M.O. 702 AIR MINISTRY

METEOROLOGICAL OFFICE

THE METEOROLOGICAL MAGAZINE

VOL. 90, No. 1070, SEPTEMBER 1961

551.511.3:551.513.1

SEASONALLY INDUCED MERIDIONAL FLUX OF MOMENTUM IN THE ATMOSPHERE

By A. H. GORDON, M.Sc.

Introduction.—The atmospheric general circulation arises as a consequence of the conversion to kinetic energy of that fractional part of the sun's radiant heat energy which is received by the earth. The energy transformation takes place because of differential heating, which is mainly meridional, but also zonal locally, particularly in the northern hemisphere. In order to investigate changes in the general circulation of the order of a month in time and on a global scale it is useful to select a simple parameter which can be easily measured. Such a parameter is found in the mean zonal index of the geostrophic wind, calculated for standard pressure levels over ten-degree belts of latitude and integrated round the world.

The recent work of Heastie and Stephenson[1] provides the basic data from which mean zonal indices of the geostrophic wind can be computed. The data extend from the North Pole to 60°S and from 700 to 100 millibars inclusive.

The induced meridional velocities.—If contour gradients are averaged around parallels of latitude it may be assumed that the mean wind is geostrophic at all latitudes and heights. For the purpose of the calculations advanced in this work the geostrophic assumption is also extended to low latitudes where it is considered that the meridional contour gradients are sufficiently small to enable geostrophic balance to be established at mean velocities of reasonable magnitude. Since the mean zonal winds are computed for the intermediate latitudes (that is, 5°, 10°, 15°, etc.) the discontinuity of an infinite velocity at the equator itself does not arise.

The geostrophic departure equation for instantaneous motion in the customary notation where the horizontal component velocities u, v are orientated along the x, y axes, respectively, is

$$\frac{du}{dt} = fv'$$
$$\frac{dv}{dt} = -fu' \qquad \ldots (1)$$

where u', v' are the departure velocities.

If, initially, the geostrophic motion is assumed wholly zonal, any change in that motion will be described by the first relation of equations (1), where $v' = v$. Expansion of the acceleration term on the left-hand side for horizontal motion gives

$$\frac{du}{dt} = \frac{\partial u}{\partial t} + \frac{u \,\partial u}{\partial x} + \frac{v \,\partial u}{\partial y}. \quad \ldots (2)$$

If the right-hand sides of equations (1) and (2) are set equal to one another, it follows that

$$v = \frac{\dfrac{\partial u}{\partial t} + \dfrac{u \,\partial u}{\partial x}}{f - \dfrac{\partial u}{\partial y}}. \quad \ldots (3)$$

Equation (3) refers to instantaneous motion; however, it is the mean motion that we wish to study, as given by the mean zonal wind index integrated around latitude circles. We will therefore denote the mean zonal motion by U, and the mean meridional motion by V. Equation (2) then becomes

$$\frac{dU}{dt} = \frac{\partial U}{\partial t} + \frac{U \,\partial U}{\partial x} + \frac{V \,\partial U}{\partial y} + \frac{\partial \overline{u'u'}}{\partial x} + \frac{\partial \overline{u'v'}}{\partial y} \quad \ldots (4)$$

as derived by Lettau.[2] In equation (4) u', v' are the turbulent velocities which are superimposed on the mean motion U, V to give the actual velocities u, v. The last two terms on the right-hand side of equation (4) are the eddy stress terms. Now if the integration is carried out around the globe along circles of latitude $\partial/\partial x = 0$ and the right-hand side of equation (4) becomes

$$\frac{\partial U}{\partial t} + \frac{V \,\partial U}{\partial y} + \frac{\partial \overline{u'v'}}{\partial y}.$$

Thus, from equation (3)

$$V = \frac{\dfrac{\partial U}{\partial t} + \dfrac{\partial \overline{u'v'}}{\partial y}}{f - \dfrac{\partial U}{\partial y}}. \quad \ldots (5)$$

The mean meridional velocity V may now be computed for specified pressure levels for the seasonally induced changes in the mean zonal wind as indicated by the term $\partial U/\partial t$. The latter term may be evaluated for the four seasonal periods January–April, April–July, July–October and October–January. The evaluation of all terms in equation (5) may be carried out in a straightforward way from the calculated mean geostrophic winds, except for the eddy stress term. An assessment of this term may be obtained from monthly charts of the eddy motion flux contained in the *Atlas of 300 mb. wind characteristics for the northern hemisphere.*[3] It is found that the eddy term at 300 millibars is at least one order of magnitude less than $\partial U/\partial t$ when averaged around the globe. Although this evaluation of the eddy motion term has only been carried out at 300 millibars it may be assumed that the relative magnitude would not be greater at other pressure levels where the mean zonal motion is less.

Figure 1 (*a*)–(*d*) shows the patterns of meridional velocities induced by the changing heat balance caused by the changing seasons; positive values represent a southerly drift in the northern hemisphere and a northerly drift in the southern hemisphere—with this convention the ordinate of the system of coordinates is directed towards the pole for both hemispheres. The order of magnitude of the velocities is about one tenth of the magnitude of the values calculated by Tucker[4] from actual wind observations. But the velocity patterns in Figure 1 (*a*)–(*d*) may be considered as being superimposed on the normal climatological meridional motion, and the latter may be looked upon as resulting from frictional stresses which prevent the establishment of geostrophic flow in the frictional layer. In a restricted, wholly frictionless atmosphere in which the differential heating was only meridional, the mean meridional velocities would be controlled solely by the seasonal changes in this heating and would be of the order of those in Figure 1 (*a*)–(*d*).

It is noted that the velocities are largest in the vicinity of the equator. Although this occurs because of the assumption that geostrophic flow exists there, the fact that the flow may not be exactly geostrophic does not invalidate the bases of the calculations in this region. Meridional velocities will be largest there whether the geostrophic assumption is made or not. If they are calculated directly from the accelerations arising from the existence of the relatively weak contour gradients the velocities will grow rapidly with increasing distance from the reference latitude. The geostrophic departure equation can give a useful guide to the induced meriodional velocities at low latitudes using a range of latitude of 10°.

The pattern in Figure 1 (*a*) illustrates the induced motion between January and April. The trend is for a northerly drift between 60°N and 40°S. Poleward of these latitudes the motion is southerly. Figure 1 (*b*) shows the pattern from April to July; the northerly velocities have increased reaching a maximum of nearly 30 cm sec^{-1} within the 200–100-millibar layer. They have also extended into the Arctic. During the following six months the motion has reversed to mainly southerlies. The flow is mainly northerly in the Arctic between October and January.

The divergence.—The seasonally induced divergence patterns may be derived from values computed from the formula

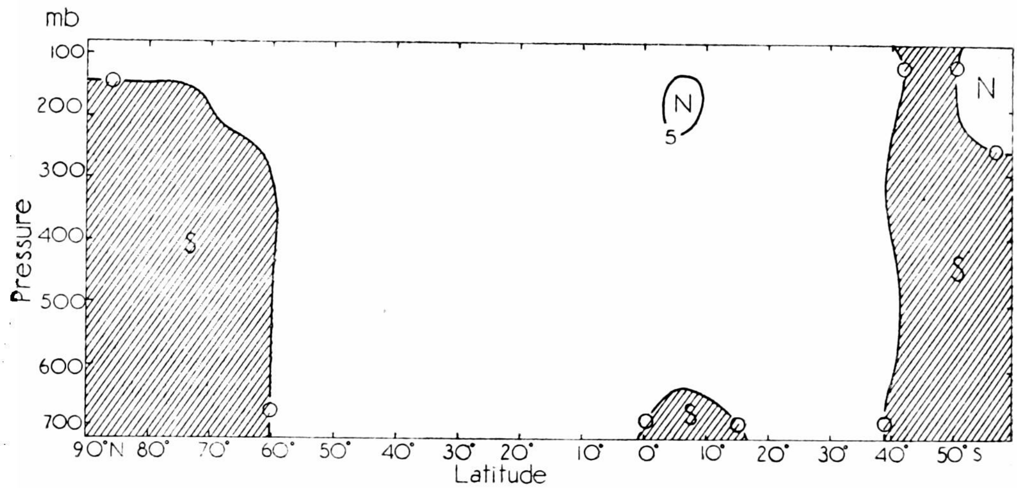
$$\text{div}\ V = \frac{\partial V}{R\partial\phi} - \frac{V}{R}\tan\phi, \qquad \ldots (6)$$

where R is the radius of the earth, ϕ the latitude and V is the mean meridional velocity calculated from equation (3). The patterns are shown in Figure 2 (*a*)–(*d*) for each of the four periods January–April, April–July, July–October and October–January.

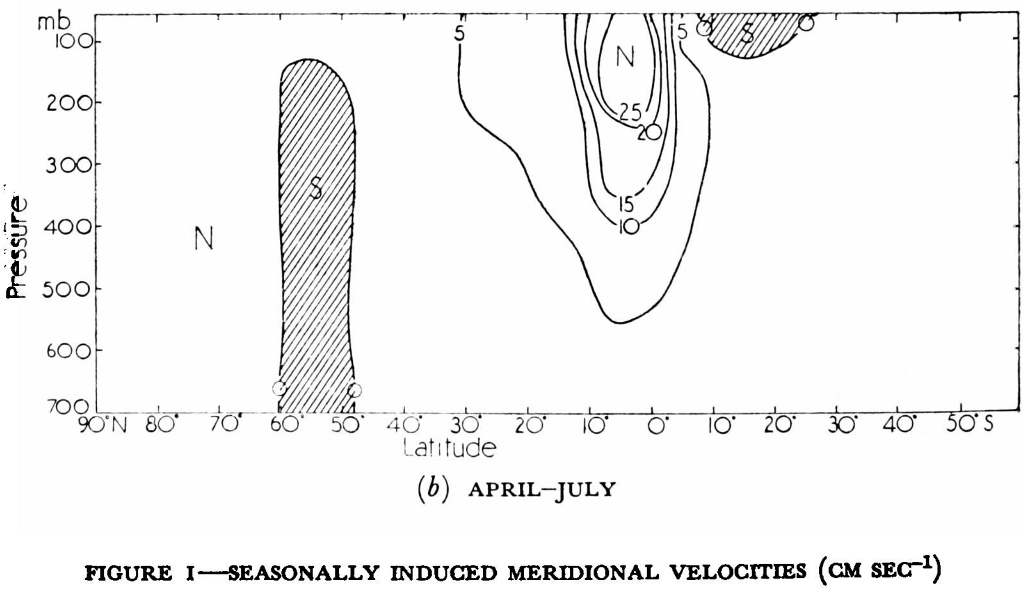
Figure 2 (*a*), January–April, shows a large area of divergence between 70°N and 10°S. The Arctic north of 70°N is under the influence of convergence. In the southern hemisphere the region between 10° latitude and 45° latitude is subject to convergence also. The general pattern agrees well with the observed changes in the mean pressure distribution. For example, it is known[5,6] that mean pressure rises in the region of the North Pole and falls in other belts of latitude in the northern hemisphere between January and April. The mass transfer from the northern to the southern hemisphere is accompanied by an increase in the intensity of the southern hemisphere subtropical anticyclone in these months.

Figure 2(*b*), April–July, shows that the divergence has extended well into the Arctic. This agrees with the fall in mean pressure observed in that area between spring and summer. An unexpected belt of convergence occurs at 60°N, a phenomenon which needs further investigation, as displacement of this belt may have effects on the northern hemisphere summers of the temperate latitudes. Elsewhere the general picture is similar to Figure 1(*a*). Maximum values appear near the equator. This is to be expected, since geostrophic control is small and induced meridional velocities are correspondingly large.

The patterns for the changes from summer to autumn and autumn to winter shown in Figure 2(*c*) and (*d*) are broadly the reverse of those occurring during the first half of the year. These, too, agree with the observed reversed mass transfer from the southern to the northern hemisphere, which is associated with the intensification of the northern hemisphere winter anticyclone.

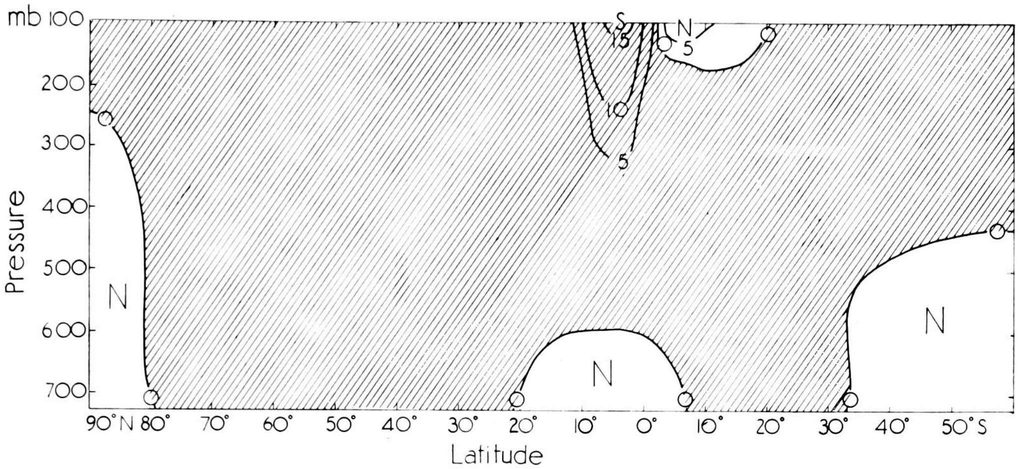


(*a*) JANUARY–APRIL

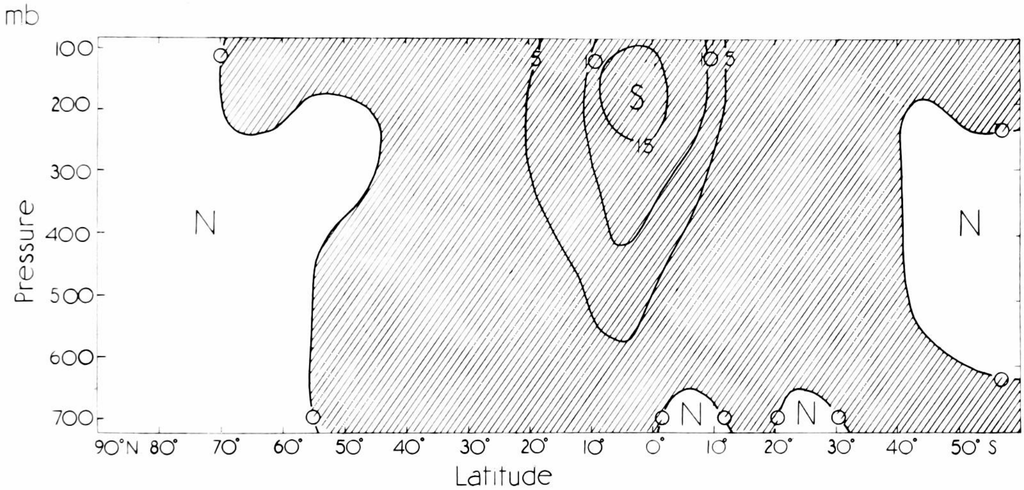


(*b*) APRIL–JULY

FIGURE 1—SEASONALLY INDUCED MERIDIONAL VELOCITIES (CM SEC^{-1})
Southerlies are shaded.

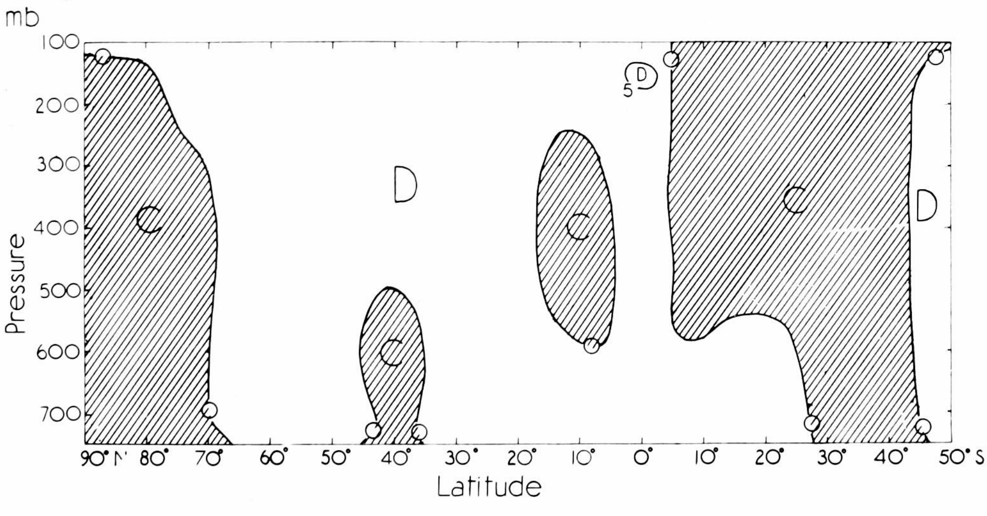


(*c*) JULY–OCTOBER



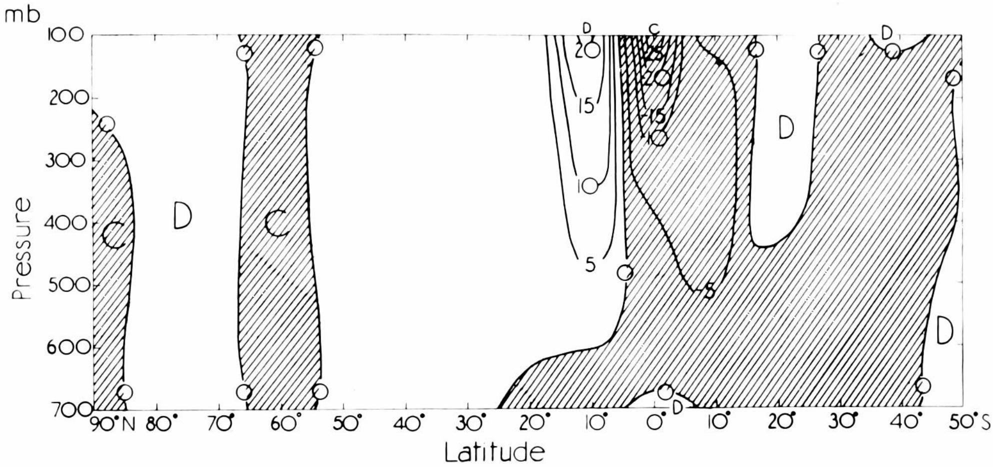
(*d*) OCTOBER–JANUARY

FIGURE 1—SEASONALLY INDUCED MERIDIONAL VELOCITIES (CM SEC^{-1}) *cont.*

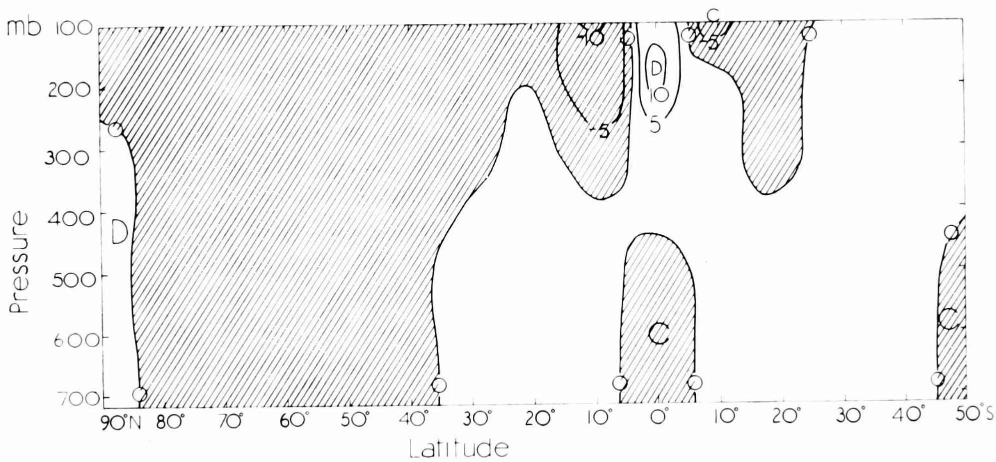


(*a*) JANUARY–APRIL

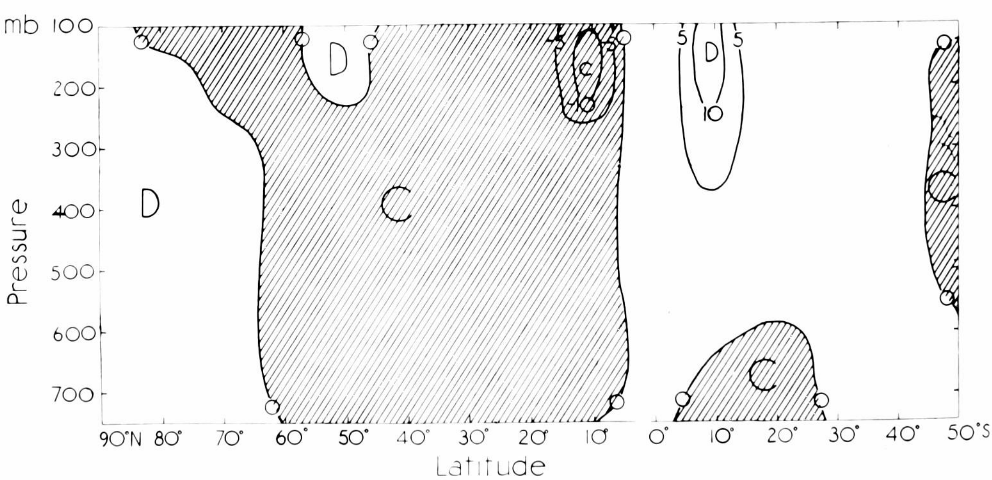
FIGURE 2—SEASONALLY INDUCED DIVERGENCE (10^{-8} SEC^{-1})



(*b*) APRIL–JULY



(*c*) JULY–OCTOBER



(*d*) OCTOBER–JANUARY

FIGURE 2—SEASONALLY INDUCED DIVERGENCE (10^{-8} SEC^{-1}) *cont.*

Conclusion.—The changing meridional heating differential which accompanies the seasonal northward and southward march of the sun creates changes in the mean zonal index of geostrophic wind. These changes in the mean zonal wind induce a mean meridional circulation which is superimposed upon the frictionally driven actual meridional circulation. The seasonally induced meridional circulation gives rise to fields of convergence and divergence which are consistent with the known pattern of changes in the mean pressure and with the known mass transfers which take place throughout the year between the hemispheres.

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SEVERE CLEAR-AIR TURBULENCE NEAR THE BRITISH ISLES

By J. BRIGGS, B.A.

Introduction.—Previous analyses by Bannon[1,2] and Jones[3] have related the occurrence of severe clear-air turbulence to features shown on the upper air charts. Since these analyses a considerable number of reports of turbulence have been received and a further analysis seemed desirable. The reports, similar to those used in the previous papers, are mainly supplied by aircrew of the Royal Air Force or Royal Navy and the severity of the turbulence is generally a qualitative estimate; to obtain some uniformity of assessment, aircrew were asked to regard severe turbulence as corresponding to accelerations exceeding $\pm 0 \cdot 5g$ and as characterized by difficulty in maintaining aircraft attitude or heading and with a marked tendency to be lifted from one's seat.

This paper examines 105 cases of severe clear-air turbulence at heights above 10,000 feet in the vicinity of the British Isles; the reports cover the period January 1958 to December 1960.

Relation of occurrences of clear-air turbulence to height and to the tropopause.—The distribution of the occurrences of turbulence in relation to the height above the ground and to the height of the tropopause, as estimated on the basis of the radio-sonde network are presented in Tables I and II.

The indicated peak frequency of turbulence at about 7500 metres (alternatively at about 3250 metres below the tropopause) and the secondary maximum near the tropopause are thought to be reliable although only very limited information is available regarding the different amount of flying time at different heights. Figures supplied by three service units have been used to

TABLE I—NUMBER OF OCCURRENCES OF SEVERE CLEAR-AIR TURBULENCE IN SPECIFIED HEIGHT BANDS

Height band *metres*	No. of occurrences	Height band *metres*	No. of occurrences
<4000	1	9001–10,000	8
4001–5000	3	10,001–11,000	13
5001–6000	9	11,001–12,000	3
6001–7000	14	12,001–13,000	11
7001–8000	22	13,001–14,000	4
8001–9000	15	>14,000	2

TABLE II—NUMBER OF OCCURRENCES OF SEVERE TURBULENCE FOR SPECIFIED HEIGHT BANDS ABOVE OR BELOW THE TROPOPAUSE

Height above tropopause *metres*	No. of occurrences	Height below tropopause *metres*	No. of occurrences
4501–5500	1	501–1500	5
3501–4500	2	1501–2500	12
2501–3500	4	2501–3500	19
1501–2500	3	3501–4500	16
501–1500	7	4501–5500	8
Within 500 metres		5501–6500	6
of tropopause	17	6501–7500	4
		>7500	1

obtain a rough estimate of the frequency of occurrence; the figures did not permit study of different height bands. With no allowance for variation with height the frequency of severe turbulence is one occurrence in 530 hours of flying between 15,000 and 45,000 feet.

The apparent decrease in incidence of turbulence with increasing penetration of the stratosphere is probably partly due to decreased flying time at the higher altitudes, but is thought to indicate a real decrease in frequency of turbulence. The highest report received, at 16,160 metres, was some 4000 metres above the tropopause though the nature of the report suggested that the "turbulence" may not have been entirely due to meteorological factors.

Relation of occurrence of severe turbulence to upper air features.—Following Bannon[1,2] and Jones [3], each occurrence was related to features shown on the *Daily Aerological Record* though, where necessary, supplementary charts and cross-sections were drawn to assist the placing of the turbulence in regard to the features of the upper air charts. Table III presents a summary of these comparisons.

TABLE III—NUMBER OF OCCURRENCES OF SEVERE TURBULENCE ASSOCIATED WITH SPECIFIED FEATURES OF UPPER AIR CHARTS

Upper air feature	No. of occurrences
Jet stream with axis not more than 100 nautical miles from occurrence ...	73
Upper trough or upper low	22
Near tropopause (but no associated jet stream)	2
Unclassified	8
Total	105

The unclassified cases showed no special features of wind or temperature shear and were mainly on the edges of upper anticyclones or ridges. Here a jet stream is regarded as a concentration of almost straight contours corresponding to a wind maximum of 80 knots or more and having a definite decrease in wind speed on each side. The 73 cases associated with jet streams were further subdivided in regard to position relative to the jet axis and across the flow. Table IV presents the results of this subdivision.

TABLE IV—NUMBER OF OCCURRENCES OF TURBULENCE IN RELATION TO JET AXIS

Position		No. of occurrences
Below jet axis and	on low pressure side	46
	on high pressure side	2
Above jet axis and	on low pressure side	10
	on high pressure side	15
	Total	73

Although estimates of the position of the jet axis based on the radiosonde network are necessarily somewhat subjective the errors should average out and the main features, presented in Table IV, are thought to be accurately shown. The almost complete absence of turbulence below the axis and on the high pressure side of the axis is the most outstanding feature; this confirms the previous analyses.

Estimates of the incidence of turbulence in regard to the position along the jet stream were not generally possible and reliable figures for this aspect cannot be given though there was some indication that the exit zone of the jet stream was the most favoured region for turbulence.

Relation of turbulence to vertical stability and horizontal wind shear.—For each report of turbulence an estimate was made, based on the radiosonde network, of temperature lapse rate, vertical wind shear and horizontal wind shear; the standard criterion of vertical stability, the Richardson number *Ri*, was then determined. Table V is a summary of the values obtained for *Ri* and for horizontal wind shear.

TABLE V—NUMBER OF OCCURRENCES OF SEVERE CLEAR-AIR TURBULENCE CORRESPONDING TO SPECIFIED VALUES OF *Ri* AND OF HORIZONTAL WIND SHEAR

Horizontal shear hr^{-1}	Value of *Ri* >10	>5 and ⩽10	>1 and ⩽5	⩽1	Total
			number of occurrences		
⩽0·1	8	1	5	1	15
>0·1 and ⩽0·2	3	3	1	12	19
>0·2 and ⩽0·3	1	2	10	1	14
>0·3 and ⩽0·4	1	0	7	2	10
>0·4 and ⩽0·5	5	3	6	2	16
>0·5	0	0	6	17	23
No estimate	2	2	3	1	8
Total	20	11	38	36	105

Interpolation between radiosonde values introduces a certain subjective element; also clear-air turbulence is generally limited to depths of the order of 1000–2000 feet and horizontal distances of 10–20 miles, whereas the radiosonde winds are spaced at distances of the order of 100 miles and are means over depths of 3000 feet or more. Large shears over a shallow depth and short horizontal distance are necessarily smoothed in the interpolation and in the radiosonde winds so that the estimated shears are likely to be underestimates of the real shears corresponding to turbulence. The value of *Ri* depends on the reciprocal of the square of the vertical shear so that an underestimate of vertical shear, particularly when the shear is relatively small, leads to an exaggerated overestimate of

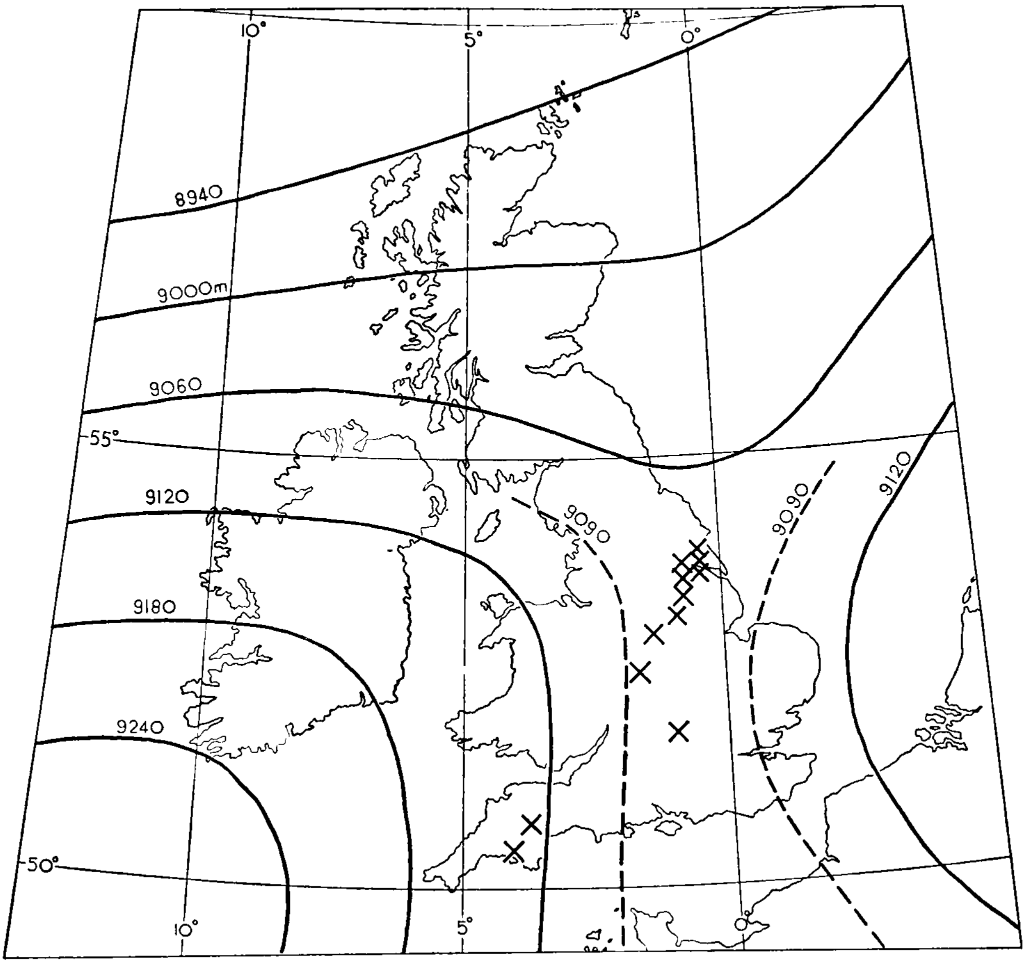

FIGURE 1—300 MB CHART FOR 1200 GMT, 30 APRIL 1959
Crosses mark positions of reports of severe clear-air turbulence.

Ri. The computed values of *Ri* must therefore be generally in excess of the real values obtaining in turbulent zones although the smaller values of *Ri*, corresponding to large shears, are likely to be quite close to the true values.

The separate effects of large horizontal shear and of large vertical shear are difficult to establish since Table V shows that, as can be expected from the frequency of association with jet streams, most occurrences had both these features. Considering the two factors separately it is seen that about 70 per cent of occurrences had values of *Ri* below 5 and that about 65 per cent had horizontal shears, of more than 0·2 hr^{-1}. These figures indicate the sort of success that estimates based on normal working charts might have in indicating turbulence but they do not provide reliable figures for the critical values of *Ri*, or of horizontal shear, associated with development of turbulence.

The occurrences of turbulence not associated with large horizontal shear nor with small values of *Ri* tended to be well into the stratosphere; thus of eleven occurrences with *Ri* exceeding 10 and horizontal shear not above 0·2 hr^{-1} six were more than 2000 metres above the tropopause, one more than 1000 metres above the tropopause, two near the tropopause and only two in the troposphere.

Notes on some individual cases

(*a*) *13 November 1958.* Very numerous and widespread reports of severe clear-air turbulence on this day have already been discussed.[4] The occurrences were associated with an exceptionally strong wind-shear in both the vertical and horizontal.

(*b*) *30 April 1959.* Twelve reports of severe turbulence on this day are marked on Figure 1 which represents the 1200 GMT 300-millibar chart. The turbulence is seen to have been in the vicinity of a sharp upper trough lying north to south across England. The winds were mainly northerly west of the axis of the trough and southerly east of the axis, although the light east–west components indicate convergence on to the trough axis. Figure 2 is a cross-section of the trough again showing the positions of reported turbulence. Isopleths of the wind speed normal to the section show the considerable horizontal wind shear between 275 and 400 millibars in the region of the trough axis; the shear was of the order of $0 \cdot 5 hr^{-1}$ for most of the reports of turbulence. The vertical shear was everywhere small except for the one report near 500 millibars and for the report at 250 millibars, that is, near the tropopause.

Of the twelve reports, seven reported the turbulence as corresponding to headings of 360 or 180 degrees and the other five reported turbulence on various headings. The aircraft were not engaged on special flights for the investigation of turbulence and it is to be expected that the relation of heading to turbulence occurrence would be mainly a matter of chance; therefore the large predominance of north and south headings in the reports suggests that the turbulence was most pronounced for these headings. This supports views put forward by Clodman[5], who has previously found some evidence for the anisotropic nature of turbulence when a strong horizontal shear of wind appears to have been the predominating factor.

(*c*) *12 December 1958.* Eight reports of severe clear-air turbulence are marked on Figure 3 which represents the 300-millibar chart for 1200 GMT. Except for the isolated report near Leuchars the occurrences were in the exit zone of the west to west-south-west jet stream lying across the southern half of Great Britain. Figure 4 is a north–south section across the main zone of turbulence and shows the jet axis at about 32,000 feet between Worcester and Hemsby. The turbulence is seen to have been in two main zones, one in the vicinity of the tropopause and another in the region of strong vertical shear below the jet axis. The two regions of turbulence above and below the jet axis just to the south of Hemsby were reported by the same aircraft and so strengthen the suggestion that the vertical wind shear appears to have been the most important factor in causing the turbulence.

(*d*) *18 December 1958.* Figure 5 shows the 1200 GMT 300-millibar chart for this day and marks two reports of very severe clear-air turbulence observed at 1400 GMT. The radiosonde ascents suggest that warm air covered Ireland, Wales and south-west England and the warm front at 300 millibars is indicated on the Figure. The front marks a change from light west or west-south-west winds to moderately strong west-north-west winds; a real jet stream is not indicated but nevertheless Figure 6, which is a section through the area of turbulence at right-angles to the west-north-west flow, shows a distribution of wind velocity similar to that of a typical jet stream and with a wind maximum of about 80 knots. The frontal zone was clearly a region of large shear of wind, both in the vertical and the horizontal. Allowing for the difference in time between the

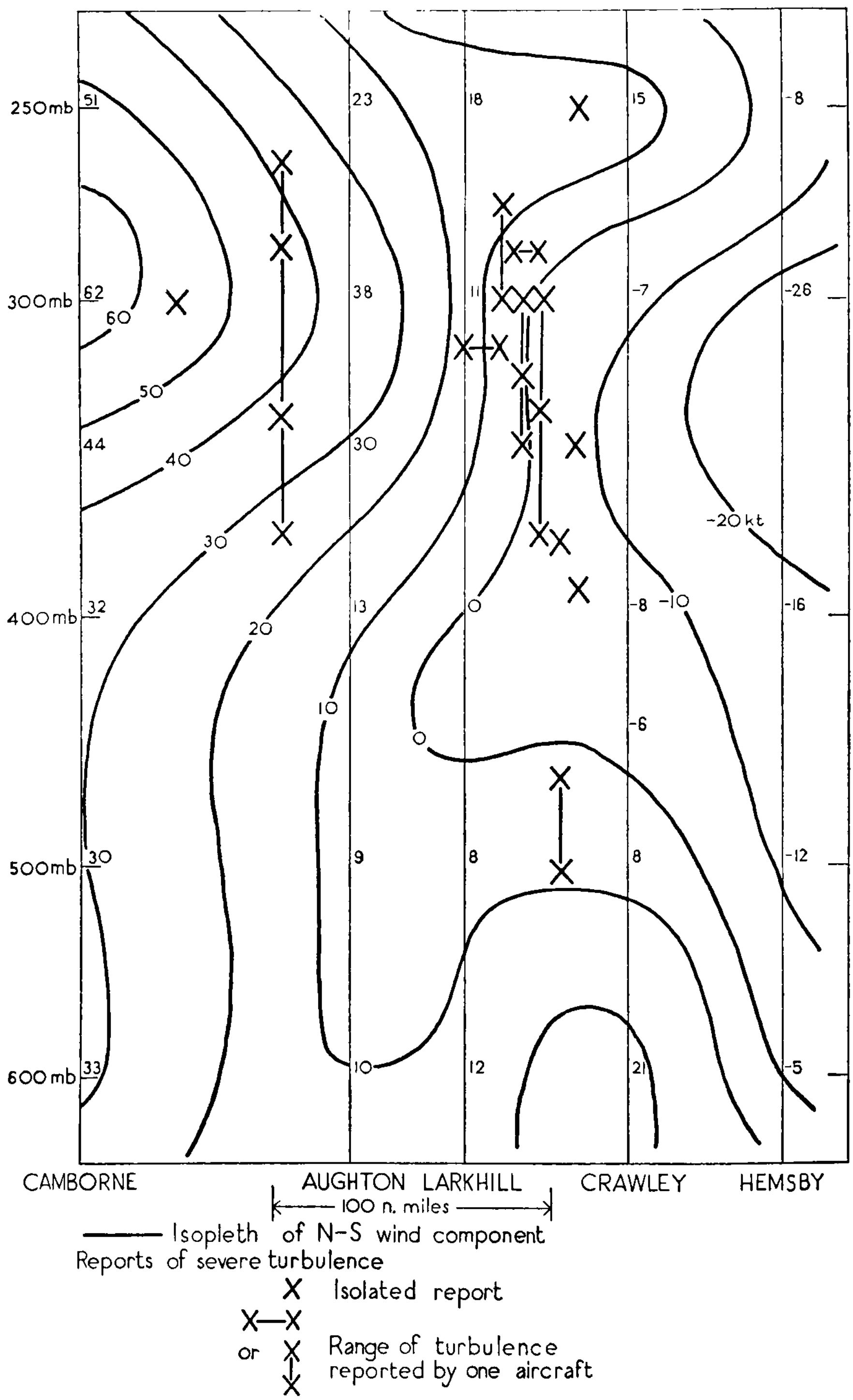

FIGURE 2—CROSS-SECTION FOR 1200 GMT, 30 APRIL 1959

Reported N-S wind components are plotted to the right of the stations.

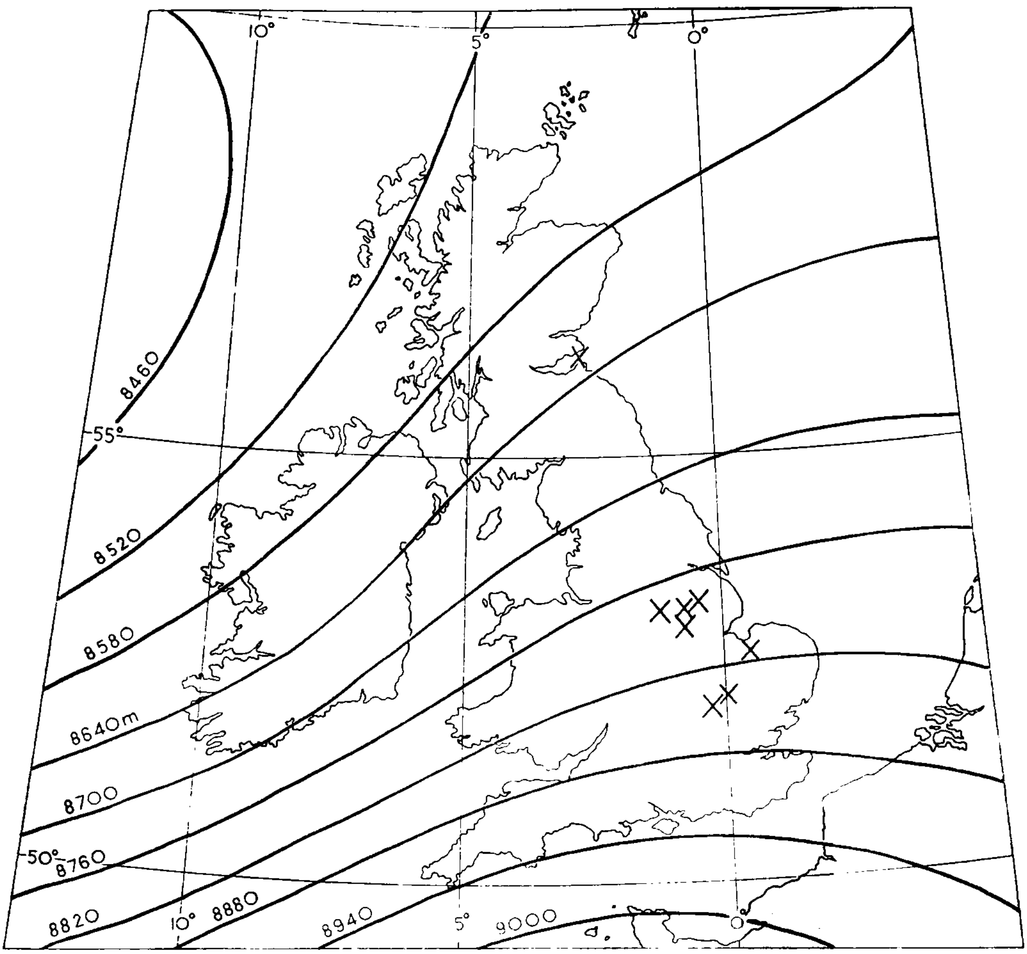

FIGURE 3—300 MB CHART FOR 1200 GMT, 12 DECEMBER 1958
Crosses mark positions of reports of severe clear-air turbulence.

section and the occurrence of turbulence it is apparent that the turbulence was almost coincident with the frontal transition zone.

Conclusions

(i) The present analysis confirms the previous findings of Bannon and Jones as regards association of severe turbulence with features of the upper air charts. The three main areas in which turbulence is found are:

(*a*) the zone of strong shear of wind usually found below a jet stream and somewhat to the low pressure side of the stream,

(*b*) the vicinity of a marked trough in the upper flow,

(*c*) near the tropopause (usually also near a jet stream).

(ii) Small values of the Richardson number and/or large values of horizontal shear are associated with most occurrences of severe turbulence. As regards forecasting it appears that mean values of *Ri* of less than 5, or of horizontal shear exceeding $0 \cdot 3$ hr^{-1}, if based on accurate forecasts of wind and temperature and computed for networks corresponding to that of the radiosondes would cover more than 80 per cent of occurrences. In this connexion it must be emphasized

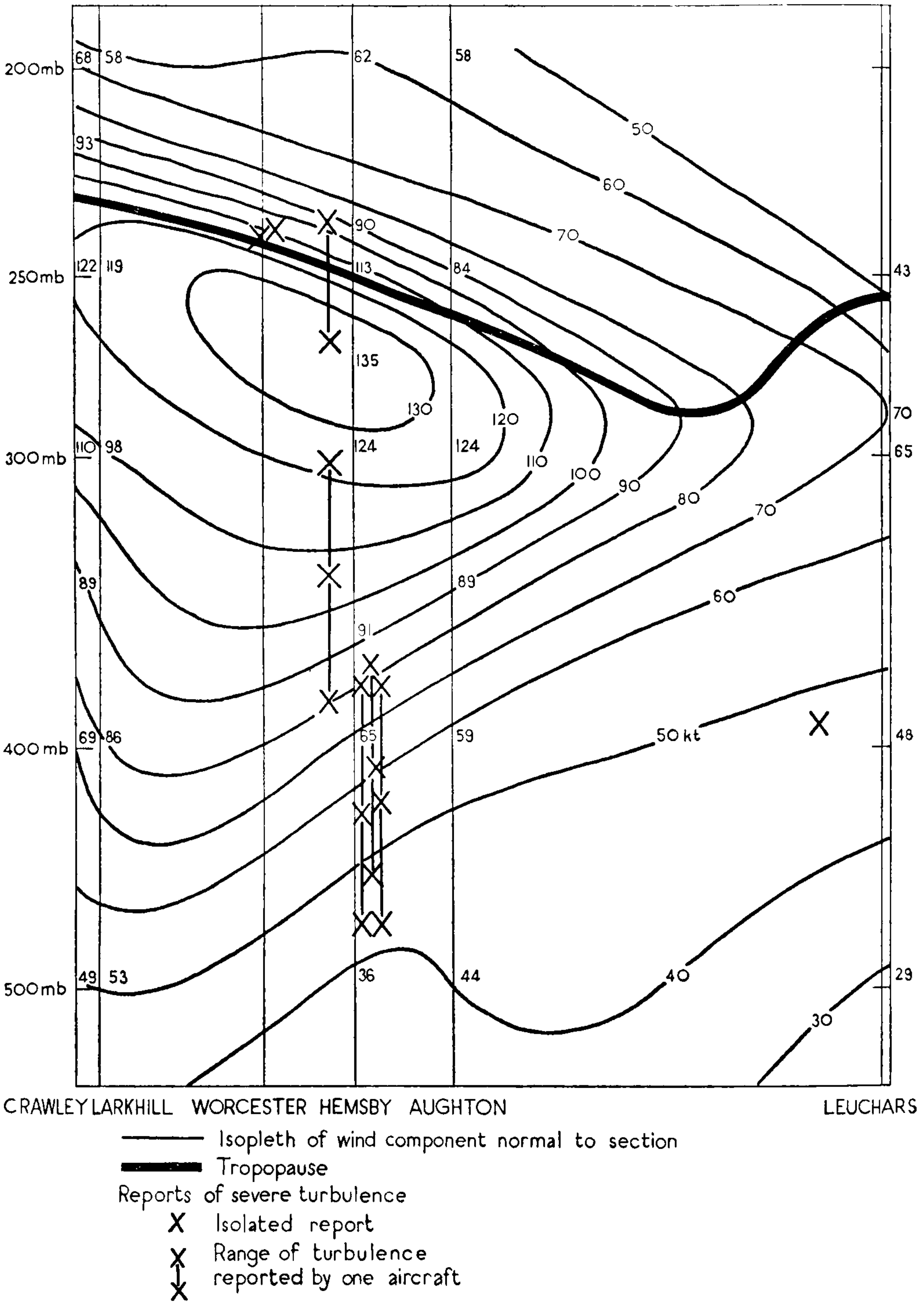

FIGURE 4—CROSS-SECTION FOR 1200 GMT, 12 DECEMBER 1958

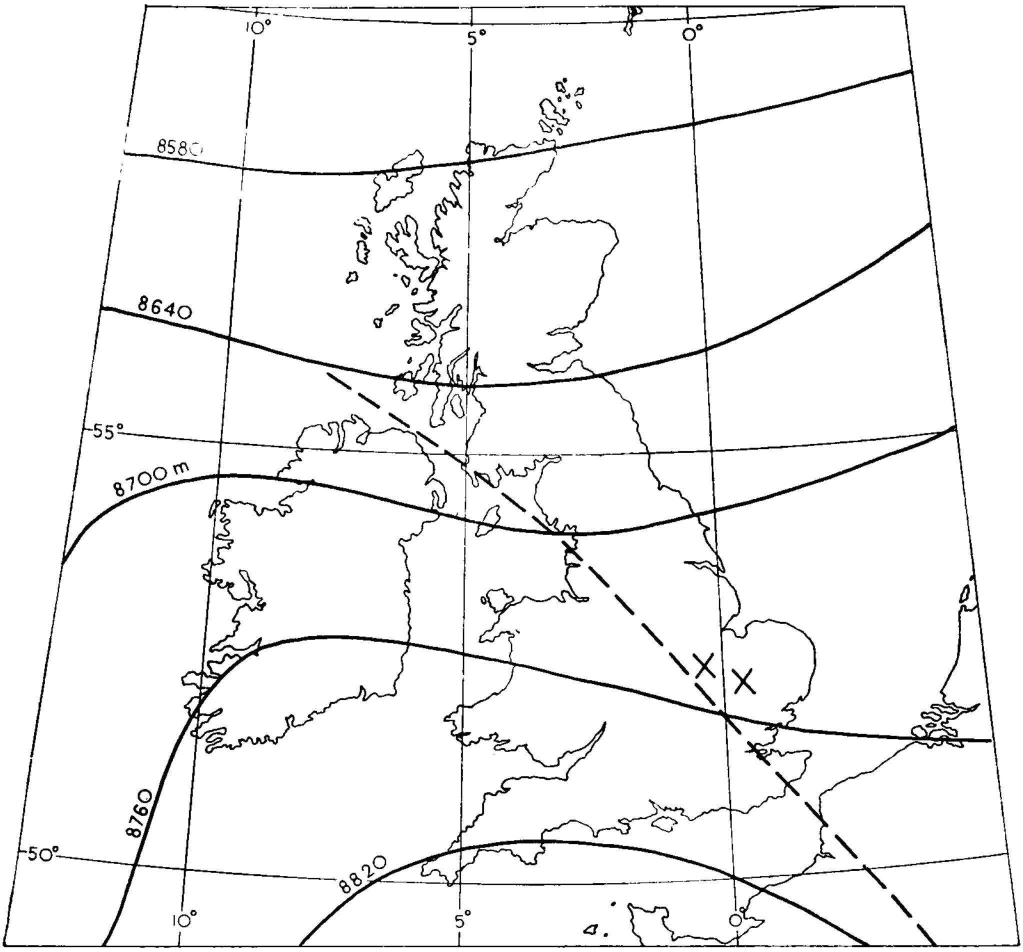

FIGURE 5—300 MB CHART FOR 1200 GMT, 18 DECEMBER 1958

Crosses mark positions of reports of severe clear-air turbulence. The dashed line indicates the front at 300 mb.

that the important shears need in fact exist for much smaller distances and height intervals so that any discontinuity, for example, associated with an otherwise insignificant front, may be important.

(iii) In the case of large horizontal shear associated with an upper trough the most pronounced turbulence may well be experienced in headings parallel to the axis of the trough.

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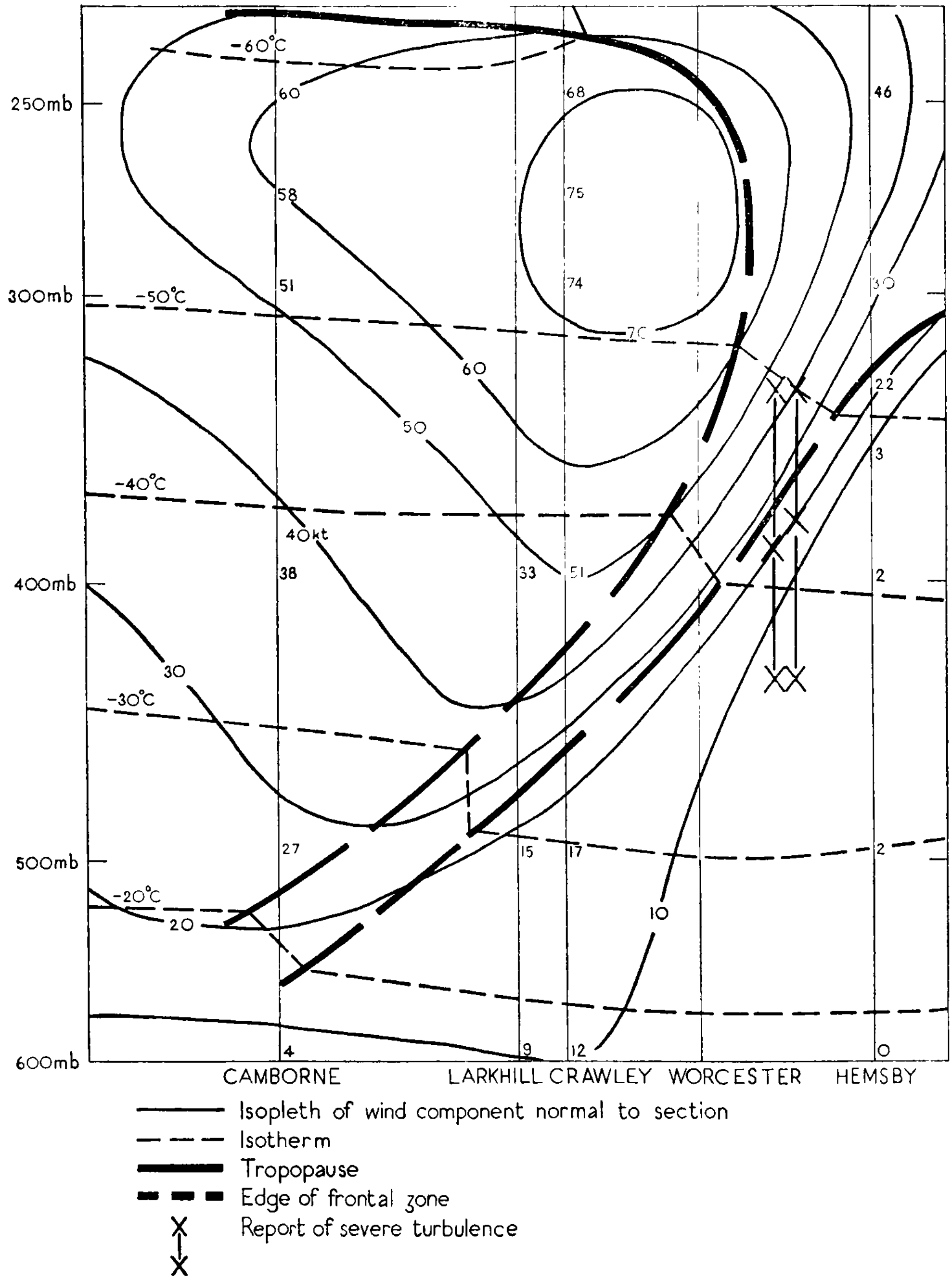

FIGURE 6—CROSS-SECTION FOR 1200 GMT, 18 DECEMBER 1958

(see p. 49)

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200 MB MEAN WINDS ON THE ROUTE EL ADEM TO ADEN DERIVED FROM AIRCRAFT REPORTS

By P. G. WICKHAM, M.A.

Introduction.—During the two-and-a-half-year period from May 1957 to November 1959, a quite considerable amount of data was accumulated relating to winds found by jet aircraft flying at levels around 40,000 feet on the route between El Adem and Aden.

These aircraft reports are not ideal data for producing mean winds. They are awkward to summarize owing to differences in the way the winds are found and presented, the varying flight levels of individual aircraft, and the discrepancies which occur between the winds reported by two or more aircraft flying over the same area at much the same height and time. In addition, over the short period considered, the total number of reports received during certain months was too small and the distribution in time of the reports during nearly every month was too irregular to allow a satisfactory statistical treatment. However, since the upper air information over Africa is so sparse, it is felt that this body of data is an independent and significant addition to our present knowledge of high-level winds in the area. While it is not possible to say how far the mean wind field may vary from year to year, the results given certainly reflect the regular seasonal rhythm which was apparent during the period.

Data.—The wind reports in this paper are taken from aircraft flying over any part of the route between El Adem and Aden, via 22°N, 25°E. A map of the route is shown in Figure 1.

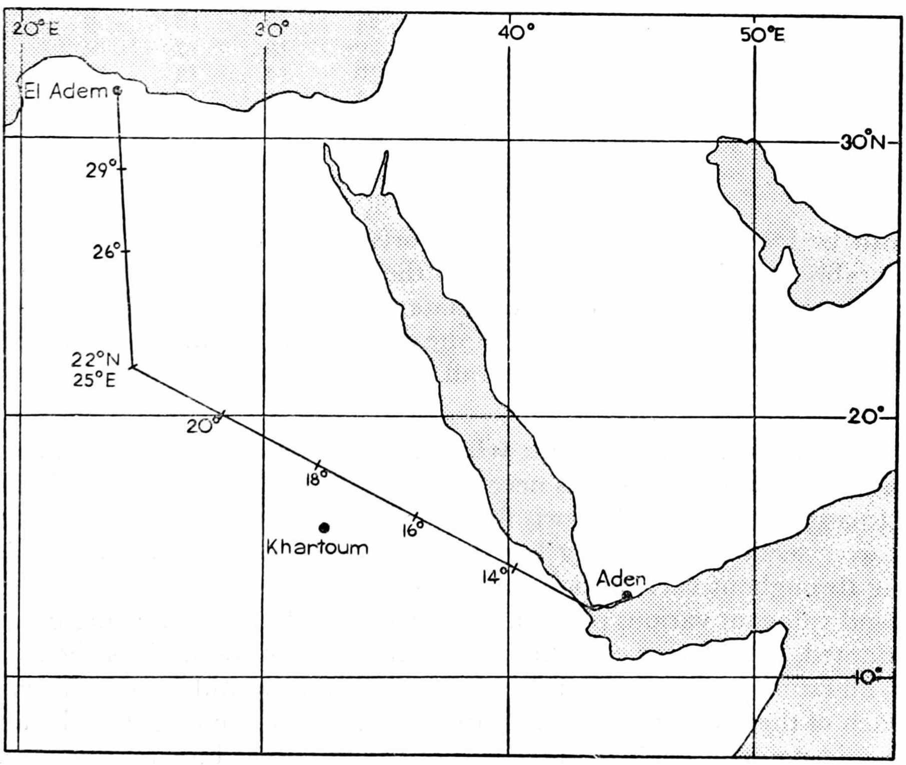

FIGURE 1—MAP OF ROUTE BETWEEN EL ADEM AND ADEN

For the purpose of analysing the reports, the route was divided into six sections. These are quite arbitrary sections and not of equal length, being chosen as convenient divisions of the route for forecasting purposes. The sections are from 29°N to 26°N; 26°N to 22°N; 22°N to 20°N; 20°N to 18°N; 18°N to 16°N and 16°N to 14°N. The mean winds presented refer approximately to the 200-millibar level and are computed from all reports received in the height band from 37,500 to 42,500 feet.

It should be pointed out that the quality of the wind reports found by different types of aircraft varies considerably. Some have to rely on visual and radio fixes in determining their position and in computing winds. This method, when used over the vast featureless expanses of north-east Africa may give some very unreliable results, or at best only give mean winds over rather long sections. Others, however, are equipped with Doppler wind-finding equipment which can give spot values of wind which are particularly valuable and reliable. The total number of flight reports used, either wholly or in part, was 278. Of these, about a third were from aircraft fitted with Doppler wind-finding equipment. Table I shows the number of aircraft reports on each section from which the monthly means have been computed.

TABLE I—NUMBER OF AIRCRAFT REPORTS AVAILABLE ON EACH SECTION

Month	Sections of route 29°N – 26°N	26°N – 22°N	22°N – 20°N	20°N – 18°N	18°N – 16°N	16°N – 14°N
	number of reports					
January	11	13	11	10	8	3
February	11	13	13	12	10	7
March	9	11	10	9	4	2
April	6	9	7	7	5	3
May	16	16	13	13	7	2
June	24	24	20	18	9	7
July	21	20	19	17	10	9
August	14	16	14	13	10	4
September	20	24	20	19	16	5
October	14	17	15	16	10	4
November	15	20	15	15	9	7
December	13	13	13	14	12	10

It can be seen that the number of reports available on each section varies considerably, and is regrettably small on the section nearest to Aden. The lack of reports on this section is an unfortunate result of the flight schedules during the period. Most of the flights were in the direction from Aden to El Adem and when flying in this direction the aircraft were almost always below the specified height band on this section.

Method of computing mean winds.—To summarize the aircraft reports and produce mean winds it was necessary to reduce the wind reports from each flight to a standard form. Reports from some aircraft were in the form of mean winds over sections of varying length, often with the altitude of the aircraft varying throughout each section. Other reports were in the form of a series of spot wind values at various positions. To deal with this, the following procedure was adopted, considering each flight in turn. First, on the basis of the reported winds, an estimate was made of the mean winds that would have been reported over each of the standard sections of the route, and of the height of the aircraft at the mid-point of each of these sections. This procedure is of course very subjective. Next, each of these estimated winds were resolved into components (north and east). For each month, the components on each section were added and meaned. The mean components were combined to give a mean wind direction and speed, rounded off to the nearest five degrees and five knots. The final means for each month were computed from the reports received during that month throughout the two-and-a-half-year period.

In general, except on occasions when more than one report was received on any one day, all available reports have been used in this work. When two or more reports were received on the same day, the reports were combined to produce a mean wind for that day. Thus the monthly mean winds have been computed from not more than one wind report a day. Even so, since the distribution of reports throughout each month was usually very irregular, the computed means for any individual month often reflect a particular wind régime that was predominant during a small part of that month. This is unfortunate and it is hoped that by combining the computed means for a particular month over two or three years, a more representative monthly mean has been produced.

Monthly mean winds.—The monthly mean winds at 200 millibars on the route are given in Table II. The broad picture of the upper wind field shown by this Table is a fairly consistent one and is in agreement with what is already known. Briefly, two broad currents of air affect North Africa during the year. On Table II, isopleths of wind directions 250° and 110° have been superimposed to bring out more clearly these two currents, one westerly and the other easterly.

Latitude (north)	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
29°–26°	270/90	260/105	275/95	280/85	285/65	245/30	150/10	180/10	255/25	245/55	270/80	265/80
26°–22°	270/95	270/100	270/90	270/70	285/60	235/25	120/20	140/15	240/15	255/50	275/70	265/85
22°–20°	270/90	260/85	265/75	275/65	275/45	200/10	105/40	115/25	160/15	245/10	275/65	265/70
20°–18°	265/80	255/65	270/60	275/40	265/40	125/10	100/40	100/30	130/20	245/15	275/50	270/65
18°–16°	260/60	265/45	265/45	285/30	245/35	140/15	090/45	100/40	105/25	170/10	285/45	275/45
16°–14°	270/50	250/35	245/20	295/15	235/30	135/20	085/40	105/40	100/25	VAR/5	295/40	275/40

TABLE II—MONTHLY MEAN WINDS AT 200 MB ON ROUTE FROM EL ADEM TO ADEN

The hatched area, enclosed between isopleths of wind direction 110° and 250°, separates the main winter westerlies from the summer easterlies.

In wintertime, a westerly flow covers the whole route and, in latitudes north of 20°N, it very frequently reaches speeds in excess of 100 knots. In the spring, this westerly flow weakens and gives place to the easterly stream which moves north with the sun from the equator. In the summer, the easterlies are well established over the south of the route as far north as 22°N, but even in the height of summer do not extend quite as far north as the North African coast at 30°N. In the autumn the easterlies quickly recede south and the westerly stream becomes re-established. The westerlies prevail over El Adem for about nine months of the year and over Aden for about six months.

Subtropical westerly jet stream.—A number of features of the westerly jet streams which cover North Africa in wintertime were shown by the wind reports. October to May is the jet stream season.

Table II shows that during the months January to March even the mean wind speeds were about 100 knots on the two northernmost sections. During this period the subtropical jet stream is a permanent feature of the upper wind field. The aircraft winds reported during these months invariably showed a maximum wind greater than 70 knots on the northern sections and on four days out of five, westerly winds greater than 100 knots were reported at heights varying between 35,000 and 45,000 feet. The neighbouring months of December and April had not quite so large a proportion of high winds, but nevertheless winds of over 100 knots were reported on half the days of these months.

It was not possible on many occasions to determine the position of the core of maximum wind speed with any certainty. However, it appeared that the mean position of the jet core moved south across the North African coast in the late autumn. During the midwinter period, from January to March, the cores of the jet streams were definitely located from the aircraft reports at some latitude south of 29°N on more than half the total number of occasions for these months. Wind maxima over 100 knots have been reported as far south as 19½°N, with cores of lesser strength even farther south. In the spring the jet stream cores moved north again.

The highest speeds reported during the period by an individual aircraft was one of 260 degrees 178 knots, at 42,000 feet on 1 December 1957—this was a mean wind over the whole section from 22°N to 29°N. The highest "spot" value of wind speed was one of 260 degrees 165 knots, at 38,500 feet at 27½°N on 26 March 1959.

On a number of occasions it was apparent that more than one core of maximum wind existed. These secondary maxima, which occurred to the south of the main wind maxima, were most common during the months from December to March. They were reported in latitudes ranging from 23°N to 14°N, usually in the region around 18°N, and the speeds exceeded 100 knots on occasions.

Zonal and meridional components of the mean flow.—Figure 2 shows isotachs of the zonal components of the mean monthly winds. This diagram shows essentially the same features as the resultant mean winds given in Table II but displays them more graphically. The high maximum speeds in the westerly components in February, the rapid change from westerlies to easterlies in June and back again in September, and the solid easterly stream over the whole route during July, are features which are clearly brought out.

The horizontal shear of the zonal components has been worked out, over intervals of two degrees of latitude, and the results are shown in Figure 3. With only small exceptions, the sense of the shear is anticyclonic over the whole route throughout the year. The actual values of the shears are mostly of the order of 0–20 knots per 120 nautical miles, with the westerly winds decreasing and the easterly winds increasing towards the south. The values of the shears in Figure 3, however, are given as percentages of the local value of the Coriolis parameter, f. It can be shown that if the wind shear in any region is anticyclonic and exceeds the value of f in that region, the resultant flow is dynamically unstable. This state of affairs may well exist from time to time in localized regions and may be very significant in explaining the formation of sudden developments in the wind

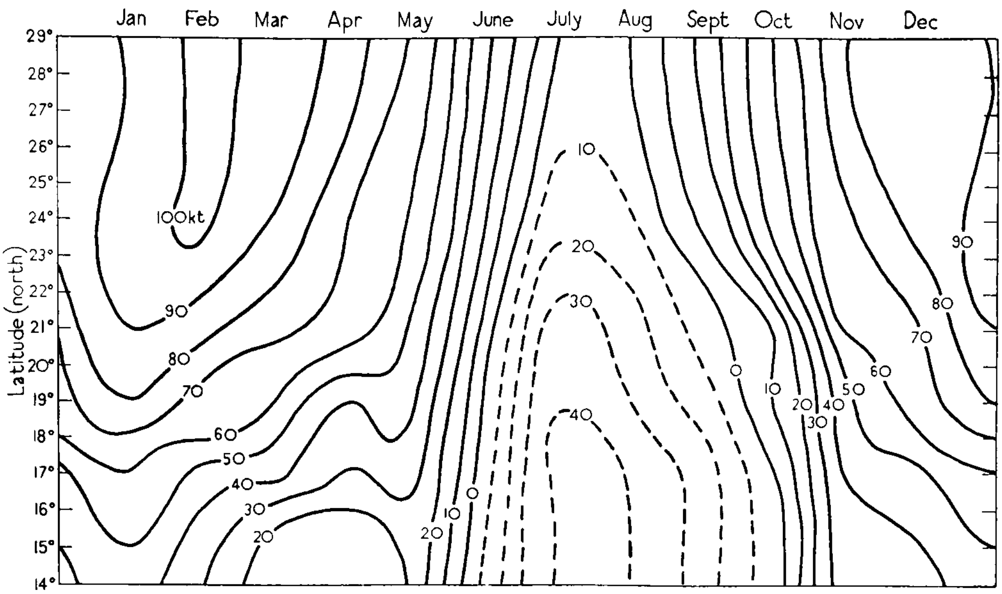

FIGURE 2—ZONAL COMPONENTS OF THE MONTHLY MEAN WINDS

Westerly and easterly components are continuous and broken lines respectively. Isotachs are drawn at 10 kt intervals.

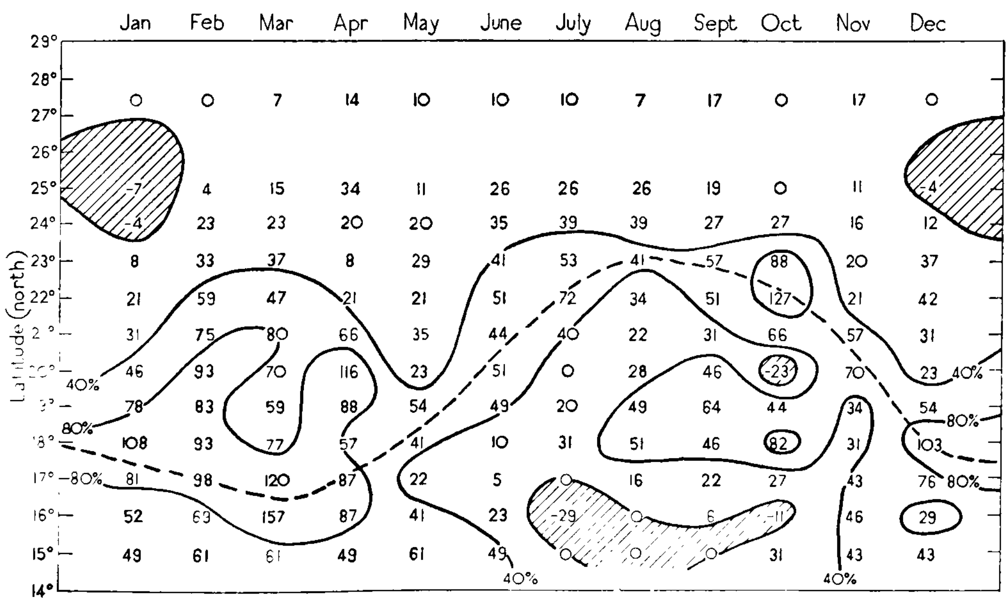

FIGURE 3—SHEAR OF ZONAL WIND COMPONENTS, EXPRESSED AS PERCENTAGES OF THE CORIOLIS PARAMETER f

Areas of cyclonic shear are shaded. Isopleths of 40 and 80 per cent of f are shown as full lines and the position of the maximum anticyclonic shear is marked by a dashed line.

and pressure fields. But it is scarcely to be supposed that the atmosphere would continue in such a state of dynamic instability in one region for periods of time long enough to register on charts of mean wind flow. Thus the very high individual values of the shear which appear in places on Figure 3 must be a consequence of the inadequate data on which the values are based. Indeed, with only very small adjustments in the values of the mean winds, all the shears could easily be reduced to values less than f. For example, if in March the mean zonal component in the southernmost section had been only 5 knots greater and that in the next had been only 5 knots less than the values given here, the shear at 16°N would have been reduced from $1 \cdot 57f$ to $0 \cdot 98f$.

However, despite the obviously doubtful values and the erratic variations of the shear from one latitude to another, it seems clear that anticyclonic shears whose values approach that of f very closely, do exist in the mean for quite a long period of time, from December to April in the vicinity of 17°–18°N. Further, by drawing isopleths on Figure 3, a zone where the shear (expressed as a percentage of f) is a maximum, is quite clearly discernible. This zone moves north during the spring and early summer to latitude 23°N in August–September and then moves south to reach about 16°N latitude in late winter. In winter the shears are frequently greater than $0 \cdot 80f$ near this zone, but in summer at higher latitudes $0 \cdot 60f$ is rarely exceeded. It would seem that this pattern of shears is an integral part of the wind field at this level, though its significance is not clear.

The meridional components of the flow are displayed in Figure 4. The features here are rather vague. During most of the year there is a south to north flow of air at this height over the whole route. This is in accord with the generally accepted picture of a thermally direct circulation pattern over low latitudes.

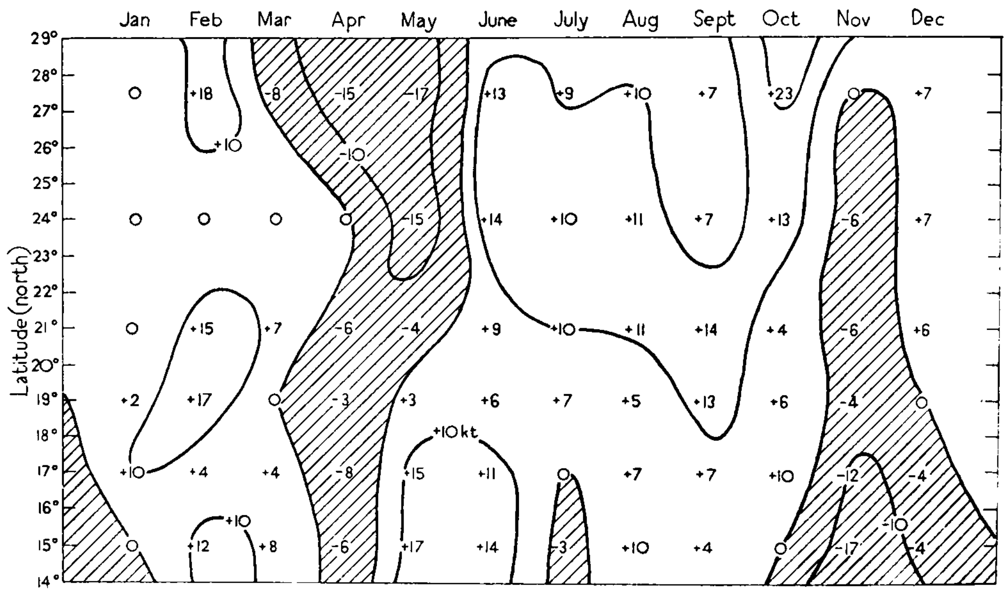

FIGURE 4—MERIDIONAL COMPONENTS OF THE MONTHLY MEAN WINDS

South–north components are marked positive and left unshaded; north–south components are negative and shaded. Isotachs are at 10 kt intervals.

Erratum—The value for January at 19°N should be +7.

Warm air rises in the equatorial trough and then moves polewards at high levels over the tropics before subsiding into the subtropical anticyclones. The circulation is completed at low levels by equatorward air flow in the trade winds from the subtropical highs to the equatorial trough once more. However, it seems that in April–May and again in November, the flow of air is from north to south at 200 millibars over this part of Africa. How regular or extensive these north-to-south flows may be is beyond the scope of the present data to determine. But it does serve to indicate that variations on the basic simple theme are very likely to occur in the pattern of the general circulation.

Symposium on monsoons of the world. 9½ in. × 7 in., pp. x + 270, *illus.*; Hind Union Press, New Delhi, India, 1960. Price: 19*s*.

The Second Session of the Commission for Synoptic Meteorology (CSM–II) was held in New Delhi during January–February 1958. This was conveniently followed by a symposium on "The monsoons of the world" under the joint auspices of the International Union of Geodesy and Geophysics and the World Meteorological Organization, ably backed by the Government of India through their Meteorological Department. The papers presented at the symposium and the discussions thereon have been published by the Government of India under the title "Monsoons of the world"; the publication is the subject of this review. The papers are presented in seven sections.

SECTION I, on the climatology of the monsoons, contains three papers, of which the first deals with the upper air climatology of India and neighbourhood in the monsoon seasons. It is largely factual, presenting the normal distribution of temperature and wind at six standard levels from 850 to 100 millibars for June and July representing the south-west monsoon season, November representing the north-east monsoon season and May, a transitional month. Temperatures have been derived from evening radiosonde ascents over a five-to-ten-year period up to the end of 1955; winds have been derived from pilot-balloon ascents up to the end of 1950 and from radio-wind ascents up to the end of 1956. Temperature features revealed by the charts include the influence of ground heating up to about three kilometres and a very warm area—attributed by the authors to heat liberated during condensation—at 100 millibars in July near the India–West Pakistan frontier. This latter feature does not appear on similar charts published elsewhere, emphasizing possible discrepancies in high-level temperatures determined by different radiosondes and the need for an accurate standard instrument. The charts illustrate the high-level easterly jet of the summer months and the subtropical westerly jet of winter

The second paper in Section I, by H. O. Walker, describes the five weather zones experienced in Ghana and neighbouring areas as the monsoon moves north and south during the year. The difficulty of air mass analysis and frontal nomenclature in tropical regions is stressed. This subject produced lengthy and very lively discussion in committee during CSM–II, leading to a compromise solution with the adoption of descriptive terms for "intertropical discontinuity" and "subtropical discontinuity".

Section I ends with a brief but informative paper by K. N. Rao of the Indian Meteorological Department. Analysing radiosonde data up to 1955 he demonstrates that convective instability up to 4 to 6 kilometres is a normal feature during the south-west monsoon in India.

SECTION II, containing twelve papers, covers monsoons and the general circulation of the atmosphere, and opens with a general review of the subject by K. R. Ramanathan. This is followed by a paper by H. Flöhn in which he examines critically the textbook conception of monsoon winds, which he summarizes as follows:

(i) Monsoon winds are predominant air currents with a marked seasonal shift.

(ii) Monsoon winds blowing from sea to land are moist, unstable and rainy; those in the opposite direction are dry, stable and rainless.

(iii) The physical cause of monsoon winds is to be found in differential heating of land and sea, *i.e.* in the different response of the earth's surface to solar radiation.

(iv) Tropical monsoons over the summer hemisphere are to be conceived as trade winds of the winter hemisphere crossing the equator and deflected by Coriolis forces.

Flöhn produces observational evidence and arguments leading to a deletion of (iv) above, and the replacement of (ii) and (iii) by the following:

(ii) Winds with westerly/easterly directions and a component towards the pole/equator have, in general, a tendency for lifting/subsidence, instability/stability and raininess/dryness produced by Coriolis forces together with the spherical shape of the globe.

(iii) The physical causes of monsoon winds are to be found (*a*) in the thermally controlled seasonal migration of the planetary pressure and wind belts in continental sections of the globe and (*b*) in the (seasonally changing) differential heating of land and sea.

In the third paper in Section II, Flöhn turns from global considerations to an account of recent investigations on the mechanism of the summer monsoon of southern and eastern Asia based on a wealth of climatological data. He touches on the persistence of westerly winds along the equator, the distribution of rainfall, the sources of moisture, and the correlation of the time of onset of the monsoon with extratropical features. Much of the paper deals with the important role played by the Tibetan Plateau as an elevated heat source and its influence on the build up of the equatorial easterly jet stream, the far-reaching switch of the planetary wind belts over southern and eastern Asia, and the "burst of the monsoon" over the Indian subcontinent.

A fourth paper, by S. L. Malurkar, is a discursive account of monsoons, particularly in the neighbourhood of India. Claims are made for the importance of shallow low pressure areas moving westwards near the equator in reinforcing the south-west monsoon by air from the south-east trades of the southern hemisphere; the role of air from the north-east trades of the North Pacific and of continental air from western Asia in the weather of the monsoon season is also discussed. Other topics discussed are certain rainfall régimes and the interaction of depressions on opposite sides of the equator.

P. Koteswaram also deals with the general circulation over the tropics during the summer monsoon, examining the equatorial easterly jet stream, and relating bursts of the south-west monsoon over India, and its fluctuations, as well as the formation of monsoon depressions, with perturbations in the upper easterly current. He emphasizes the importance of the Tibetian Plateau as a heat source and important features of his suggested schematic model of the vertical circulation in the Asian summer monsoon have been confirmed by recent work by Tucker on mean meridional air trajectories.

P. R. Pisharoty and G. C. Asnani contribute a paper on the flow pattern over India and neighbourhood at 500 millibars during the monsoon. The flow patterns fall broadly into two categories, one typical of normal monsoon conditions with well distributed rain over much of India, and the other typical of "breaks in the monsoon" when the rainfall over much of India, particularly the central parts, almost ceases and noteworthy rains occur along and near the eastern Himalayas.

Of the remaining papers in Section II one comes to the conclusion that the monsoon does not exist over Madagascar, whilst the remaining five are merely abstracts of papers published elsewhere.

SECTION III deals with the dynamics of monsoons and opens with a review of the main studies in the field of monsoons in Europe and Asia by Soviet meteorologists. These studies are considered under three headings—climatological, synoptic and hydrodynamic. Generally speaking, the climatological school attributes monsoons to thermal non-uniformity of the earth's surface. On the other hand, the synoptic school does not regard this as the principal factor in the origin of monsoons. This school considers monsoons as a stage in a series of synoptic developments and that they cannot be considered as a problem divorced from that of the general circulation. Within recent years Khromav has completely abandoned the thermal non-uniformity idea on the origin of monsoons; he has also, in common with Flöhn, come to the conclusion that monsoons do not bring a certain type of weather. The hydrodynamical school associates monsoons closely with the general circulation, free convection, and heat sources and sinks. The review ends with problems still under investigation, as, for example, the exact nature of monsoons, their vertical formation, their weather characteristics, their association with the general circulation and the like.

The second paper in Section III is a survey of dynamical theories of monsoons by Pisharoty and Asnani, and contains a critical examination of theories by Jeffreys and Böhme. They conclude that the Indian monsoon cannot be regarded as a land- and sea-breeze on a continental and annual scale and lean towards the view that it is primarily due to the seasonal shifting of thermally produced planetary belts of pressure and winds due to differential heating of air over continents and oceans.

The final paper in Section III—"On the intertropical front and intertropical convergence zone over Africa and adjacent oceans" by K. H. Soliman—recalls the lively debate in committee during CSM–II between the frontal and non-frontal schools of tropical meteorology. Soliman, whilst recognizing the intertropical convergence zone between the high pressure belts over the tropical oceans, makes a strong plea for the recognition of an intertropical front and a subtropical front over large land masses such as Africa. He points out that whereas there is a narrow zone of low pressure where the trades meet over the ocean, we find over Africa and Asia in the northern hemisphere summer a wide belt of thermal lows. The associated air is extremely hot and dry. Soliman advocates the existence of an intertropical front between this hot, dry air and relatively moist and cool south-west monsoon air to the south; he also recognizes the existence of a subtropical front between the hot, dry air and cooler air on its northern flank. There was considerable support for Soliman's views at CSM–II and equally strong opposition from those who advocate that frontal characteristics cannot be attributed to these boundaries. CSM–II ended up with an international compromise solution—intertropical and subtropical "discontinuities".

SECTION IV deals with depressions and other perturbations in the monsoon, and opens with a case study of a monsoon depression in the Bay of Bengal by P. Koteswaram. The history of the depression is followed from its formation under the influence of a westward-moving high-level easterly wave, through its north-westward movement in keeping with the fields of warm and cold advection, to its recurvature around the high-level anticyclone over Tibet and subsequent break-up over the Himalayas. Ananthakrishnan and Bhatia follow with a more general study of tracks of monsoon depressions to determine why a few depressions of the south-west monsoon recurve northwards towards Kashmir whilst the majority continue to move west-north-west to merge with the seasonal depression over north-west India. The paper maps the origin, place of recurvature, and dissipation of depressions by months for the period 1924–52. These maps indicate that depressions form over the sea in all months at the southern periphery of the anticyclonic cell at 10–12 kilometres and tend to follow the flow at this level. In keeping with this, depressions reaching the centre of the country during the south-west monsoon tend to curve north-west or north. However, a marked recurvature into Kashmir is rare, and is demonstrated to occur when there is a deep trough in the westerlies moving eastward from the north-west.

SECTION V deals with rain and cloud, mostly of the south-west monsoon. The opening papers deal with radar observations on rainfall and with an analysis of cloud heights and turbulence in the south-west monsoon as reported by Comet aircraft. These are followed by a study of rainfall in India during the south-west monsoon season by K. Parthasarathy. The south-west monsoon is responsible for 70 to 90 per cent of the annual rainfall over most of the country. The coefficient of variability of the monsoon rain for the country as a whole is only 10 per cent, but many parts of the country have a considerably higher variability. Rarely is a season of normal rainfall one of normal rainfall in all parts of the country, but one of excesses in some parts being compensated by deficiencies in others; neither is a wet year wet in all parts, nor a dry year dry in all parts. Few seasons occur without disastrous floods in one part or other of the country. Floods and droughts are characteristics of the south-west monsoon season. The role of monsoon depressions in producing flooding is described, as is also that of "breaks" in the monsoon producing excessive rainfalls in the lower Himalayas and a deficit of rain in the Gangetic plains and the central parts of the country. A claim is made for the important part played by the upper tropospheric anticyclone in controlling the regions of activity of the monsoon; westerly waves moving across the lower Himalayas play nearly as important a role as the easterly waves farther south in determining intensity and distribution of heavy rainfall.

Ramakrishnan and Gopinatha Rao deal with aspects of non-depressional rain during the south-west monsoon, including diurnal variations on the coast and inland, areas of maximum rainfall, duration and variability of rainfall. The section ends with a paper by K. N. Rao on the average amount of rainfall on a rainy day during the south-west and north-east monsoons.

SECTION VI deals with the variability of monsoons and opens with a paper by H. G. Bond on the drought of 1951–52 in northern Australia, resulting from a failure of the north-west monsoon and associated depressions. A good relationship is established between the pressure difference between Singapore and Darwin on the one hand, and southward movement of the intertropical convergence zone in the region of Australia and monsoonal and tropical storm activity over northern Australia on the other. The drought was associated with a series of stray and persistent anticyclones in the Australia–New Zealand region concurrently with a general pressure deficiency in the east Asia region.

Rao and Jagannathan, in a study of monsoon and annual rainfalls in India, failed to find any significant seasonal or annual trends for the country as a

[*To face p.* 264

By courtesy of B.O.A.C

CAPTAIN A. L. FRENCH OF B.E.A. (LEFT) AND CAPTAIN E. M. JONES, A.F.C., OF B.O.A.C. (RIGHT) WITH DR. A. C. BEST, O.B.E., D.SC.

(see p. 267)

By courtesy of B.E.A.

CAPTAIN A. L. FRENCH OF B.E.A. RECEIVING A BRIEF-CASE FROM
DR. A. C. BEST, O.B.E., D.SC.
(see p. 267)

whole; Moghe has found a periodicity approximating to seven days in the flow of the south-west monsoon over the west coast of India.

The volume ends with SECTION VII on extended and long-range forecasting of the monsoon, and opens with a paper on seasonal (monsoon) rainfall forecasting in India by Rao and Ramamoorthy. It is a tribute to Walker that the correlation method he introduced in 1907 is still the basis of the method used for issuing seasonal forecasts. Of the many factors investigated, South American pressure and Southern Rhodesian rainfall continue to be dominating factors in the seasonal forecasting formulae; however, there are increasing hopes that use can be made of the more recently available upper air data. The accuracy of these forecasts and their value to the national economy are held to justify their continued issue.

The final paper, by L. A. Ramdas, discusses the establishment, fluctuations and retreat of the south-west monsoon in India. Drought and flood years are defined and the characteristics of the rainfalls in thirty areas of the country for each of seventy-six monsoons are tabulated. An interesting relationship has been found between flood and drought years on the one hand, and pressure over south-east Australia on the other. Formulae for forecasting the date of onset and retreat of the monsoon are described briefly, indicating the lines of current research. Ramdas also draws attention to the importance of long-range forecasts of the frequency of depressions during the monsoon and also that of breaks in the monsoon.

The Asiatic monsoon is the best known of the monsoons. The oft-used saying that India's budget is a "monsoon gamble" reflects the importance of monsoon rainfall to the Indian economy. Food production and prosperity in India and some neighbouring countries are vitally dependent upon the monsoon, and it has been the subject of intensive study by meteorologists in India for many years; the work continues apace. Indian meteorologists, in common with their colleagues in many parts of the world, are faced with increasing demands for accurate long-range forecasts; the task is enormous, but the spur is great, for success would bring incalculable benefits to India.

Despite the major role of the Asiatic monsoon, and despite the setting of the symposium and the prominent part played by Indian meteorologists there, it is greatly to the credit of the Organizing Committee that more than a third of the papers discuss monsoons in general, or particular monsoons other than those over and near India. The result is a volume that forms a ready reference to general monsoon theories as well as containing a wealth of information on the all-important south-west monsoon of India. The editors deserve our thanks and congratulations.

J. HARDING

Meteorology for glider pilots, by C. E. Wallington. 8½ in. × 5½ in., pp. xii+284, *illus.*; John Murray, 50 Albemarle Street, London, W.1, 1961. Price: 25*s*.

I have been gliding now for nearly thirty years, during which time my knowledge of the air has been acquired by a mixture of the "suck it and see" method, of endless conversations in bars and on the field, and a groundwork obtained by reading a few books on elementary meteorology.

Reading Mr. Wallington's book has in one stroke put all this information in the right order, has enabled me to cast out many misconceptions, and has enormously added to my previous knowledge. In part this is a fair exchange, since I am sure that Mr. Wallington would be the first to acknowledge that much of what he now gives us has been obtained by analysing information obtained from glider pilots themselves by him and others like him. For whereas when I first started to glide, any unusual experience of a glider pilot would meet with incredulity from the meteorologists, for many years now the latter have been only too anxious to listen to any such events, and ingenious in producing theories to account for them. Much of this book is undoubtedly a crystallization of these decades of collaboration between people each in their own ways enthusiasts about the air.

Again and again throughout the book I came on explanations of things which I have experienced in flight, and there are few questions remaining to ask. The ultimate mystery about the air seems to me that we ever experience a calm day. The picture of a thermal as a kind of smoke-ring revolving about itself answers many problems, but the spectacle sometimes seen of a column of circling sailplanes at all altitudes from a few hundred feet to say 3000 feet underlines that these rings are often quite like the crude rising columns of my young days.

On page 209 I came on the exact diagram of the corrugated cardboard sheet of wave-cloud, flat on the underside and waved on top, amongst which I found myself flying over Sheffield during the 1954 World Championships. I am not sure, however, that I understand how in fact I climbed into and through this from a starting point some 1500–2000 feet below its flat base.

On page 230 I read that the upwind jump of a wave cloud is a rare phenomenon, seldom observed from the ground. From the banks of Lake Ohau in the Mackenzie Country of New Zealand I watched a stream of perfect lens clouds drifting downwind and each time the leading one drifted one wavelength a fresh one appeared like magic overhead. It was a conjuring trick of Nature, and I am glad it is not yet understood, though I expect Mr. Wallington or one of his colleagues will nail it down before long.

I long to understand and love the tephigram, but being a bear of very little brain find it hard to take in the conception of entropy. Telling me that I can think of it as the potential heat energy of the air doesn't quite get me there—I have an exasperating feeling that perhaps just one more sentence would open the door for me.

I have in store just one or two incidents yet to be cleared up—a belt of smooth rising air parallel to the Durham coast about 10 miles inland under a completely grey and featureless sky in May 1958, a sea-breeze effect of sorts around the north-easternmost bulge of England in July 1959 under a stormy grey sky, and so on.

But make no mistake about it, this book is a classic. It will go on being bought and read eagerly by glider pilots—and, I hope, by meteorologists—for years to come. So when Mr. Wallington comes to revise it, may I ask for two additions: an analysis of the dynamic upcurrents used by sea-birds such as the albatross in the lowest levels of the air, to indicate whether we could ever construct a sailplane to make use of them; and secondly some information on the vertical electrostatic potential gradient, to see if we can conceive an instrument enabling us to detect thermals from a distance, using radioactive probes on the wing-tips and possibly the nose and tail of our aircraft to measure any potential differential. For either of these developments would of course revolutionize our sport.

P. A. WILLS

NOTES AND NEWS

Meteorological Office awards to captains and navigators of civil aircraft

The Meteorological Office awards for 1961 to captains and navigators of civil aircraft for outstanding service in providing weather reports were presented by Dr. A. C. Best, Director of Services of the Meteorological Office, at a ceremony held by the Guild of Air Pilots and Air Navigators on 4 July 1961. In the unavoidable absence of the Master of the Guild, Dr. K. G. Bergin, the guests were welcomed by Sir Frederick Tymms, a former Master, who mentioned how conscious the Guild was of the value of the meteorological services provided to its members.

Dr. Best, in a brief speech before presenting the awards, reminded those present that the first of these ceremonies was held six years ago and they had now acquired the status of an annual event. The ceremonies had one characteristic which distinguished them from most meetings attended by professional meteorologists. Usually meteorologists were asking for something to improve the service—more frequent reports, reports from greater heights or reports of a different type—but, on these occasions, they were offering something as a token of their gratitude for the information they had received from members of the Guild. He emphasized that, despite the high quality of automatic instruments and continued efforts to improve them still further, the human intelligence was still the most effective instrument for reporting weather because automatic instruments lacked the flexibility and discretion of the human brain. Sometimes meteorological knowledge, obtained from instruments, at new and greater operational heights tended to lag a little behind that required for successful operation of aircraft but this lag could be and was being minimized by weather reports from aircraft.

Dr. Best then presented brief-cases to Captain E. M. Jones, A.F.C., of B.O.A.C. and Captain A. L. French of B.E.A.

Awards of suitably inscribed books will be sent to the following captains and navigators who provided the best series of reports (in-flight, post-flight, or on de-briefing):

Navigator R. Brown, B.O.A.C.
Navigator T. M. Clarke, B.O.A.C.
Captain R. Hartley, B.E.A.
Navigator J. D. Hogg, B.O.A.C.
Navigator G. G. Kingsmill, B.O.A.C.
Navigator G. A. Kirkwood, B.O.A.C.
Captain C. N. Longdon, B.O.A.C.
Captain D. Mason, B.E.A.
Navigator W. C. L. McKay, B.O.A.C.
Captain K. D. G. Mitchell, B.E.A.
Navigator M. D. Richards, B.O.A.C.
Captain G. Thomas, B.U.A.
Captain B. J. Thwaites, B.E.A.
Captain W. J. Wakelin, B.E.A.
Captain R. W. F. Wightman, B.O.A.C.

The names of Captain W. J. Wakelin (who received a brief-case in 1958) and Navigating Officer M. D. Richards (who received a book in 1958) appear for the second time within three years.

CONGRATULATIONS

We offer our congratulations to Mr. Ernest Gold, C.B., D.S.O., F.R.S., on reaching his 80th birthday on 24 July 1961. Mr. Gold's retirement from the Meteorological Office after 41 years' service was announced in the November 1947 number of the *Meteorological Magazine*.

OFFICIAL PUBLICATION

The following publication has recently been issued:

GEOPHYSICAL MEMOIRS

No. 105—*Upper winds over the world, Part III. Standard vector deviation of wind up to the 100 mb level over the world.* By G. B Tucker, Ph.D.

Charts of standard vector deviation of wind have been prepared to accompany the contour height and streamline and isotach charts in Parts I and II of "Upper winds over the world" (*Geophysical Memoirs* No. 103). Over the standard five-year period 1949–53 a set of mean charts have been constructed at each of the standard pressure levels 700, 500, 300, 200, 150 and 100 millibars for the midseason months of January, April, July and October. The techniques used in compiling the charts are described. The method of constructing a wind rose from a given resultant wind speed and direction, and standard vector deviation has been reprinted from the earlier *Geophysical Memoirs* No. 85.

METEOROLOGICAL OFFICE NEWS

Meteorological Office Headquarters, Bracknell

It has been announced that the three components of the new Meteorological Office building at Bracknell will be known by names commemorating distinguished men of science. The central building will supersede the Napier Shaw Laboratory at Dunstable and will be known as the NAPIER SHAW BUILDING. The east wing housing the senior directing staff will be called the FITZROY WING and the west wing, largely devoted to instrumental laboratories of various kinds, will be known as the DINES WING.

Admiral Fitzroy was the first head of the Meteorological Office, being Superintendent of the Meteorological Department of the Board of Trade from 1855–65. Sir Napier Shaw was Director of the Meteorological Office 1900–18 and is particularly well known for his *Manual of Meteorology*. W. H. Dines was an exceptionally gifted designer of meteorological instruments; most of his work was performed in conjunction with the Office.

Staff suggestions scheme

Mr. L. G. Bird, Experimental Officer, was awarded £25 for a device for reducing loss of rain during the siphoning period of a Dines tilting-siphon rain recorder.