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## **Mr. J. S. SAWYER, FELLOW OF THE ROYAL SOCIETY**

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

Some four years ago it was my pleasant task to write for the *Meteorological Magazine* an appreciative note recording the promotion of Mr. J. S. Sawyer, by special merit, to Deputy Chief Scientific Officer and now, with his election as Fellow of the Royal Society on 21 March 1962, I gladly take the opportunity to express once more our gratification, shared by all meteorologists who have worked with him or have followed his output of original work over the past fifteen years.

Mr. Sawyer joined the Office just prior to the outbreak of World War II as a first appointment after taking the Cambridge Mathematical Tripos and served during the war years with various Royal Air Force units in England and abroad. Although there was little opportunity for research during those vital years there was a great concentration of experience in the ways of the atmosphere and Mr. Sawyer's latent abilities emerged as soon as the opportunity came, first while working under the late C. S. Durst on Special Investigations and, from 1948, in the newly-formed forecasting research group at Dunstable. Mr. Sawyer was appointed Principal Scientific Officer in charge of short-range forecasting research and maintained a steady stream of research papers which had, in 1958, already exceeded 50 in number and which has since gained some notable additions as exemplified by the following papers in the *Quarterly Journal of the Royal Meteorological Society*: in 1959, "The introduction of the effects of topography into methods of numerical forecasting"; in 1960, "Numerical calculation of the displacements of a stratified airstream crossing a ridge of small height"; in 1961, "Quasi-periodic wind variations with height in the lower stratosphere". We may be sure that this is not the end.

In his present post as Deputy Director for Dynamical Research Mr. Sawyer has responsibilities for forecasting research, including long-range forecasting, climatological research and general circulation studies, as well as for that field of dynamical and synoptic meteorology with which his own name is especially associated. There are eminent meteorologists distinguished by their skill and insight as synoptic analysts and others with enviable mathematical prowess, but few indeed who combine these talents as successfully and fruitfully as does Mr. Sawyer, and the Meteorological Office may count itself fortunate in his services. Election to the Royal Society is a most fitting recognition.

# DIURNAL, SEASONAL AND ANNUAL CHANGES IN THE INTENSITY OF LONDON'S HEAT-ISLAND

By T. J. CHANDLER  
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An urban climate is a function of three variables: the general climate of the region, the modifying influences of local morphology, and the "self-induced" modifications following the congregation of houses, factories, power stations and surfaced roads into the complex of the city. Each house, factory, wall and road creates its own microthermal conditions and these combine to produce a fairly distinct climatic entity—the urban climate. The city modifies almost all aspects of the regional climate, including local thermal conditions.

London, in common with other towns, is usually (though not invariably) characterized by temperatures above those prevailing in the surrounding country districts. The warm air, or heat-island, which lies within and above the city is the product of a number of factors including the high thermal capacity of the city fabric: back radiation from the pollution haze and from tall buildings; heat released in the combustion of fuel in factories, offices, homes and vehicles; and the cellular structure of the city which reduces heat diffusion. The efficiency of these factors is controlled by a number of meteorological elements, including cloud amount, preceding and present regional temperatures, humidity, wind velocity and direction and the extent and morphology of the urban area.

Being the sum of so many varied influences, the degree of warming of the city's air is very variable. The intensity of the heat-island, its extent and form change in sympathy with variations in the above mentioned factors but in spite of the ever-changing form of the mass of warm air, there are discernible variations of a periodic nature. These cover time scales ranging from hours to years.

The temperature difference between a city and the surrounding rural districts is generally strongest by night as Figure 1 shows. Bayfordbury, in the

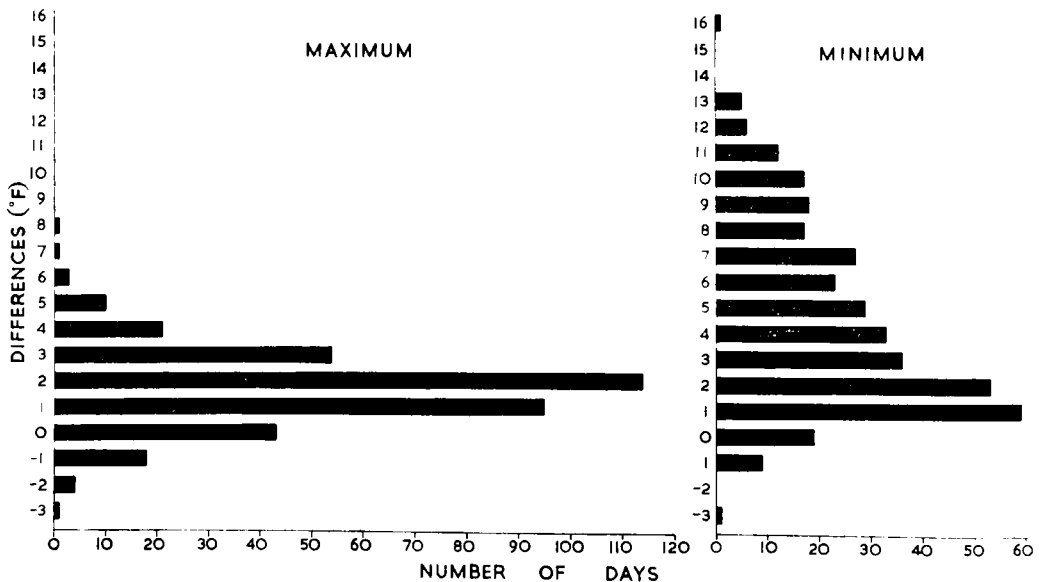


FIGURE 1—DIFFERENCES IN MAXIMUM AND MINIMUM TEMPERATURES,  
KENSINGTON-BAYFORDBURY, 1959

(Reproduced by courtesy of the Hon. Editor of *Geography*)

green belt north of London, is 140 feet higher than Kensington in the centre and under normal lapse rate conditions we should expect a difference owing to altitude of about  $0.5^{\circ}\text{F}$ . The generally higher differences in minimum temperatures than in maximum temperatures is immediately obvious. During 1959 there were 76 occasions with a difference in minimum temperatures of  $8^{\circ}\text{F}$  or more, although the median value was  $4^{\circ}\text{F}$  and the mode  $1^{\circ}\text{F}$ . Extreme differences in minimum temperatures were  $-3^{\circ}\text{F}$  and  $16^{\circ}\text{F}$ . By contrast, the median difference in maximum daily temperatures at the two stations was much less, namely  $2^{\circ}\text{F}$ , varying between  $-3^{\circ}\text{F}$  and  $8^{\circ}\text{F}$ . It will be noted that on a number of occasions both during the day and night, Bayfordbury, a rural station, was warmer than Kensington in central London. Many such instances can be explained in terms of the locations of fronts or local differences in cloud amounts (perhaps for very short periods on a generally cloudy day) or through pollution and fog density contrasts. Others are more difficult to understand and not all of the explanations given for similar features in other cities are applicable.<sup>1</sup>

But although the margins of the heat-island normally parallel those of the built-up area, the mass of warm air is rarely symmetrical and Kensington only infrequently lies in its peak area. This seems to be in the Stoke Newington, Islington, Shoreditch, Hackney and Bethnal Green districts of the north-east. This is owing both to the intensity of urban development in these areas and the frequent displacement of peak intensities by the prevailing south-westerly winds. Two distributions will serve to show the primary characteristics of daytime and night-time temperatures in London. The maps (Figures 2 and 3) are based upon readings from 17 official climatological stations sending returns to the Meteorological Office, and from a close network of 32 newly established stations in the lower Lea valley district of the north-east. These formed part of the Lea Valley Climatological Survey which operated between January 1959 and December 1960. In January 1961 the Survey was enlarged to cover the whole London district and re-named the London Climatological Survey.<sup>2</sup> Broken lines are used where the station network was open and some uncertainty existed in the precise location of isotherms.

Figure 2 shows the pattern of maximum temperatures on Saturday, 27 June 1959. One cannot be certain that this distribution is instantaneous, although thermograph traces at several stations within and beyond the city margin indicate negligible differences in the timing of maximum temperatures.

At mid-day on 27 June 1959 a small depression centred over Ireland was moving east. A northward-moving warm front lay across northern England and in the London region, winds of 10 to 15 knots blew from between south-south-west and south-west. There was a seven-eighths cover of cumulus and stratocumulus cloud. The associated heat-island was intense by daytime standards with an extreme anomaly of  $8^{\circ}\text{F}$  (though temperatures at Kensington and Bayfordbury differed by only  $5^{\circ}\text{F}$ ) but the complicated, cellular temperature pattern is typical of daytime conditions. Pockets of warm and cold air, reflecting closely built-up and open urban areas as well as an irregular and constantly changing pattern of thermals, no doubt existed on all scales from several square miles to a few square yards. Only in the north-east was the station network close enough to record even the largest of these. Extensive cloud and moderate turbulence no doubt limited the heat-island's intensity.

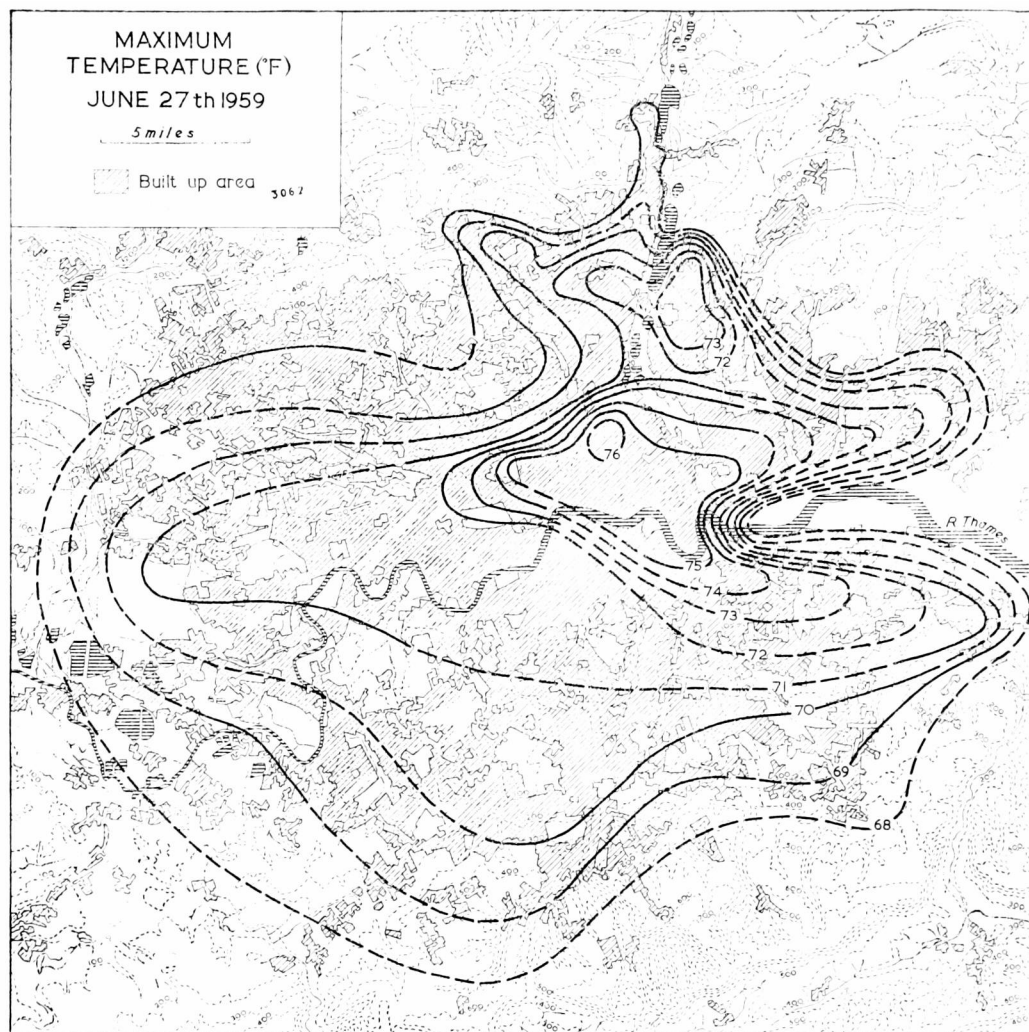


FIGURE 2—MAXIMUM TEMPERATURE ( $^{\circ}\text{F}$ ) ON 27 JUNE 1959

Wind controls are very obvious. In south-west London, winds of 10 to 15 knots were associated with strong vertical heat diffusion which led to weak thermal gradients in these areas, although the complicated interlacing of houses and open spaces so characteristic of the south-west suburbs no doubt intensified the effect. In the north-east, leeward part of the city, near-surface wind-speeds were less and local urban development is characterized by closely spaced nineteenth century and early twentieth century terrace houses with few open spaces and possessing a high thermal capacity. Winds were warmed as they moved north-east to the inner suburbs of the lower Lea valley where temperatures were further increased owing to the above mentioned atmospheric and geographical conditions. The result was a displaced heat-island centre with the highest temperatures in Islington and Shoreditch and steep thermal gradients along the north-east city limits. It seems likely that local reverse, thermally induced winds occasionally pulse along these margins, moving toward the centre of the heat-island but soon halted by friction with the serrated surface of the city<sup>3,4</sup>. These winds may have sharpened temperature gradients between



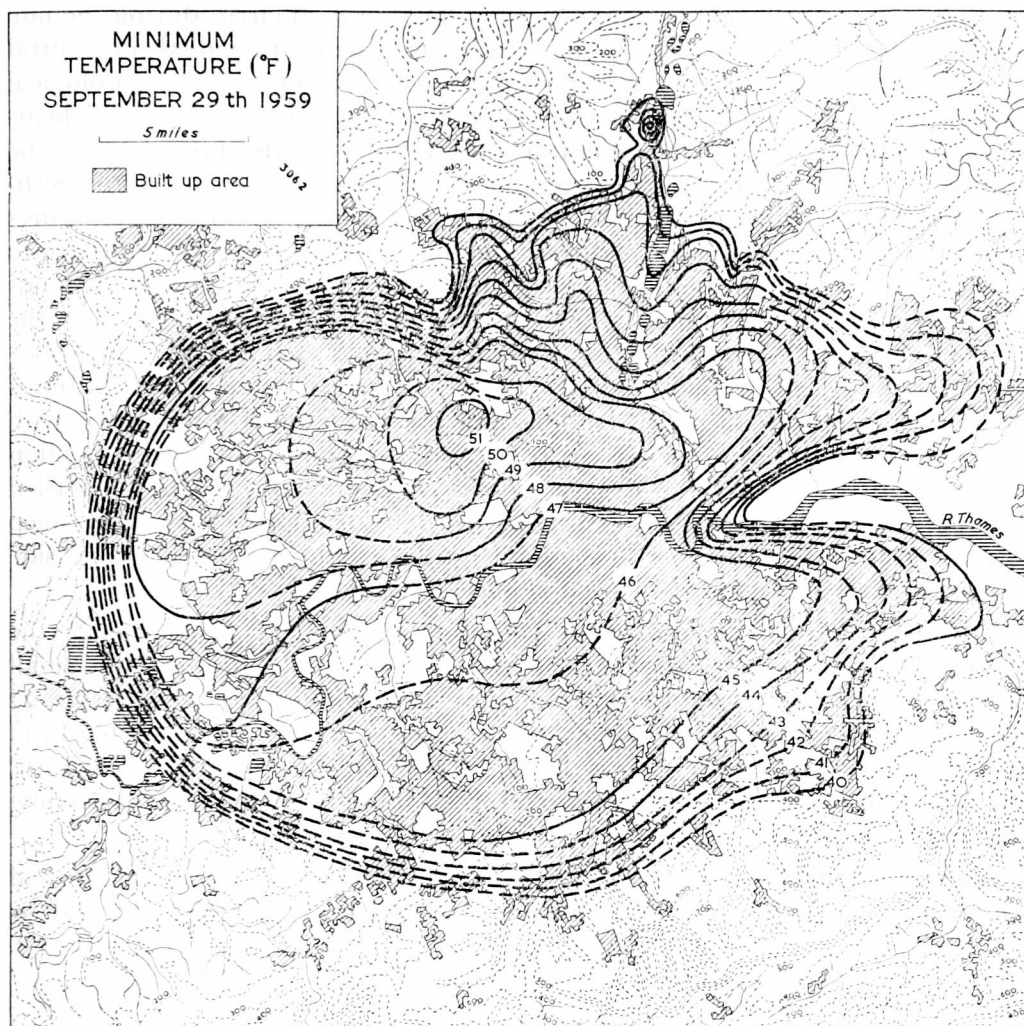


FIGURE 3—MINIMUM TEMPERATURE ( $^{\circ}\text{F}$ ) ON 29 SEPTEMBER 1959

the closely settled districts of West Ham, Greenwich and Woolwich and the open marshlands of lower Thames-side, for there is some evidence that near-surface currents, similar in genesis to sea-breezes, frequently blow westward along the Thames towards the peak of the heat-island. Together with reduced frictional drag, these may account for the light easterly breezes one experiences near the river below Westminster on days when there is hardly any air movement in central districts. Owing to the reduction of wind speeds on the leeward side of the city, such local winds are more frequent there than along windward margins.

Night-time heat-islands tend to be stronger and simpler in form, the latter mainly because turbulence is generally weaker than during the day and local variations in cloud cover are less regionally differentiating. Figure 3 shows a situation typical of the more intense night-time heat-islands. During the night of 28–29 September 1959, Great Britain lay on the western fringes of an anti-cyclone centred over Poland and covering most of Europe. In the London region, winds of about five knots backed from south-east to north-east during

the night; the only cloud was a two-eighths cover of high cirrus during the late evening and early morning. Light winds (near-calm prevailed in central London) and almost clear skies allowed the full interplay of meteorological factors contributing to urban-rural temperature contrasts and a 11°F heat-island developed with peak temperatures displaced towards Hampstead in the north-west. North-west suburbs were about three degrees warmer than south-east districts at comparable distances from the centre. Lower temperatures above the Lea floodplain in north-east London were probably owing more to its open nature than to the downflow of chilled air, for although cool air tends to move down from open high ground such as the flanks of Epping Ridge, the air ponds against the margins of low-lying urban areas such as Waltham Abbey where its movement is almost halted. Extensive frost-hollows are rarer in built-up areas owing both to urban heating and the mechanical interference with airflow<sup>5,6</sup>, but open areas such as the parks and commons of south-west London are frequently two or three degrees cooler at their centre than the settled districts around their margins. As in the previous example, remarkably steep thermal gradients border the heat-island on the north-western, leeward, side of London, and above the open areas of lower Thames-side in the east.

In less favourable meteorological conditions than on 27 June 1959 or the night of 28–29 September 1959, heat-islands are weakly developed. Only small anomalies accompany wind speeds of more than about 14 knots (above 22 knots London temperatures usually equal those outside), extensive banks of thick cloud (a factor more critical by night than day for in summer, at least, the reduction of net radiation is greater), high humidities, and cool preceding or present weather.

**Seasonal changes.**—An analysis of the differences in daily maximum and minimum temperatures at Kensington and Bayfordbury during 1959 and by

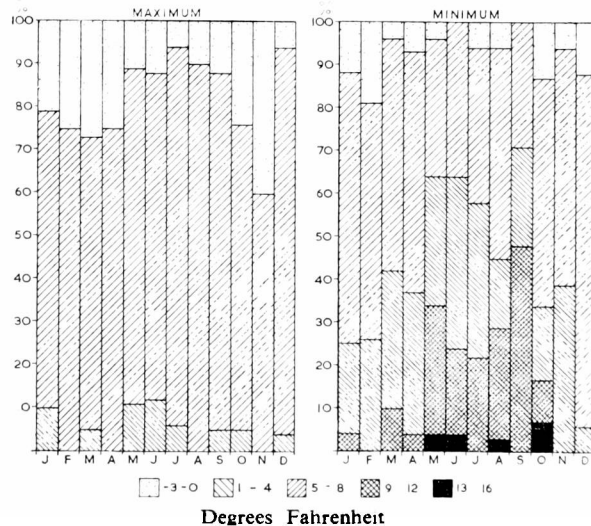


FIGURE 4—DIFFERENCES IN MAXIMUM AND MINIMUM TEMPERATURES, KENSINGTON-BAYFORDBURY, 1959

months reveals seasonal variations in the intensity of London's heat-island (Figure 4). Contrasts of daily maximum temperatures show a weak tendency to a summer and early autumn maximum and spring minimum but, as already

noted, differences in maximum temperatures at Kensington and Bayfordbury were generally small throughout the year.

Differences in daily minimum temperatures were not only greater but showed a pronounced and more regular seasonal variation with a summer and autumn maximum and a winter and early spring minimum. The substantial differences of January 1959 were probably owing to an unusually sunny month. This pattern is typical of most years although differences were sometimes small.

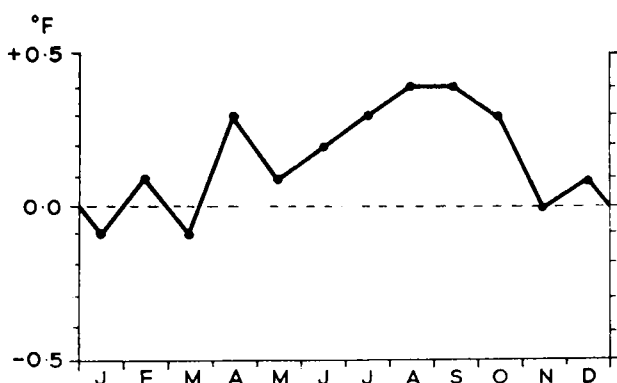


FIGURE 5—DIFFERENCE IN MAXIMUM TEMPERATURES, KENSINGTON-WISLEY, 1921-50

Mean monthly maxima and minima differences at Kensington and Wisley for the period 1921-50 show the same general pattern of change as during 1959 (Figures 5 and 6). Bayfordbury's records begin in 1953 and cannot be used in such long-period analyses.

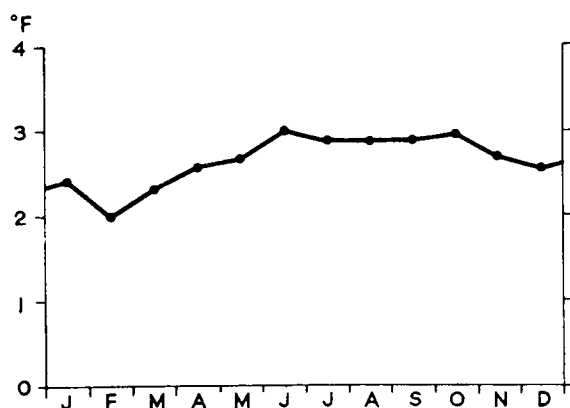


FIGURE 6—DIFFERENCE IN MINIMUM TEMPERATURES, KENSINGTON-WISLEY, 1921-50

**Annual changes.**—Lengthening the time scale once more, the differences in mean annual maxima and in mean annual minima at Kensington and Wisley between 1921 and 1960 are shown in Figures 7 and 8. Differences in mean annual maxima at the two stations were small in all years, varying between  $-0.6^{\circ}\text{F}$  (in 1944) and  $1.0^{\circ}\text{F}$  (in 1959). The difference in mean annual minimum temperatures at Kensington and Wisley between 1921 and 1960 varied between  $1.9^{\circ}\text{F}$  (in 1924) and  $3.2^{\circ}\text{F}$  (in 1929 and 1933).

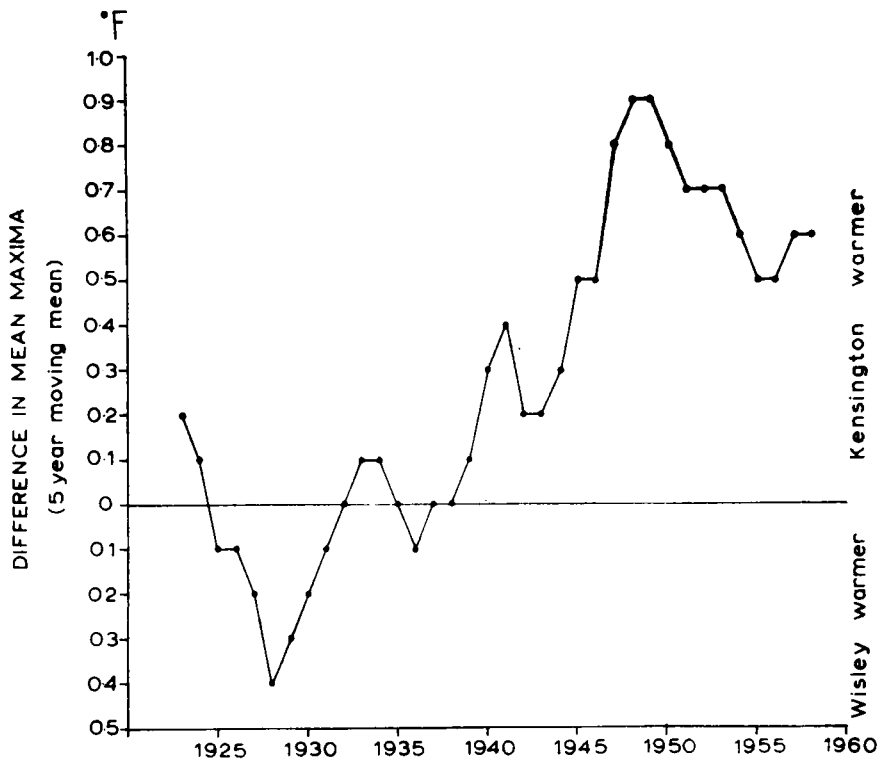


FIGURE 7—DIFFERENCE IN MAXIMUM TEMPERATURES, KENSINGTON-WISLEY, 1921-60

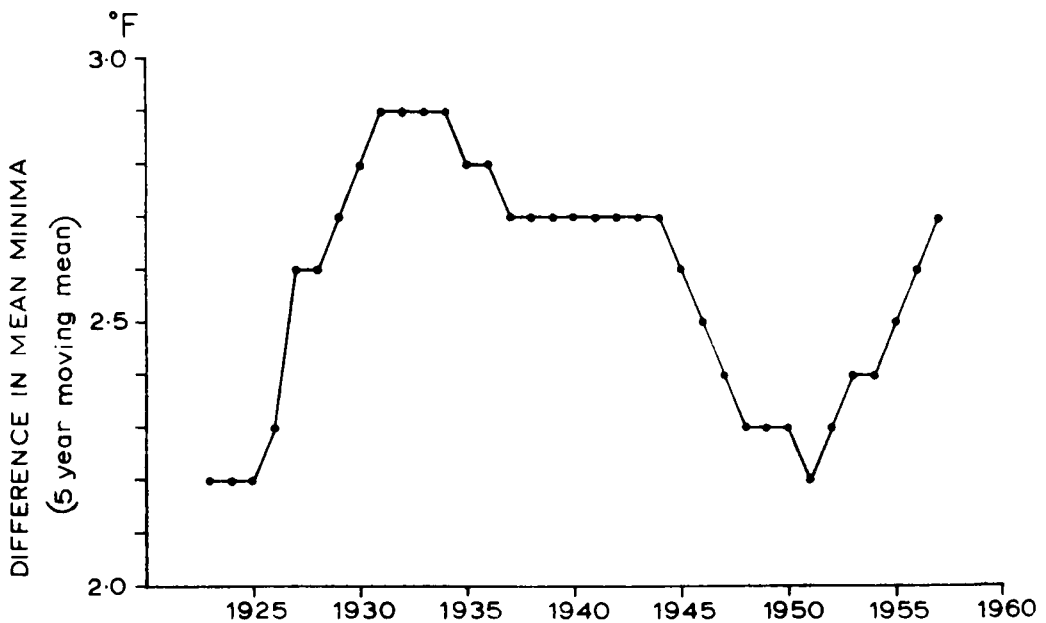


FIGURE 8—DIFFERENCE IN MINIMUM TEMPERATURES, KENSINGTON-WISLEY, 1921-60

**Conclusions.**—The intensity of London's heat-island shows significant variations over diurnal, seasonal and annual time scales, and recognizable periodic trends occur in spite of perturbations imposed by irregular changes in weather. Amongst these trends are the marked contrast between daytime and night-time intensities and, only a little less pronounced, the differences between

seasons: changes from year to year are smaller and less regular. The form of these variations throws some light on the relative importance of the several factors leading to urban-rural temperature contrasts.

At dawn, air temperatures within and above London will usually be several degrees higher than in its rural envelope (the anomaly is usually greatest shortly before dawn) but the city air fails to warm as quickly as that above the fields and woods of the green belt. This is partly owing to differences in heat capacity and conductivity between the city-fabric and the vegetation-covered soils; partly to the effect of a haze hood above London intercepting radiation from the sun; and partly to the strong mechanical turbulence of air in contact with city buildings mixing the warmer air near the ground with the cooler air above. For these and other less important reasons temperatures around London soon reach values very near those in the centre and maximum temperatures are little different. By night, however, these same factors cause a more rapid fall of temperature in rural areas than in the city and of very great significance is the heat retained by the buildings and surfaced roads. This warms the air within and immediately above the city, and being part back-radiated from the walls of tall buildings, serves to diminish the net rate of cooling. The supreme importance of thermal capacity contrasts between urban and country districts also explains the summer and early autumn peak of London's heat-island intensity—a time of the year when the pollution haze is weakest and when the combustion within the city is least. It is almost certain that London's heat-island is mainly owing to heat retained by the fabric of the city to be released later, thus giving the typical night-time and summer and autumn maxima.

Annual changes reflect yearly changes in those aspects of the general climate bearing upon heat exchange processes. This is most clearly seen in the case of the larger minimum temperature contrasts. The cool, unsettled and generally cloudy years from 1922 to 1924 were no doubt mainly responsible for the low values of the night-time urban anomaly in those years, while the wet, somewhat stormy years from 1946 to 1948 and in 1950 and 1951 probably account for the weak heat-islands at these times. The years 1933 and 1934 were milder and calmer than the preceding years and drier than those which immediately followed. These features influence the degree to which the several factors producing the urban-rural anomaly are effective, and are no doubt the main determinants of annual changes in the intensity of London's heat-island.

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## A NEW PRECISION ANEROID BAROMETER

By C. HINKEL, B.Sc.

**Abstract.**—A new type of precision aneroid barometer is briefly described. Test results both for outstation and headquarters trials are given.

**Description of the instrument.**—A two-stage aneroid capsule (A) (see Figure 1) made of beryllium-copper alloy is rigidly fixed at one side. The other side is free to move with changes of air pressure and deflects a pivoted bar (B) which is maintained in contact with the free side of the capsule by the hairspring (C). The bar pivot is mounted in jewelled bearings and the hairspring causes the bar to exert, on the capsule, a pressure which is only a very small fraction of that imposed by a conventional system of gears and levers. The displacement of the

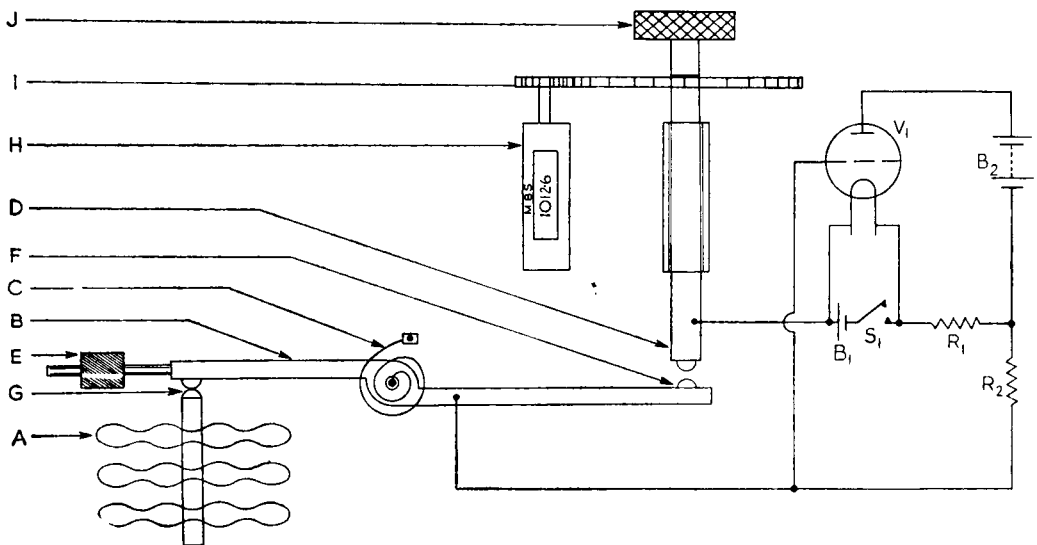


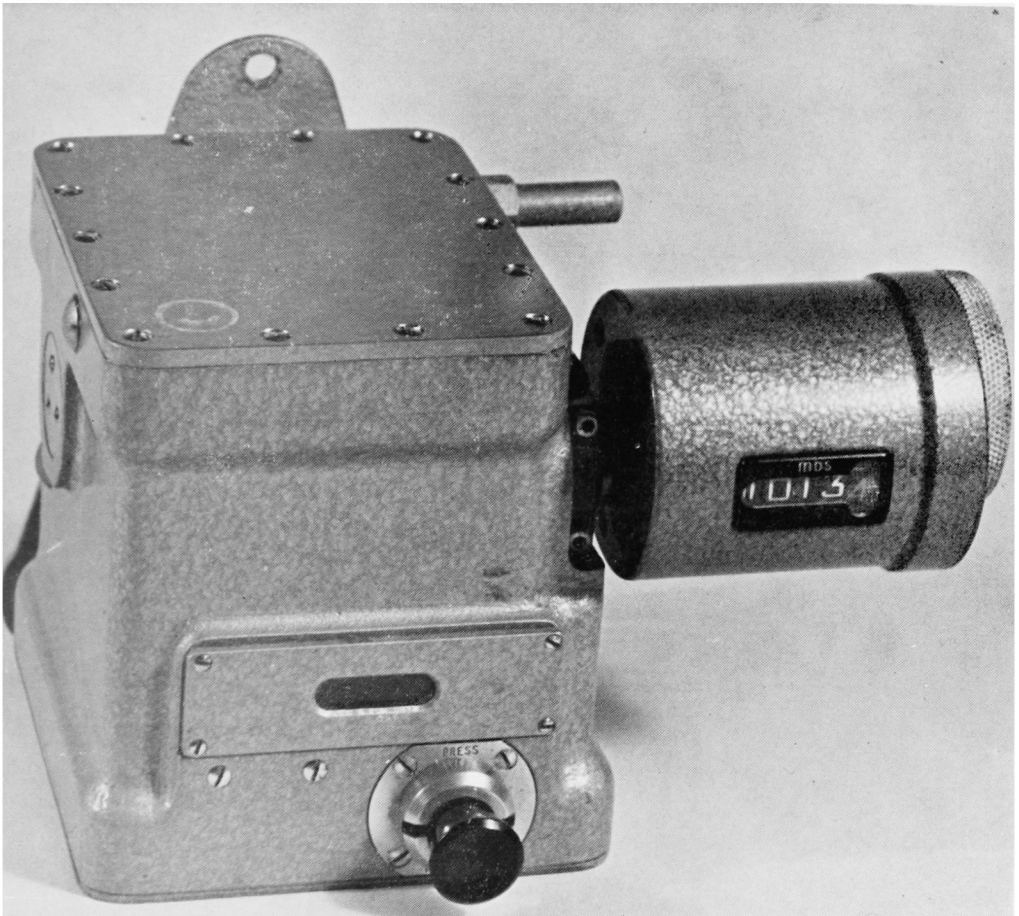
FIGURE 1—SCHEMATIC DIAGRAM AND CIRCUIT OF PRECISION ANEROID BAROMETER

- |   |                                 |       |                                 |
|---|---------------------------------|-------|---------------------------------|
| A | aneroid capsule assembly        | I     | gearing                         |
| B | pivoted arm                     | J     | operating knob                  |
| C | hairspring                      | $V_1$ | "magic-eye" indicator type DM70 |
| D | micrometer-type spindle and nut | $S_1$ | switch                          |
| E | counterbalance                  | $B_1$ | battery, 1.5V                   |
| F | sliding electrical contacts     | $B_2$ | battery, 60V                    |
| G | mechanical contacts             | $R_1$ | resistance                      |
| H | digital display                 | $R_2$ | resistance                      |

other end of the bar, caused by movement of the capsule, is measured by the micrometer screw (D) graduated directly in millibars and tenths. Contact between the bar and the micrometer is sensed electrically and displayed by means of a cathode-ray indicator tube. The assembly is enclosed in a metal case which can be completely sealed from the ambient air if required. The micrometer drum is situated on the outside of the case. The instrument covers the pressure range from 930 mb to 1055 mb.

The initial tests were carried out at headquarters using the manufacturers' prototype, but all subsequent tests were performed on production models embodying a number of improvements. One of these was the replacement of the micrometer by a counter giving a digital presentation of the pressure in whole millibars and tenths.

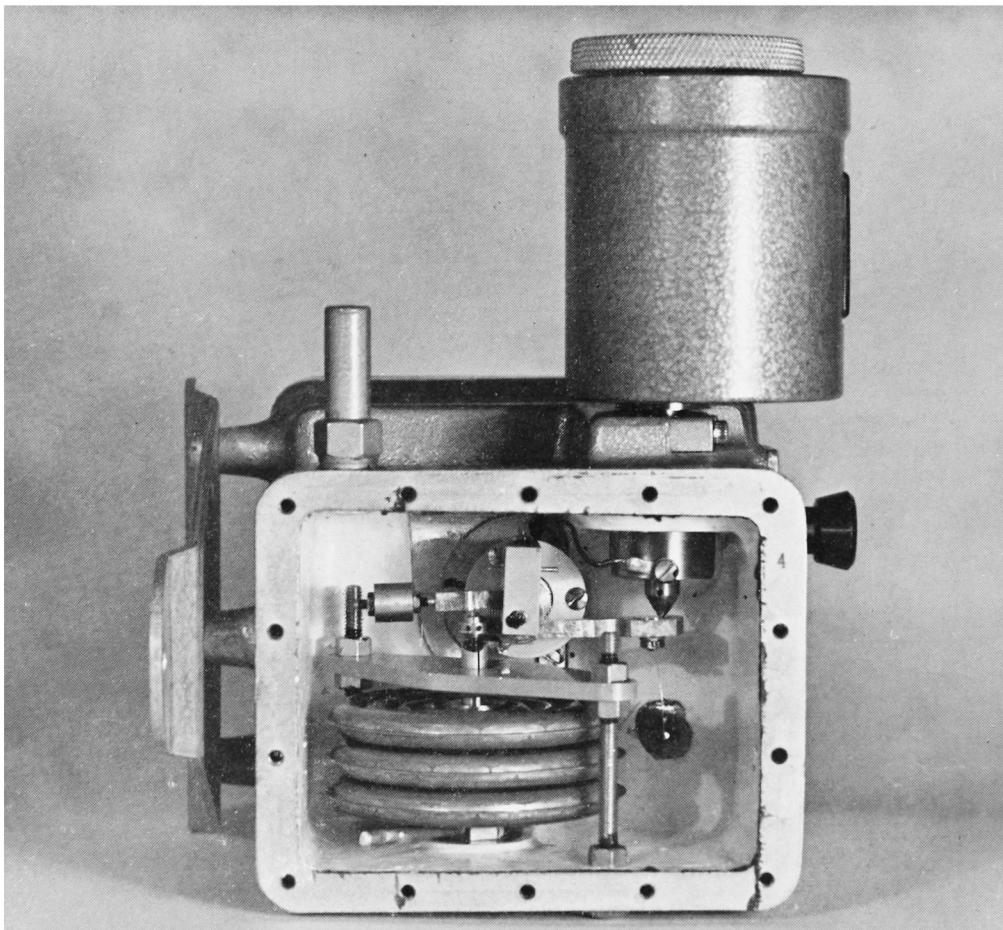
*To face p. 154*



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PLATE I—GENERAL VIEW OF NEW PRECISION ANEROID BAROMETER

*To face p. 155*



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PLATE II—VIEW OF INTERIOR OF NEW PRECISION ANEROID BAROMETER



General views of the instrument are shown in Plates I and II between pp. 154-155.

**Trial procedure.**—Each of the aneroid barometers used in the trials was tested at atmosphere pressure by comparison with a mercury barometer, simultaneous readings of each instrument being taken once or twice daily. The trials fall naturally into three parts:

- (i) The manufacturers' prototype was tested over a period of about three months. It was then sent by road to the Ocean Weather Ship Base at Greenock and back. No special packing precautions were taken. The instrument in its box was placed on the seat beside the driver and left there for the whole journey. Unusually bad road conditions existed on the northern half of the route and the aneroid received extremely harsh treatment. On return it was allowed a week to settle down and then a further set of readings was taken.
- (ii) A production instrument was sent to each of four outstations for three months' comparison with the station mercury barometer, simultaneous readings of both being taken twice daily. At the end of the period the instruments were returned to headquarters, the micrometers were replaced by a counter and the instruments sent back to their respective outstations for a further three months' trial.
- (iii) Ancillary tests were undertaken to clarify the results obtained from the outstations. In addition the aneroids were all read simultaneously before despatch to and on return from the outstations. Only the aneroid tested at outstation "C" showed a mean difference greater than 0.1 mb between these two sets of readings.

As part of the trial procedure under (ii) above the aneroids were transported, packed in their transit cases, by road, rail, air and even through the ordinary parcel post. No ill-effects or changes in calibration resulted from this treatment although they underwent similar rough treatment to that experienced by the prototype.

**Results and discussion.**—Mean differences of the readings of the mercury barometers minus those of the corresponding aneroids were computed together with the standard deviations of the differences. These results are set out in Table I.

The initial comparison shows that the prototype underwent a change of calibration of about 0.6 mb after its rough handling during transport. The difference was found to be purely a shift of zero. As a result of this experience the makers introduced modifications in the production instruments to prevent similar shifts and so far none has occurred.

The results from the outstation trials, using production instruments fitted with micrometers, require little comment. The somewhat large mean difference at station "A" is now known to be due to the mercury barometer being in error. The large standard deviation at station "D" is somewhat disappointing, but otherwise the standard deviations compare very favourably with that for two mercury barometers which is given in the "Handbook of meteorological instruments"<sup>1</sup> as 0.18 mb.

The trial using production instruments fitted with counters was of interest in that it allowed the pressure to be read directly as a unique set of figures. Station "D" again shows an unexpectedly large standard deviation. This was so large that the instrument was given a separate test on its return to headquarters.

TABLE I—COMPARISON OF ANEROID AND MERCURY BAROMETERS

Aneroid fitted with micrometer			
	Mean difference (mercury-aneroid) mb	Standard deviation mb	No. of observations
<i>Initial Comparison in HQ Instruments Branch</i> (makers prototype)			
Before road journey	0.09	0.15	137
After road journey	0.73	0.10	125
<i>Comparison at four outstations</i> (production models)			
"A"	0.51	0.20	169
"B"	0.06	0.15	184
"C" before 7 February 1961	0.08	0.19	184
"C" after 7 February 1961	—	—	—
"D"	0.13	0.29	156
All occasions		0.21	693
Aneroid fitted with counter			
	Mean difference (mercury-aneroid) mb	Standard deviation mb	No. of observations
<i>Comparison at four outstations</i> (production models)			
"A"	0.47	0.15	171
"B"	0.13	0.09	194
"C" before 7 February 1961	0.56	0.15	133
"C" after 7 February 1961	0.25	0.10	44
"D"	0.40	0.42	163
All occasions		0.23	705
<i>Miscellaneous tests</i> (production models)			
Aneroid at "D" in HQ test room	0.13	0.05	62
Aneroid at "C" in HQ test room	0.53	0.09	45

The results, summarized in the last section of Table I, point to causes other than the aneroid, such as large temperature variations in the attached thermometer of the mercury barometer and difficulty in reading either barometer. The other instruments all showed an improved standard deviation and the unanimous opinion of all four stations was that they preferred the instrument fitted with the counter to that with the micrometer.

At outstation "C" an unaccountable shift on zero occurred between 6 and 7 February 1961. Zero shifts of this type have been known to occur with aneroid barometers before. The magnitude of the shift was 0.31 mb and is the only one of its kind to occur with this particular type of aneroid over a period of nearly two years. The instrument was tested on return and it was confirmed that a zero shift had taken place. The altered zero has been retained and has subsequently shown no sign of returning to the original value. The causes of shifts of this type are not yet fully understood, but are thought to be due to the relief of strains in the capsule material introduced during manufacture and which have not been completely eliminated by artificial ageing.

A comparison of two aneroids was also undertaken. Instruments (fitted with counters) returned from outstations were used for this purpose. This showed that the two instruments were mutually very consistent, the mean difference of 67 pairs of readings being 0.16 mb with a standard deviation of 0.03 mb.

**Conclusions.**—The aneroid barometers tested at headquarters have shown that they are at least as accurate as a standard mercury Kew pattern barometer. They are considerably easier to read and outstation opinion confirms this view. The results from station "D" are not consistent with those from the other three but, if they are ignored for the reasons given above, the instrument fitted with the counter shows a slightly improved performance over the micrometer version. The instruments are able to stand up to a considerable amount of rough treatment and the problem of transporting them is much simpler than for a mercury barometer. The zero shift of the instrument used at station "C" shows that a check against a standard at regular intervals is desirable in order to detect any shifts of this nature. It is, however, easier to carry out this check with the aneroids than with mercury barometers.

**Acknowledgements.**—Acknowledgements are gratefully made to Miss M. K. Hinds and Mr. P. B. Sarson for their assistance with the computer programme and to the members of both the headquarters and outstation staff who carried out the barometer trials.

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## MEAN WINDS OVER SINGAPORE, WITH SPECIAL REFERENCE TO THE 40,000 AND 50,000 FOOT LEVELS

By P. F. McALLEN

**Introduction.**—In the first part of this paper an attempt is made to show, as clearly as possible, the seasonal changes in the tropospheric wind régime over Singapore using monthly mean winds between the surface and 50,000 feet obtained from radar-wind observations and pilot-balloon ascents. In the second part the ten-year mean winds at 40,000 and 50,000 feet over Singapore are discussed in detail.

**Vertical cross-section.**—The vertical cross-section Figure 1 depicts the mean winds over Singapore classified into quadrants. In the construction of this diagram the mean winds at the surface and 1500 feet were taken from pilot-balloon observations made between 0630 and 0830 local time at Kallang Airport by the Malayan Meteorological Service for the period 1934-41. Although it had originally been expected that wind observations made between these hours might be biased slightly by a land-breeze effect, these wind observations are in close agreement with the mean surface observations made over a five-year period at the Royal Air Force Station, Changi at 1030 local time when the wind is unlikely to be affected by either land- or sea-breezes, and it is considered therefore that these winds can be accepted as representative means. The mean winds at levels above 1500 feet are also based on observations made by the Malayan Meteorological Service. The mean winds at standard pressure

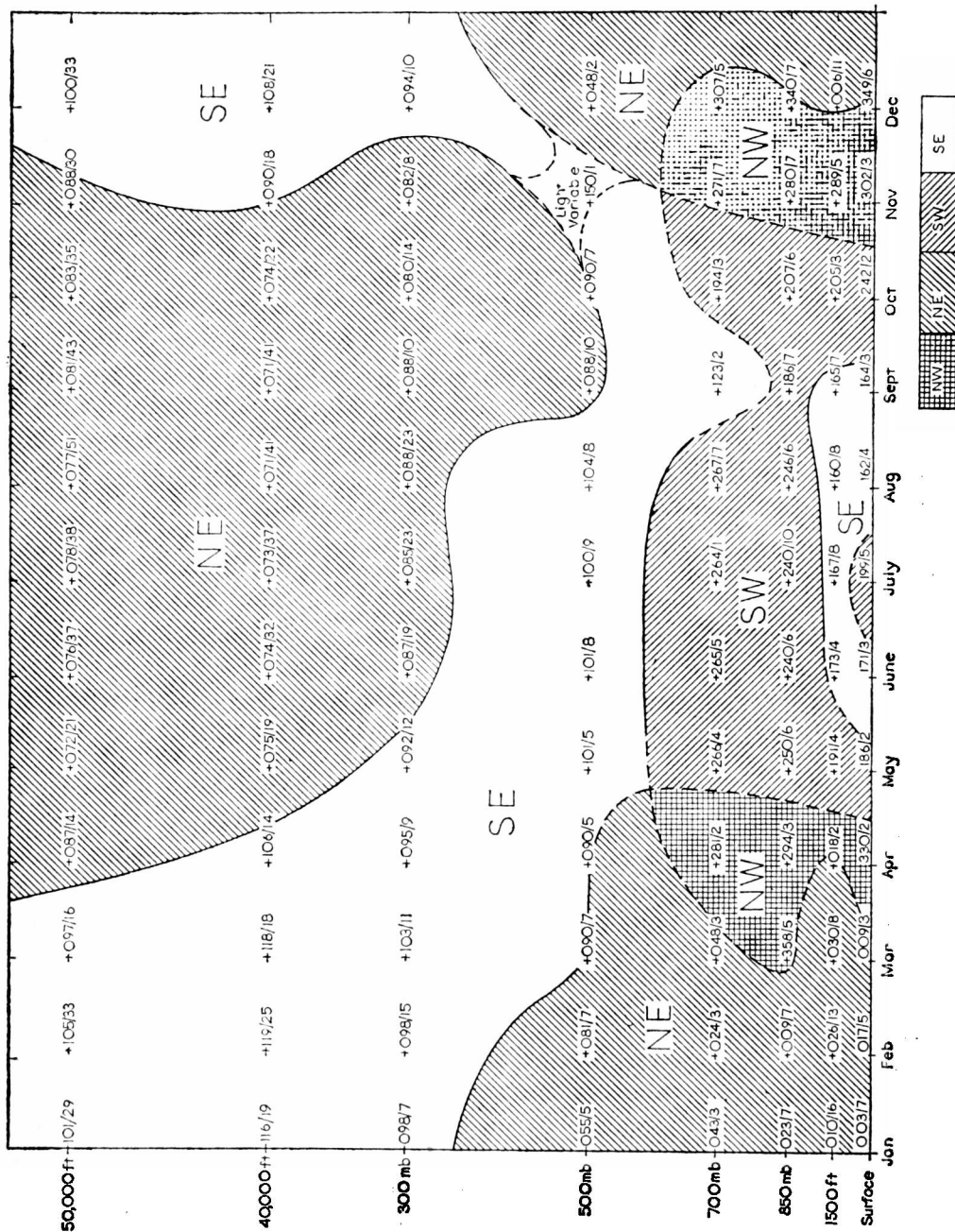


FIGURE 1—VERTICAL CROSS-SECTION OF VECTOR MEAN WINDS, DIVIDED INTO QUADRANTS, OVER SINGAPORE  
Broken lines divide quadrants where velocity is less than 5 knots.

levels shewn in Figure 1 refer to the period February 1955 to December 1959, while the mean winds at 40,000 and 50,000 feet are for the ten-year period from January 1951 to December 1960.

It is of interest to see that the popular conception of two inter-monsoon periods over Singapore, centred about April and November and associated with light and variable winds, is not strictly true, for the winds, though light, are during these periods consistently westerly or north-westerly from the surface to between 700 and 500 millibars.

During the south-west monsoon there is a suggestion of south-easterly winds both at the surface and 1500 feet in June, August and September. This is most probably due to the incursion of the south-east trades across the equator, although it may also be due, but to a lesser degree, to the diversion of the south-westerly flow at low levels by the land mass of Sumatra. As far as Singapore is concerned this monsoon could be more accurately described as the south or south-east monsoon.

In view of these observations it may be more reasonable to say that the low-level winds over Singapore fall into four main divisions, namely north-easterly winds between January and March, light north-westerlies in April, southerlies between May and October and north-westerlies in November and December.

The increase in the wind at low levels normally associated with the north-east monsoon is masked at the surface by the sheltering effect of south-east Malaya, but is well marked in December, January and February at 1500 feet. It is also apparent that these north-easterly winds, which extend from the surface to about 20,000 feet during the winter months, are very light above 5000 feet.

**Mean winds at 40,000 and 50,000 feet.**—In a previous paper Clarkson<sup>1</sup> presented an analysis of winds at 40,000 feet and 50,000 feet over Singapore, based on all available radar-wind observations between January 1951 and April 1955. Clarkson's statistics are shown in Tables I and II at *A*. The statistics of monthly mean winds at 40,000 feet and 50,000 feet over a period of ten years, January 1951–December 1960 are also shown in Tables I and II at *B*. The vector mean wind  $\mathbf{V}_R$  was obtained for each month from the mean components  $V_N$  and  $V_E$ , and the standard deviations  $\sigma$  were computed when combining the individual years by the method prescribed by Brooks and Carruthers.<sup>2</sup>

Since at both 40,000 feet and 50,000 feet the shorter- and longer-period means are for the most part in very close agreement, it is proposed to concentrate mainly on those results which show a marked difference.

**Constancy.**—One means of expressing the steadiness of the wind, which is shown in Tables I and II, is by the constancy  $q$  which is defined as the percentage ratio of the vector mean speed to the scalar mean speed  $V_S$ . With this definition, if the wind over a period of a month remained always in the same direction and only the speed varied, then the constancy would be 100 per cent. However, if the wind came with equal frequency and strength from opposing directions, then the constancy would be zero.

Palmer<sup>3</sup> has stated that a constancy of 90 per cent may be obtained in the most steady trade winds, whilst a constancy of 97 per cent is obtained in some months in the Krakatoa easterlies at a height of 30 kilometres between 15°N and 15°S, and in the Von Berson westerlies, a narrow band at approximately 20

TABLE I—MONTHLY MEAN WINDS AT 40,000 FT OVER SINGAPORE

		No. of obs.	$V_S$ kt	$V_N$ kt	$V_E$ kt	$V_R$ deg.	$V_R$ kt	$\sigma$ kt	$q$ %
Jan.	A	65	23.3	-7.2	20.2	110	21	13.1	92
	B	355	23.0	-8.3	16.8	116	19	17.4	81
Feb.	A	78	28.0	-10.7	23.3	110	26	17.2	92
	B	347	27.8	-12.2	21.6	119	25	15.4	90
Mar.	A	85	20.8	-6.4	15.1	110	17	16.2	79
	B	384	21.7	-8.6	15.9	118	18	15.2	83
Apr.	A	79	19.4	-2.0	16.3	100	16	14.1	85
	B	368	17.7	-3.7	13.1	106	14	14.4	79
May	A	50	22.4	3.4	17.9	80	18	15.7	81
	B	381	22.3	4.9	18.6	75	19	16.7	85
June	A	52	34.5	9.9	31.1	70	33	15.9	95
	B	375	34.3	8.8	30.8	74	32	17.9	93
July	A	53	39.2	14.1	34.6	70	37	15.6	96
	B	395	39.0	11.0	35.8	73	37	16.7	95
Aug.	A	46	44.2	14.4	39.9	70	42	17.6	96
	B	393	42.4	13.4	38.5	71	41	17.3	97
Sept.	A	44	41.4	14.1	37.2	70	40	17.5	96
	B	316	36.9	11.2	33.4	71	35	15.9	95
Oct.	A	51	25.9	3.8	23.9	80	24	15.1	93
	B	368	25.3	6.3	21.7	74	22	16.9	87
Nov.	A	67	25.0	-4.0	23.0	100	23	13.0	93
	B	407	21.5	0.2	18.3	90	18	16.2	84
Dec.	A	47	22.3	-5.6	18.6	110	19	15.3	87
	B	393	24.2	-6.5	20.3	108	21	15.0	87

A. Clarkson's means for observations at 0300 GMT between January 1951 and April 1955.

B. 10-year means, January 1951 to December 1960 i.e. Clarkson's means A plus means for observations at 0300 and 1500 GMT from May 1955 to March 1957 and at 0001 and 1200 GMT from April 1957 to December 1960.

TABLE II—MONTHLY MEAN WINDS AT 50,000 FT OVER SINGAPORE

		No. of obs.	$V_S$ kt	$V_N$ kt	$V_E$ kt	$V_R$ deg.	$V_R$ kt	$\sigma$ kt	$q$ %
Jan.	A	64	39.7	-6.0	36.3	100	37	22.1	93
	B	330	34.9	-5.2	28.0	101	29	29.5	83
Feb.	A	75	38.6	7.7	28.7	100	30	33.9	77
	B	329	39.8	8.5	31.3	105	33	30.0	83
Mar.	A	85	23.9	3.7	9.4	70	10	26.0	42
	B	380	25.1	2.1	16.1	97	16	24.3	63
Apr.	A	78	23.9	2.9	19.5	80	20	19.6	82
	B	356	20.6	0.8	13.9	87	14	18.9	68
May	A	48	30.2	9.8	25.2	70	27	18.0	90
	B	366	25.9	6.8	20.3	72	21	20.3	81
June	A	46	36.1	7.9	31.4	80	32	25.3	90
	B	344	39.9	9.1	35.9	76	37	24.0	93
July	A	45	41.6	6.7	37.8	80	39	23.9	93
	B	354	40.6	8.1	37.2	78	38	23.2	94
Aug.	A	35	53.0	12.4	49.6	80	51	25.0	97
	B	355	52.6	11.2	49.7	77	51	24.3	97
Sept.	A	41	52.1	9.6	49.1	80	50	28.2	96
	B	291	46.5	6.7	42.9	81	43	23.2	93
Oct.	A	48	38.4	6.6	35.8	80	36	20.9	95
	B	342	36.3	4.1	34.4	83	35	19.2	95
Nov.	A	68	42.4	-0.3	41.7	90	42	20.7	98
	B	393	34.9	0.9	30.2	88	30	23.8	86
Dec.	A	39	32.5	-2.6	29.6	100	30	22.3	91
	B	361	31.2	3.8	22.4	100	23	28.0	74

kilometres centred about  $2^{\circ}\text{N}$ . By these standards, therefore, it can be seen in Tables I and II that the winds at 40,000 feet and 50,000 feet over Singapore show a surprisingly high constancy, especially in August at the height of the south-west monsoon, when the steadiness of the wind at both these levels equals that of the Krakatoa easterlies and Von Berson westerlies.

The lower constancy figures of 63 per cent and 68 per cent respectively at 50,000 feet reflects the incursion of stratospheric westerly winds into the high tropospheric easterly flow in March and April. In March 1960 westerly winds were observed at 50,000 feet on 16 days; in March 1956 westerly winds were observed on 13 days at 50,000 feet and on 6 days at 40,000 feet. Similar incursions have been observed at 50,000 feet in the winter months, the most outstanding case being a period of 17 consecutive days of westerly winds between 29 November and 15 December 1958.

It is obvious from this that means with incomplete observations taken over a short period could give misleading results, and Clarkson was perhaps fortunate in the period he was obliged to select. Had he used a similar set of observations covering the period 1956 to 1960 he would have obtained results, especially for November and December, which would have borne a less close relationship to the longer-period means.

*Zonal component ( $V_E$ )*—Clarkson's<sup>1</sup> means for the shorter period suggest that the easterly zonal component is least in the month of March at both 40,000 feet and 50,000 feet. The ten-year means, however, show that this component, due mainly to the incursion of the westerlies discussed above, is a minimum at both levels in April. The longer-period means are therefore consistent with Figure 1 which shows that April and not March is the transitional month.

There is close agreement between the long- and short-period means, both of which give August maxima of approximately 40 knots and 50 knots at 40,000 and 50,000 feet respectively at the peak of the south-west monsoon period. However, the suggestion of a secondary maximum in January in the shorter period appears over the longer period to occur in February at both levels. Both this secondary maximum in February and the minimum zonal component in April are also found at the 300-millibar level (see Figure 1).

*Meridional component ( $V_N$ )*.—In Figure 2 the mean meridional components at 40,000 feet and 50,000 feet for the ten-year period are shown for each month, and for interest the mean meridional components at standard pressure levels for the period February 1955 to December 1959 have also been incorporated. It can be seen from this diagram that the seasonal reversal in the meridional flow occurs three to six weeks after the equinoxes, and it is interesting to note that the reversal in the meridional flow in April first sets in at 50,000 feet.

The maximum high-level meridional flow in August and February, during the south-west monsoon and north-east monsoon respectively is consistent with the picture of the meridional vertical cross-section presented by Goldie.<sup>4</sup>

**Summary of the general wind régime.**—The wind régime over Singapore up to about the 600–500-millibar levels shows clearly the dominating influence of the two well known monsoons, namely the north-east monsoon from late November or early December to mid or late March, and the south-west monsoon from late April or early May to the end of October. As far as Singapore is concerned, however, the northern hemisphere summer monsoon

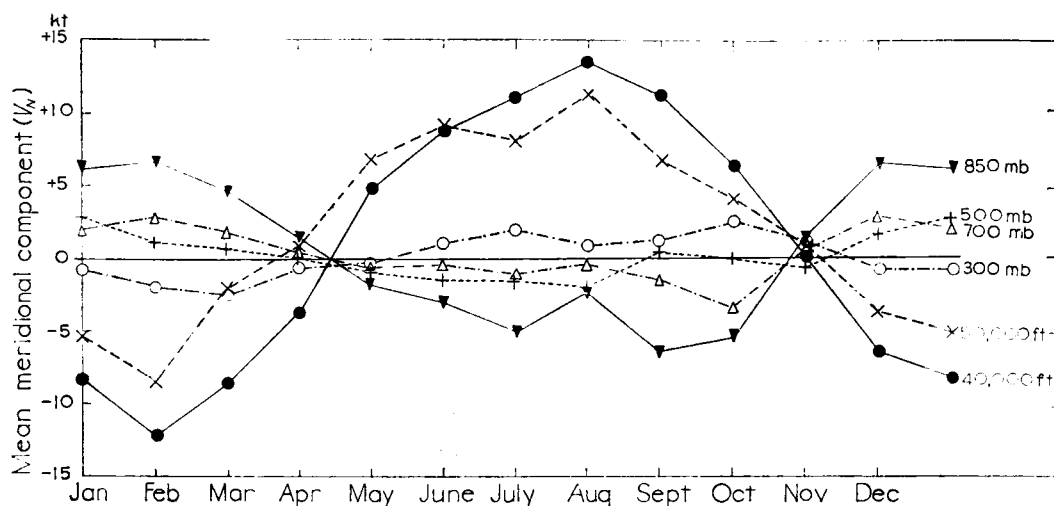


FIGURE 2—MEAN MERIDIONAL COMPONENTS ( $V_N$ ) AT 40,000 AND 50,000 FT AND STANDARD PRESSURE LEVELS OVER SINGAPORE

could be more accurately described as the south or south-east monsoon. These monsoons are separated by two short transitional periods centred about April and November respectively, when the winds from the surface to at least 700 millibars are light north-westerlies.

Above the 600–500-millibar level the winds are predominantly easterly. At 40,000 and 50,000 feet they show a high constancy between June and October, especially in August. However, incursions of stratospheric westerly winds chiefly at 50,000 feet occur in March and April and occasionally during the winter months, the most outstanding case noted in recent years being in November–December 1958.

The maximum zonal component at both 40,000 feet and 50,000 feet occurs in August with a secondary maximum at both levels in February. The maximum meridional components also occur in the same months. The seasonal reversal in the meridional flow occurs three to six weeks after the equinoxes at 40,000 feet and 50,000 feet and the reversal in April appears to set in first at 50,000 feet. This latter effect is not however apparent in the other reversal in October–November.

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## FOG AT LIVERPOOL AIRPORT

By G. J. BINDON

**Introduction.**—The diurnal and annual variation of fog and thick fog at Liverpool Airport has been studied and compared with the results of similar investigations for other stations.



Liverpool Airport is situated 80 feet above mean sea level on the north bank of the river Mersey, six miles upstream from the centres of Liverpool and Birkenhead. Within a very close semicircle round the north side of the airport are many sources of both domestic and industrial smoke; over three miles across the river, on the Wirral Peninsula, are further concentrations of industry. Smoke from industrial east Lancashire, and to some extent from the Midlands also, affects visibility at Liverpool.

**Analysis.**—Two diagrams have been prepared based upon a statistical analysis of occasions when the visibility was less than 1100 yards (Figure 1), and less than 220 yards (Figure 2) at each hour of the day over a period of 15 years, from September 1945 to August 1960. Each month was subdivided into

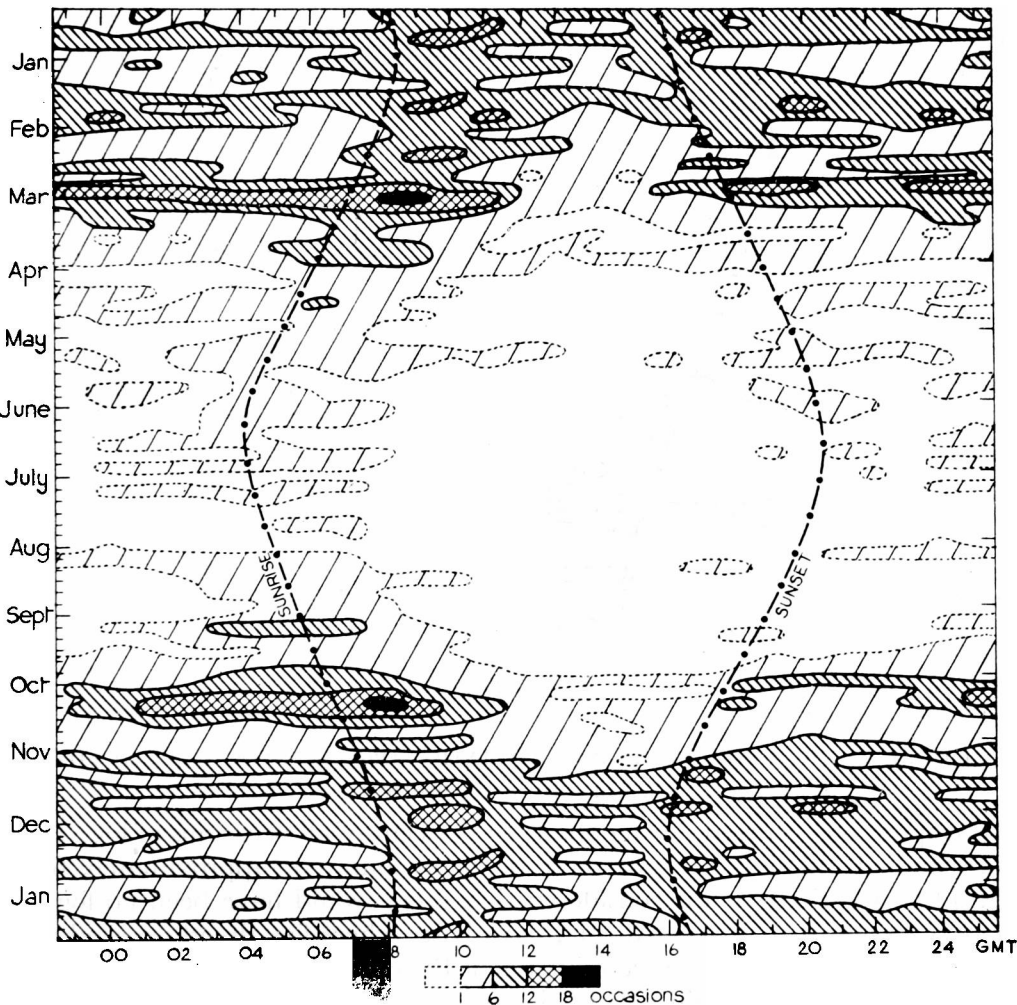


FIGURE 1—DIURNAL AND ANNUAL VARIATION OF FOG (< 1100 YD.) AT LIVERPOOL AIRPORT

six 5-day periods, 1st–5th, 6th–10th and so on; a proportional reduction of totals was necessary in the last period of the 31-day months and also a proportional weighting at the end of February. The isopleths in Figures 1 and 2 show the number of occasions on which visibilities within the specified ranges

occurred at each hour in 15 years, i.e. out of 75 possible occasions in any 5-day period. Tables I and II reproduce the hourly figures as monthly and annual totals.

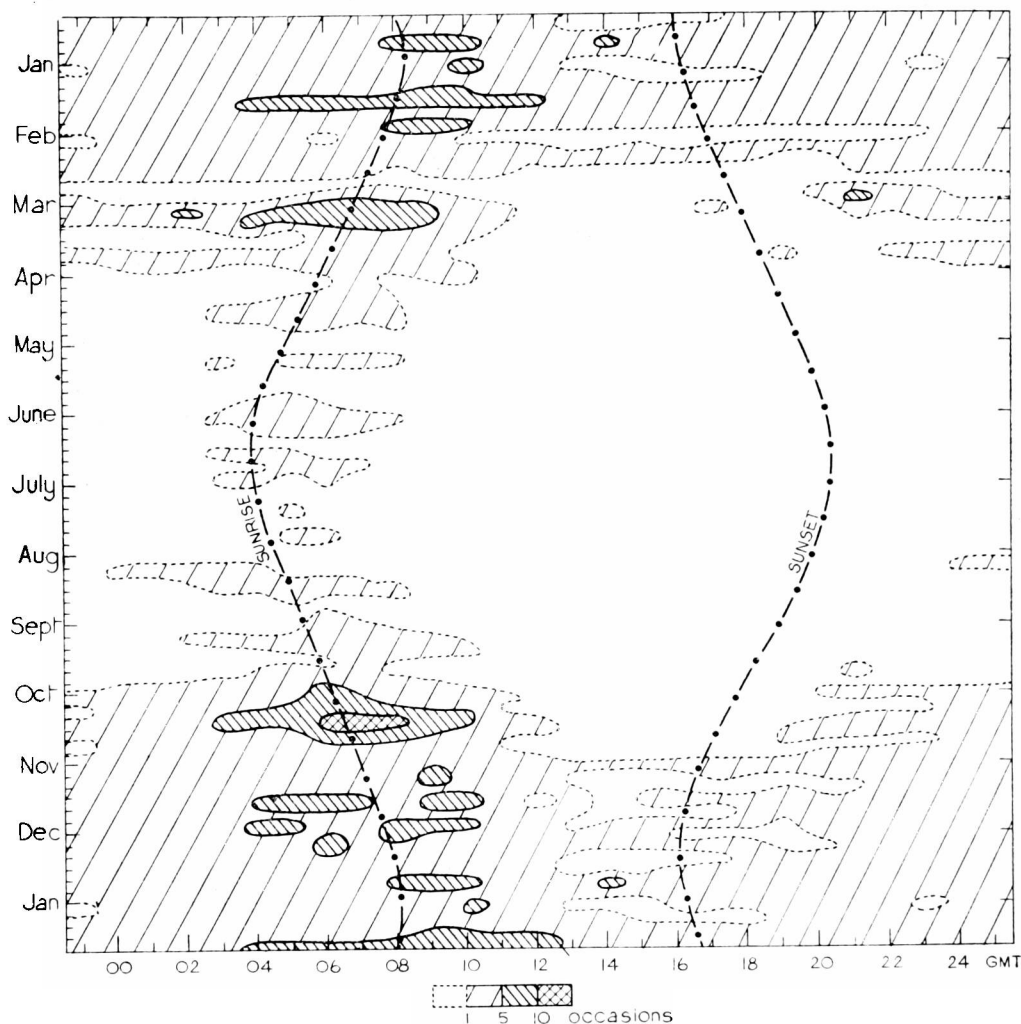


FIGURE 2—DIURNAL AND ANNUAL VARIATION OF THICK FOG (< 220 YD) AT LIVERPOOL AIRPORT

Precipitation occurred during about 13 per cent of all occasions of fog. These were studied individually, and those occasions omitted (approximately 6 per cent of total) where it was considered that there would have been no fog had there been no precipitation. Mostly, those cases where fog already existed prior to the onset of precipitation were included. Precipitation was rarely considered a factor in reducing visibility to thick fog.

The outstanding features of fog at Liverpool Airport appear to be:

- (i) Two peak periods of fog frequency.
  - (a) From late February to early March from about sunset to 1100 GMT with maximum at 0800–0900 GMT.
  - (b) From early to mid-October, chiefly between midnight and 1000 GMT with maximum at 0800 GMT.

TABLE I—FREQUENCY OF OCCASIONS WITH VISIBILITY BELOW 220 YARDS AT  
LIVERPOOL AIRPORT, SEPTEMBER 1945–AUGUST 1960

Time GMT	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
frequency of occasions													
0000	19	8	7	..	..	..	..	1	1	12	13	12	73
0100	22	8	10	..	..	..	..	1	1	13	18	12	85
0200	20	8	10	..	..	..	..	2	4	15	17	17	93
0300	19	7	11	1	1	3	..	3	6	21	17	17	106
0400	22	7	14	1	1	5	..	3	7	26	21	16	123
0500	21	5	15	4	4	6	2	3	9	27	18	17	131
0600	19	7	17	5	4	6	1	3	10	34	17	24	147
0700	19	9	21	4	2	4	..	2	12	36	18	20	147
0800	24	7	18	4	1	1	..	1	7	34	24	24	145
0900	27	9	16	1	..	..	..	..	4	25	25	23	130
1000	31	4	9	1	..	..	..	..	1	15	23	19	103
1100	22	4	2	..	..	..	..	..	..	8	14	16	66
1200	22	3	..	..	..	..	..	..	..	5	8	10	48
1300	12	1	..	..	..	..	..	..	..	..	5	10	28
1400	10	1	..	..	..	..	..	..	..	..	3	11	25
1500	9	2	..	..	..	..	..	..	..	..	5	8	24
1600	11	1	..	..	..	..	..	..	..	..	5	10	27
1700	14	2	1	..	..	..	..	..	..	..	7	8	32
1800	12	2	..	..	..	..	..	..	..	..	7	11	32
1900	13	1	1	..	..	..	..	..	..	1	8	9	33
2000	15	3	..	..	..	..	..	..	..	4	9	8	39
2100	15	8	2	..	..	..	..	..	1	5	10	9	50
2200	15	8	4	..	..	..	..	..	..	6	11	10	54
2300	16	8	6	..	..	..	..	..	..	9	9	12	60
Total	429	123	164	21	13	25	3	19	63	296	312	333	1801
hours per month													
Mean	28.6	8.2	10.9	1.4	0.9	1.7	0.2	1.3	4.2	19.7	20.8	22.2	
Average number of hours per annum: 120													

TABLE II—FREQUENCY OF OCCASIONS WITH VISIBILITY BELOW 1100 YARDS AT  
LIVERPOOL AIRPORT, SEPTEMBER 1945–AUGUST 1960

Time GMT	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
frequency of occasions													
0000	45	31	29	2	3	2	1	2	8	36	38	39	236
0100	41	29	31	2	2	3	1	1	10	44	36	39	239
0200	35	28	28	3	4	2	1	4	12	51	35	38	241
0300	35	28	30	6	3	7	1	5	16	50	32	38	251
0400	39	22	30	8	9	10	1	9	19	48	37	30	262
0500	34	24	32	10	12	12	4	17	23	46	38	29	281
0600	32	23	48	22	11	13	3	16	28	56	35	33	320
0700	35	35	55	14	8	6	4	14	29	60	50	35	345
0800	48	46	58	10	6	3	..	3	19	64	55	46	358
0900	55	58	46	5	2	..	..	1	13	50	59	63	352
1000	57	43	36	2	1	..	..	1	7	36	56	63	302
1100	54	28	22	1	1	..	..	..	3	20	42	53	224
1200	50	21	10	2	1	..	..	..	..	16	34	39	173
1300	40	17	6	..	1	..	..	..	..	7	28	34	133
1400	29	16	5	..	..	..	..	..	..	4	26	40	120
1500	35	13	4	..	..	..	..	..	..	5	26	41	124
1600	39	16	9	..	1	..	..	..	..	8	36	55	164
1700	52	27	14	1	..	..	..	1	..	18	56	61	230
1800	51	40	28	1	1	..	..	1	1	26	39	43	231
1900	49	31	32	2	5	1	..	..	4	28	42	45	239
2000	47	27	25	5	6	1	..	..	1	27	46	47	232
2100	47	29	24	5	2	3	..	1	3	23	48	44	229
2200	44	31	24	4	1	2	1	1	4	22	45	41	220
2300	41	31	24	3	1	..	..	1	6	29	40	40	216
Total	1034	694	650	108	81	65	17	78	206	774	979	1036	5722
hours per month													
Mean	68.9	46.3	43.3	7.2	5.4	4.3	1.1	5.2	13.7	51.6	65.3	69.1	
Average number of hours per annum: 381													

- (ii) The diurnal maximum frequency occurs about one and a half hours after sunrise. There is also a smaller evening peak about half to one hour after sunset.
- (iii) The high frequency of thick fog in January is followed by the relatively low frequency in February.
- (iv) The low fog frequency from early April to mid-September has a minimum frequency in July. The few thick fogs during these months are mostly confined to the hours 0300–0900 GMT.

The use of 5-day periods rather than 15-day or monthly periods has resulted in more precise diagrams. It may be therefore that some small differences noticed, when comparing individual weeks on other diagrams, could be accounted for by the differing methods used.

Considering the normal causes of fog formation relative to the length of night, it is not surprising to find a marked similarity between the results for Liverpool and those published for London Airport<sup>1,2</sup>, Northolt<sup>3</sup> and Leeuwarden<sup>4</sup> (the Netherlands). There are however some differences worthy of note:

- (i) Leeuwarden, being in a rural situation, has the diurnal maximum fog frequency at sunrise or a little earlier. London, Northolt and Liverpool airports, all greatly affected by smoke pollution, have their maximum frequency between one and three hours after sunrise.
- (ii) During winter evenings at the London stations there is normally a gradual increase in fog frequency from about dusk, reaching a secondary peak around midnight. At Liverpool this secondary peak is usually just after sunset, followed frequently by an improvement in visibility an hour or two later. The reason for this earlier peak at Liverpool may possibly lie in the closer proximity of local smoke sources to the airport.
- (iii) From a closer study of 1058 occasions of visibility below 1100 yards it was discovered that in 45 per cent of fogs in the range 220–1100 yards and in  $7\frac{1}{2}$  per cent of thick fogs (below 220 yards) the relative humidity was less than 95 per cent. Fogs with relative humidity 65–75 per cent were not uncommon. On rare occasions, with relative humidity as low as 60 per cent, visibility fell to around 400 yards. This contrasts with Buma's<sup>4</sup> statement that in almost all cases of fog at Leeuwarden the relative humidity was more than 95 per cent.
- (iv) The annual mean number of hours of fog at Liverpool and Leeuwarden are very similar, being 40 per cent fewer than at London or Northolt.
- (v) The ratio of "all occasions of fog" to "thick fog occasions" at Liverpool, London and Northolt is about 3 : 1. Compared to fog frequencies for some stations in south-east England estimated by Shellard<sup>5</sup>, this appears to be about normal. Even at Leeuwarden this ratio appears to be maintained, so far as can be deduced from figures available, in spite of the generally high humidities mentioned earlier.

The individual yearly total hours of fog at Liverpool showed no pattern or trend towards an increase or decrease over the 15 years; the totals varied between 264 and 636 hours per annum. It may be interesting in future years to note the trend when smokeless zones become more widespread on Merseyside.

*To face p. 166*



*Photograph by R. M. Brass.*

O.W.S. "WEATHER REPORTER" IN A HEAVY SEA

*To face p. 167*



*Photograph by R. M. Brass.*

WINCH HOUSE ON THE FO'C'SLE DECK OF O.W.S. "WEATHER REPORTER"

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## TECHNIQUES FOR HIGH-LEVEL ANALYSIS AND FORECASTING OF WIND AND TEMPERATURE FIELDS

By C. L. HAWSON

The subject of upper air analysis and the forecasting of wind and temperature fields is fundamental to many modern techniques for forecasting the weather itself. It is also directly important to the aviation forecaster. Thus it is a subject which concerns nearly all forecasters, whether they are employed on a national or local scale, or forecasting for civil or military flights.

The publication under review \* is therefore of great potential interest to meteorologists in many fields. This book is both interesting and informative, packed with ideas and opinions, and written by an international collection of authors which only the World Meteorological Organization (WMO) could command. It comprises 187 pages and consists of an assembly of reports contributed by twelve Members, describing the techniques they have developed for the analysis and forecasting of wind and temperature fields from 1000 millibars up to pressure levels ranging from 300 to 100 millibars. Also included is a subject index, in the form of a table, which facilitates ready reference to the way any particular facet of the subject is dealt with by any of the contributing Members. It is a worthy member of the series of WMO "Technical Notes". However, we must accept the fact that there is as yet no universally adopted method; perhaps a complete exposition of every country's methods would prove not only too voluminous and monumental to be enclosed in a single cover, but also distinctly tedious to absorb.

It may be disappointing that at this stage individualism is still rampant and that different methods are championed by different countries, but this is not really surprising. The subject is complex, touching many aspects of meteorology and although the aim for all seems the same, this would be so only if perfect and complete precision in analysis and in forecasting were possible. Such perfection is not possible at present. In consequence each particular service tends to concentrate its efforts on those issues most useful to its own customers. In service offices it is better thus, rather than reduce this effort to encompass detail of less immediate practical value to the users. To illustrate the point, a forecaster at London Airport, faced with an Atlantic westbound flight in a situation involving a headwind jet stream, is less concerned with the detailed, level-to-level structure of the jet stream than with the detailed vertical and

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\* *Techniques for high-level analysis and forecasting of wind and temperature fields*, WMO Technical Note No. 35. 11 in. x 8½ in., pp. xvi + 187, illus., World Meteorological Organization, Geneva, Switzerland, 1961. Price: Sw. fr. 8.—.



horizontal fields well away from the jet core. He concentrates rightly on the space and time through which his particular customers will choose to fly. He is of course deeply concerned with the location and evolution of the jet stream because these vitally affect his problem. Nevertheless he is much less interested in the detail around the jet core than an American forecaster faced with the same weather situation, but with an eastbound flight for which the same jet stream is a tailwind. Even forecasters on the same side of the Atlantic, dealing with transatlantic aircraft, but at different stations, face different problems because of circumstances such as available manpower or the heights and periods of the forecasts. The common requirement is a safe, efficient and economic service. The different viewpoints of the Members influence their contributions.

Volumes of individual papers are often marred by errors, inconsistencies and repetitions. This book has its share and the items vary widely in their quality and length. The U.S.S.R. contributes three pages of concentrated information which give the bare bones of their methods and provide six references to enable those interested to pursue their study and clothe the skeleton. The U.S.A. contributes an informative eight-page survey, plus a 24-page appendix discussing the tropopause-vertical wind shear chart at length without recourse to further references. Every meteorologist will not accept all the U.S.A.'s basic assumptions, but their chapter makes stimulating reading. It is encouraging to learn that they find the most useful tool in analysis is the use of the numerically prepared 12-hour barotropic prognosis from the preceding set of charts. Introduction of this prognosis ensures a rigorous and consistent time continuity.

The Canadian contribution is the longest. It begins with seven pages, with references in the text, devoted to the broad aspects of their particular problems, including a section on the organization of forecast offices. It follows with five appendixes, dealing with different aspects of the subject, running to another 39 pages. This is perhaps the most enjoyable section to read. It is written in a forthright manner from a practical viewpoint, contains the fruits of much experience and sets down pithy advice to guide the reader. It is not implied that the reviewer agrees with all their statements or that the contribution is beyond criticism, but here is stimulating material which can hardly fail to challenge meteorologists who are ever ready for the chance to examine expert opinion critically in the light of their own experiences.

The German service contributes an excellent twenty pages of lucid information and references. It includes assessments of the accuracy of forecasts and a table for deriving the level and speed of the maximum wind from the winds at 300 and 200 millibars. It is evident that the Germans are actively engaged in research in this field, a point they underline by giving the date of their contribution, July 1959.

The contribution of the United Kingdom and Northern Ireland is a commentary on the organization of work and the methods used at London Airport. Again the date of the contribution, October 1960, is given, and it is clear that, although the present methods provide a reasonably satisfactory means of meeting the operators' requirements at the moment, an open mind is maintained for the future and efforts to improve on present standards are being made. One would like to have seen some mention here of their efforts to build down to the 200-millibar level from the more conservative level of 100 millibars. Perhaps it is too



early for this to be reported but, in summer at least, the idea has considerable attraction and nowhere in the book is such a possibility suggested.

The book is further enriched by contributions from British East African Territories, France, French Equatorial Africa, Israel, the Netherlands, Norway and the Sudan. These all contain something of interest, extend the regions covered to include equatorial areas and outline a method of numerical analysis suitable for use on an electronic computer. It is difficult however to understand how the Sudanese technique, arising from a suggestion by Grimes involving dynamic pressure, is actually applied in practice. It is also difficult to accept the Sudanese suggestion that upper winds tend to increase their speeds by approximately 50 per cent at night.

Despite the multiplicity of the methods described some factors stand out: (a) the pre-eminence of the mean sea level surface pressure chart, because this is the level for which the observations are most numerous, most rapidly available and least subject to error; (b) the linking of the topographies of the standard levels by the relative topographies or thickness patterns, to form a clear idea of the three-dimensional thermal structure and to build up the higher-level analyses; (c) the necessity for critical, scientifically guided assessment of the errors inherent in the measurements of the various upper air parameters; (d) the prime importance of continuity, both in time and vertically from level to level; (e) not least the need for progressive revision. These are the major factors which raise the quality of analysis and forecasting.

To sum up, the note is a useful assembly of articles to stimulate experienced workers and guide newcomers in the upper air fields. It tells of the days when contour and thickness lines manipulated by human forecasters are the main tools and of the days when mathematicians and physicists are harnessing electronic computers to challenge human forecasters, but have not completely encompassed the problems of atmospheric motion within the confinement of a practical mathematical discipline. It will be some years yet before scientific trials weed out the weaker methods.

## **METEOROLOGICAL OFFICE DISCUSSIONS**

### **Turbulence and diffusion**

Opening the Monday discussion on 15 January 1962, Dr. F. Pasquill gave a brief survey of the history and present position of the work on turbulence and diffusion in the atmosphere. Reference was made to three important branches of the work, namely the measurement and systematic description of the turbulence, the experimental study of diffusion, and the relation between diffusion and turbulence. Emphasis was laid on the fundamental importance and practical utility of developments in the statistical approach to turbulence and diffusion, though it was pointed out that in some aspects of the problem progress still relied on the use of diffusion coefficients.

This introduction was followed by three more detailed and specific presentations. Mr. M. J. Blackwell of the Meteorological Office Research Unit, Cambridge, talked about the vertical diffusion of water vapour near the ground, especially in the light of previous and current work at Cambridge. Attention was focused largely on the aerodynamic method of determining evaporation

from the vertical profiles of wind speed and humidity, and especially on the difficulties and limitations which arise from thermal stratification of the atmosphere and lack of homogeneity in the relevant properties of natural surfaces. Dr. J. K. Angell of the United States Weather Bureau followed with a description of the use of constant-level balloons in studying turbulence on a much larger scale. Examples were shown of results from "transosonde" flights at the 300-millibar level over the North Pacific, and of "tetron" flights in the lower troposphere over Nevada. These techniques provide information on the Lagrangian (following the motion) aspects of airflow and in this sense are particularly relevant to the consideration of diffusion on medium or large scale. Finally Mr. N. Thompson, of the Meteorology Research Division, Chemical Defence Experimental Establishment, Porton, described recent experience with the fluorescent particle tracer method of examining medium-range diffusion. This brought out the difficulties which can arise in using a tracer material in an absolute sense when long times of travel are concerned and unexpected decay of the tracer material occurs. However such a decay does not preclude the use of the tracer in a relative sense (i.e. for defining the lateral and vertical spread of material) and results therefrom can be used to calculate the concentrations of material of negligible or specified time-decay.

The discussion, opened by the Director-General, reflected the rather specialized and complex nature of the problems. Some of the outstanding fundamental and practical issues were immediately brought to the fore in opening questions by Professor Sheppard. It was clear, to quote the Director-General, that "the work in this field had not been sterile or static, and it was characteristic that the results had thrown up more problems all the time, showing a vigorous development of the science".

F. P.

### **Climatic variation**

The second Meteorological Office discussion of the winter season was held at the Royal Society of Arts on 18 December 1961. The subject was "Climatic variation".

Mr. A. I. Johnson opened the discussion with a brief survey of some of the more important factors (astronomical, solar, etc.) which constituted possible causes of climatic variation. Subsequently he described some recent studies in which mean circulation patterns have been constructed for each January and July of the past 200 years, making use of records of atmospheric pressure from all parts of the world. These patterns have revealed an increase in vigour of the zonal circulation, apparently over the whole world and in both January and July from early in the nineteenth century to some time in recent decades.

The second opening speaker, Mr. H. H. Lamb, emphasized that apart from their intrinsic interest investigations of climatic change were of real practical value. He pointed out that they had contributed to our knowledge of the general circulation and also that meteorologists had a responsibility to establish the historical facts of climate for workers in allied fields such as archaeology and botany. Furthermore, some understanding of climatic change would be essential before any large-scale attempt to modify climate. It was even essential for interpreting the most relevant climatic trends or other statistics for advice to such concerns as the builders of long-term irrigation projects, etc. Mr. Lamb

concluded with an account of a survey of documentary evidence of the character of summers and winters in different European longitudes from A.D. 1100 to the present day.

In the ensuing discussion Professor Manley suggested further investigation of the effect of changing Atlantic sea temperatures on British climate. Mr. Veryard doubted the usefulness of these studies in forecasting future climatic trends; he preferred a dynamical approach. Various speakers referred to difficulties encountered when standard statistical methods were applied in climatology. Closing the meeting, the Director-General commented on the way in which climatological and synoptic research appeared to be drawing closer together: the work which had been described was very relevant to many forecasting problems.

H. H. L., A. I. J.

## NOTES AND NEWS

### Seminars on high-level forecasting

Seminars on high-level forecasting for turbine-powered aircraft operations over Africa and the Middle East were held in Cairo from 30 October to 17 November 1961, and in Nicosia from 21 November to 9 December 1961, under joint WMO and ICAO auspices. The purpose of the seminars was to enable forecasters to pool their knowledge and experience and so help their services to meet the growing demands for forecasts over long routes at high levels, and the exacting requirements of terminal forecasting for jet aircraft operations.

Experienced forecasters from many countries took part in programmes of practical work and attended lectures given by invited experts, under the direction in Cairo, of Professor W. Bleeker and in Nicosia, of Professor R. Scherhag. Each seminar was divided into two parts: one part dealt with the area comprising North Africa, the Mediterranean, and the Middle East as far as Pakistan; and the other part was concerned with the problems met by forecasters working at airports in tropical Africa.

The practical work included the analysis of three selected situations, each extending over several days. Participants worked in pairs to analyse surface charts, and upper air charts for standard levels from 850 millibars to 200 millibars for each day. Lively discussions followed when analyses were compared with each other and with master analyses prepared by chief analysts T. H. Kirk, Chief Meteorological Officer, Malta, and D. H. Johnson, Climatological Research Branch, Meteorological Office, Bracknell. There were two sessions for the preparation of flight forecasts over selected routes using recommended forms of flight documentation which required the preparation of prontours. In Nicosia, Professor Scherhag discovered with some delight that for one route, the mean of the high-level winds predicted independently by 15 pairs of forecasters verified precisely with the actual.

Lectures were given by Professor H. Flohn; D. V. Rao, Senior Meteorological Officer, Calcutta Airport; the chief analysts; and, in Cairo, by A. I. El-Tantawy and S. S. abd El-Hady. A wide range of topics of interest in aviation forecasting was discussed including: analysis techniques; synoptic models; thickness

patterns; cold pools; jet streams; high-altitude turbulence; high-level clouds; tropopause, maximum wind and shear charts; discontinuities; aerodrome forecasting; and climatological and objective aids.

The work of the seminars revealed old truths and fresh outlooks. The need in forecasting for painstaking, but not over-elaborate, analysis was amply demonstrated, and it was clear that the parochial approach in aviation forecasting is giving way even in its last stronghold, the tropics, as relations between middle- and low-latitude developments become better understood, and demands are met for forecasting and briefing for high-level flight stages direct from equatorial countries to Europe. The value of bringing together meteorologists fresh from the forecasting bench, to discuss techniques and problems during a working programme, hardly needs stressing. From the number of international airports represented in the list of addresses of the participants—Amman, Munich, Tel-Aviv, Abidjan, Athens, Damascus, Accra, Paris, Cairo, Tunis, Ankara, Khartoum, Belgrade, Geneva, Calcutta, Rome, Nicosia, Warsaw, Addis Ababa, Copenhagen, Beirut, Fort Lamy, Budapest, Tananarive, Malta, Lagos, Zurich, Bombay, Jedda, and Tehran—the extent of the dissemination of experience and knowledge can be gauged.

In Cairo, participants appreciated the excellent working facilities made available at the Meteorological Training Centre by the Director-General of the Meteorological Department, United Arab Republic. The seminar in Nicosia had the distinction of being the first international meeting to be held in the New Republic of Cyprus, local arrangements being made by the Chief Civil Aviation Officer. Foundations well laid by representatives of WMO and ICAO ensured full and interesting programmes both during and outside the working hours of the seminars.

Participants from the Meteorological Office were: in Cairo, R. O. Roberts (Meteorological Office Training School); and in Nicosia, P. K. D'Allenger (Akrotiri), D. Gibbons (El Adem) and R. C. Sivill (Nicosia).

Arrangements are being made for the publication of the cases studied and lectures given during the seminars. Seminars in other regions are being planned.

D. H. J.

## OBITUARY

*Mr. Ernest Harry Clarke.*—It is with deep regret that we learn of the death on 27 April 1962 of Mr. E. H. Clarke, Experimental Officer, at the age of 57. Mr. Clarke entered the Meteorological Office in 1935 as an Observer at Lympne and remained there until 1939. He was promoted to Assistant III in 1941 and to Assistant II in 1944, becoming a very keen forecaster on RAF stations. He was commissioned in the RAF in 1943 and after service in the United Kingdom was posted to 83 Group in 2nd TAF. Since his return to the Office in a civilian capacity as an Assistant Experimental Officer in 1946, and since 1949 as an Experimental Officer, he spent almost his whole career on the more remote stations, including two years at Stornoway, about six years at Lerwick, where he was in charge of the magnetic section, and seven years at Eskmeals.

He had many valuable qualities, and a real enthusiasm for his work. He took a fatherly interest in the welfare of the assistants working under him and was well liked by all who worked with him.

We offer our deepest sympathy to his widow and family.

## METEOROLOGICAL OFFICE NEWS

**Retirements.**—The Director-General records his appreciation of the services of:

*Dr. D. N. Harrison, O.B.E.* who retired from the Meteorological Office on 28 February 1962, after 35 years of service. Arriving from Balliol College, Oxford on 1 October 1926, he brought with him a knowledge of work with Professor Dobson on the early development of the ozone spectrophotometer, and a valued trophy in the form of an oar, signed by the Balliol College "Eight" of which Dr. Harrison had been a member.

After a very short period in M.O.2 in Kingsway, a branch even then responsible for public forecasts as at present, Dr. Harrison took up the more specialized aspects of observational meteorology which were to form his main interest for the remainder of his career. He spent six months at Kew Observatory, after which time he arrived at Edinburgh where he remained for the next seven years, later going to Lerwick Observatory. In 1937 he was transferred to M.O.4, then in South Kensington, until the outbreak of war and subsequently took part in the war dispersal move to Stroud. At this time M.O.4 was responsible not only for the Meteorological Office stores but also for the design of instruments, and Dr. Harrison was closely connected with the early development of the radio direction-finding system for upper wind measurement. Continuing in this line, he was posted to Larkhill in 1940, returned to M.O.4, then at Harrow, in 1947 and joined the Instrument Development section on its formation in 1948, where he remained until retirement. From 1948 until the reorganization of 1957 he served as Head of M.O.17, the upper air development branch, until its absorption into the existing M.O.16.

From the introduction of routine upper air measurements, Dr. Harrison played a considerable part in the development of the equipment, including the use of radar for upper wind measurements and the assessment of the accuracy of radiosonde and radarwind measurements. He produced several papers on the matter of upper air accuracies, the last, a massive study of a prolonged trial under routine operating conditions, being in course of publication.

For the past few years Dr. Harrison has been engaged on a complete redevelopment of the British radiosonde. Although manufactured versions of this will not be available for some while, the basic system and much of the detailed design have been completed under his guidance.

Dr. Harrison attended as principal United Kingdom delegate the first and second sessions of the World Meteorological Organization Commission for Instruments and Methods of Observation (CIMO), at Toronto, in 1953 and at Paris, in 1957 respectively. He also served as an active member of the working group set up at CIMO-I, and continued by CIMO-II, to arrange for the international comparison of radiosondes. Dr. Harrison took part in the two international field trials held in this connexion at Payerne, Switzerland.

In private life, Dr. Harrison has a variety of interests. His skill as a carpenter and model maker was demonstrated by an excellent model yacht. As an amateur photographer he won first prize at the Meteorological Office, Harrow photographic exhibition and he is currently undertaking a series of photographs of landscapes and buildings on behalf of the National Trust. Throughout his career Dr. Harrison used a carefully maintained motor-cycle as his normal means of reaching his office and achieved remarkable regularity and punctuality in battling against the most adverse conditions which could be achieved

either over Salisbury Plain or in the traffic chaos of the northern London suburbs.

Gardening and the enjoyment of classical music, both at "live" concerts and by the use of high fidelity reproductions, have formed other aspects of his interests. With such a wide and varied choice we can confidently wish Dr. Harrison the greatest possible happiness in his retirement. A. L. M.

*Mr. J. D. Ashton*, Experimental Officer, who retired on 20 February 1962, after 42 years' service. Mr. Ashton joined the Office in January 1920 as a Technical Assistant at Hounslow. He served on many aviation stations including Heliopolis and Ismailia and was mobilized as a Flight Lieutenant from 1943 until 1946. Since 1946 he has been concerned almost exclusively with Civil Aviation including postings to London (Heathrow), Eastleigh, Croydon and London (Gatwick) Airports.

*Mr. J. L. Marshall*, Experimental Officer, who retired on 28 February 1962, after 33 years' service. Although Jack Marshall did not join the Meteorological Office until 1929 he managed to become involved with meteorology during his Royal Air Force career prior to that date and joined the R.A.F. Reserve as a meteorologist in November 1927 serving at Calshot until he took up his civilian appointment. He served at many aviation stations during his career, including the period 1943-46, when he was commissioned in the Royal Air Force. He was transferred to the Instruments Provisioning Branch (M.O.4) in 1955 and remained there until he retired.

**Academic successes.**—Information has reached us that the following members of the staff have been successful in recent examinations. We offer them our congratulations.

General Certificate of Education—"A" Level

Pure Mathematics: D. H. Clark, E. Hall, K. M. Jones, J. P. Kimber,  
D. A. MacIntyre and R. E. W. Pettifer.

Applied Mathematics: J. P. Kimber.

Physics: Miss J. A. Davies and R. Ward.

## REVIEW

*Bibliography of agricultural meteorology*, edited and compiled by Jen Yu Wang and Gerald L. Barger. 10½ in. x 6½ in., pp. xi × 673, University of Wisconsin Press, 430 Sterling Court, Madison 6, Wisconsin, 1962. Price: \$6.75.

One of the first requirements of any research worker is an adequate and up-to-date bibliography in his subject. Such a reference book is especially essential in a field such as agricultural meteorology which covers two disciplines. To be reliable, the publication must be comprehensive, accurate and up-to-date.

The editors of this book, and their numerous collaborators both in the United States and elsewhere, have gone a very long way to meet this requirement. Over 10,000 references are included, covering work in 27 different languages, and a great deal of care has been taken to try and make them as accurate as possible, at times an almost impossible task.

There are two indexes, an author index and a subject index; the references are arranged by subjects with the authors in alphabetical order. If any criticism of this method of presentation had to be made, it would be that it would have

been additionally helpful to have the references under each subject heading arranged in chronological order. This not only leads the user to the latest work in the easiest manner, but also eases the manner of compilation of a future edition, which, it is greatly hoped, will eventually appear. This type of book is far too important to be confined to a once-for-all exercise, and those who have been concerned in it deserve the thanks of all workers in the subject. Every library that makes any claim to be a source of references will find this publication invaluable.

L. P. SMITH

### OFFICIAL PUBLICATION

The following publication has recently been issued:

*A course in elementary meteorology*, London, HMSO, 1962. Price: 17s 6d.

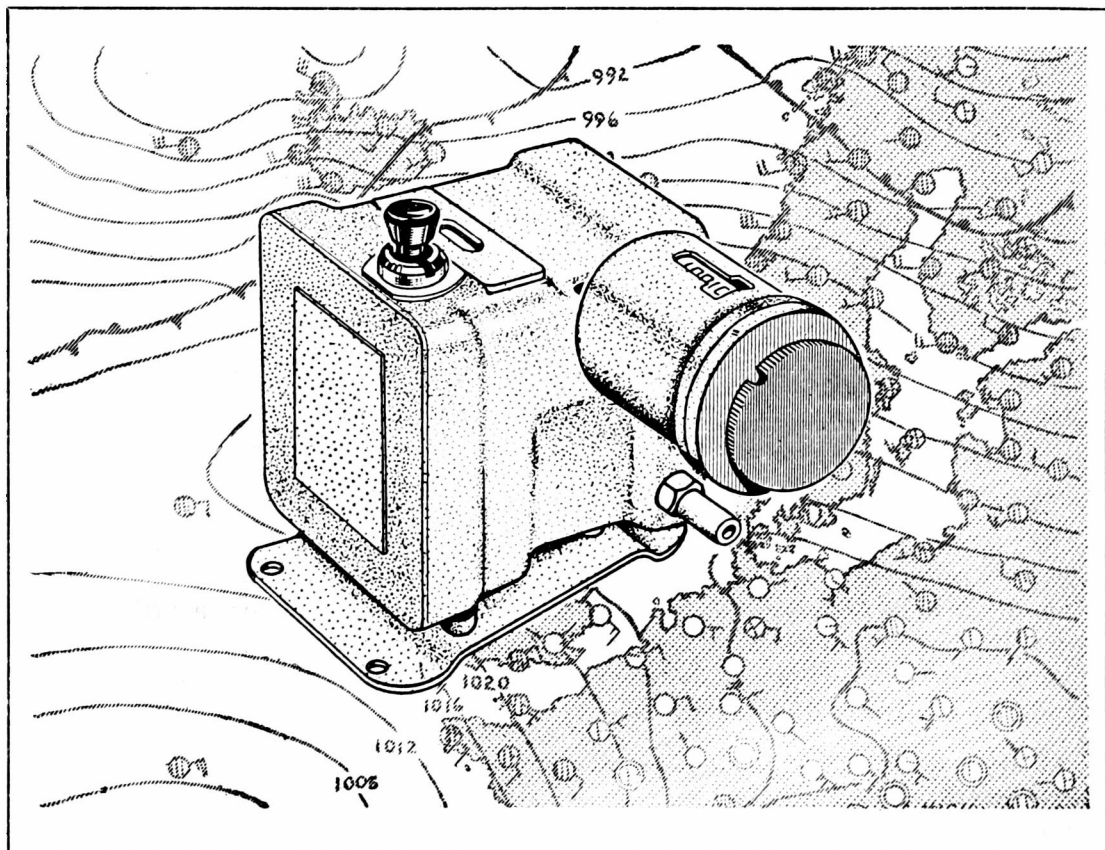
The late W. H. Pick wrote the first edition of *A short course in elementary meteorology* some forty years ago. It was revised at intervals until the fifth edition was issued in 1938, and is now out of print. Since that time great advances have been made in meteorological knowledge, largely owing to the accumulation of observations at high levels in the atmosphere by means of aircraft and radio-sondes. The inter-relation of surface and upper air effects is so close that revision of W. H. Pick's text to bring it up to date was impracticable, so an entirely new book, *A course in elementary meteorology*, was written by D. E. Pedgley, B.Sc. while he was an instructor at the Meteorological Office Training School.

The book is intended for the reader whose knowledge of physics is roughly equivalent to that of upper science forms in schools, though there are a few sections, given in smaller print, of a rather higher standard. These are included for the benefit of those who may wish to delve into the subject a little more deeply. The new book is no longer called a short course, and is about half as long again as W. H. Pick's book; a great deal of information is concentrated into the 183 pages in a clear concise style.

Part I is concerned with physical meteorology. Chapters 1 to 3 deal with temperature, pressure and wind, and water in the atmosphere, and comprise the first third of the book. The emphasis here is on the basic physical principles. The remaining five chapters of the first part are more descriptive and are concerned with "weather" as it is observed; the topics are visibility, clouds, precipitation, thunderstorms and optical phenomena. The cloud section includes 18 plates. The last third of the book is taken up with Part II, which is entitled synoptic meteorology. Chapters on air masses and fronts, depressions, and anticyclones describe how the elements dealt with in Part I, temperature, clouds etc., are related in space and time and these sections lead on to a final short chapter on forecasting.

Each chapter concludes with a full bibliography, giving the interested reader a ready means of extending his knowledge further; most of the articles quoted are easily readable, and many are from the *Meteorological Magazine* or *Weather*. *A course in elementary meteorology* forms an admirable textbook for observers, sixth-form scholars or others who require an authoritative yet simple account of the basic facts of present-day meteorology.

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