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LOWER STRATOSPHERIC WIND AND TEMPERATURE DISTRIBUTIONS

By R. A. EBDON

Summary. This paper emphasizes the difficulties encountered in the presentation of climatological statistics relating to winds and temperatures in the lower stratosphere. It draws attention to the risks of presenting such statistics unless emphasis is given to (*a*) the bimodal nature of the temperature distributions, particularly in high latitudes in winter and (*b*) the elliptical nature of the wind distribution, particularly in low latitudes.

Introduction. For many years it has been the accepted practice in the Meteorological Office to portray upper winds, on a hemispheric scale, by means of streamline-isotach charts and charts of standard vector deviation, and to portray upper air temperatures by means of charts of average temperatures and their standard deviations. Given this form of presentation the reader will usually assume that the temperatures are distributed according to the normal Gaussian distribution and that the individual winds are homogeneous and conform to a normal circular distribution. When meteorologists were concerned principally with describing and presenting the climatology of the lower and upper troposphere, doubts were sometimes expressed about the validity of the assumption that the winds were, in fact, circularly distributed — especially in some areas of the world. At the present time, and for some years past, there has been an increasing interest in stratospheric meteorology and, as radiosonde and radar wind data for stratospheric levels became more plentiful and more regular, there have been various attempts to describe the climatology of the atmosphere at levels above 100 mb. These have taken the form of hemispheric maps, studies restricted to specific areas or stations, and studies dealing with stratospheric phenomena, such as the approximately 26-month fluctuation in tropical stratospheric winds or the 'final warming' of the Arctic stratosphere in late winter.

These studies have drawn attention to the fact that, in the stratosphere, wind and temperature distributions can be such that to continue to present climatological statistics in the ways hitherto used can be very misleading. The purpose of this paper is to illustrate this point by taking examples from work carried out in the Synoptic Climatology Branch of the Meteorological Office during the preparation of 50-mb average wind and temperature charts for the northern hemisphere, based mainly on data for the period 1957–61. In the course of this work the data for several hundreds of stations over the northern hemisphere were extracted from various sources; average winds and standard vector deviations and average temperatures and their standard deviations were obtained for the mid-season months of January, April, July and October. Data from stations north of approximately 45°N were used for a study of conditions which prevailed during the months of February and March.

Stratospheric winds. It is apparent that in the tropical and equatorial stratosphere, where the approximately 26-month fluctuation in the zonal component is the dominant feature, the wind distribution is neither homogeneous nor circular about the long-period average wind for a particular month. The scatter diagram for Canton Island (2°46′S 171°43′W) for July (Figure 1) illustrates this. In this diagram the plotted points represent departures of the individual winds from the average wind. The distribution is typical of the other mid-season months at that station and it can be regarded as representative of the 50-mb wind distribution in low-latitude areas generally. Similar

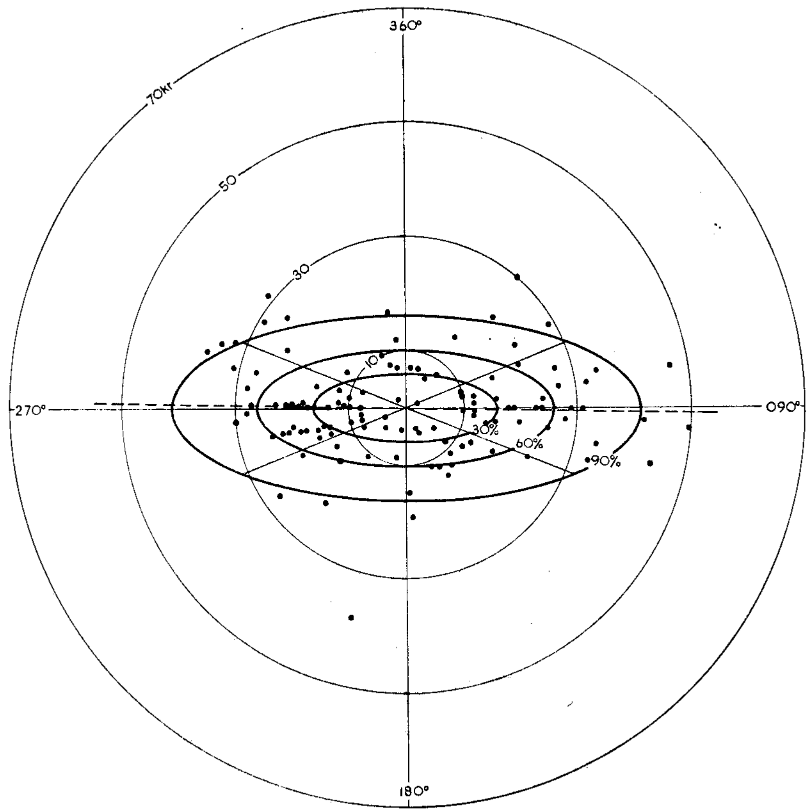

FIGURE 1—DISTRIBUTION OF DEPARTURES FROM THE AVERAGE 50-MB WIND, CANTON ISLAND (2°46′S 171°43′W) JULY 1957–61

– – – – True major axis of ellipse (091°–271°); Vector mean wind (V_R) = 269° 6 kt, standard vector deviation (*S.V.D.*) = 20·7 kt, average zonal component ($\bar{u}$) = 6·2 kt, average meridional component ($\bar{v}$) = 0·1 kt, standard deviation of the zonal component (σ_u) = 19·2 kt, standard deviation of the meridional component (σ_v) = 7·7 kt, number of observations (N) = 134.

diagrams were constructed for a selection of stations in different areas of the northern hemisphere and those for January and July for Portland (43°39′N 70°19′W) are shown in Figures 2 and 3. These diagrams (and also others which are not reproduced here) suggest that the distribution is apparently not circular and may well be more nearly elliptical.*

In order to examine the nature of the wind distribution in more detail chi-square tests were performed on 25 selected stations, using 50-mb data for the period 1957–61. The average wind was subtracted from the individual winds and these winds, effectively departures from average, were tested for both circularity and ellipticity. The stations used were chosen partly because adequate data were available and partly because they could be taken as typical of different climatological regions. All the calculations were carried out on the Meteorological Office KDF 9 computer.

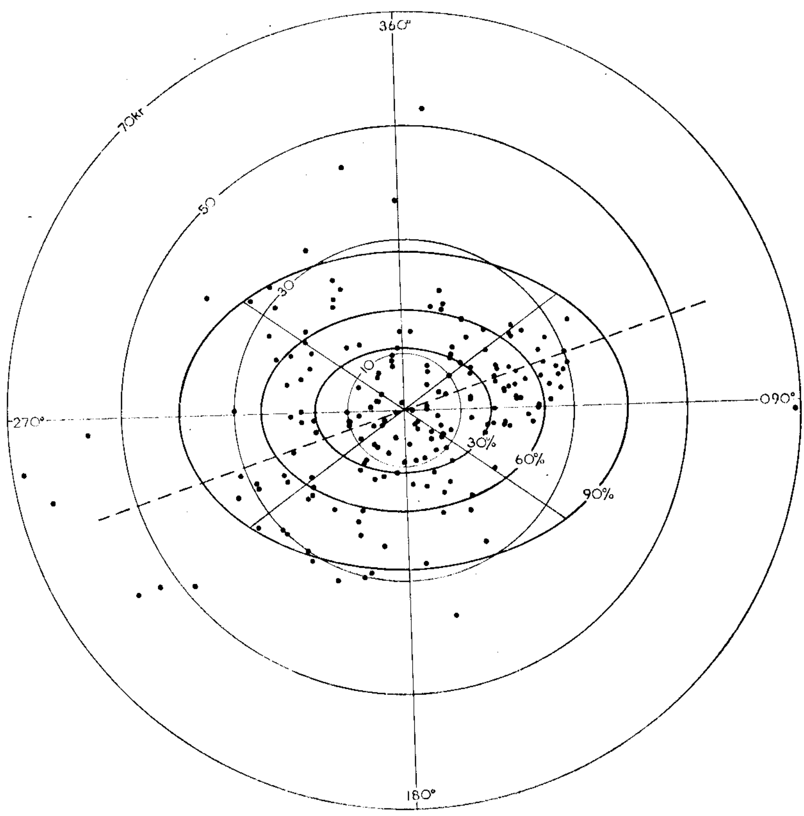

FIGURE 2—DISTRIBUTION OF DEPARTURES FROM THE AVERAGE 50-MB WIND, PORTLAND (43° 39′N 70° 19′W) JANUARY 1957–61

– – – – True major axis of ellipse (072°–252°). V_R = 265° 36 kt, *S.V.D.* = 22·6 kt, $\bar{u}$ = 35·8 kt, $\bar{v}$ = 3·1 kt, σ_u = 18·4 kt, σ_v = 13·1 kt, *N* = 195.

*A distribution in a series of vector quantities (e.g. winds) such that, when the individual vectors are drawn on a polar diagram, the lines of equal frequency of the vector end points are ellipses centred on the end point of the vector mean wind of the series.

For both the circularity and ellipticity tests the winds were sorted into four direction ranges, each representing a quarter of the area. For the circle the four boundaries were 045°, 135°, 225° and 315° and for the ellipse they were 270° $\pm$ $\tan^{-1} \sigma_v/\sigma_u$ and 090° $\pm$ $\tan^{-1} \sigma_v/\sigma_u$, where σ_u and σ_v are the standard deviations of the zonal and meridional components respectively. The numbers of observations falling inside the 30 per cent, between the 30–60 per cent and between the 60–90 per cent probability circles and ellipses, were compared with the expected frequencies and were used to compute the chi-square values. The circles were obtained by using radii appropriate to the normal circular distribution, i.e. 0·59, 0·96 and 1·52 times the standard vector deviation. In constructing the ellipses, the appropriate axis (usually the major one) was taken along the east–west axis and the lengths of the major and minor axes were determined by using the standard deviation of the zonal and meridional wind components multiplied by 0·84, 1·36 and 2·15 for the 30, 60 and 90 per cent distribution ellipses respectively.

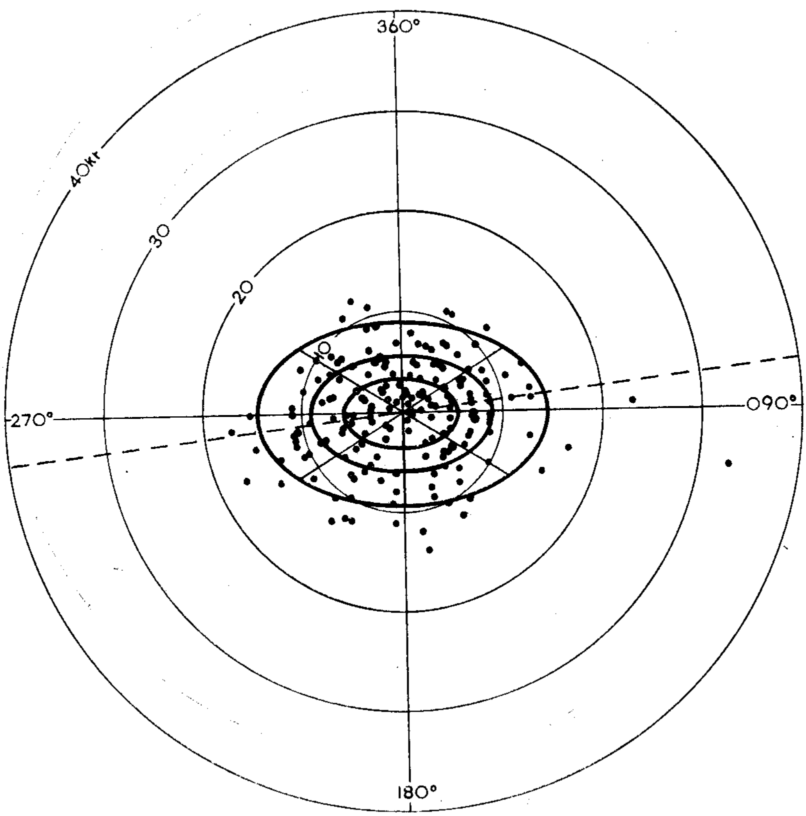

FIGURE 3—DISTRIBUTION OF DEPARTURES FROM THE AVERAGE 50-MB WIND, PORTLAND (43° 39′N 70° 19′W) JULY 1957–61

– – – – True major axis of ellipse (083°–263°). Probability ellipses are at 30, 60 and 90 per cent. V_R = 085° 7 kt, *S.V.D.* = 8·1 kt, $\bar{u}$ = –7·2 kt, $\bar{v}$ = –0·6 kt, σ_u = 6·8 kt, σ_v = 4·3 kt, N = 255.

Note. The scale of this figure is almost double those of Figures 1 and 2.

Whilst the exact number of degrees of freedom in these circumstances is somewhat uncertain, clearly it will be fractionally less for the ellipse because, if the chi-square test is applied to all 12 'boxes' together, there is one fewer constraint.

In both the circularity and ellipticity tests the chi-square value for the 5 per cent significance level with three degrees of freedom has been used as the critical value and occasions in excess of this (i.e. greater than 7·81, indicating significant non-ellipticity or non-circularity) are summarized in Table I. In January, only 24 stations were used because one station (Nicosia) had too few observations to apply the chi-square test and so the totals in the last two columns of Table I represent the number of occasions out of 99 tests when the chi-square value exceeded 7·81. Of the 25 stations used, 16 were situated north of 35°N.

Clearly, these results are highly significant; they indicate that the distribution is almost certainly not circular and that it is better described by an ellipse. An inspection of the distribution for all 25 stations for the four months reveals that between the 60–90 per cent boundaries there were 71 occasions of non-circularity but only 29 occasions of non-ellipticity. If Table I is studied in more detail it is evident that south of 35°N the circular distribution cannot possibly be regarded as an adequate description of the observed distribution as there were no less than 86 and 92 per cent of the tests at the 30–60 and 60–90 per cent bands respectively which indicated significant non-circularity. (In April and October the figure was 100 per cent for the 60–90 per cent band.) From the scatter diagram for Canton Island it is clear that the distribution is very far from circular and that an elliptical distribution provides a much better description of the observed distribution. However, in low-latitude areas, where the alternation between easterly and westerly régimes results in a bimodal distribution, the observed winds would almost certainly be better described by constructing two ellipses — one about the easterly mode and the other about the westerly mode. North of 35°N the distribution proved to be significantly non-circular on 57 and 60 per cent of occasions over the corresponding ranges. However, it should be noted that although the ellipse provides a much better estimate of the observed distribution, it is by no means a complete description and in all cases the number of occasions when the distributions proved to be non-elliptical far exceeded 5 per cent of the totals.

In interpreting the summary of the results in Table I it should be borne in mind that the user of climatological wind statistics is usually far more concerned with the distribution of large departures from average (i.e. the 60–90 per cent part of the distribution) than with the distribution of winds which are near average (i.e. the 0–30 per cent part); also, that in July, over much of the hemisphere except lower latitudes, wind speeds are very light and variability is at a minimum (often less than that indicated at Portland in Figure 3). Therefore, in July at many stations, and in the 0–30 per cent range for other months at some stations, winds are often so close to the average that very small variations in speed or direction result in large changes in the chi-square value.

One of the assumptions made in constructing the theoretical ellipses was that the major axis is coincident with the east–west (or north–south) axis.

TABLE I — NUMBER OF OCCASIONS WITH CHI-SQUARE VALUE GREATER THAN 7·81 (i.e. 5 PER CENT LEVEL WITH 3 DEGREES OF FREEDOM)

Col. (*a*) — circularity test. Col. (*b*) — ellipticity test.

Probability bands	January						April						July						October						Totals – four months					
	Number of stations						*Number of stations*						*Number of stations*						*Number of stations*						*Number of stations*					
	North of 35°N		South of 35°N		Total		North of 35°N		South of 35°N		Total		North of 35°N		South of 35°N		Total		North of 35°N		South of 35°N		Total		North of 35°N		South of 35°N		Total	
	15		9		24		16		9		25		16		9		25		16		9		25		16		9		25	
	a	*b*	*a*	*b*	*a*	*b*	*a*	*b*	*a*	*b*	*a*	*b*	*a*	*b*	*a*	*b*	*a*	*b*	*a*	*b*	*a*	*b*	*a*	*b*	*a*	*b*	*a*	*b*	*a*	*b*
0–30%	6	5	5	2	11	7	7	8	5	3	12	11	9	9	5	3	14	12	7	6	4	5	11	11	29	28	19	13	48	41
30–60%	12	10	8	4	20	14	10	5	8	4	18	9	5	3	7	2	12	5	9	8	8	3	17	11	36	26	31	13	67	39
60–90%	10	3	8	2	18	5	10	5	9	4	19	9	7	5	7	3	14	8	11	5	9	2	20	7	38	18	33	11	71	29

This is often not so. The angle of rotation of the true major axis was calculated for each set of data and these results, for the 25 stations used in the chi-square tests, indicate that had the true major axis been used in those cases where the angle is greater than 20 degrees then for both the 60–90 and 30–60 per cent bands of the distribution there would have been some small reduction in the number of occasions significant at the 5 per cent level. However, a number of non-elliptical distributions would remain and so it is felt that the added complication necessary to present details of the true major axis would hardly be justified by the small improvement. In the larger project, of which this paper forms a small part, the aim is to describe average winds and their variability on a hemispheric scale and this imposes certain restrictions on the manner in which the statistics can be presented. Almost certainly the most convenient form of presentation is by maps of the hemisphere; although if detailed statistics for an individual station were the primary requirement then it would be advisable, and perhaps desirable, to compute the angle of rotation of the major axis of the ellipse and to use the standard deviations of the components relative to the new axes to determine the lengths of the major and minor axes when constructing the theoretical ellipses. However, it can be said that ellipses constructed with the major axis along the east–west (or north–south) axis and the length of the major and minor axes determined in terms of the standard deviations of the zonal and meridional components will, generally, portray the distribution more accurately than circles with radii based on the standard vector deviation. In fact, use of the average wind and the standard vector deviation in any way which assumes that the distribution is circular may give very misleading results; in most cases it will tend to overestimate the stronger meridional components and underestimate the stronger zonal components.

A second set of chi-square tests was carried out in an identical manner to that outlined above, using the same values of σ_u and σ_v, but with the major axis of the ellipse taken along the average wind direction. In nearly all cases the number of occasions of significant non-ellipticity proved to be slightly greater than when the major axis was assumed to lie east–west or (occasionally) north–south.

Papers dealing in some detail with the distribution of winds to about the 100-mb level over India and Australia, also show that there is a marked tendency for the distribution to be elliptical rather than circular. Rangarajin and Mokashi[1] present statistical parameters for all months for three Indian stations and describe their method of constructing the distribution ellipses. Maher and McRae[2] present basic statistics for 23 Australian stations and describe the methods they used for testing for circularity and ellipticity based on estimates of skewness and kurtosis of the zonal and meridional wind components. They also give three examples of the construction of probability ellipses based on their own statistics.

Stratospheric temperatures. During the winter the high-latitude stratosphere experiences large temperature oscillations with, at some stage, a sudden, rapid warming (often of about 30 degC) which can be described as the 'final warming' and marks the onset of a temperature régime more typical of summer months. However, the time at which, and the manner in which, this 'final warming' occurs can, and does, vary considerably from year to year. During the winter season the Arctic stratosphere is, in fact, dominated by two very different thermal régimes and this is confirmed by the distinctly bimodal character of the histogram for Eureka, (80°00′N 86°56′W) in Figure 4. The dotted lines indicate the theoretical frequencies obtained by numerical integration of the expression $(1/\sigma)(2\pi)^{-\frac{1}{2}} \exp(-(T-\overline{T})^2/2\sigma^2)$, which is the normal error curve, where $\overline{T}$ is the average temperature and σ is the standard deviation. Ordinates at intervals of 0·5 degC were used for the integration. It can be seen that the observed distribution cannot possibly be regarded as 'normal'.

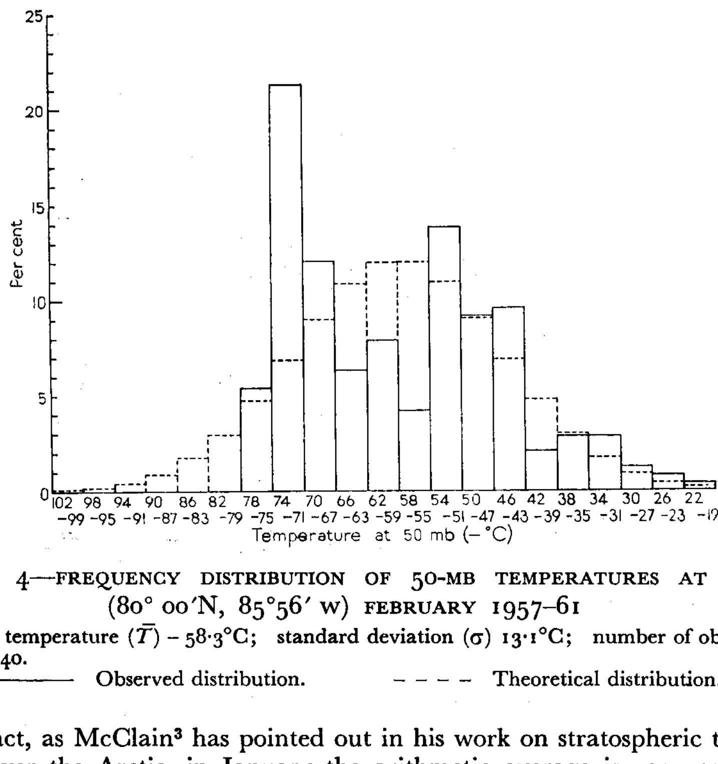

FIGURE 4—FREQUENCY DISTRIBUTION OF 50-MB TEMPERATURES AT EUREKA (80° 00′N, 85°56′ W) FEBRUARY 1957–61

Average temperature ($\overline{T}$) − 58·3°C; standard deviation (σ) 13·1°C; number of observations (N) = 240.

——— Observed distribution. – – – – Theoretical distribution.

In fact, as McClain[3] has pointed out in his work on stratospheric temperatures over the Arctic, in January the arithmetic average is very nearly the least likely estimate of the temperature and it is difficult to interpret the standard deviation properly.

Histograms (comparable with that in Figure 4) have been prepared for a number of stations for the months of January, February, March and April and, for a limited selection of stations only, for July and October. These indicate that in low latitudes the temperature distribution is unimodal (and near normal) in all months and that this appears to be so for most parts of the northern hemisphere during April, July and October. The distinctly bimodal distribution is principally a feature of high-latitude (and some middle-latitude) areas during the late winter and early spring months. To illustrate this, histograms showing the observed and theoretical frequency-distributions for Eureka, Sapporo and Balboa for the mid-season months are shown in Figure 5.

The bimodal nature of the stratospheric temperature distribution, and the consequences of it, need to be stressed when presenting and interpreting the climatological statistics for the areas affected by it. For instance, the data show that over north-east Canada, during the period 1955–62, both the warmest (−23°C) and the coldest (−83°C) recorded 50-mb temperatures occurred during the winter months. The standard deviation of all the observations about the average value can be as high as 14 degC in some areas in February although it is only 4 degC about the monthly mean value in a month when either the 'cold' or the 'warm' régime persists.

Eureka 80°00′N, 85°56′W | Sapporo 43°03′N, 141°20′E | Balboa 8°56′N, 79°34′W

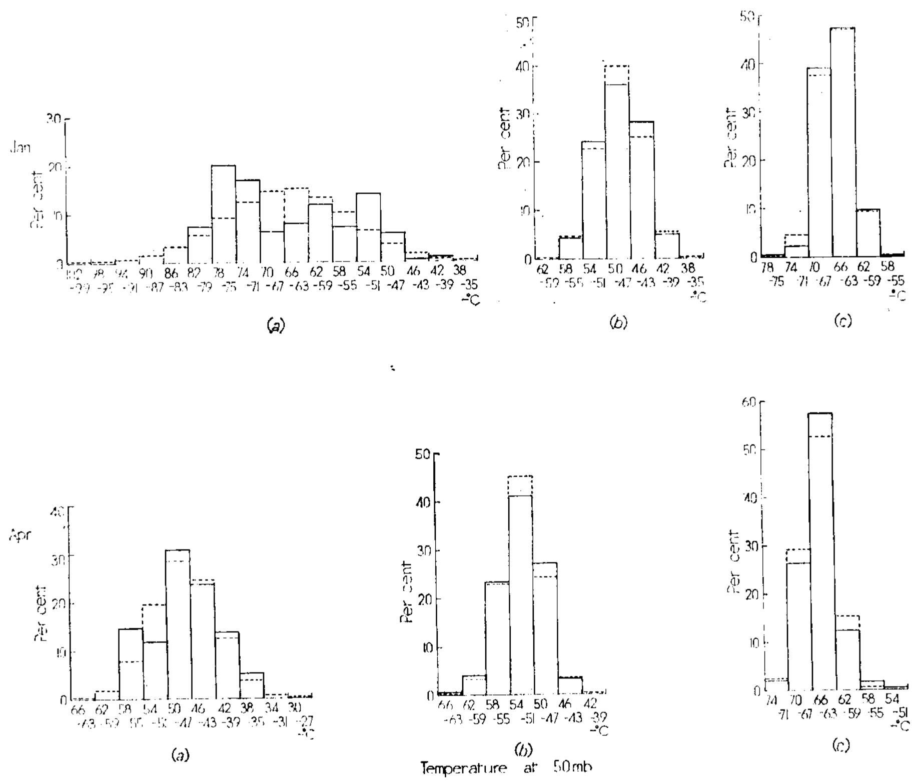

FIGURE 5—FREQUENCY DISTRIBUTION OF 50-MB TEMPERATURES FOR STATIONS AT HIGH, MIDDLE AND LOW LATITUDES 1957–61.

(*a*) Eureka, 80°00′N, 85°56′W. (*b*) Sapporo, 43°03′N, 141°20′E. (*c*) Balboa, 8°56′N, 79°34′W. $\bar{T}$ is the average temperature, σ is the standard deviation and N is the number of occasions.

——— Observed distribution. – – – – Theoretical distribution.

	(*a*)			(*b*)			(*c*)		
	$\bar{T}$	σ	N	$\bar{T}$	σ	N	$\bar{T}$	σ	N
	degrees Celsius			*degrees Celsius*			*degrees Celsius*		
Jan.	−65·7	10·4	198	−48·2	3·8	246	−65·9	2·7	228
Apr.	−47·5	5·4	253	−52·3	3·3	199	−65·1	2·7	246

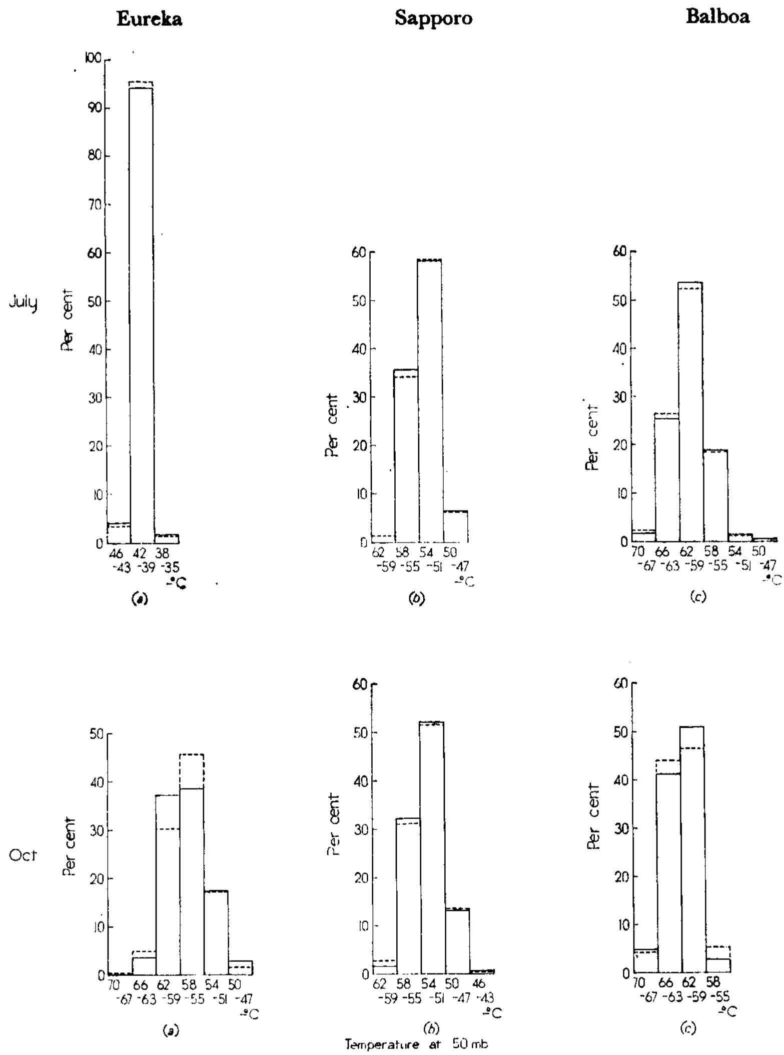

FIGURE 5—*continued*

	(a)			(b)			(c)		
	$\bar{T}$	σ	N	$\bar{T}$	σ	N	$\bar{T}$	σ	N
	degrees Celsius			*degrees Celsius*			*degrees Celsius*		
July	−40·6	1·0	289	−53·6	2·1	256	−60·8	2·8	233
Oct.	−57·2	3·2	274	−53·3	2·7	264	−62·3	2·4	204

Conclusions. The work described in this paper is part of a larger project directed towards the production of a descriptive climatology of the 50-mb level for the whole of the northern hemisphere. Preliminary unpublished reports[4] include northern hemisphere maps of average winds and standard vector deviations together with average zonal and meridional wind components and their standard deviations. The data presented here indicate that, in the lower stratosphere, wind distributions are often not circular and that if the distribution is reconstructed assuming that it is, then the results may be quite misleading. It is suggested that the distribution is more adequately described by an ellipse and, for ease of presentation, the major axis was assumed to lie along the east–west (or north–south) axis. The lengths of the axes were determined in terms of the standard deviation of the zonal and meridional components. The ellipse constructed in this way is very far from a perfect representation of the distribution, nevertheless it is, in many areas, more adequate than the circle, especially when large departures from the average wind are considered.

Although hemispheric charts depicting average temperatures and their standard deviation, at stratospheric levels, provide useful and reliable information for large parts of the hemisphere for most of the year, they should be used with extreme caution in areas where the distribution is known to be bimodal. In these areas a considerable amount of additional useful information can be obtained from the relevant temperature frequency distributions.

Acknowledgement. The author wishes to thank Mr C. R. Flood for his helpful advice during the course of the work on wind distributions.

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THE LASER CLOUD-BASE RECORDER

By L. G. BIRD and N. E. RIDER

Summary. As part of a continuing effort to improve existing methods used for the measurement and presentation of cloud-base height, an experimental equipment, based on the use of a laser as the light source, has been built.

The equipment is described in general terms and a short discussion of its performance in early trials is included.

Brief history of the development and use of cloud-base recorders (CBR) in the U.K. The need for such equipment arises because aircraft require accurate cloud-base heights for landing purposes. The heights so measured need to be particularly precise when the cloud base is within the lowest few hundred feet, that is, in marginal conditions, because an unnecessary diversion to an alternative airfield results in considerable economic loss. Cloud-base heights above about 4000 ft are of no interest in this context. Hence, a desirable performance specification calls for height determination to, say, $\pm$ 20 ft up to 500 ft, with a decreasing accuracy at greater heights up to 4000 ft. Operation by day and night is necessary.

The equipment currently in use in the U.K. employs a modulated-light beam which is made to sweep in the vertical plane. A receiver, sited 350 ft from the transmitter, looks vertically upwards and detects the presence of modulated light scattered from the cloud base as the transmitted beam passes overhead. A knowledge of the transmitter–receiver separation distance and the angle of the transmitted beam from the horizontal then enables the cloud height to be evaluated. The original suggestion that modulated light might be used in this way is believed to have originated in France around 1938. It was not, however, until the late 1940's that serious work was undertaken in this country, first at the Telecommunications Research Establishment (TRE), Malvern, and later in the Meteorological Office. At the same time and in parallel with attempts to produce a triangulation system, another system, based on the use of a spark gap to produce a short pulse of light, was built. In this latter system the cloud height was determined by the time interval between the emission of the vertically directed pulse and the reception of the back-scattered return signal. Both systems were made to work but the second was abandoned in favour of the first, because, owing to the time occupied by the light pulse (1 microsecond, equivalent to a height of about 1000 ft), no reliable information about the important first few hundred feet of the atmosphere could be obtained from the second system. Further, at that time, this second system was non-recording and the technique to display cloud information at more than a few tens of feet from the transmitter/receiver assembly did not exist. This 'optical radar', however, had an extended range and it was possible, on certain occasions, to detect signals returned from cloud at 20 000–30 000 ft.

The triangulation system, including recording facilities, was further developed to cover the operational requirements then, and now, existing. After extensive field trials of early pre-production models, the equipment, known as the CBR Mk 3a, was accepted as 'standard' and about 40 sets are now in service. The present intention is to install a further 40–60 sets during the next 2–3 years. The CBR Mk 3a has proved to be reliable in operation, it is relatively cheap to produce and it is easily and cheaply maintained. It is not, however, wholly convenient to install at all sites because a 350-ft base line is necessary, also its output cannot be easily presented at positions more than 1000 yd from the transmitter/receiver site. To meet a recent operational requirement a telemetry attachment has been designed and is now in production. The cost of this attachment is about the same as that of the basic equipment.

It will be remembered that a basic objection to the optical radar based on a spark gap, was the length of time occupied by the pulse. The laser (light amplification by stimulated emission of radiation) was developed in the late 1950's but for some years its cost remained high. By 1963–64 the laser was well established, some forms of laser crystals were in routine production and it appeared possible to construct an 'optical radar' CBR, based on such a device, to produce the necessary short and intense light pulse. The previous few years had also seen rapid development of electronic techniques which, it was thought, might well overcome the recording and display problems experienced with the early spark-gap equipment. In 1965 a specification was drawn up and a contract was placed for the manufacture of an experimental laser CBR. The development work which resulted from this contract has been a joint effort by the manufacturer, G. and E. Bradley Ltd, and the Instruments and Observations Branch of the Meteorological Office. The performance required was based on that of the CBR Mk 3a but it was considered that in the development of a laser CBR, advantage might be taken of its potentially greater range, almost constant accuracy at all heights, simpler telemetry and possibly shorter intervals between cloud height measurements. The basic equipment was delivered and installed at the Experimental Site, Bracknell, in the autumn of 1966 and, since then, has undergone considerable modification and improvement: evaluation trials are still proceeding. The remainder of this paper will describe the broad principle of operation and present some early results.

Principle of operation.

(i) The design of the laser CBR was based on the assumption that the back-scattering of light within a cloud would give an adequate return signal at the ground. The lowest cloud height to be measured is 100 ft and provision was made to overlap the transmitter and receiver 'beams' at this height. A large back-scatter signal is, however, received from particles suspended within the first few hundred feet of the volume of overlap even when cloud is not present (see Plate V (a)). The identification of cloud signals within this back-scatter signal was a major problem during the development work and the manner in which it was overcome is considered to be a noteworthy achievement of the work to date. The requirement to measure at such short ranges with this type of equipment, is unique. Generally, range-finders based on lasers as, for example, in a military role, ignore the first 1000 ft of range by electronically gating-out this interval.

(ii) Previous work at TRE and Northolt, using conventional spark-gap equipment, suggested that multiple scattering within the cloud when it was below the height of beam overlap, was sufficient to give a signal detectable at the ground. In the laser CBR provision was made for the axes of the 'beams' to be moved relative to one another, to allow further investigation. A possible arrangement is shown on the right of Figure 1. Here the inner edges of the two beams are parallel and very close together. Multiple scattering from particles beneath the cloud base should give a very small signal compared with that from multiple scattering from droplets within the cloud. Most of the work to date, however, has been done with the beams overlapping at 100 ft and with their axes parallel.

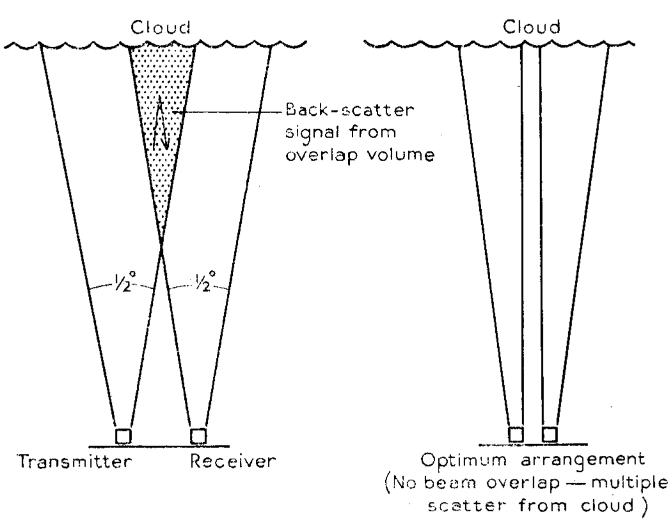


FIGURE 1—BEAM ALIGNMENT OF LASER CBR

(iii) A pulse of light is fired at the cloud base and the time taken for it to travel to the cloud and back to the ground is a measure of the height of the cloud. Cloud heights so derived are presented on a strip-chart record. In order to achieve good resolution and accuracy the pulse of light must be short. Accuracies of the order of $\pm$ 10 ft at 200 ft are required, so the laser is arranged to emit a pulse of about 20 nanoseconds (1 nanosecond = 10^{-9} second and is the time taken for light to travel one foot, approximately). The magnitude of the return signal decreases with the square of the distance from the cloud to the receiver telescope. The signal output from the receiver amplifier, due to a cloud at 200 ft, is arranged to be about the same as that received from a cloud at 4000 ft. This is achieved by increasing, with time, the voltage applied to the photo-multiplier in the receiver. As the photo-multiplier gain does not increase linearly with voltage, the voltage applied is increased according to a law determined by both the inverse square law and the voltage/gain characteristic of the photo-multiplier itself. The curve of voltage against time is called the ramp function and the voltage is supplied by the ramp-function generator. (Early field trials have led to subsequent minor modifications to the theoretical ramp shape.)

Description of the equipment.

(i) *General.* A block diagram of the equipment is shown in Figure 2 and the sequence of events is shown in Figure 3. General views of sections of the equipment are presented in Plates I, II, III and IV.

As Figure 2 shows, the control unit allows for either manual or automatic firing of the laser. In the automatic mode the laser fires every 30 seconds. A motor-driven cam operates a micro-switch which causes a charge to build up in the capacitor. A few seconds after charging stops, the flash tube is pre-ionized and the capacitor is then discharged through this tube. The resulting light is the pumping energy for the ruby crystal and causes a short pulse of light, at 6943 Å, to emerge from the laser cavity.

At the same time as the flash tube is pre-ionized, a gating circuit inhibits both the ramp-function generator and the data store. This prevents either unit from being triggered by a spurious pulse which may be generated during the early stages of the flash-tube discharge. A few hundred microseconds after the flash-tube discharge starts but a few tens of microseconds before the light pulse is emitted by the ruby, the gate is allowed to open and the ramp-function generator and the data store become active. As the laser pulse passes to the prism box which deflects it vertically to the cloud, a signal is generated in a photo-diode (Plate III) which initiates the supply of the rapidly increasing voltage (ramp) to the photo-multiplier and also causes the data store to start measuring the 'time of flight' of the pulse. Light returned from the cloud enters the receiver telescope (shown to the left of the prism box in Plate IV) and, after passing through a narrow band filter 15 Å wide and centred on 6943 Å, causes a signal to appear at the photo-multiplier. This signal, after amplification, is used to stop the data store. The 'time of flight' of the pulse is thus determined. The data-store output can be displayed directly as an analogue trace on the oscilloscope tube which may then be photographed. A further output, in the form of a small voltage proportional to the 'time of flight' of the laser pulse, is applied to a simple voltage-recorder which produces a dot on an electro-sensitive paper chart.

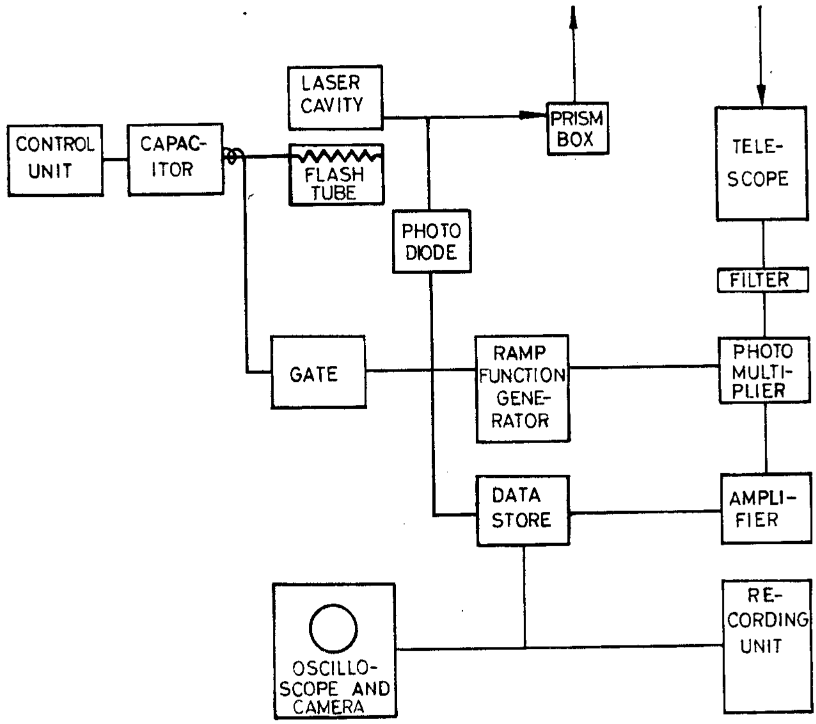


FIGURE 2—LASER CBR BLOCK DIAGRAM

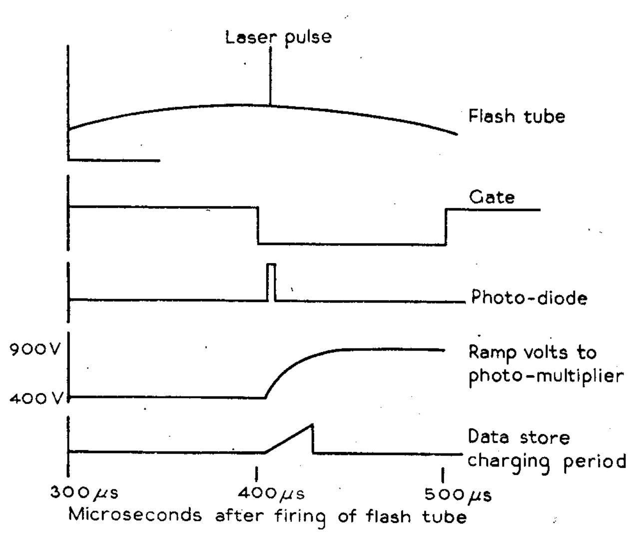


FIGURE 3—SEQUENCE OF OPERATION

The electronic components used must have constant, fast rise-times. That of the photo-diode is less than 10 nanoseconds and that of the photo-multiplier amplifier is about 8 nanoseconds. Calibrated delay lines are used, where appropriate, to ensure that accurate cloud-height information is displayed. The photo-multiplier is an EMI type 9558a which is particularly sensitive to red light.

(ii) *The laser* (Plate III). This is a ruby crystal, with 0·04 per cent chrome doping, which is 4 in long and $\frac{3}{8}$ in diameter and is cut at 60° to the optical axis. The energy output is approximately 0.45 joules with a pulse duration of 15–20 nanoseconds. The natural beam-width of the ruby used is 0·5°. The peak power output is about 30 megawatts.

(iii) *The 'Q' switch* (Plate III). Study of rotary switches showed that the shortest pulse that could be conveniently attained was about 50 nanoseconds. It was decided, therefore, to use a passive switch which, although relatively new in this application, would give the required pulse length of 15–20 nanoseconds. Crypto-cyanine solution in iso-propyl alcohol was chosen and it has proved to be fairly reliable in use. The solution has a working life of several weeks and although double-pulsing does occasionally occur, careful control of the strength of the mixture ensures that the second pulse occurs several tens of microseconds after the first and so it does not interfere with cloud-height measurements made with the first pulse.

(iv) *The flash tube* (Plate III). A xenon tube is used. Energy input is 900 joules derived from a 300 microfarad capacitor charged to 2·6 kilovolts. Both ruby and flash tube are enclosed in water jackets and de-ionized water is used as the cooling liquid.

(v) *The prism box* (Plate IV). This allows movement of the right-angled prism of borosilicate crown glass (19·1 mm side) over a range of 5 degrees in two planes at right angles.

(vi) *The telescope* (Plate IV). This consists of an aspheric objective lens, diameter 88 mm, focal length 103 mm, which focuses the incoming light on to an iris which may be varied to give acceptance angles between 2 and 50 milliradians. The light is then passed through a doublet and via a filter, which has a bandwidth of 15 Å centred at 6943 Å, to the photo-multiplier.

The laser, prism box and telescope are mounted on a gantry which allows ± 20° of movement from the vertical. In addition, the separation of the prism box and telescope may be varied between 10 in and 45 in. All work to date has been done with a separation of 10 in.

(vii) *The ramp-function generator.* As indicated previously, the magnitude of cloud signals decreases with the square of the distance from the cloud to the receiver telescope. To ensure that signals from all clouds would be within the dynamic range of the amplifier, it was decided to increase the sensitivity of the photo-multiplier progressively with the square of the distance travelled by the outgoing pulse. So that all return signals would be similar in amplitude, allowance also had to be made for the fact that the photo-multiplier gain does not increase linearly with the applied voltage. The ramp-function generator provides this varying voltage and the change from minimum volts (300 V) to maximum volts (900 V) occurs within about 10 microseconds

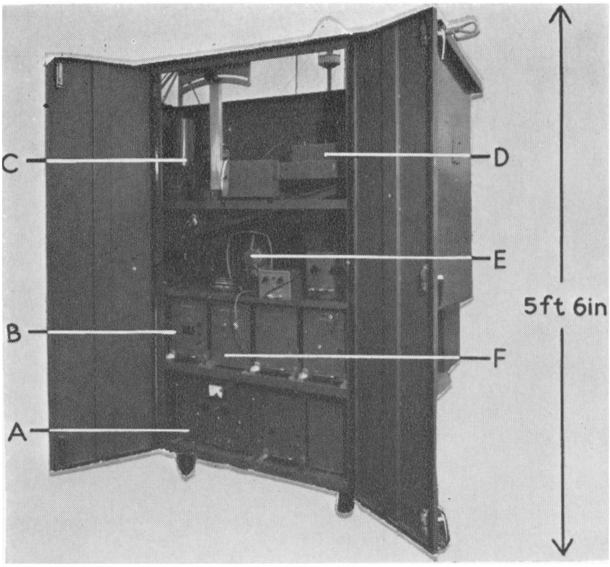


PLATE I—GENERAL VIEW OF EQUIPMENT

A. Control unit. B. Data store. C. Photo-multiplier. D. Laser. E. Heaters. F. Ramp-function generator.

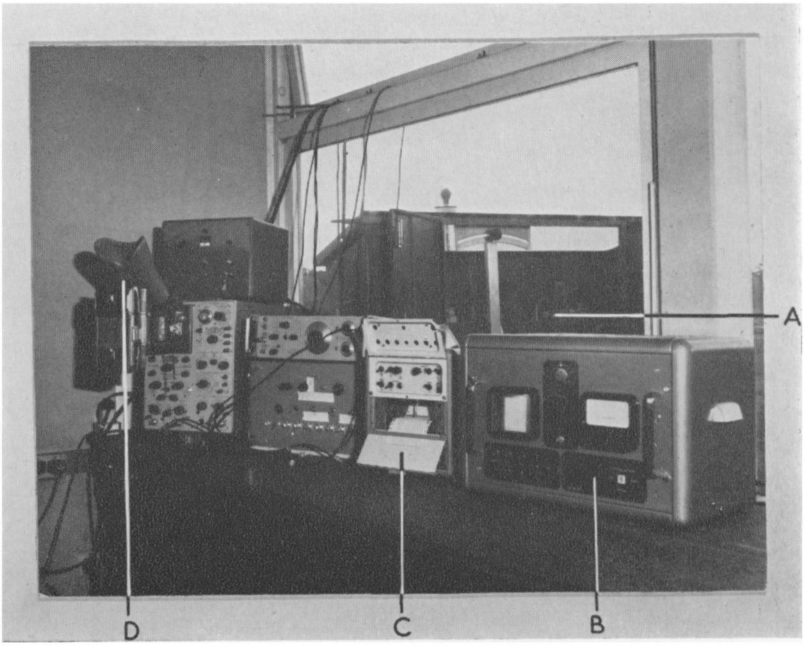


PLATE II—MONITORING AND RECORDING UNITS

A. Laser transmitter/receiver. B. CBR Mk 3a recording unit. C. Laser CBR recording unit. D. Oscilloscope camera.

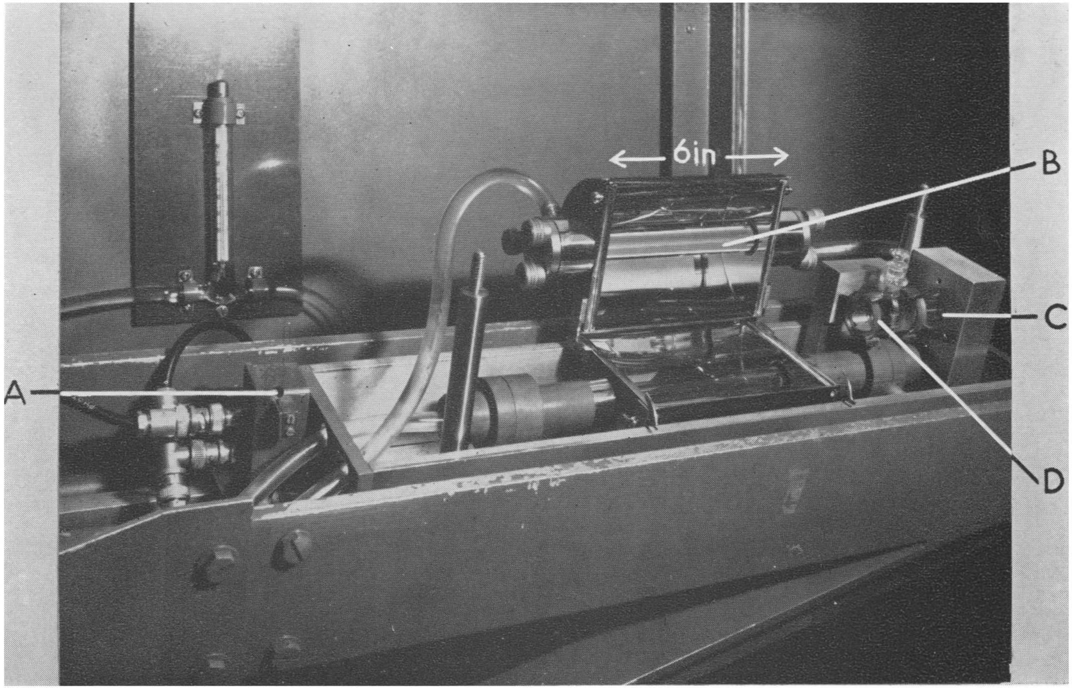


PLATE III—LASER CAVITY

A. Photo-diode. B. Ruby. C. Rear mirror. D. 'Q' switch.

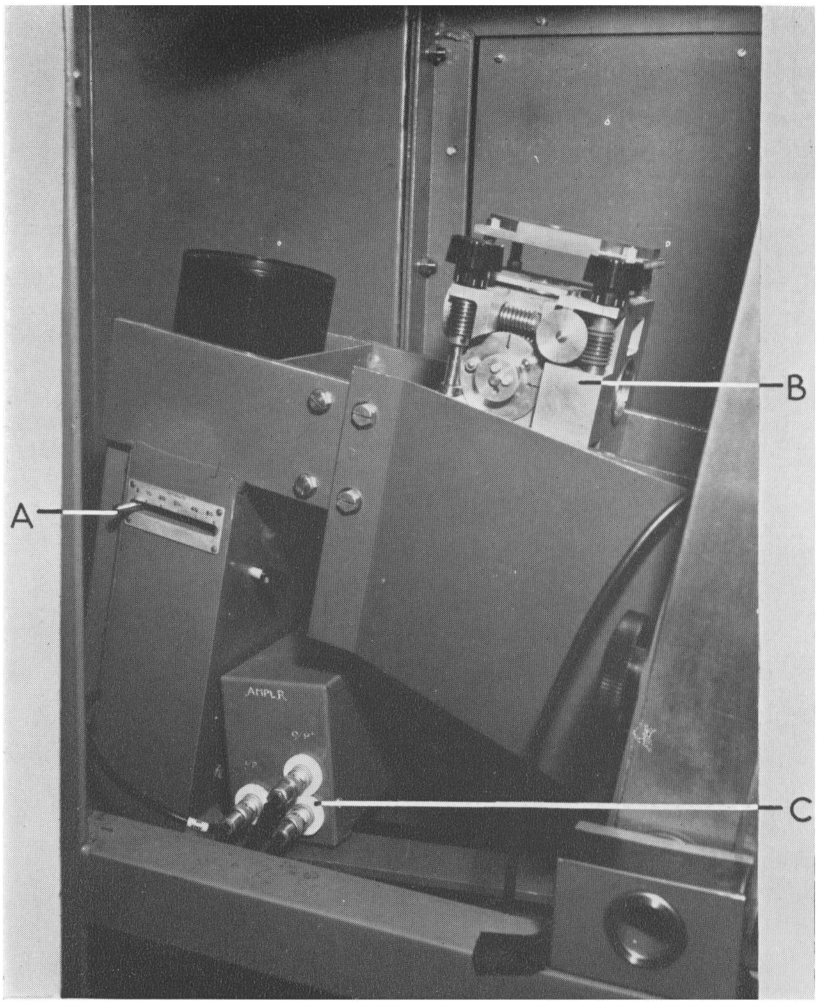
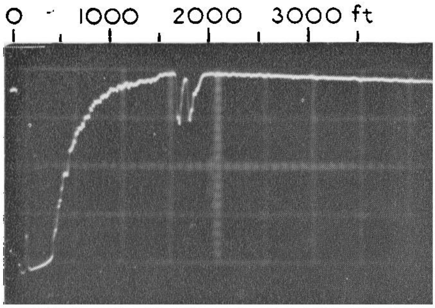
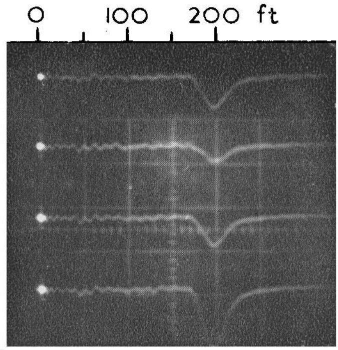


PLATE IV—PRISM BOX AND PHOTO-MULTIPLIER

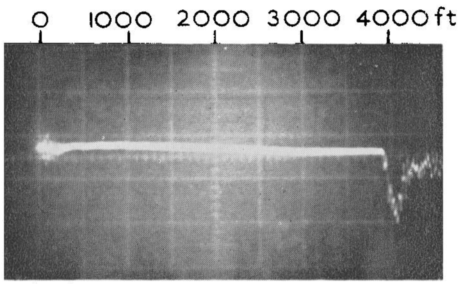
A. Iris control. B. Prism box. C. Photo-multiplier amplifier.



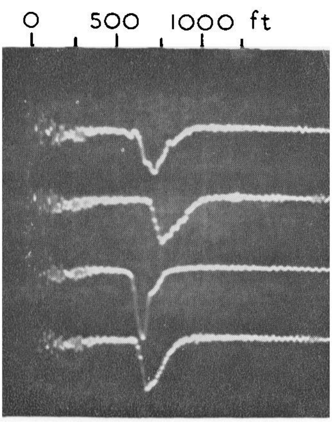
(*a*) *Fixed voltage to photo-multiplier.*
Large back-scatter echo in first 1000 ft and echoes from cloud layers at 1650 ft and 1800 ft.



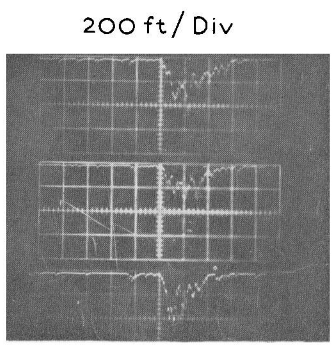
(*b*) *Ramp voltage to photo-multiplier.*
Back-scatter echo erased but echo from target at 170 ft displayed. Variable amplitude shows variation of laser output.



(*c*) *Ramp voltage to photo-multiplier.*
Echo from cloud at 3900 ft. Light rain falling.



(*d*) *Ramp voltage to photo-multiplier.*
Echoes from cloud at 600–700 ft (30 seconds between shots). Light rain falling.



(*e*) *Typical cloud signals.*
Echo expanded to show fine structure.

PLATE V—TYPICAL OSCILLOGRAMS FROM THE LASER CBR

There are also facilities for varying both the start and finish volts of the ramp shape and for operating the photo-multiplier with a fixed voltage applied, so that the back-scatter signal may be inspected.

(viii) *The data store.* This unit expands the 'time of flight' about 1000 times and then applies a charge, corresponding to this time, to a capacitor. A voltage derived from this capacitor is then passed to the recording unit.

(ix) *Environment control.* The laser cabinet is fitted with a thermostatically controlled heater. A refrigerator unit is incorporated in the de-ionized water system. The temperature of the water as it leaves the ruby is maintained at 15–17°C.

(x) *Recording unit.* This is a standard voltage recorder. Chart speed may be varied between ½ in and 6 in per hour, the chart width is 4 in.

(xi) *Oscilloscope.* A Marconi type TF2200 has been used and sweep times of a few hundred nanoseconds may be viewed.

(xii) *Camera.* A standard oscilloscope camera is fitted with an adaptor which allows 'Polaroid' film to be used for rapid processing of the exposure. It is possible to process and view a photograph of a cloud-height measurement in the interval between consecutive laser pulses (30 seconds between firings).

Calibration of the system. Targets have been set up at distances of 55 ft and 170 ft from the laser CBR. A mirror, placed on top of the cabinet, deflects the light pulse onto the near target for alignment purposes. Doors in the near target may then be opened so that measurements may be made on the far target. All of the beam is collected by the targets but, for added safety, the path of the light pulse is made to slope upwards slightly.

Discussion of results.

(i) *General.* The laser in the CBR has now been fired some 25 000 times. Most of these firings were made for reasons unconnected with measuring the cloud base, e.g. the alignment of the laser, derivation of optimum settings for the controls, calibration of the 'Q' switch and data store, and for ranging on the solid targets. Several hundred photographs of cloud echoes have been taken, however, and a selection is shown in Plate V. A start has also been made on comparing strip chart cloud-base records from the CBR Mk 3a with measurements from the laser CBR located on the same site. Close agreement between the two recorders is evident but no detailed analysis has yet been done.

(ii) *Oscillograms* (Plate V). All oscillograms shown here are taken from the photo-multiplier amplifier output. Plate V (*a*) shows the typical back-scatter signal received when a fixed voltage is applied to the photo-multiplier, in this case about 900 V. It would not be possible to distinguish a cloud signal within the first 700 ft or so. Two shallow layers of cloud are shown, however, at 1650 ft and 1800 ft; each layer is about 100 ft thick.

When the ramp voltage is applied to the photo-multiplier the back-scatter signal is erased as shown in (*c*) which also shows cloud at 3900 ft. Plate V (*d*) shows cloud at 600–700 ft, normally within the back-scatter signal. The similarity of amplitude of these cloud signals in (*c*) and (*d*), where the clouds are at very different ranges, suggests that the shape of the ramp voltage applied to the photo-multiplier is near the optimum. Light rain was falling when (*c*) and (*d*) were taken and the slightly irregular trace in the first 300 ft or so may be due to scatter from raindrops. This irregularity is not present in (*b*) when measurements were being made on a fixed, wooden target at 170 ft and no precipitation was falling. Plate V (*b*) also shows that the variation of range recorded is small when a solid target is used. The range error at this distance is about ± 2 ft. This small error arises from the fact that the amplitude of the return signal varies from shot to shot, which results in a small variation in the rise time as shown. It is known that the power output from the ruby laser varies by as much as ± 15 per cent. This is of little importance in the CBR application because only small increases in range error are introduced. This variation would have to be allowed for, however, if a pulsed laser were to be used for other purposes, such as measuring the transmissivity of the air. Plate V (*e*) shows a cloud signal displayed on an extended time-base. The fine variation in signal output indicated on this oscillogram may be due either to variations within the laser pulse itself or to true variations of reflectivity as the pulse enters the cloud. It seems likely that the latter is the case because there is a distinct difference in character between the signals received from solid targets, (*b*), and those from clouds at (*c*), (*d*) and (*e*). The oscilloscope is not capable of following the 'spikes' of high output which are known to exist within the laser pulse itself, because these are, typically, less than a nanosecond long; therefore, a smooth trace results from the solid target. However, the oscilloscope is capable of responding to variations of the order of a few nanoseconds duration and close inspection of one 200-ft division of (*e*) shows that there are about 8 discrete signal-levels recorded as the pulse enters the cloud. The general shape of this expanded echo is similar to those derived from the triangulation CBR, both being characterized by a rapidly rising signal from the lowest 50–100 ft of cloud in any layer. This means that the setting of a signal threshold level in the recording system of a CBR is not critical, fairly wide variations of threshold setting result in only small changes in the cloud height recorded.

(iii) *Chart record* (Figure 4). This shows cloud varying between 1900 ft and 2600 ft. When this record was made, holes a few tens of feet across were seen to be present in this cloud layer and these holes give rise to the dots between the 4000-ft graduation and full-scale deflection. Upper cloud was present on this occasion: had there been no upper cloud the dots would have appeared at full scale deflection. A record from the CBR Mk 3a taken at the same time did not show the holes in the lowest layer. This is because the 'beams' of the CBR Mk 3a were wider (2°) than the holes in the cloud.

Conclusions on trials to date. The experimental laser CBR has measured actual clouds over the range 400–9200 ft and, as no very low cloud has yet been present during the trial, solid targets at 55 ft and 170 ft have been used for short-range measurements. Thus, the performance of this equipment meets the range requirements of the specification to which it was built.

It is considered feasible to use such equipment as a cloud-base height recorder and plans are under way for a small number of these recorders to be manufactured to a simplified design. These will be capable of making measurements at 10-second intervals and it is hoped to increase the height range to 40 000 ft.

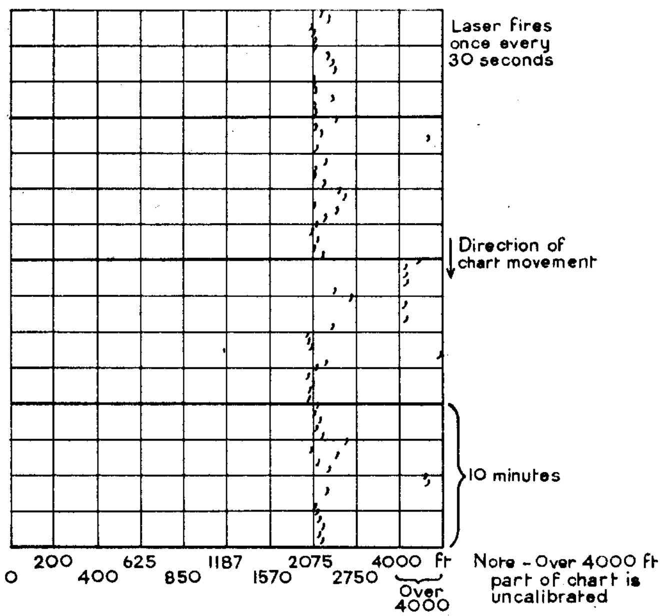


FIGURE 4—LASER CBR RECORD (SIMPLIFIED REPRODUCTION)

Future use of the present equipment. The experimental equipment described here may, with suitable modification, be used for other work after its evaluation as a cloud-base recorder is completed. Work done already suggests that the heights of concentrations of particles trapped beneath inversions may be measured. It might also be possible to measure changes in such concentrations with time, provided that due allowance can be made for variations in laser output.

Improvement of the optics of the experimental equipment would allow clouds at much greater ranges to be measured and the phenomenon of back-scatter could be further investigated.

It should be possible to obtain further information about the nature of the cloud base as previously indicated.

Use of other lasers. Laser development is progressing rapidly and many hundreds of wavelengths may now be explored using different types of laser. It is now possible to fire a low-power ruby laser several hundred times a second. Such a laser, used in the manner of a television tube, might be employed to obtain profiles of cloud bases in rapid succession and perhaps lead to a better understanding of the processes going on within the cloud.

551.5(09):551.501.9

A HUNDRED YEARS OF METEOROLOGY AT SHOEBURYNESS

By A. SCRAGG

A site at Shoeburyness, Essex, has been used for gunnery and ballistic experiments since the Napoleonic Wars; Lt Col Harry Shrapnel of the Royal Regiment of Artillery conducted some early experiments there in 1805. The first purchase of land was made by the Government from the Lord of the Manor, one Dale Knapping, in 1848. The present range area, which embraces a considerable part of the Maplin Sands and that narrow strip of coast extending some ten miles north-east from Shoeburyness to Foulness Point, is termed the Proof and Experimental Establishment, Ministry of Defence, New Ranges. Over the years meteorology was gradually introduced because winds, temperature and weather were found to be necessary for the successful firing and evaluation of trials.

An old file of correspondence, which contains the earliest available mention of meteorology at Shoeburyness, commences with a letter in copperplate handwriting dated 10 April 1863. In it the Ordnance Select Committee requested the Superintendent and Commandant at Shoeburyness to maintain a 'daily tabulated meteorological register' and placed at his disposal a barometer and wet and dry thermometers which 'can be hung up wherever you may think most suitable and it is requested that they may be noted at regular hours twice a day — viz. 10 am and 3 pm . . . . .'. The reply, dated 13 April 1863, stated:

> 'I have the honour to acknowledge receipt of your letter of the 10th and to inform you that for the last 5 years a registry of the changes of the Thermometer and Barometer have been kept at this Station and I shall be happy to afford to the Committee any information they may require concerning the Atmospheric changes shewn by them.
>
> I shall be glad to receive the Barometer and Thermometers mentioned in your letter and will cause them to be placed in a suitable situation.
>
> I will also cause the changes and force of Wind to be registered in future as requested in your office.'

Although this letter implies that regular records were made from 1858, the earliest record now available, apart from monthly rainfall returns from June 1865, is that for 1 January 1903. Observations from Shoeburyness have been published since 1903 in the *Weekly Weather Report.*

On 8 December 1866 a gentleman from the 'Royal Laboratory' asked 'do you use at Shoeburyness any instrument for measuring the force of the wind or do you merely guess it?' Some form of anemometer was, however, in use at this time for, on 24 May 1867, a letter to the Ordnance Select Committee stated that 'the anemometer on charge at this station having been accidentally rendered unfit for further use, I have the honour to request you will be pleased to cause a new one, of Howletts pattern — with instructions, to be forwarded at your earliest convenience.'

An interesting enclosure is a weather report for Thursday, 25 April 1872 issued by the Meteorological Office (Robert H. Scott, Director). It contains the 8 a.m. reports from some 34 British and adjacent continental stations, the previous day's 2 p.m. reports from 9 stations, along with 'Weather Charts and Remarks' of the barometer, temperature, wind and sea, and cloud, rain, etc.

A Russel's anemometer was taken into use some time prior to July 1880, for field work; this was a portable cup-type instrument registering revolutions and timed with the aid of 7½, 15 and 30 seconds sand-glasses. Alas, it was broken by 'coming into contact with the measuring stick carried by the Range Sergt. when riding out along the sands.' A letter dated 2.2.82 pleads —

'could not some improvement in this instrument be made which would render it less liable to injury and make it more reliable. At present it is extremely awkward and clumsy to carry on horseback, and the range sergts say it is very difficult to avoid knocking the cups against the saddle or against the measuring stick which they have to carry. Perhaps the cups might be made to lift off the spindle so as to be carried in one pocket . . . . Besides this the instruments are frequently rendered inaccurate by becoming choked up with sand and grit . . . .' Despite this plea, 'a memo' of 29.3.82 records that 'the instrument as now returned to us is nearly as useless for range work as when it was sent up.'

Rainfall records are published in *British Rainfall* from 1866 and the association with *British Rainfall* is apparent in a letter from D. Radford Sharpe on 12 July 1882 who wrote, at the suggestion of the Committee of Delegates of Scientific Societies and with the concurrence of Mr S. J. Symons, 'in an endeavour to collect month by month a record of the Rainfall of the County of Essex and I write to ask you if you would be willing to aid me in this work . . . .' Agreement was given and records were submitted but the book-keeping was sometimes at fault; an enquiry is made as to whether a heavy fall of 0·81 inches reported on the 12th September did not in fact fall on the 11th; further, a rainfall of 6·66 inches reported during January 1883 was questioned as being 'more than anywhere else in the country' — the decimal point was in the wrong place, and in August it rained a day late at Shoeburyness.

The search for a satisfactory anemometer for range and accuracy practice continued. An advertisement appeared for 'Gordon's Recording Anemometer and Pressure Gauge — Patented' around 1886 and is of sufficient interest to quote in full :

> 'This instrument indicates on a dial and at the same time records on a Chart the force or pressure of wind currents with absolute accuracy. It registers the exact force and duration of every separate breeze from mildest Zephyr to the most violent Hurricane, it shews the length of interval between each blast of wind and enables the mariner to see at a glance whether the storm is increasing or abating. It will register the pressure on a ship during the whole voyage from shore to shore, and enable a Captain to lay before his Owners an authentic statement of the weather through which he has passed, with the exact time when each variation occurred.
>
> This instrument resembles in form an ordinary time-piece, is strongly and elegantly made, and is guaranteed and upheld for Five years. It can be placed in a Cabin, Office, Observatory, or any other convenient place, and attached to a tube which may be carried from it to any point of exposure — 100 yards distant if desired.
>
> This instrument is equally valuable for indicating the force of currents in Mines, Shafts, Steam-Boilers, and for showing the variations in pressure of Gas.
>
> Prices from £10. 10s. to £15. 15s.'

An offer by Mr Gordon, during September 1886, to send an instrument for trial and report was accepted, but it was not a success and an improved model which was 'tried on several occasions with winds varying from 1 to

40 feet per second' was no better. Further models were submitted for trial, still without success, and the correspondence died after a letter during November 1888, so the search for a suitable instrument continued.

A request was made by Mr Symons, during January 1890, that a new rain-gauge which he had been asked to supply, should be placed on the ground and not, as previously, mounted on a post 7 ft 3 in above ground.

Many letters were written and many anemometers were exchanged and repaired, and on 27 May 1891 the then Superintendent of Experiments wrote to the Astronomer Royal asking his advice and opinion as to a suitable instrument. The Astronomer Royal advised a Robinson's anemometer and suggested getting in touch with a Mr R. W. Munro and Messrs Negretti and Zambra. A Prestel's anemometer was eventually ordered from Negretti and Zambra in 1895 but the desired accuracy was not yet obtained and in 1900 advice was sought from the Superintendent of Kew Observatory. At the suggestion of Dr Glazebrook, the Director of the National Physical Laboratory (which was now merged with the Kew Observatory), an officer from Shoeburyness visited that establishment for discussion. The eventual outcome was that in July 1901 the Ordnance Committee approved the purchase of a Dines anemometer, so the long search for a suitable instrument was virtually at an end — and the long association with Messrs R. W. Munro, the manufacturers, was begun. The instrument was erected on the conning tower, at a height of 101 feet above ground level, and was brought into operation on 1 April 1902.

There is a record of an unusual purchase, in 1898, of a 2-ft advertising thermometer from 'Stevens Inks'; however, its intended use was not mentioned, neither can it be imagined.

The beginning of a long association with the Meteorological Office was evident in 1902, with an exchange of correspondence relating to the provision of meteorological data by Shoeburyness commencing with the exchange of anemometer records for storm warning telegrams. Back records were loaned to the Meteorological Office, and Shoeburyness appeared in the *Weekly Weather Report* in January 1903.

Of historical interest, a Meteorological Office pamphlet No. 46A, issued in April 1904, stated that during the harvest season the council would supply, on payment of 6*d.* for the telegraph message including an address of three words, a forecast of weather applicable for 24 hours from midnight following the time of issue.

Apart from a file of correspondence covering the first 18 years of the present century, and consisting almost entirely of letters relating to anemometer maintenance, there is little information regarding the progress of meteorology at Shoeburyness during this period.

The Meteorological Office at Landwick, the site of the present upper air station and some 1¼ miles from the synoptic office, was opened on 26 April 1918 and was housed in cottages which are still in existence.

Upper winds, for use in connexion with artillery trials, were calculated from double theodolite and tail method pilot-balloon ascents and these were augmented when necessary by observations of shell bursts using a Hill's mirror. Upper air temperatures were calculated from meteorographs designed by Richards suspended from a kite balloon operated from Landwick, the balloon in use being some 50 ft long and having a nominal capacity of 5000 ft^3. When temperatures were required to a greater height than the kite balloon's capabilities, measurements were made by a Royal Air Force detachment on the Isle of Grain. The kite balloon was eventually placed into permanent store during September 1920, on the discontinuation of meteorograph measurements at Shoeburyness.

During the second half of the twenties, investigations were made into the acoustic problems involved during the firing of large-calibre weapons. The local Press stated that a deputation from the borough of Southend-on-Sea, consisting of the mayor and a number of aldermen and councillors, recently waited upon the Under-Secretary of State for War to complain of the alleged nuisance caused by gunfire from the Isle of Grain. The Under-Secretary promised, *inter alia*, to consider the possibility of deflecting or screening the sound so as to minimize the effect in the borough. Milne's seismographs were used at one time and hot-wire microphones were used to measure the wave-front intensity during firing. At the conclusion of the investigation the suggestion was made, through the Director of Naval Ordnance, that the provision of acoustic forecasts should devolve upon the staff of the Meteorological Office, Shoeburyness and, on 25 May 1926, sanction to undertake this additional duty was received from headquarters. Although firings no longer take place from the Isle of Grain the acoustic problems remain, the occasional complaints are still received and the Shoeburyness Meteorological Office, from that time on, has acted in an advisory capacity to the Superintendent, on matters pertaining to sound propagation.

The Landwick Meteorological Office was closed on 4 April 1935 and moved to the area in which the present office is situated. The instruments were transferred to an adjacent new enclosure but upper winds were still measured from the Landwick site. During this period requirements for upper air temperatures were met by flights made by the Royal Air Force at Duxford and later, in 1937, from Mildenhall and in 1941 from Bircham Newton.

As may be expected, upon the outbreak of war in 1939 there was a resurgence of activity on these ranges; the office was placed on a 24-hour basis and innumerable meteor telegrams were issued for air defence purposes. There was much coming and going of staff, and upwards of 70 personnel were trained at Shoeburyness during the war years.

The installation of a G.L.III radar set, in 1944, marked a turning-point in the routine of the office with a greatly diminishing output of double theodolite pilot-balloon ascents. The observing staff used to spend many an hour on the sea-wall following pilot balloons one after the other — as many as 419 balloons were followed during one month. The comfort of a seat in a radar cabin is something that is probably not fully appreciated by the present-day observing staff.

The tenor changed again in 1951 when surface and upper-air charts were frequently drawn and analysed for the estimation of temperature profiles over the ranges but it was not until January 1953, with the local installation of radiosonde, that Shoeburyness finally settled down with its 'own' temperatures.

One major event during this period was the east coast floods of the night of 31 January/1 February 1953 when considerable areas of the firing ranges, including the staff office and the separate radar/radiosonde office at Landwick, were inundated with sea water to a depth, in the offices, of some four feet.

Since the early 1950's techniques have continued to improve gradually with the acquisition of more-sophisticated equipment, including Cintel, Mufax, air-operated telescopic anemometer-masts and sensitive fan-anemometers; and, undoubtedly, the present installations of wind-finding instruments on various ranges would have been manna from heaven to the range staff on horseback 100 years ago.

REVIEWS

Processes of coastal development, by V. P. Zenkovitch. $10\frac{1}{2}$ in × 7 in, pp. xv + 738, *illus.*, Oliver and Boyd Ltd, Tweeddale Court, 14 High Street, Edinburgh 1, 1967. Price: £12 12*s.*

This is a beautiful book full of expert observations, discussions and conclusions about a fascinating and important subject to which the U.S.S.R. has obviously made a valuable contribution. Translated by D. G. Fry from the Russian edition of 1962, and edited by J. A. Steers, Professor Emeritus of Geography at the University of Cambridge, and assisted by C. A. M. King, Reader in Geography at the University of Nottingham, it is a commendable work of its kind. It includes a comprehensive bibliography of both Russian and non-Russian work, 35 pages in all, and a good subject/author index.

The book is concerned with the processes of coastal development associated with the interaction between the land, the sea and the air. The wind blowing over the coastal land and sea surfaces is the main initiating force responsible for the subsequent complex systems of motion in the sea and seashore. The wind generates waves and currents which interact with the coastal region in a powerful and often spectacular way. These interactions lead to the wonderful patterns of sand and shingle which we observe on the beach, and to the beautiful lagoons, spits, barriers and cliffs, and, on the larger scale still, to the complete erosion or creation of large areas of land. Most of the book's 738 pages, naturally divided into 14 chapters, concern these developments.

As with all natural sciences there are, seemingly, insurmountable difficulties. In the case of processes of coastal development there are problems associated with the non-linear distortion of waves in shallow water, undefined bottom currents, river discharge, changes in the effective mean sea level and the random occurrence of storms. These are all considered in the text. One of the main chapters is on the effect of tidal conditions and storm surges and the author emphasizes the practical importance of these, particularly the latter, to the coastal engineers, harbour authorities and companies operating drilling-rigs in the sea, etc. The author repeatedly stresses the importance of the displacement of beach material along the shore by waves and currents and this is obviously where he thinks that most existing theories on coastal development are weakest. The direct action of the wind, in moving sand and sometimes gravel about the beach, is of much less importance. Even so, the author devotes the whole of one chapter and parts of others to these very intriguing processes.

Zenkovitch is principally a geographer and has been a leading authority on coastal dynamics in the U.S.S.R. for many years. This, doubtless, explains the enormous scope of this book in subject content and in regional material, mainly from Europe and Asia. The text is almost void of mathematics and the English is clear, concise and comprehensive. It is, therefore, extremely easy to read except in a few places where the rather wordy arguments could be confusing, for example on page 25. The 328 illustrations are particularly clear and more than a third of these are photographs showing the results of processes of coastal development.

This book would be a useful addition to a major reference library mainly for two reasons. Firstly, because it extends our knowledge of coastal development to little-known (to the western countries) regions of Asia and these include a vast variety of types covering a wide range of latitude. Secondly, because the book reviews the work carried on in this subject in the U.S.S.R., up to the year 1961, and includes comparisons with the work carried out in other countries.

Finally, it remains to be said that this book is an excellent example of scientific international collaboration and a credit to all those concerned, including the publishers, Oliver and Boyd.

J. F. KEERS

Viewing weather from space, by E. C. Barrett. $8\frac{1}{2}$ in × $5\frac{3}{4}$ in, pp. xii + 140, *illus.*, Longmans, Green and Co. Ltd, Pinnacles, Harlow, Essex, 1967. Price: 21*s*.

The new satellite-view of the earth and its weather systems is probably the greatest and most exciting development in the history of meteorology. This author captures the interest and excitement of the experimental stage of this development and describes it with an ease and lucidity which is attractive to professional and non-professional alike. It is evident that he has made himself thoroughly conversant with every aspect of satellite technology relevant to his theme, and that he has drawn on several years' experience of using satellite photographs as an aid to teaching meteorology. The professional meteorologist may question the competence of a geographer to write on progress in meteorology, but a geographer with a thorough grounding in the techniques and problems of map projection may have the edge on authors from other disciplines when it comes to the interpretation of photographs taken from space.

Chapter 1, a historical survey, is an easy lead-in to the subject for the dilettante. Chapter 2 is just as readable and describes very adequately the various TIROS and NIMBUS satellite systems. There follows a discussion of the problems of data analysis and cloud recognition. Unfortunately, both here and in Chapter 7, there appears to be a lack of appreciation of the importance of the 'thermal wind', or the wind shear through the cloud-producing layer, in determining the alignment of most cloud patterns and systems. There is no specific mention of the commonly observed 'cold pool' or 'centre of vorticity' type of cloud system and, to make matters worse, wind shear is incorrectly defined (p. 43).

Chapters 4 to 9 are concerned with the progress made, through satellite photography, in our understanding of the atmosphere and the earth beneath. After a brief look at the general circulation (Chapter 4) the author turns to tropical weather systems and gives an excellent review of the present state of knowledge of hurricanes.

Temperate latitude weather systems occupy only seven pages. The various types of depressions are dealt with in summary form but it should be made clear that the summary is incomplete. For instance there is no mention of frequently occurring non-frontal 'polar depressions' such as develop in a cold airstream over warm sea.

Chapter 7 looks at the variety of observed mesoscale cloud patterns which were, hitherto, largely unknown and unsuspected. The short section on convective and cellular patterns is poor and, on page 88, open cellular patterns are wrongly said to be associated with conditions more stable than those for closed patterns. A final chapter on future developments and some useful reference tables, complete the book. There is a good selection of satellite photographs in the centre, and a well selected and comprehensive bibliography is attached to each chapter.

It is necessary to draw attention to the more obvious shortcomings and errors which appear, but they are relatively few and one cannot expect in a short space, or at this stage of the development of space photography, a complete and exhaustive account of what may be learned from satellite observations of the clouds. This book is a good introduction to the subject and at the same time a stimulating, reasonably self-contained and up-to-date text book in observed meteorology.

D. M. HOUGHTON

Luftverunreinigung und Stadtklima im Rheinisch-Westfälischen Industriegebiet und ihre Auswirkung auf den Flechtenbewuchs der Bäume (Air pollution and urban climate in the industrial area of Rhineland-Westphalia and their effect on the lichen vegetation of trees), by M. Domrös. 9 in × 6 in, pp. 132, *illus.*, Geographisches Institut der Universitat, Bonn, Franziskanerstrasse 2, Bonn, West Germany, 1966. Price: 17 DM.

Biological integrators are being used on an increasing scale to provide a useful summary of those features of the environment which vary rapidly and irregularly both in space and in time, and whose complete geographical description thus requires inordinately large resources of equipment or man-power. Air pollution is one such feature, and in this book Dr Domrös explores the possibility that the lichens which grow on the trunks of free-standing trees might provide a biological integrator for it. Most such lichens are known to be damaged by some forms of air pollution, and such an integrator would be available wherever there are street trees. Dr Domrös, with the proverbial thoroughness of his countrymen, has recorded the growth of lichens on over 25 000 street trees in an area of some 200 square miles, and he attempts to correlate this with air pollution. The data available to him on the latter, unfortunately, are not sufficiently extensive to match his own monumental analysis, and as yet the correlation cannot be established in quantitative detail. In particular, although Dr Domrös disposes of the theory (still current in Germany) that the absence of lichens in town centres is due mainly to reduced relative humidity rather than to air pollution, he is unable to discriminate between the effects of sulphur dioxide and of solid pollutants.

This is a valuable investigation (parallel to others in Britain and the United States) involving two branches of science usually thought of as widely separated. The small monograph in which it appears assumes that the reader has no knowledge of either meteorology or lichenology, so that about half the book has to be devoted to a discussion of urban microclimates, air pollution, and lichens in general.

The book is, on the whole, clearly written and readable by the non-specialist, although it is repetitive in places and the reader might wish that it had been somewhat compressed. It contains comparatively few misprints or errors of fact. The bibliography of some 250 references shows the author's deep knowledge of the Germanic literature, but illustrates rather clearly the extent to which the North Sea is still a barrier to scholarly intercourse.

O. RACKHAM

PUBLICATIONS RECEIVED

Weather modification in the Soviet Union, 1946–1966: *a selected annotated bibliography*, by Nikolay T. Zikeev and George A. Doumani. The Library of Congress, Washington, D.C., 1967. (Available from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402.) Price: 55c.

A new bibliography published by the Library of Congress highlights recent technical literature on weather modification in the Soviet Union, which has developed significantly since World War II in such areas as rain production, thunderstorm and hail suppression, and fog dispersion.

The bibliography lists and briefly describes 503 items published between 1946 and 1966 and received in the Library before 1 November, 1966. For items published between 1961 and 1966, the coverage of scientific publications is almost complete; earlier items were selected for their originality and importance.

The 78-page publication also contains three tables summarizing U.S.S.R. experiments in the field since 1933, and three appendices containing: (i) the titles and Library of Congress shelf numbers of the 54 Russian scientific serials represented in the bibliography; (ii) the names of Soviet specialists active in weather modification, with their affiliation and subject of research; and (iii) to facilitate international co-operation among scientists interested in weather modification, the addresses and telephone numbers (if available) of the Soviet institutions active in operations of weather and climate modification.

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LETTER TO THE EDITOR

The diurnal range of temperature in Scottish glens

It is interesting to consider some of the factors which may lead to the rather large diurnal range of temperature which is often experienced in Highland glens, as shown by Dight.[1] The mechanism of the heat-exchange cycle near the ground is complex, particularly so in irregular terrain, consisting, as it does, of a number of interacting processes. It is still possible, however, to make a qualitative assessment of the effectiveness of some of the processes in producing a large-amplitude temperature wave.

The diurnal ranges in summer probably occur more often as a result of low night minima than of especially high day-time temperatures. Thus, although the Highland air is usually very clean, allowing large amounts of solar radiation to reach the ground during clear weather, the day-time temperature rise is a function of more than the total insolation and, in most synoptic conditions, an effective temperature-limit is set by the convection which tends to re-distribute heat through ever-deeper layers as the surface temperature rises. The nights are short but the very clear skies result in greater outward radiation than in smokier atmospheres, such as at London/Heathrow Airport. At Kincraig, which is near the floor of a valley, a katabatic flow might be expected to occur for some time during the night, before 'pooling' of the cooled air sets in, and this would, probably, often produce lower minima than on flat open sites. Thus the katabatic wind would maintain, for a time, stirring of the atmosphere near the ground, and the cooling would tend to be spread through a deeper layer than in the example of stagnant air over a large flat surface. The katabatic flows would persist on the higher slopes throughout the night and thus cooled air would continue to fill up the valley. The bulk of the long-wave radiation from the atmosphere (assuming clear skies) is contributed by the layers of air, one or two hundred metres thick, which are in contact with the ground (Czepa and Reuter[2]). Thus, at a site near the bottom of a valley influenced for part of the night by katabatic flows, the mean temperature of these layers is likely to be lower than in flat, open terrain, and the net (outward) radiation is larger, allowing a more rapid fall of temperature at night. Also, the katabatic flow is likely to occur for only the first part of the night near the valley bottom, with subsequent stagnation of the air and then only very slow downward transfer of heat from the warmer air aloft. At open sites, on the other hand, unless pressure gradients are very small, there is often sufficient wind shear to break down, periodically, the intense temperature gradient which develops near the ground, and thus to transfer heat downwards.

The rapid rise of temperature after sunrise in winter may well be due to the same sort of mechanism as Dight[1] proposes for the other times of the year. His explanation, for the winter case, was of a downward transfer of turbulence generated at higher levels by interaction between the general airflow and the hill tops. However, this cannot be the normal process producing the diurnal temperature-rise after a radiation night. If it occurred, then it would do so at any time during the day or night, and thus the possibility of low night minima would be eliminated. In any case, it cannot be effective on the many occasions when the upper flow is very light.

It seems much more likely that the incoming solar radiation provides the key to the rapid diurnal warming, even in winter. Caution should be exercised in dismissing the amounts of solar radiation as negligible, particularly if the slope of the ground effectively increases the solar altitude. A few figures help to put the matter in perspective. Measurements of the intensity of solar radiation on a surface perpendicular to the direct beam on clear days at Kew (Stagg[3]) yield maximum values of about 20 and 40 milliwatts per square centimetre (mW/cm^2) for altitudes of 5° and 10° respectively, in December and January. In late January in the Highlands, the solar altitude is about 6° one hour after sunrise, and at this time on a clear morning one would, therefore, expect up to 25 mW/cm^2 incident on a surface normal to the radiation. The albedo of a snow surface in Scotland is likely to be about 0·7, unless the snow is very fresh. Thus a snow slope inclined at 30° to the radiation would absorb about 4 mW/cm^2. Most of this is absorbed in the upper few centimetres (see, for example, Liljequist,[4] Geiger,[5] Gavrilova[6]). The specific heat of the snow is about 0·5 calories per gram per degree centigrade, and if the density is around 0·3, then, ignoring conduction, the rate of rise of temperature of the upper layers of the snow would be 3 or 4 degC per hour. The rate of rise very near the surface would be larger, probably in excess of 5 degC per hour. If only half of the absorbed short-wave radiation was used to heat the air in contact with the ground, then the rate of rise of temperature of the air in a layer 10 metres thick would be around 6 degC per hour. Warming of this magnitude would be likely to initiate anabatic flows and local overturning and, ultimately, produce a more general overturning of the air in the valley. However, relatively small amounts of radiation are being considered and account must, therefore, be taken of the influence of long-wave radiation soon after sunrise. At the end of the winter night, when surface temperatures are much lower than in the free atmosphere a few tens of metres above, the net (outward) long-wave radiation at the surface is small enough to be nearly balanced by the small, downward, turbulent transfer of heat, or by conduction of heat through the snow from below (see, for example, Munn[7]). Condensation of water vapour on to the snow and the consequent release of latent heat will also help to prevent surface temperatures falling. In these circumstances, even the diffuse short-wave radiation at sunrise may be sufficient to initiate the diurnal temperature rise.

N. THOMPSON

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NOTES AND NEWS

Retirement of Mr T. W. V. Jones, I.S.O.

Mr T. W. V. Jones joined the Meteorological Office in June 1925 as a Junior Professional Assistant. His career spanned more than 40 years and reached its culmination in 1952 when he was promoted to Senior Principal Scientific Officer. In the Birthday Honours 1961, he was made a Companion of the Imperial Service Order, a well-deserved honour for his long and faithful service to the Office. He retired from his senior appointment in 1963 but continued to serve the Office as a Senior Scientific Officer until his final retirement at the end of October 1967.

'V.J.', as he was affectionately and widely known, held many posts at Headquarters and at outstations both at home and overseas. He served overseas at Hinaidi (Iraq), Aden, the Canal Zone in Egypt, and Cyprus — most of which no longer exist as postings for Meteorological Office staff. Their very mention brings a nostalgia to mind which V.J. will share when he muses over events of the four decades of his career. Whether at Headquarters or at outstations he always brought a very practical approach to bear on the tasks before him. This strong sense of the practical stood him in good stead on his last overseas tour — as Chief Meteorological Officer, H.Q., Near East Air Force. At the commencement of his tour the H.Q. was in the Canal Zone and V.J. had to organize the transfer of meteorological services to Cyprus. On his return from Cyprus he held the post of Assistant Director in charge of meteorological services for the Royal Air Force and the Army and from 1960 to 1963 he was responsible for meteorological services to both military and civil aviation. His long and wide experience of aviation and the armed services and their need for meteorological support were valuable attributes which fitted him well for these appointments. Throughout his tenure of these and other appointments at Headquarters, he contrived to remain knowledgeable of the needs and difficulties of his outstations and he had the efficiency of the Office and the well-being of the staff very much at heart.

His concern for others found additional practical expression through his work for the Staff Side and Staff Associations. For many years he was an active member of the Institution of Professional Civil Servants and served on many committees. In the years following World War II, he and the late F. M. Dean formed a formidable pair when negotiating with the Official Side. Although his Staff Side work took much of his spare time, an individual with a personal problem could be sure of a sympathetic ear from V.J. and there must be many individuals (as well as the author of this note) who are still very appreciative of the valuable and helpful advice which he gave.

We offer to him and his wife, Margery, our best wishes for a long and happy retirement.

N. BRADBURY

CORRIGENDUM

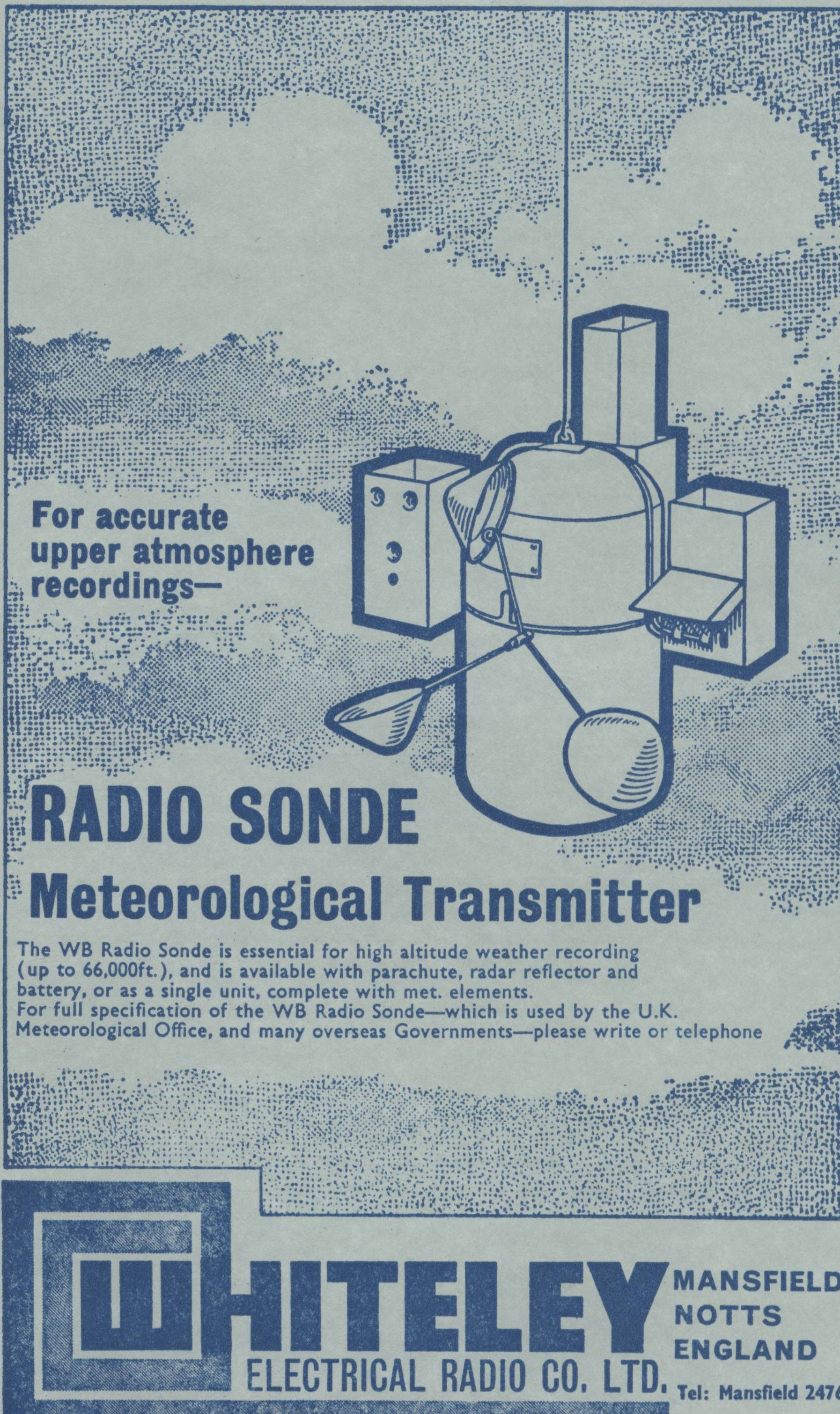
Meteorological Magazine, January 1968, p. 31, for '. . . read $\sigma T^4(a - b\sqrt{e})$' substitute '. . . read $\sigma T^4(a + b\sqrt{e})$'.

HONOUR

The following award to a member of the Meteorological Office was announced in the New Year Honours List, 1968 :

O.B.E.

S. E. Virgo, Senior Principal Scientific Officer, Headquarters, Bomber Command.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