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## A PARAMETER FOR THE OBJECTIVE LOCATION OF FRONTAL ZONES

By T. H. KIRK

In their interesting note[1] Messrs Carlson, Galloway and Haering call attention to a paper[2] dealing with the objective location of frontal zones. The present note is concerned with the same problem ; given a thermal distribution at any isobaric level aloft, what is the appropriate parameter to use for the location or delineation of a frontal zone ?

Suppose the element $\alpha$ is chosen for use, i.e. suppose that isopleths of $\alpha$ are depicted on a chosen isobaric surface. These isopleths define the distribution of the gradient of $\alpha$ which will vary from place to place, not only in magnitude but also in direction. If it is desired to depict the zones where the largest changes in the gradient of $\alpha$ occur then there appear to be alternative procedures.

The first is to ignore the changes of direction of $-\nabla\alpha$ and to consider the magnitude of this vector as being of sole relevance to the problem. This magnitude may be written as $|\nabla\alpha|$ and the relevant parameter for consideration would then be $(\nabla|\nabla\alpha|).\bar{a}$ where $\bar{a}$ is a unit vector in the direction $\nabla\alpha$.

The second procedure is that of taking account of changes in the direction of the gradient of $\alpha$ because there can be no *a priori* reason for supposing that these are not dynamically of relevance. The question then arises : what is the appropriate parameter to use ? In deciding this, the following considerations are of assistance :

(i) Whatever parameter is chosen, its use should give the same answer for straight isopleths as the parameter $(\nabla|\nabla\alpha|).a$ so as to be consistent with normal practice and ideas.

(ii) The parameter should have obvious physical significance.

(iii) The parameter should be of simple mathematical form.

One might expect that the divergence of the gradient of $\alpha$ would be an appropriate measure. This quantity can be written Div $(-\nabla\alpha) = -\nabla^2\alpha$, where $\nabla^2$ is the Laplacian operator. The criteria (ii) and (iii), above, are obviously satisfied.

Also

$$\begin{aligned} \text{Div}\, \nabla\alpha &= \text{Div}\, (|\nabla\alpha|\bar{a}) \\ &= (\nabla|\nabla\alpha|).\bar{a} + |\nabla\alpha|\text{Div}\, \bar{a}. \end{aligned}$$

For straight isopleths of $\alpha$, Div $\bar{a} = 0$ and therefore criterion (i) is satisfied. The theoretical implications of this new approach will be discussed elsewhere.

Figure 1 shows an 850 mb chart for N. America for 0000 GMT, 4 February 1963 on which the isotherms have been drawn. Figure 2 shows the distribution of $\nabla^2\alpha$ worked by hand using the normal simple grid technique.

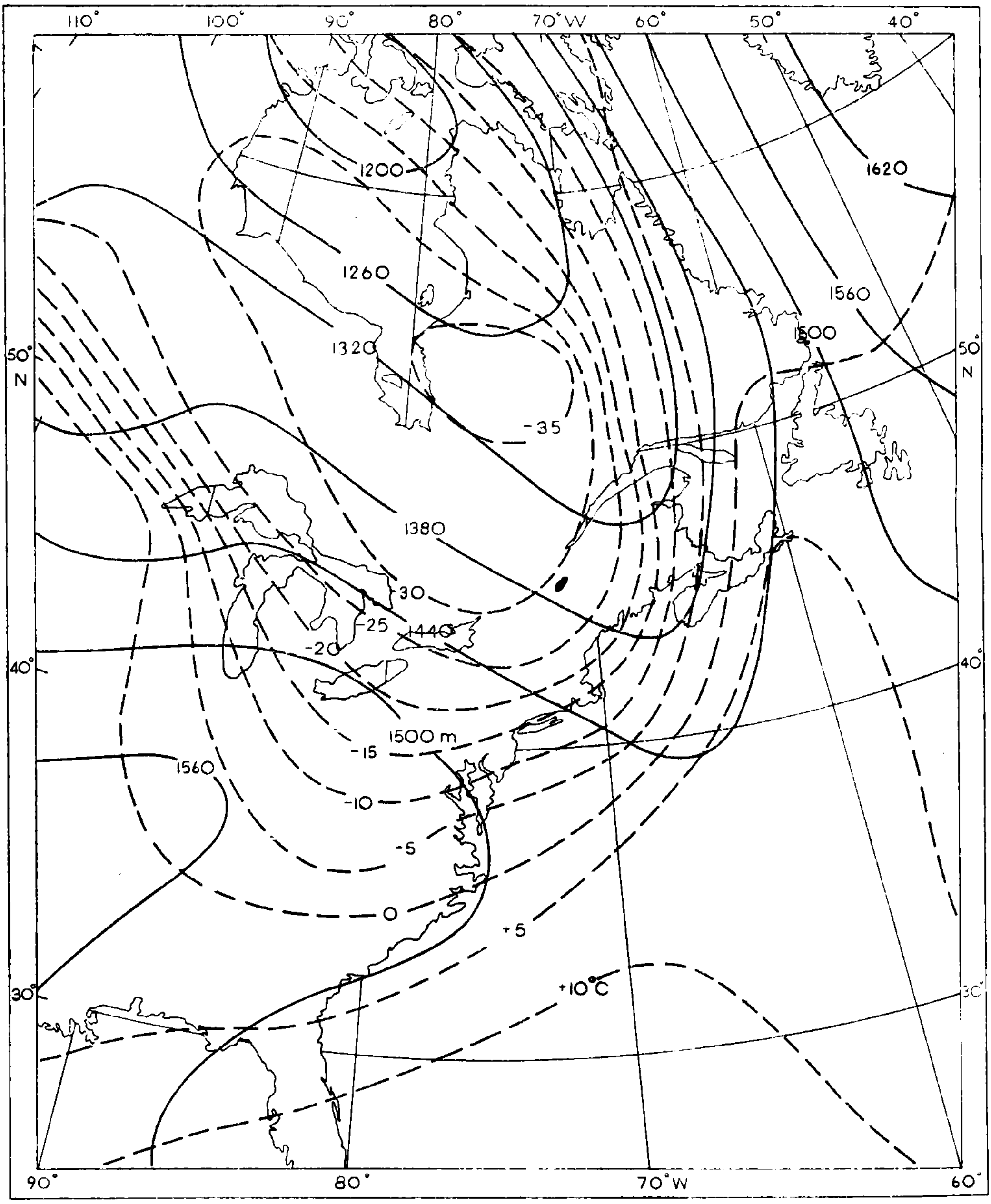


FIGURE 1—850 MB CHART FOR 0000 GMT, 4 FEBRUARY 1963

——— contours — — isotherms

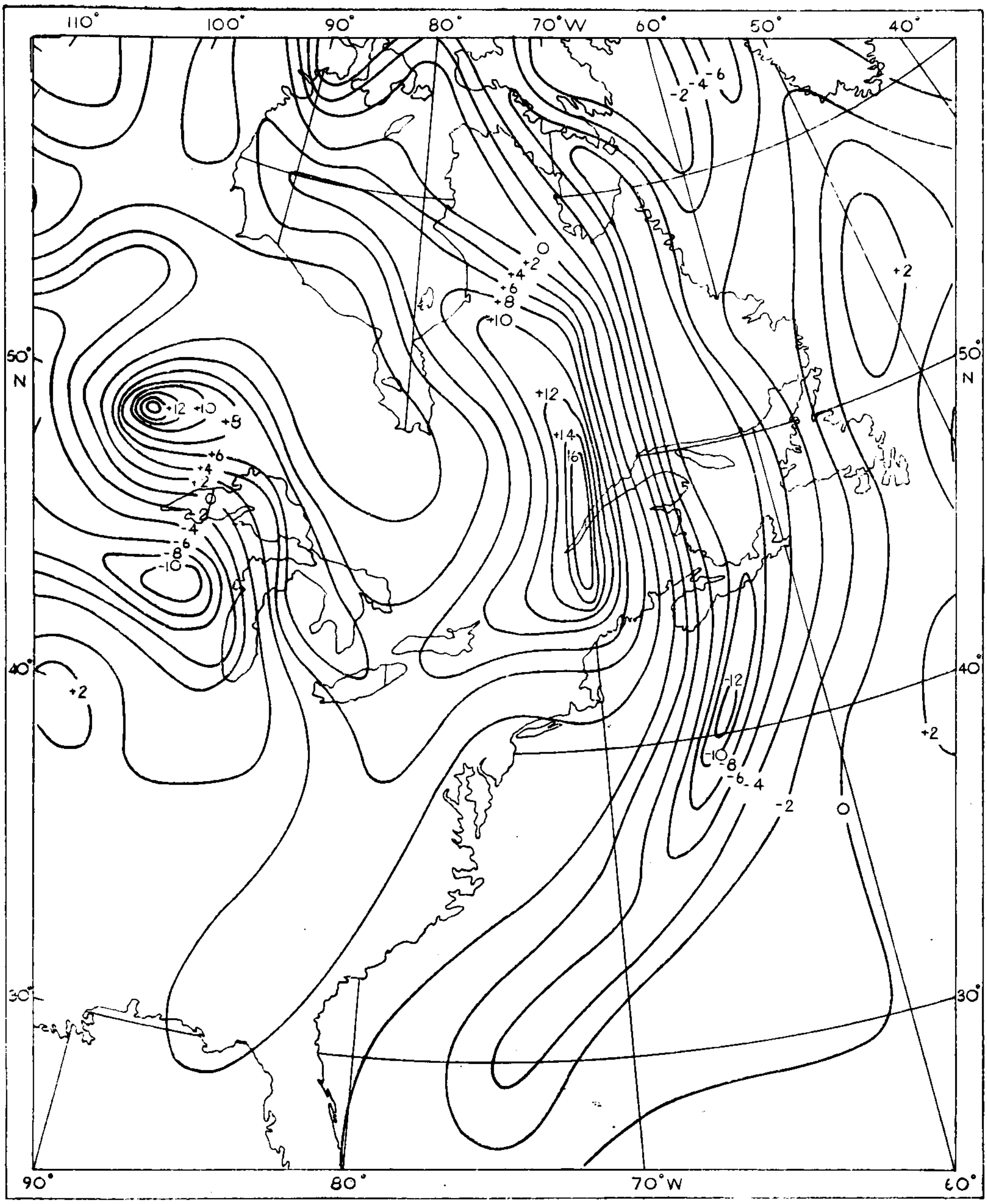


FIGURE 2—DISTRIBUTION OF $\nabla^2\alpha$ BASED ON A SQUARE GRID OF 300 NAUTICAL MILES FOR 0000 GMT, 4 FEBRUARY 1963

The edges of the frontal zone are marked by the critical values of $\nabla^2\alpha$ on either side, the frontal zone itself consisting of a strong gradient of the quantity $\nabla^2\alpha$.

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# VERY LOW CLOUD AT LONDON (HEATHROW) AIRPORT DURING THE WINTER HALF-YEAR

By J. E. ATKINS

**Summary.**—For London (Heathrow) Airport occurrences of very low cloud during the months of October to March have been analysed in relation to geostrophic wind and time of day. Features are shown which appear to have significance for the forecaster but it is difficult to distinguish effects that are purely local from those due to general synoptic tendencies. Some features vary considerably from one part of the winter half-year to another.

**Introduction.**—In describing the local weather characteristics of an aerodrome, a forecaster will often say that the likelihood of a very low cloud base is considerable with winds from one direction but slight or negligible with winds from another direction. This sort of statement may be qualified by mention of wind speed, e.g. with winds from a certain direction the cloud base is unlikely to be very low so long as the wind is stronger than a given value. Such guidance is valuable to any forecaster who has little experience of forecasting for that aerodrome. It is not altogether satisfactory, however, that guidance should be entirely dependent on personal experience and judgement. Consequently ways have been considered of presenting statistics of the height of cloud base according to wind.

Statistics could be compiled to relate cloud height with either surface or geostrophic wind. For convenience in data processing the surface wind is a particularly suitable parameter : for many places observations are recorded on punched cards, each card containing the simultaneous values of cloud height and surface wind. From the forecaster's point of view, however, there is some advantage in using geostrophic wind rather than surface wind as a parameter because the pressure distribution is forecast before consideration is given to the individual elements of weather to be expected. The routine forecasting of pressure distribution will increasingly be carried out by electronic computer so that geostrophic wind may to a large extent be forecast objectively in future.

Though the geostrophic wind is frequently determined from the synoptic chart during the course of forecasting, values have rarely been recorded systematically so that use of the geostrophic wind as a parameter in statistical investigations has been difficult. Now, however, evaluations can be made by electronic computer using a method devised by Freeman.[1] Geostrophic winds have been calculated by this method for Heathrow for each synoptic hour, i.e. three-hourly during the 13 winter half-years from October 1949 to March 1962. The analysis given here was made possible by the existence of these data.

Though the main object of the analysis has been to relate cloud height with geostrophic wind, the frequency of very low cloud at each synoptic hour of the different months has also been given since these results were readily available and appeared to be of some interest.

**Cloud ceiling.**—For convenience the cloud height analysed in this article is referred to as the ceiling and is the height above the aerodrome of the base of the lowest cloud of five oktas or more in amount, or — if the sky was obscured — the vertical visibility. If the sky was obscured but no vertical visibility recorded, the ceiling was taken as zero.

This definition may blur the distinction between very low stratus, beneath which visibility is not poor enough to prevent the landing of aircraft, and fog with a vertical visibility of one or two hundred feet. Nevertheless if the ceiling is very low conditions must at least be marginal for the landing of aircraft.

Another objection might be raised against the use of cloud ceiling because the forecaster tends to regard as separate phenomena :

(*a*) fog (or lifted fog), and

(*b*) cloud on or near the surface.

However, the formation of both is most commonly due to air being in contact with a cold surface — whether fog or stratus forms depends largely on wind speed. Also when compiling statistics the observation alone does not permit distinction between fog (with sky obscured) and cloud on the surface, or between lifted fog and stratus.

**Presentation of results.**—At first, frequencies of ceilings were tabulated separately for the two-month periods October/November, December/January and February/March, according to the following ranges of geostrophic wind :

Less than 7 knots (without regard to direction)

| | |
|---|---|
| 7–14 knots<br>15–24 knots<br>25–39 knots<br>40 knots or more | For wind-direction sectors 350–010°, 020–040°, 050–070°, etc. |

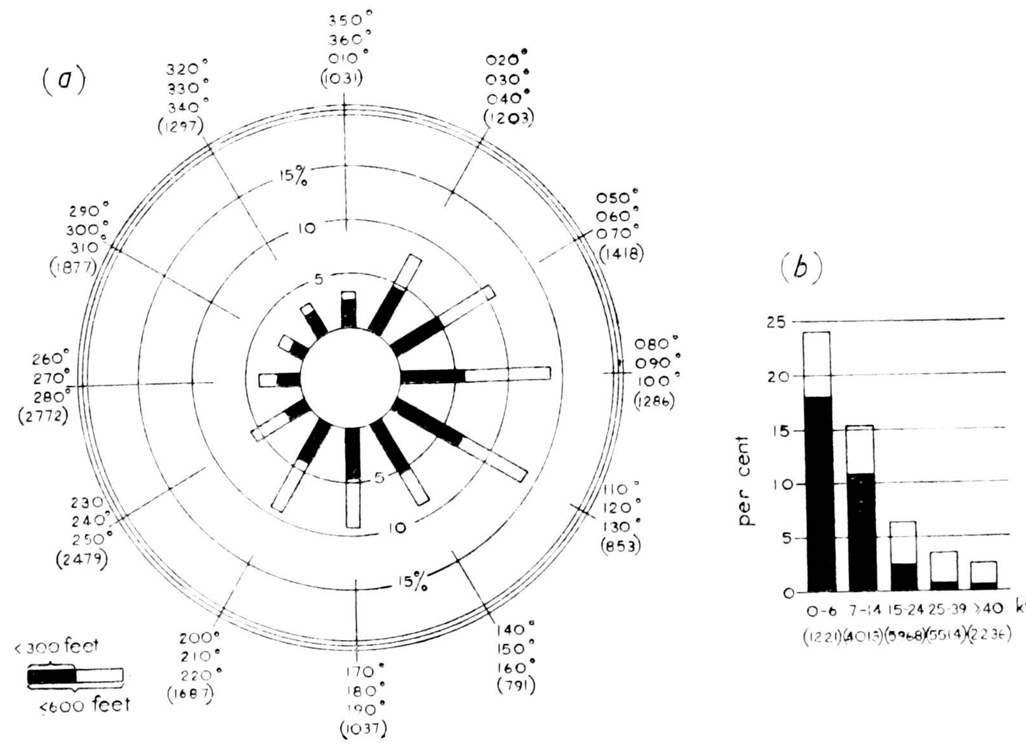
Although nearly 19,000 values of geostrophic wind were available for analysis, the number of observations in many of the classes was small. Consequently various combinations of classes have been made as seemed best suited to illustrate different aspects. The results are presented in Figures 1–3 and Table I ; where a range of geostrophic wind is specified the number of occasions of wind within that range is given in brackets so that too much reliance is not placed on any result based on few observations. For simplicity only results for ceilings below 300 feet and below 600 feet have been presented though results are available for other ranges of cloud ceiling up to 1000 feet above the aerodrome.

The statistics are designed to answer the question : "For a given forecast geostrophic wind (e.g. from a prognostic chart) how likely is the cloud ceiling to be very low ?" This, of course, is an over-simplification of the forecaster's reasoning since he considers not only the expected geostrophic wind but other synoptic information, attaching particular importance to details of temperature and humidity in the lowest layers of the atmosphere. Nevertheless it is of some value to consider the general effects associated with wind. Even with synoptic features which tend to give very low cloud (warm sectors, active fronts, airflow off the North Sea), variation of cloud height from aerodrome to aerodrome is usual and frequently great enough to be of operational importance — the locally important factors are often the shelter or exposure associated with winds from a particular direction.

**Some results for the winter half-year as a whole.**—The separate effects of wind direction and wind speed during the winter half-year are shown in Figure 1.

Figure 1 (*a*) shows that very low ceilings are less likely with geostrophic winds from about north-west than from other directions ; for example with winds from the sector 290°–010° the probability of a ceiling below 600 feet is less than a quarter of that with winds from the sector 080°–130°. To a large extent this must be a reflection of the synoptic tendency for north-westerly winds to be associated with polar maritime air, i.e. air which is unstable when it reaches the British Isles and consequently is unsuitable for the formation of fog or stratus. However the improbability of north-westerly winds being accompanied by fog or stratus may be partly accounted for by the local topography and this aspect will be discussed later.

From Figure 1 (*b*) it is seen that the likelihood of very low cloud or fog deep enough to obscure the sky decreases sharply as the speed of the geostrophic wind increases. This tendency is, of course, to be expected at an inland aerodrome on rather flat terrain and at only a small height above sea level (80 feet).




(*a*) According to direction of geostrophic wind for winds of more than 6 knots

(*b*) According to speed of geostrophic wind

FIGURE 1—PERCENTAGE PROBABILITIES OF CLOUD CEILING BELOW 300 FEET AND BELOW 600 FEET DURING THE WINTER HALF-YEAR AT HEATHROW

A forecaster might expect the statistics to show that with geostrophic winds stronger than a critical value there is little likelihood of a very low ceiling. The ranges of wind speed used in this analysis were too broad to suggest any well-defined value, but it is notable that out of 7750 occasions when the geostrophic wind was 25 knots or stronger, the ceiling was below 300 feet on only 39 occasions (0·5 per cent) which is few enough to make examination of the individual cases practicable. Certain common features of weather and synoptic situation can be noted in these cases as follows :

(i) On 17 of the occasions advection was occurring of air which was much warmer and moister than that being displaced. Often the low ceiling occurred near a front between tropical maritime air and either polar continental air or air of polar origin which had become stagnant and been cooled by prolonged radiation. Usually temperatures overnight had recently been very low, the grass minimum temperature recorded at 0900 GMT on the day in question or the previous day being well below 0°C–in one case as low as —16°C.

(ii) On 14 of the occasions snow was falling.

(iii) On 4 of the occasions a low ceiling had persisted for a time after the tightening of the pressure gradient. Three hours before the occasions the ceiling had been below 300 feet with geostrophic winds of less than 25 knots. Three hours after the occasions either the ceiling had lifted or the geostrophic wind had decreased to become less than 25 knots again.

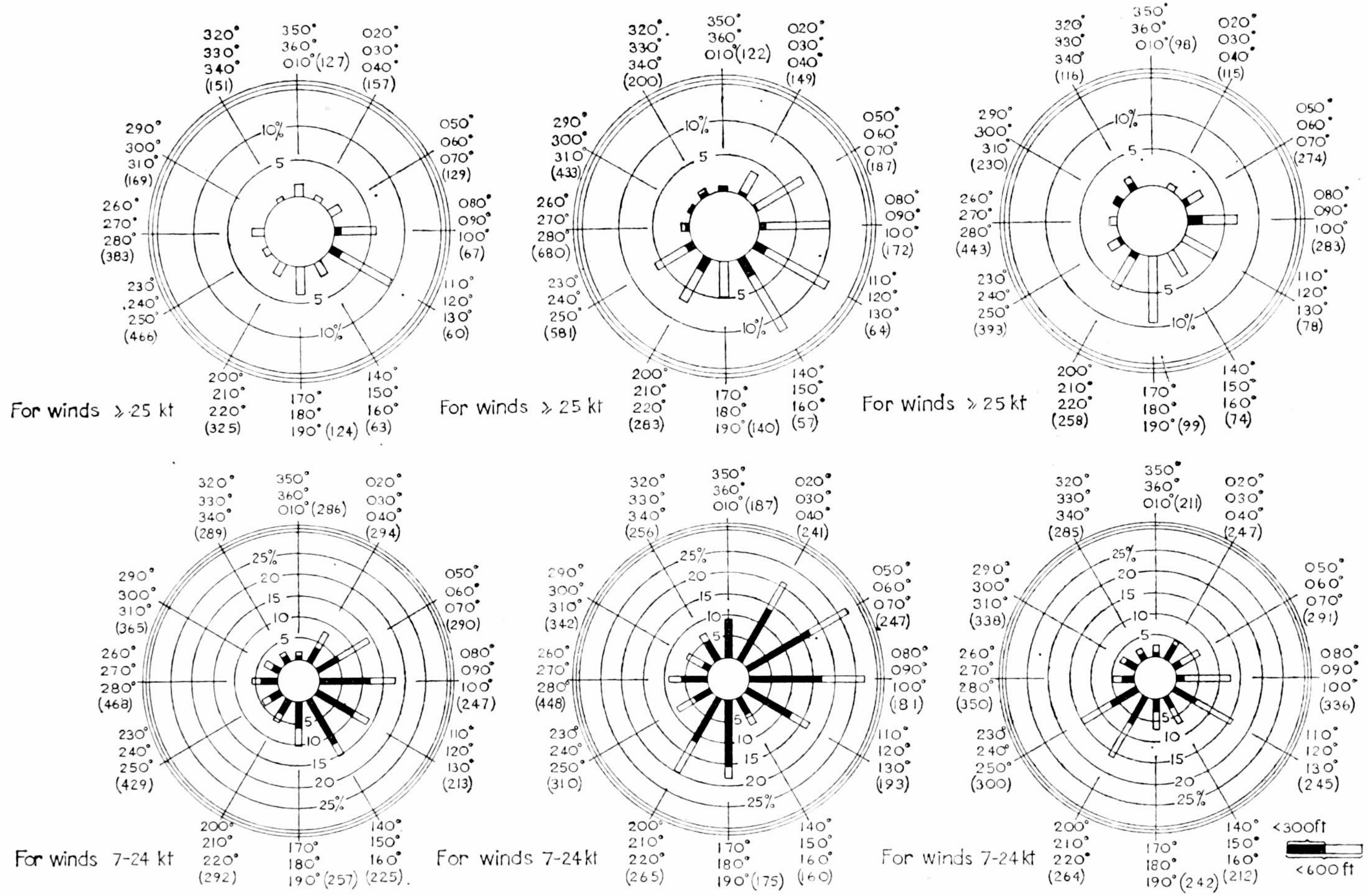
Thus the large majority of cases with geostrophic wind of more than 25 knots and ceiling below 300 feet occur with snow falling or with warm moist air being advected over cold ground, i.e. in special circumstances when the forecaster would not expect strong winds to give the normal immunity from very low cloud.

**Detailed results for different parts of the winter half-year.**—In Figure 2 results are shown for two-month periods and for two ranges of wind speed. The comparative freedom from low ceilings when geostrophic winds are from the north-west is notable during each of the two-month periods and with both ranges of geostrophic wind speed.

From the upper diagrams of Figure 2 it appears that with the stronger winds ceilings below 600 feet are, on the whole, more likely with winds from the south-east quarter than from other directions ; the infrequency of ceilings below 300 feet needs no further comment.

From the lower diagrams it is seen that for geostrophic winds of 7–24 knots there is considerable variation from one part of the winter half-year to another in the wind directions which give particular risk of low ceilings. Notable for such risk are the winds from the sector 020°–100° during December and January ; yet winds from part of this sector, i.e. 020°–070°, seem to give no special risk during October and November or during February and March. During the former period winds from south of east are more important. The probability of low ceilings with southerly or south-westerly geostrophic winds is small during October and November but not in the later parts of the winter half-year.

The extent to which an aerodrome is liable to low ceilings with winds from a given direction is dependent not only on local factors, e.g. slope of ground or shelter afforded by hills, but also on the most common characteristics of air arriving from that direction (especially with regard to humidity near the surface, and stability). The rather confusing variations mentioned above seem most likely to arise because characteristics which may be typical of air from a certain direction during one part of the winter half-year are not so during another. In particular, characteristics of continental air masses can be expected to change considerably between October and March.




(*a*) October/November (*b*) December/January (*c*) February/March

FIGURE 2—PERCENTAGE PROBABILITIES OF CLOUD CEILING BELOW 300 FEET AND BELOW 600 FEET ACCORDING TO GEOSTROPHIC WIND DURING DIFFERENT PARTS OF THE WINTER HALF-YEAR AT HEATHROW

(*a*)

(*b*)

PLATE I (*a*)–(*d*)—FOUR STAGES IN THE DEVELOPMENT AND DECAY OF A FUNNEL CLOUD OBSERVED FROM PLAYA DE ARO, SPAIN (41° 48′N, 3° 05′E), AT 1615 GMT 2 SEPTEMBER 1965

The camera was facing south-west and the time interval covered by the sequence is 12 minutes. The funnel cloud is about ¾ mile distant and its diameter at the base in Plate I (*b*) is 30 yards. The cloud base is estimated to be at 2000 feet. The disturbance occurred in extremely unstable air near the centre of an intense cold pool over the western Mediterranean. The central 1000–500 mb thickness (545 decametres) was well below the 5-year minimum for the time of year.

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(c)

(d) Photographs by T. C. Hughes

PLATE I (contd)

Whatever the reasons for features shown in the lower diagrams of Figure 2 it seems significant for the forecaster that with geostrophic winds in the range 7–24 knots there are broad sectors of wind direction which give a special risk of a low ceiling (the sectors varying according to month) ; in contrast, with winds in the same range of speed but from the sector 290°–010° the likelihood of a low ceiling is small during any of the months October to March. Table I shows the contrast. With the use of broad sectors it has been possible to show the effects for two ranges of wind speed without having to base individual results on small numbers of observations.

TABLE I—PERCENTAGE PROBABILITIES OF LOW CLOUD CEILING AT HEATHROW ACCORDING TO THE GEOSTROPHIC WIND FOR WINDS FROM SELECTED SECTORS

| Months | Geostrophic wind | Percentage probability of ceiling : below 300 feet | below 600 feet |
|---|---|---|---|
| October/ November | 7–14 knots | | |
| | 080°–160°(352) | 16 | 20 |
| | 290°–010°(399) | 5 | 7 |
| | 15–24 knots | | |
| | 080°–160°(333) | 7 | 11 |
| | 290°–010°(541) | 0 | 0·4 |
| December/ January | 7–14 knots | | |
| | 050°–100°(167) | 35 | 44 |
| | 290°–010°(294) | 12 | 15 |
| | 15–24 knots | | |
| | 050°–100°(216) | 5 | 17 |
| | 290°–010°(491) | 0·4 | 2 |
| February/ March | 7–14 knots | | |
| | 200°–250°(223) | 11 | 20 |
| | 290°–010°(345) | 4 | 6 |
| | 15–24 knots | | |
| | 200°–250°(341) | 4 | 12 |
| | 290°–010°(489) | 1 | 2 |

Figures in brackets give the number of occasions within the range.

The contrasts between the two chosen sectors are large with winds in the range 15–24 knots. But even when the geostrophic wind is as light as 7–14 knots the probability of a low ceiling with a wind from the sector 290°–010° is only about one third of that with a wind from another broad sector. One might expect, on synoptic grounds, that with slack pressure gradients the direction of any light wind would be of little importance because the association of individual wind directions with specific advective tendencies or air masses would be only weak. Forecasters at Heathrow have commented on the relative freedom from low ceilings with slack pressure gradients when the geostrophic wind is from the north-west. They attribute this to the general slope of ground from the crest of the Chiltern Hills (some 20 miles to the north-west and about 750 feet above MSL) down to the aerodrome. It had been noted that on radiation nights the formation of fog appears to be delayed if there is a slight wind from north-west ; fog forms some distance to the south-east and when the aerodrome is eventually affected it is as a result of the fog spreading from this direction, i.e. against the general drift of air.

The results of Table I suggest that even when the pressure gradient is expected to be slack, if a forecast can be made of the direction of the geostrophic wind — at least between broad limits — this would be of help in assessing the likelihood of a low ceiling.

**Variations according to time of day.**—Diurnal variations cannot be shown in detail because only three-hourly observations were used. Figure 3

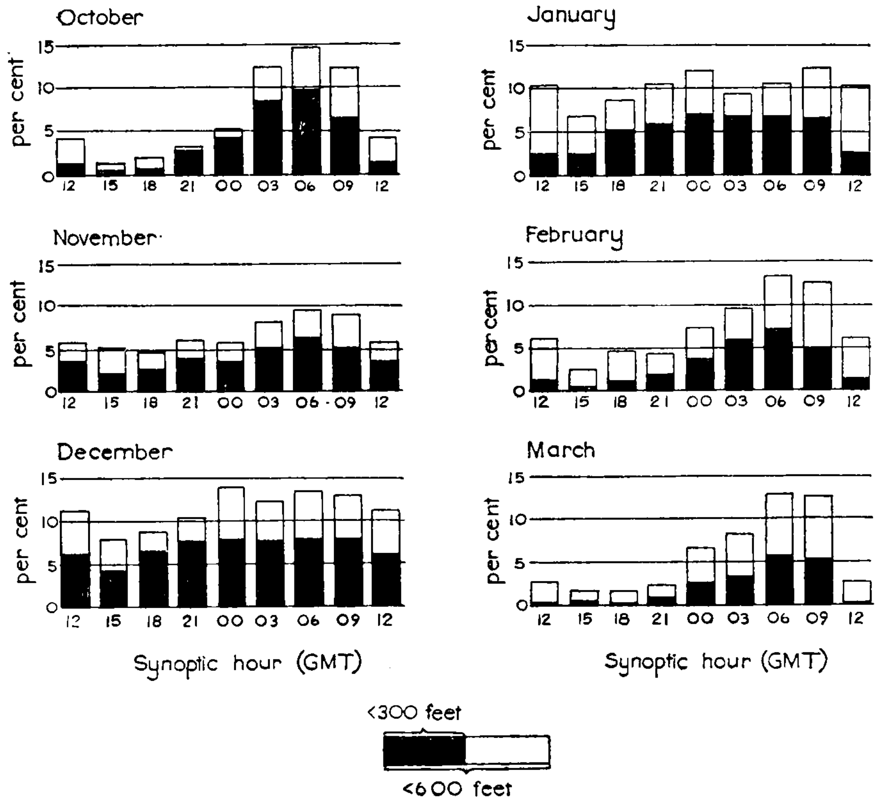


FIGURE 3—PERCENTAGE PROBABILITIES OF CLOUD CEILING BELOW 300 FEET AND BELOW 600 FEET FOR EACH SYNOPTIC HOUR DURING THE MONTHS OCTOBER TO MARCH AT HEATHROW

shows that (as would be expected) low ceilings are least frequent in the afternoon and that the smallest diurnal variations are in the middle of the winter. In the diagrams the frequencies are arranged from midday to midday instead of from midnight to midnight so that changes through the evening and night can be readily appreciated. In October, November, February and March low ceilings become more likely as the night progresses. In December and January, however, the frequency of low ceilings does not increase between midnight and 0900 GMT, indeed the frequencies of ceiling below 600 feet are a little less at 0300 GMT than at midnight. This is a rather puzzling feature. It is as if, during the mid-winter period, a potentiality for formation of fog or stratus overnight is realized by about midnight and any further nocturnal cooling makes little difference. On individual occasions fog or stratus must develop or disperse between midnight and 0900 GMT but one would not expect frequencies based on 13 winters to give a misleading impression of the general trend. The fogs included in the frequencies were, of course, only those in which the sky was obscured and so would tend to be water fogs rather than smoke fogs. It is interesting to note the similarities month by month between the diurnal trends in low ceiling and those in poor visibility — Figure 3 can be compared with histograms given by Evans[2] to show fog frequencies at Heathrow.

**Conclusions.**—Though the results are interesting it is disappointing that the purely local characteristics cannot readily be distinguished from characteristics which are related to synoptic tendencies and so must be more general. Similar analyses for other aerodromes would be valuable in helping to make such a distinction and in showing effects where the surrounding terrain is more rugged than at Heathrow.

**Acknowledgement.**—The author is grateful for comments and suggestions from Mr. T. N. S. Harrower, Mr. W. D. S. McCaffery, Mr. G. A. Howkins and forecasters at London (Heathrow) Airport.

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## SOME EMPIRICAL RELATIONSHIPS CONCERNING THE INTENSITY OF DIRECT SOLAR RADIATION

By R. W. GLOYNE and M. E. KYLES

**Introduction.**—There is an increasing interest in radiation climatology as applied to the biological sciences such as agriculture and forestry. Thus the paucity of information on solar radiation in the British Isles — particularly north of a line from about the Wash to South Wales — renders it essential to explore any means whereby the available data can be fully exploited. Two empirical results produced by Lauscher[1] in 1934 give helpful indications of what can be deduced from the noon value of the intensity of the vertical component of the direct solar beam when skies are clear. Data from Kew have now been examined in the light of Lauscher's results and it is planned to analyse in a similar way a short period of data from Lerwick on total and diffuse radiation received on a horizontal surface.

The purpose of the present note is :

(i) To test Lauscher's results on an extensive series of data in Britain. The data used were those given by Stagg[2] on the direct solar radiation at normal incidence at Kew, and covered a period which was different from the period used by Lauscher.

(ii) To detect any seasonal variations which may be relevant to Lauscher's results. Solar declination at noon at mid-month was used as a measure of the season.

(iii) To see if results similar to those of Lauscher could be obtained for conditions when skies were not clear. The data examined were those given by Stagg for groups of data classified according to various levels of recorded radiation including a group containing all available days of recorded radiation.

**Lauscher's results.**—The intensity of the vertical component ($V$) of the direct solar beam has a value $V_n$ at local noon and a mean daily value $V_{mean}$. Lauscher's first result stated that the ratio ($L$) of the mean daily value of $V$ and the local noon value obeyed the relationship

$$L = V_{mean}/V_n = 0{\cdot}55$$

Lauscher's two results were applicable under clear skies for latitudes 0 to 70°N for all times of the year. The second result related the intensity at various times of day with the intensity at local noon. He showed that if the time of day was converted into an interval from local noon and expressed as a percentage of the half-day length (i.e. if the scale for time were normalized), then the intensity of the vertical component of the direct solar beam could be expressed as a percentage of the noon intensity (Table I).

TABLE I—RELATIONSHIP (FOR CLEAR SKY CONDITIONS) BETWEEN THE TIME OF DAY AND THE INTENSITY OF THE VERTICAL COMPONENT OF THE DIRECT SOLAR BEAM (FROM LAUSCHER).

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Time of day* | 0 | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 | 45 | |
| Intensity† | 100·0 | 98·6 | 97·0 | 95·1 | 92·7 | 89·5 | 85·0 | 78·8 | 72·3 | 65·3 | |
| Time of day* | 50 | 55 | 60 | 65 | 70 | 75 | 80 | 85 | 90 | 95 | 100 |
| Intensity† | 58·3 | 51·2 | 44·0 | 36·8 | 29·7 | 22·7 | 16·0 | 10·5 | 6·1 | 2·5 | 0·0 |

* Expressed as a percentage of the half-day length from local noon.

† Expressed as a percentage of the corresponding intensity at local noon.

**The Kew data.**—Sets of mean daily values for each month were derived by Stagg for different groups of data of normally incident radiation from the direct solar beam. It was found necessary to classify according to the recorded radiation because of the difficulty of detecting by eye thin cirrus cloud and differences of air clarity either of which has a marked effect on the recorded radiation. The data were grouped as *A*, *B*, *C* and *D* as follows, and Stagg gave average daily totals of normally incident radiation for the various groups :

*A* All days : all available days of recorded radiation in each month (1933–46).

*B* Days of high radiation : in each month of a given name a limited but representative number of complete days of radiation were selected for their high total daily radiation (exceeding a value separately chosen for each month). These formed about 8 per cent of the total number of available days.

*C* Days of highest recorded radiation : from group *B* were selected a very limited number of days to form groups of days with the highest daily radiation recorded. These amounted to 5 or 6 days for a month of a given name and formed about 1 per cent of the total number of available days.

*D* Maximum recorded (or ceiling) values for daily radiation : by selecting peak values of recorded radiation on exceptionally clear occasions, maximum radiation values at Kew were estimated for each month (mean hourly and daily totals). The durations of these peak or ceiling intensities might only be for a few minutes and were obtained by selecting the highest rate of input recorded within periods of 60 minutes ending each hour (local mean time (LMT) ). The peak values were related to the sun's altitude and a smooth curve obtained from which mean hourly and daily totals were computed for each month.

**The intensity at local noon.**—In his sets of mean daily values Stagg gave mean values over an hour ending at each exact hour local time and his values were thus centred at the half-hour (LMT). For testing Lauscher's results the intensity at local noon is required and a number of possible procedures were employed for obtaining this information.

The data for intensity of normally incident radiation against LMT given by Stagg in his tables VII, VIII, IX and X (respectively for classes *A*, *B*, *C*, *D*) were plotted and an estimate of the local noon value obtained in the following ways :

(*a*) The intensity/time curve constructed from readings centred at the half-hour was extended to intersect the noon axis. Because of certain irregularities in the curves for some months (see also Figure 2) attention was concentrated on whichever of the half-days (pre- or post-noon) gave rise to the more regular trend.

(*b*) The course of curves (*a*) for two hours or so about local noon was adjusted, if so required, to run approximately parallel to that for the 'ceiling' values — class *D* — which were assumed to define the idealized form of the relationship.

(*c*) The values of the intensity at noon obtained by the free-hand extrapolation in (*a*) were plotted against solar declination in Figure 1 for classes *A* and *D* and in Figure 2 for classes *B* and *C*. Smooth curves were

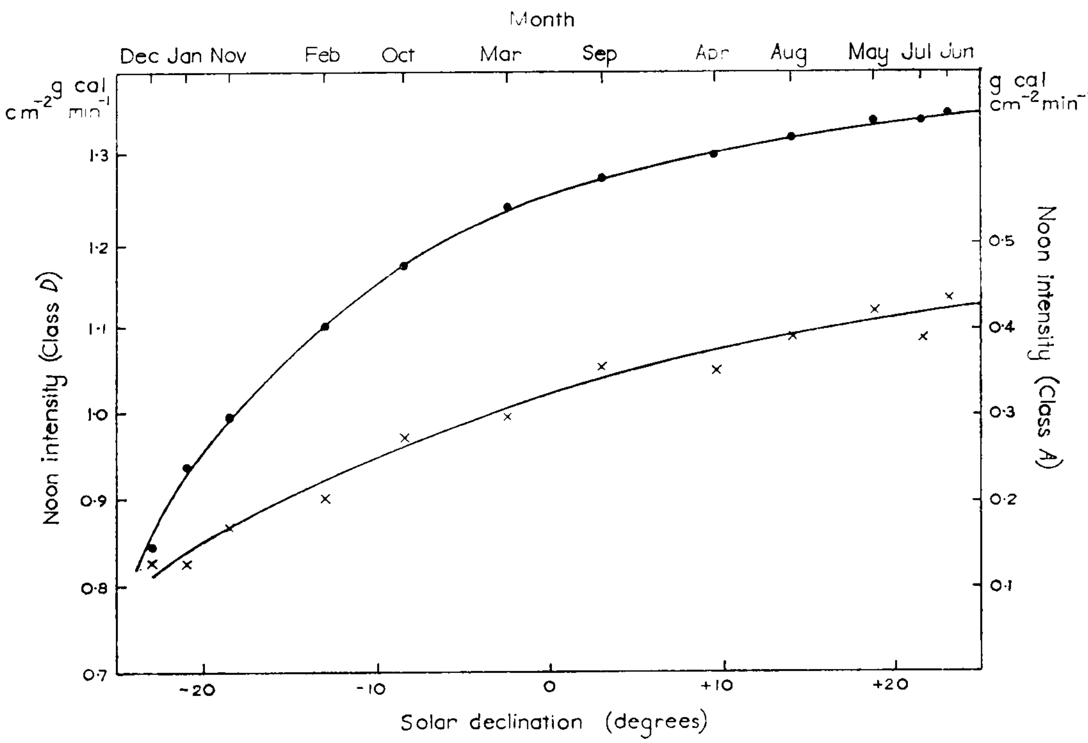


FIGURE 1—NOON INTENSITY OF DIRECT SOLAR BEAM AT NORMAL INCIDENCE AT KEW PLOTTED AGAINST SOLAR DECLINATION ON MIDDLE DAY OF THE MONTH

.————. Class *D* or 'ceiling days' (left-hand ordinate)
x————x Class *A* or 'all' days (right-hand ordinate)
(Using data classified by Stagg[2] as class *A* and *D*.)

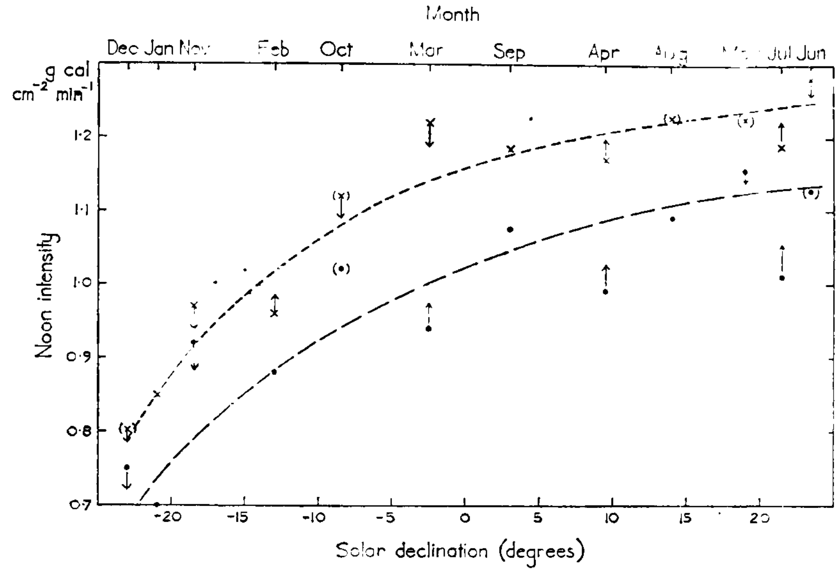


FIGURE 2—NOON INTENSITY OF DIRECT SOLAR BEAM AT NORMAL INCIDENCE AT KEW PLOTTED AGAINST SOLAR DECLINATION ON MIDDLE DAY OF THE MONTH

•— —• Class *B* or 'high' radiation days
x— —x Class *C* or 'highest' radiation days
(Using data classified by Stagg[2] as class *B* and *C*.)

Upward pointing arrows imply that results are low relative to those in class *D* and downward pointing arrows that results are high.

The existence of a considerable asymmetry of the intensity/time plot about local noon is indicated by brackets round the values.

drawn in accordance with principles described in Appendix I and the noon intensity for a month of given name was read off from the smoothed curve.

A common feature of the diurnal variation of normally incident radiation (particularly with classes *B* and *C*) was a definite asymmetry — the highest values occurring before rather than after local noon. Stagg invoked synoptic arguments to explain this feature. However if results are to be generalized it is obviously necessary to adopt procedures which may tend to minimize any peculiarities dependent upon local and regional factors or on the particular period chosen. These objectives were partially achieved by using various families of curves to obtain adjusted noon intensities for the various classes (see Appendix I).

**Extension of Lauscher's first result.**—After some trials with the Kew data it was found that the most stable values of $L$, the ratio between $V_{mean}$ and $V_n$, were derived directly from the observed quantities. Thus $V_{mean}$ was computed from whichever of the half-days (pre- or post-noon) gave the most regular curve of normal intensity plotted against time, and $V_n$ was obtained by free-hand extrapolation of the intensity-time curve as in method (*a*) page 363.

Computed values of $L$ for the four classes discussed are given in Table II along with smoothed values for classes *A*, *B* and *D*. For class *A* the scatter about the mean value of 0·50 is appreciable but a smooth curve of the same form as for class *D* can reasonably be constructed. Furthermore for class *B* it is possible to discern a similar underlying trend and tentative smoothed values are included in Table II. A similar regularity does not emerge from the plot

TABLE II—LAUSCHER RATIO $L$ FOR KEW FOR VARIOUS CLASSES GIVEN BY STAGG

| Class | Jan. | Feb. | Mar. | Apr. | May | June | July | Aug. | Sept. | Oct. | Nov. | Dec. | Mean |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Lauscher ratio $L$ | | | | | | | | | | | | |
| *D* (Actual) . . . | 0·550 | 0·557 | 0·558 | 0·558 | 0·547 | 0·546 | 0·547 | 0·554 | 0·560 | 0·558 | 0·544 | 0·536 | 0·551 |
| (Smoothed) . . | 0·543 | 0·555 | 0·559 | 0·557 | 0·551 | 0·544 | 0·547 | 0·556 | 0·559 | 0·557 | 0·548 | 0·536 | 0·551 |
| *A* (Actual) . . . | 0·511 | 0·503 | 0·499 | 0·503 | 0·495 | 0·519 | 0·487 | 0·513 | 0·524 | 0·506 | 0·471 | 0·490 | 0·502 |
| (Smoothed) . . | 0·486 | 0·500 | 0·509 | 0·509 | 0·503 | 0·494 | 0·498 | 0·507 | 0·511 | 0·505 | 0·491 | 0·482 | 0·500 |
| *B* (Actual) . . . | 0·500 | 0·510 | 0·520 | 0·510 | 0·510 | 0·500 | 0·500 | 0·490 | 0·510 | 0·530 | 0·500 | 0·510 | 0·510 |
| (Smoothed) . . | 0·500 | 0·515 | 0·520 | 0·510 | 0·505 | 0·495 | 0·500 | 0·510 | 0·515 | 0·520 | 0·500 | 0·495 | 0·510 |
| *C* (Actual) . . . . | 0·500 | 0·500 | 0·520 | 0·530 | 0·500 | 0·520 | 0·530 | 0·530 | 0·490 | 0·550 | 0·540 | 0·510 | 0·520 |

of values for class *C* and only the computed values appear in Table II. A partial explanation for this anomalous behaviour may be that this group lacks the rigorous selection procedures adopted for class *D* and also because it suffers from being a very small 1 per cent sample.

The annual mean value of $L$ increases consistently from class *A* to class *D*.

In Figure 3 monthly values of $L$ are plotted against solar declination at mid-month for classes *A* and *D*. These curves suggest a seasonal variation of $L$ and it is clear that the curve for class *D* is sufficiently smooth and well defined to justify using it to obtain a value of L for each month. The mean annual value of $L$ is almost exactly 0·55 as given by Lauscher.

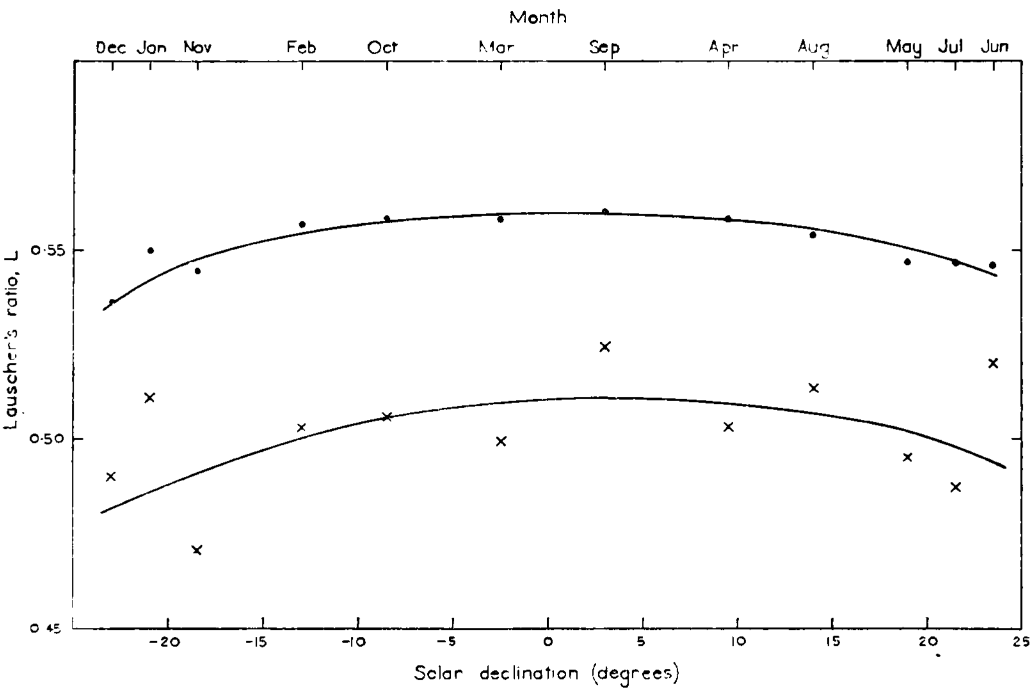


FIGURE 3—LAUSCHER'S RATIO, $L$, FOR EACH MONTH OF THE YEAR ON CLASS D AND CLASS A DAYS AGAINST SOLAR DECLINATION

·————· Class *D* or 'ceiling' days

x————x Class *A* or 'all' days

(Using data classified by Stagg[2] as class *A* and *D*.)

**Extension of Lauscher's second result.**—The Kew data were examined to obtain the equivalent of Lauscher's second result which, for various times of day, quoted the vertical component of the intensity as a percentage of that at noon. The value of $V_n$ at Kew was taken as the value calculated from the noon intensity found by the procedure (*a*) described on page 363. The intensity (*V*) at the various times of day was derived from whichever half-day gave the most regular plot of normally incident intensity against time. The intensity as a percentage of that at noon was plotted against the normalized time scale for classes *D* and *A* irrespective of time of year (Figures 4 and 5). It is clear that Lauscher's findings (plotted in Figure 4) are closely followed for class *D* data and that a similar, almost equally close, relationship holds for class *A* data.

For a slightly more detailed analysis plots were prepared for each class of data and for each month. Smooth curves of the form shown in Figures 4 and 5 were drawn through the plotted points. The agreement between the plots for successive months was such as to permit the following aggregation :

Class *D* : all months together ;

Class *A*, *B* and *C* : March to August together as a summer half-year, and September to February together as a winter half-year.

Pearson Type II Curves (Appendix II) were then fitted to the various aggregations. Sufficient points to define these curves are given in Table III which may be compared to Lauscher's findings in Table I. It will be seen that the differences between the several classes of data are quite negligible for periods around noon within an interval of 20 per cent of the half-day.

TABLE III—INTENSITY OF THE VERTICAL COMPONENT OF THE DIRECT BEAM AS A PERCENTAGE OF THE VALUE AT LOCAL NOON IN RELATION TO THE PERIOD FROM LOCAL NOON EXPRESSED AS A PERCENTAGE OF THE HALF-DAY (USING DATA FOR KEW GIVEN BY STAGG)

| | Period from local noon (percentage of half-day) | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0 | 5 | 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 | 90 | 95 | 100 |
| Class | *percentage of intensity at local noon* | | | | | | | | | | | | |
| *D* | 100 | 99·5 | 98·0 | 92·5 | 84·0 | 72·5 | 58·5 | 44·0 | 29·5 | 16·0 | 6·0 | 2·5 | 0 |
| *C* | | | | | | | | | | | | | |
| Summer | 100 | 99·5 | 98·0 | 91·7 | 82·0 | 69·3 | 54·5 | 39·3 | 24·5 | 12·0 | 3·7 | 1·0 | 0 |
| Winter | 100 | 99·5 | 98·0 | 92·0 | 82·5 | 70·3 | 56·0 | 40·5 | 25·7 | 13·0 | 3·7 | 1·1 | 0 |
| *B* | | | | | | | | | | | | | |
| Summer | 100 | 99·5 | 97·5 | 90·3 | 79·0 | 65·0 | 49·3 | 33·7 | 20·0 | 9·5 | 3·0 | 1·1 | 0 |
| Winter | 100 | 99·5 | 97·7 | 91·5 | 81·7 | 68·7 | 54·0 | 38·5 | 23·5 | 11·3 | 2·5 | 0·7 | 0 |
| *A* | | | | | | | | | | | | | |
| Summer | 100 | 99·5 | 97·7 | 91·0 | 80·3 | 66·3 | 50·7 | 34·5 | 19·7 | 8·0 | 1·3 | 0 | 0 |
| Winter | 100 | 99·5 | 97·7 | 91·5 | 80·7 | 67·0 | 51·5 | 35·0 | 19·7 | 7·7 | 0·7 | 0 | 0 |

**Summary and discussion.**—

1. Lauscher's results detailed on page 362 have been confirmed for Kew for days having ceiling values of incident radiation (Tables II and III).
2. A seasonal variation in Lauscher's ratio *L* has been detected, though the variation about the mean is probably too small to be of practical significance (Figure 3).
3. Results of the Lauscher type have been derived for data of certain classes defined on page 362 — broadly described as very sunny days and all days (Tables II and III).

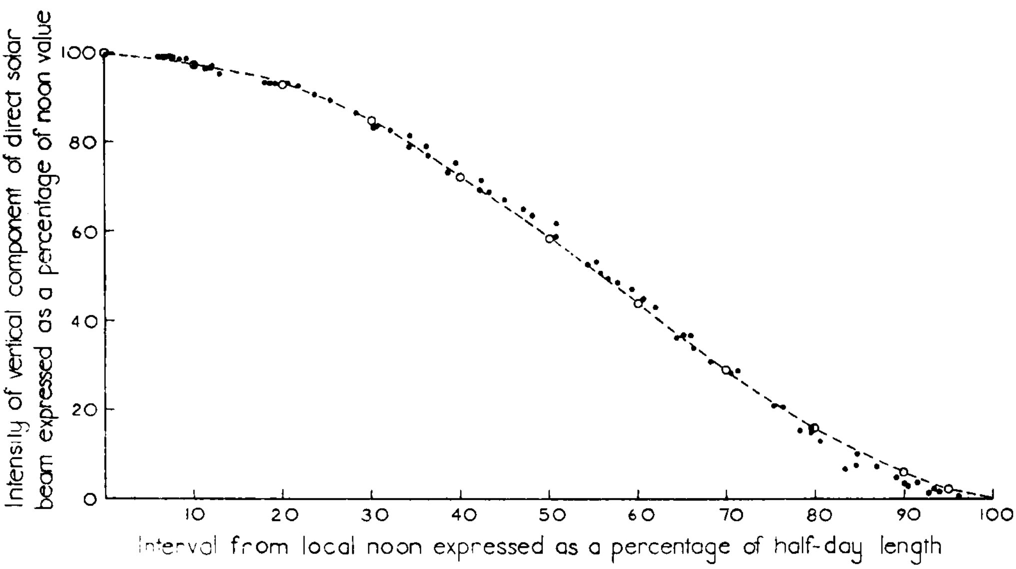


FIGURE 4—INTENSITY OF THE VERTICAL COMPONENT OF THE DIRECT SOLAR BEAM, EXPRESSED AS A PERCENTAGE OF THE NOON VALUE, AGAINST THE INTERVAL FROM LOCAL NOON AT KEW, EXPRESSED AS A PERCENTAGE OF THE HALF-DAY LENGTH, FOR CLASS *D* DAYS

o Points plotted according to Lauscher's second result

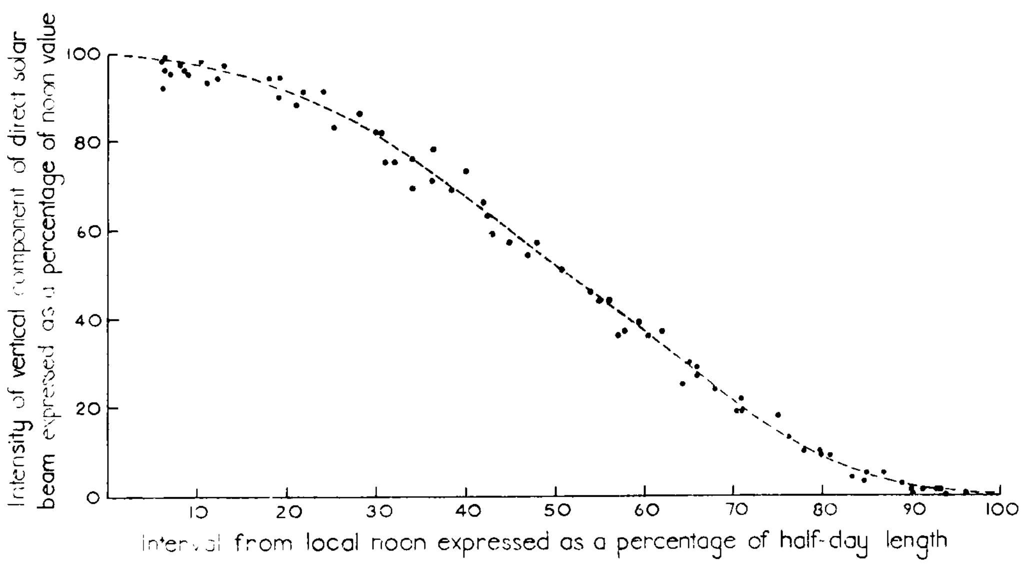


FIGURE 5—INTENSITY OF THE VERTICAL COMPONENT OF THE DIRECT SOLAR BEAM, EXPRESSED AS A PERCENTAGE OF THE NOON VALUE, AGAINST THE INTERVAL FROM LOCAL NOON AT KEW, EXPRESSED AS A PERCENTAGE OF THE HALF-DAY LENGTH, FOR CLASS *A* DAYS

4. Lauscher's second result for clear conditions and similar results derived for data of certain other classes are shown to be closely fitted by a family of Pearson Type II curves (Table III and Appendix II).

5. A set of reasonably satisfactory linear regressions has been derived relating the value of normally incident radiation at noon with the expression log (declination + 25°) for the several classes. (Figure 6).
6. Given a reliable estimate of the noon intensity of the direct beam in clear conditions in a locality, empirical relationships of the Lauscher type can probably be employed to obtain useful results. The practical application to localities far from Kew requires that the techniques described be first tested with data from areas whose sky conditions differ appreciably from those of Kew.

## Appendix I

*Direct solar radiation at normal incidence at Kew in relation to solar declination*

In an attempt to obtain a reliable estimate of the intensity at noon, the relationship between this quantity and solar declination at noon at mid-month was examined ; the results were sufficiently informative and useful to merit a brief discussion.

If it is assumed that a smooth curve, such as is obtained by plotting Stagg's 'ceiling' values against local time, represents the type of relationship to be expected when sampling variance is largely eliminated, then two sources of error in the data for classes *B* and *C* can be specified, namely :

(i) Irregular fluctuations, between months of different name, in the magnitudes of the deviation of the estimated noon values from those obtaining for class *D*.

(ii) Irregularities in the plot of normally incident radiation against time, namely either unsteady increase from sunrise (or sunset) towards noon, and/or marked asymmetry of the curve about noon.

The values of the normal intensity at noon, obtained by the free-hand extrapolation described (page 363), are plotted against solar declination in Figure 1 (for classes *A* and *D*) and Figure 2 (for classes *B* and *C*). When constructing the smooth curves in the figures, the existence of errors mentioned above was borne in mind and the points were annotated as follows :

(*a*) Upward pointing arrows imply that results are low relative to those in class *D* and downward pointing arrows that results are high.

(*b*) The existence of a considerable asymmetry of the intensity/time plot about local noon is indicated by brackets round the values.

Obviously greatest weight was given to points lacking these annotations.

Stagg suggested that the radiation quality of (Class *B*) days selected from the months of November, December and (perhaps to a lesser degree) October was probably above the average for the remaining months of the year — remarks consistent with the indications in Figure 2 which also suggests analogous conclusions for other months, such as June and March.

A useful summary for all classes of the connexion between intensity and solar declination is given in Figure 6 which consists of a plot of the noon intensity at normal incidence against log $x$, where :

$$x = \text{declination} + 25°,$$

the addition of an arbitrary 25° being adopted in order to avoid negative values.

Although all curves are sigmoid in character, a linear least squares solution based upon all available points for declinations equal to or greater than —20°

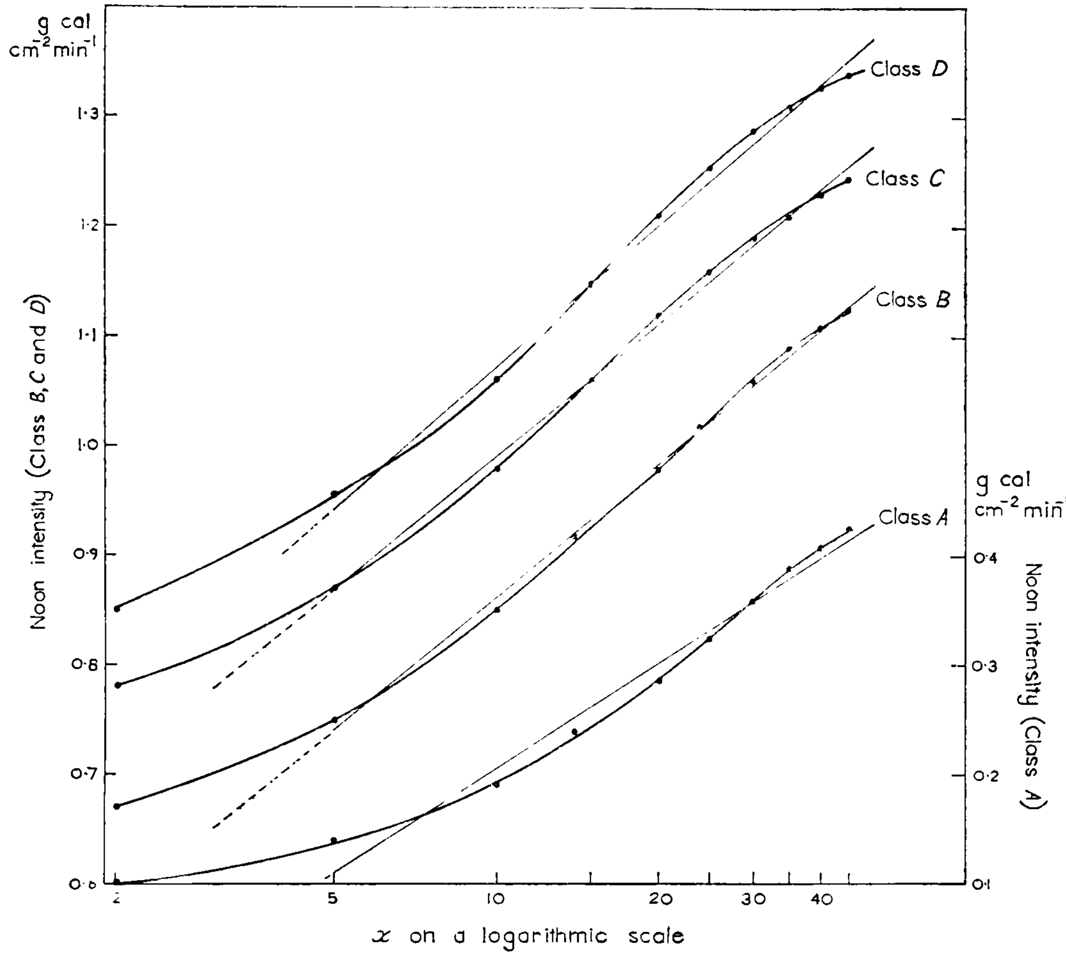


FIGURE 6—RELATIONSHIP BETWEEN NOON INTENSITY OF DIRECT SOLAR BEAM AT NORMAL INCIDENCE AND LOG $x$ AT KEW, TOGETHER WITH LINES OF BEST FIT FOR DECLINATIONS GREATER THAN −20°

$x$ = declination + 25°

| | | | |
|---|---|---|---|
| *A* | All days (1933–46) | B | Days of high radiation |
| *C* | Days of highest recorded radiation | *D* | 'Ceiling' radiation values |

(Using data classified by Stagg[2] as class *A*, *B*, *C* and *D*.)
The straight lines are the lines of best fit.

(i.e. applying to the period 21 January to 21 November) represented the run of values very satisfactorily. Table IV gives the values of the constants used in the equation,

$$\text{Intensity} = b \log cx.$$

TABLE IV—VALUES OF THE CONSTANTS $b$ AND $c$ IN THE EQUATION, FOR VARIOUS CLASSES

| Class | Value of constants $b$ | $c$ |
|---|---|---|
| *A* | 0·318 | 0·44 |
| *B* | 0·412 | 12·23 |
| *C* | 0·407 | 27·07 |
| *D* | 0·429 | 31·88 |

For the classes *A*, *B*, *C* and *D* the correlations between log $x$ and intensity are 0·982, 0·997, 0·994 and 0·997 respectively.

For classes $B$, $C$, $D$ the departure from a linear dependence exceeded 2 or 3 per cent only for declinations less than $-21°$ (i.e. between 27 November and 17 January). For class $A$ and for declinations less than about $-19°$ (i.e. between 18 November and 24 January) the linear assumption would be misleading and give a relative error of 10 per cent or more. There is a tendency for $b$, the gradient of the line, to increase from class $A$ to class $D$, suggesting some underlying physical factor — however the gap between the mere 8 per cent of days constituting class $B$ the to 'all' days of class $A$ renders arguments on these lines hazardous.

## Appendix II

It was required to fit a series of curves having the following properties :

(i) an assumed complete symmetry about the vertical (local noon) axis,

(ii) a significant degree of negative kurtosis, and

(iii) a high degree of contact at the lower end.

After extensive trials with a number of possible analytical expressions, it was judged that one of the form given below, i.e. a Pearson Type II-curve, fitted best with the minimum of parameters, namely

$$y = \left(1 - \frac{t^2}{a^2}\right)^m$$

where

$y$ = ratio of the intensity of the vertical component of solar radiation at interval $t$ from local noon, to the intensity at noon,

and $t$ = interval from noon expressed as a percentage of the half-day length.

Based upon values read from the smoothed curve of the intensity of the vertical component against 'time' at ten equally spaced points on the abscissa, (i.e. at 5 per cent, 15 per cent, etc. of the half-day length), the numerical values of associated pairs of the parameters $m$ and $a$ are as follows :

| Class | $m$ | $a$ |
|---|---|---|
| $D$ | 2·035 | 103·9 |
| $C$ (summer) | 2·188 | 101·7 |
| $C$ (winter) | 2·063 | 100·9 |
| $B$ (summer) | 2·853 | 106·7 |
| $B$ (winter) | 2·162 | 100·4 |
| $A$ (summer) | 2·188 | 96·8 |
| $A$ (winter) | 2·036 | 94·5 |

There is no obvious systematic variation in the values of $m$ and $a$ although when the curves are plotted they form a set following the sequence indicated above. The divergence, at any point, between the original smoothed curve and the associated Type II-curve did not exceed one part in 100 of the noon value.

### REFERENCES


1. LAUSCHER, F. ; Beziehungen zwischen der Sonnenscheindauer und Sonnenstrahlungssummen für alle Zonen der Erde. *Met. Z., Braunschweig*, **51**, 1934, p. 437.
2. STAGG, J. M.; Solar radiation at Kew Observatory. *Geophys. Mem., London*, No. **86**, 1950, p. 3.

551.5:378.4

# METEOROLOGY AT THE UNIVERSITY OF READING

By PROFESSOR R. C. SUTCLIFFE, C.B., O.B.E., F.R.S.

It was not long after the Headquarters of the Meteorological Office had been brought together at Bracknell in 1961 that the authorities of the University of Reading showed an interest in the establishment of a department of meteorology, an enterprise to which the Director-General of the Office gave all the official encouragement he could and to which I as Director of Research was equally well disposed. It has long been felt that meteorology in British universities could justifiably be expanded, although where and how was less obvious, and the close proximity of Bracknell to Reading seemed a particularly favourable factor which would allow of co-operation in various directions. There is no need to list here the many hypothetical ways in which the one institution might benefit from good relations with the other but rather, now that the University department has been created, we have the practical task of making the most of the opportunities. Having long been interested in meteorological education I am naturally delighted to be given the chance to make a tangible contribution.

When meteorology is considered as a university subject a number of embarrassing facts have to be faced, facts which are in part peculiar to the subject and in part peculiar to the conditions in the country concerned. The science is the foundation of a useful and thoroughly well-established professional service but it is and presumably must remain a comparatively small profession, smaller by one or two orders of magnitude than the large scientific technical professions of medicine, engineering or agricultural science : it has been too small in Britain to make any exigent demand for vocational training departments. Furthermore the profession is a near-monopoly of the state Meteorological Office offering no guarantee of employment to anyone who may choose to study the subject at a university. Again, meteorology, neglected by physicists, has been adopted and much studied by departments of geography, and rightly so, for weather and climate are relevant considerations for the geographer whether his interest is physical, historical, social or economic. But the geographer cannot, or at least does not and I believe should not, assume responsibility for the training of meteorological specialists or for the main development of the subject as a branch of science which steadily becomes more dependent on laboratory and mathematical physics.

In planning meteorological teaching at Reading I have taken it as axiomatic that a comprehensive course must be basically a course in theoretical, experimental and observational physics. The empirical exploration and analysis of the wide range of specific phenomena which uniquely define meteorology must certainly not be despised ; the aim is to have knowledge and understanding of weather and climate and not merely to exercise skills in mathematics or laboratory physics. Nevertheless meteorology belongs to geophysics; it is a branch of physical science and it cannot get very far without the basic tools. Ideally, no doubt, meteorology is most effectively studied in graduate schools following on from a degree course in basic science but it is not easy to attract sufficient students at that stage in their careers and I have thought it desirable to take recruits immediately from school at a time when many young people seem to have a natural inclination towards the subject.

The outcome of all this is then a first-degree course for honours B.Sc. with meteorology, mathematics and conventional physics receiving roughly equal attention throughout the three years. This is the first time that a comprehensive first-degree course, or any course in meteorology continuing through three years, has been offered in a British university and I believe the time available will suffice for the subject to be tolerably well covered. The graduate will still be recognizably a physicist, in fact and in name, but one who has the advantage of having specialized in an environmental science and so may find a vocation along many other avenues if professional meteorology is not his final choice.

In the course of the next two or three years the plan is to build up a viable department with six or seven permanent teaching staff so that individually the share of undergraduate teaching will be light and will leave opportunity for the development of an effective research school. The first fruits of the close connexion with the Meteorological Office is the promise, with official approval, of very substantial help in lecturing during the first year from research staff in the Office. Dr. R. Frith, Mr. A. Gilchrist and Dr. F. B. Smith, all established research scientists, have each undertaken to provide a regular series of lectures within the agreed syllabus. The undergraduate course is thus getting off to a flying start.

A postscript may be of interest. It is possible within the University's regulations to enrol for research, with a view to the Ph.D. degree, graduates — from this or other universities — who may pursue their research entirely extramurally, subject to some degree of supervision by the university tutor. I shall, as would be expected, be especially happy if we can somehow take advantage of this facility so that I may assist to their doctorates members of the Office staff whose private or official research work is acceptable also to the university, as, in most cases, it must surely be.

551.5:061.3

## THE FOURTH SESSION OF THE COMMISSION FOR AEROLOGY, BRUSSELS, 1965

The Commission for Aerology of the World Meteorological Organization (WMO) held its fourth session in Brussels from 6 to 19 July 1965. The Commission is primarily concerned with ensuring the international co-ordination which is necessary for many aspects of meteorological research and, in particular, for recommending programmes of observation necessary for the study of large-scale phenomena and for arranging the publication and exchange of the meteorological data which are required for studies of the atmosphere.

During the course of the meetings a wide range of meteorological research came under review, but recommendations for new or augmented observational programmes concerned mainly observations of ozone and the high atmosphere. In particular a world-wide network of stations to determine winds in the high atmosphere from the drift of meteor trails has been proposed, and further study of the drift of ionization in the '*E*' layer. Current arrangements to watch for signs of rapid warming of the stratosphere in winter and to notify the occurrence of such warming to those who wish to carry out special research programmes were discussed, and it was recommended that they should continue until 1970.

Subjects in which the Commission showed a new and lively interest were (*a*) atmospheric pollution, (*b*) the exchange and storage of data in forms suitable for computer use and (*c*) tropical meteorology. Working groups have been established by the Commission to keep all these topics under review.

In discussing atmospheric pollution it was evident that delegates considered that this problem could no longer be considered solely as a local matter of the environment of a single factory or city, but that there was a need to monitor the pollution of the atmosphere on a much wider scale. The new Working Group will seek to establish comparability in observing techniques and will make proposals for establishing and monitoring the background contamination of the atmosphere as a whole.

The Commission's concern with the exchange of data in the form of punched cards, paper tape, magnetic tape, etc. can be understood at a time such as the present when technological innovation makes the maintenance of standards of form and format in such media particularly difficult. The Working Group which will review the problem can also be expected to keep in close touch with the development of the scheme for World Weather Watch in the hope that the World, Regional and National Weather Centres which it includes will maintain comprehensive archives of meteorological data in a form in which they can readily be used for research.

In tropical meteorology it is hoped that WMO may stimulate and organize an augmented observational network in some part of the tropical belt.

Among the more specific recommendations made by the Commission for Aerology, was the decision to make no change in the definition of the tropopause for another 4 years at least, despite occasional criticisms of it. Emphasis was also placed on the desirability of meteorological observations from high towers (television masts, etc.) to provide proper understanding of the boundary layer needed for numerical forecasting and studies of the general circulation.

It may be noted that the increased international activity in meteorological research has had the result that many questions are referred to the President of the Commission between the sessions which are held at intervals of 4 years. The Commission therefore formed an Executive Working Group of five members which, it is hoped, will meet annually to advise the President on current problems.

Delegates to the fourth session of the Commission for Aerology greatly appreciated the remarkable hospitality of their Belgian hosts and of the excellent arrangements made for the meetings which contributed greatly to their success.

J. S. SAWYER

## NOTES AND NEWS

### Meteorological Magazine: increase in price

We regret that owing to the need to recover the full cost of postage it will be necessary to increase the price of the *Meteorological Magazine* beginning with the January 1966 issue. The net annual subscription will become 41*s*. including postage.

### Royal Netherlands Meteorological Institute

Professor D. W. Bleeker succeeded Mr. C. J. Warners as Director-in-Chief of the Royal Netherlands Meteorological Institute on 1 September 1965 and has also been designated Permanent Representative of the Netherlands with the World Meteorological Organization.

### India Meteorological Department

Mr. C. Ramaswamy succeeds Mr. P. R. Krishna Rao as Director General of Observatories, India Meteorological Department. Mr. Krishna Rao retired on 24 July 1965.

## METEOROLOGICAL OFFICE NEWS

### Retirement presentation to Sir Graham Sutton, C.B.E., F.R.S.

At a ceremony held in the Lecture Theatre at Bracknell Headquarters on Wednesday 29 September Dr. A. C. Best, Director of Services, made a presentation on behalf of members of the Office to Sir Graham Sutton on the occasion of his retirement as Director-General. Mr. W. C. Curtis, Assistant Secretary in F6 (Air) represented members of the Permanent Under Secretary's Department who had also contributed to the presentation.

Sir Graham paid tribute to his immediate advisers in the Higher Directorate, and to his personal staff and many others, but stressed the loyal services rendered by the staff as a whole. He intimated that he intended to purchase a stereogram with the money subscribed for his retirement gift.

Lady Sutton spoke of her happy associations with the social activities of the Office and of how she had been made welcome by all concerned. On behalf of Sir Graham and herself she then presented to the Office a silver rosebowl, to be awarded annually to the individual making the most worthy contribution to the social life of the Office. Mr. C. W. G. Daking as Chairman of the Meteorological Office Social and Sports Committee accepted this handsome gift to the Office (Plate II) and emphasized how much members of the staff appreciated the deep interest taken by Sir Graham and Lady Sutton in the social activities of the Office. Miss Wordsworth presented a bouquet to Lady Sutton, and the assembly, at the invitation of Sir Graham, then adjourned to the Restaurant for a more informal farewell party.

C.W.G.D.

## REVIEWS

*General relativity and cosmology* (International astrophysics Series, Vol. 4), by G. C. McVittie. $9\frac{1}{2}$ in × 6 in, pp. xii + 241, Chapman and Hall Ltd., 11 New Fetter Lane, London EC4, 1965. Price: 50*s*.

Dr. G. C. McVittie is well known to meteorologists for his active interest in some of their basic problems of the representation of dynamical theory in suitable co-ordinate systems. His papers in the meteorological journals show admirable clarity, directness and simplicity and these are the hallmark of this second edition of *General Relativity and Cosmology*. As the author remarks, the plan of the book is similar to that of Tolman, focusing attention on the mathematical preliminaries, on the special and general theories and then dealing with gas dynamics and model universes. There is, of course, much new material both theoretical and observational; the theory of gas dynamics is due in a large part to the author himself, as is the working out of the details of the model universes in order to test the predicted properties against observation.

*Photograph by G. A. Corby*

PLATE II—SIR GRAHAM SUTTON AND LADY SUTTON WITH THE CHAIRMAN OF THE METEOROLOGICAL OFFICE SOCIAL AND SPORTS COMMITTEE, MR. C. W. G. DAKING (LEFT).

The rosebowl will be awarded annually to the individual making the most worthy contribution to the social life of the Office (see p. 374).

To face page 375

Photograph by P. Vella

PLATE III—LENTICULAR LEE-WAVE CLOUDS AT GIBRALTAR EARLY IN THE EVENING ON 27 DECEMBER, 1964

However, the main interest to the dynamical meteorologist undoubtedly lies in the middle chapters on gas-dynamics; hydrodynamics may be a more familiar term. These chapters give a new slant on hydrodynamical theory and indeed on possible methods of solving the equations. The author sets out to find functions which determine the density, pressure and velocity vector identically satisfying the equations of motion and continuity; the thermodynamic equation would then provide a differential equation for the function, with initial and boundary conditions specified. Perhaps this attack is well known to workers in the field of relativity. I have not seen it in meteorological literature; it may not be possible to adopt this method for our problems but at least it makes us think about them in a new way.

E. KNIGHTING

*Atmospheric pollution: its origins and prevention*, 3rd revised edition, by A. R. Meetham, D. W. Bottom and S. Cayton. 9 in×6 in, pp. xii+301, *illus.*, Pergamon Press, Headington Hill Hall, Oxford, 1964. Price: 70*s*.

The second edition of this book was reviewed in this magazine in November 1956.* The appearance of a third edition, within 12 years of the original publication, is adequate testimony both to the demand for a comprehensive technical account of air pollution and to the quality of this book in meeting the demand. The new edition has three authors, Dr. Meetham having been joined by D. W. Bottom and S. Cayton who are experts in the public health aspects.

The period since the notorious London smog, which occurred in 1952, has been one of sustained activity in the study and prevention of air pollution and in a number of countries measures have been taken in attempts to bring the problem under control. In the United Kingdom, for example, the Clean Air Act, in conjunction with earlier legislation such as the various Alkali Acts, has already given good results in reducing pollution levels. Clearly, governmental action on these lines provides an effective stimulus to basic studies and research in the many and complicated aspects of air pollution.

This book which, one supposes, will continue to be referred to as 'Meetham's book' is a thorough revision of earlier editions and contains much new material. As far as can be judged by a reviewer with rather specialized interests in the subject, considerable pains have been taken to cover the whole field in as up-to-date a manner as possible. The subject is covered in an ordered sequence. The first four chapters after the introduction cover the different kinds of fuel, then follow four chapters on the methods and appliances—boilers, furnaces, etc.—by means of which fuel is consumed. Succeeding chapters then deal with pollution and its many complicated problems—constituents, detection and measurement, the varying pattern of distribution, meteorological considerations, effects on health and materials, preventative measures. Finally there is a chapter on the law and its administration, mainly concerned with English law and its implementation, but also containing a review of anti-pollution legislation in other industrial countries.

This book provides an excellent general account of air pollution. It does not replace specialized texts but, aided by bibliographies appended to each chapter, provides helpful pointers to those who wish to go more deeply. Specialists would themselves find this book invaluable for background reading. The book is very well produced.

P. J. MEADE

*MEADE, P. J.; Review of *Atmospheric pollution: its origin and prevention*, 2nd edn. *Met. Mag., London*, **85**, 1956, p.348.

*Atlantic hurricanes*, by G. E. Dunn and B. I. Miller. $9\frac{1}{4}$ in × 9 in, pp. xx + 377, *illus.*, Louisiana State University Press, Baton Rouge 3, La., 1964. Price: $7.50.

This book was first published in 1960; the content of this revised edition is essentially the same as that of the original but with a few additions to bring it up to date. These are descriptive accounts of all the hurricanes of recent years, and a section on the detection and forecasting of hurricanes including the use of meteorological satellites.

There is much in the book that will have a wide appeal, notably some accounts of personal experiences on the ground and in the air in the central parts of violent hurricanes, including some aerial penetrations into the eyes of storms. Some sections have the flavour of popular magazine articles, for example, the opening transcription of a coded hurricane message followed by its decode, and a paragraph on "why hurricanes are given girls' names". Other parts of the book will be meaningful only to the professional meteorologist.

The first five chapters cover well-known ground, including descriptions of hurricanes, seasons and locations of their occurrence, and the associated weather; new material includes some charts of rainfall distribution along the tracks of particular hurricanes.

Then follow six short chapters of a more technical nature, concerned with the energy of the hurricane, its life history, and observing and forecasting techniques. The observational study of hurricanes has advanced in recent years with the help of radar and organized aircraft surveillance, and satellite photography has led to earlier detection; nevertheless, hurricane forecasting still appears to depend much on experience and judgement. No satisfactory method has been devised for the numerical forecasting of hurricanes, neither does a model emerge to enable the energy transformations of the hurricane to be treated quantitatively.

Two chapters deal with the destructive forces of the hurricane — winds, tides and floods — and some practical advice on the action to be taken when one's home is threatened. This ranges from long-term considerations of building construction and choice of site to short-term advice suggestive of preparing for a siege when the hurricane strikes. Then, after a descriptive chapter about some individual hurricanes of the past 10 years, the readers' thoughts are again turned towards technical matters with a recapitulation of present knowledge and recent advances in hurricane research. As is perhaps inevitable with systems whose detailed structure is so little known, no clear line of future progress is indicated.

The book concludes with a number of appendixes listing all hurricanes of which there are records, with brief notes on each mostly relating to casualties or damage. An earlier work *Hurricanes* by Tannehill included a chronological account of all hurricanes between 1901 and 1955; the present work continues this account over the period 1956 – 63.

The book can be recommended to a wide circle of readers: to dynamical meteorologists because the hurricane problem is clearly presented; to the climatologist because of the wealth of facts and figures about hurricanes; and to the non-professional reader because of the lively descriptions of hurricanes and some striking illustrations of hurricane damage and of hurricanes seen from aircraft.

A. G. FORSDYKE

*Humidity and moisture*: Volume one, *Principles and methods of measuring humidity in gases*, edited by Robert E. Ruskin. 10¼ in × 7 in, pp. xv + 687, *illus.*, Chapman and Hall Ltd., 11 New Fetter Lane, London EC4, 1965. Price: £12.

This book is the first part of a four-volume work representing the expanded proceedings of the 1963 International Symposium on Humidity and Moisture Control held in Washington, D.C. It consists of a selection of papers read at the symposium, an author index and a comprehensive subject index. Each paper is reproduced with the minimum of editing and with its original references. The papers are grouped under six general headings according to the principle of the method of measurement described.

Section I, Psychrometry, contains 11 papers which show that there is room for new techniques even in this old and well-established method of measurement. Of particular interest to the meteorologists are 2 papers describing methods of improving the accuracy and convenience of the psychrometer in 'difficult' conditions. One dealing with the problem of measurement in a hot, dry atmosphere describes a method of precooling the water supplied to the wet bulb. In the other paper it is suggested that the difficulties of maintaining an ice bulb can be avoided by heating the air taken in to the psychrometer to raise the wet-bulb temperature above 0°C. This does not, of course, alter the dew-point.

Section II, Dew-point Hygrometry, also contains 11 papers and reflects the considerable effort of recent years, particularly in the U.S.A., to perfect a convenient and accurate dew-point/frost-point hygrometer. There is a good paper on the basic process of the dew-point hygrometer; the remaining papers describe instruments ranging from manually controlled hygrometers with visual detection of the dew deposit to completely automatic instruments in which the thickness of the dew is measured by observing the energy attenuation of alpha radiation passing through it.

Section III, Electrical Hygrometry, consists of 19 papers describing sensors that change their resistance, capacitance, or both, in response to relative-humidity changes. There is an almost bewildering array of these relative-humidity sensors available, and since none has yet demonstrated its superiority over all others for all purposes, this collection of papers describing the characteristics of most sensor types in a single volume is useful.

Section IV, Spectroscopic Hygrometry, contains 7 papers all by North American authors; one is on the absorption of radiation by water vapour, the remaining 6 describe measuring systems. The exaggerated claims of accuracy and sensitivity of spectroscopic systems that were common a few years ago are no longer made and reasonable assessments of the advantages, disadvantages and possibilities of these systems are presented. The papers leave no doubt that the long-path infra-red hygrometer is a useful instrument when a special average of humidity is required or that the Lyman-Alpha hygrometer has no equal when fast response at low dew-points is required and cost, complexity and stability of calibration are of secondary importance.

Section V, Coulometric Hygrometry, contains 4 papers describing the phosphorus-pentoxide electrolytic hygrometer. Three of the papers discuss humidity measurement in air, the fourth deals with the detection of moisture in refrigerants. The difficulties of operating the cells over a very large range of dew-point are discussed (cells suitable for detecting dew-points of –80°C tend to overheat at surface ambient dew-points) and a method of operation employing a diffusion barrier at high dew-points is described in one paper.

Section VI, Miscellaneous Methods, contains 16 papers describing sensors ranging from chemical spots on blotting paper that change colour at a given relative humidity ± 5 per cent, to a dew-point instrument employing a single ionic crystal for which a precision of 0·01°C is claimed. The papers in this section with the greatest immediate interest to the meteorologist are 2 on hair as a humidity sensor and 2 on the lithium-chloride, heated hygrometer, since instruments employing these sensing methods are in regular use at synoptic stations.

The publishers say that "This volume forms a complete reference work on instrumentation for water vapour measurement"; this is a bold claim which the book almost substantiates. However, as one must expect, work carried out in the U.S.A. dominates and there are no papers originating in the U.S.S.R. It is rather more surprising that there is no paper on the microwave refractometer, this instrument being mentioned only briefly in one paper.

In a book with papers by more than 60 different authors the scientific quality of the work and the style of presentation obviously varies widely and it is worth remembering, when one is comparing the performance claimed for one instrument with that of another, that some of the authors represent manufacturers hoping to sell their products.

In spite of these shortcomings the book is a very welcome addition to the literature on humidity measurement. It will be of interest to the meteorologist who is concerned about the accuracy of the basic information he uses and is essential reading for anyone responsible for selecting instruments for humidity measurements.

W. R. SPARKS

*Atmospheric processes in the high latitudes of the southern hemisphere*, by P. D. Astapenko. $9\frac{3}{4}$ in × $6\frac{3}{4}$ in, pp. ix + 286, *illus.* (translated from the Russian by the Israel Program for Scientific Translations, Jerusalem), Oldbourne Press, 1–5 Portpool Lane, London EC1, 1964. Price: 63*s.*

This comprehensive book provides a further advance in the knowledge of the meteorology of the Antarctic continent consequent upon the analysis of data collected during the first year of the International Geophysical Year (IGY). Previously, meteorologists who had written on the subject were perforce limited to using much fragmentary data, many gaps being filled by deduction and imagination. The book does much to clear up areas of doubt and reconcile divergent views. Thus it is conclusively demonstrated that the weather over the Antarctic continent can be largely attributed to the penetration of depressions from the ocean areas and that the Antarctic anticyclone is often comparatively weak and capable of displacement at any time of the year. This permits frontal systems associated with oceanic depressions to cross the coastline and penetrate to the polar plateau and beyond. The zonal flow over the ocean areas is by no means regular and is frequently upset by extensions of the sub-tropical anticyclones, causing depressions to be channelled to the high latitudes. So much has been deduced previously by other authors but the degree of importance to be attached to meridional flow has never before been so conclusively demonstrated.

The book fully amplifies the difficulties facing a forecaster in high southern latitudes and on early acquaintance he can be readily baffled since much of the surface data is totally unrepresentative of the true synoptic situation. This is due to the topography which is particularly mountainous and surmounted by a thick ice-cap. Forecasting demands the employment of techniques of vertical structure analysis which are often shown to be much more effective than conventional synoptic analysis. Any meteorologist required to forecast in or near the Antarctic continent will find previous study of this book invaluable.

In the final chapter, certain questions relating to the general circulation of the atmosphere are discussed together with the role which the Antarctic continent plays in the problem of long-range forecasting. Considerations and comparisons of the southern hemisphere circulation are demonstrated as being most important to the northern hemisphere problem, but the author rejects any suggestion that the Antarctic continent itself plays a greater part in the consideration than any other continent of similar size and asks the naive question "Does the presence of continents really deserve the importance attributed to it to-day"? The comparative weakness of the anticyclone compared with similar continental anticyclones which form over frigid lands in the northern hemisphere may well justify the asking of this question. It leaves the impression that it was unfortunate that the efforts during the IGY were not, or could not be, matched by corresponding large-scale efforts over the southern oceans using weather ships and survey vessels.

The book appears to lose nothing in translation, the style being easy and the text readily comprehensible. Readers not familiar with the Antarctic may well find the need of more detailed maps giving place names and topography.

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## LETTER TO THE EDITOR

### The measurement of sea surface temperature

With reference to Mr. M. W. Stubbs' article,[1] it is desirable to explain why a canvas bucket is used for measuring sea temperature aboard the British Weather Ships, when on station, and an insulated bucket when on passage. The insulated bucket is described in the Marine Observer's Handbook[2] and has been shown to be very accurate. It contains only a small water sample, and depends for its accuracy upon its double skin of rubber and upon the circulations which are quickly set up in the inner spaces of the double-skinned bucket when it is dragged through the water at the speed of the ship. It was specially designed for use aboard voluntary observing merchant ships, to eliminate the errors due to the minor delays that inevitably occur between immersing a thermometer in the water and taking the actual readings. One such delay is due to the relatively large height that the bucket has to be hove up from the water line to the bridge in such ships.

Ocean Weather Ships, when on station, spend most of their time lying stopped and on such occasions it is not practicable to use the insulated bucket. In these ships, the meteorologist takes his sea temperature readings on the after-deck, which is only about six feet above sea level. Using the canvas bucket he gets a large sample of water, can very quickly haul it up on deck and reads the thermometer instantly, so that a minimum of error occurs.

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1. STUBBS, M. W.; The standard error of a sea surface temperature as measured using a canvas bucket. *Met. Mag., London*, **94**, 1965, p. 66.

2. London, Meteorological Office. Marine Observer's Handbook. 8th Edition. London, HMSO, 1963, p. 29.