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WIND SUMMARIES AND AIRFIELD USABILITY

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The usability of the runways of an airfield is limited to some extent by the wind, for if the cross-wind component (component of the wind at right-angles to the runway) exceeds a certain strength it may be hazardous to attempt to land an aircraft. An estimate of the amount of time during which an airfield runway may be out of action owing to the strength of the cross-wind component may be derived from a summary of the winds experienced there over a number of years, which must be compiled in such a way that the frequency distribution of the wind forces or wind speeds is shown for each sector of the compass into which the summary is divided. If the frequency distribution of wind force and wind direction is then exhibited on a polar diagram the proportion of time during which the cross-wind component on any particular runway exceeds some specified limit may readily be estimated by a graphical method[1].

The preparation of a complete wind summary of this nature demands however a considerable amount of work, and at many stations the summaries of wind are not available in such an elaborate form. In the past it has rather been the custom to summarize the wind forces separately irrespective of wind direction, and likewise the wind direction separately irrespective of the speed of the wind. An approximate estimate of the usability of a runway can nevertheless still be obtained from these simpler forms of wind summary by applying a method due to L. Jacobs[2]. This method depends on an empirical result which is expressed in the equation

$$\log_e n_v = a - bv^2 \quad , \qquad \ldots\ldots (1)$$

where v is the speed of wind, n_v is the frequency of wind observations exceeding a specified speed v, and a and b are constants.

The tables and graphs presented by Jacobs in his memorandum are designed to enable the computer to assess directly the amount of time during which the cross-wind component on any particular runway, the orientation of which must be known, exceeds any specified limit. The limits commonly adopted for cross-wind components are of the order of 15, 20 or 25 m.p.h., varying according to the size and type of the aircraft. The method proposed by Jacobs implies tacitly that a wind rose can be constructed from the wind data available; but it is not necessary to set out the wind rose explicitly in order to calculate, by this method, the runway usability as limited by cross-winds.

The operation of aircraft is also affected, to some extent by components of wind directed along the runway, which if arising as headwinds may improve

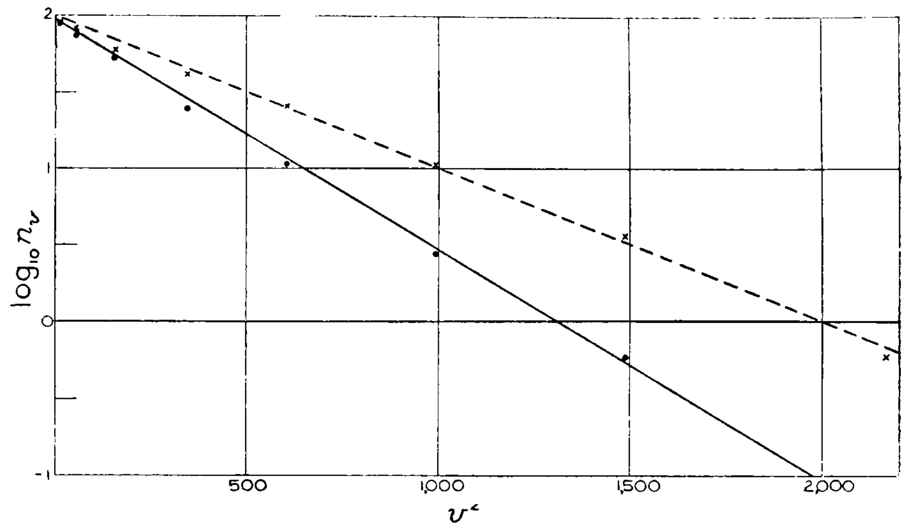

FIG. 1—GRAPHS OF $\log n_v = a - bv^2$

the usability of a short runway or alternatively as tailwinds may diminish it, and it is now suggested that in computations involving wind frequency the summary of speeds and directions should be set out in full in a table or a polar diagram, using the relation (1) to determine the frequency distribution of the various forces of wind within each sector of the wind rose. For this purpose Table I has been calculated giving values of $\exp(bv^2)$ to assist in the computation.

The relation (1) between n_a and v^2 is equivalent to

$$n_v = \frac{\exp{(a)}}{\exp{(bv^2)}}$$

The quantity e^a is the number of observations of wind within a certain sector of the compass exclusive of calms[2]. The quantity b appears to depend on the exposure of the meteorological station, and it is also related to the mean speed of the wind, again exclusive of calms[3]. In the British Isles the numerical values of b for wind speeds expressed in miles per hour vary according to Jacobs from about 2×10^{-3} in well exposed places to 7×10^{-3} at sheltered inland sites*. If we take v to be equal successively to the upper limits of the Beaufort wind forces we obtain a series of values of n_v from which by subtraction we may obtain the frequencies of the separate Beaufort forces. The resulting wind summary may then be set out on a polar diagram and from it we may obtain graphically the runway usability as limited by cross-wind components in the manner already described by Durst[1]. Besides this we shall also be in a position to estimate the effects of wind components along the runway or for new aerodromes to decide on the best orientation of the main runway. This method of computation naturally produces the same results as far as time loss due to cross-wind components is concerned as that due to Jacobs but it has the merit of greater simplicity.

Examples.—The wind-frequency distributions at Guernsey and Skeabrae are given in Table II, condensed to 8 points of the compass and in Beaufort wind force.

Guernsey.—From the summary of wind forces at Guernsey the numerical value of the coefficient b in the equation $\log_e n_v = a - bv^2$ is found, by the

* The validity of the larger values of b is somewhat doubtful, because in sheltered sites the range of wind speeds is restricted.

TABLE I.—NUMERICAL VALUES OF $\exp(bv^2)$

v	$b \times 10^3$: 2·0	2·5	3·0	3·5	4·0	4·5	5·0	5·5	6·0	6·5
m.p.h.										
0·5	1·00	1·00	1·00	1·00	1·00	1·00	1·00	1·00	1·00	1·00
3·5	1·02	1·03	1·04	1·04	1·05	1·06	1·06	1·07	1·08	1·09
7·5	1·12	1·15	1·18	1·22	1·25	1·29	1·33	1·36	1·40	1·44
12·5	1·37	1·48	1·60	1·73	1·87	2·02	2·18	2·36	2·55	2·76
18·5	1·98	2·35	2·79	3·31	3·93	4·67	5·54	6·57	7·79	9·25
24·5	3·32	4·48	6·05	8·17	11·0	14·9	20·1	27·2	36·7	49·5
31·5	7·28	11·9	19·6	32·2	52·9	86·9	143	234	385	632
38·5	19·4	40·7	85·3	179	376	788	1650	3470	7280	15300
46·5	75·5	223	656	1930	5690	16800	49600	146000	431000	1270000

TABLE II.—WIND FREQUENCY DISTRIBUTION AT GUERNSEY AND SKEABRAE

Direction: NE.	E.	SE.	S.	SW.	W.	NW.	N.	Calm	Beaufort force: 1	2	3	4	5	6	7	8	9
								per mille									
Guernsey, States Airport 49° N. 2°35′ W., 1950–54																	
114	61	65	135	144	159	142	122	58	45	142	220	287	139	81	22	6	<1
Skeabrea 59°04′ N. 3°16′ W., 1943–45																	
55	48	170	128	178	143	122	103	53	30	90	217	201	154	148	70	31	6

TABLE III—OBSERVED AND COMPUTED WIND FREQUENCIES AT GUERNSEY AND SKEABRAE

Beaufort force		NE.	E.	SE.	S.	SW.	W.	NW.	N.
					per mille				
Guernsey (States Airport) 1950–54							Calms: 58 per mille		
1	Computed	5	3	3	6	6	7	6	5
	Observed	6	4	5	6	4	5	5	10
2	Computed	15	8	9	18	20	22	19	17
	Observed	20	12	15	21	15	16	18	25
3	Computed	28	15	15	33	35	38	35	29
	Observed	26	17	23	34	31	31	30	30
4	Computed	32	17	18	37	39	44	39	33
	Observed	31	17	16	43	51	54	42	31
5	Computed	20	11	12	24	26	29	24	23
	Observed	19	6	4	19	26	29	22	14
6	Computed	10	5	6	12	13	15	15	11
	Observed	10	4	1	9	14	15	18	10
7	Computed	3	2	2	3	4	4	4	3
	Observed	2	1	<1	3	3	5	5	3
8	Computed	1	<1	<1	1	1	1	1	1
	Observed	<1	<1	<1	1	1	2	2	1
9	Computed	...	...	...	...	...	...	...	...
	Observed	...	...	...	...	<1	<1	<1	<1
Skeabrae 1943–45							Calms: 53 per mille		
1	Computed	2	1	5	4	5	4	3	3
	Observed	3	1	8	4	4	4	3	3
2	Computed	5	5	16	12	17	14	12	10
	Observed	9	7	19	12	11	10	9	11
3	Computed	10	8	30	22	32	25	22	18
	Observed	13	13	39	32	41	28	27	24
4	Computed	13	12	42	32	43	35	30	25
	Observed	13	11	35	31	38	29	25	20
5	Computed	11	10	34	26	36	29	24	21
	Observed	9	7	28	21	26	25	20	18
6	Computed	8	7	26	19	27	21	19	15
	Observed	7	7	27	18	29	29	19	13
7	Computed	4	3	11	9	12	10	8	8
	Observed	1	2	8	7	17	14	13	8
8	Computed	1	1	4	3	5	4	3	2
	Observed	<1	1	5	1	9	5	5	5
9	Computed	<1	<1	1	1	1	1	1	1
	Observed	<1	<1	<1	<1	1	2	1	1

method of least squares, to be $3 \cdot 43 \times 10^{-3}$ (common logarithms being used in Fig. 1 the values of the coefficients are $a = 1 \cdot 95$ and $b = 1 \cdot 49 \times 10^{-3}$). The numerical value of b can still be calculated even if the wind forces are grouped, which is commonly the case. The mean value of the wind speed, excluding calms, is found to be 14·7 m.p.h. and the corresponding standard deviation is 7·9 m.p.h.

The value of b calculated from the standard deviation by means of the formula $\sigma^2 = (1-\pi/4)/b$ is $3{\cdot}44 \times 10^{-3}$ (Napierian logarithms) and the mean wind speed (excluding calms) given by the formula $\bar{v} = \frac{1}{2}\sqrt{(\pi/b)}$ is 15·1 m.p.h. in satisfactory agreement with the observed values. Taking the value of b as $3{\cdot}5 \times 10^{-3}$ and using the values of exp (bv^2) given in Table I the derived frequency distribution of wind directions and wind speeds at Guernsey is as shown in Table III.

Skeabrae.—The value of b deduced from the summary of wind forces in Table II by the method of least squares is $2{\cdot}28 \times 10^{-3}$. In Fig. 1 where common logarithms are used, the coefficients of the equation $\log_{10} n_v = a - bv^2$ become $a = 1{\cdot}98$ and $b = 0{\cdot}99$. We also find that, excluding calms the mean wind speed is 18·3 m.p.h. and the standard deviation 10·2 m.p.h.

The corresponding average wind speed, calculated by means of the formula $\bar{v} = \frac{1}{2}\sqrt{(\pi/b)}$, is 18·6 m.p.h., and the standard deviation, calculated from the formula $\sigma^2 = (1-\pi/4)/b$, is $\sigma = 9{\cdot}7$ m.p.h., again in good agreement with the observed values.

The frequency distribution of wind speeds and wind directions at Skeabrae, computed on the assumption that b is equal to $2{\cdot}3 \times 10^{-3}$, is shown in Table III.

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SERIES OF COMPUTED FORECAST CHARTS AND THE MOVEMENT OF A DEPRESSION, AUGUST 19–21, 1954

By I. J. W. POTHECARY, B.Sc. and F. H. BUSHBY, B.Sc.

Introduction.—On August 19, 1954, a depression became stationary over the North Sea, contrary to expectation at the Central Forecasting Office at Dunstable until shortly before it occurred. The use of conventional methods of forecasting suggested that the depression would continue eastward to western Germany.

Computed forecasts of the 1000-mb. and 500-mb. contour charts and the associated thicknesses were made at 12-hr. intervals to cover the period from 1500 G.M.T., August 19, to 0300 G.M.T., August 21, which included the cessation of the eastward movement of the depression and its subsequent drift southwestward. Although a number of individual numerical forecasts had previously been computed with results which were, on the whole, comparable in accuracy with those obtained by conventional methods, this was the first time that a sequence of such numerical forecasts, dealing with the evolution of the synoptic situation over 60 hr. had been computed in the Forecasting Research Division at Dunstable. The series of computed charts (Charts (*c*) and (*d*) of Figs. 3–6) achieved considerable success in respect of the movement of the depression.

Synoptic history.—The depression had developed from a wave on a trailing cold front and acquired its first closed isobar (1008 mb.) south-east of ocean weather station J (50°N. 18°W.) at 0000, August 17. During the following 48 hr. the depression moved north-east to the North Sea where the centre remained stationary for nearly 30 hr. By 0600, August 20, the centre had begun to move south-west and 24 hr. later it had crossed the Midlands and southern England and was filling up over the western English Channel. This movement is illustrated in the 1000-mb. charts covering the period (Charts (*a*) of Figs. 1–6).

The movement of the depression was related to events on a larger scale over the North Atlantic. Low pressure extended from eastern Canada to the Denmark Strait and a warm south-westerly air stream extended northward over Iceland. This stream persisted until, by 0300, August 20, the 18,000-ft. thickness line was approaching its northernmost extreme.

A cold trough in the 1000–500-mb. thickness pattern was being maintained over the west of the British Isles by the depression as it moved across the country, and this, with the warm ridge extending north of Iceland, led to the formation of an anticyclogenetic region from the Azores to northern Scandinavia. High pressure eventually extended from the Azores to north-west Russia and a cold pool was cut off west of the British Isles.

At 0300, August 19, the depression became slow moving over the North Sea, and by 1500 it was stationary and the circulation over it was closed up to 100 mb. The cutting-off process was complete.

Discussion of the electronic computations.—In order to facilitate comparison of the charts shown in Figs. 1–6 the following order of presentation is used:

Charts (*a*): Actual 1000–500-mb. thickness and 1000-mb. contours.
Charts (*b*): Actual 500-mb. contours.
Charts (*c*): Computed 1000–500-mb. thickness and 1000-mb. contours.
Charts (*d*): Computed 500-mb. contours.

The first 24-hr. forecast charts were computed from the data for 1500, August 18, at which time the depression was moving east into the North Sea after crossing northern England. The last forecasts of the series were computed from the data for 0300, August 20, when the depression was still stationary over the southern North Sea.

The computations were based on the Sawyer-Bushby two-parameter model which has been described elsewhere[1,2]. For this series the observed changes around the edge of the area were used as boundary conditions during the calculations, but it is thought that the computed values near the British Isles are not materially affected by the boundary assumptions. A non-adiabatic heating term was introduced to allow for the modifying effect of heating over the sea. Some of the computations were based on data for an upper level of 600 mb., but the results were extrapolated to 500 mb. for comparison with the 500-mb. charts. The computed forecasts and the actual charts are briefly compared in the following paragraphs.

1500, August 19 (Fig. 3).—The pattern of the computed 1000-mb. contours shows substantial agreement with the actual chart and the movement of the centre was correctly forecast, although the central pressure was computed to be about 5 mb. too low. The maintenance of cyclonic curvature over the

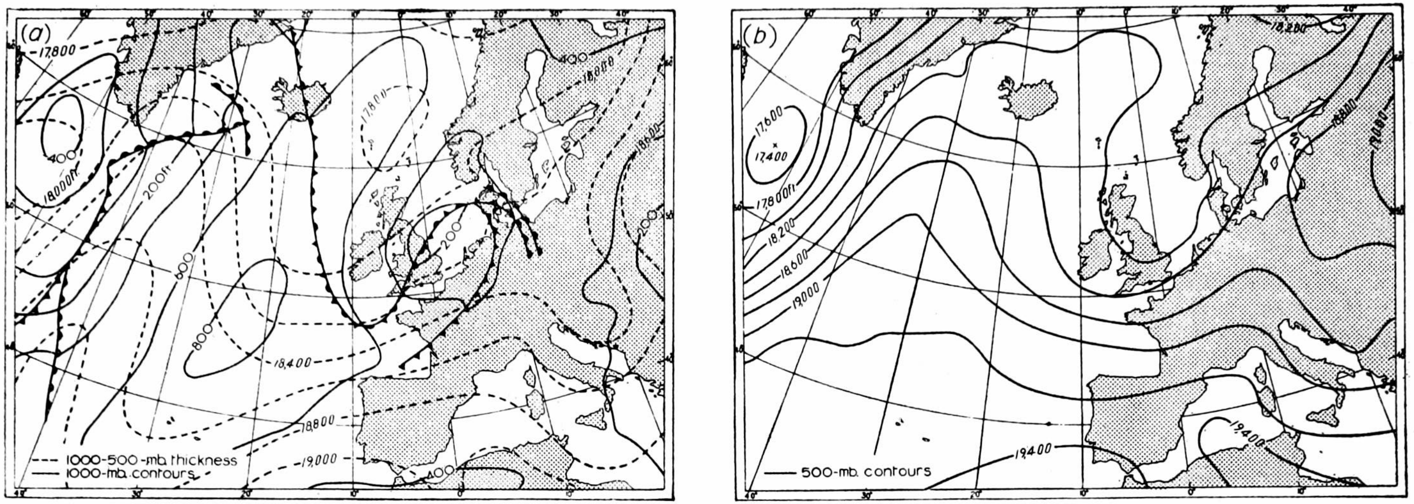

FIG. 1—ACTUAL CONTOUR AND THICKNESS CHARTS, 1500 G.M.T., AUGUST 18, 1954

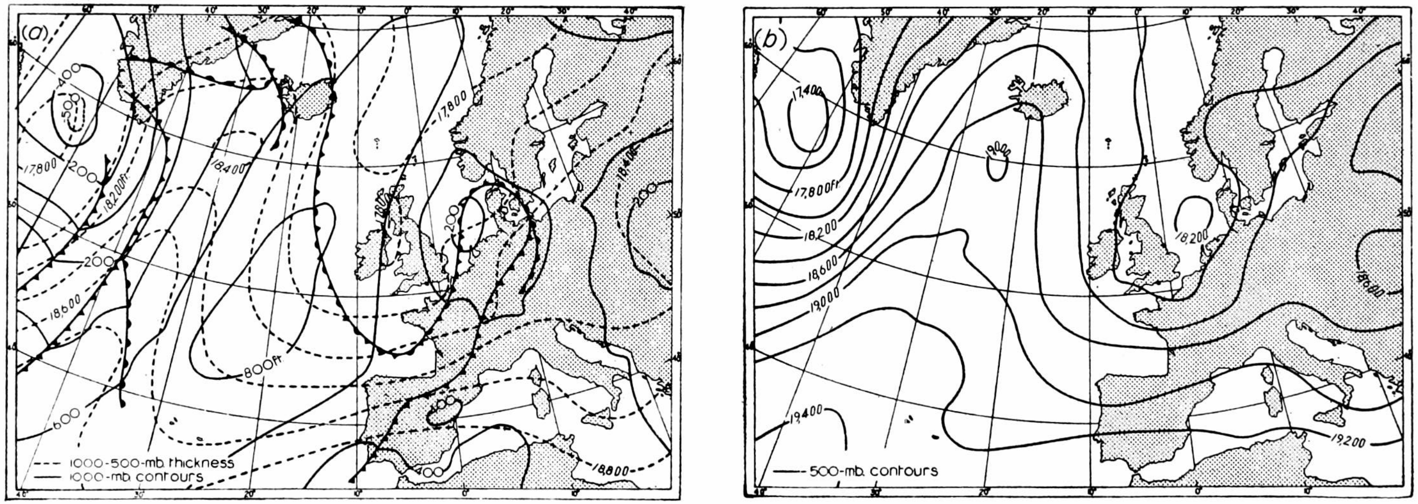

FIG. 2—ACTUAL CONTOUR AND THICKNESS CHARTS, 0300 G.M.T., AUGUST 19, 1954

Actual charts

Computed charts

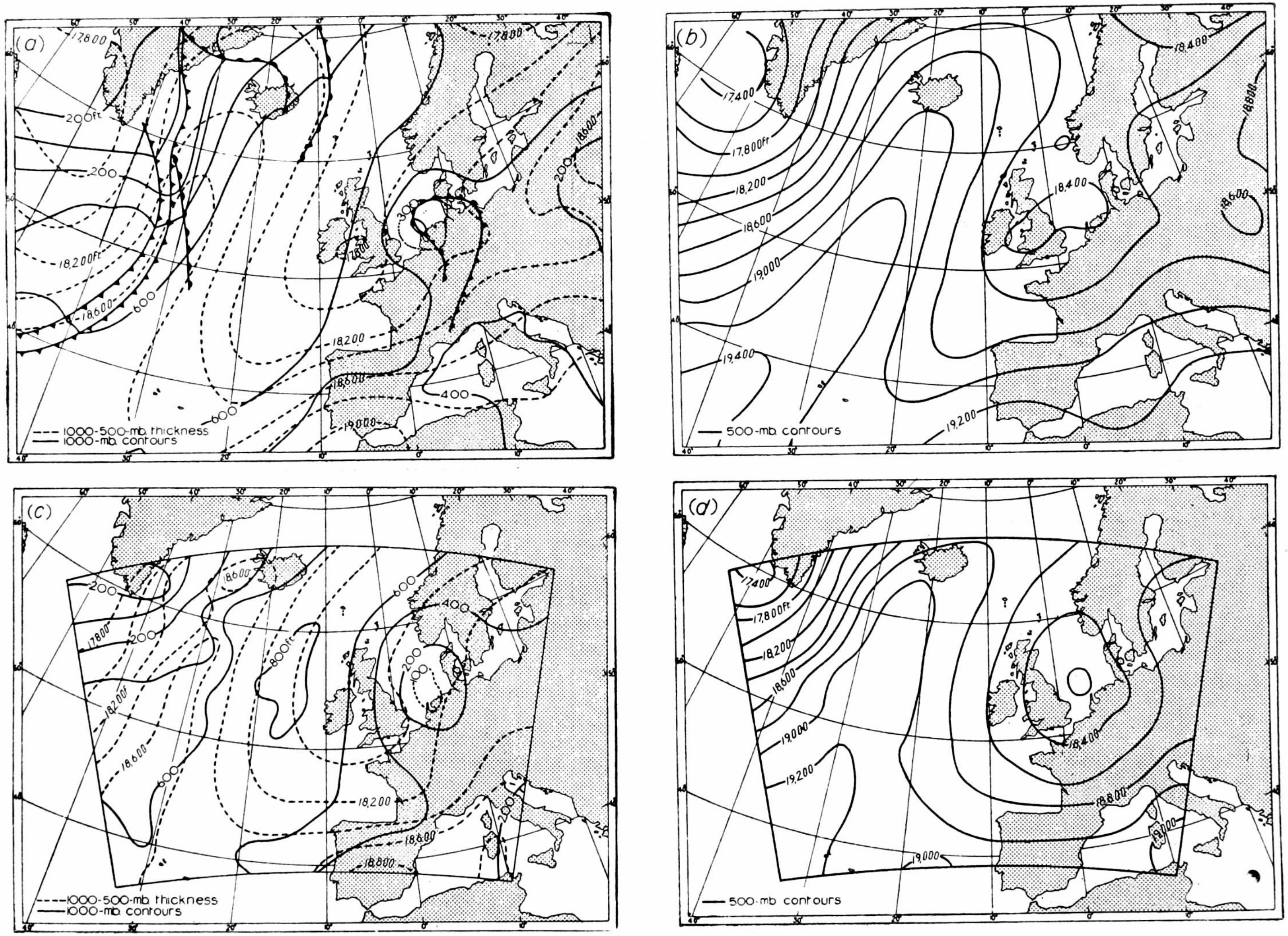

FIG. 3—CONTOUR AND THICKNESS CHARTS, 1500 G.M.T., AUGUST 19, 1954

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MOCK SUNS SEEN FROM KEW, 0740 G.M.T., MARCH 1, 1956

Reproduced by courtesy of A. W. E. Barber

SUN PILLAR, EAST HILL, 1655 G.M.T., FEBRUARY 23, 1956
Photographic details: Film FP3, exposure 1/100 sec., aperture F5·6, Ilford Tricolour red filter.
(see p. 155)

Actual charts

Computed charts

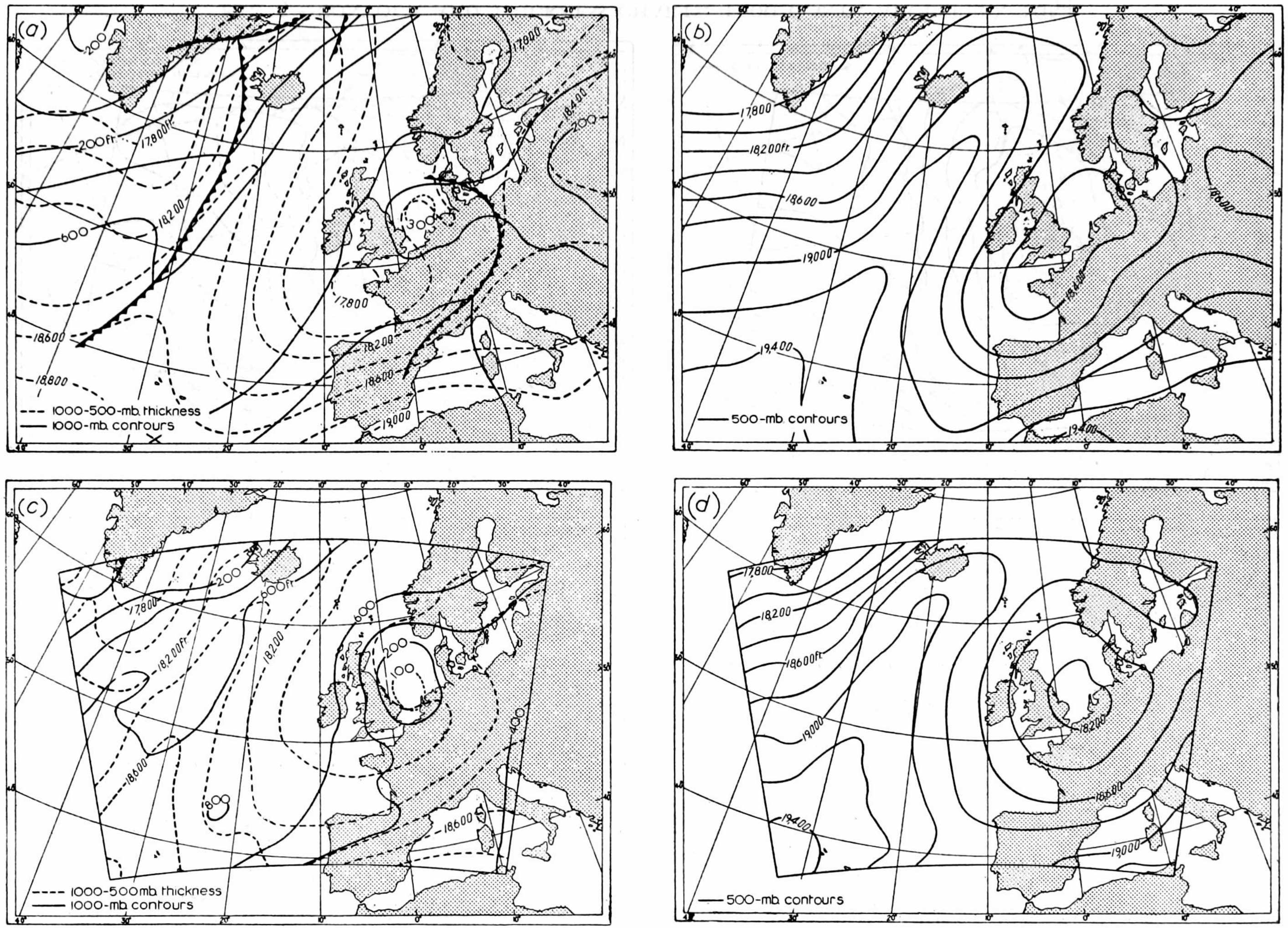

FIG. 4—CONTOUR AND THICKNESS CHARTS, 0300 G.M.T., AUGUST 20, 1954

Actual charts

Computed charts

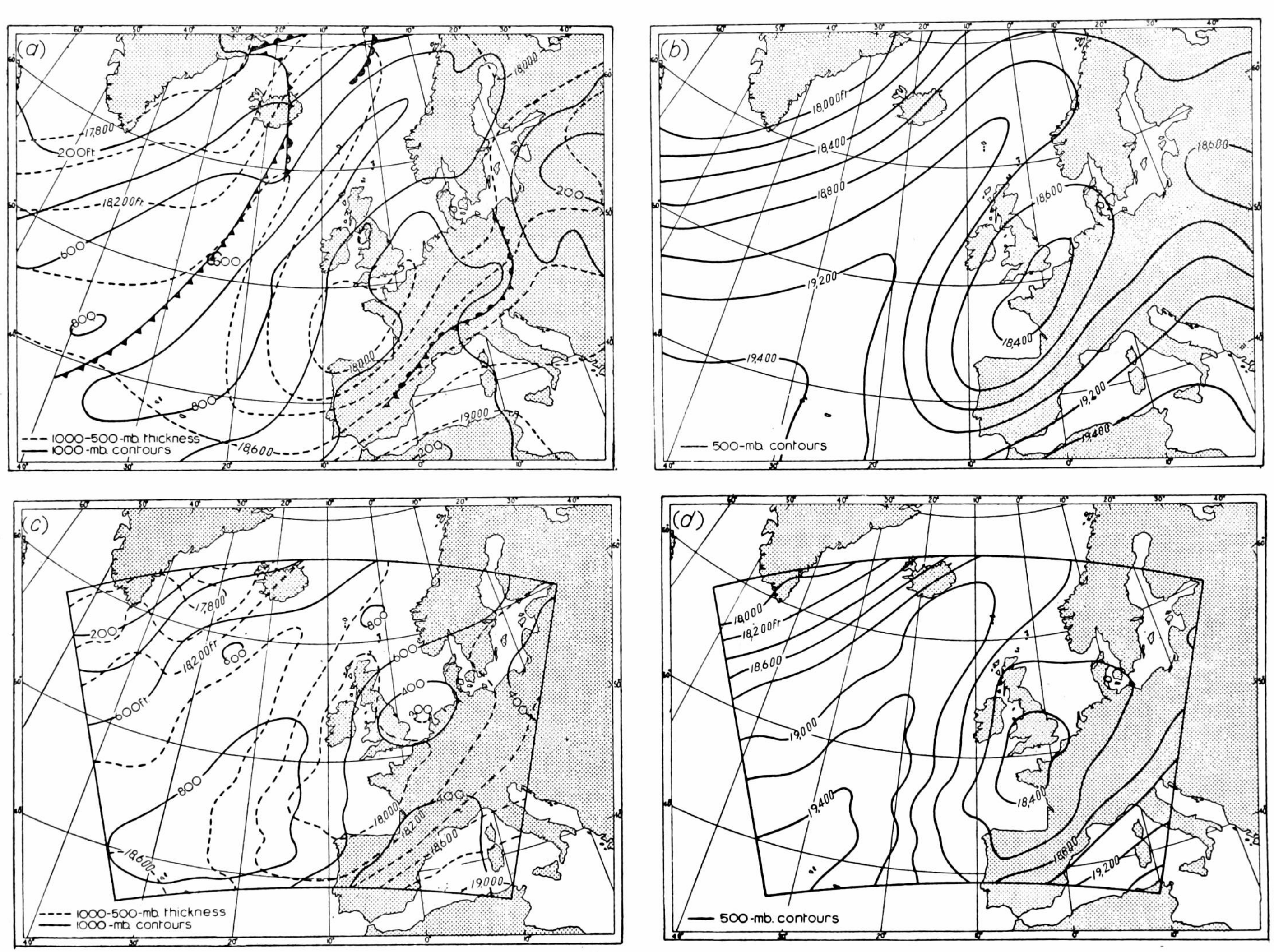

FIG. 5—CONTOUR AND THICKNESS CHARTS, 1500 G.M.T., AUGUST 20, 1954

Actual charts

Computed charts

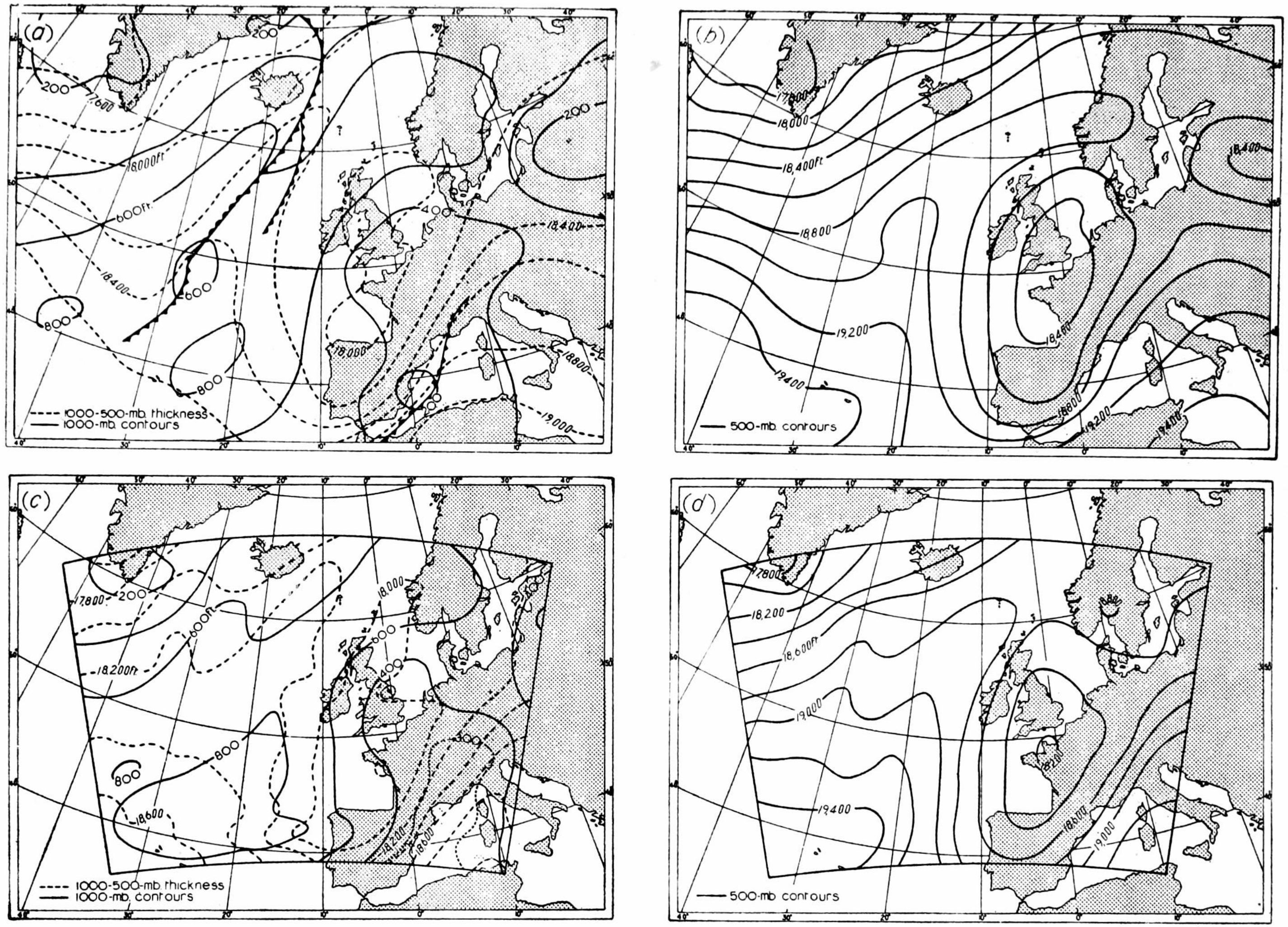

FIG. 6—CONTOUR AND THICKNESS CHARTS, 0300 G.M.T., AUGUST 21, 1954

British Isles and the position and intensity of the 1000-mb. ridge over the eastern Atlantic correspond with the actual chart. The amplitude of the thickness ridge over the Atlantic was reasonably well forecast, but the small cut-off cold pool over the Irish Sea was not indicated although the broad outline of the cold trough was maintained. The computed 500-mb. contours are in close agreement with the actual chart.

0300, August 20 (Fig. 4).—The centre of the depression was held stationary over the southern North Sea in close agreement with actual events. The extension of high pressure from the Azores to northern Scandinavia was correctly indicated and cyclonic curvature of the 1000-mb. contours was maintained over England and Wales. The position and intensity of the cold trough over the British Isles was correctly indicated but the formation of a cut-off pool over the western English Channel was not shown.

1500, August 20 (Fig. 5).—The centre of the depression was actually moving south-west over East Anglia and filling up at this time. The relatively low pressure over south-east England is indicated by the computations but the centre was held back over the southern North Sea. The cut-off cold pool over the Bay of Biscay and the western approaches and the maintenance of the warm ridge over the eastern Atlantic are shown in the computed charts. The computed and actual 500-mb. contours are almost exactly similar.

0300, August 21 (Fig. 6).—By this time the remnant of the actual centre was over the western English Channel. The computations placed a weak centre over Lincolnshire but the larger-scale distribution of the actual and computed 1000-mb. level is similar. The cut-off cold pool was computed to be more extensive and deeper than shown on the actual chart. The 500-mb. computed and actual contours show a similar distribution.

Examination of some other forecasting methods.—The initial information available on the charts for 1500 and 1800, August 18 and 0000, August 19, shortly before the depression became stationary, was examined in detail, apart from electronic computation, to find how much evidence for the future movement it contained, since, as mentioned earlier, conventional forecasting methods proved inadequate at that stage. Some of the techniques of analysis, such as the calculation of isopleths of the Sutcliffe development term, are rather too complicated for routine use in a forecast office.

The Rossby stationary wave-length was greater than the actual trough-to-trough wave-length of the 500-mb. pattern over the Atlantic and Europe which indicated eastward progression of the pattern. But by 1500 August 18 the amplitude of the oscillation in the 500-mb. flow over the Atlantic was becoming very large with a strong flow north-eastward forward of the up-stream trough over Newfoundland. Only part of this flow was involved in the down-stream trough over western Europe, and, in the event, the wave-length measurements were misleading. The formation of a cut-off circulation over or near the British Isles occurred.

Calculation of the Sutcliffe development terms alone at 1500, August 18 showed a cyclonic development area over the Skagerrak, and suggested the formation of a new centre there and the swinging south-east of the original centre to a cyclonic development area over the Low Countries. These developments would have led to the continued eastward motion of the depression.

The isallobaric evidence at 1800, August 18, indicated that these developments were in progress, but at 0000, August 19, the greatest pressure falls were concentrated over the Low Countries and the falls elsewhere, particularly between Denmark and Sweden, were very much reduced, which was more consistent with the subsequent actual movement of the centre.

The 1000-mb. flow around the depression at the times the forecast charts were prepared was asymmetric with the strongest flow, and considerable advection of cyclonic vorticity, on the north-western side.

If the upper level in the Sutcliffe development equation[3] is considered non-divergent then

$$- l \operatorname{div}_p \mathbf{V}_0 = \frac{D\zeta_0}{Dt} = \frac{\partial \zeta_0}{\partial t} + \mathbf{V}_0 . \operatorname{grad} \zeta_0 = - \mathbf{V}' . \operatorname{grad} (l + \zeta' + 2\zeta_0)$$

and the local rate of change of 1000-mb. vorticity, $\partial\zeta_0/\partial t$, can be obtained from

$$\frac{\partial \zeta_0}{\partial t} = - \mathbf{V}' . \operatorname{grad} (l + \zeta' + 2\zeta_0) - \mathbf{V}_0 . \operatorname{grad} \zeta_0$$

where l is the Coriolis parameter, $\mathbf{V}_0$ is the 1000-mb. wind, ζ_0 is the vorticity at 1000 mb., $\mathbf{V}'$ is the thermal wind in the 1000–500-mb. layer and ζ' is the thermal vorticity.

The final term, which represents the advection of vorticity with the surface flow, may be important with asymmetric depressions. Isopleths of the surface vorticity advection can be constructed by use of the Sawyer-Matthewman scale and the field of $\partial\zeta_0/\partial t$ is then obtained by gridding with the isopleths of relative divergence.

By 1500, August 18, the circulation of the depression was asymmetric with a much stronger flow on its north-western side; surface vorticity advection was computed for this time and the local rate of change of 1000-mb. vorticity was obtained.

The Sutcliffe development terms indicate the type and intensity of development following the motion, whereas the local rate of change of surface vorticity indicates the change of circulation at a fixed point. The local development was becoming more cyclonic over the Skagerrak, and over the Low Countries and eastern England, and less cyclonic over the eastern half of the North Sea and the rest of the British Isles.

The Sutcliffe development equation neglects the effect of vertical stability on development. This factor was taken into account in an evaluation of vertical velocity and thickness tendency from Sutcliffe's theory[4], and an empirical factor of 0·27 emerged by which the vertical velocity, closely related to the development, should be modified to take account of vertical stability. Isopleths of the development reduced in this way were gridded with isopleths of the advection of vorticity at 1000 mb. to produce a modified field of the local rate of change of surface vorticity.

The distribution of the local rate of change of surface vorticity when stability was taken into account did not indicate the transference or the movement of the centre eastward, but there was some indication that the centre should either have become stationary over the North Sea or have moved south-east. In the event the centre continued to move slowly north-east until the early hours of August 19, and then became stationary with a tendency to drift slowly south.

Conclusion.—The case history of this depression illustrates a type of situation in which an upper depression over the British Isles was being cut off from the main westerlies, and this had an important effect on the motion of the surface depression and associated weather over the British Isles.

The inclusion of the stability in the derivation of the local rate of change of surface vorticity, assuming zero divergence at 500 mb., provided a little more information about the future motion, but it would have been difficult to have foreseen the actual motion of the centre even had this information been available to the forecaster. Such information cannot, in any case, be produced by hand in the limited time at his disposal.

This situation was adequately dealt with by electronic computation, presumably because the model takes into account processes which could not properly be assessed by visual inspection of the charts. The success of the computed forecasts must also be attributed partly to the method of computation which involves steps of one hour and hence the calculation of development from continually changing data; this must be a considerable advantage where the motion of a depression undergoes a radical change.

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METEOROLOGICAL OFFICE DISCUSSION

International Geophysical Year

The Discussion on Monday, February 20, 1956, held at the Royal Society of Arts was opened by Mr. R. F. M. Hay who dealt with the programme and objectives of the International Geophysical Year (I.G.Y.). Some of the more detailed aspects of the I.G.Y. described by Mr. Hay have been omitted from this report; they are given in Mr. Absalom's article in the February 1956 number of this Magazine. After pointing out that the programme of scientific work on the scale to be attempted between July 1957 and December 1958 was being supported by 40 nations, Mr. Hay briefly recalled that International Polar Years were held in 1882–83 and 1932–33. The United Kingdom took part in both these efforts and maintained a station at Fort Rae on both occasions. Under the leadership of Dr. Stagg the Fort Rae party had carried out an extensive programme of auroral, magnetic, ionospheric and meteorological observations in the Second Polar Year.

When in 1950 Dr. Berkner proposed a repetition of the International Polar Year, the International Council of Scientific Unions suggested the more ambitious scheme now known as the International Geophysical Year, and appointed the Special Committee for the International Geophysical Year, with Professor S. Chapman as President, to be responsible for its organization.

Each participating country has appointed a National Committee and programmes of work would be carried out by sections with responsibilities as follows:— World Days, Meteorology, Geomagnetism, Aurora and Air glow, Ionosphere, Solar Activity, Cosmic Rays, Latitudes and Longitudes, Glaciology, Oceanography, Rockets, Publications and Publicity. The cost of the project would probably amount to about £35,000,000 and the central organization is being strongly supported by the United Nations Educational, Scientific and Cultural Organization. The United Kingdom I.G.Y. Expedition to Coats Land would cost about £250,000, a sum which is being provided by the Royal Society, while the additional Meteorological Office expenditure would amount to about £76,000.

Describing the organization proposed for I.G.Y. Mr. Hay began with the activities of the "World Days" Section. The intention behind the choice of "World Days" is to ensure that the largest possible number of observations are made on days coinciding with eclipses and meteor showers and, if possible, with periods of marked solar activity, all of which events are linked with phenomena in the high atmosphere. Hence this section had devised the classification of World Days which has been described in Mr. Absalom's article.

The Special Committee for the I.G.Y. aims to set up many additional stations, and is concentrating in particular upon the arctic, antarctic and equatorial regions. They attach importance to providing several close networks from pole to pole along certain meridians of longitude in particular those of 80°W., 10°E. and 140°E., besides some shorter lines of stations for the purpose of obtaining meteorological vertical cross-sections. These include a northern-hemisphere meridian section at 20°W. to which the ocean weather stations will make an important contribution. Mr. Hay next drew attention to the 21 expeditions that will be setting up bases on the Antarctic mainland during the I.G.Y.

Dealing with the main problems to be studied, the opener first reviewed briefly some features of solar activity. Attention was drawn to the 11-yr. sun-spot cycle and to the physical characteristics and magnetic fields of sun-spots. One of the main reasons for holding the I.G.Y. in 1957–58 was that the next fairly intense sun-spot maximum is expected to occur then. Solar flares, short-lived great increases of energy in the ultra-violet, responsible for at least a small part of the variation in the solar constant were then described. These flares are associated with "faculae"—bright patches near or surrounding sun-spots which suddenly and unpredictably become very bright for periods lasting up to 3 hr.—and are believed to originate as a result of streams of electrons upwelling from the sun's centre.

During the I.G.Y. a "solar-flare patrol" would be maintained to keep an uninterrupted world-wide watch on the sun. This would be done by solar observatories equipped with spectroheliographs, the intention being to take photographs of the entire solar disc in hydrogen light automatically at half-minute intervals.

The forecasts of solar activity would be made by the United States Central Radio Propagation Laboratory. When the forecasters at the Laboratory judged the activity of a newly appeared spot region to be high, their judgement being based on reports of flares, sun-spot size, radio noise and magnetic fields, they would issue a "Special World Alert". Whenever such activity is maintained for the next few days—the time between a spot appearing first at the sun's limb and crossing its central meridian being about 7 days—they would call for a "Special World Interval" at 12 hr. notice. In this way they hope to have full-scale observations "laid on" just before the terrestrial effects of a solar flare begin to be felt.

The United Kingdom intends to contribute to this programme with observations at the Royal Greenwich Observatory, Jodrell Bank Radio-Astronomy Observatory and in British East Africa, among other places.

After briefly recalling a few facts about the ionosphere, including Appleton and Naismith's discovery in 1939 that the electron concentration in the ionospheric layers increased between sun-spot minimum and sun-spot maximum, which afforded proof that the solar intensity varied in the ultra-violet, Mr. Hay drew attention to the practical importance of the layers for reflecting radio signals used by long-distance navigational aids for ships and aircraft. Since the concentration of electrons needed to reflect the waves increases with frequency, there is, for a given layer, always a "maximum usable frequency" for satisfactory transmissions. This maximum usable frequency conforms in periodicity with the variations of electron concentration through the sun-spot cycle, a fact used by radio engineers to predict maximum usable frequencies some months ahead. However, these predicted values are not yet considered to be accurate enough. A 50-per-cent. increase in the existing number of ionospheric observing stations is aimed for during the I.G.Y., special interest attaching to the geomagnetic equator and the Antarctic. The "vertical-incidence" method of sounding will be the chief method to be used at most of the stations. In addition there will be studies of the world-wide pattern of ionospheric drifts, and part of the programme will be devoted to an intensive study of radio fade-outs associated with the onset of solar flares.

Ionospheric investigations by the United Kingdom would comprise programmes by the Radio Research Organization of the Department of Scientific and Industrial Research in this country and in the Falkland Islands as well as by Jodrell Bank.

After drawing attention to the main features of aurorae and to the practical and theoretical work of Birkeland and Størmer respectively in explaining some of the more important features connected with them, and mentioning some problems which are still unexplained, such as the discrepancy between the actual radii of the zones of maximum auroral frequency and those predicted by Størmer's theory, the opener dealt with the I.G.Y. auroral programme. For the purpose of the I.G.Y. the world has been divided into three regions, the most important to be called the "auroral region" lying between 60° geomagnetic latitude north and south, and the north and south magnetic poles respectively. Observations would be undertaken by means of a visual watch to be kept by meteorologists, astronomers and amateurs, and by programmes of photographic, photometric and spectral observations. It is hoped that many more measurements of auroral height using the Størmer method will be made together with numerous determinations of wave-lengths and intensities in conjunction with observations of auroral height and type. The Gartlein all-sky camera, which takes a picture every 5 min. on 16 mm. film and can be managed by untrained personnel, should greatly assist the photographic programme. Lastly, investigations will be made at Jodrell Bank of the scintillation of radio stars observed while aurora is in progress. Also in the United Kingdom the auroral survey operated from Edinburgh over many years will provide a contribution to the I.G.Y. which will be reinforced by spectrographic studies at St. Andrew's University.

The opener recalled the special importance of terrestrial magnetism for air and sea navigation, in the interests of which it is advisable for a world-wide survey of the earth's magnetic field to be made about every 25 yr. The small-scale fluctuations lasting a few minutes to several days were also described, and the theory outlined which relates the occurrence of great magnetic storms with the arrival of solar corpuscular radiation reaching the earth about 26 hr. after the onset of a solar flare lying within about 45° of the central solar meridian. The main feature of these storms—the weakening of the earth's field—during their main phase is ascribed by the Chapman-Ferraro-Martyn theory to the formation of a ring current in space around the earth in the equatorial plane whenever the earth traverses a neutral corpuscular stream. Mention was made of the difficulty that smaller magnetic storms which show no obvious relation to sun-spots often recur at 27-day intervals for months on end. The existence of so-called M-regions actively emitting corpuscles for long periods is put forward to account for storms of this type, although such regions have not yet been identified with any visible feature on the sun. The opener recalled that the experimental proof of the existence of streams of solar corpuscles and of their velocity of approach to the earth, which must be of the order of 1,600 Km./sec., is so far very unconvincing.

The Special Committee for the I.G.Y. have already commented that few complete records of any great magnetic storms were obtained during the two Polar Years, and that a denser network of magnetic observatories than before is needed during the I.G.Y. to infer even the broader features of the ionospheric-current systems. They also recommend that auxiliary recording instruments should be operated up to 40 Km. from certain parent stations. Their aim here is to provide additional information on the height and intensity of the narrow localized currents—electro-jets—in these regions. The Meteorological Office intends setting up two such auxiliary stations around the Observatory at Lerwick.

Mr. Hay next described the Special Committee's programme for meteorology, to which the World Meteorological Organization has substantially contributed. Most of the problems relate to the general circulation. They are

(i) re-distribution of momentum, absolute vorticity and all forms of energy.

(ii) influence of surface features—the largest mountain ranges—on momentum and heat exchange between the atmosphere and the earth's surface.

(iii) thermal economy of the atmosphere. This includes radiation studies, albedo and determinations of ozone distribution.

Besides the arrangements already described for setting up additional stations, the opener mentioned that Whaling Companies are being asked to allow meteorologists to accompany their factory ships to secure upper air soundings in the Southern Ocean. Thus sufficient stations may well be available from which to derive mean values of the three-dimensional temperature, water-vapour and wind distributions prevailing for the particular period of the I.G.Y. However, it remains to be seen whether the observational network in space and time will really be detailed enough to allow a viable theory of the general circulation to be constructed.

Mr. Hay then showed some slides of temperature and wind cross-sections including two showing mean zonal components of wind for the northern hemisphere for January and July. These slides give the most detailed vertical cross-sections at present available.

Further examples of investigations which should be helped by data from the I.G.Y. are the splitting of a jet stream to westward of a continent, for which the data from the cross-section at 20°W. would be valuable; and atmospheric circulation over the polar regions, including the behaviour of the tropopause over the Antarctic in winter. High-level wind information to be provided during the I.G.Y. should also enable the seasonal reversal of winds at great heights to be studied in greater detail, besides being of great value operationally and economically to present-day and future aviation. The opener could not explain the restriction of "World Meteorological Intervals" to the solstices and equinoxes which have no great significance from the meteorological standpoint.

Instruments for use in radiation studies included the Moll-Gorczynski thermopile solarimeter and the vertical-flux plate radiometer, the latter instrument having been developed in the Meteorological Office.

Attention was drawn to the need for making observations of the earth's total albedo during the I.G.Y. by the method of Danjon which had long been neglected. Danjon's individual measurements gave values varying between 30 per cent. and 50 per cent. and all his measurements were made in France. Hence the observations should be repeated from other parts of the world to ensure measurements of the total albedo being made while the Pacific Ocean faced the sun. The Special Committee of the I.G.Y. have asked the International Astronomical Union to do this during 1957–58. At the same time it is intended to make measurements of cloudiness as accurately as possible aboard merchant ships and at ocean weather stations.

After briefly reviewing the contribution of Dobson and others to our knowledge of the world distribution of ozone, the opener showed two slides giving the seasonal distribution and the vertical distribution of ozone respectively. He drew attention to two principal difficulties in explaining the distribution of ozone theoretically. First, the fact that day-to-day changes in total ozone amount at a single locality such as Oxford are larger than the normal difference in total ozone amount between equatorial and polar regions at most seasons, implies that the short-period changes cannot be explained by north–south advection. In the second place ozone vertical-distribution determinations have also been made from balloons as well as from rockets, but there is still disagreement between the vertical distribution derived from all these observing methods and by means of calculations such as those of Craig. Craig computed the equilibrium concentrations which must exist at various levels between molecular and atomic oxygen and ozone, dependent as the photo-chemical equilibrium between these constituents is upon the intensity of the sun's ultra-violet radiation and upon the absorption coefficients of these gases. The theoretical and computed distributions agree well above 35 Km., but below 20 Km. there is considerably more ozone in reality than the calculations suggest. Craig's calculations also failed to explain the latitudinal and seasonal variations of ozone amount and the association of ozone with surface weather systems and upper air flow patterns.

In addition, Fleagle has shown that stratospheric air, in moving from a ridge to a trough in the upper flow, undergoes marked lateral convergence and vertical subsidence. However, this subsidence is most marked close to the tropopause and hardly shows at 17 Km. To make matters worse, the layer where the rate of increase of ozone concentration with height is steepest has been believed to lie still higher than 17 Km. Some very recent work by Brewer, however, who made ozone determinations from an aircraft in northern Norway, suggests that there is a rather rapid increase of ozone upwards through the tropopause which may serve partly to overcome this difficulty.

Wulf and others have shown that the rates of opposing photo-chemical processes, those which destroy and create ozone respectively, vary greatly with altitude. Above about 35 Km. equilibrium must be reached very quickly in daylight, i.e. within a few hours; below this level photo-chemical equilibrium is seldom, if ever, reached. Hence below this level the ozone mixing ratio is generally a conservative property and descending air will carry its high ozone content down with it.

Evidently the observed distribution of ozone is brought about largely by vertical mixing, although it appears that downward velocities of about 1 m./sec. are necessary to explain the difference between Craig's computations and the observed values.

In its programme the Special Committee of the I.G.Y. recommends that ozone-measuring instruments (Dobson's spectrophotometers) be installed at stations near the meridians of 10°E. and 140°E., and on both sides of the subtropical jet stream. They consider many more detailed measurements of horizontal and vertical distribution of ozone are required.

Mr. Hay next described the United Kingdom's contribution to the meteorological programme, pointing out that the ocean weather stations I, J and K would contribute data to the 20°W., Malta to the 10°E. and Aden to the 15°N. (zonal) vertical cross-sections. He explained that on ordinary days throughout the I.G.Y. the normal number of soundings would be made to at least 50 mb., but in one of the combined daily temperature-wind ascents a large (1,250 gm.) balloon would be used to get up to 100,000 ft. (10 mb.) when possible. All these arrangements conformed closely with the Special Committee's recommendations. On "World Meteorological Interval" days, four combined temperature wind ascents with large balloons would be made at the ocean weather ship stations, at three stations in the United Kingdom and in the Mediterranean and Middle East.

Dealing with the radiation programme, he explained that observations would be made by Hemsby, Aberporth, Cambridge, the Meteorological Office Observatories, the Meteorological Research Flight, Malta, Aden and Port Stanley (Falklands).

In the United Kingdom measurements of total ozone amounts using the Dobson instrument would be continued at Oxford and made in addition at Lerwick, Aldergrove and Camborne. It was hoped a chemical method for measuring ozone concentration would be used by the Meteorological Research Flight for investigating relations between ozone amount, the subtropical jet stream and double tropopause structure. It was also intended to make ozone measurements at Aden, Bahrain and Habbaniya. The British sferics network in the United Kingdom linked to the Central Forecasting Office, Dunstable, would, of course, be available for thunderstorm location as required by the Special Committee.

Dealing with physical oceanography Mr. Hay said that a main requirement at present was for temperature and current measurements and water samplings to be made at all depths along selected ocean traverses. In this way a better understanding could be obtained of the ocean to atmosphere energy exchange and of the fluctuating fortunes of the fishing industry, among other important problems.

Oceanographers also wanted a programme included in the I.G.Y. for improving our understanding of short-period and long-period changes in sea level. For long-period changes of sea levels the recorders to be used would not respond to ordinary waves and swell, but would take account of those changes of level due to storms and seismic surges, to tides and seasonal fluctuations. A better understanding of unexpected changes in sea level which affect harbours and result in coastal flooding should follow from such work. The Royal Research Ship *Discovery II* and the Fishery Research vessels *Scotia* and *Ernest Holt* would take part, and the National Institute of Oceanography would be installing tide gauges in the United Kingdom and overseas.

Another recommendation of the Special Committee of the I.G.Y. was that sea-temperature measurements should be made regularly down to at least 200 m. using bathythermographs. Only discontinuous series of such observations have so far been made at any one point in the open ocean, mainly upon British and United States ocean weather ships. Meteorologists should thus be provided with data for investigating the relation between seasonal and longer-term fluctuations of anomalies of sea temperature in the topmost 200 m. The large-scale distribution of sea-temperature anomalies in this 200-m. layer and the overlying air-temperature anomalies, together with snow and ice cover over the polar regions and winter continental areas, must be very significant factors for determining seasonal climatic anomalies. The interdependence between them still needed working out in detail.

Glaciological problems under consideration by the Special Committee are mainly comprised under three headings. There are, first the characteristics of glaciers, their shape, size, thickness, rate of flow and advance and retreat, and then changes in these factors as an indication of present climatic trends. Internal glacier structure, seasonal bandings and so forth, will be used to derive recent climatic fluctuations. Lastly, all these studies together with thickness determinations of the ice caps in Greenland and Antarctica should yield more accurate estimates of rates of change of sea level. For instance, the rise of sea level due to melting ice is now estimated as 4 in. a century. In a region where land is subsiding for isostatic reasons, as in south-east England, at a rate of about 6 in. a century, the problem may become quite serious in due course.

Such measurements of ablation, accumulation and movements of glaciers are included in the Special Committee's programme, while the importance of establishing fixed survey points is emphasized to allow changes in glacier characteristics to be accurately measured in future Geophysical Years. Antarctica is given priority, although programmes are also recommended for little-known areas like the east African mountain glaciers (Kilimanjaro) and the far north of Canada.

Prof. Manley, in a letter regretting his inability to attend the Discussion, has drawn attention to the main features of the United Kingdom glaciological programme. In addition to the points mentioned in the Special Committee's programme the measurements already described will be made on one or two glaciers in South Georgia and related to meteorological factors. This island lies so near the Antarctic convergence that this programme may serve to elucidate the oceanic circulation as well as the atmospheric circulation in that area. Similar work at King George Island (62°S.) which has less precipitation and lower temperatures should show whether glacier movement and behaviour there are in phase or not with South Georgia, and better results should be obtained from annual bandings. Similar work which the I.G.Y. party based on Coats Land intend to carry out should yield valuable information on the climate of at least that part of the Antarctic.

Describing the rocket programme for the I.G.Y., Mr. Hay said the United States intends launching about 36 Aerobees, each capable of carrying up to 160 lb. of research instrumentation into the thermosphere, besides a large number of smaller rockets to be launched from balloons or aircraft. France also intended sending up a few rockets. Details of any rocket-launching programme under consideration by the United Kingdom are not yet available*.

It was intended to launch these rockets on selected "World Days". They could help to solve many problems. For instance, they could tell us more about the extension of the solar spectrum in the ultra-violet, they could be used to investigate the current systems responsible for the short-period fluctuations in the earth's magnetic field, for cosmic-ray investigations and to determine the constitution of the ionosphere. It was hoped a rocket could be launched to coincide with a solar flare, although such coincidence would be hard to achieve since preparations for an Aerobee launch take up to 24 hr. even when the geophysical equipment is ready at the outset. Launching of small satellite vehicles during the I.G.Y. is seriously recommended, since the time-scale of the information they could provide under all these headings would be so greatly extended.

Mr. Hay finally alluded to the work of the section responsible for publications and publicity, which is already preparing a history of the two earlier Polar Years, handbooks covering programmes, lists of instruments, observation manuals and so forth. The main task of this section would be to ensure speedy publication after the I.G.Y. of results from all the different fields of activity and to get this done on a uniform plan.

Cmdr Frankcom, opening the general discussion, referred to the opener's statement that it was hoped to make observations of total radiation aboard British ocean weather ships during the I.G.Y. He understood from Dr. Robinson that observations could be made satisfactorily with

* See JONES, F. E. and MASSEY, H. S. W.; Rocket exploration of the upper atmosphere. *Nature, London*, 177, 1956, p. 643.

fixed instruments providing the ship's roll did not exceed 5°. This was true as regards the thermopile solarimeter. He went on to say that ocean weather ships have been observing aurorae on behalf of Mr. Paton's auroral survey for several years. He added that the Marine Division had always encouraged "selected" ships to make observation of meteor trails, and asked Mr. Hay whether such observations could be of any use for determinations of ionospheric drifts. Mr. Hay replied that this point had been mentioned by Mr. Graystone at a recent Meteorological Office Discussion. He understood that such visual measurements were useful providing the position of the trail was accurately determined against its background of stars. Visual observations could not compete in value with photographic records of meteor trails, particularly when made with a ciné camera. In both cases measurements from a single base only gave velocity components perpendicular to the line of sight.

Mr. Gold remarked that as one half of the atmosphere is contained between the parallels of 30°N. and 30°S., and in addition the tropics receive more than half the solar energy, he would like to know how many additional synoptic observations would be obtained from the tropics. He felt that the tropical regions ought to be allotted a substantial part of the £35,000,000 to be spent during the I.G.Y. He would like to know what plans are being made to set up an organization to deal with all the results. Admittedly the working up of the results of the last Polar Year was interfered with by the Second World War, but from the start there was a lack of a satisfactory organization to record and publish the observations. The synoptic data for the Antarctic should be a magnificent improvement on anything we have had before; Antarctica was the nearest approach to a symmetrical portion of the earth's land surface we could get. There was a need for an organization to tackle the meteorological results, not only to publish them but to see what can be got out of them. Mr. Hay said that the Special Committee had also provided for the running of a large number of additional stations along the whole length of the equator and for some shorter zonal strips in low latitudes. These stations were all in addition to those included in the pole-to-pole meridional sections already shown in a slide. He understood the coverage of stations proposed for the tropics would be reasonably adequate. As regards publishing the data, the Publications Section had already arranged for the Solar Activity Section to begin publishing its results directly the I.G.Y. ended, and to take necessary steps to ensure other sections published their data without delay.

Dr. Stagg said that he also felt some concern about the adequacy of the equatorial network. The original idea for 1957–58 had been another Polar Year, but meteorologists had insisted upon it being given a wider scope to cover the equatorial regions. Some people felt that a larger part of the British contribution might have been allotted to the equatorial regions; for instance it would have been a very good thing if stations could have been set up for the I.G.Y. on Christmas Island (south of Sumatra), in the Maldive and Laccadive Groups and at Addu Atoll. There certainly was a great need to provide adequate arrangements including provision of staff for publishing the data and for working up the results.

Dr. Eady considered that a concentration of stations on meridians was unsatisfactory, and that it would be better to have the stations spread out more uniformly.

Mr. Absalom explained that other meridians were going to be operated during the I.G.Y. besides those shown in Mr. Hay's slide; for instance, there was one at 30°E. between latitudes 30°N. and 30°S. which would be well covered with stations. The requirements for aerological work in the tropics were being increased in certain quarters, for instance, by Australia and New Zealand in the Pacific Islands. The World Meteorological Organization had already drawn up forms of presentation for the data. A great deal of work was being put in on these problems at the present time.

Mr. McNaughton explained that he had been in charge of upper air stations in the Falkland Islands for 10 years, building up a synoptic and aerological network in the Falkland Islands Dependencies. He would like to know if synoptic meteorologists believed that the setting up of the network already described for two years would solve the problems of Antarctic circulation or merely give them an appetite for more.

Mr. Lamb said that the one and a half years' co-ordinated observations would certainly be of value, and he hoped that they would confirm previous ideas. He doubted whether the idea of pressure surges emanating from the interior of the Antarctic continent put forward by Sir George Simpson still had a real validity today in scientific circles, although it was certainly true that the United States I.G.Y. programme provided for further investigation on this problem. He felt that until recently the Antarctic had been considered, meteorologically speaking, rather in isolation.

Mr. Leeson inquired whether there was any publication which gave an overall picture of the I.G.Y. activities as contemplated. Mr. Hay replied that a great deal of information about the I.G.Y. programme was contained in the *News Letters* Nos. 7, 8 and 9 of the International Union of Geodesy and Geophysics. Also, one of the tasks of the Publications Section of the Special Committee was the production of a handbook covering the full activity and programme of the I.G.Y. In reply to a query from Dr. Stagg, the United Kingdom National Correspondent for the Publications Section, Dr. Moore, who was present at the Meeting, said he did not wish to add anything to Mr. Hay's remarks.

Mr. Veryard asked whether details were available of the programmes for making surface observations such as soil temperatures. Mr. Absalom replied that these matters were under consideration.

Mr. Houghton asked for details regarding standardization of instruments, instancing variations between the aerological observations of different nations. He said that he had also found differences in sea temperatures as observed by French and British ships at the same place. He asked whether any plans had been devised for making measurements of surface observations over the sea, or over the land in an individual depression. Mr. Hay pointed out the obvious difficulty of selecting a suitable depression beforehand. To fulfil Mr. Houghton's suggestion some form of radio-communications linkage between national forecast offices would need to be arranged before the I.G.Y. on the same pattern as that already devised by the Solar Activity Section for notifying Special World Alerts. As regards standardization he hoped that the Radio-Sonde and Aircraft Instruments Branch of the Meteorological Office would be able to provide some information about the position.

Dr. Scrase said that a second series of instrument comparisons are due to be made in May. This would cover 12 different types of radio-sonde.

Mr. Ali Abandar (Jordanian Meteorological Service) asked for more explanation of the difference between the theoretical and actual curves shown in the slide giving the vertical distribution of ozone. Mr. Hay explained that the discrepancy between the calculated and the actual amounts of ozone below 20 Km. shown on the slide earlier was one of the outstanding difficulties of the subject. He referred to the seasonal distribution of total ozone amounts described earlier, and pointed out that if photochemical processes alone predominated the maximum ozone amounts should be found over the equator. Some very recent work had shown that, with winds of polar origin in spring a second ozone maximum was found at about 15–20 Km., this maximum did not show with winds of equatorial origin. It was very difficult to explain the observed distribution of ozone other than as a dynamic balance between photochemical processes creating ozone at high levels perhaps in low latitudes, with advection of ozone at high levels from low to high latitudes, after which descending currents carry ozone-rich air to lower levels, whence it is removed by dissociation. The process was complicated by the fact that the temperature of the stratosphere depended upon the amount of ozone present at various levels, while the absorption coefficients of ozone showed a dependence upon stratospheric temperature.

Cmdr Frankcom said that the question of the standardization of sea-surface-temperature observations was receiving consideration. He referred to the two methods: measurement by a canvas bucket and measurement of condenser intake temperatures, and said that this problem would be the subject of further study at the forthcoming Conference of the Commission for Maritime Meteorology to be held next September.

Mr. Reed said that he understood the United States was going to open a station at the South Pole itself during the I.G.Y. Was it the intention that scientific staff were going to live at the South Pole throughout the period? He also wanted to know whether it was seriously intended to launch earth satellites during the I.G.Y. Finally he referred to the difficulty of launching very large balloons from ocean weather ships during gales, and wished to know whether this had received consideration? The meteorological programme which had been described for the United Kingdom would require a large number of additional scientific staff and he would like to know whether these were to be found?

Mr. Absalom said that the £76,000 mentioned for the United Kingdom expenditure was purely intended for equipment, The additional number of staff needed was very small, and most of the additional commitments in the programme could probably be covered by present staff complements.

Mr. Lamb referred to the working up of meteorological data and to the desirability of a fairly uniform distribution of observations. He pointed out that two of the chosen pole-to-pole meridians lay along semi-permanent upper air troughs. He would also like to know whether consideration had been given to making radio-sonde observations from passenger liners.

Cmdr Frankcom said that it was hoped to obtain radio-sonde observations from whaling ships. The Japanese had agreed to do this and the United Kingdom were about to signify their agreement. United States Army Transports would also make radio-sonde observations, while the United States Weather Bureau also intended to put special observers on United States merchant ships traversing the Caribbean.

Dr. Scrase asked whether the World Meteorological Intervals were intended to cover consecutive days. He pointed out that they would not cover the whole period during which the east–west high-level wind transitions were known to occur, and considered the choice of equinoctial periods was unsatisfactory for this purpose. Mr. Hay replied that the World Meteorological Intervals were intended to be periods of 10 consecutive days. Although the date of their commencement was fixed, provision was made for their extension as necessary.

Dr. Stagg remarked that some authorities had not agreed with the intervals being fixed at the equinoxes, and had wanted them to be included to cover other portions of the calendar.

Dr. Sutcliffe said that the idea of World Meteorological Intervals had only developed from that of World Days. It was very easy to criticize the arrangements at this stage now that the main ideas for the meteorological programme had been put forward. In fact, meteorology is an advanced science compared with the other geophysical sciences. It was important that agreement had been secured that only problems needing world-wide observations should be included in the programme. The number of special stations needed was relatively small compared to the total of stations normally operating.

Dr. Eady considered that problems of more limited interest should nevertheless not be lost sight of. He would like to see a greater effort made in ocean regions.

Dr. Stagg, in conclusion, said that so far not very much thought had been given to minor items such as measurement of soil temperature. The Special Committee had spent most of their time on major items such as provision of up-to-date radar equipment. He again wished to emphasize the need for a proper evaluation of the data after the close of the I.G.Y. and the need to provide the necessary staff for the purpose. A great deal of effort had been devoted to the fitting out of the Royal Society's Expedition to Coats Land, and Meteorological Office staff were at present being selected to carry out the programme at Coats Land during the actual period of the I.G.Y. Referring to his own experiences in organizing the United Kingdom party to Fort Rae in 1932–33, he reminded his audience that in 1932 radio-sondes were just coming into existence. They had tried hard to get some of Multanovsky's radio-sondes for 1932–33 without success. He thought it not without significance that in 1932 radio-sondes were just coming over the horizon while at the outset of the coming International Geophysical Year the potentialities of satellites and rockets lay just ahead in the same sort of way.

METEOROLOGICAL RESEARCH COMMITTEE

The 37th meeting of the Synoptic and Dynamical Sub-Committee was held on November 15, 1955. An interesting item in the paper by Dr. D. G. James[1] is that cirrus occurred in the lower stratosphere on about 10 per cent. of the occasions considered, and the suggestion that there is some evidence of upward vertical motion in the lower stratosphere on these occasions. Mr. F. H. Bushby gave an account of his recent experience of the experiments in progress in Sweden on the electronic computation of 24, 48 and 72-hr. forecasts of the 500-mb. chart using a barotropic model of the atmosphere. Mr. E. Knighting then outlined parallel experiments which he had witnessed during a nine-months visit to the Joint Numerical Weather Prediction Unit, in the United States, where 12, 24 and 36-hr. forecasts of pressure contour heights for 900, 700 and 400 mb. are obtained using a three-level atmospheric model. The Sub-Committee welcomed Mr. J. S. Sawyer's proposal[2] for the use of an incompressible fluid model to facilitate the laboratory investigation of natural air flow over a ridge, and recommended that the practicability of the model suggested should be examined. The paper by Mr. G. A. Corby and Mr. C. E. Wallington[3], and the discussion of it, brought out the complex and sensitive relationships between lee waves and the characteristics of the air stream and the generating obstacle, and suggested that some earlier assumptions and ideas require reconsideration.

The Meteorological Research Committee held its 70th meeting on November 23, 1955, under the chairmanship of Sir Charles Normand who has succeeded Sir David Brunt. Dr. A. W. Brewer and Mr. J. Paton are new members of the Committee. The Committee accepted the Instruments Sub-Committee's recommendation that the modulated-beam searchlight method should be developed for the determination of atmospheric density at high altitudes, and noted that the Meteorological Research Flight had been equipped for the better investigation of clear-air turbulence to heights of about 50,000 ft. Progress during the past half-year in main items of the research programme was reviewed. Gratification was expressed that the Meteorological Office is to acquire an electronic computer for use in work on the application of numerical methods in forecasting problems. After the formal business Mr. E. Knighting, lately returned from a visit to the Joint Numerical Weather Prediction Unit, near Washington, United States, described the numerical techniques used by that unit, and the degree of success achieved in forecasting contour charts for 900, 700 and 400 mb. for periods up to 36 hr.

The 35th meeting of the Physical Sub-Committee was held on December 8, 1955. It was agreed, on a suggestion received from Dr. E. G. Bowen of Australia, that the Meteorological Research Flight would endeavour to carry out a programme for sampling the freezing-nucleus concentration in the free atmosphere during January 1956, in co-operation with similar attempts in Australia and South Africa to examine a possible connexion between the nucleus concentration and the occurrence of meteoritic showers. There was general agreement that the paper by Mr. W. T. Roach[4] is a mine of information, and that Dr. G. D. Robinson's discussion[5] on the energy balance of the earth's surface and atmosphere is a pertinent contribution. The increase in atmospheric ozone content at the tropopause in northern Norway, reported by Dr. A. W. Brewer[6], differs from the results obtained a few years ago in southern England. Further similar determinations by aircraft sampling in Norway, England and other latitudes were considered to be desirable. In the discussion of Mr. P. J. Meade's paper[7], which was prepared with a view to application to the problem of the plume emitted by a factory chimney, it was mentioned that an account of a theoretical and experimental investigation (at Cambridge University) of a plume in a stable atmosphere would be published soon.

ABSTRACTS

1. JAMES, D. G.; Investigations relating to cirrus cloud. *Met. Res. Pap., London,* No. 933, S.C. II/196, 1955.

Observations of cirrus from aircraft over the British Isles were analysed for frequency distribution of tops and bases relative to tropopause, heights of base and thickness. Ten cases (in 220) had tops above 40,000 ft. The surface charts, upper air soundings, 1000–500-mb. thicknesses, advection vorticity at 300 mb. and 300-mb. contours were also examined. Cirrus was associated with the area ahead of surface fronts, the high-pressure side of the jet stream, thermal ridges, high humidities at 500–300 mb., winds between S. and W. at 500–300 mb. (advection of warm air) and positive cyclonic vorticity at 300 mb.

2. SAWYER, J. S.; Dynamical similarity in an incompressible fluid model of two-dimensional air flow over a ridge. *Met. Res. Pap., London,* No. 935, S.C. III/191 and S.C. II/198, 1955.

To overcome the difficulty that air is compressible and to simulate a flow of air over a range of hills a model is examined in which an incompressible fluid flows through a narrow channel tapering upwards.

3. CORBY, G. A. and WALLINGTON, C. E.; Air flow over mountains—the lee-wave amplitude. *Met. Res. Pap., London,* No. 939, S.C. II/199. 1955.

Theoretical considerations (sufficient decrease of l^2 with height) suggest that lee waves should be common over the British Isles, but they are rarely reported by aircraft. This is because, to produce waves of large amplitude, large mountains need strong winds with an increase of speed and/or decrease of stability with height, and the air-stream characteristics must be favourable. The maximum amplitude and vertical velocity of lee waves in given conditions, and the variations of lee-wave amplitude and length, are calculated; they are very susceptible to small changes of conditions.

4. ROACH, W. T.; Measurements of atmospheric radiation and the heat balance at the ground at Kew, May 1953–May 1954. *Met. Res. Pap., London,* No. 936, S.C. III/192, 1955.

The theory of heat balance on a grass surface is discussed and the instrument set up described. Photographic records of surface temperature, radiation flux and flux of heat at 6 cm. in soil were obtained over a complete year; specimen records are shown. Values of net vertical flux of total, short-wave and long-wave radiation, downward flux of long-wave radiation, surface temperature, heat flux into ground, flux of water vapour and rainfall are tabulated for each month. Appendices describe calibration of instruments and a standard black-body cavity radiator.

5. ROBINSON, G. D.; The energy balance of surface and atmosphere at Kew, May 1953 to April 1954. *Met. Res. Pap., London*, No. 929, S.C. III/189, 1955.

Trial measurements from the ground of the radiation flux over the whole atmosphere were made in preparation for the International Geophysical Year. Determination of the albedo (photometric, visual and ultra-violet, and infra-red) under various assumptions as to absorption etc., gave estimates of: year 0·475, summer 0·46, winter 0·525. Terrestrial radiation at the limit of the atmosphere is set at 20 ± 3 mW./cm.^{2}. Terms in the energy budget are computed for year, summer and winter. It is concluded that measurements during the International Geophysical Year can be made with useful accuracy, which can be improved by measurements in the air, but in view of the year-to-year variations some stations should operate for at least 5 yr.

6. BREWER, A. W.; Ozone concentration measurements from an aircraft in north Norway. *Met. Res. Pap., London*, No. 946, S.C. III/195, 1955.

Ascents with a thermometer, dew-point hygrometer and ozone sampler were made to 40,000 ft. from Trondheim on June 27 and 28 and July 3 and 11, 1955. The results, shown graphically, indicate a three-fold increase in ozone concentration above the tropopause.

7. MEADE, P. J.; Convection from a small, continuous source of heat in a calm, neutral atmosphere (with an appendix on the bent-over plume). *Met. Res. Pap., London*, No. 952, S.C. III/196, 1955.

The theory of velocity and temperature field and the vertical variations of radius in the ascending plume from a point source of heat are discussed. Approximate solutions of the basic equations are set out and compared with observations. Computed values of excess potential temperature and vertical velocity against height are compared with laboratory observations by Railston and Schmidt, with good agreement. An appendix compares computed data with those of Priestley and Ball for two chimneys in the Oak Ridge area.

ROYAL METEOROLOGICAL SOCIETY

Measurement of humidity at high altitudes

At the meeting of the Society held on February 15, 1956, after the transaction of formal business, the President, Dr. R. C. Sutcliffe handed over the Chair to Dr. A. W. Brewer to take charge of the ensuing discussion on the measurement of humidity at high altitude.

Dr. Brewer opened the discussion with a historical review of the development of, and observations obtained by, the Dobson-Brewer frost-point hygrometer first brought into use in 1943. He described the instrument and exhibited the first and current models. He emphasized the surprise with which he had found that the humidity of the lower stratosphere was so low, and of how on one early flight a condensation trail being made in the troposphere was cut off as though by a knife on crossing the tropopause. Curves of the variation of frost point with height, measured by the hygrometer and by radio-sonde, were shown, and the importance of the rapid changes revealed by the hygrometer but not by the radio-sonde pointed out.

He was followed by Mr. Goldsmith, formerly of the Meteorological Research Flight, who described the pressure-increase method of increasing the frost point. The artificial increase in frost point is necessary because at temperatures below -85°C. (-120°F.) the ice deposit on the cold plate of the hygrometer is glassy and invisible. If the frost point can be artificially raised above this temperature the deposit becomes crystalline and clearly visible. Compression of the air from the 115-mb. pressure (appropriate to 50,000 ft. in height) to 1013 mb. raises the frost point by over 20°C. The result follows at once from conservation of humidity mixing ratio. Mr. Goldsmith explained that the method had been conceived many years ago by Prof. Dobson, but could not be put into force until jet aircraft were employed for meteorological purposes. The system of obtaining air compressed about sixfold from the jet-engine compressor was explained in detail, as were the satisfactory results of checks against the ordinary method.

Mr. Murgatroyd then described the observations of the humidity of the lower stratosphere up to 50,000 ft. made by the Meteorological Research Flight on 35 flights over southern England during 1954. The frost point decreased with height in the lowest part of the stratosphere. The lapse of frost point also decreased with height until about 10,000–15,000 ft. above the tropopause to a constant value, independent of season, of about -82°C. (-115°F.) with relative humidity with respect to ice about 1 per cent. He thought sufficient was now known about the humidity structure in the stratosphere up to 50,000 ft. over England to make it unnecessary to make further flights especially to measure humidity, though observations of it would continue to be made on flights made primarily for other purposes. The need was for higher flights which called for special pressure suits, and especially for observations in other parts of the world to obtain the world pattern.

Prof. Dobson discussed the reasons for the low humidities of the lower stratosphere. Such low humidities could only be obtained by supposing the air had been cooled at some time to the observed frost point. Such low temperatures occurred at the same height only at the top of the equatorial tropopause and in the winter polar stratosphere. He believed the low frost points over England were in air which had risen in the equatorial regions, had nearly all its water vapour condensed out there, and then moved northward.

Dr. Houghton next described measurements of the precipitable water content of the stratosphere by radiation methods using the atmosphere and the sun as sources of radiation based on absorption of infra-red radiation by water vapour. These showed a precipitable water content of the order of 1 or 2 μ.

Dr. Gates of the United States Office of Naval Research described observations made with a balloon-borne spectrograph having a sun-seeking device to measure the absorption of solar radiation in the infra-red by water vapour. This gave values of precipitable water agreeing with those found by Houghton.

In the discussion which followed, Dr. Robinson inquired how many times the frost point had been measured in cirrus cloud and how many times it had been at the saturation value. He also asked if it was possible that at very low temperatures when the crystalline deposit disappeared the water was exchanging molecules with the surface. Mr. B. J. Mason described the different forms of ice obtained in the laboratory at low temperatures. Below −150°C. the ice was amorphous, and it was difficult to obtain a deposit at all, and asked to what extent this was a surface effect. Dr. Brewer said the ice formed at low temperatures gave no electronic diffraction pattern. At the temperatures where visible ice crystals were formed they were separated by crystal-free spaces on the plate. At very low temperatures the molecules had insufficient energy to move over the plate and aggregate into crystals. As regards observations in cirrus, it was difficult to tell from an aircraft that it was flying in cirrus. The hoar-frost apparatus gave a frost point when known to be in cirrus about 1°C. below saturation value. The latter points were confirmed by Mr. Murgatroyd who gave 2°C. as the frost-point depression in cirrus.

The question of the real existence of cirrus in the stratosphere as had been occasionally described was raised. Mr. Murgatroyd said he was not sure if it was not really dust, though he recalled one occasion when a vigorous cumulonimbus cloud lifted the tropopause. There was no occasion of seeing cirrus with a high humidity in the stratosphere.

REFERENCES

1. MURGATROYD, R. J., GOLDSMITH, P. and HOLLINGS, W. E. H.; Some recent measurements of humidity from aircraft up to heights of about 50,000 ft. over southern England. *Quart. J. R. met. Soc., London,* **81**, 1955, p. 533.
2. GOLDSMITH, P.; A method of increasing the range of the Dobson-Brewer frost-point hygrometer in jet aircraft. *Quart. J. R. met. Soc., London,* **81**, 1955, p. 607.

INSTITUTE OF NAVIGATION

Meteorological aspects of high-level navigation

On Friday January 20, 1956, three papers were read. Capt. Frost, a senior pilot of British Overseas Airways Corporation, described the jet streams of the North Atlantic from the point of view of the pilot trying to make the best use of these narrow "rivers" of fast-moving air. He was concerned with the layers between 18,000 and 25,000 ft., i.e. below the level of strongest winds, and he described in general terms where the strongest winds are to be found in relation to a typical North Atlantic depression and its associated fronts. Capt. Frost discussed the clues which help the pilot to locate and stay in the strongest winds. Temperature in the free air is the most reliable indication, the pilot endeavouring to find the warm edge of the strong horizontal temperature gradient which is always associated with jet streams. The position and orientation of bands of cirrus clouds are also of great assistance on some occasions, marking the approximate position and direction of the strongest winds. Unfortunately, only about 10 per cent. of North Atlantic jet streams have this distinctive cirrus band. Capt. Frost showed a number of remarkable photographs, taken from the pilot's seat, of clouds associated with jet streams, including one taken near the Bahamas which showed cloud which was probably along the subtropical jet stream. In one photograph the cirrus cloud could be seen to bend round on the horizon 600 or 700 miles away in association with a surface cold front.

Mr. Bannon, of the Meteorological Office, next described the principal regions of strong upper winds over the world. The subtropical jet stream between latitudes 20° and 35° in winter is broader and more stable and therefore perhaps a more useful stream to the aerial navigator than the better known jet streams of temperate and high latitudes; its axis, the level of strongest winds, is about 40,000 ft., approximately 10,000 ft. higher than that of the jet streams in temperate latitudes. A comparatively low-level jet stream occurs infrequently in the Arctic in winter which has a structure similar to that of the temperate jet stream, but its axis is at about 20,000 ft. Westerly winds are also strong in the stratosphere on the edge of the Arctic and Antarctic in their respective midwinters, speeds exceeding 100 kt. at 50,000ft. and above on some occasions and probably increasing with height. A strong steady easterly flow occurs from June to August from Malaya across Ceylon and Africa to Nigeria which may also be important to navigation

[To face p. 152

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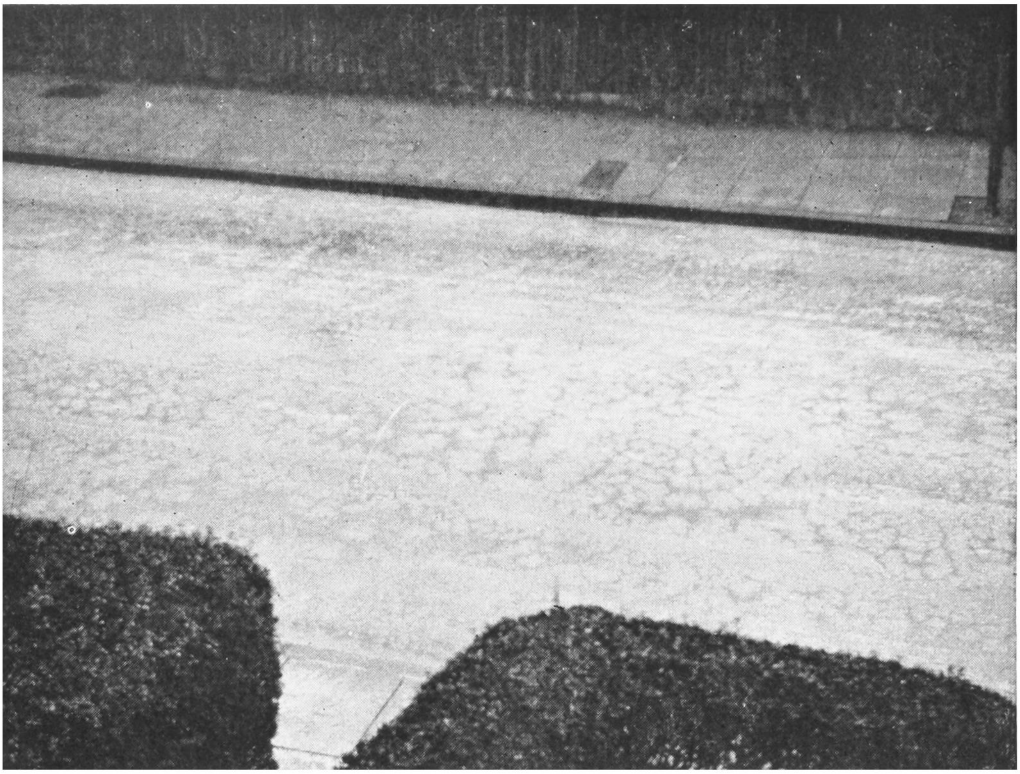
ANVIL OF CUMULONIMBUS CLOUD
The photograph was taken looking vertically upwards.



Reproduced by courtesy of K. E. Woodley

ICE PATTERNS ON A ROAD, KEW, 0715 G.M.T., FEBRUARY 13, 1956 in the future. The axis of this stream is at about 47,000 ft., and though maximum speeds exceed 100 kt. on occasions they are usually about 60 kt. The strong winds are restricted to the upper troposphere and lower stratosphere.

Mr. Kirk (Meteorological Office) discussed some of the problems experienced by forecasters at London Airport in forecasting for high-altitude flight. The number of observations of temperature and wind in the upper air by sounding balloons are fewer at greater heights, and inaccuracies in the observations and in the forecasting techniques increase with height. The time taken to analyse the higher observations is also an adverse factor; observations for 30,000 ft. and above are received later than those for lower levels, and their analysis depends to some extent on the analysis of the data for lower levels. For example, the chart for 200 mb. (approximately 40,000ft.) for the North Atlantic is not completed at London Airport until nine hours after the relevant observations have been made. Forecasters at London Airport have gained experience on routine forecasting for Viscount aircraft operating at 20,000–25,000 ft. over European and Mediterranean routes, for Comet I aircraft operating at 35,000–40,000 ft. on the route London to Rome, and for "paper" operation of Comet III aircraft over the North Atlantic at similar levels. Mr. Kirk showed a diagram comparing the forecast equivalent headwinds on the London-to-Gander route with those which occurred; the forecasts were for 12–24 hr. at the level of 200 mb. and, although the agreement was on the whole quite good, on one occasion the error was as much as 40 kt. He stressed that when the track of the aircraft can be varied at will in accordance with meteorological advice at briefing, the effect of uncertainty in the meteorological situation can be reduced. Mr. Kirk pointed out that though, as explained by Capt. Frost, the temperature method of finding and staying in strong winds worked well below the level of strongest winds, the temperature field above the axis of the jet stream becomes more complicated, and the interpretation of aircraft observations more difficult. He explained that carefree riding of meandering jet streams may often take the aircraft so far off track that time may be lost; there is no substitute for careful flight planning. He also described other high-altitude weather features of interest to the navigator, namely "cut off" lows and highs and "shear lines".

In the discussion following these papers a number of interesting points were made. The routes for probably 90 per cent. of transatlantic flights westwards, direct crossing, are planned to take into account forecast weather and wind. So many aircraft are now flying over the Atlantic, however, that it may be necessary to restrict flights to certain lanes. Pilots would like to have more specific forecasts of the position of jet streams. One speaker praised the forecasts of jet streams given by the Canadian Meteorological Service at Montreal. Upper cloud is absent from the subtropical jet stream near Japan in winter and spring.

ROYAL ASTRONOMICAL SOCIETY

Large-scale water circulation over the earth

A geophysical discussion on the above subject was held at the Royal Astronomical Society on December 16, 1955, with Dr. G. E. R. Deacon, F.R.S. in the Chair.

The first speaker, Mrs. Mary Morgan, dealt with the hydrological equation, precipitation equals evaporation plus run-off plus storage, for land areas. Evaporation and run-off depend critically on local conditions; deforestation increases run-off by 60 per cent., most of which is compensated by a decrease in evaporation. As regards storage of the water of the earth, 97 per cent. was in the sea, 1 per cent. in snow and glaciers and 2 per cent. in the soil; the contribution of water in the atmosphere was very small in comparison.

Dr. Munk spoke on the annual water budget of the oceans and the annual water interchange between sea and land. Tide-gauge records, which gave coherent results over thousands of kilometres, revealed annual changes in sea level mostly of 1 or 2 dm., but reaching 1 m. in the Bay of Bengal. The latitudinal variation of level is large poleward of the belts of westerly winds, small in the westerlies, increases again in the subtropical anticyclone belt, and falls to a few centimetres along the equator. Changes in sea level can be due to changes in total mass of water or to changes in temperature of the upper layers of the sea; the former predominates in the polar regions and the second in the equatorial belt. The variations in the southern hemisphere are less than in the northern one.

The total mass of water in the seas varied during the year by 3 gm./cm.^{2} of the surface. The mass of snow in the northern winter accounted at the right time of year for about one third of this fluctuation. Dr. Privett spoke about the transfer of water from sea to air, applying the simple equation, evaporation equals the product of a constant wind speed and saturation deficit, to climatological data. His data were compared with those of Jacobs and differed appreciably from them. Privett found on calculating the evaporation by zones that over the zone 0–40°N. it was 120 cm./yr. whereas over the zone 0–50°S. it was 140 cm./yr. The evaporation was highest over the warm currents reaching 0·7 cm./day over the Gulf Stream. The latent heat carried by the evaporated water vapour, derived from solar radiation, is the main source of energy in the atmosphere.

Dr. Sutcliffe described recent work in the Meteorological Office on the water content of the atmosphere as found from radio-sonde data, and gave mean humidity-mixing-ratio values at various heights on a diagram with a cosine scale of latitude. The amount of precipitable water averaged over the areas stated was found to be in January, 1·9 cm. over the northern hemisphere, 2·5 cm. over the southern and 2·2 cm. over the world; the corresponding values for July were 3·4 cm., 2·0 cm. and 2·7 cm. As the average annual rainfall over the world was 90 cm., the period of turn-over was about 10 days. The fluctuations in atmospheric water content were not known exactly, but could account for a substantial part of the variations in sea level. He believed the aerological water-balance equation, precipitation equals advection plus evaporation minus atmospheric storage, could be more readily solved than the hydrological equation, precipitation equals evaporation plus run-off plus land storage.

In the course of the discussion the importance in the balance of the release of "fossil" water by burning oil and coal was mentioned.

LETTER TO THE EDITOR

The occurrence of spells in London rainfall and temperature

Mr. D. H. McIntosh in his article on the above subject states, on p. 366 and p. 369 of the *Meteorological Magazine* for December 1955, that he does not confirm some of my earlier work. This earlier work has been published under the title of "The reliability of rainfall", and the conclusions have stood the test of time, since the first paper was published by the Institution of Water Engineers in 1930. Mr. McIntosh states "the effect reported by Glasspoole is absent from these London data". This effect was interpreted by the reviewer in *Weather* as follows: "if a run of four very dry months have provided only about a third of the average rainfall, then the next four months are likely to redress the deficit to some extent, though the whole period may be below average". While this statement is not so precise as that given originally[1] in the *Quarterly Journal of the Royal Meteorological Society*, there is no justification for the interpretation given by Mr. McIntosh that this shows that compensating wet spells must necessarily follow four very dry months. Indeed, Mr. McIntosh finds on p.369 that "In the 61 dry spells. . . the succession of three dry months had an aggregate rainfall about 40 per cent. of normal; the four following months were all dry on the average, and aggregated 90 per cent. of normal". Thus the 40 per cent. did not continue, but was followed by a period with 90 per cent., thus confirmnig my original statement. The diagrams also bring out the decrease in the deficiency with periods longer than three months.

Mr. McIntosh does not appear to have seen earlier statistical work on rainfall sequences. Thus Mr. Bilham has shown[2] that "the chances of a given month being wet or dry are roughly even, independently of past history".

While much has been written about rainfall fluctuations and frequencies, there is room for further statistical work; but the first essential is to examine existing literature on the subject. Some references are given in the paper on "Rainfall in relation to water supply".

J. GLASSPOOLE

REFERENCES

1. GLASSPOOLE, J.; Rainfall in relation to water supply. *Quart. J. R. met. Soc., London*, **81**, 1955, p. 268.
2. BILHAM, E. G.; Notes on sequences of dry and wet months in England and Wales. *Quart. J. R. met. Soc., London*, **60**, 1934, p. 514.

[I owe Dr. Glasspoole an apology for accepting without confirmation a reviewer's version of his contribution to a discussion of water supply, held in November 1954. I agree that the presence of a "compensation" effect cannot be inferred from the written contribution that subsequently appeared in the

Quarterly Journal of the Royal Meteorological Society. A precise interpretation of Dr. Glasspoole's figures in terms of a possible compensation effect is however not straightforward because the effect of the annual variation of rainfall is not eliminated.

Dr. Glasspoole appears to imply that my paper would not have been written had I been more conversant with existing literature. The conclusion of Bilham is, of course, sufficiently true for practical purposes. But the various investigations of rainfall (and temperature) monthly sequences have in fact shown a small excess of longer, and deficit of shorter, sequences as compared with chance expectations. It was for this reason that it was stated in the Introduction to the paper that various investigations had shown that the probable result of an investigation concentrating on systematic effects associated with spells would be to reveal some degree of persistence in the monthly values before a return to normal. The results obtained give a measure of the magnitude and duration of these effects which, so far as I know, is not available elsewhere and cannot readily be deduced from other work. The probable duration of the effects—four months in rainfall and even longer in temperature—seems to me to be a matter of some interest and even surprise.—D. H. MCINTOSH]

NOTES AND NEWS

Sun pillar

On Thursday, February 23, 1956 at 1655 G.M.T. a sun pillar was observed from East Hill, Houghton Regis.

It was amber in colour and tapered to the top. The phenomenon lasted 15 min. during which time short-term fluctuations of height accompanied by corresponding changes of brightness could be seen. Such fluctuations covered periods of between 3 and 10 sec.

The photograph facing p. 137 was taken at 1708 G.M.T. and shows the sun pillar at its greatest intensity.

Low cloud was 2 oktas stratocumulus at 4,500 ft. Cirrostratus was not obvious at this time, but half an hour later it appeared to cover half the celestial dome. Above the western horizon there were numerous decaying condensation trails. Visibility was 8–10 miles. Radar showed no weather echo within 120 miles of the station.

At 1800 G.M.T. a weak cold front moving slowly southwards extended from north Jutland to the Moray Firth and an occluded frontal system was approaching from mid Atlantic.

A. W. E. BARBER

REVIEW

Weather and the Land. Prepared by the Agricultural Branch of the Meteorological Office (Air Ministry) *Bull. Minist. Agric., London*, No. 165. 9½ in × 6 in., pp. iv + 36, *Illus*. H.M. Stationery Office, London, 1955. Price: 3*s*.

Economic success in farming is subject to so many variables that until yesterday few farmers kept books. It was widely held that no conclusions could safely be drawn from them, and the case of old John furnished food for much merriment. (That prosperous worthy was persuaded by a reforming landlord to start account keeping; but he found the accounts always showed a loss so he burnt his books and lived happily ever afterwards.)

The position is different today. Thanks to patient accumulation through several decades of detailed financial records of many farms—and in part to those seemingly endless forms farmers had to fill in during the war—it is now possible to deduce the main principles of farm finance, though admittedly the "laws" have to be hedged about with a good many provisos and qualifications.

In the light of this experience farmers and their scientific advisers will be predisposed to welcome this bulletin which embodies the results of study of even greater masses of data on interacting variables. They are prepared for it also by the striking improvement in the reliability of forecasts in post-war years. The bulletin divides broadly into three sections dealing, respectively, with analysis of climatic factors, the impact of climate on farm practice and weather forecasting.

The analytical section sets forth with admirable clarity the succession of events in the development of "fronts", depressions and anticyclones, and details the types of weather associated with typical synoptic situations. It is much too brief to convey to a lay reader a clear conception of cause and effect, and plan drawings, though useful, are of but limited value in illustrating three-dimensional changes. Nevertheless, the section forms a useful introduction to the description of climatic differences within the country and the effects of climate on farming. Naturally the influence of rainfall and temperature is stressed. More might perhaps have been said on the influence of length of day on growth curves of crop plants.

In treating of weather and farmers, priority is given to the problems of the fruit grower and market gardener. Fruit growing in this country is everywhere subject to a certain amount of frost risk; so is vegetable growing since the livelihood of the market gardener depends largely on the earliness of his crops. But enough evidence has now been accumulated to enable the meteorologist to calculate these risks with some accuracy and to define the geographical and topographical conditions in which they are small or large. This marks a real advance. Many other risks of course remain—in particular those of markets—but it is a great gain to be able to estimate chances of failures from frost, for of the various devices for guarding against it none offers much real hope of success.

A good beginning has also been made in the study of irrigation-need. Measurements of crop transpiration and comparisons with rainfall figures have made it possible to define the frequency with which crop growth is likely, without irrigation, to fall below the maximum. The "law" can again only be stated in terms of degrees of probability, but within these limits a map of England's irrigation needs can now be constructed.

Scientifically great interest attaches to a recent development in forecasting as an aid to control of plant disease. The spread of potato blight is determined by the occurrence of favourable climatic conditions. It can be controlled by timely spraying—early warning of "blight weather" is therefore valuable.

But relatively blight spraying is of little consequence compared with preserving our grass crops. As agricultural techniques advance the timing of hay harvest becomes ever more important. In the days of horses and lumbering wagons and abundant labour hay harvest was in any event long drawn out. Though everyone hoped for fine weather it could not reasonably be expected to last throughout the whole harvest. Modern tools and modern speeds enable us to reduce the period to a few days, given favourable weather; but if the power available is to be used to advantage it is essential to choose the precise moment to start. In lesser degree the same is true of silage making, for, though silage can be made in any weather, rain is a sore handicap and a source of much spoiled material.

The bulletin does well therefore, while explaining the manner in which forecasts are interpreted and the bearing of local conditions thereon, to call attention to the special services now available. They cannot banish the farmer's primeval hazards, but at least they set bounds to his anxieties.

W. B. MERCER

OBITUARY

John Patterson, O.B.E., M.A., LL.D., F.R.S.C.—We regret to learn of the death of Dr. Patterson, formerly Controller of the Meteorological Division, Ministry of Transport, Canada, on February 22, 1956, in his 85th year.

Dr. Patterson was a schoolmaster for some years before he entered the University of Toronto where he studied physics and mathematics. He graduated in 1900 and won an 1851 Exhibition Science Research Scholarship in the same year. After two years at the Cavendish Laboratory, Cambridge, he became Professor of Physics in the University of Allahabad. In 1905 he was appointed Meteorologist to the Government of India, but he returned to Canada in 1910 to join the Canadian Meteorological Service. He was appointed Assistant Controller of this Service in 1925 and Controller in 1929.

He was a pioneer investigator of the upper air by balloon meteorographs and made important advances in anemometer and barometer design.

Dr. Patterson will be remembered too for his many contributions to international meteorology, and his deep interest in the International Meteorological Organization and later in the World Meteorological Organization. Soon after the Commission for Instruments and Methods of Observation was instituted in 1946 Dr. Patterson became its President, and at the first meeting at Toronto in 1947, where most of the members were less than half his age, he surprised them by the energy with which he set about the task of organizing the work of the new Commission. He was re-elected President at the end of the meeting, and continued to lead the activities of the Commission for the next seven years. He again presided at the second meeting also at Toronto in 1954, and it was only after then, at the age of 83, that his active service for international meteorology ceased, but his interest in the work of the Commission for Instruments and Methods of Observation continued.

He was President of the Conference of British Empire Meteorologists held in 1935, and attended the similar Conferences held in 1929 and 1946.

Perhaps his greatest achievement was the guidance of the Canadian Meteorological Service through a period of unparalleled expansion in the early days of the Second World War to meet the meteorological requirements of the British Commonwealth Air Training Plan. He was unsparing in his efforts to make members of the Meteorological Office staff, sent to stations in Canada for duty at R.A.F. Training Schools, feel at home, and dealt sympathetically with the problems and difficulties affecting the work and welfare of his British colleagues. His wisdom, judgement and absolute integrity played a large part in settling many difficult questions of meteorological organization in which the British

Commonwealth and the United States of America were involved, before and after Pearl Harbour.

Among the honours he received from scientific societies were his election as President of the American Meteorological Society in 1931, and to Honorary Membership of the Royal Meteorological Society in 1941, and of the American Meteorological Society in 1953. The citation for his honorary membership of the American Meteorological Society referred to him as the "grand old man" of Canadian meteorology, Director of Canadian Meteorological Services through periods when those Services seemed to be subject to neglect by higher authority and through periods of great growth and achievement. The citation continued to state that he performed his duty as Director with great dignity and the highest of professional and scientific ideals, and to recognize his great contribution to meteorological instrumentation and his services as Councillor and President of the Society.

He retired as Controller in September 1946, but continued to take an active interest in meteorology until a few months before his death. His long and outstanding services to meteorology were recognized by the inauguration of the Patterson Medal to be awarded annually by the Canadian Government to a Canadian resident for achievement in meteorology. Dr. Patterson was the first recipient of this medal in March 1955.

O. G. SUTTON

METEOROLOGICAL OFFICE NEWS

Ocean weather ships.—The following is an extract from the Radio Overseer's report of Voyage 66 of the *Weather Watcher*.

As usual on Station A certain difficulties were encountered in maintaining communication on the channels available; this was particularly so during the major ionospheric disturbance which started on the morning of Thursday, February 23 and which affected the station's communications for varying periods from that date until Sunday, February 26. It was noted that particularly during the first 24 hr. of this disturbance frequencies down to about 600 Kc./sec. were affected, whereas from previous experience such disturbances had only affected frequencies down to approximately 2,500 Kc./sec. During these periods of poor propagation traffic was cleared on M/F through Reykjavik or else through an American weather ship to Washington. Also during this period a number of signals were cleared for overflying aircraft when this ship was very often the only radio contact the aircraft had had since getting out of VHF range of their departure point.

It was during this period that a British submarine was reported missing for several hours, the reason being that she could not communicate with the Admiralty.

Sports activities.—Mr. M. Garrod was a member of the Air Ministry team which won the Civil Service 14-mile road relay race around the City of London on Saturday, March 17.

WEATHER OF MARCH 1956

Information was very incomplete for much of the northern hemisphere, particularly over the oceans and in the Asiatic sector, at the date of writing. Most features of the general circulation appear, however, to have followed very much the normal pattern for March. Chief interest might well be attached to the notable frequency of intense circulations, particularly of depressions over the western North Atlantic where the lowest mean pressure for the month was close to normal (1003 mb.) near 60°N. 35°W. This was accompanied by deeper than normal depressions (990 mb.) passing into the Arctic by way of east Greenland and the Barents Sea where there was pronounced advection of warm air. At the same time the Eurasian anticyclones established a dominance over Europe throughout the month, mean pressure at Helsinki reaching 1023 mb. (anomaly + 10 mb.) with persistent cold easterly and south-easterly winds over southern and central Europe occasionally reaching England. Low pressures over the Canadian archipelago were largely the result of depressions passing through Davis Strait from the Atlantic, but at least one intense depression came across northern Canada from the Pacific. About the middle of the month cyclonic activity from both sides of Greenland spread to the region of the North Pole. Mean pressure for the month was 6–8 mb. below normal over all Greenland, and there was a notable absence of northerly outbreaks in the east Greenland Sea.

There were no outstanding temperature anomalies, though most of Europe and North America were rather cold, the anomaly reaching −6°C. in the Canadian archipelago, whereas Bear Island and much of the Barents Sea were 5–6°C. less cold than normal.

Precipitation was excessive in a broad region of the Canadian Rockies and Prairies, along a strip from the Appalachians and New England to north-east Greenland, where three times the normal amount was collected at one station, and also in the Iberian peninsula, the central and eastern Mediterranean, Turkey and a small area in central Europe including the eastern Alps.

In the British Isles, apart from the first week which was changeable with generally westerly winds, the weather was mainly dry and sunny and dominated by winds from between S. and SE. which were maintained by a persistent anticyclone over European Russia and an equally persistent low-pressure area to the south-west of Ireland.

During the first three days strong westerly winds brought dull, mild weather with periods of rain. Most of the rain fell in Scotland where it was heavy on the 1st, more than 1 in. falling at Renfrew in 24 hr., but apart from this, daily totals of rainfall were small throughout the whole month. Winds veered towards the NW. on the 4th and the cooler, less stable air stream gave sunny but showery weather; the showers were well scattered in the south, but in Scotland they were rather frequent and occasionally fell as snow or sleet. The following day was also sunny, the showers in the south died out and winds backed again to W. as an anticyclone developed over the western English Channel. Another anticyclone moving south-east from Greenland reached the northern North Sea on the 7th where it joined with a ridge from the anticyclone off our south-west coasts. The resulting high-pressure system moved eastwards and was centred over northern Germany on the 9th, and the next day was absorbed into an anticyclone which had developed over European Russia. Except for a dull wet day over Scotland and Northern Ireland on the 9th, the second week of the month was generally dry, sunny and rather cold over most of the country with mainly light south-easterly winds. Day temperatures were about normal except in the south, but there was widespread frost at night, temperature falling as low as 21°F. at Birmingham on the 12th. On the 14th and 15th colder air from the Continent brought slight snow to the eastern districts of England and Scotland, but on the 16th winds veered somewhat and temperature returned to normal in most places, though the weather was rather dull with occasional rain as a small secondary depression moved over south-west Ireland. By the 20th a deep depression had formed off western Ireland, and winds reaching southern England were mainly of Atlantic origin. The following week was mild with rain at times in all parts of the country but some sunshine on most days. Temperature exceeded 60°F. at many places on the 23rd and 26th; on the latter date 65°F. was reached at Mildenhall and Cardington and there were fairly widespread thunderstorms. Winds became easterly again on the 27th as the depression off south-west Ireland filled up, but on the 29th a low-pressure area developed over the North Sea and winds backed further towards the north. Weather was mainly dry with variable cloud during the last five days of the month, but on Good Friday, the 30th, and the following day, the north-easterly winds gave dull and cold conditions over parts of north-east Scotland and eastern England, but further west it was sunny and rather warm, outstandingly so in the Hebrides where sunshine for the last week of the month averaged 10 hr. / day.

The dry sunny weather was nearly ideal for all land cultivations and sowings. Work is therefore well forward, even on heavy soils. Sheep, lambs and cattle are in good condition, but the growth of grass for which warm rain is needed has been retarded. In the south-west the main crop of daffodils, though late, is good, but last month's frost has caused widespread devastation of most other flowers and early vegetables.

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 ...	66	16	+0·3	46	−6	119
Scotland	65	17	+0·5	58	−7	114
Northern Ireland ...	60	27	+1·4	64	−4	107

RAINFALL OF MARCH 1956

Great Britain and Northern Ireland

County	Station	In.	Per cent. of Av.	County	Station	In.	Per cent. of Av.
London	Camden Square ...	0·99	54	*Glam.*	Cardiff, Penylan ...	1·37	43
Kent	Dover	0·44	21	*Pemb.*	Tenby	0·95	31
,,	Edenbridge, Falconhurst	1·07	43	*Radnor*	Tyrmynydd	4·05	75
Sussex	Compton, Compton Ho.	0·59	21	*Mont.*	Lake Vyrnwy	3·24	72
,,	Worthing, Beach Ho. Pk.	0·27	14	*Mer.*	Blaenau Festiniog ...	5·06	59
Hants.	St. Catherine's L'thouse	0·31	16	,,	Aberdovey	2·04	61
,,	Southampton (East Pk.)	0·68	30	*Carn.*	Llandudno	1·31	65
,,	South Farnborough ...	0·53	27	*Angl.*	Llanerchymedd ...	1·20	40
Herts.	Harpenden, Rothamsted	0·97	47	*I. Man*	Douglas, Borough Cem.	1·37	46
Bucks.	Slough, Upton	0·63	36	*Wigtown*	Newton Stewart ...	2·03	59
Oxford	Oxford, Radcliffe ...	0·68	41	*Dumf.*	Dumfries, Crichton R.I.	1·56	52
N'hants.	Wellingboro' Swanspool	0·85	47	,,	Eskdalemuir Obsy. ...	2·58	53
Essex	Southend, W. W. ...	0·60	39	*Roxb.*	Crailing...	0·75	35
Suffolk	Felixstowe	0·85	57	*Peebles*	Stobo Castle	1·84	63
,,	Lowestoft Sec. School ...	0·71	44	*Berwick*	Marchmont House ...	0·79	30
,,	Bury St. Ed., Westley H.	0·65	34	*E. Loth.*	North Berwick Gas Wks.	0·80	43
Norfolk	Sandringham Ho. Gdns.	0·76	40	*Midl'n.*	Edinburgh, Blackf'd. H.	1·07	54
Wilts.	Aldbourne	0·43	18	*Lanark*	Hamilton W. W., T'nhill	2·05	73
Dorset	Creech Grange... ...	0·94	33	*Ayr*	Prestwick	1·23	53
,,	Beaminster, East St. ...	1·01	34	,,	Glen Afton, Ayr San. ...	3·68	88
Devon	Teignmouth, Den Gdns.	0·98	38	*Renfrew*	Greenock, Prospect Hill	3·14	68
,,	Ilfracombe	1·13	39	*Bute*	Rothesay, Ardencraig ...	3·10	86
,,	Princetown	3·96	58	*Argyll*	Morven, Drimnin ...	2·20	45
Cornwall	Bude, School House ...	2·52	103	,,	Poltalloch	2·87	75
,,	Penzance	1·61	50	,,	Inveraray Castle ...	5·03	79
,,	St. Austell	2·26	66	,,	Islay, Eallabus	2·66	70
,,	Scilly, Tresco Abbey ...	1·69	65	,,	Tiree	1·42	42
Somerset	Taunton	0·85	41	*Kinross*	Loch Leven Sluice ...	1·75	59
Glos.	Cirencester	0·53	22	*Fife*	Leuchars Airfield ...	1·04	53
Salop	Church Stretton ...	1·52	63	*Perth*	Loch Dhu	4·62	70
,,	Shrewsbury, Monkmore	1·00	60	,,	Crieff, Strathearn Hyd.	2·29	72
Worcs.	Malvern, Free Library...	0·86	44	,,	Pitlochry, Fincastle ...	2·93	106
Warwick	Birmingham, Edgbaston	1·04	49	*Angus*	Montrose, Sunnyside ...	1·17	56
Leics.	Thornton Reservoir ...	1·05	57	*Aberd.*	Braemar	2·34	79
Lincs.	Boston, Skirbeck ...	0·93	60	,,	Dyce, Craibstone ...	1·59	60
,,	Skegness, Marine Gdns.	0·84	51	,,	New Deer School House	1·36	53
Notts.	Mansfield, Carr Bank ...	0·67	32	*Moray*	Gordon Castle	0·67	29
Derby	Buxton, Terrace Slopes	2·31	56	*Nairn*	Nairn, Achareidh ...	0·74	40
Ches.	Bidston Observatory ...	1·25	66	*Inverness*	Loch Ness, Garthbeg ...	1·82	55
,,	Manchester, Ringway...	1·07	49	,,	Loch Hourn, Kinl'hourn	3·64	39
Lancs.	Stonyhurst College ...	1·47	40	,,	Fort William, Teviot ...	3·94	59
,,	Squires Gate	0·89	39	,,	Skye, Broadford ...	3·58	59
Yorks.	Wakefield, Clarence Pk.	0·64	36	,,	Skye, Duntuilm ...	1·63	37
,,	Hull, Pearson Park ...	1·06	58	*R. & C.*	Tain, Mayfield... ...	1·19	53
,,	Felixkirk, Mt. St. John...	0·60	30	,,	Inverbroom, Glackour...	2·83	57
,,	York Museum	1·11	66	,,	Achnashellach	1·57	23
,,	Scarborough	0·88	49	*Suth.*	Lochinver, Bank Ho. ...	0·90	24
,,	Middlesbrough... ...	0·48	31	*Caith.*	Wick Airfield	1·63	72
,,	Baldersdale, Hury Res.	2·36	82	*Shetland*	Lerwick Observatory ...	2·30	73
Norl'd.	Newcastle, Leazes Pk....	1·03	50	*Ferm.*	Crom Castle	2·36	76
,,	Bellingham, High Green	0·92	31	*Armagh*	Armagh Observatory ...	2·74	117
,,	Lilburn Tower Gdns. ...	0·93	35	*Down*	Seaforde	1·80	62
Cumb.	Geltsdale	1·75	63	*Antrim*	Aldergrove Airfield ...	1·45	58
,,	Keswick, High Hill ...	2·13	47	,,	Ballymena, Harryville...	1·50	48
,,	Ravenglass, The Grove	1·37	44	*L'derry*	Garvagh, Moneydig ...	1·27	41
Mon.	A'gavenny, Plâs Derwen	1·40	42	,,	Londonderry, Creggan	1·34	42
Glam.	Ystalyfera, Wern House	2·50	47	*Tyrone*	Omagh, Edenfel ...	2·11	67

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