 12–13th and reached 70°F. locally in south-east England during the afternoons of the 13th and 14th. On the 14th and 15th a very intense depression moved northwards just to the west of Ireland. Wind increased generally, becoming strong to gale force in the west, and rain spread northwards to all districts followed by brighter showery weather on the 15th. The next day a small depression from the south-west became slow-moving over France and there was rain over most of England and Wales; the rain was heavy in places, especially in Somerset, where over two inches was recorded in some places in 24 hours.

An anticyclone, from the region of the Azores, which became centred over the country on the 21st, brought a spell of dry settled weather to most districts from about the 19th to 24th. By the 21st temperatures were above average almost everywhere, and on the 22nd and 23rd early morning fog formed in parts of central and southern England and continued to affect some local areas throughout the day. On the 25th a depression deepened rapidly and moved across Ireland to Scotland; winds became strong in most districts and rain was widespread and heavy in places. The remainder of the month was showery with thunderstorms and outbreaks of rain but a developing ridge of high pressure on the 30th resulted in a mainly fine end to the month.

April was mild in all areas and markedly free from air frosts. Sunshine was a little above average in the eastern part of the country and a little below in the west. With 130 per cent of the average rainfall it was the wettest April over England and Wales since 1935. Scotland and Northern Ireland each had about 125 per cent of their average. Rainfall was below the average around the Thames estuary, over much of East Anglia and the east Midlands as far north as the Humber, over much of Ayrshire and northern Lanarkshire and in County Down and eastern Antrim. Twice the average was exceeded in the Wrexham area and in the Isle of Lewis.

Weather on the whole was favourable to most crops; germination was good and most transplanted crops were growing well. Blossom was abundant on most soft and top fruit trees. Tomatoes under glass responded well to the increased sunshine and early potatoes in the south-west showed satisfactory growth.

WEATHER OF MAY 1959

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 ...	82	21	+2·1	44	−7	121
Scotland	79	20	+3·0	53	−7	114
Northern Ireland ...	76	27	+2·9	50	−7	120

*1916–1950 †1921–1950

RAINFALL OF MAY 1959

Great Britain and Northern Ireland

County	Station	In.	*Per cent of Av.	County	Station	In.	*Per cent of Av.
London	Camden Square ...	·91	51	*Pemb.*	Maenclochog, Dolwen Br.	1·74	49
Kent	Dover	·98	56	*Carm.*	Aberporth	1·82	76
"	Edenbridge, Falconhurst	·86	40	*Radnor*	Llandrindod Wells ...	2·45	90
Sussex	Compton, Compton Ho.	·34	14	*Mont.*	Lake Vyrnwy	1·96	54
"	Worthing, Beach Ho. Pk.	·79	48	*Mer.*	Blaenau Festiniog ...	1·88	30
Hants	St. Catherine's L'thouse	·95	52	"	Aberdovey	1·11	38
"	Southampton, East Pk.	·68	33	*Carn.*	Llandudno	1·37	66
"	South Farnborough ...	·73	38	*Angl.*	Llanerchymedd ...	1·57	58
Herts.	Harpenden, Rothamsted	1·27	61	*I. Man*	Douglas, Borough Cem.	·97	34
Bucks.	Slough, Upton ...	·66	33	*Wigtown*	Newtown Stewart ...	1·84	62
Oxford	Oxford, Radcliffe ...	1·01	50	*Dumf.*	Dumfries, Crichton R.I.	·80	29
N'hants.	Wellingboro' Swanspool	·42	21	"	Eskdalemuir Obsy. ...	3·02	80
Essex	Southend W.W. ...	·97	62	*Roxb.*	Crailing...	·38	19
Suffolk	Ipswich, Belstead Hall	·27	16	*Peebles*	Stobo Castle	1·78	69
"	Lowestoft Sec. School	·38	25	*Berwick*	Marchmont House ...	·45	20
"	Bury St. Ed., Westley H.	·25	14	*E. Loth.*	N. Berwick	·56	27
Norfolk	Sandringham Ho. Gdns.	·58	28	*Midl'n.*	Edinburgh, Blackf'd H.	·41	19
Dorset	Creech Grange... ...	·82	35	*Lanark*	Hamilton W.W., T'nhill	1·29	49
"	Beaminster, East St. ...	·81	31	*Ayr*	Prestwick	1·14	51
Devon	Teignmouth, Den Gdns.	1·49	66	"	Glen Afton, Ayr. San ...	1·56	46
"	Ilfracombe	1·47	65	*Renfrew*	Greenock, Prospect Hill	1·37	38
"	Princetown	1·93	39	*Bute*	Rothesay	1·04	30
Cornwall	Bude	1·14	54	*Argyll*	Morven, Drimnin ...	1·24	37
"	Penzance	1·60	66	"	Ardrishaig, Canal Office	1·69	46
"	St. Austell	1·56	51	"	Inveraray Castle ...	2·77	59
"	Scilly, St. Marys ...	1·25	58	"	Islay, Eallabus ...	1·55	51
Somerset	Bath	2·08	91	"	Tiree	·68	27
"	Taunton	·73	33	*Kinross*	Loch Leven Sluice ...	·80	29
Glos.	Cirencester	1·05	40	*Fife*	Leuchars Airfield ...	·56	25
Salop	Church Stretton ...	1·48	56	*Perth*	Loch Dhu	2·04	45
"	Shrewsbury, Monkmore	1·42	68	"	Crieff, Strathearn Hyd.	1·36	48
Worcs.	Worcester, Red Hill ...	1·43	62	"	Pitlochry, Fincastle	1·02	40
Warwick	Birmingham, Edgbaston	1·07	41	*Angus*	Montrose Hospital ...	1·61	71
Leics.	Thornton Reservoir ...	·43	19	*Aberd.*	Braemar	1·20	46
Lincs.	Cranwell Airfield ...	·78	39	"	Dyce, Craibstone ...	1·66	62
"	Skegness, Marine Gdns.	·29	18	"	New Deer School House	1·02	40
Notts.	Mansfield, Carr Bank...	·90	42	*Moray*	Gordon Castle	·58	28
Derby	Buxton, Terrace Slopes	·72	25	*Inverness*	Loch Ness, Garthbeg ...	1·89	69
Ches.	Bidston Observatory ...	1·97	87	"	Fort William	1·44	36
"	Manchester, Airport ...	1·18	53	"	Skye, Duntulm... ...	1·22	43
Lancs.	Stonyhurst College ...	2·49	89	"	Benbecula	·89	32
"	Squires Gate	1·47	63	R. & C.	Fearn, Geanies ...	·91	45
Yorks.	Wakefield, Clarence Pk.	·94	42	"	Inverbroom, Glackour...	1·93	75
"	Hull, Pearson Park ...	·42	22	"	Loch Duich, Ratagan...	2·59	66
"	Felixkirk, Mt. St. John...	·59	29	"	Achnashellach	3·32	87
"	York Museum	·45	23	"	Stornoway	1·41	62
"	Scarborough	·47	26	*Caith.*	Wick Airfield	1·52	84
"	Middlesbrough... ...	·54	32	*Shetland*	Lerwick Observatory ...	1·47	67
"	Baldersdale, Hury Res.	·37	16	*Ferm.*	Belleek	1·42	49
Nor'l'd	Newcastle, Leazes Pk....	·51	24	*Armagh*	Armagh Observatory ...	1·32	56
"	Bellingham, High Green	·48	21	*Down*	Seaforde	1·91	65
"	Lilburn Tower Gdns ...	·55	26	*Antrim*	Aldergrove Airfield ...	·96	39
Cumb.	Geltsdale	1·98	80	"	Ballymena, Harryville...	1·37	45
"	Keswick, Derwent Island	1·19	36	*L'derry*	Garvagh, Moneydig ...	1·72	62
"	Ravenglass, The Grove	1·13	41	"	Londonderry, Creggan	·99	34
Mon.	A'gavenney, Plâs Derwen	2·70	92	*Tyrone*	Omagh, Edenfel ...	1·25	44
Glam.	Cardiff, Penylan ...	1·20	41				

* 1916–1950

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