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FORECASTING WET SPELLS IN SOUTH-EAST ENGLAND

By R. A. S. RATCLIFFE and A. E. PARKER

Summary. From a study of 500 mb flow patterns over the years 1951–60 inclusive, criteria for forecasting wet spells in south-east England are developed. When tested against independent data for 1961–65 inclusive, the criteria are shown to be capable of forecasting more than half of the wet spells occurring in south-east England throughout the year.

Introduction. Lowndes[1] has formulated rules for forecasting wet spells at London based on the negative 500 mb height anomaly in upper troughs to the west of the British Isles and the surface pressure at Valentia or London. He found different criteria for different times of the year and his wet spell definitions were rather restrictive, resulting in an average of about 8 or 10 spells per year.

Ratcliffe[2] has developed criteria for forecasting fine spells in south-east England based largely on the position of the jet stream at 500 mb over the Atlantic. Benwell[3] also demonstrated that the jet stream at 500 mb could be used as a predictor for heavy rain. Following on these ideas it was realized that in all probability it would be possible to define other fairly simple 500 mb patterns based largely on the jet stream which would precede wet spells on a large number of occasions. The present work is an attempt to bring out the appropriate criteria. A wet spell has been defined rather less stringently than in Lowndes's work and this results in an average of about 18 wet spells per year in south-east England.

Data used. All the 500 mb charts for 1200 GMT (1500 GMT before April 1957) in the 10-year period from 1951–60 inclusive were scrutinized with a view to uncovering any relationship which might exist between the 500 mb flow patterns to the west of the British Isles and the occurrence of wet spells in south-east England. The Agriculture and Hydrometeorology Branch of the Meteorological Office had already extracted daily rainfall amounts for a number of stations in the British Isles and seven of these stations were chosen to represent south-east England in this investigation. These stations were Cranwell, Gorleston, Cambridge, Oxford, Kew, Southampton and Hastings (Figure 1). The standard definition of a wet day, namely 1 mm of rain or more over a 24-hour period, was adopted and a wet day in south-east England was defined as a day when the *average* amount of rain at the seven selected

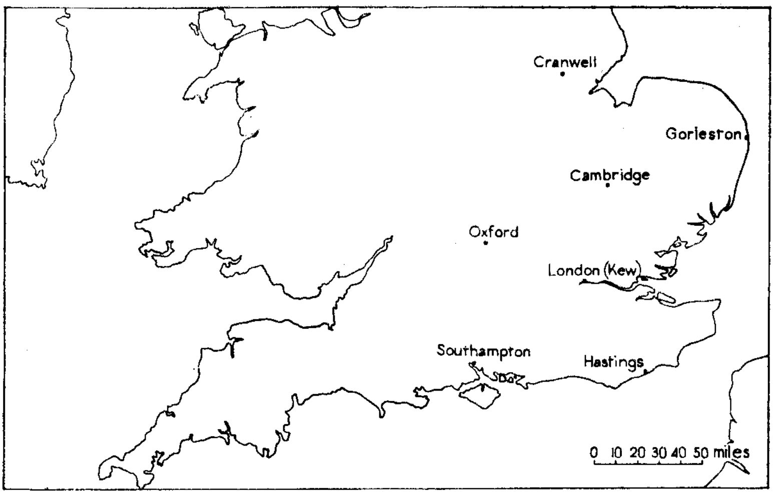


FIGURE I—STATIONS CHOSEN TO REPRESENT SOUTH-EAST ENGLAND IN THE INVESTIGATION

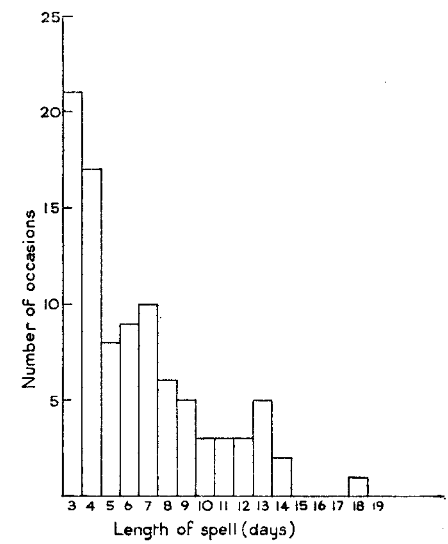


FIGURE 2—FREQUENCY DISTRIBUTION OF SPELLS OF DIFFERENT LENGTHS

stations was 1 mm or more. A three-day wet spell was arbitrarily defined as three days each of which was 'wet' but in addition the rainfall averaged over south-east England was at least 6 mm over the three days.

In spells lasting more than three days, the definition chosen was that the first and last days of the spell and also at least two out of every three successive days must be 'wet', while the average rainfall over the spell must be at least 2 mm per day.

In effect this definition allows dry days in a spell provided such days do not occur more often than one day in three, but the overall amount of rainfall is twice that required under the standard 'wet day' definition.

Over the period 1961–65 inclusive, there were 93 such spells lasting between 3 and 18 days, the mean length of spells being 6·4 days. Figure 2 shows the frequency distribution of spells of different lengths; this figure is noteworthy in that minima in the frequency of spells occur at about 5 and 10 days with no cases around 15 days though there is one occasion of a spell lasting 18 days. In view of the relatively large number of occasions (93) the minima at 5 and 10 days are probably real and suggest perhaps that the long-wave pattern tends to change after about 5 days although a similar pattern may recur almost immediately.

In order to give the forecaster some idea of the most likely amounts of rain during wet spells, Figure 3 was produced. This diagram indicates the frequency distribution of amounts of rain per day in millimetres averaged over the 7 stations during a wet spell as defined earlier. The mean amount of rain to be expected per day is 4·1 mm. Taken in conjunction with the mean length of spell (6·4 days), this indicates that on the average the forecaster may expect about 26 mm of rainfall over south-east England as a whole during the wet spells described in this paper.

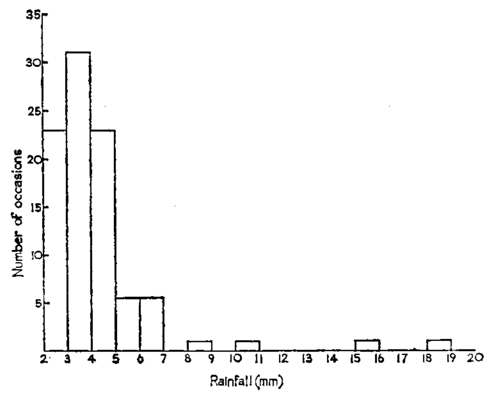


FIGURE 3—AVERAGE DAILY RATE OF RAINFALL PER STATION DURING WET SPELLS

Forecasting criteria.

(i) From the study of 500 mb charts over the period 1951–60 it became apparent that wet spells tend to occur in south-east England whenever London lies near to the core or slightly on the left side of a long and fairly straight jet stream. London may be just downwind from the exit region of the jet stream as in Figure 4 if the jet is expected to propagate forwards along its path. The exact distance of London from the axis or exit region of the jet is not critical but about 100 miles is a useful guide. The main requirement is that London should be close enough to the depression tracks for south-east England to receive the appropriate amount of rain.

(ii) The jet stream, which is normally the strongest flow in the Atlantic area from about 40°N to 70°N and from 10°E to 60°W, should be of the

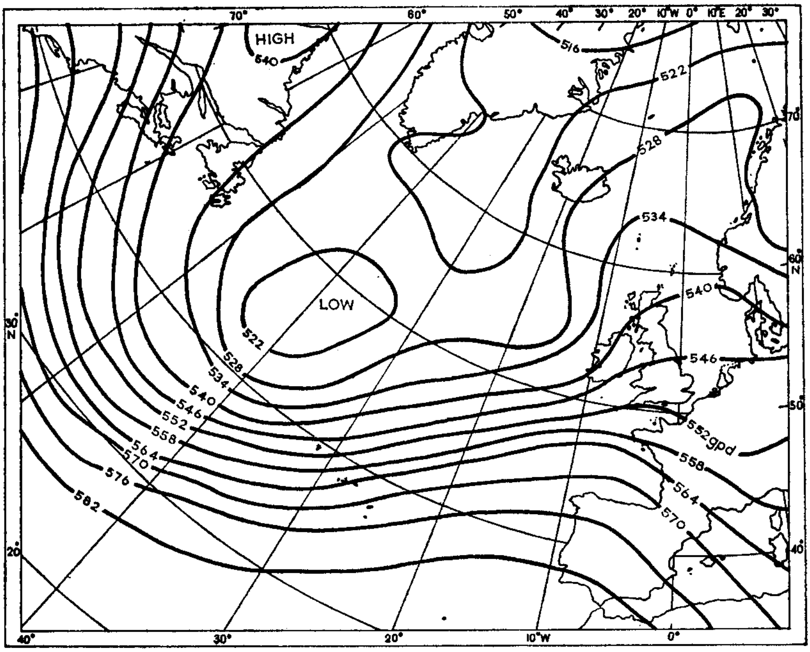


FIGURE 4—A TYPICAL 500 MB PATTERN ASSOCIATED WITH A WET SPELL IN SOUTH-EAST ENGLAND, 10 DECEMBER 1961

order of 1000 nautical miles long and the greater part of its length should be west of 10°W. Although most of these jets are fairly straight, many are slightly cyclonically curved and some may be preceded by a diffluent trough with London near the left exit of the jet stream; an anticyclonically curved jet stream or one with London on the right side of the core is rarely followed by a wet spell.

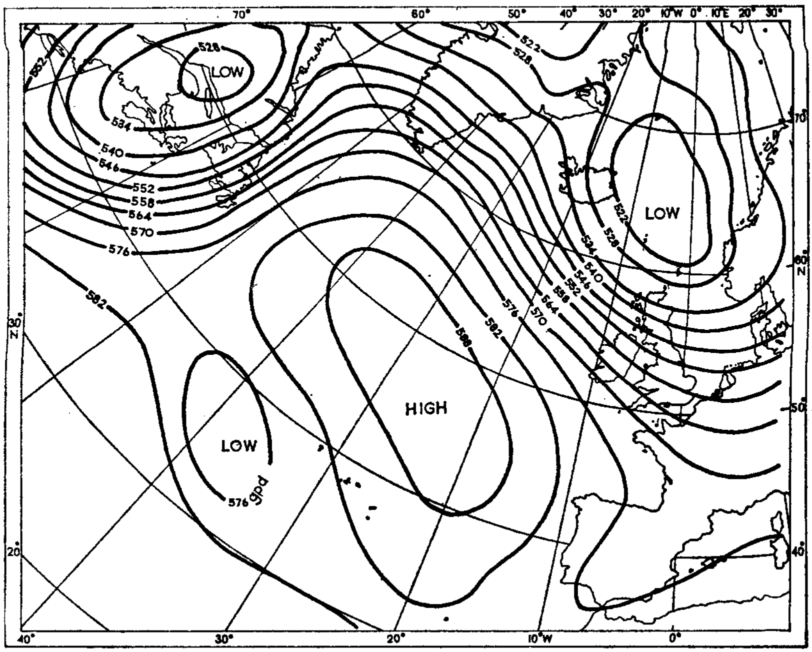
(iii) There should not be a 500 mb ridge over the British Isles.

(iv) There should not be a closed 500 mb vortex over the Iberian peninsula.

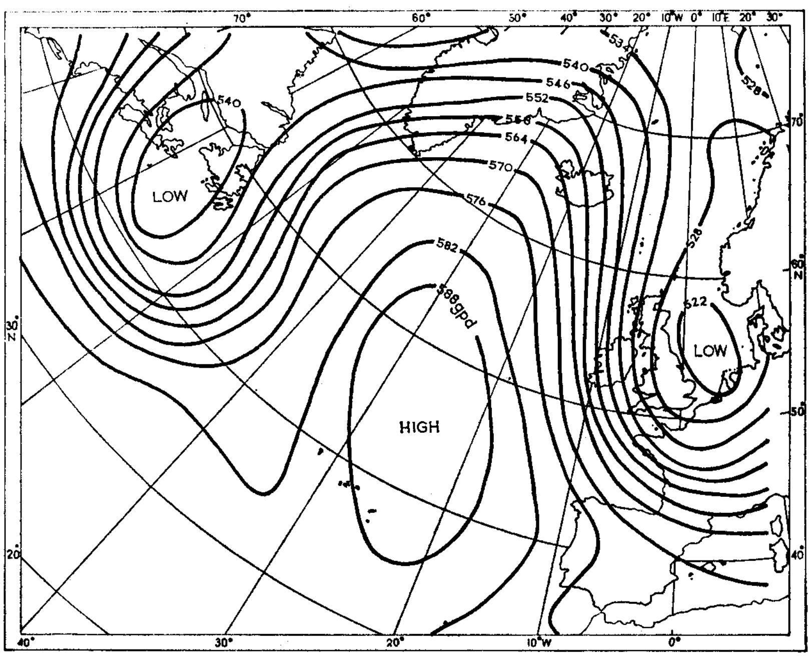
In practice the jet stream type of wet spell may be divided into three fairly well-defined sub-divisions, but wet spells can also occur with flow patterns intermediate in type between the three main types. Typical 500 mb charts illustrating the three most common types of pattern are shown at Figures 4–6.

The features of the three main types are as follows:

(i) A north-westerly jet lies from south-east Greenland to Ocean Weather Station I (59°N, 19°W) to Ireland and south-west England (Figure 5*a*). The orientation of the jet may also be from north-north-west or north, in which case the jet should lie from east Iceland to west Scotland and thence to north-west France (Figure 5*b*).



(a) 17 October 1961



(b) 18 October 1961

FIGURE 5—A TYPICAL 500 MB PATTERN ASSOCIATED WITH A WET SPELL IN SOUTH-EAST ENGLAND

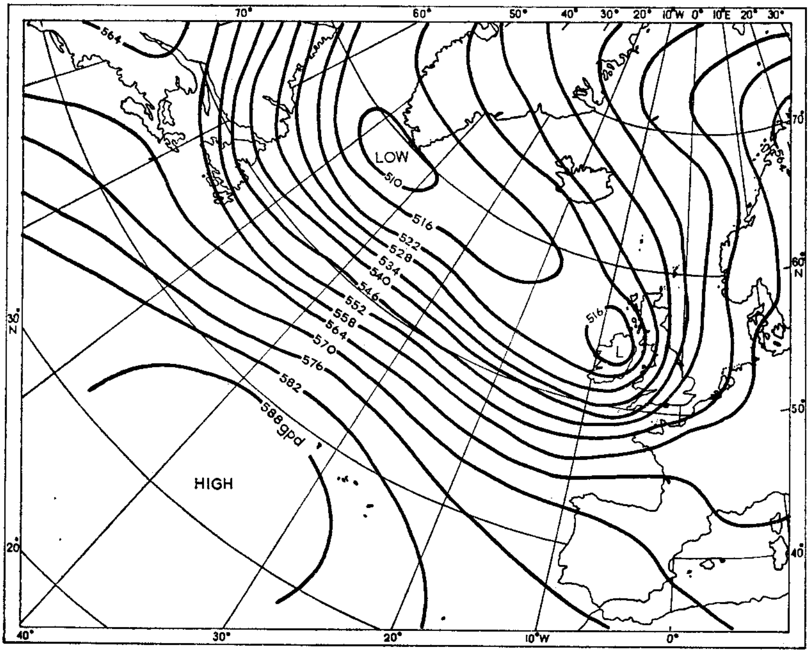


FIGURE 6—A TYPICAL 500 MB PATTERN ASSOCIATED WITH A WET SPELL IN SOUTH-EAST ENGLAND, 23 OCTOBER 1961

(ii) The core of the strongest winds lies close to Ocean Weather Stations C (53°N 35°W) and J (53°N 20°W) and thence towards south-west England. In this case the direction of the jet is approximately from west to a little north of west (Figure 6).

(iii) A south-westerly jet lies from the Azores to near Ocean Weather Station K (45°N 16°W) then to the western English Channel (Figure 4).

Normally when any of the above three types of 500 mb flow exist a wet spell is about to begin or has already begun, but exceptionally the spell may not commence for another day. Some examples of main pattern variations which were followed by wet spells are shown in Figures 7–9. Table I gives a summary of the results obtained on test against independent data.

TABLE I—THE NUMBER OF WET SPELLS IN SOUTH-EAST ENGLAND 1961–65 AND THE NUMBER FORECAST BY THE CRITERIA

Year	1961	1962	1963	1964	1965	All years
Number of wet spells	19	18	17	20	19	93
Number forecast by the criteria	14	11	12	11	14	62

Although the criteria have been developed empirically, it is clear that they have some dynamical basis. The left side of a jet stream is clearly an area in which cyclonic shear is large and if the contours are cyclonically

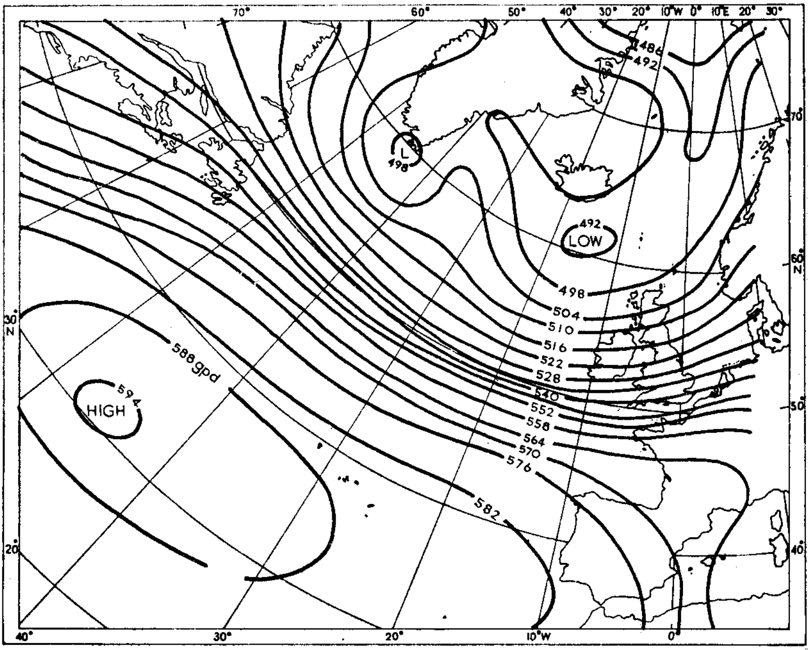


FIGURE 7—EXAMPLE OF A MAIN PATTERN VARIATION AT 500 MB GIVING A WET SPELL, 17 JANUARY 1965

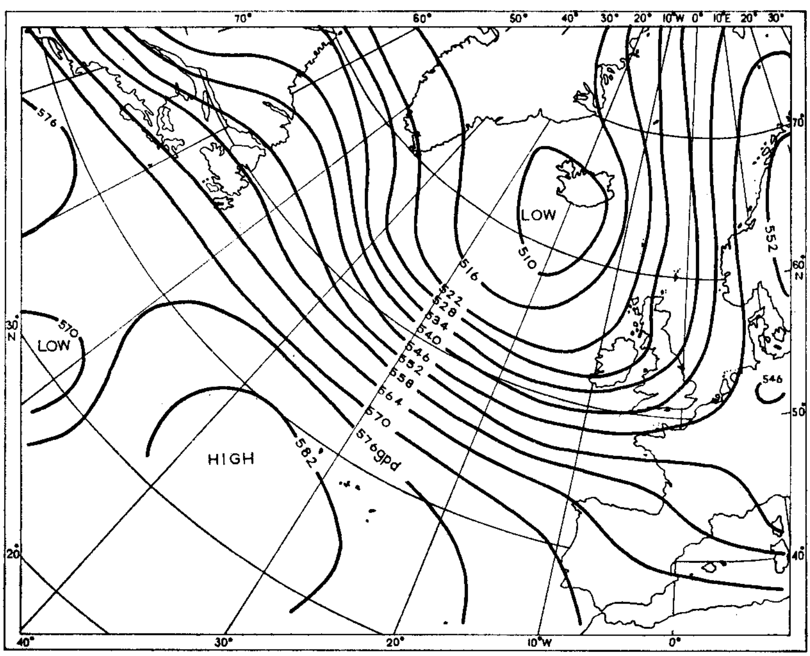


FIGURE 8—EXAMPLE OF A MAIN PATTERN VARIATION AT 500 MB GIVING A WET SPELL, 8 NOVEMBER 1961

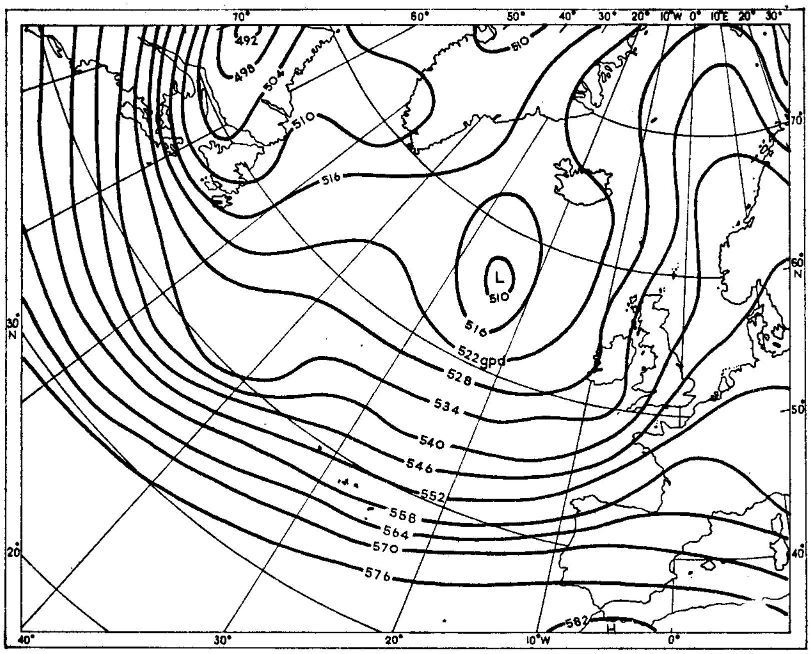


FIGURE 9—EXAMPLE OF A MAIN PATTERN VARIATION AT 500 MB GIVING A WET SPELL, 16 MARCH 1963

curved there will be an added contribution to cyclonic vorticity in the area. In addition the area of diffluence at the left exit of a jet stream is a very favourable position for cyclonic development as described by Sutcliffe and Forsdyke.[4] Normally a jet stream propagates itself forwards in a direction parallel to its length so that in the types described south-east England is likely to stay in the cyclonic development area for some considerable time.

Comments on the criteria.

(*a*) The restriction that there should not be a 500 mb vortex over the Iberian peninsula is necessary. Such a vortex is rarely associated with a wet spell even if the jet position is favourable. The reason for this lies in the fact that there is, necessarily, a persistent surface ridge north of a cut-off vortex and if the latter is over Iberia the ridge is very liable to cover south-east England with the jet moving a little northwards.

(*b*) The requirement of no 500 mb ridge over the British Isles applies mainly when the jet is south-westerly; in this case a small backing of the wind direction in the jet can lead to building of the upper ridge and no wet spell.

(*c*) Particular care is required in assessing the wet spell criteria if there is a 500 mb trough in the west Atlantic between 50°W and 60°W and between 45°N and 50°N. Such a trough is one of the pre-conditions for a Lowndes fine spell.[5] If such a trough is not well developed and there is a further trough within 40° longitude upwind of it over America, which would tend to cause the trough between 50°W and 60°W to weaken, then a wet spell may safely be forecast if the jet conditions are satisfied. On the other hand the trough between 50°W and 60°W may be well developed if the flow downstream from it is markedly meridional as in Figure 5*b*. On this occasion zonal flow at 50°N is weak enough for the wavelength to be close to the stationary value. Nevertheless, whenever there is a trough between 50°W and 60°W the forecaster must be on guard against the occurrence of a backing flow over the east Atlantic leading to ridge development over Britain. Figure 10 shows an example of a pattern with a trough between 50°W and 60°W which preceded a wet spell, while Figure 11 is an example of a rather similar pattern when a wet spell did not follow.

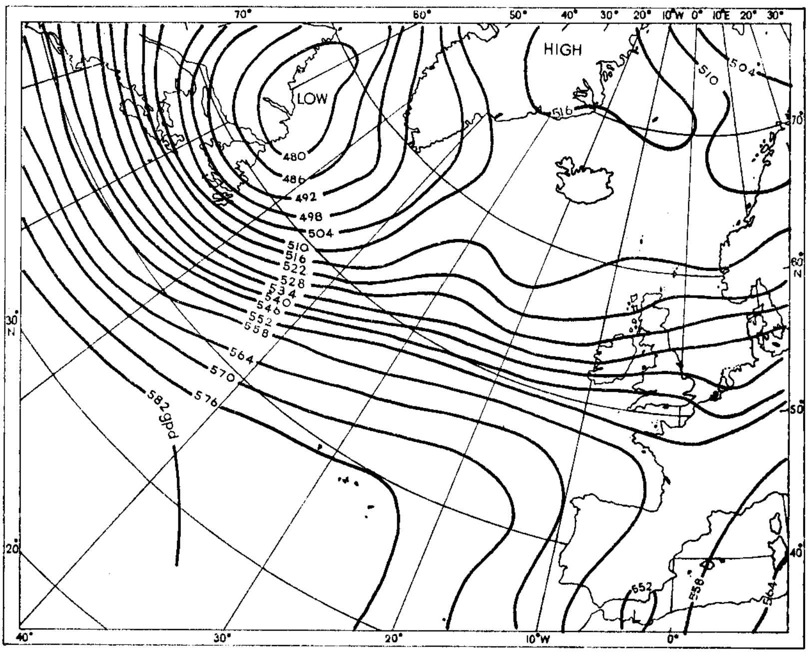


FIGURE 10—EXAMPLE OF A 500 MB TROUGH BETWEEN 50°W AND 60°W WHICH PRECEDED A WET SPELL, 19 JANUARY 1962

Additional tests of the criteria. It has been demonstrated that it is possible to forecast about 60 per cent of wet spells occurring in south-east England by the criteria which have been developed. It is necessary also to show that the number of occasions when the criteria are satisfied and no wet spell follows is few. With this object in view all occasions when the rules were satisfied in the years 1961–65 inclusive were examined and tested to see whether or not they were followed by wet spells. Results are shown in Table II.

TABLE II—ANALYSIS OF FORECASTS OF WET SPELLS 1961–65

Year	Number of days on which criteria are satisfied			Comments on failures
	With success*	Near misses†	With failure	
1961	35	6	1	12 June—weak 500 mb flow
1962	16	10	1	10 Aug. — westerly jet with London perhaps a little on the right of the jet
1963	33	4	2	14 May — trough at 55°W, another at 95°W. 9 Sept. — some rain on two following days.
1964	21	6	3	4 May — trough at 60°W 23 Oct. — only one wet day 7 June — only one wet day
1965	32	4	4	19 Apr. — followed by 3 days with rain but insufficient. 18 June — began a 2-day break between spells. 19 Dec. — began a 2-day break between spells. 24 June — only one wet day
Totals	137	30	11	

*Criteria were applied to the 0000 GMT chart for all days and were deemed to be satisfied with success if followed within 1 day by a spell as defined in the text.

†A near miss was defined as an occasion followed by 2 wet days, perhaps with rain on the 3rd day but insufficient to classify it as a wet day.

The rather large number of occasions of 'near misses' arises partly because of the definition of a wet spell which has been adopted. On the majority of these occasions there was rain on each of the 3 following days but on one of the days the amount summed over the seven stations amounted to less than 7 mm.

As an example of a near miss one may quote 14 March 1964 which was a day when the criteria were satisfied. On 14 and 15 March that year over 279 mm of rain fell at the seven stations representing south-east England but on the 16th less than the required amount fell so that the three days as a whole did not qualify as a wet spell. Many cases of this type are included in the near misses in Table II and therefore this category is not regarded as seriously in error.

In order to give a guide as to how much rain to expect in the three days following the day on which the wet spell rules were satisfied, Figure 12 has been produced. In preparing this figure all cases (137) when the rules were satisfied in the years 1961–65 were included whether they were classified in Table II as successes, near misses or failures, 90 per cent of occasions were followed by more than 3 mm of rain while 77 per cent were followed by more than 6 mm of rain in south-east England. The average daily amount of rain in the first three days of a forecast wet spell was 3·5 mm; if on the other hand only the successful occasions were included then the average daily rainfall was 3·8 mm which compares with the 4·1 mm quoted earlier as the average daily rainfall during wet spells. If one considers the average daily rainfall for the cases of near misses and failures this still comes out at 2·4 mm per day, over twice the amount required to qualify for a 'wet' day.

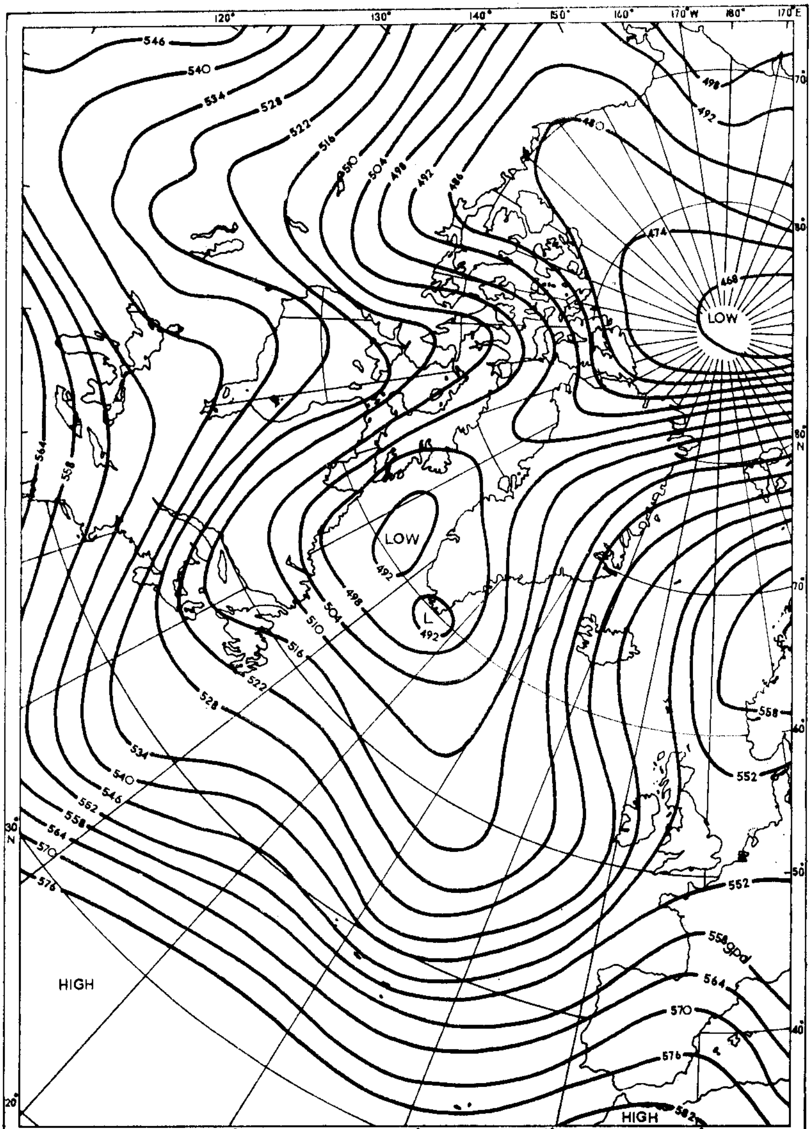


FIGURE 11—EXAMPLE SIMILAR TO FIGURE 10 WHEN A WET SPELL DID NOT FOLLOW, 14 MARCH 1964

Conclusions. It is shown that it is possible to forecast more than half of the wet spells which occur in south-east England by considering the 500 mb flow patterns over the Atlantic.

In general, if the core or left side of a long and fairly straight or cyclonically curved jet stream at 500 mb comes within 100 nautical miles of London with certain restrictive conditions, a wet spell can be forecast to follow in south-east England with a fair amount of confidence.

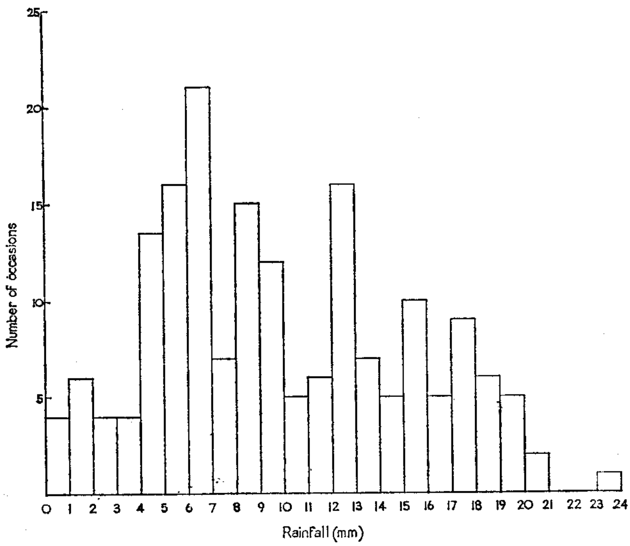


FIGURE 12—AVERAGE TOTAL RAINFALL PER STATION IN THE THREE DAYS FOLLOWING THE FORECAST

Acknowledgement. The authors are grateful to Mr H. Robertson for extraction and tabulation of rainfall data.

REFERENCES

1. LOWNDES, C. A. S.; Forecasting wet spells at London. *Met. Mag., London*, **91**, 1962, p. 284.
2. RATCLIFFE, R. A. S.; New criteria concerning fine spells in south-east England during the period May to October. *Met. Mag., London*, **94**, 1965, p. 129.
3. BENWELL, G. R. R.; The jet stream at 500 mb as a predictor of heavy rain. *Met. Mag., London*, **96**, 1967, p. 4.
4. SUTCLIFFE, R. C. and FORSDYKE, A. G.; The theory and use of upper air thickness patterns in forecasting. *Q. Jnl R. met. Soc. London*, **76**, 1950, p. 189.
5. LOWNDES, C. A. S.; Forecasting dry spells of three days or more in south-east England from May to October: a revised model. *Met. Mag., London*, **94**, 1965, p. 241.

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SAMPLING ERRORS IN MEASUREMENTS OF PARTICLE SIZE DISTRIBUTIONS

By S. G. CORNFORD

Summary. The concentration of each particle size in an aerosol must be measured more accurately when the particle size distribution is measured for its own sake than when the distribution is to be integrated to find the total mass of material in unit volume, the total precipitation rate and so on. The numbers of particles which must be counted to achieve specified high levels of accuracy are calculated and the results are applied to the design of airborne instruments for measuring cloud droplet, raindrop and ice particle size distributions.

Introduction. In a previous article[1] the author discussed the accuracy of concentrations of drops or particles measured by airborne impaction techniques, with particular reference to the measurement of rainfall rates.

It was found, for example, that if 23 drops were sampled the measured concentration would be within 50 per cent of the true value on 95 per cent of occasions. Such limited accuracy may be acceptable when measuring rainfall rates and other quantities involving an integrated spectrum because the sampling errors in neighbouring size ranges tend to cancel. It is not acceptable when a measurement of the relative concentration of different sizes, i.e. the size distribution spectrum, is required because the interest then is in the relatively small difference between the large concentrations in neighbouring size ranges. To determine the larger numbers which must be sampled if this interest in higher accuracies is to be satisfied, the calculations made in the previous paper have been extended. The calculations are equivalent to finding the confidence limits for the expectation of a Poisson variable, when the variable is in the range 50 – 10 000.

Method. The basis of the calculations was discussed in the previous paper and will not be repeated. Although for more accurate work the number of particles sampled is large, the probability of a single event (the arrival of a particle of a specific size on a given element of the sampling surface) remains small and the Poissonian approach remains valid.*

The probability, $\Pi\ (i,\ m)$ of sampling i particles when the mean is m is

$$\Pi\ (i,\ m) = \frac{e^{-m} m^i}{i\,!}\ .$$

For large values of i,

$$i! = i^i\, e^{-i}\ (2\pi i)^{\frac{1}{2}}$$

by Stirling's Theorem. Therefore the probability, $\Pi\ (k,\ k(1-\varepsilon) \rightarrow k(1+\varepsilon)\ )$, that when k particles are found in a sample, m lies within $\pm\ \varepsilon k$ of k is

$$\Pi\,(k,\ k(1-\varepsilon) \rightarrow k(1+\varepsilon)\ ) = (2\pi k)^{-\frac{1}{2}} \int_{k(1-\varepsilon)}^{k(1+\varepsilon)} \left(\frac{m}{k}\right)^k \exp\,(k-m)\mathrm{d}m \qquad \ldots\ (1)$$

For brevity the probability on the left-hand side of equation 1 will be written as f. The integration to give f has been carried out numerically using a step size of one for m. Thus the calculated value of f is

$$\sum_{m_1}^{m_2} (2\,\pi k)^{-\frac{1}{2}} \left(\frac{m}{k}\right)^k \exp(k-m)$$

where m_1 and m_2 are the integral parts of $k\ (1-\varepsilon)$ and $k\ (1+\varepsilon)$. In this way f has been calculated for a range of values of ε for values of k ranging from 50 to 10 000. The results are plotted in Figure 1. Isopleths of k are drawn on arithmetical probability paper with axes ε and f. For the smaller numbers the curves represent some very slight smoothing of the results. This is because the curves, while drawn continuously as this is convenient for practical use, represent an essentially digital computation.

* For large mean numbers, m, the Poisson distribution of sampled numbers, i, approximates to a normal distribution with standard deviation $m^{\frac{1}{2}}$. The use of this approximation does not however simplify the present calculations.

Accuracy required. The accuracy with which concentrations of particles in given size ranges must be measured in order to obtain a reliable measurement of the size distribution spectrum depends on the steepness of the spectrum and the width of the individual size ranges. It will vary from spectrum to spectrum and with the accuracy with which particle size can be measured. The following examples illustrate the reasoning involved in selecting a suitable accuracy.

In rain it is normally possible to grade the drops into $\frac{1}{4}$-mm wide ranges of diameter. The steepness of the spectrum is often (e.g. Cornford,[1] Mason and Andrews[2]) such that concentrations in adjacent size ranges differ by about 30 per cent so for them to be distinguished each concentration must be measured to within about $\pm$ 10 per cent ($\varepsilon = 0{\cdot}1$). We may see from Figure 1 that to achieve this on 95 per cent of occasions (f= 95 per cent) the sample must contain between 300 and 500 drops. Calculation shows the number to be 375. Figure 1 also shows that for the concentration to be within $\pm$ 5 per cent of the true value ($\varepsilon = 0.05$) on 95 per cent of occasions (f= 95 per cent) the sample must contain about 1500 drops.

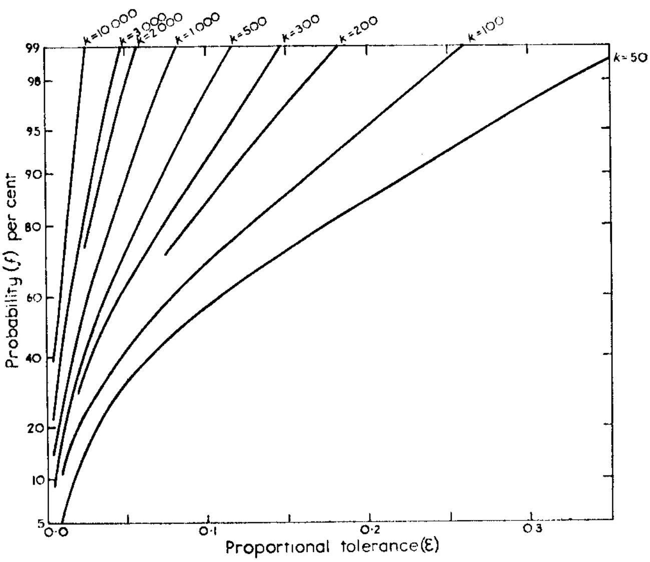

FIGURE 1—PROBABILITY, f, OF THE TRUE MEAN CATCH, m, BEING BETWEEN $k \pm \varepsilon k$

Each isopleth represents a catch of k particles, $50 \leqslant k \leqslant 10\,000$.

Airborne instruments. Airborne instruments designed with these criteria in mind are required for measuring cloud droplet, raindrop and ice-particle size distributions. For convenience all these particles will be referred to as drops. In the previous paper it was found that if concentrations are to be measured to within $\pm$ 50 per cent (on 95 per cent of occasions) at least 23 drops must be counted in the measured volume. In the last paragraph we found that for concentrations to be within $\pm$ 10 per cent and $\pm$ 5 per cent, at least 375 and 1500 drops, respectively, must be counted. In order to ensure that our instruments sample these many drops on most (say 95 per cent of) occasions we must arrange for the average sample taken by the instrument to contain rather more drops. For the $\pm$ 50 per cent case this was previously found to be a total of 33 drops. For the $\pm$ 10 and $\pm$ 5 per cent cases, we must find the number m' such that only 5 per cent of samples would contain less than 375 drops and 1500 drops. Calculation* shows that the increase in the number of drops to be caught is relatively small at this level of sampling accuracy and, in view of the variety of conditions in which instruments are used, it is clear that little is lost if m is used instead of m'.

Table II of the previous paper gave the dimensions of sampling surfaces which would on average collect 33 drops from the volume (of cloud and precipitation with typical drop concentrations) swept out by a thin ribbon exposed at right angles to the air stream and moving forward a distance equal to its own length. This shape of sampled volume gives the finest resolution of horizontal changes of concentration which are consistent with the instrument's being narrow enough to have a high collection efficiency. Table I of this paper gives the corresponding, easily calculated figures for the two higher sampling accuracies now considered. As was to be expected from the previous results, ideal collectors for cloud droplets have optimum dimensions and exposure times which are practical, whereas the optimum dimensions for an instrument for measuring raindrop size distributions are quite unpractical. The greatest practical length of a sampling aperture is of the order of one metre. The distances in part (*c*) of Table I represent, for several drop concentrations and the $\pm$ 10 and $\pm$ 5 per cent levels of accuracy, the finest resolution obtainable in straight and level flight with an

TABLE I—SPATIAL RESOLUTION OBTAINABLE BY AIRBORNE INSTRUMENTS FOR MEASURING DROP SIZE DISTRIBUTIONS ASSUMING INSTRUMENTS MOVE AT ABOUT 75 M/S

	Average drop concentration	Resolution with $\varepsilon=0.1$	Resolution with $\varepsilon=0.05$
	cm^{-3}	*cm*	*cm*
(*a*) Aperture for cloud droplet sampling, width 0·5 cm, length equal to the scale of resolution	10^3	0·9	1·8
	10^2	2·9	5·6
	10	9	18
	1	29	56
	m^{-3}	*m*	*m*
(*b*) Aperture for raindrop sampling, width 2·5 cm, length equal to the scale of resolution	10^3	4	7·9
	10^2	13	25
	10	40	79
	1	130	250
	m^{-3}	*km*	*km*
(*c*) Aperture for raindrop sampling, width 2·5 cm, length 1 m.	10^3	0·016	0·063
	10^2	0·16	0·63
	10	1·6	6·3
	1	16	63

* Since m' is large, i is distributed normally about m', with standard deviation $(m')^{\frac{1}{2}}$. Tables of the normal probability function[3,4] show that 95 per cent of the possible values of i exceed $m' - 1.645\ (m')^{\frac{1}{2}}$. For $i=375$, $m'=408$. For $i=1500$, $m'=1565$. These figures may also conveniently be found from Figure 1. The method is one of successive approximations, although in most cases the first trial can hardly be improved upon. Five per cent of samples contain less than $m' - \varepsilon m'$ drops, therefore 10 per cent lie outside $m' \pm \varepsilon m'$. Enter Figure 1 at $f=90$ per cent. We know $m'>375$. As a first approximation suppose it is 400. At the intersection with the interpolated isopleth for 400 drops, $\varepsilon \simeq 0.08$ so that $\varepsilon m' \simeq 32$ and $m' \simeq 375+32$. For the second approximation use the isopleth for 407 drops and so on.

instrument of this length. In the previous paper it was shown that in typical cases the main downward flux of water is achieved by those sizes of drops which, in a ¼-mm range of diameter, have concentrations of between 10 and 100 per cubic metre. We see from part (*c*) of Table I that the concentration of these 'main stream' drop sizes can be resolved on a scale of about one kilometre. The distribution of the rare (say, $<1\ m^{-3}$) large drops, however, can never be realistically measured by airborne instruments using an aperture. Although this end of the raindrop size distribution spectrum in general contributes little to the rainfall, it is of interest in itself as it represents the upper limit of the growth processes. It is, however, of much less interest than the other end of the spectrum, which contains the multitudinous 'coalescent' drops. It is clear from part (*c*) of Table I that airborne instruments are potentially quite adequate for studies of the spatial distribution of the size spectrum of these coalescent drops and of their growth into main stream raindrops.

REFERENCES

1. CORNFORD, S. G.; Sampling errors in measurements of raindrop and cloud droplet concentrations. *Met. Mag., London*, **96**, 1967, p. 271.
2. MASON, B. J. and ANDREWS, J. B.; Drop-size distributions from various types of rain. *Q. Jnl R. met. Soc., London*, **86**, 1960, p. 346.
3. BROOKES, B. C. and DICK, W. F. L.; Introduction to statistical method. London, William Heinemann, 1951, p. 132.
4. PEARSON, E. S. and HARTLEY, H. O.; Biometrika tables for statisticians, Vol. 1, 3rd Edn. Cambridge University Press, 1966, p. 112.

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A MODIFIED CAMPBELL-STOKES SUNSHINE RECORDER

By B. G. COLLINS*

Summary. A modified sunshine recorder integrates electrically the total daily sunshine duration and provides a consistent record not subject to errors in observer evaluation or by overburn.

Introduction. The Campbell-Stokes sunshine recorder, has, since its invention by Campbell in 1853 and modification to its present form by Stokes in 1879, become the most widely used instrument for recording daily duration of sunshine. Evaluation of the record cards, is, however, not straightforward and can become almost as much an exercise in subjective appraisal as in precise measurement. For example in the case of weak sunshine giving only a faint scorch on the card it is recommended[1] that the trace should be measured 'as far as it can fairly be seen'. Appreciable differences can thus arise between the values assigned to any one trace by different observers. Errors are also particularly likely to occur during strong but intermittent sunshine, as there will be extension of the burns due to the finite diameter of the sun's image on the record card. This 'overburning' results in a trace very nearly as long for a few seconds of bright sunshine as for two or three minutes. According to Bider[2] comparisons between a Campbell-Stokes and a Maurer heliochronograph over a period of eight years at Basle, Switzerland showed that,

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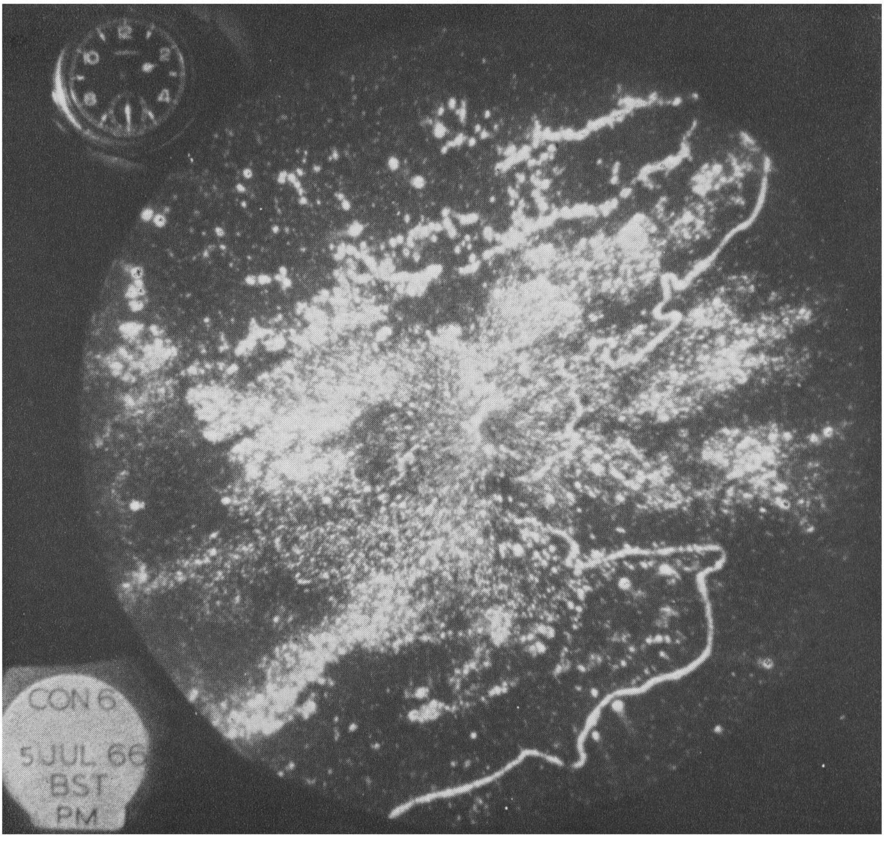
To face page 16



Photograph by courtesy of Marconi Research Laboratory

PLATE I(*a*)—RADAR DISPLAY AT 1330 GMT ON 5 JULY 1966

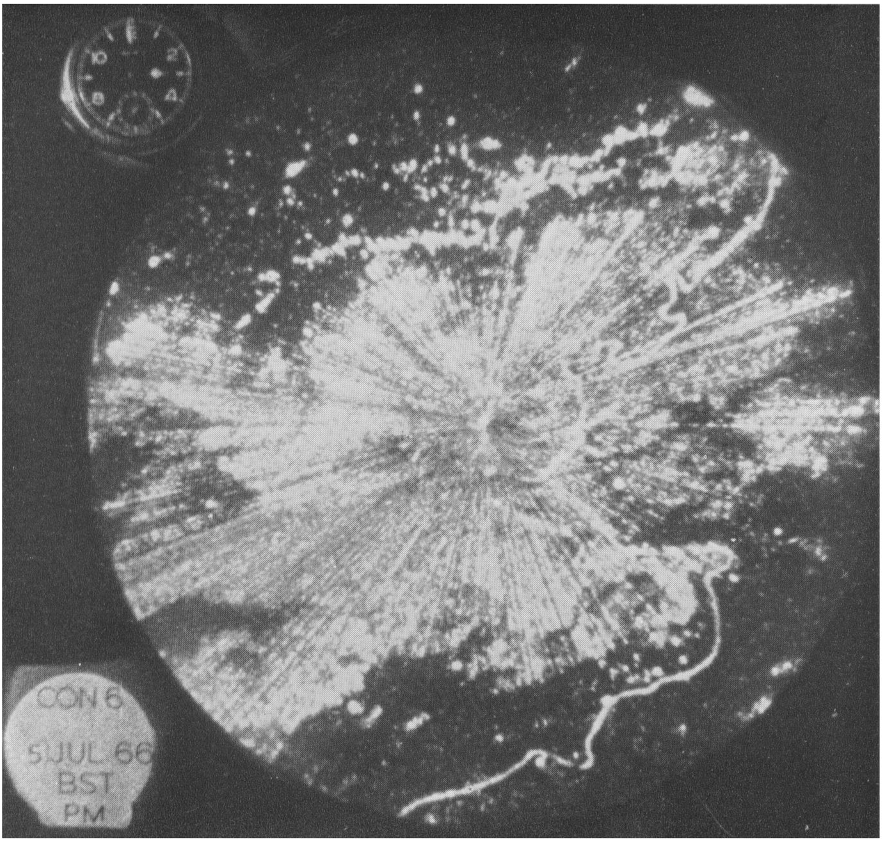


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PLATE 1(*b*)—RADAR DISPLAY AT 1400 GMT ON 5 JULY 1966

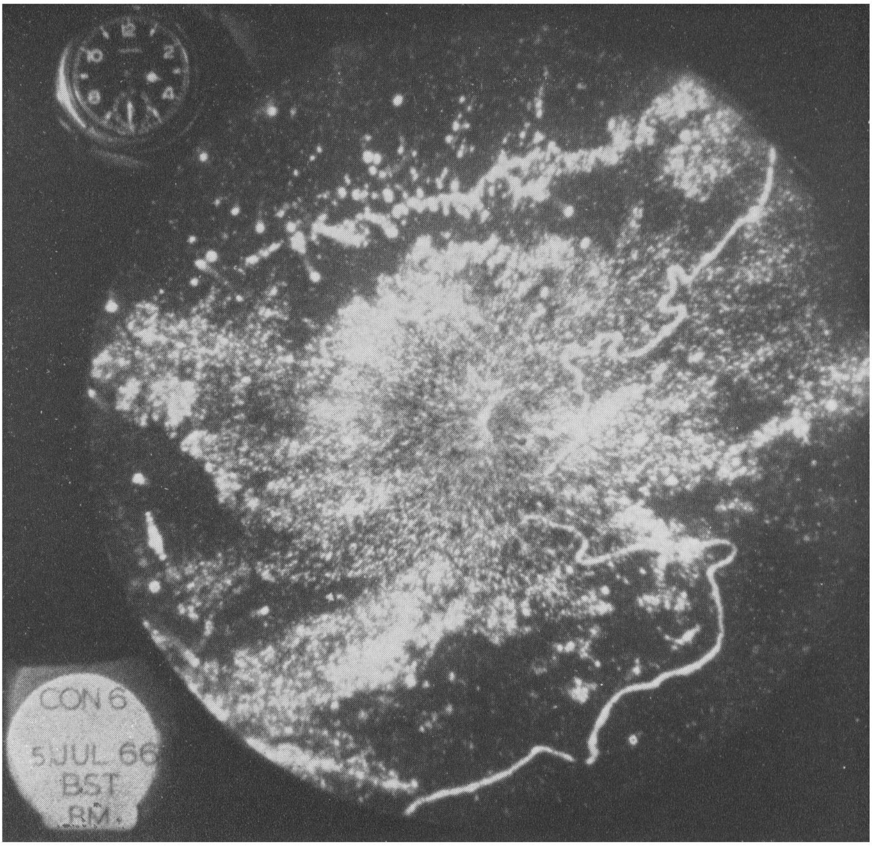

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PLATE I(*c*)—RADAR DISPLAY AT 1430 GMT ON 5 JULY 1966

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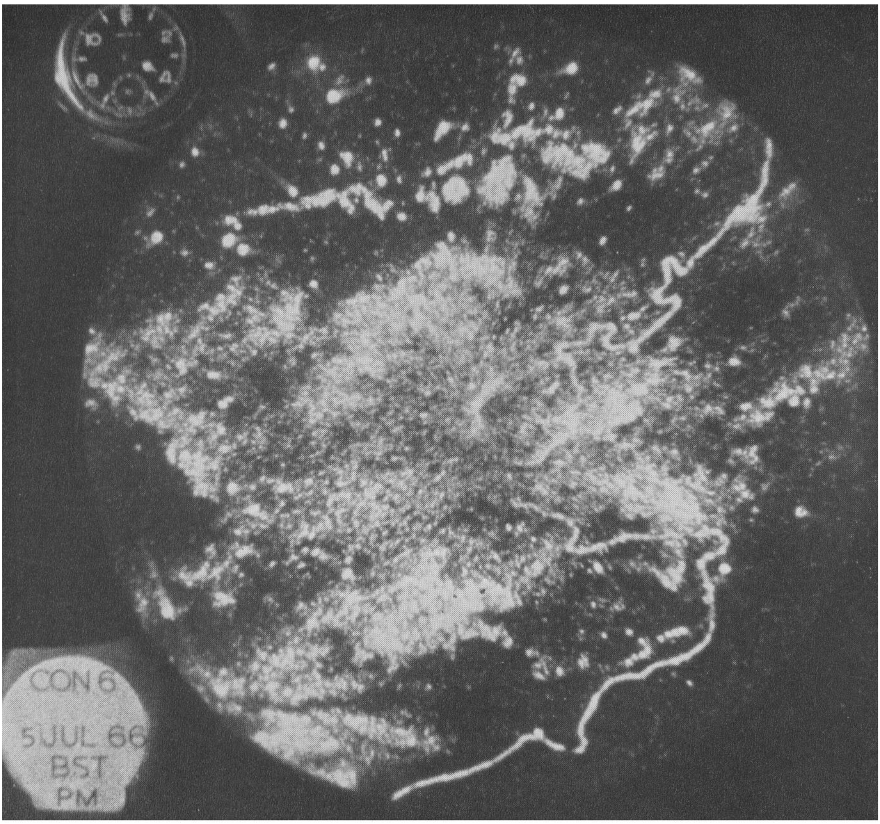

Photograph by courtesy of Marconi Research Laboratory

PLATE I(*d*)—RADAR DISPLAY AT 1500 GMT ON 5 JULY 1966 on an average, 117 hours per year were incorrectly shown by the Campbell-Stokes as having unbroken sunshine. This is an excess of 12·3 per cent. More or less complex ways of correcting the records have been described, e.g. by Robinson[3], but it is doubtful whether these are strictly applied in all daily routine observations. The instrument now described integrates the total duration of sunshine electrically, and thus eliminates errors in assessing the chart, and errors due to overburn.

Description of the modified instrument. An electrical method of detecting the focused image of the sun is used instead of burning a track on a special card, as in the standard Campbell-Stokes recorder. The frame which holds the glass sphere is replaced by a differently shaped mounting carrying a semi-circular thermopile, on which the sun's image is focused. It is made by winding 32-s.w.g. constantan wire on to a 0·5-cm square former of PTFE (polyteterafluoroethylene) which is sufficiently flexible to take up the desired curvature, and which will withstand the temperatures involved. Half of the constantan winding is stopped off by a wax or stopping-off lacquer, and copper is electrolytically deposited on the other half so that copper/constantan thermojunctions are formed in series connexion (Figure 1). The PTFE rod is located in a slot milled in an aluminium mounting with one set of junctions in good thermal contact with it, but electrically insulated from it by a thin mylar film. The other set of junctions is exposed so that when the sun shines, its focused image falls on them. A mica shield 0·5 cm. in front of the exposed junctions protects them from wind and precipitation. The transmissivity of the mica is not critical, as the threshold of the instrument is adjustable electrically. The framework of the instrument is made so that the glass sphere can be aligned with its axis parallel to the earth's axis in the normal way and an engraved latitude scale is provided. The framework has a slot along which the thermopile mounting may be moved to accommodate the seasonal change in solar elevation, and a series of parallel lines is engraved on the frame to assist in keeping the plane of the thermopile strip at right angles to the axis of the sphere when this adjustment is made (normally at intervals of a few days). The shape of the slot is such that the mid-point of the thermopile strip remains at the focal distance from the sphere.

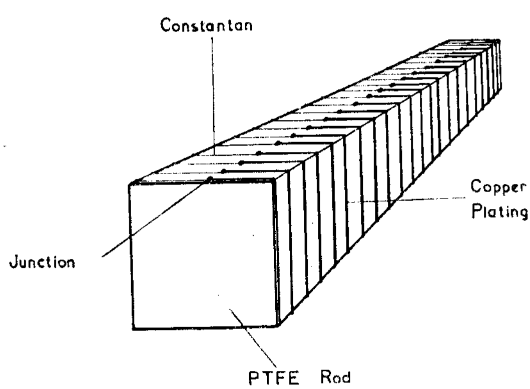

FIGURE 1—CONSTRUCTION OF THE THERMOPILE

Its outer ends will not be at exactly this distance throughout the year since it has a fixed curvature but it is arranged so that the focus is correct mid-way between the equinox and the solstice, thus minimizing the small amount of defocusing which occurs.

Recording circuit. The output of the thermopile is about 7·5 mV at a radiation intensity equal to the mean threshold value for the Campbell-Stokes. Its resistance is 200 ohms. The current generated is fed to one winding of a sensitive double-wound moving coil relay (A/1), the second winding of which is energized by the current from a 1·35-volt mercury cell. A series rheostat controls this current so that the relay contact will close when the intensity of direct beam solar radiation exceeds the selected threshold value. In the particular instrument described a current of 0·4 mA was required, which is small enough to ensure almost shelf life for the mercury cell. An indicating milliammeter is fitted to monitor the constancy of this current (Figure 2).

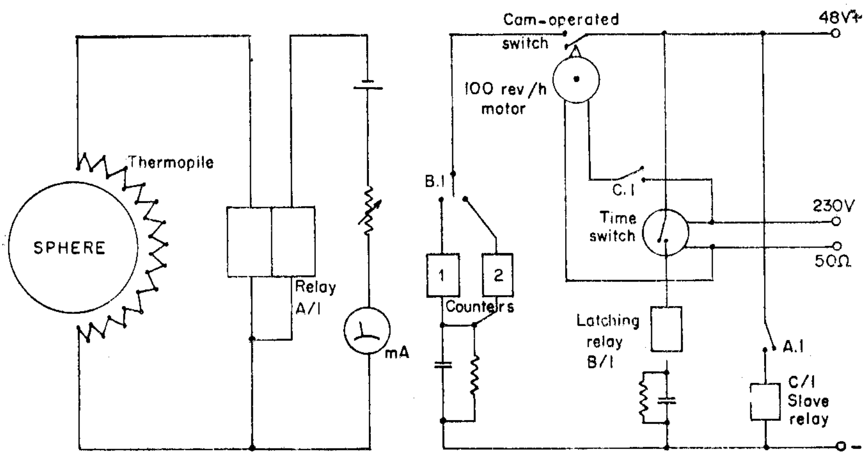

FIGURE 2—ELECTRICAL CIRCUIT OF THE MODIFIED SUNSHINE RECORDER

A synchronous motor with a cam operating a micro-switch generates 100 pulses an hour from a 48-volts d.c. supply. It is switched on and off by the moving coil relay (A/1), driving a slave relay (C/1), thus feeding pulses to one of the two electro-mechanical counters which are brought into circuit alternately by a switch system (B/1) operated on successive days by a 24-hour time switch (Figure 2). Thus if the sun is shining continuously 100 counts are recorded per hour, and if it is not shining at all, no counts are registered. This arrangement gives continuous integration of the duration of sunshine, and at the end of the day the appropriate counter registers the total to the nearest hundredth of an hour.

The changeover from one counter to the other takes place between sunset and sunrise, so that the day's reading can be taken off and the counter reset to zero at any time on the following day.

Results. Some results obtained at Aspendale during July 1967 are shown in Table I.

TABLE I—COMPARISONS OF RECORDED DURATION OF SUNSHINE USING THE STANDARD AND MODIFIED INSTRUMENTS

Date	Cloud at 1200 h		Sunshine duration in hours	
July 1967	Oktas	Type	Campbell-Stokes instrument	Modified instrument
5	0	—	8·9	8·8
7	0	—	8·4	8·4
10	2	Cu	5·6	5·1
13	7	Cu, Sc	3·2	2·5
14	4	Cu	4·9	4·0

REFERENCES

1. London, Meteorological Office. Observer's handbook. London, HMSO, 1956, p. 123.
2. BIDER, M.; Über die Genauigkeit der Registrierungen des Sonnenscheinautographen Campbell-Stokes. *Arch. Met. Geophys. Bioklim., Wien*, Serie B, **9**, 1959, p. 199.
3. ROBINSON, N.; Solar radiation. London, Elsevier Publishing Co., 1966.

551.553.11(412)

THE DIURNAL VARIATION OF THE SEA-BREEZE AT THREE STATIONS IN NORTH-EAST SCOTLAND

By D. S. GILL

Introduction. A log of days when, in the opinion of the forecaster, a sea-breeze had occurred at Kinloss has been kept at Kinloss since 1958. The criteria used in the selection of 'sea-breeze days' were that there should be an excess of land temperature over sea temperature at the onset of the sea-breeze and that the surface wind should be veered from the gradient wind or, occasionally, stronger than the gradient wind when the latter was light and variable or on shore. Some occasions were omitted because the surface wind exceeded 20 kt or the sea-breeze lasted for only a short period or because troughs of low pressure crossed the area.

The vector mean winds at each hour of the day for all 'sea-breeze days' in May between 1958 and 1962 were computed by hand at Kinloss in 1962. When plotted on a hodograph the distribution of the ends of the wind vectors was elliptical with a steady change of direction of the wind during the 24 hours. It was considered worth-while to continue logging 'sea-breeze days' so that the computation could be repeated for other months.

Data available. By 1966 hourly synoptic observations for Kinloss from 1959 to 1965, previously available only on punched cards, had been transferred to magnetic tape. A programme was written to enable the Meteorological Office computer COMET to extract the required data from the magnetic tape and obtain the vector mean winds, thus eliminating the tedious and lengthy process of hand computation. Accordingly, hourly vector mean winds were computed monthly for all 'sea-breeze days' occurring in the months March to October inclusive between 1959 and 1965. The month was chosen as the basis for the means because it was considered that the diurnal variation would remain reasonably constant over this period.

As an extension of the work, data for Wick and Aberdeen/Dyce were used to produce hourly vector mean winds on the days when a sea-breeze occurred at Kinloss, the assumption being made that these were also days when a sea-breeze occurred at Wick and Dyce. The validity of this assumption was tested by computing hourly vector mean winds for Wick and Dyce on days when no sea-breeze occurred at Kinloss. The ends of the mean wind vectors on these days were found to be distributed randomly round a point.

The relative positions of the stations used are shown in Figure 1.

FIGURE 1—NORTH-EAST SCOTLAND SHOWING STATIONS USED

Theory. A theoretical treatment of the diurnal variation of the sea-breeze has been given by Haurwitz.[1] The diurnal variations based on two different assumptions were derived as equations for components of the wind along and across the land–water boundary. Haurwitz argued that if friction was neglected the speed of the sea-breeze should continue to increase until the temperature difference causing it decreased to zero, but if the frictional force was allowed for there would be some critical value of the temperature difference at which the sea-breeze would start to decrease. His first assumption was that equilibrium existed between the Coriolis force, general pressure-gradient force, pressure-gradient force due to the land–sea temperature difference, and the frictional force. In that case, the ends of the wind vectors calculated from the equations lay on a straight line, i.e. the speed of the sea-breeze changed but not the direction.

He then took account of the fact that the air, owing to its inertia, was not in balanced motion and derived a second set of equations. When the wind vectors calculated from these equations were plotted on a hodograph their ends lay on an ellipse and moved round the ellipse in a clockwise direction with time. The eccentricity of the ellipse varied as the value of the frictional force in the equations was varied, being low when the frictional force was low.

Results. The results at Kinloss for sea-breeze days in August together with the orientation of the coastline are shown plotted on a hodograph in Figure 2. The points on the hodograph are the ends of the wind vectors for each hour plotted from the origin of the diagram towards the direction from which the wind blows and are labelled with the hour to which they apply. The orientation of the coastline near the station is shown, the origin of the diagram being the position of the meteorological office. The results are typical of those for the months April to September inclusive. The ends of the wind vectors are distributed approximately on an ellipse, the direction of the wind remaining almost unchanged during the night and early morning and veering gradually during the day, the speed reaching a maximum between 1300 and 1500 GMT. The only variation from April to September is in the time at which the sea-breeze starts and ends and in the speed and time of occurrence of the maximum wind, the times at which the sea-breeze starts and ends being taken as the times at which the wind vector is parallel to the coast line in the morning and evening respectively.

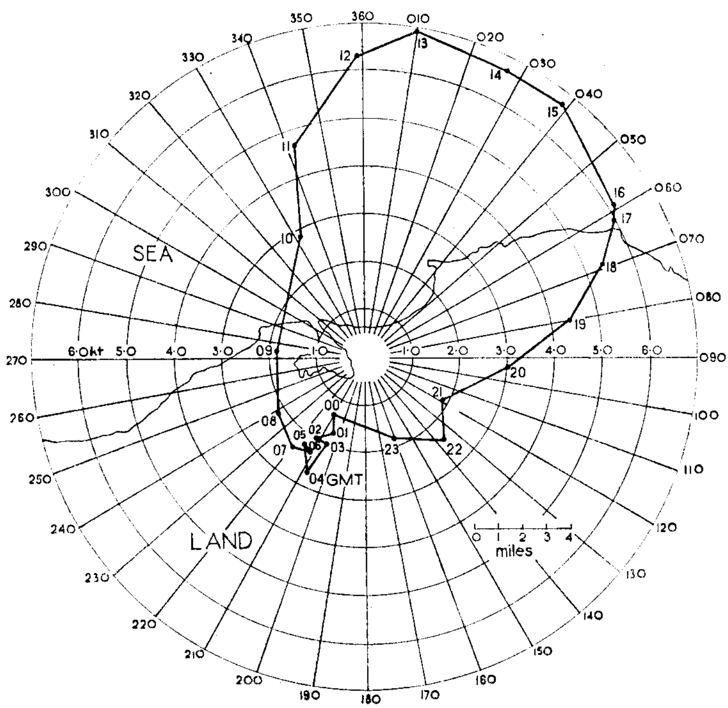

FIGURE 2—HOURLY VECTOR MEAN WINDS AT KINLOSS IN AUGUST BASED ON DATA FOR 40 SEA-BREEZE DAYS BETWEEN 1959 AND 1965

At either end of the sea-breeze season in March and October the winds are variable for a longer period than in the other months, the sea-breeze developing less gradually and for only a short period in the afternoon.

Using the definition of the times of start and end of the sea-breeze previously mentioned, these times can be calculated for each month of the sea-breeze season. Figure 3 shows the curves obtained when these times are plotted together with curves of the mid-month times of sunrise and sunset at Kinloss. There is almost constant difference between sunrise and the onset of the sea-breeze of 3–4 hours increasing to 6 hours in October and March, and between the end of the sea-breeze and sunset of 2–3 hours except for June when it increases to 4 hours.

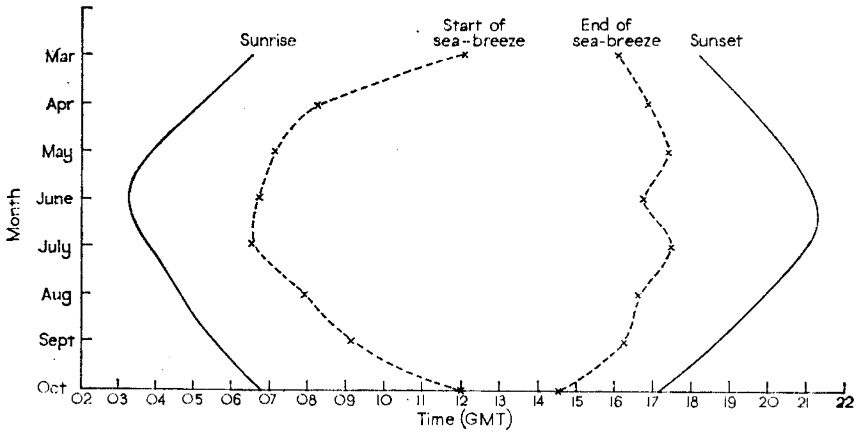

FIGURE 3—TIMES OF SUNRISE, SUNSET, START AND END OF SEA-BREEZE AT KINLOSS

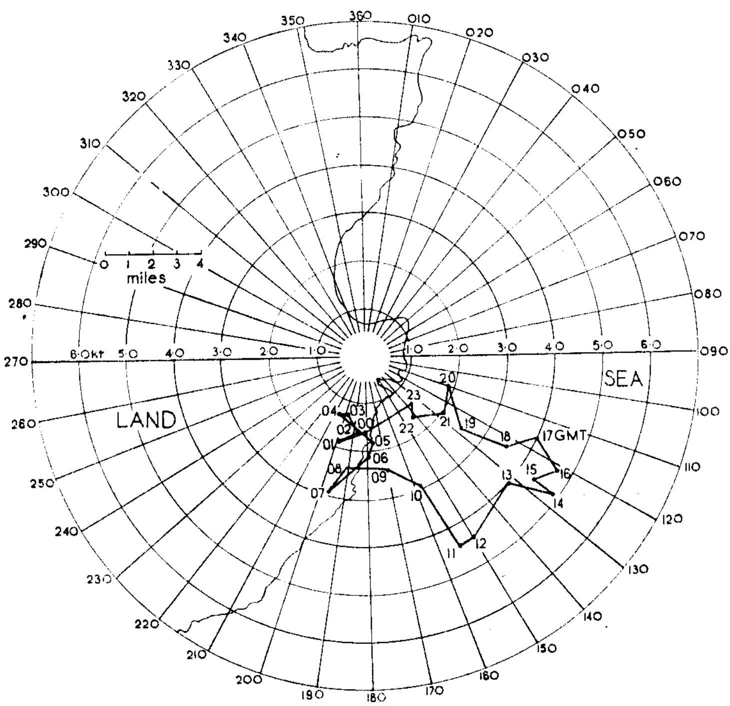

FIGURE 4—HOURLY VECTOR MEAN WINDS AT WICK IN AUGUST BASED ON DATA FOR 42 SEA-BREEZE DAYS BETWEEN 1958 AND 1964

Figure 4 shows the results at Wick for days when a sea-breeze occurred at Kinloss in August for the years 1958–64 inclusive. The ends of the wind vectors are again distributed approximately along an ellipse but in this case the ellipse has a higher eccentricity than that for Kinloss and the wind backs during the sea-breeze part of the day. The backing of the wind is not easily explained but the theoretical distribution was derived for a straight coast-line and it will be noted from Figures 1 and 4 that Wick is situated near the base of a promontory. The varying orientation of the coast line in the vicinity of the aerodrome may account for the departure of the actual wind distribution from the theoretical.

Figure 5 is a hodograph for Dyce using the same days as Figure 4. Only eight observations per day were available for Dyce so the vector mean winds for these hours only are plotted. The ellipse on which the ends of the mean wind vectors lie has a very high eccentricity and is almost a straight line. This is in accordance with the theoretical results since the intensity of the frictional force is presumably greater at Dyce where the winds are measured at a point 5 miles from the coast, compared with 1 mile at Kinloss, and the ground is rougher.

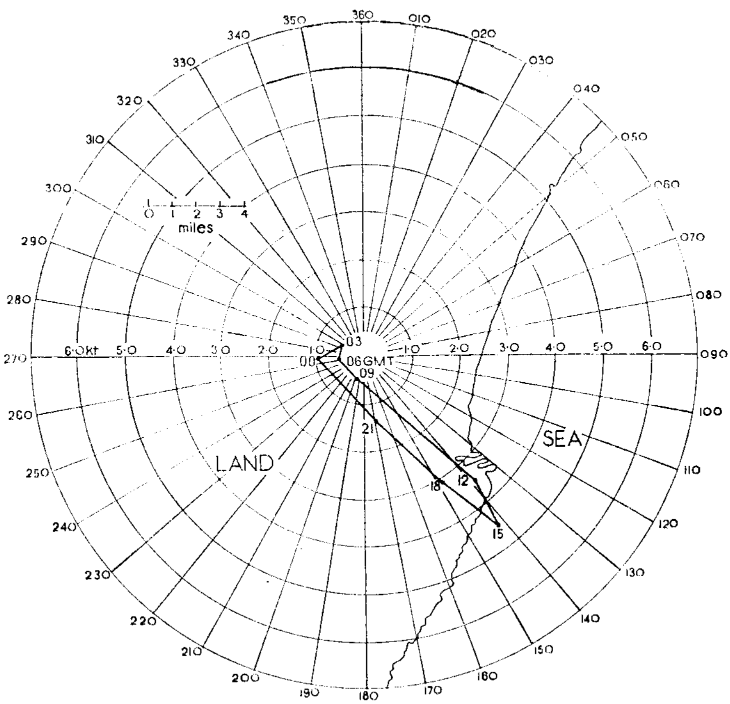

FIGURE 5—HOURLY VECTOR MEAN WINDS AT DYCE IN AUGUST BASED ON DATA FOR 42 SEA-BREEZE DAYS BETWEEN 1958 AND 1964

Conclusion. The results obtained show that at the three stations the location governs not only the direction from which the sea-breeze occurs but also the diurnal variation of the sea-breeze. At Kinloss the ends of the hourly wind vectors on sea-breeze days are distributed on an ellipse of low eccentricity and at Dyce on an ellipse of high eccentricity as would be expected from the theory. At Wick the distribution is elliptical but the rotation of the vectors is not in agreement with the theory, possibly due to the shape of the coastline near Wick.

REFERENCE

1. HAURWITZ, B.; Comments on the sea-breeze circulation. *Jnl Met., Lancaster, Pa.*, 1947, p. 1.

551.501.81:551.515.8:551.553.11

TWO CROSSING FRONTS ON RADAR

By G. C. RIDER* and J. E. SIMPSON†

Summary. Two parallel thin lines were observed on radar approaching each other; after meeting they apparently crossed. One was associated with an outflow of cold air from an area of thundery rain, and the other with a sea-breeze front from the Norfolk coast. After they had crossed, showers formed in the area between them.

Introduction. On 5 July 1966, in the course of time-lapse studies of the display from a 23-cm radar at Bushy Hill, near Chelmsford, a striking sequence was obtained in which two thin lines of echo over Essex and Cambridgeshire were seen approaching each other. After meeting and merging (they were almost parallel) they apparently separated and continued on their original courses (Plate I). A somewhat similar case has been described by Boyd[1] in Florida, where a sea-breeze front intersected another fine line, without either immediately losing its identity.

Weather situation. At the beginning of July there was a low-pressure area near Iceland and an anticyclone near the Azores.

On 5 July there was a fairly flat pressure gradient over the British Isles and small thundery depressions were moving gradually eastwards (Figure 1); changes in local flow pattern which could be attributed to large-scale circulation features were minimal.

Differential surface heating. Thundery rain and thunderstorms were widespread in the south of England, but Norfolk and Lincoln had as many as six hours of sunshine and the maximum temperatures reached were 21°C. In some places south of London, temperatures only reached 14°C. Figure 2 shows the surface temperatures at 1200 GMT, just before the radar record was started. In the area of continuous heavy rain in Hampshire there was a cooling at the surface to 14°C, which was two degrees cooler than the air temperature at that time above the sea at Shambles Lightship. Sawyer[2] has given an example in which a pressure difference of 9 mb was caused by the cooling of air by rain; in this case there was a definite small increase in pressure over the cool area, as shown in Figure 3.

The continuous sunshine during the morning in the district further north raised surface temperatures to 20°C, giving a temperature difference of 6 degC from the air over the Norfolk coast. This temperature difference is associated with the weak 'heat low' shown on the map.

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†Lasham Gliding Centre.

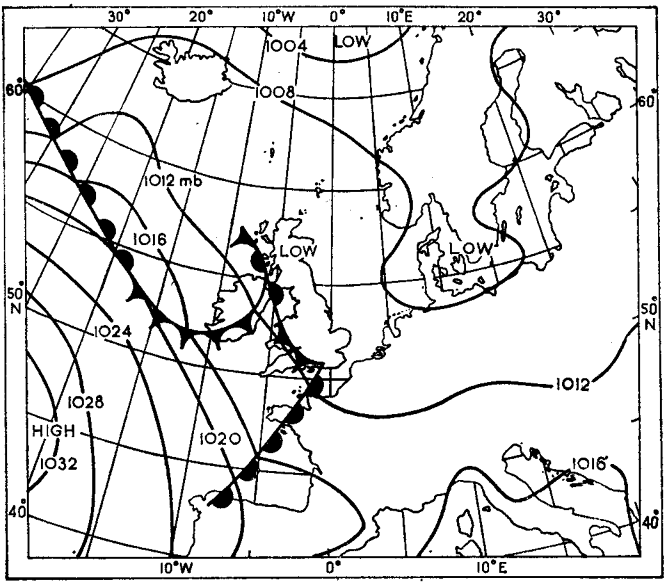

FIGURE 1—SYNOPTIC SITUATION AT 1200 GMT, 5 JULY 1966

The northward-moving line on radar. At this line (called 'line A') there was a sudden change in surface wind from north-east to south at a boundary of advancing cold air. This shear-line was advancing at about 8 kt, and the echo showed scintillations such as wheeling and soaring birds would cause, and a similar echo has been shown to be due to swifts soaring and presumably feeding in a line of rising air.[3,4]

The most vigorous frontal change detected at ground stations at the passage of line A was at 1235 GMT at Stansted. There was a sudden wind shift of 120° (Figure 4), and 18 per cent rise of relative humidity and, within an hour, a temperature drop of 4 degC. The changes were also sharp at Cardington, but at Mildenhall at about the same time, the changes were more gradual. Farther south, for example at London Weather Centre and Shoeburyness, the southerly wind built up more gradually. The pressure records did not show any sudden variations at the front.

The southward-moving line on radar. The changes across this line (called 'line B') were much less marked, and it seems likely that this was a short sea-breeze front which had moved inland from the Norfolk Coast. The 1130 GMT upper wind record at Hemsby shows a north-east wind of 9 kt from surface up to only about 1500 ft, and above that a light west-north-west wind. Onset at Mildenhall was quite sudden at about 1300 GMT (Figure 5).

Events after the fronts had 'crossed'. The crossing occurred at about 1500 GMT, and the surface winds to the south of line A remained southerly; so presumably the air behind line B was being lifted off the ground.

Fulks[5] has described 'pseudo-cold fronts' produced by precipitation from showers over a localized region, the outer edge of the cold air at the surface

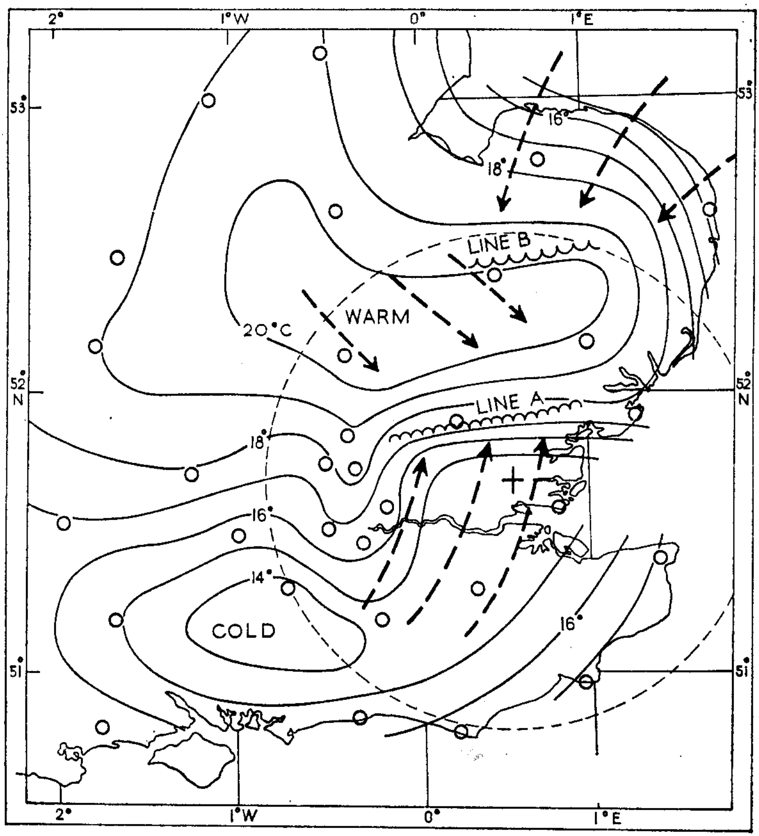

FIGURE 2—SURFACE TEMPERATURES AT 1200 GMT, 5 JULY 1966

Lines A and B represent discontinuities. Arrows show wind flow. Isopleths are at one-degree intervals.

marking the pseudo-cold front. As the cold air spreads out, new thunderstorms or showers tend to develop along the front in areas where the wind direction on the warm side of the front is favourable for lifting over the cooler surface air. In this case, as the rain-chilled air spreading north-east undercut the potentially unstable sea-breeze air, the line B lost its thin sharp form and appeared as more diffuse large lumps of echo. A probable explanation is that the swifts previously causing the echoes at lines A and B all transferred to line A (still near the surface). The diffuse form of the original line B now represents showers forming in the sea-breeze air being lifted above the advancing cold air at line A (Figures 6 and 7). This is borne out by the observation at 1525 GMT, soon after the time of crossing, of thunderstorms at Wattisham. The movement of the air in which these showers were being formed still had a considerable northerly component.

Finally it is shown that these postulated explanations would provide targets visible to the radar.

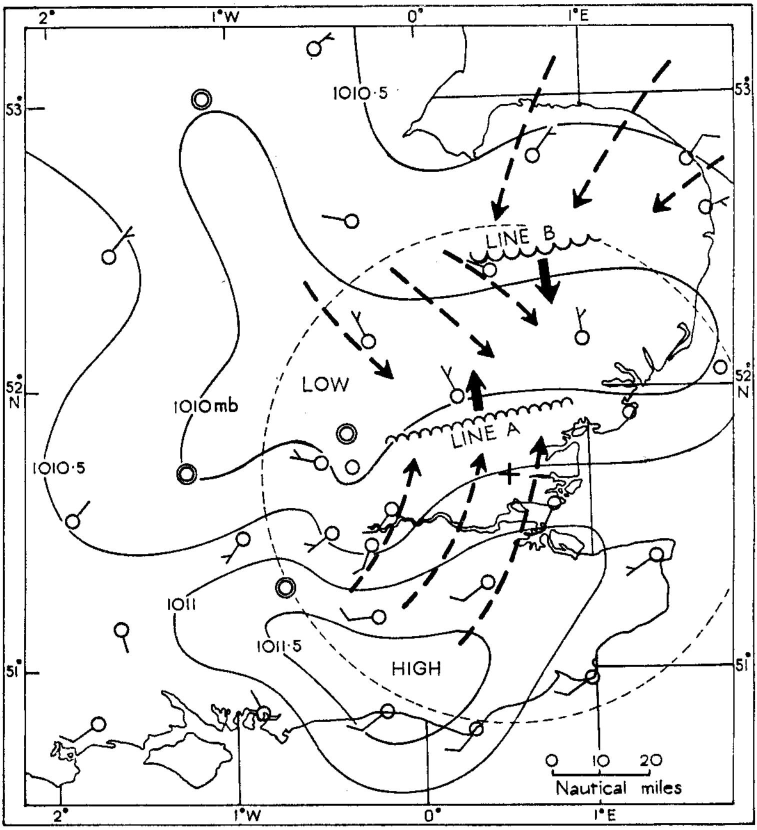

FIGURE 3—SURFACE PRESSURES AND WINDS AT 1200 GMT, 5 JULY 1966

Nature of the radar used for these observations. The radar has been described elsewhere,[6,7] and it will suffice to note the parameters relevant to the present discussions.

Radar wavelength		23 cm
Aerial beamwidth (half power — one way)		
Horizontal		0·8°
Vertical ($cosec^2$)	approx.	20°
Pulse length		5 μs (= 750 metres)
Minimum detectable echoing area at 40 n. miles		10 cm^2

The pulse volume at 40 n. miles, approximately the range of interest, may be shown to be about $1·5 \times 10^9$ m^3.

It is of interest to consider the bird and weather targets which may just be seen on this radar at 40 n. miles. Edwards and Houghton[8] have measured the echoing area of some birds and found for a starling values between 20 and 1·3 cm^2, according to the aspect of the bird, namely broadside or tail-on, and for a house sparrow 7 and 0·18 cm^2. The swift may be taken to be similar in echoing area to the sparrow.

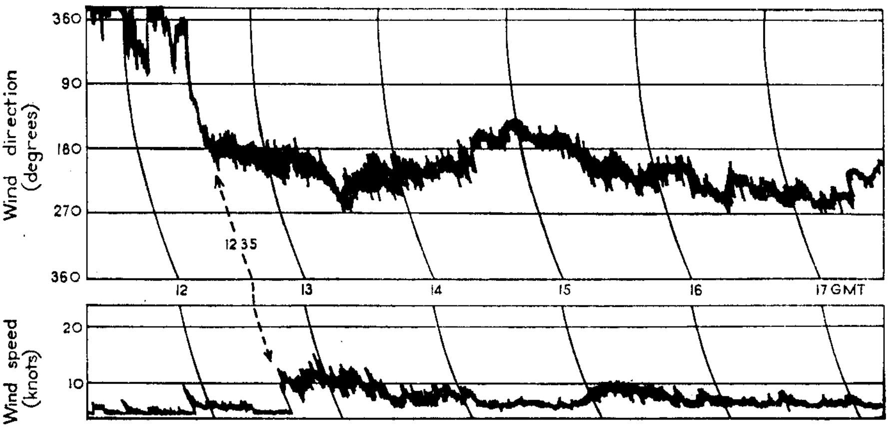

FIGURE 4—STANSTED ANEMOGRAM FOR 5 JULY 1966

Thus a single swift in the pulse volume is just about detectable when favourably orientated, and several swifts flying over an area nearly 1 km squared provide quite an adequate target. Harper[3] has observed 10-cm radar echoes from swifts flying near the edge of rainstorms and thunderstorms and observed the birds passing his station by telescope. More recently Simpson[4,9] has been able to associate radar echoes from sea-breeze fronts, detected by the equipment described here, with swifts observed from gliders and aeroplanes.

In the case of rain it is the individual raindrops which provide the necessary echoing area, e.g. Rider,[10] and it may be shown that if the rain completely fills the pulse volume a rainfall rate of $\geqslant 0 \cdot 1$ mm/hour is detectable at 40 n. miles. It is most unlikely though that the pulse volume will be filled both on account of its vertical extent and because of the 'patchiness' of rain. If

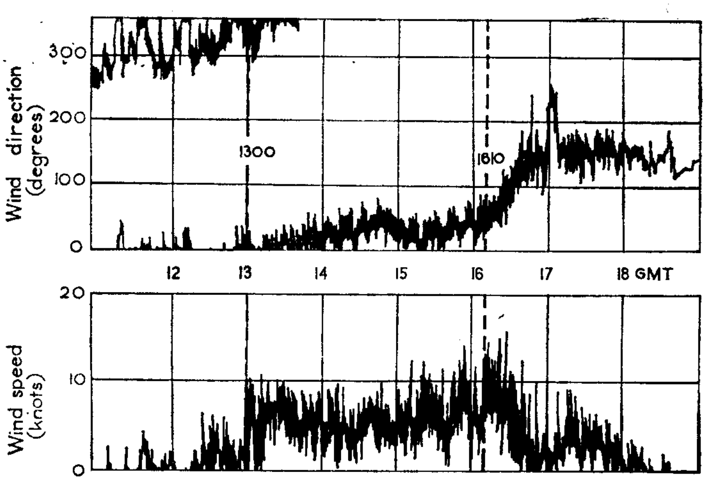

FIGURE 5—MILDENHALL ANEMOGRAM FOR 5 JULY 1966

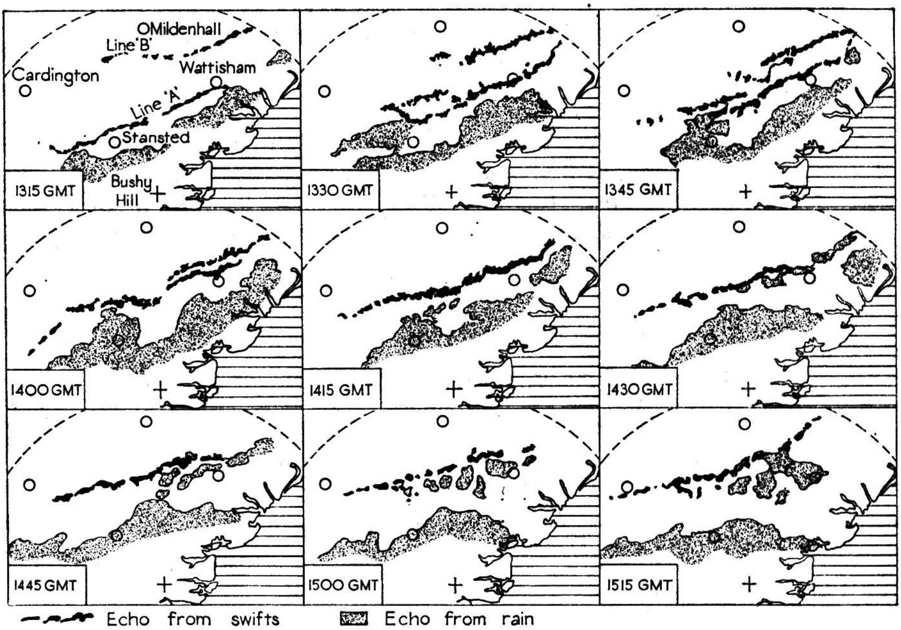

FIGURE 6—DIAGRAMMATIC REPRESENTATION OF NINE STAGES OF CROSSING FRONTS ON RADAR, 5 JULY 1966

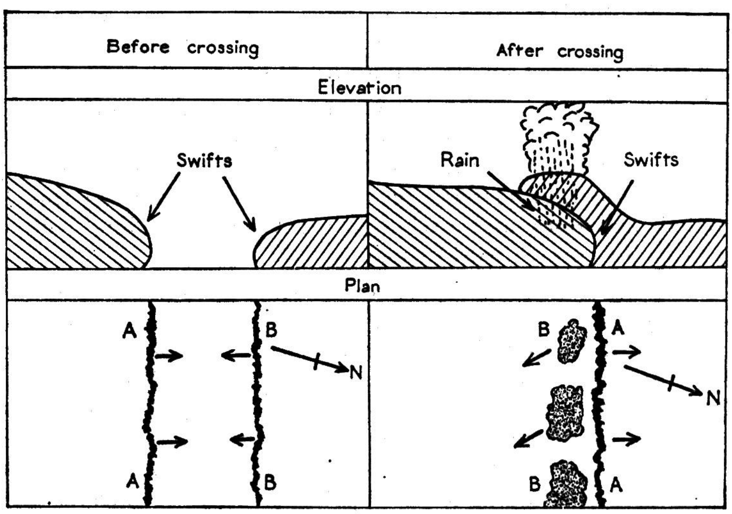

FIGURE 7—INTERPRETATION OF RADAR ECHOES FROM CROSSING FRONTS

For legend, see Figure 6

1/1000 of the volume is filled, its rate of rainfall must be equivalent to 10 mm/h for detection. Thus rain of a showery nature probably would be detected at the range of interest.

Acknowledgements. We thank the members of the Photographic Section of the Marconi Research Laboratory for the radar photographs, Dr E. Eastwood, Chief Scientist, English Electric Group for his interest and permission to publish, and the Director-General of the Meteorological Office for facilities given to examine the synoptic data and for the two anemograms.

REFERENCES

1. BOYD, J. G.; Observation of two intersecting radar fine lines. *Mon. Weath. Rev., Washington*, **93**, 1965, p. 188.
2. SAWYER, J. S.; Cooling of air by rain as a factor in convection. *Prof. Notes met. Off., London*, **6**, No. 96, 1949.
3. HARPER, W. G.; An unusual indicator of convection. *Proc. 7th Weath. Radar Conf., Boston*, 1958.
4. SIMPSON, J. E.; Swifts in sea-breeze fronts. *Br. Birds, London*, **60**, 1967, p. 225.
5. FULKS, J. R.; The instability line. MALONE, T. F.; Compendium of meteorology. Boston, American Meteorological Society, 1951, p. 647.
6. EASTWOOD, E., ISTED, G. A. and RIDER, G. C.; Radar ring angels and the roosting behaviour of starlings. *Proc. R. Soc., London*, **156**, 1962, p. 242.
7. EASTWOOD, E. and RIDER, G. C.; Grouping of nocturnal migrants. *Nature, London*, **211**, 1966, p. 1143.
8. EDWARDS, J. and HOUGHTON, E. W.; Radar echoing area polar diagrams of birds. *Nature London*, **184**, 1959, p. 1059.
9. SIMPSON, J. E.; Aerial and radar observations of some sea-breeze fronts. *Weather, London*, **22**, 1967, p. 306.
10. RIDER, G. C.; Weather and radar. *Marconi Rev., London*, **26**, 1963, p. 144.

REVIEW

Mikroklimatologie : Mikroklima der bodennahen Atmosphäre, by D. Berenyi. $6\frac{3}{4}$ in × $8\frac{1}{2}$ in, pp. 328, *illus.*, Gustav Fischer Verlag, Stuttgart, 1967. Price : DM 48.

Although published in 1967, the manuscript of this text was, it appears, substantially completed by mid-1962, and more recent work is explicitly mentioned only in a brief supplementary list of references.

A short introductory section (pp. 11–29) — in which the scope and importance of the subject is discussed—is followed by useful accounts of the main physical components involved, viz. : solar radiation (pp. 30–36); terrestrial radiation (pp. 37–63); heat transfer in air and soil (pp. 63–89); and turbulent processes and exchange mechanisms (ending with a brief reference to Kolmogorow's work) (pp. 90–123).

The author then turns to more complex systems and to interactions, deploying the results already obtained, but introducing other related concepts and information as required. The reader must therefore be prepared to search throughout the book for information on a particular topic, but in this he is materially helped by a full subject index and a comprehensive list of contents. Temporal variations of the radiation components are examined on pp. 121–142, followed by rather comprehensive accounts of the heating and cooling processes near the ground (pp. 143–204); the principal expressions for airflow in the friction layer are considered on pp. 204–238. The final section (pp. 237–284) deals first with humidity — where, as with temperature and air motion the possibility of a standardized power law and logarithmic height dependence is given some prominence — and is followed by an account of evaporation in which all the familiar approaches, and others less familiar to western readers, are discussed. It is worth mentioning that no less than 74 of the total of 304 numbered references relate to aspects of this wide-ranging review. A short account (pp. 295–304) of the evaluation and measurement of the components of surface energy and water balances and their employment as bases for climatic classification complete the main text. In addition to the numbered references in the text, a list is given of those issues of the American Meteorological Society's 'Meteorological Abstracts and Bibliography' which contain the cumulative annotated bibliographies on topics of relevance.

Diffusion of particulate matter and gases is not mentioned, otherwise the range of topics is much as considered in Sutton's 'Micrometeorology' although the level of mathematics used is significantly lower. Work originating in central and eastern Europe and in the U.S.S.R. is frequently cited, nevertheless British meteorologists (notably those associated with Porton) and the leading American investigators, feature with at least equal prominence.

The book is marred by some careless proof reading and typesetting of the mathematics. Such mistakes are too numerous to detail but some of the most annoying occur on pp. 46 and 47, viz. :

for $K_{eff} = \sigma T^4(a+be)$ read $\sigma T^4(a - b\sqrt{e})$

for $r(e_o) = K_{atm}/K_{ob}$ read K_{eH}/K_{ob}

for $r(e_o) = 0{\cdot}144 + 0{\cdot}236 \,.\, 10^{-0{\cdot}096\, e_o}$

read $r(e_o) = 0{\cdot}194 + 0{\cdot}236 \,.\, 10^{-0{\cdot}069\, e_o}$

(the table following this expression agrees with the corrected formulation).

English-speaking students are, of course, already generously served by the many admirable texts (at several levels), monographs, and journals dealing with 'micrometeorology'. Nevertheless this book should find a place in specialist libraries and on the shelves of lecturers and research workers for whom it will provide information, data and approaches which are either unfamiliar or possess an element of novelty.

Apart from misprints, the book is well produced, usefully laid out and pleasant to handle.

R. W. GLOYNE

OFFICIAL PUBLICATION

Estimated soil moisture deficits over Great Britain.

This publication provides estimates of soil moisture deficit in map form over Great Britain and in tabular statement for River Authority areas in England and Wales. The publication is issued twice monthly on the second and fourth Thursdays of the month. An introductory statement relates changes in soil moisture deficit to weather in the period since the last issue. Soil moisture deficits are derived basically from the difference between rainfall and evaporation; a leaflet is available to explain the method of derivation.

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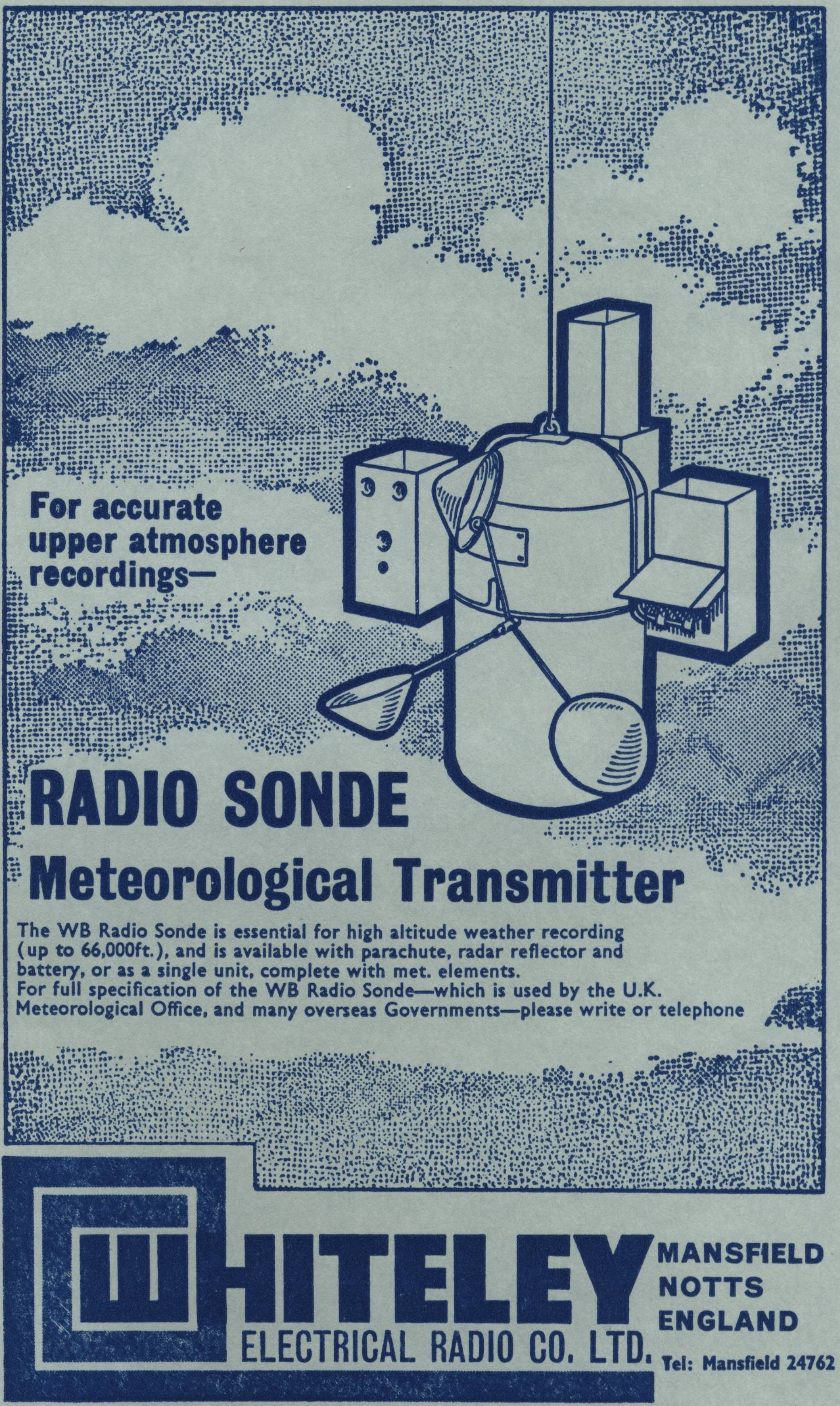
OBITUARY

It is with regret that we have to announce the death of Mr W. H. Ireson (X.O.) on 21 October 1967.



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CONTENTS

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