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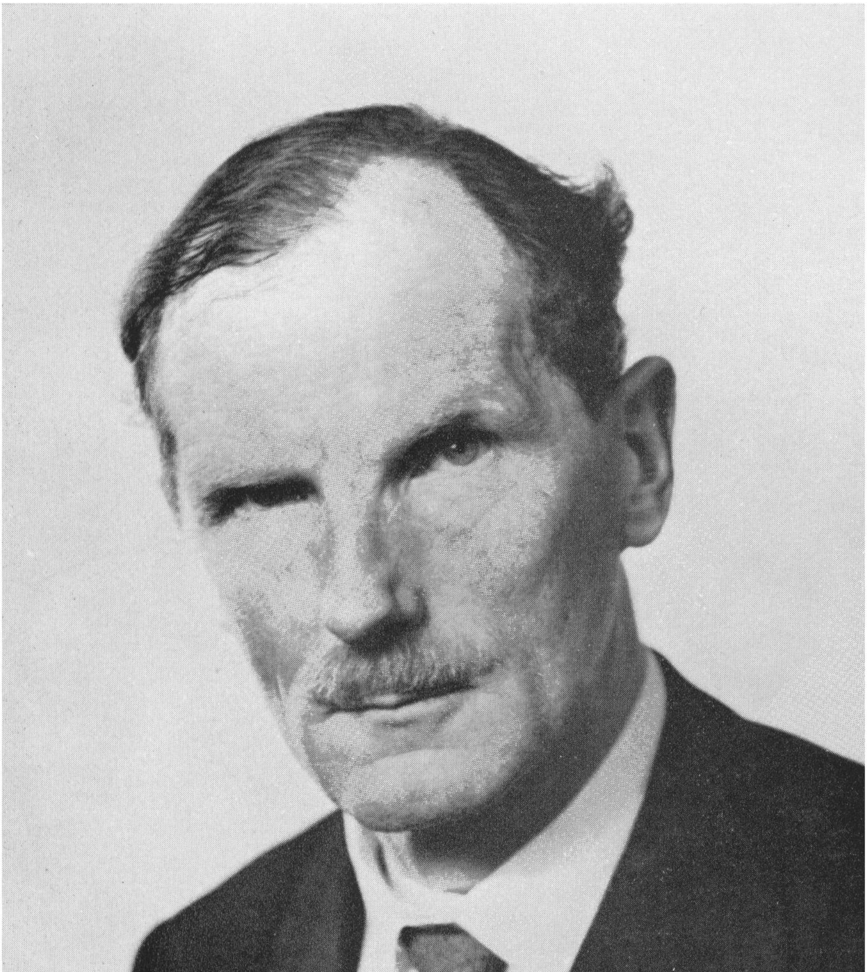

DR J. M. STAGG, C.B., O.B.E., F.R.S.E.

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DR J. M. STAGG, C.B., O.B.E., F.R.S.E.

Dr James Martin Stagg, C.B., O.B.E., F.R.S.E., died on 23 June 1975, aged 74 years, at his home at Seaford, Sussex. He will be remembered by scientist and non-scientist for different reasons.

Dr Stagg was educated in Edinburgh at Broughton School and afterwards at the University. Following two years as a science master at George Heriot's School in the same city he joined the Meteorological Office in 1924. During his first eight years with the Office his postings were all to stations which were concerned with geophysical work and in 1932 he was selected to lead the British Polar Year Expedition to Fort Rae in Canada. The work of this expedition covered a wide range of geophysical studies and confirmed Dr Stagg as an ardent geophysicist. On release from the Polar Year duties he was posted back to Edinburgh for two years after which came the inevitable overseas posting for two years followed by a move to Kew Observatory in the spring of 1939. During the greater part of these 15 years he produced a steady flow of papers on geophysical subjects and he seemed set for a career in very congenial work.

Shortly after the outbreak of the Second World War Dr Stagg was transferred to an administrative post at headquarters where, for four years, he played his part in promoting the war effort of the Meteorological Office.

In the autumn of 1943 Dr Stagg learned with surprise that he was to be appointed as Chief Meteorological Adviser to the invasion planning staff. His work during the next seven months or so, culminating in the meteorological forecast for the actual invasion, is fully described in his own book—*Forecast for Overlord*. Throughout that account his integrity and force of character stands out. For the time he had to drop the scientific work which was his first love and deal with vitally urgent and important problems in which human relationships were some of the most important variables. His success in this field is now a matter for the history books and for many will constitute his claim to fame.

After the war and a further short period at Kew Observatory Dr Stagg was made Principal Deputy Director and later Director of Services. This was the start of the last phase of his work in the Office. During this period the operational side of the Office was developed both for aviation and for non-aviation users. The success which attended this post-war development on the operational side was due in no small measure to the character and ability of the man who directed it. Despite this preoccupation with operational meteorology he found time to continue his geophysical work. From 1946 to 1951 Dr Stagg was General Secretary of the International Union of Geodesy and Geophysics and subsequently a member of the Finance Committee. He was elected President of the Royal Meteorological Society in 1959 and retired from the Office in 1960. After his retirement he maintained his interest in geophysical work and continued to serve on a number of national committees.

The marks of distinction awarded to Dr Stagg are a fitting commentary on his tripartite career. They were: O.B.E. (1937), Officer of the Legion of Merit conferred by the President of the United States of America (1945), C.B. (1954), Gauss–Weber Medal awarded by the Academy of Science, Göttingen (1955). Above all, he was a man of integrity who always fought hard for what he believed to be right.

A. C. BEST

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THE QUASI-BIENNIAL OSCILLATION AND ITS ASSOCIATION WITH TROPOSPHERIC CIRCULATION PATTERNS

By R. A. EBDON

Summary. Mean tropospheric circulation patterns for the northern hemisphere are examined for mid-season months when the phase of the equatorial stratospheric winds is either strong easterly or westerly. The results indicate significant differences particularly in January and July and suggest that the quasi-biennial oscillation in equatorial stratospheric winds may be an important feature in determining the character of the tropospheric circulation in middle and high latitudes.

Introduction. About 15 years ago attention was drawn to the fact that stratospheric winds over the equator showed considerable year-to-year variability with strong easterlies in one year being followed by strong westerlies in the following year.[1] This periodic fluctuation became known as the 'quasi-biennial oscillation' (QBO) and as more data became available and as interest in it developed a large number of papers appeared describing the behaviour of the QBO,[2,3] its possible causes,[4,5] and its role as a component part of the general circulation[6] apparently capable of influencing developments away from the equatorial region in both the stratosphere[7,8] and the troposphere.[9]

Long before wind and temperature data for the stratosphere became available various workers had detected periodicities of a biennial nature in tropospheric parameters[10] and, in recent years, it has been suggested that these may be correlated with the QBO.[11]

If such a relationship exists then it would be an important consideration in modelling the general circulation and also in the preparation of monthly and seasonal forecasts as it is usually a relatively simple matter to extrapolate for a few months ahead from the graph of 30-mb monthly mean zonal wind components near the equator (Figure 1).

In this paper the mean surface pressure patterns for the mid-season months (January, April, July and October) are examined to see if they show any

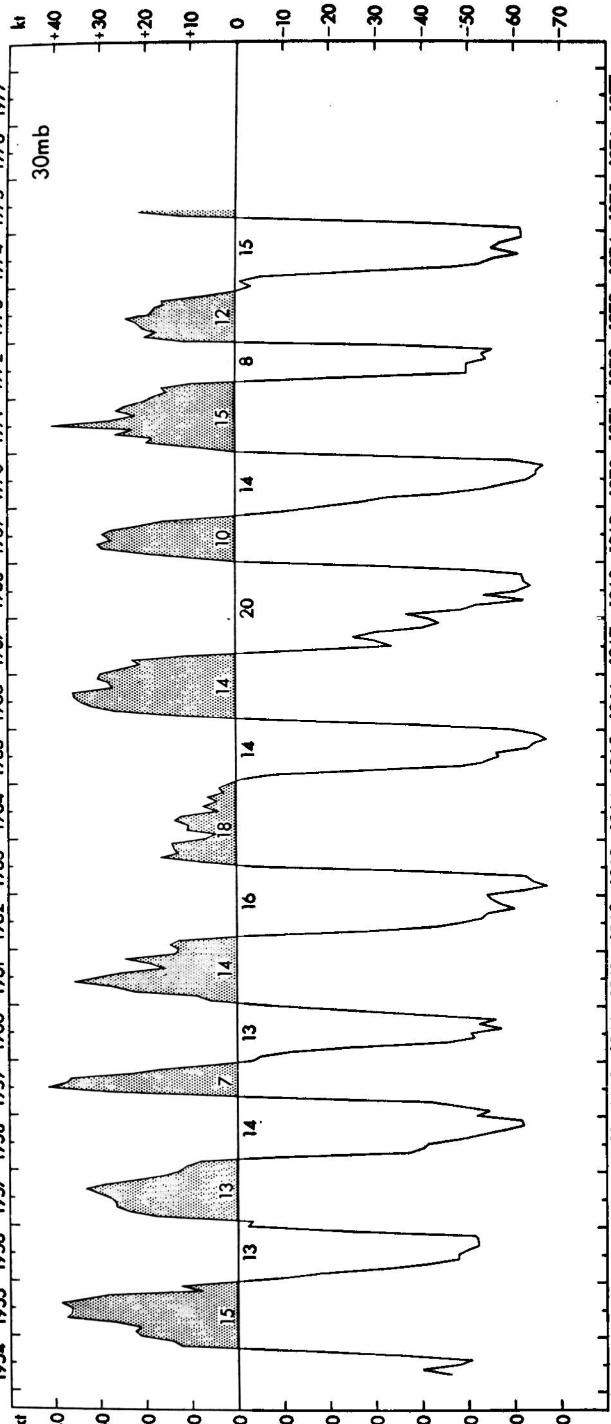

FIGURE 1—30-mb MONTHLY MEAN ZONAL WIND COMPONENTS AT CANTON ISLAND/GAN

Components towards the east are positive and stippled. Figures along the zero line indicate the duration, in months, of westerlies or of easterlies.

significant differences when the phase of the QBO (as measured by the 30-mb monthly mean zonal wind component over the equator) is either strong easterly or strong westerly.

Earlier work[2] has shown that the QBO appears to be in the same phase all around the equator and so the monthly mean 30-mb wind speeds quoted in the text, although for Canton Island or Gan only, may be taken as representative of speeds elsewhere close to the equator.

January. During the period July 1954 to July 1974 there were five Januarys when the phase of the QBO was such that the zonal wind component was a strong, or relatively strong, easterly. These were 1959 (52 knots), 1963 (54 knots), 1966 (60 knots), 1968 (38 knots) and 1970 (21 knots). Mean surface-pressure and 500-mb contour height charts were produced based on these five Januarys and the anomalies of the mean surface-pressure charts from the 1951–70 average, which are broadly similar to those at 500 mb, are shown in Figure 2.

The Januarys when the phase of the QBO was markedly westerly were in 1955 (21 knots), 1958 (13 knots), 1962 (13 knots), 1967 (29 knots) and 1972

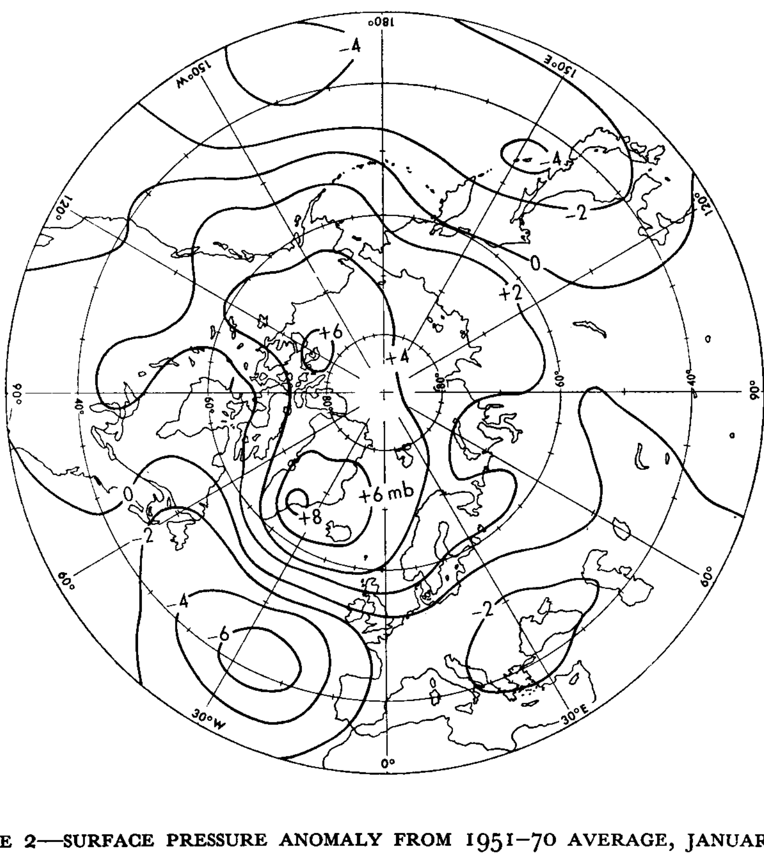

FIGURE 2—SURFACE PRESSURE ANOMALY FROM 1951–70 AVERAGE, JANUARY

Mean of five Januarys with easterly phase of QBO at 30 mb.

(18 knots). The anomalies, from the 1951–70 average, of the mean surface pressure based on these five months are shown in Figure 3. Corresponding 500-mb anomalies are similar.

The charts in Figures 2 and 3 show that there are considerable differences between the two sets of years. With a strong easterly phase of the QBO at 30 mb (Figure 2) the surface pressure chart shows a large area of positive anomalies in high latitudes with an almost continuous ring of negative anomalies in middle latitudes. When the QBO is in the opposite phase then Figure 3 shows an almost complete reversal of the surface pressure anomaly pattern. In high latitudes negative anomalies prevail and there is an almost complete ring of positive anomalies in middle latitudes.

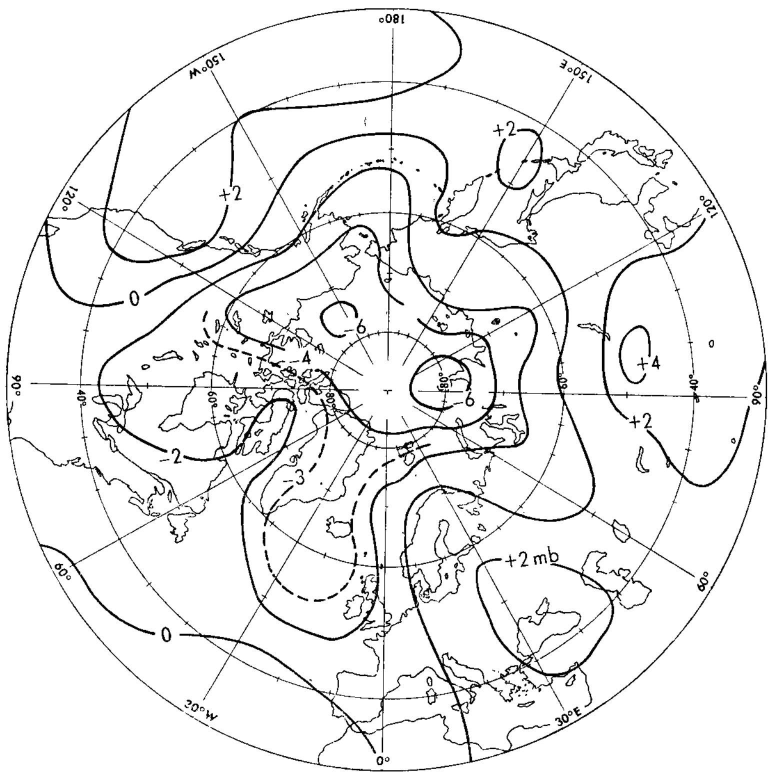

FIGURE 3—SURFACE PRESSURE ANOMALY FROM 1951–70 AVERAGE, JANUARY

Mean of five Januarys with westerly phase of QBO at 30 mb.

The mean surface pressure charts for the two sets of years show that during the easterly phase of the QBO positive anomalies in high latitudes lead to a separate high centre over the Canadian Arctic and a marked increase in the easterly gradient over north-east Siberia and Alaska. In the Atlantic sector the patterns differ very considerably. During the westerly phase of the QBO the Iceland low is apparently close to the 1951–70 average position but the mean pressure at the centre is a little lower, while the Azores high is close to its usual latitude with pressures marginally above average. This results in a very marked increase in the westerly gradient over the central North Atlantic and north-west Europe. On the other hand, the mean surface pressure chart based on those Januarys when the QBO was easterly shows the Iceland low to be displaced about 5 to 10 degrees of latitude south of the 1951–70 average position, with pressure gradients across the central North Atlantic and north-west Europe much weaker than average. In addition, the troughing over eastern Europe to the eastern Mediterranean is very pronounced.

The differences between the two sets of January charts were tested for significance using the program written for Welch's test as described by Ratcliffe[12] and the areas in which the averages differ significantly are shown in Figure 4. The total number of significant points over the hemisphere north of 35°N (but excluding the North Pacific south of 50°N owing to the paucity of data) was 90 for surface pressure and 52 for 500-mb heights. These values probably indicate significance at greater than the 1 per cent level though the exact value is in doubt due to the relatively small sample size (5 years only).

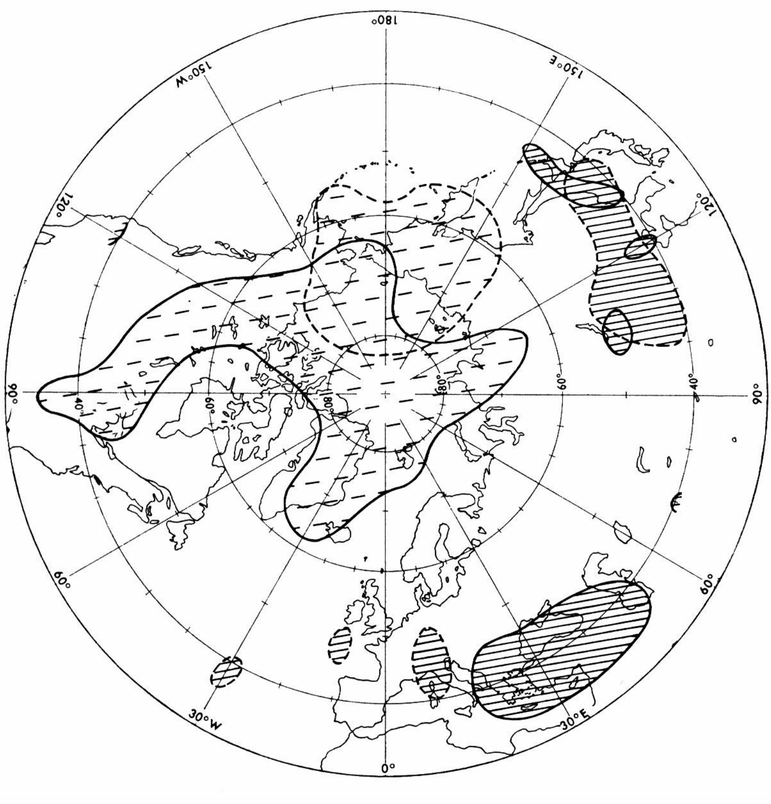

FIGURE 4—AREAS WHERE MEAN SURFACE PRESSURES AND 500-mb CONTOUR HEIGHTS WERE SIGNIFICANTLY DIFFERENT DURING WESTERLY AND EASTERLY PHASES OF THE QBO AT 30 mb IN JANUARY

——— Surface pressure – – – – 500-mb height
Hatched areas denote areas of positive anomaly; dashed areas denote negative anomaly.

In view of the suggestion that these very large differences in the lower tropospheric patterns might be attributable in some way to the phase of the QBO in equatorial stratospheric winds, cross-sections of zonal wind component along 80°W were prepared to see if the data indicated a possible relationship between the stratosphere in high and low latitudes and/or between the stratosphere and the troposphere. The reason for selecting 80°W is that, near this longitude, upper-air stations with monthly mean data to 30 mb or above are more plentiful than over other parts of the hemisphere and, for recent years, are readily available from *Monthly Climatic Data for the World*.[13] From Figures 2 and 3 it is apparent that similar cross-sections at other longitudes might prove more interesting if the necessary data were available.

Mean cross-sections were prepared using data for January 1967, 1972 and 1973 as representative of the westerly phase of the QBO and for January 1966, 1968 and 1970 as representative of the easterly phase. The cross-section showing the difference between these two is at Figure 5. It should be noted that the months were selected on the criterion of the phase of the QBO at 30 mb and, in some of the months the zonal wind component was of opposite sign at other stratospheric levels. From this analysis it appears that when the phase of the

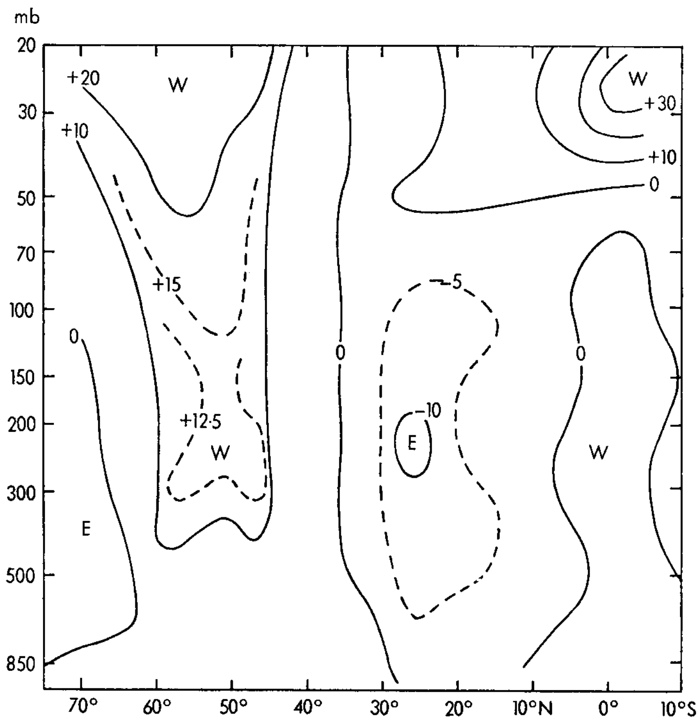

FIGURE 5—VERTICAL CROSS-SECTION AT 80°W SHOWING DIFFERENCES BETWEEN ZONAL COMPONENT DURING WESTERLY AND EASTERLY PHASES OF THE QBO AT 30 mb IN JANUARY

Speeds are in metres/second.

QBO is westerly at 30 mb then, over middle and high latitudes, the westerly circulation is stronger than in the easterly phase of the QBO—at least at 80°W—at the 30-mb level.

An examination of the 30-mb monthly mean charts for the six Januarys used shows that, in general terms, this statement can be extended to cover a large part of the hemisphere. In the three Januarys 1967, 1972 and 1973 (all with westerly phase of the QBO at 30 mb) the monthly mean 30-mb contour charts showed a very strong winter circulation and in each month the heights at the centre of the vortex were below 22·0 km. In the other three Januarys (1966, 1968 and 1970) the monthly mean 30-mb patterns were more variable—in 1966 the lowest heights were probably about 22·2 km, in 1968 about 23·0 km and in 1970 about 22·7 km. These three Januarys (coinciding with a pronounced easterly phase of the QBO at 30 mb) certainly appear to have a weaker westerly flow over high latitudes. In using these stratospheric charts it must, of course, be borne in mind that the sample (only three in each set) is far too small to enable one to draw reliable conclusions. Nevertheless it is interesting to speculate as to whether or not the polar night stratospheric jet in January is stronger because the QBO is in a westerly phase and weaker because it is in an easterly phase. However, if such a relationship does exist, a much longer period of data will be needed before it can be shown with any degree of confidence.

Another interesting feature of the cross-section in Figure 5 is the suggestion that the enhanced westerly flow in the stratosphere appears to be associated with stronger westerlies in the troposphere with a secondary maximum between 300 and 200 mb at about 45 to 55°N. Certainly the chart in Figure 3 indicates that enhanced surface westerly flow occurs over most of the hemisphere north of about 50°N when the phase of the QBO at 30 mb is westerly.

This enhanced westerly flow was also apparent on the corresponding 500-mb charts and, in order to examine whether or not the mean latitude of the maximum flow at 500 mb does vary significantly between these two sets of Januarys, the monthly mean wind speeds at 500 mb were calculated and averaged around latitude circles. The mean speeds were obtained by using daily 500-mb height grid-point values with a spacing of 5 degrees latitude and 10 degrees longitude to calculate the zonal (u) and meridional (v) components. The speed was then derived from $(u^2 + v^2)^{\frac{1}{2}}$. The monthly mean values around the latitude circles at 5-degree intervals from 60 to 30°N and also the five-year means (Figure 6) show that, over the hemisphere as a whole, when the phase of the QBO is westerly the average latitude of the strongest flow is about 35°N with individual Januarys varying between 35 and 45°N (1958 is an exception although in that January, there is a weak secondary maximum at 50°). During those Januarys when the phase of the QBO is easterly the monthly mean latitude of the maximum flow is farther south and varies between 30 and 40°N with a five-year mean of 30°N.

Reference was made earlier to the considerable differences in the Atlantic sector and these are confirmed by the mean 500-mb wind speeds along latitude circles from 60 to 30°N between 60°W and the Greenwich meridian (Figure 7). The five-year means show that during the easterly phase of the QBO the latitude of the maximum wind speed is about 35°N whilst the mean during the westerly phase is about 45°N. The curves for the individual Januarys show that when the QBO is easterly there is only one month (1968) when the maximum is north of 40°N and that with the westerly phase there is only one month (1955) when the maximum is south of 40°N. This diagram also shows the enhanced westerly flow which accompanies the westerly phase of the QBO.

The central England temperatures and the England and Wales rainfall and sunshine data for these Januarys were examined but, despite the differences in tropospheric circulation patterns, there were no significant differences between the two sets of five years.

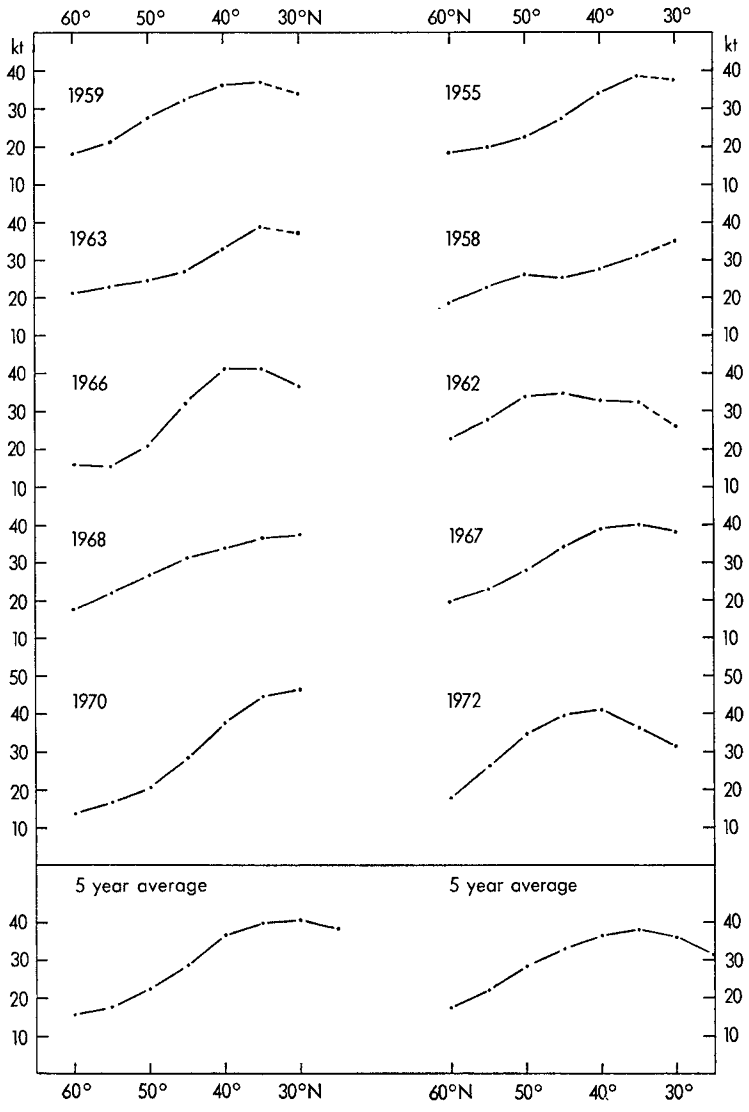

FIGURE 6—LATITUDINAL MEAN WIND SPEED AT 500 mb IN JANUARY

(a) Januarys with easterly phase of QBO at 30 mb,
(b) Januarys with westerly phase of QBO at 30 mb.
Wind speeds are in knots.

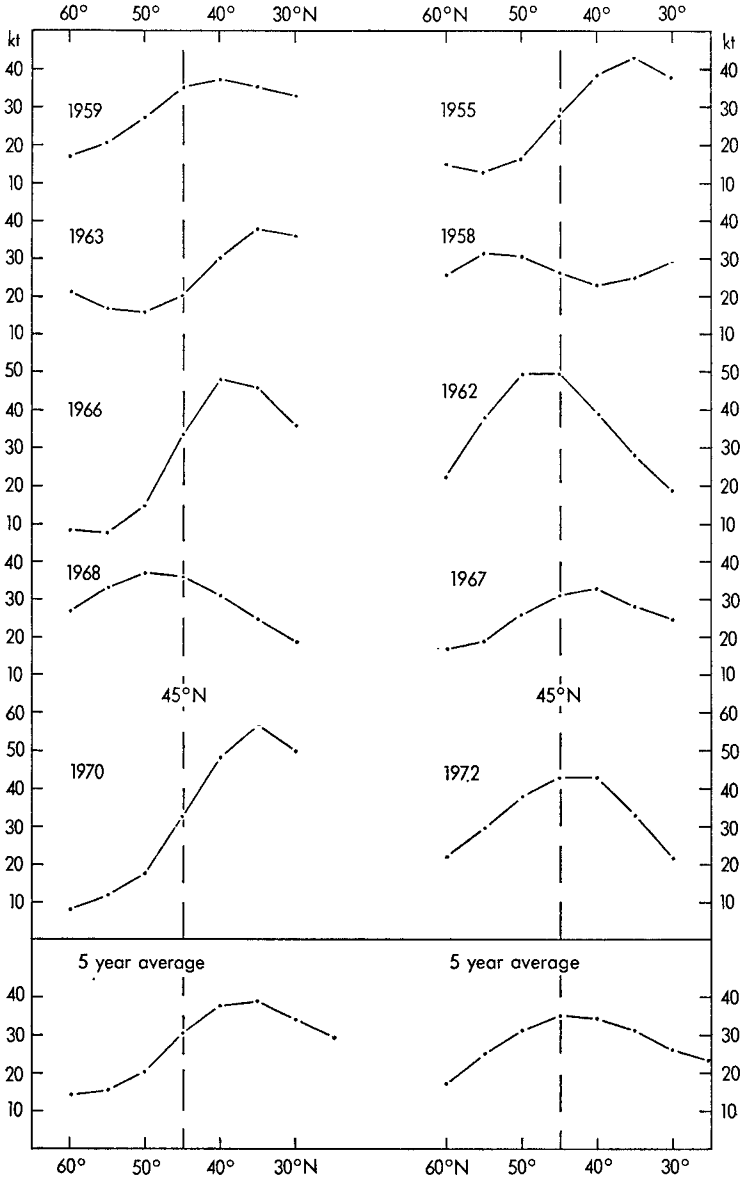

FIGURE 7—500-mb WIND SPEEDS MEANED ALONG LATITUDE CIRCLES OVER THE ATLANTIC FROM 60°W TO 0°, JANUARY

(a) Januarys with easterly phase of QBO at 30 mb,
(b) Januarys with westerly phase of QBO at 30 mb.
Wind speeds are in knots.

July. Sets of mean pressure and 500-mb contour height charts were produced for the eight Julys when the QBO was in a strong easterly phase. The years were 1954 (48 knots), 1956 (48 knots), 1960 (51 knots), 1962 (49 knots), 1965 (57 knots), 1968 (60 knots), 1970 (62 knots) and 1972 (50 knots). Similar charts were also produced for the eight Julys when the QBO was strong westerly and these were 1955 (36 knots), 1957 (27 knots), 1959 (41 knots), 1961 (30 knots), 1966 (34 knots), 1969 (28 knots), 1971 (40 knots) and 1973 (19 knots). The anomalies of surface pressure of these sets of eight-year-mean charts from the 1951–70 average are shown in Figures 8 and 9. The anomalies are much smaller than those for January but this is not surprising in view of the large differences in standard deviation between the two months. However, there are areas where the difference between the average charts for the two sets of Julys are statistically significant and these are shown in Figure 10. The number of significant points in July (48 for surface pressure and 31 for 500-mb contour height) is less than in January but, using Welch's test these are significant at the 1 per cent level for surface pressure and between the 5 per cent and 10 per cent levels for 500-mb height.

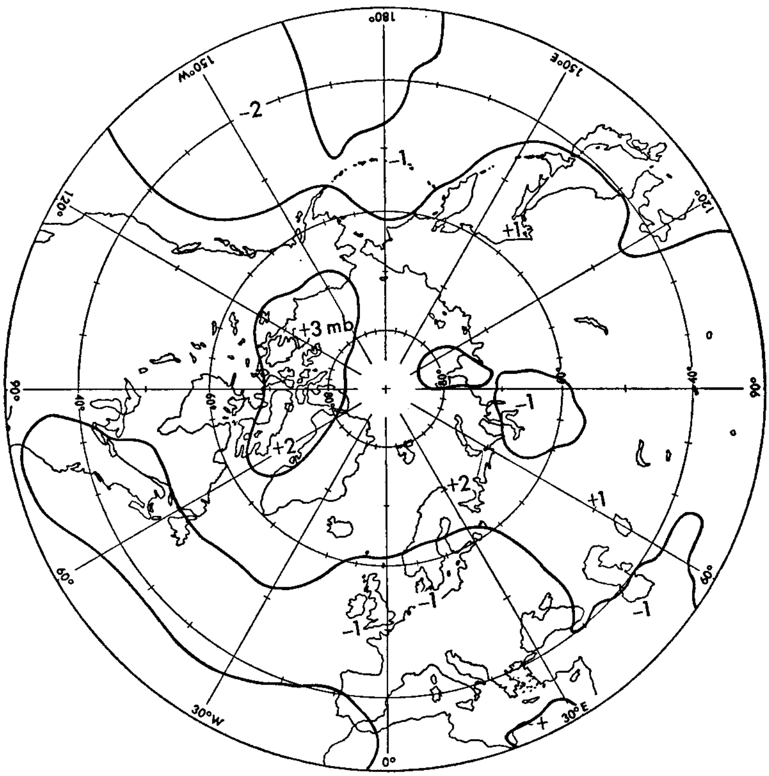

FIGURE 8—SURFACE PRESSURE ANOMALY FROM 1951–70 AVERAGE, JULY

Mean of eight Julys with easterly phase of QBO at 30 mb.

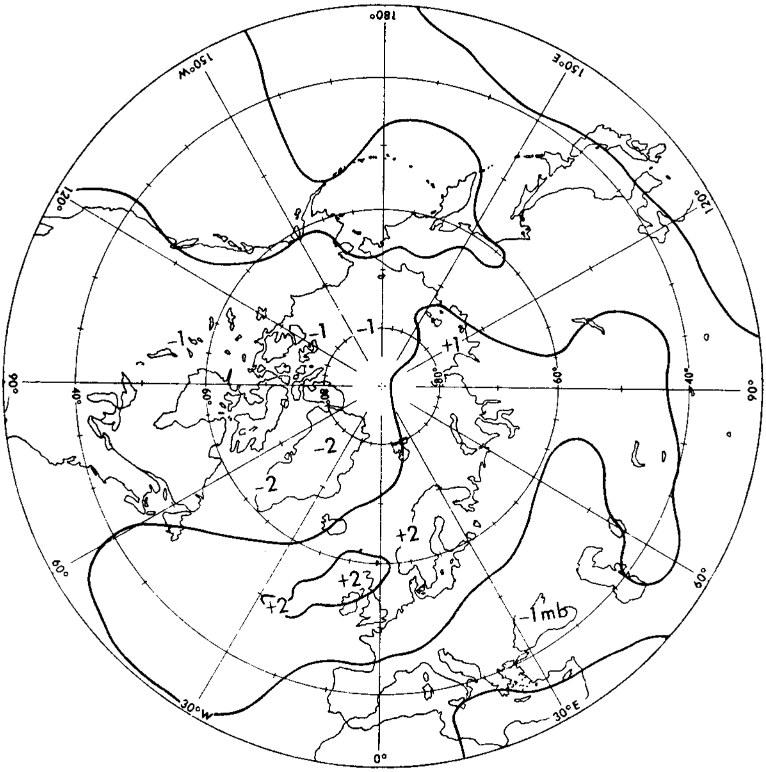

FIGURE 9—SURFACE PRESSURE ANOMALY FROM 1951–70 AVERAGE, JULY

Mean of eight Julys with westerly phase of QBO at 30 mb.

In July, as in the case of January, there is a suggestion that the mean charts based on the years when the QBO was easterly have surface pressures above average in high latitudes. Areas of particular interest are those around the British Isles, where the anomaly is negative, and northern Canada, where the anomaly is positive on the mean chart during the easterly phase of the QBO (Figure 8) changing to anomalies of opposite sign on the mean charts during the westerly phase of the QBO (Figure 9).

The cross-section of zonal wind components at 80°W (Figure 11) shows the differences between the easterly and westerly phases of the QBO at 30 mb (July, 1965, 1968, 1970 and 1972 representing the easterly phase and July 1966, 1969, 1971 and 1973 representing the westerly phase). At the 30-mb level, at 80°W the differences are very small outside the tropics and, in the troposphere, the only noticeable difference is the weak maximum at 250 to 150 mb near 40–45°N which suggests that the westerlies there might be a little stronger during the westerly phase of the QBO.

The mean charts based on the two sets of eight Julys show that the differences are such that the average position of the ridge extending north-eastwards from the Azores anticyclone is about 5 degrees of latitude farther north in those years when the phase of the QBO at 30 mb is westerly.

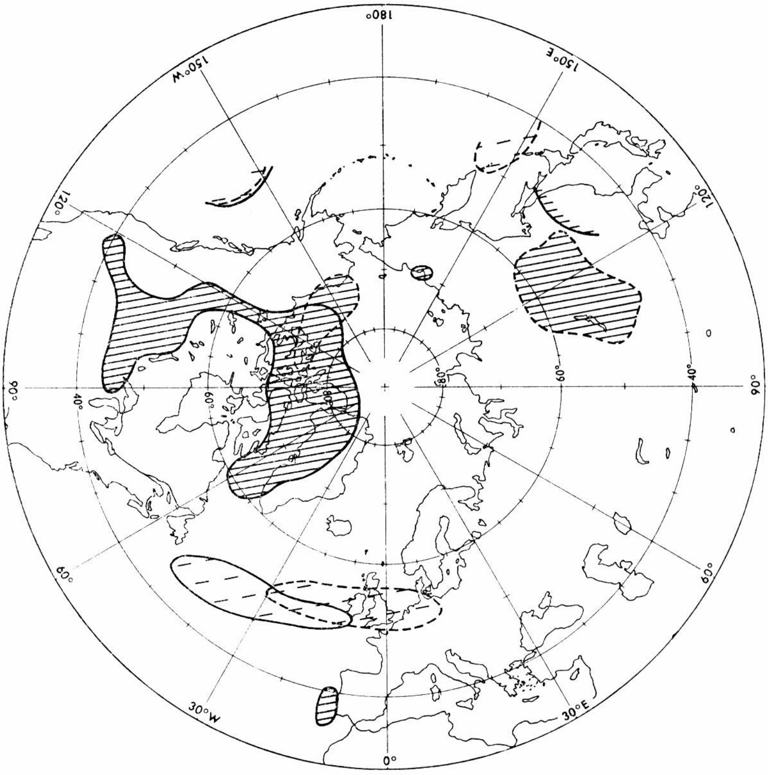

FIGURE 10—AREAS WHERE MEAN SURFACE PRESSURES AND 500-mb CONTOUR HEIGHTS WERE SIGNIFICANTLY DIFFERENT DURING WESTERLY AND EASTERLY PHASES OF THE QBO AT 30 mb IN JULY

——— Surface pressure - - - - 500-mb height
Hatched areas denote areas of positive anomaly; dashed areas denote negative anomaly.

The 500-mb wind speeds meaned around latitude circles over the whole hemisphere show little or no difference in the latitude of the strongest flow between the two sets of Julys. In both cases the maximum flow appears to be at 45°N. The eight-year mean values for the Atlantic sector (60°W to the Greenwich meridian) are shown in Figure 12 and, although in both cases the maximum is at 50°N, it can be seen from the curves that during the easterly phase of the QBO the maximum occurs between 45 and 50°N whereas during the westerly phase it occurs between 50 and 55°N. The individual monthly mean curves show that during the westerly phase all the maxima are near or north of 50°N whereas during the easterly phase four of the maxima occur at or south of 45°N and only one (1972) is north of 50°N. This is in agreement with the January result that during the westerly phase of the QBO the strongest flow at 500 mb is farther north than during the easterly phase. The differences between the two sets of years are reflected in the July temperatures for central England and the sunshine values for England and Wales.

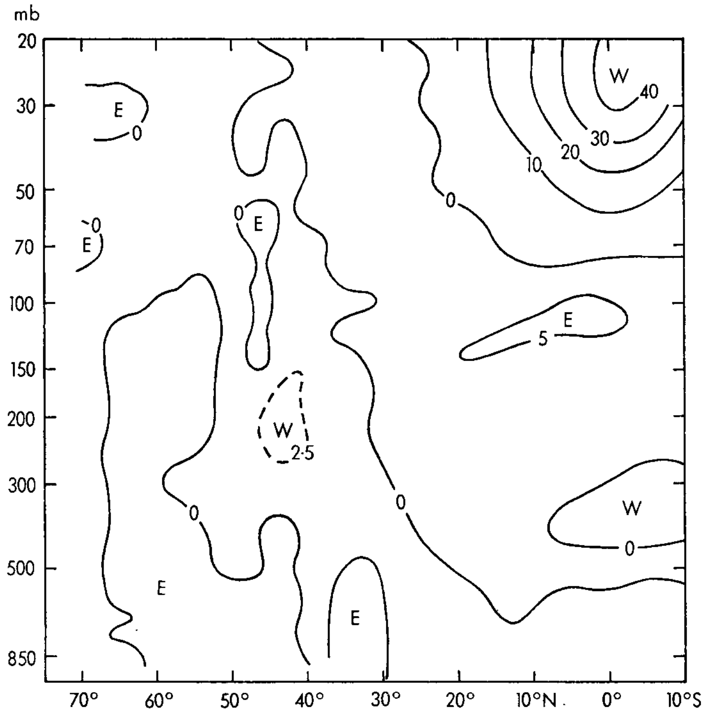

FIGURE 11—VERTICAL CROSS-SECTION AT 80°W SHOWING DIFFERENCES BETWEEN ZONAL COMPONENT DURING WESTERLY AND EASTERLY PHASES OF THE QBO AT 30 mb IN JULY

Speeds are in metres/second.

From Table I it can be seen that in the nine Julys, including 1974, when the phase of the QBO was easterly, seven of the monthly mean temperatures were in quintiles 1 and 2 and in the eight Julys when the phase was westerly five of the months were in quintiles 4 and 5.

The sunshine totals for the same Julys show that during the easterly phase of the QBO all nine years fell in tercile 1. The sunshine totals for the Julys associated with the westerly phase of the QBO are equally divided between terciles 1 and 3.

TABLE I—TEMPERATURES FOR CENTRAL ENGLAND AND SUNSHINE FOR ENGLAND AND WALES FOR JULYS, REFLECTING THE DIFFERENCES BETWEEN EASTERLY AND WESTERLY PHASES OF THE QBO

(a) Central England Temperatures (quintiles)

Phase of QBO at 30 mb	1	2	3	4	5
Easterly	5	2	2	0	0
Westerly	1	1	1	3	2

(b) Sunshine for England and Wales (terciles)

Phase of QBO at 30 mb	1	2	3
Easterly	9	0	0
Westerly	4	0	4

Papers have been published suggesting that the summer weather over some parts of the northern hemisphere[14,15] and, in particular, southern England[16] may be associated with the behaviour of the stratosphere in high latitudes in spring. Table II summarizes this by showing the relationship between the summer index at Kew (as defined by Poulter[17]) and the date of the spring reversal (from winter westerly to summer easterly) of 30-mb zonal-wind components at Shanwell.

TABLE II—RELATIONSHIP BETWEEN SPRING REVERSAL OF 30-mb WINDS AT SHANWELL AND INDEX OF THE FOLLOWING SUMMER AT KEW, 1958–74

Time of spring reversal	Kew Summer Index		
	≥690	689–671	≤670
Late	0	2	5
Average	2	0	1
Early	5	2	0

A point of interest from this table is that, following an early change-over there has, so far, not been an outstandingly poor summer (June, July and August) and the only two summers which were average were 1972 and 1974. Although the spring wind reversal at 30 mb occurred early in both 1972 and 1974 these were years when the phase of the QBO was strong easterly and the inference from Table I would be for a cool and cloudy July. If the two very pronounced stratospheric events—the breakdown of the stratospheric winter polar vortex and the phase of the QBO in equatorial stratospheric winds—do influence the weather at the surface it may well be that they both make their separate contribution and that the indication from one of them should be modified to take account of the indication from the other.

April and October. Similar sets of charts were prepared for April (seven months in each sample) and October (eight months in each sample). In both cases there were relatively few grid points at which the differences were significant. An examination of the temperature, rainfall and sunshine values for the months used did not indicate any preference for warm or cold, dry or wet, sunny or cloudy Aprils or Octobers to occur over England and Wales more frequently with one phase of the QBO than with the other.

Conclusion. The results from this study are necessarily somewhat tentative in view of the fact that adequate stratospheric data are available for only a limited period. Nevertheless, the charts produced here support the view that the complete reversal of winds in the equatorial stratosphere does play a part in determining the character of the circulation in the middle and high latitude troposphere, at least during mid winter and mid summer.

In view of the small sample of years used in calculating the mean charts it would be unwise to regard the results presented as 'rules'. However, it might well be that when the data period, and our understanding of the general circulation, improves then the major stratospheric events, such as the QBO and the spring and autumn reversals of wind, will prove to be very useful parameters for forecasting on longer time scales.

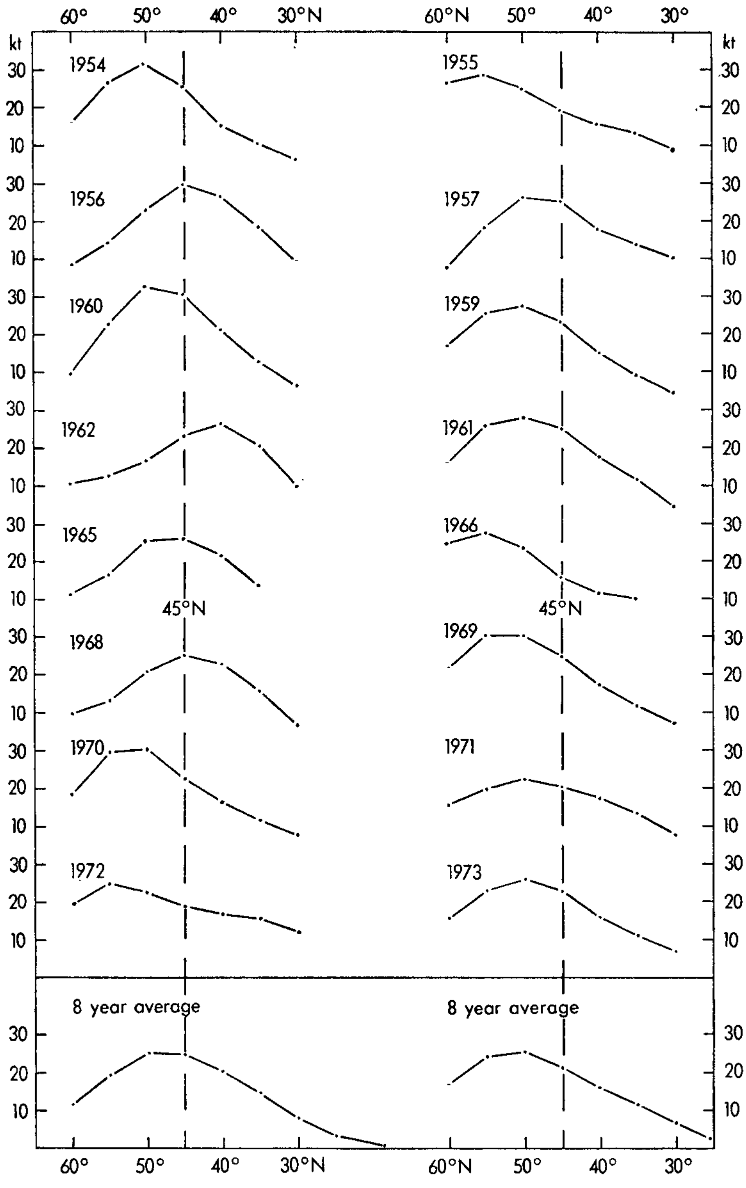

FIGURE 12—500-mb WIND SPEEDS MEANED ALONG LATITUDE CIRCLES OVER THE ATLANTIC FROM 60°W TO 0°, JULY

(a) Julys with easterly phase of QBO at 30 mb,
(b) Julys with westerly phase of QBO at 30 mb.
Wind speeds are in knots.

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Photograph by C. J. Richards

PLATE I—TOWERING CUMULUS AND CUMULONIMBUS

The photograph, taken from Bristol Downs, looking north, on the evening of 24 July 1971, shows towering cumulus and cumulonimbus within a line of convergence over South Wales exhibiting pronounced convective activity within an unstable atmosphere.

PLATE II—NEW JOINT FINANCING AGREEMENT ON NORTH ATLANTIC OCEAN STATIONS

Mr N. Bradbury, Deputy Director (Observational Services) in the Meteorological Office, signing the Final Act of the Conference of Plenipotentiary Delegates on 15 November 1974. (At the time of writing the agreement still awaits ratification.)
See page 311.

PLATE III—NEW JOINT FINANCING AGREEMENT ON NORTH ATLANTIC OCEAN STATIONS

Sir David Hildyard, K.C.M.G., D.F.C., H.M. Ambassador and U.K. Permanent Representative at the U.K. Mission to the United Nations at Geneva, signing the agreement (subject to ratification) on 12 February 1975.

Seated next to Sir David Hildyard: Dr D. A. Davies, Secretary-General, WMO.

Standing, left to right: Mr Sen Gupta, Personal Assistant to the Secretary-General of WMO, Mr J. J. D. Ashdown of the U.K. Mission in Geneva, Dr G. K. Weiss of the Operations and Facilities Division of WMO, and Dr K. Langlo, Deputy Secretary-General of WMO.

See page 311.

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Photograph by C. J. Richards

PLATE IV—OPTICAL PHENOMENA AT SUNSET ON 17 DECEMBER 1973 AT BRACKNELL, BERKS., OBSERVED THROUGH BANDS OF CIRRUS AND CIRROSTRATUS

Acknowledgements. The author gratefully acknowledges the help given by Miss H. Tellam, who wrote the computer program to apply Welch's test, and Mr. S. Lawson whose computer program provided the 500-mb mean wind speeds.

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551.543.6:517.512.2

ON A METHOD FOR ANALYSING ATMOSPHERIC OSCILLATIONS

By R. DEL LLANO and J. Mª NUÑEZ

(IBM Madrid Scientific Center and Barcelona University respectively)

Summary. The results of analysing pressure data by means of Fast Fourier Transform techniques for the detection of atmospheric tides and other periodical phenomena are presented.

Introduction. The results of analysing pressure data by means of Fast Fourier Transform (FFT) techniques are presented. With this method, frequencies of all atmospheric tides can be detected as well as frequencies of other periodical phenomena which the classic Chapman–Miller method[1] of studying atmospheric tides cannot discover.

Method of analysis. The aim is to calculate the power spectrum of a complete time series of three years' (1970–72) hourly pressure data (26 304 data in total). The measurements have been made from records registered by a microbarograph located in Barcelona (at 94 m above mean sea level, latitude 41°23′07″ N and longitude 2°07′03″ E). Each datum represents the average hourly pressure and not its instantaneous value, the mean being obtained graphically from the records by the equal-area method.* In this way the original time series is found to be convoluted with a regular time window of one hour width, and afterwards sampled at one-hour time intervals.

The calculus of the power spectrum is performed by means of the FFT algorithm proposed by Singleton[2] and is carried out in only one program-run with all the 26 304 data at the same time. Once the power spectrum is obtained it is multiplied by $(\pi f\tau)^2/\sin^2(\pi f\tau)$, (where τ is the averaging time, 1 hour in this case) in order to counteract the effect of the time averaging. In the Figures the value of $p \times f$ is plotted against $\ln f$ (p being the value of the calculated power spectrum corresponding to the frequency f).

The complete spectrum. The results of the calculations previously described give us about 13 000 power estimates, covering a range of frequencies from $3{\cdot}8 \times 10^{-5}$ to $0{\cdot}5$ cycles/hour.

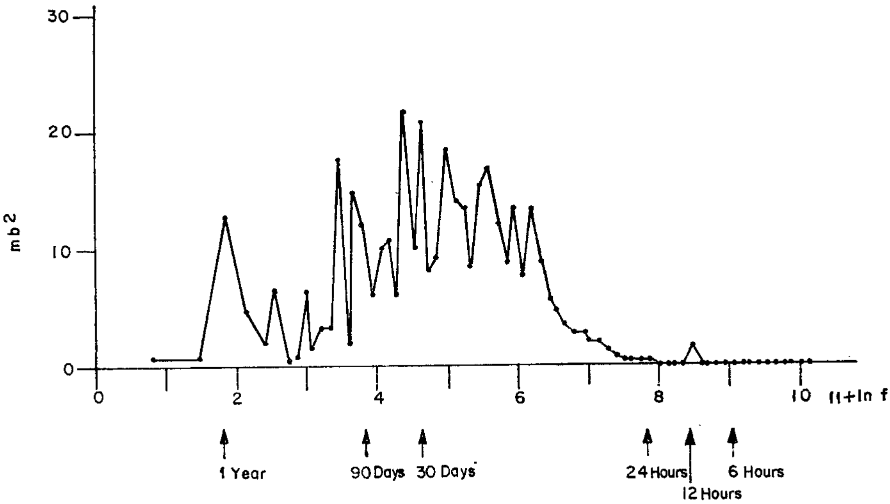

FIGURE 1—POWER SPECTRUM OF THREE YEARS' HOURLY PRESSURE DATA IN BARCELONA

* Such data are available on an 800-bpi magnetic tape in the 'Departamento de Física de la Tierra y del Cosmos', Avda. Generalísimo Franco, 647. Barcelona–14, Spain.

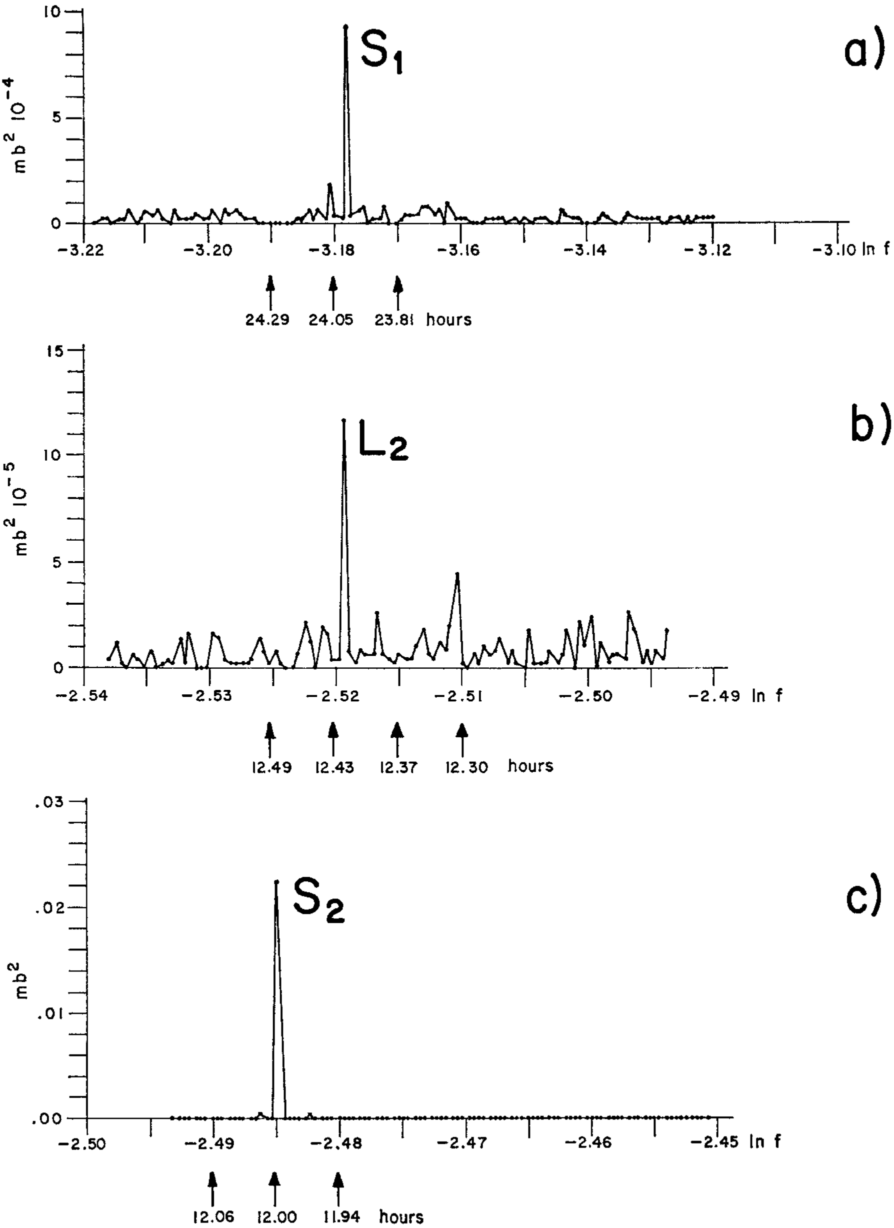

FIGURE 2—DETAILS OF PRESSURE POWER SPECTRUM: SPECTRAL BANDS SHOWING SOLAR AND LUNAR TIDES

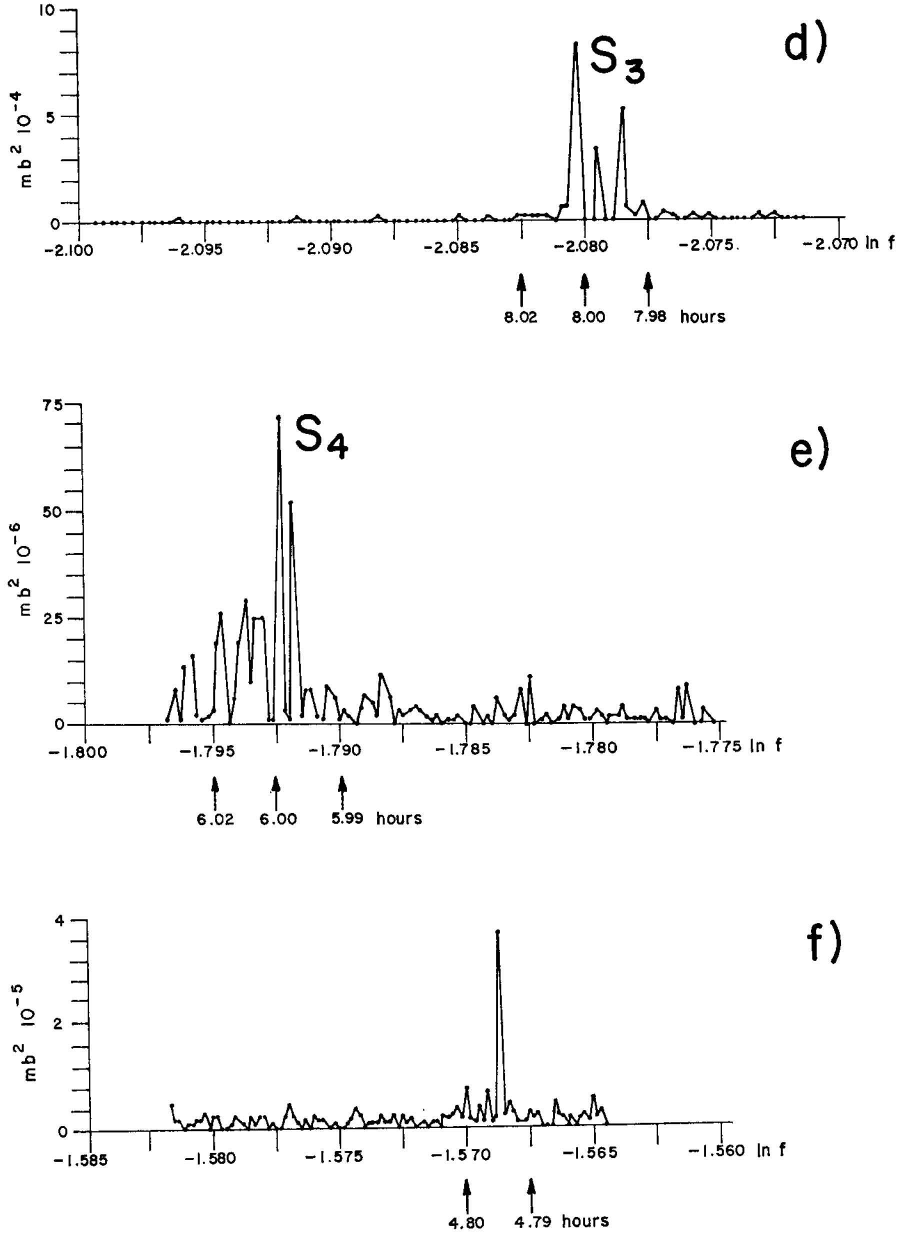

FIGURE 2—*continued*

In order to have a complete description of the spectrum and to solve the problem of plotting the 13 000 power estimates in the same Figure, the following procedure has been used: the frequency axis is divided into 69 uniform spectral bands in accordance with a logarithmic scale (in such a way that the higher the frequency, the greater the number of spectral estimates in each band). In Figure 1, the average $\overline{p \times f}$ in each of the 69 bands is plotted against the corresponding average $\overline{\ln f}$. An extra scale has been added to the abscissae, where the periods in hours and days are shown to make the interpretation of the graphs easier.

There are two characteristics that can be clearly detected in this first Figure: on the one side, the yearly pressure oscillation, associated with a very clear peak that appears in the low-frequency part of the spectrum, and on the other side, pressure oscillations with periods greater than 24 hours whose amplitudes dominate clear oscillations with higher frequencies (this fact must be understood as the influence of the synoptic baric systems).

For periods smaller than 24 hours only one peak can be detected clearly, and it can be associated with the semidiurnal solar tide. The fact that other components of atmospheric tides are not present in this Figure can be understood if we take into account that the points in the graph are the average of several estimates and not the estimates themselves, so the narrow peaks associated with atmospheric tides are eliminated by the averaging procedure.

Conclusions. Figure 2 shows in detail all these spectral bands, of 100 estimates each, which show interesting aspects. From the clearness of the peaks which appear in some of the spectral zones and from their perfect concurrence with the fundamental periods, they can be made to correspond perfectly to the principal components of the atmospheric tides: Figure 2(a) with daily solar tide S_1, Figure 2(b) with semidiurnal lunar tide L_2, Figure 2(c) with semidiurnal solar tide S_2, and Figure 2(d) with terdiurnal solar tide S_3. On the other hand in Figure 2(e) a pressure fluctuation appears less clearly and also shows a slight discrepancy between the peak period and the theoretical six-hour period which would correspond to the quaterdiurnal solar tide S_4. It is also interesting to point out another peak area in Figure 2(f) which corresponds to an approximate period of five hours. Keeping in mind the geographical variability which Kertz[3] had already obtained for the S_4 component, these results bring us to consider the necessity of introducing other elements, possibly local ones, in the theory of thermal influence on atmospheric oscillations. In any case, this method appears to be highly promising for a complete study of atmospheric oscillations.

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551.509.333

ESTIMATION OF THE LIFE SPAN OF ATMOSPHERIC MOTION SYSTEMS BY MEANS OF ATMOSPHERIC ENERGETICS

By GY. KOPPÁNY
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Summary. Comparisons have been made between the kinetic energy and the life span of various atmospheric motion systems. The mechanical power of the motion systems increases with the increase in size, but it is limited by the solar energy absorbed in the earth–atmosphere system on the one hand and by the net efficiency of the atmosphere on the other. An estimate is made of the period needed for the generation or transformation of the global atmospheric circulation.

When either statistical or dynamical methods are applied to the preparation of long-range weather forecasts it is most important to ask how long the forecasts can be extended with a relatively high probability of success; in other words, how long is current weather dependent on the previous stage of the earth–atmosphere system.

An attempt was made by Bonacina[1] to answer this question. He pointed out that according to some estimates, the weather depends on the past 15 days or for several times that period. Lorenz[2] applied a numerical model to the investigation of the predictability of the weather. In this numerical model he distinguished between 20 scales, each covering an octave of the spectrum, starting with the smallest air motion and going on to the largest atmospheric current, that is to say the global circulation of the atmosphere. He concluded that the predictability depends on the size of the motion, and that even the largest atmospheric currents cannot be predicted by means of a numerical model for longer than two or three weeks.

Baur[3] used monthly mean values of atmospheric parameters in his thorough statistical analysis. He investigated the iterations of the monthly anomalies of atmospheric parameters and found that those in the first three months are smaller, but in the fifth and sixth months they are larger than those expected in theory. His conclusion is that the atmosphere has a tendency towards repetition rather than towards persistence—*Wiederholungsneigung* instead of *Erhaltungsneigung*.

It is well known that the life span of air motion increases with the size of the motion, for example the duration of a small whirlwind is no longer than one minute, a local thunderstorm is over within a couple of hours, the life span of a cyclone is 7–15 days, and so on. Since both horizontal and vertical dimensions of an air motion system can be estimated more or less accurately we are able to estimate the mass of moving air in a motion system. Thus, taking into account that most air motions have a wind speed of 10 metres per second, we may calculate the amount of kinetic energy in a motion system.

Let us pick out seven motion systems of various sizes, starting with the smallest and going to the largest, and compare their kinetic energy with their life duration. If the kinetic energy is given in joules (J) and the time in seconds (s), the following estimates can be made:

1. Small whirlwind	10^4–10^5 J	10 s
2. Local circulation cell without precipitation, e.g. single cumulus	10^{10}–10^{11} J	10^2 s

3.	Local thunderstorm	10^{14} J	10^3 s
4.	Cold front	10^{17} J	10^5 s
5.	Extratropical cyclone	10^{18}–10^{19} J	10^6 s
6.	Frontal zone consisting of series of cyclones on surface accompanied by Rossby waves aloft	10^{20} J	10^7 s
7.	General circulation of the atmosphere	10^{21} J	?

The above values can be depicted in a co-ordinate system, in which the X-axis denotes kinetic energy and the Y-axis is the life span of the motion systems, these being represented by the letters A–G.

From Figure 1 it can be seen that the life span of motion systems increases slowly at smaller motions with increasing kinetic energy, but it increases rapidly at larger motions. However, the question remains what is the life span of the general circulation? Actually we know the order of magnitude of kinetic energy of the general circulation; thus we may draw a vertical line in Figure 1 at 10^{21} J indicating that this is the highest limit of kinetic energy forming in the atmosphere. The task is to determine the point where the curve in Figure 1 crosses the vertical line of 10^{21} J. The ordinate of this point will give the duration of the general circulation.

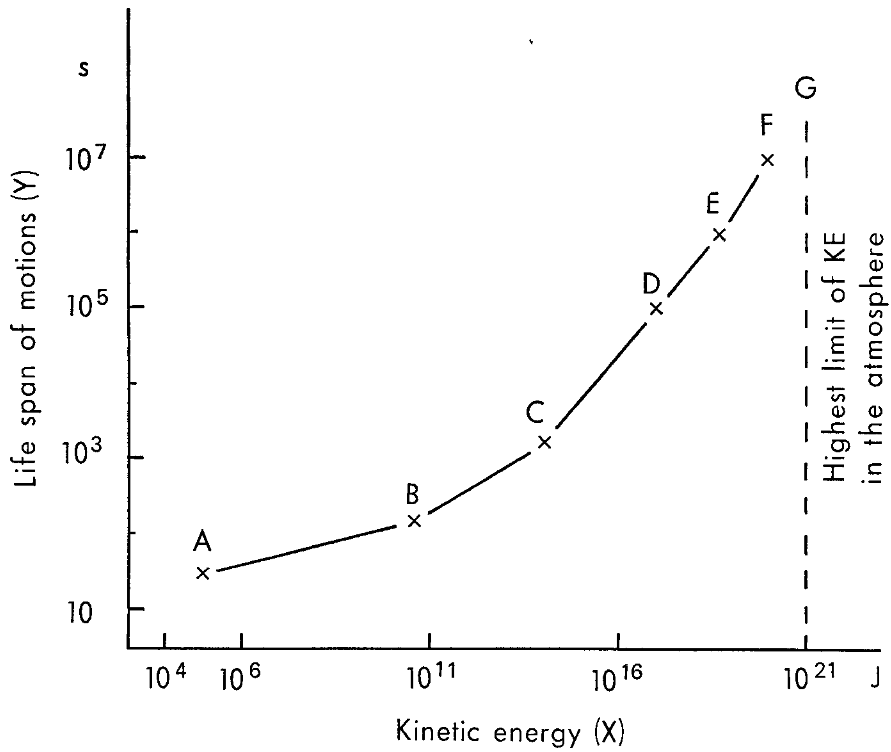

FIGURE 1—LIFE SPAN OF ATMOSPHERIC MOTION SYSTEMS AS A FUNCTION OF KINETIC ENERGY

The letters A–G represent systems of increasing size from small whirlwinds to the general circulation.

In order to answer this question let us calculate the ratio X/Y, that is to say (kinetic energy)/(life span of the motions). In fact the ratio X/Y has a well-defined physical meaning—generation, conversion or dissipation of kinetic energy; in general, the mechanical power of the motion system. In this case the conversion of kinetic energy will be given in joules/second or watts. We have next to estimate the area in m^2 touched by a given motion system and calculating the ratio W/m^2 we shall obtain the conversion of kinetic energy per square metre. This quantity is comparable with the solar energy absorbed by the earth–atmosphere system over 1 m^2 horizontal area.

The order of magnitude of the solar energy is 10^{17} watts over the whole earth, or 10^3 watts per square metre. On the other hand, the ratio of conversion of kinetic energy to solar energy, that is to say the *net efficiency of the earth–atmosphere system,* has been determined by many authors. The value of this ratio is approximately equal to 10^{-3}; thus about one-thousandth of the solar energy is being converted to kinetic energy in the earth's atmosphere (Borisenkov[4]). Thus we have two very important characteristics of the mechanism of the general circulation of the atmosphere, namely the solar energy as the source of energy generating all motion in the atmosphere, and the net efficiency of the earth–atmosphere system.

Having calculated the ratio X/Y in joules/second, we have obtained very important results, summed up in Table I. The ratios of X/Y, i.e. the *mechanical powers* of motion systems increase with the size of the motions. However, they have a highest limit value of 10^{14} J/s or 10^{14} W, which is determined by the solar energy and the net efficiency of the atmosphere. Dividing the kinetic energy by the mechanical power of the atmosphere we get 10^7 s for the life span of the general circulation. One possible interpretation of this result may be that the generation of the global circulation system of the earth's atmosphere by given solar radiation lasts 10^7 s, that is to say about four months or so.

TABLE I—KINETIC ENERGY, DURATION, AND MECHANICAL POWER OF ATMOSPHERIC MOTION SYSTEMS OF DIFFERENT SIZES

Motion system	Kinetic energy (X)	Life span (Y)	Power (X/Y)	Area	Power per unit area
	joules	*seconds*	*watts*	m^2	W/m^2
Small whirlwind (A)	10^4–10^5	10	10^3	10^2	10
Local convection cell without precipitation (B)	10^{10}–10^{11}	10^2–10^3	10^8	10^6	10^2
Local thunderstorm (C)	10^{14}	10^3–10^4	10^{10}	10^8	10^2
Cold front(D)	10^{17}	10^5	10^{12}	10^{11}	10
Extratropical cyclone (E)	10^{18}–10^{19}	10^6	10^{13}	10^{13}	1
Frontal zone (F)	10^{20}	10^7	10^{13}	10^{13}	1
General circulation (G)	10^{21}	10^7 (?)	10^{14}	10^{14}	1

This result may be compared with results obtained from other planets; for instance Venus has an atmosphere about 90 times larger in mass than that of the earth, and perhaps 100 or 1000 times the kinetic energy is possible in the atmosphere on Venus than on earth, but not more than twice the solar energy. If the net efficiency of the atmosphere on Venus is 10^{-2} or 10^{-1}, then the span of life of the global circulation on Venus may be estimated at 10^9 seconds, about 100 times longer than on the earth. Similar estimates could be made for Mars, and we get a value of 10^6 seconds for the life span of the general circulation on Mars.

Computations were made by Adem[6] to examine the response of the Atmospheric–Oceanic–Continental system to an initial surface ocean temperature anomaly of 2 degC over the whole oceanic area. The results proved that such an anomaly could even affect the mean surface temperature of the earth as much as three or four months later.

Some other comparisons of the results are seen in Table I. At present the largest source of man-made energy, hydroelectric stations have achieved a mechanical power of about 10^9 watts, which is comparable to the power of a local thunderstorm, but the latter only works for a couple of hours. A bus has generally a mechanical power of 10^4–10^5 watts, which is the equivalent in mechanical power of a small whirlwind; the former is about 10 times larger. An airliner may have a mechanical power of 10^7 watts which is thus comparable with that of a local convection cell. It is evident that the total power of a local convection cell might keep an aircraft in the air for 10–20 minutes.

The last column of Table I contains the results obtained for the mechanical power of the motion systems per square metre. It is worthy of note that the net efficiency of the smaller motion systems may exceed that calculated as characteristic of the whole atmosphere, but that of motion systems like extra-tropical cyclones or larger motions does not exceed that value. It must be taken into consideration that cold fronts, local thunderstorms and smaller atmospheric motions have their energy conversion effects concentrated in a relatively small area.

Finally we have to consider that the earth–atmosphere system is much more complicated than any man-made engine. The energy conversions in the earth–atmosphere system can be outlined thus: radiation, sensible heat (and latent heat), potential energy, available potential energy, kinetic energy, sensible heat, radiation. A great number of factors contribute to this energy cycle, such as turbidity of the atmosphere, albedo both of the atmosphere and of the surface, cloudiness, humidity of the soil, ocean currents and so on. A drastic change in one of these factors will cause changes in other factors. This process has been called 'feedback mechanism' by Namias[5] and has been extensively examined by him.

It is evident that the stronger the initial change (anomaly or disturbance) or the larger the area affected by this initial change, the longer the duration of the anomaly in the general circulation and weather. Hence the duration of transformation of large-scale motions in the atmosphere may be much longer, perhaps several times longer than we calculated by means of the mechanical power of the solar radiation and the net efficiency of the earth–atmosphere system.

It should be mentioned that the recent investigation of the long-range extrapolation of analogies has produced conclusions which apparently support the above calculation of the life span of large-scale motions (Koppány[7,8]). It was found that the success of extrapolations of similar years based on hemispheric monthly mean temperature fields does not decrease at a steady rate with the length of the extrapolation, but takes the form of a slowly declining oscillation. The effectiveness of extrapolation of the monthly temperature data for Budapest decreases with the length of the extrapolation up to the seventh month, then regular maxima are found until the 21st month. This means that the initial stage of the atmosphere may affect the weather for nearly two years.

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REVIEWS

Air pollution and atmospheric diffusion, edited by M. E. Berlyand. 245 mm × 175 mm, pp. vi + 242, *illus.* (translated from Russian by Israel Program for Scientific Translations, Jerusalem), John Wiley & Sons Ltd, Baffins Lane, Chichester, Sussex, 1974. Price: £10.80.

This publication is a collection of 27 papers on various aspects of atmospheric pollution. Edited by M. E. Berlyand, it probably represents an overall view of recent trends in Soviet research on the subject. The original Russian version was published in 1973, and the process of translation has been reasonably quick, so that the contents are still reasonably up to date.

The papers cover a wide range of topics, and are not in any systematic order, but the subjects may be classified in four groups, namely:

(a) methods of sampling and measurement of various types of pollutant,

(b) observations of the distribution of pollutants,

(c) forecasting atmospheric pollution, using meteorological observations or forecasts, and

(d) pure meteorology.

The reviewer is not well qualified to judge the papers in the first group, but one commendable feature is the recognition of the need for comparison of the instruments used in different countries, and for the standardization of procedures. Much effort appears to be going into the development of new techniques and the improvement of existing ones.

Of the papers dealing with measurements of atmospheric pollution, most discuss also the interpretation of the observed distributions in terms of the nature and location of the sources and of the pertinent meteorological factors. These papers vary a good deal in their approach to the interpretation of the observations. Particularly interesting is the use by some authors of statistical tools such as spectral analysis and empirical orthogonal functions to separate the effects of local and distant sources and to distinguish between variations arising from meteorological causes and those dependent upon source characteristics. A further use of the statistical studies is in the determination of the optimum network of sampling stations and the best sampling programme, depending upon the variability of the pollution concentration in time and space and upon the error of measurement, as well as on cost. At the other end of the scale, some papers merely quote the measurements or give a very simple qualitative explanation of the findings.

Two further topics may be included in this group. One paper deals with the design of an experiment to test theoretical models, developed by Berlyand, of the dispersion of pollutants from a stack in a wide range of meteorological conditions. The results appear to show reasonable agreement between theory and experiment. The second topic, the wash-out of aerosol by precipitation, is discussed in two papers. One paper suggests that the largest aerosol particles are washed out most efficiently, while the other concludes that there is a range of particles for which wash-out is least efficient, the lower limit (0·75 to 4 μm) depending upon the intensity of turbulence, while the upper limit (3 to 10 μm) is determined by the size of the precipitation particles.

The two papers on the forecasting of pollution approach the problem from a statistical viewpoint: one study uses a multiple discriminant analysis, but one cannot be confident that in this type of work such complexity is necessary or worth while.

The final group of papers deals with pure meteorology, the longest and most important being a contribution by Berlyand himself on a numerical model of radiation fog formation and development, with a short section on the effect of fog on the behaviour of pollutants. Other papers discuss urban effects on temperatures near the surface and in the boundary layer, the duration of light winds and inversion conditions at various locations, and, finally, the requirement for more detailed and accurate meteorological measurements in the boundary layer for improving our knowledge and understanding of the behaviour of pollution.

Overall, the publication shows that pollution problems are receiving a good deal of attention from Soviet scientists, and that much useful work is being done. Although at the price few individuals will wish to buy the book it is a worthwhile acquisition for the libraries of any establishment which carries out work related to pollution.

J. CRABTREE

Science and the weatherman, by Trevor Baker. 245 mm × 175 mm, pp. viii + 63, *illus.*, A. Wheaton and Company, Hennock Road, Exeter EX2 8RP, 1974. Price: 75p.

This is a light-weight addition to the range of popular books on 'the weather business', written by an ex-forecaster who now works for commercial television. It is published by a firm of educational publishers, but the book seems really to be directed beyond the schools to the whole range of the author's television audience, of all ages.

There are 11 short chapters including one on the author's daily drill as a television weatherman. Pictures take up one third of the available space and are good, but the diagrams are a disappointment. It is a pity that all the skills of modern television presentation cannot combine simplicity with realism in a more satisfactory manner. The text is written in a hearty, popular style and is as free of misleading statements as one can expect in a popular book. Though even at this level, to read 'We are all affected by the winds' makes one wonder if one is tuned in to the right programme.

In schools this would be a book for the library, not the classroom. It is a well-produced trifle and could stimulate the general interest of many.

P. G. WICKHAM

Atmospheric thermodynamics, by J. V. Iribarne and W. L. Godson. 245 mm × 170 mm, pp. x + 222, *illus.*, D. Reidel Publishing Company, P.O. Box 17, Dordrecht, Holland, 1973. Price: Dfl.65.

The authors point out that while many textbooks on dynamical meteorology contain one or more chapters on the thermodynamics of the atmosphere, there is no work in English devoted entirely to the subject. This book has been written to fill the gap and does indeed give a fuller and more satisfactory treatment.

The first three chapters, comprising about one-quarter of the text, give a brief review of the basic principles of general thermodynamics. The first and second laws of thermodynamics are discussed and related to topics which arise in the later chapters. Entropy is introduced by applying an integrating factor to the energy equation and the Carnot cycle is used to define a thermodynamic temperature scale. Although condensed, these chapters are sufficiently full to enable the interested science graduate to cope with the remainder of the text. In Chapter 4 'Water–Air Systems' the idea of a heterogeneous system is introduced and illustrated by considering water substance and its phase changes in the atmosphere. A section on the thermodynamics of moist air follows in which virtual temperature and various humidity parameters are defined.

The remaining two-thirds of this book are more completely meteorological in content. A chapter on aerological diagrams describes the most widely used diagrams and the sets of fundamental isopleths. This is followed by a chapter on thermodynamic processes in the atmosphere in which consideration of isobaric and wet and dry adiabatic processes leads to the definitions of dew and frost points and wet-bulb and equivalent temperatures. The problem of condensation trails receives a fuller treatment than is usual in more general meteorological texts. After a short chapter covering geopotential and lapse rates in a variety of special atmospheres, the final and longest chapter deals with vertical stability in some detail. Here the parcel method is fully developed and the effect of vertical motion on the stability of a layer discussed. There is also a detailed treatment of the factors leading to variation of stability of both dry and saturated air. The chapter closes with an introduction to internal and potential energy in the atmosphere and the treatment of Margules is used to illustrate the idea of available potential energy.

Each chapter is followed by a set of problems to which answers are given at the back of the book. These problems are well chosen to test the student's understanding of the preceding chapter and form a valuable adjunct to the text.

The authors have succeeded in producing a monograph adequate to the needs of students in meteorology and helpful to workers in allied disciplines. Unfortunately the price (over £12 at current exchange rates) is likely to keep it out of the hands of both sets of workers.

H. HEASTIE

Display and analysis of spatial data, edited by J. C. Davis and M. J. McCullagh. 220 mm × 150 mm, pp. xiv + 378, *illus.*, John Wiley and Sons Ltd, Baffins Lane, Chichester, Sussex, 1975. Price: £12.

The editors of this book are John C. Davis of the Kansas Geological Survey, University of Kansas and Michael J. McCullagh, Department of Geography, University of Nottingham. It consists of papers written by participants at the NATO Advanced Study Institute Conference on Display and Analysis of Spatial Data, held in Nottingham in July 1973. There are three sections dealing respectively with the theoretical aspects of objective analysis, contouring algorithms, and the practical uses of objective analysis.

The title and the preface might lead readers to suppose that it is a book giving a comprehensive account of the state of the art in the very many sciences which have data-analysis problems. This is not so. In the theoretical section computer scientists and others will note the absence of material related to the, development of the vector-space foundations of the subject. Scientists in those disciplines having analysis problems which are non-linear in the coefficient-space will find no account of the work of Fletcher, Powell, Davies, Swann, and Rosenbrock, to name but a few. Meteorologists, aware of the prodigious effort which has gone into objective analysis in their own field over the past two decades, may feel that the single sentence 'Meteorologists (Cressman 1959) use as a weighting function $\lambda = \frac{R^2 - d^2}{R^2 + d^2}$', at the top of page 98, is somewhat less than adequate reportage. The section on contouring is heavily biased towards American work in petrology, mineralogy, mining and related matters. There is no account of the large amount of work done on this topic at the National Physical Laboratory and at the Atomic Energy Research Establishment and the contribution of the Meteorological Office is covered, on page 153, by the quotation of half a sentence from a paper by Sawyer in the *Meteorological Magazine* for 1960. The last section deals with the use of objective analysis of stratigraphic data in pursuit of oil and mineral wealth, agricultural and sociological data in pursuit of better land-resource management, and topographical data to meet a variety of cartographical requirements. There is no mention of the massive daily routine use of objective analysis of meterological data at various world centres, nor is there any mention of the very large-scale problems in particle-trajectory analysis tackled at CERN (the European Organization for Nuclear Research), and the impressive achievements of the British aircraft industry, in collaboration with the Royal Aircraft Establishment and the National Physical Laboratory, in using multidimensional splines for the analysis of wind-tunnel data have apparently gone unnoticed.

None of the above strictures matter very much if the book is accepted for what it really is, namely an informative and valuable window on to the world of data analysis in the geological and geographical sciences, broadly interpreted. Geologists and meteorologists have worked on the same problem over the years but have been subjected to different pressures. For geologists the problem has been to make the best use of relatively small amounts of expensively acquired data. Their analyses have had to provide a basis for decisions the implementation of which might well involve further expense of an almost astronomical order. Not unnaturally, they have been much concerned with problems of assessment and interpretation. For meteorologists the problem is that they are confronted daily by a vast amount of data which has to be reduced to acceptable objective analysis by certain deadlines. It is a formidable real-time exercise, placing a premium on robustness and speed, with not a great deal left over for numerical introspection. With this different emphasis in mind, the book is required reading for all meteorologists having an interest in this area. The book is well set out, individual papers deal with their topics succinctly, and there are extensive references opening up a wide horizon for us. Of particular note for meteorologists are the papers dealing with 'Kriging', a form of objective analysis very closely related to Gandin's optimal interpolation.

R. DIXON

PUBLICATIONS RECEIVED

The following have been received from the Meteorological Institute of the University of Thessaloniki:

Meteorologika 41: *Soil temperature in Thessaloniki—Greece.* By G. C. Livadas and Yan. Ath. Goutsidou. 1974.

Meteorologika 42: *Weather types and atmospheric pressure in Thessaloniki—Greece.* By T. J. Makroyannis. 1974.

Meteorologika 43: *On the annual variation of air temperature in Larissa—Greece.* By A. A. Flocas. 1974.

NOTES AND NEWS

The new network of North Atlantic Ocean Stations comes into operation

The network of ocean meteorological stations in the North Atlantic, installed on special ships in fixed positions (NAOS network) came into operation on a new basis on 1 July 1975. Pending the entry into force of the new Agreement adopted by a Conference of Plenipotentiary Delegations in November 1974 for Joint Financing of these stations under the auspices of the World Meteorological Organization (see *Meteorological Magazine*, March 1975, pp. 90–91), the governments operating the ships decided to commence operation of the network in accordance with the terms of the Agreement. This decision was taken in view of the importance of such a network for forecasting and for providing meteorological services for various users in the North Atlantic, the Mediterranean and Europe and to a very large extent even the whole of the northern hemisphere.

The four ocean stations forming the network are located in the centre and east of the North Atlantic. Details of the network are as follows:

Station	Position	Operating country
C	52°45'N 35°30'W	Union of Soviet Socialist Republics
L	57°00'N 20°00'W	United Kingdom
R	47°00'N 17°00'W	France
M	66°00'N 02°00'E	Netherlands, Norway/Sweden

Each position will be permanently occupied by a ship specially equipped and staffed for carrying out a regular programme of meteorological observations: surface observations every hour, upper winds four times a day (at 00, 06, 12 and 18 GMT), upper-air pressure, temperature and humidity (radiosondes) at least twice a day (00 and 12 GMT), preferably up to an altitude of 24 km or higher. These ships will also provide secondary services in connection with safety for the benefit of other ships or aircraft and making oceanographic observations. Continuous operation of each station necessitates two or three ocean-going ships.

Originally, in 1948, the NAOS network was set up under the auspices of the International Civil Aviation Organization mainly to provide adequate air-navigation facilities over the North Atlantic, including meteorological assistance. Since that time the importance of the network from an aeronautical point of view has decreased, whereas the network still plays an essential role for meteorological purposes. The continued operation of the network within the framework of an international agreement under the auspices of WMO is considered to be fully justified until such time as it is proved that the observations from these stations can be replaced by data obtained by other means such as satellites.

WMO PRESS RELEASE

Editor's note

The International Conference that decided on the establishment of the old network was held in London in September 1946. The first British weather ship to sail under these arrangements went on station in August 1947.

AWARD

Award of IMO Prize to Dr Warren Lehman Godson

We note with pleasure that the twentieth International Meteorological Organization Prize for outstanding work in meteorology and in international collaboration has been awarded this year to Dr Warren Lehman Godson, Associate Director-General, Atmospheric Research Directorate of the Atmospheric Environment Service, Department of the Environment, Canada, by the Executive Committee of the World Meteorological Organization.

THE INTERNATIONAL METEOROLOGICAL ORGANIZATION PRIZE

The International Meteorological Organization Prize was established in 1955 by the World Meteorological Organization in honour of the former non-governmental organization which initiated international collaboration in meteorology in 1873 and which was replaced in 1951 by the World Meteorological Organization when the latter was created as a United Nations Specialized Agency.

The award is marked by a gold medal, 1200 dollars (U.S.) and a diploma giving the citation of the award. The full list of recipients of the award since its inception is given below.

Dr T. Hesselberg (Norway)—1956
Professor C.-G. Rossby (Sweden and U.S.A.)—1957
Mr E. Gold (United Kingdom)—1958
Professor J. Bjerknes (Norway and U.S.A.)—1959
Professor J. Van Mieghem (Belgium)—1960
Professor K. R. Ramanathan (India)—1961
Dr A. Ångström (Sweden)—1962
Dr R. C. Sutcliffe (United Kingdom)—1963
Dr F. Reichelderfer (U.S.A.)—1964
Professor S. Petterssen (Norway and U.S.A.)—1965
Professor T. Bergeron (Sweden)—1966
Professor C. J. Kondratiev (U.S.S.R.)—1967
Sir Graham Sutton (United Kingdom)—1968
Professor E. H. Palmén (Finland)—1969
Dr R. T. A. Scherhag (Federal Republic of Germany)—1970
Professor J. G. Charney (U.S.A.)—1971
Academician V. A. Bugaev (U.S.S.R.)—1972
Dr C. H. B. Priestley (Australia) and Mr J. S. Sawyer (United Kingdom)—1973
Professor J. Smagorinsky (U.S.A.)—1974
Dr W. L. Godson (Canada)—1975

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NOTICES

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