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## **SIR DAVID BRUNT, K.B.E., F.R.S.**

In June 1956, on the occasion of Sir David Brunt's seventieth birthday, the *Meteorological Magazine* published an appreciative account of his life and work by the Director-General of the Office, Sir Graham Sutton. It was a happy occasion and the warm tribute paid in that birthday notice should be read again at this time. Written by one who had known Sir David intimately over many years it captures the spirit of his scientific work and presents a picture of a remarkable personality in a way which no short account can improve upon. The present notice is an endorsement of that earlier tribute, made on behalf of many members of the staff of the Meteorological Office for whom Sir David's death on 5 February 1965 was a sad reminder of the debt they owe to one of the greatest personalities in their professional lives.

Although Brunt's famous textbook *Physical and Dynamical Meteorology* appeared more than thirty years ago there is probably still no meteorologist in this country, however young, who has not profited from its pages. It is something in which the Office may take satisfaction that this pioneer work was compiled while its author was a scientific civil servant and a member of the staff. Although he may be better remembered as a distinguished professor, effectively creator of the Department of Meteorology of the Imperial College, and as one of the most influential figures in the academic scientific world of his day, through his nine years as Physical Secretary of the Royal Society, yet it was the period of nearly twenty years spent in the Meteorological Office from 1916 to 1934 which provided the incentive and opportunity to survey the science of meteorology over a very wide field, to make important original contributions and to put together an outstanding textbook. It was also in his period in the Office and under his wing that full-time research into the problems of turbulence and diffusion was begun by a Meteorological Office unit at the Chemical Warfare Experimental Station at Porton. N. K. Johnson, O.G. Sutton and P. A. Sheppard are three who served in that distinguished unit during the time when Brunt was the responsible "Superintendent."

One recalls an occasion—it was the Centenary of the Royal Meteorological Society in 1950—when Brunt, in a characteristic address, claimed that meteorology was not only a science, it was a way of life. An occasion of that kind encourages and justifies extravagance but for Brunt himself it was no exaggeration: in meteorology, for many years, he found endless variety and satisfaction. It will not be as a synoptic meteorologist that he will mostly be remembered,

although his early period with the Army in France—when Lt. Col. E. Gold was his Commanding Officer—gave him first-hand experience of forecasting from which he was always ready to recall some remarkable successes when forecasting became the topic of conversation. But Brunt was never at a loss for a story drawn from his rare experience—with the military world, the Whitehall world, the academic world and later, the business world where one of his appointments was as Chairman of the Electricity Supply Research Council.

The career of Sir David Brunt was an outstanding example of a road to success which, in his time, began perhaps more frequently in Wales or Scotland than in England but was everywhere difficult to follow before the days of educational grants for all. From a remote Welsh village where the little school was in the hands of one teacher, Brunt passed through the Intermediate School at Abertillery, on to the Aberystwyth University College where he graduated with high honours in Mathematics, thence to Trinity College, Cambridge, for the Mathematical Tripos (1910), which was followed in 1913, at the age of 27, by the beginning of a career as a University lecturer. Possibly this would have led to a satisfying life as scholar and teacher had not World War I given an opening for the exercise of those wider talents for administration and negotiation which were to find their full scope in the work of the eminent Secretary of the Royal Society, an office which he relinquished in 1957.

Many will also wish to recall that Brunt was, especially during the difficult years of World War II, a tower of strength in the Royal Meteorological Society which he served in many capacities, including the Presidency from 1942 to 1945, and whose awards he was proud to have received. Brunt took pleasure from success and he was visibly warmed by recognition when it came his way, but of him, more than most, it can be said that his efforts were always to advance a cause in which he believed intensely, and few could claim to have been so consistently successful. Science generally and meteorology especially owe a great deal to David Brunt.

R. C. SUTCLIFFE

551.501.45:551.577.21:311.214:681.14

## THE PROCESSING OF RAINFALL DATA BY COMPUTER

By A. BLEASDALE and A. B. FARRAR

**Summary.**—This article outlines some of the methods which have been developed in the Meteorological Office during the last few years for using an electronic computer in the routine work of checking and summarizing rainfall data. The types of data error are listed as well as the steps of a computer programme designed to carry out objective quality control rapidly on a very large amount of data. It is pointed out that summaries and analyses of data can be produced by computer much more quickly than by hand, and that the computer permits new methods of presentation. Some types of improvements in the various computer programmes are discussed.

**Sources and nature of rainfall data available.**—There are at present more than 6000 rainfall stations in the United Kingdom (Great Britain and Northern Ireland) distributed over an area of about 94,000 square miles (244,000 square kilometres). The number has increased from about 5000 since 1930. Roughly three-quarters of the stations are in England and Wales, representing rather less than two-thirds of the total area.

The distribution of stations is very uneven. Over an area of more than 1000 square miles in and around London the average density approaches 1 station

for 4 square miles (about 10 square kilometres). But in some areas, especially in northern Scotland, the density fails to reach 1 station for 100 square miles. The distribution is very broadly influenced by the distribution of population, though there are some pronounced departures from this rule, notably the relatively dense rain-gauge networks in many of the reservoird mountainous areas and some curious anomalies in the opposite sense in a few moderately well-populated areas.

Synoptic and climatological stations make up about 10 per cent of the rain-gauge network; but with regard to rainfall data alone, all stations belong to two main types. The majority contribute daily values based on measurements made once a day at 0900 GMT (the rainfall day is defined accordingly). A substantial minority, about 25 per cent, located largely in mountain and moorland areas, have monthly gauges read (nominally) at 0900 GMT on the 1st day of the month only. A small number of weekly gauges, with supplementary readings on the 1st day of each month whenever the occasion is not covered by a weekly reading, are included with the monthly gauges for the purposes of this discussion. The detailed information obtained from the charts of a few hundred recording rain-gauges has not yet been considered in the context of regular routine computer processing, though some special investigations using recording rain-gauge data have been carried out using computer techniques.

Under present consideration there are therefore, for each month, several thousand returns of daily values of rainfall, and about 1500 monthly totals in addition. At the time of writing (1964) all such data for England and Wales are processed by computer on a monthly routine, supplemented by an annual routine covering the whole body of data for the calendar year. Data for Scotland and Northern Ireland will sooner or later be included in the monthly routine, though it is thought that existing computer methods may not be adequate for areas of very sparse data, and supplementary examination of such data may remain necessary, unless networks are improved in these areas.

**Types of error.**—The data as received are very variable in quality, ranging from the virtually perfect to a small quantity of material which cannot usefully be amended and must be rejected outright. The overwhelming mass of data, however, contains very useful information, the value of which is substantially increased as a result of quite minor corrections. The faults which occur may be classified as follows:

- (i) Systematic errors due to faulty exposure or defective equipment.
- (ii) Occasional errors due to temporary disturbance of exposure or mischievous interference. (Occasional errors could possibly be due to temporary instrumental faults, soon detected and rectified, but this would be rather rare. A more familiar situation is the detection, after some delay, of a progressive deterioration, a case which merges with (i)).
- (iii) Misreadings, misplaced decimals, mistakes in copying, mistakes in arithmetic, and so on.
- (iv) Inadvertent omissions (observations made but not written down).
- (v) Accumulations over more than one day, sometimes indicated, but quite frequently entered as normal daily readings.
- (vi) Displacement of correct readings to incorrect days, persistently, fairly often but irregularly, or only occasionally and erratically.

(vii) Displacement of partial amounts due to deviations from standard times of observation.

Faults (i) and (ii) cover incorrect catch, and correct catch transferred to an incorrect measure; faults (iii) to (vi) cover inadequate observation and recording of measurements which may be quite correct in themselves. Faults of more than one kind may be combined. The full list applies, of course, only to daily rainfall data and not to monthly totals. Examples of the former, as received, with notes on suggested amendments, are given in Appendix I.

**Objects of computer methods.**—In the present context the objects of data treatment in general may be summarized under two broad aims. The first is to detect faults and to eliminate, correct or allow for them. Somewhat arbitrary criteria must be adopted for the rejection of data which are shown to be probably faulty but cannot be adequately corrected. The second general aim is to summarize and analyse the data in various ways so that important features may be brought forward, and presented in compact forms, such that the results may be readily appreciated and assimilated.

In relation to these aims the introduction of computer methods has the following main objects:

(i) To carry out quality control on a very large amount of data quickly, by methods which are strictly objective and uniform. Any variations of method which are introduced are planned, deliberate variations. Quality control by the older methods was likely to be marred by unrecorded subjective variations; these methods, if thoroughly and carefully carried out, were very tedious and slow.

(ii) To produce summaries and analyses of the data much more quickly than by hand; as a consequence to include far greater amounts of data in the simpler but possibly laborious summaries, and to carry out much more elaborate analyses for which the labour, by hand methods, would be prohibitive as a routine and could be undertaken only occasionally in special investigations.

**Maps.**—At the present stage of development the plotting of rainfall data on maps and the drawing of isopleths for individual occasions or for months, seasons or years, either in absolute measure (inches or millimetres) or in percentages of average, is a very important process both as a method of summarizing and presenting the data and as a form of quality control, since faulty values may often be readily detected and investigated during this process. Whilst the extension of computer methods to cover this field thoroughly cannot by any means be ruled out as a future development, as yet this has not been attempted, except that some data are tabulated by computer in a form which is very convenient for hand plotting. This may be specifically arranged or may happen as a by-product of some other computer process.

**The computer programme.**—The computer programme at present in use has been under development for a period of four or five years. After an experimental period it was first introduced into routine work, covering about half the data for England and Wales, in January 1962, and the routine was extended to cover the whole of the data for England and Wales in January 1963. It has not yet reached its final form and only a general description will be attempted, since anything more detailed would very soon require amendment. Changes which have been made from time to time as a result of experience are of two general types:

- (i) Changes designed to increase the precision, or otherwise improve the quality, of a computer operation and of the resultant product.
- (ii) Changes designed to simplify a computer operation, without seriously affecting the quality of the resultant product, in order to increase the speed of the operation or to relieve the load on the capacity of the computer, so that a larger amount of data can be processed in one operation. This type of change includes the elimination of unnecessary operations, the results of which have been found in practice to be covered by other operations.

**Quality control.**—The basic idea of the quality control part of the programme was, to begin with, to construct a reasonably close analogy with the former subjective hand and eye procedures for detecting the various types of error. From the start it was realized that this analogy could not be exact, and that whilst the new methods would prove to be in some respects better than the old, in other respects they would perhaps be poorer. A rough correspondence was aimed at in the confident expectation that the computer procedures, once started, could be steadily improved.

Whether by the old methods or the new, quality control of data is of course carried out in two main stages. The information for each separate station is checked for completeness and internal consistency and then the information for each station is compared with that for neighbouring stations, to detect anomalies lying outside acceptable limits of variation, which are estimated from what is already known to be possible in nature.

It is worth noting that although at both stages there can be difficulty in making a confident estimate of a necessary correction, the evidence that some error is present is always more definite if it occurs at the first stage than if it occurs at the second. However strong the evidence may be, it is very often true to say, at the second stage, that the suspected value could possibly be correct.

**Steps of the computer programme for quality control.**—The steps of the computer programme covering the two main stages are carried out month by month on the data for stations grouped in areas which are based on natural river basins. A number of the steps constitute specific tests which the data are required to satisfy and a value which does not satisfy the test is printed out against the station number with some form of coded information about the suspected defect. For any one month and a particular area, the steps may be briefly described as follows:

(i) The data are punched on tapes in a form which already includes various indicators used in the subsequent processing, one of which denotes a known error of the accumulation type (page 99), that is a value representing an accumulation over more than one day amongst regular daily values.

(ii) Allowing for (i), a count is made of the number of daily readings in the month at each station, and the sum of these readings is checked against the monthly total.

(iii) Values for the minority of stations reporting in millimetres are converted to inches and values for the minority of stations reporting 12-hour amounts are paired to make 24-hour amounts.

(iv) Any indicated accumulation in (i) is apportioned over the appropriate number of days by straightforward comparison with the mean daily values for a small number of neighbouring stations; this number is usually six but variation is allowed for in areas of low network density where there are fewer than six other daily stations within about 12 kilometres (but see page 104).

(v) For each day of the month the spatial variability of rainfall over the area is assessed by calculating the mean and standard deviation of the station values within the area, using all stations with (apparently) complete data. All daily values are then checked to pick out those which seem too high or too low. Allowance is made for stations with relatively high or low average annual rainfall (a.a.r.) compared with that for the whole area, the ratio of area a.a.r. to station a.a.r. being used as a scaling factor. Otherwise daily values for many high-altitude, high average rainfall stations would be printed out repeatedly for inspection, and similarly for some low average rainfall stations.

(vi) All zeros are now tested for any day on which the mean for the area is more than 0.10 inches (2.5 mm) and the standard deviation of all values for the area is less than the mean. Some of these will already have been printed out for inspection under (v). Such zeros are tested for inadvertent omissions, accumulations (other than those dealt with in (iv)) and displacements (page 99). The computer seeks the first non-zero value, later by date and then, if necessary, earlier by date, and tests for possible excess. Some of these excess values may already have been selected for inspection under (v). If excess is found, the value is apportioned as for indicated accumulations (iv). A value correctly measured but entered against the wrong date will usually be shown in the form of an overwhelming apportionment against the correct date. If neither accumulation error nor displacement error is found as a probable explanation, the print-out of the suspected zero suggests a missing value.

(vii) Monthly values from monthly rain-gauges are now brought in, to be checked together with the monthly totals from daily rain-gauges. Each value is tested by comparison with the mean of the six nearest stations, the departure from this mean being expressed as a proportion of the standard deviation of the six values. As with (iv) a smaller number than six is allowed for in areas of low network density. (Note: this test as originally written into the computer programme was carried out on monthly totals expressed in absolute measure (inches). It is proposed to modify the programme to include also the same test on monthly totals expressed as percentages of average annual rainfall for each station, and to compare the relative effectiveness of the two alternatives.)

(viii) A full print-out of all daily and monthly values is made, with one column for each station, the station order following a regular, familiar system so that the print-out of all suspected values from the earlier steps can be readily appraised by eye.

At this stage a long list of suspect values has been obtained. These are scrutinized and subjected to further checks by eye, then some are accepted as probably correct values though the computer has selected them as suspect following one test or another. For those not accepted, correspondence with observers follows in an endeavour to arrive at agreed corrections, sometimes a long and tedious process which raises problems of its own. However, the most

important fact is that through the operation of the computer programme a very large body of data has been passed as substantially correct and trustworthy, and for these data the time-consuming process of scrutiny by the former subjective methods is not necessary. It is no great disadvantage that the computer selects many suspect values for scrutiny which are eventually accepted. There should be time for this work, since the great body of trustworthy data need not be scrutinized by eye. It is important that the computer should not accept anything which would be obviously suspect by eye.

### **Production of summaries and analyses.—**

(i) *Preliminary print-outs.*—Further stages in the computer programme are concerned with summaries and analyses of the data rather than quality control, and are carried out as an annual instead of a monthly routine. But it has been found convenient as a preliminary stage in the annual routine to print out in regular familiar station order certain information which provides a final step in quality control, namely:

- (a) Monthly and annual totals in absolute measure (inches).
- (b) Monthly and annual totals expressed as percentages of average annual rainfall for the station.
- (c) Departures of the percentage values (b) from the means for the nearest stations; similar to step (vii) (page 102), but all months of the year presented together so that a station with a series of suspect monthly values shows up very prominently. The departures are not printed if they fall within a certain narrow range, so that those which are printed indicate monthly values approaching or surpassing the criterion of acceptability. For a station with a missing value under (a) or (b) instead of a departure under (c) an estimated value is printed, this being based on the mean of the percentage values for the nearest six stations.
- (d) Seasonal percentages, based on sums from (b) but rounded off to integral values.

(ii) *Tabulations and summaries.*—The remainder of the programme (annual routine) consists mainly of quite straightforward tabulations and summaries of the data. These include estimates of areal values of rainfall, frequency distributions of daily values, and tabulations of maximum daily falls; some of the material is presented in a form which is as far as possible immediately ready for printing and publication. It is intended to develop this part of the programme to produce new forms of analysis of the data. In this sense, the frequency distributions of daily values have already been produced in much greater detail, and for a larger number of stations, than has ever been attempted hitherto, and certain other straightforward developments of a similar nature have been made. So far only one major development, presenting information in an entirely new form, has been introduced.

(iii) *Graphical presentation.*—This was introduced in an attempt to overcome the limitations of some earlier forms of data treatment in terms of rather arbitrary definitions of events, such as 'droughts' and 'wet spells'. Cumulative amounts of rainfall throughout the year are first expressed as percentages of the average annual rainfall for the station and then, in these percentages, as departures from the amounts which would accumulate at the uniform rate corresponding to the average. The results may be printed out graphically with

points at any specified interval, five days being in many respects convenient. An example is shown in Figure 1. The rapidly falling or rapidly rising sections of the graph represent the notably dry and wet periods, with a limiting slope, corresponding to no rain at all, for the former. The eventual aim is for all tabular and graphical print-out to be sufficiently clear and accurate for direct photographic reproduction. But this stage has not yet been reached.

The graphical form of presentation has several advantages:

- (a) All stations, whatever their average rainfall, are reduced to a common basis, for immediate comparison. This is important for wet periods and no disadvantage for dry periods because of the easily recognized limiting slope.
- (b) The severity and duration of any relatively dry or wet spells may be seen at a glance, and particularly interesting periods covering a group of stations may be readily picked out for further, more detailed, analysis and discussion.
- (c) It should be possible to develop this method to obtain a combined presentation of rainfall with other elements in the hydrological cycle, notably evaporation and run-off, according to realistic requirements. In particular there could be in this way an approach to a definition of 'drought' allowing for the seasonal variation of evaporation.

**Some comments on the present computer programme.**—The programme as it is being currently used (1964) for routine data processing covering all information received for England and Wales, has already been further developed in some respects, in readiness for a change-over to the new computer of much larger capacity. The general description which has been given applies reasonably well to the present programme and to the future version, as far as this can now be foreseen, but a few comments on matters of detail may be useful.

*Size of area processed.*—With the METEOR computer, of relatively small capacity, the data are processed area by area, covering up to 256 stations at a time. With the larger computer it will be possible to group the data within larger areas, at the same time allowing for some overlapping of areas and thereby eliminating a weakness which at present affects the procedure for some stations near the edges of certain areas. It will never be possible to eliminate this weakness entirely for stations near the coasts but this applies equally to any method of quality control.

*Check with adjacent stations.*—At an early stage in the development of the quality-control programme a phrase such as 'the six nearest stations' was interpreted literally in terms of horizontal distances. The computer was required to carry out for steps (iv) and (vii) on page 102, and the print-outs (c) (page 103) in particular, an appropriate number of sums-of-squares calculations on the differences in the eastings and northings of the grid references of the station primarily involved in the test and other stations nearby. The nearest stations thus found were enclosed within a circle centred on the test station. It was subsequently appreciated that in most cases, and probably all, virtually identical results would be obtained by programming the computer for a much quicker operation based simply on the linear sums, not sums of squares, of the differences, regardless of sign, in the eastings and northings of grid references. The



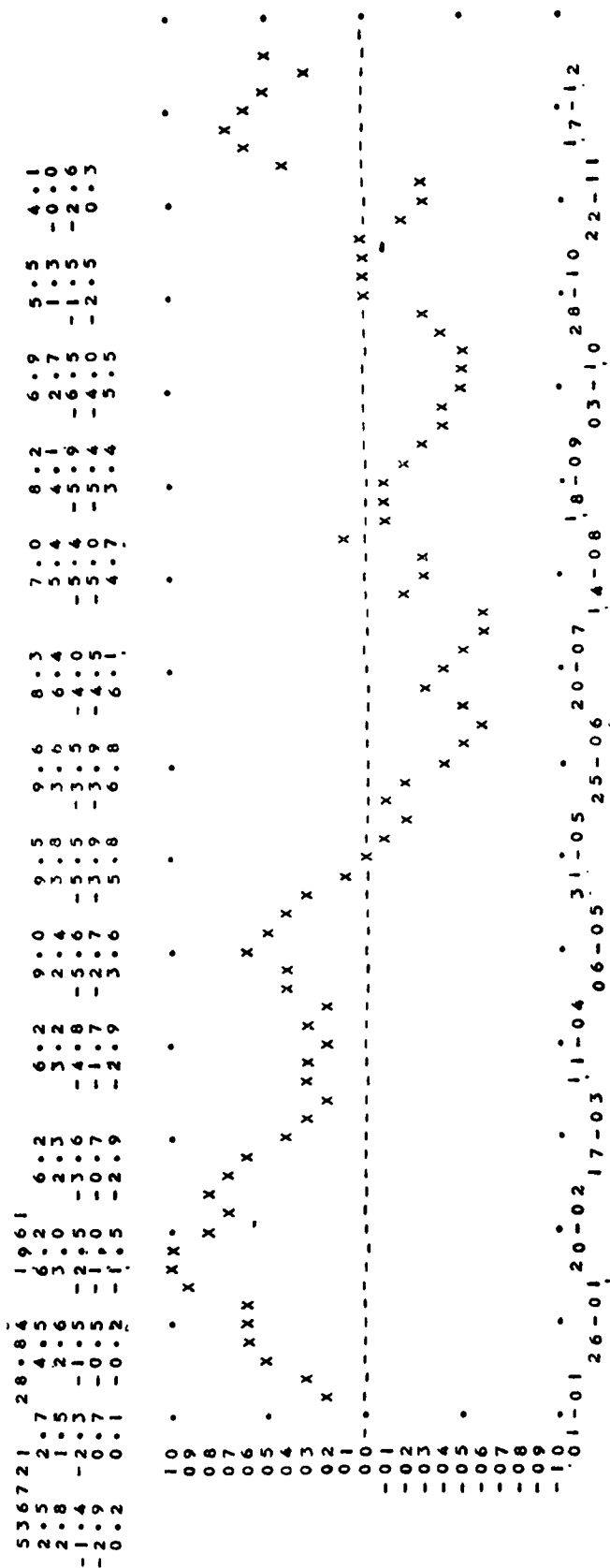


FIGURE 1—GRAPHICAL REPRESENTATION OF RAINFALL DURING THE YEAR

Top line—Station number: average annual rainfall in inches: year.

Lines 2-6—Values of cumulative departures at 5-day intervals expressed as percentages to one place of decimals.

Graph—73 points representing the values in lines 2-6 plotted by the computer to the nearest integral values.

Base-line—Dots mark 25-day intervals; below each dot are four figures, the two on the left give the day of the month and the two on the right the month on a 12-point scale from January to December. Thus 25-06 represents 25 June.

Note: The line-printer on which this figure was produced was not very accurate as shown by the rather unstable line of dashes which corresponds to zero departure. A superior machine would produce graphs of this type suitable for photographic reproduction.

nearest stations found by this method lie within a square centred on the test station with diagonals west to east and south to north. They are not necessarily the nearest stations, in terms of distances along radius vectors from the test station, but are the 'nearest' in terms of distances along rectangular co-ordinates with the test station as origin. With  $(e_o, n_o)$  as the grid co-ordinates of the test station and  $(e_i, n_i)$  for others, the test is now based on:

$$|e_i - e_o| + |n_i - n_o|$$

instead of:

$$[(e_i - e_o)^2 + (n_i - n_o)^2]^{\frac{1}{2}}.$$

The saving of computer time introduced has not been estimated, but with many, many thousands of calculations of this type every month it cannot be negligible. A further small point of interest is that for this type of operation, instead of a limiting radius of 12 kilometres which was formerly used, for the circle, a limiting semi-diagonal of 12.8 kilometres is being substituted for the roughly equivalent square. The area covered is in fact appreciably smaller but 12.8 has been selected as a very convenient number in binary form.

*Treatment of multiple errors.*—The outline of the computer programme which has been given, has been written, for simplicity, in such a way as to suggest that quality control is usually a matter of picking out the occasional erroneous value amongst a body of correct data. This is very often true but there is the possibility of sometimes meeting multiple errors so numerous that they could conceivably be used as the basis for adjusting correct data, or of meeting forms of multiple error with which the programme could not cope. One example of the latter might be data for a whole month, or even year, recorded incorrectly with regard to date, as with station number 255554 in example (d) of Appendix I. This is a fault immediately apparent to the trained eye and very easily corrected by the earlier subjective methods of quality control, but not necessarily so easily dealt with by the computer. In practice, in almost any rainfall régime, the computer will in such a case select as suspect such a high proportion of the rainfall amounts that the nature of the fault is readily apparent. In this and other cases of multiple error, where the data are at first sight apparently complete and self-consistent, there remains however the disturbing possibility that incorrect values may have been used to check other data. It would be possible to go through an indefinite process of recycling the data, refining the corrections introduced at every stage until all possibility of the undesirable use of incorrect data had been eliminated. In practice a single recycling, paying particular attention to wrong-date corrections, and the apportionment of accumulations, indicated or otherwise, will probably be enough. Other types of error occur very largely in relative isolation, except for the data for a very few stations which are so poor as to be virtually useless and fit only for complete rejection at the earliest stage. As yet, however, there is insufficient experience to make final decisions about the extent of the need for recycling and, so far, no attempt has been made to make the process of scrutiny and correction between cycles in any way automatic. A recycling problem also exists in the very early stages of computer processing when the punched tapes are being checked for accuracy, corrected (re-punched, at least in part), and checked again. A firm decision has not yet been made concerning the degree to which a close approach to complete accuracy should be attempted. It is obvious that all gross errors must

be eliminated but a very small number of trivial errors in an enormous mass of data would have negligible effect on any practical use of the information, and it is equally obvious that at some point striving after complete accuracy for academic reasons must become quite uneconomic.

*Improvements in individual tests.*—Various refinements of individual tests are under consideration. In particular when the time comes for data covering larger areas to be processed together in a computer of larger capacity, it may no longer be desirable to carry out certain steps such as (v) and (vi) (page 102) over the whole area simultaneously. Smaller overlapping areas may be used, or some different system may be developed. The testing of zeros (vi) (page 102), in particular, may need refinement, since it is certain that some accumulations at present escape detection on occasions when there are periods of a few days with low total rainfall over an area and the criterion for starting the test is not fulfilled. An important question is whether this matters very much, except for academic reasons, as discussed in a different context on page 106, provided that all the large accumulations are detected and dealt with. There is one type of test, however, which certainly requires improvement in order to make quality control by computer more independent of supplementary scrutiny by eye. At step (vii) (page 102) a station value is compared with values in the immediate neighbourhood by taking the mean and the standard deviation of surrounding values and expressing the station departure from this mean as a proportion of the standard deviation. Whenever the station value represents a near approach to a local maximum or minimum, there is a danger that the surrounding values will be very nearly equal, at a slightly lower or higher level, resulting in a very small standard deviation and a very high ratio for the station departure. The station value, on this evidence alone, is selected as suspect by the computer. To take the ratio in conjunction with the absolute value of the departure does not completely overcome the difficulty in all cases. The simplest way of overcoming the difficulty is in fact to glance at the corresponding map of rainfall distribution, if this has already been plotted, when it is usually obvious whether the station value can be accepted as a local maximum or minimum. An equivalent computer test may yet be devised but this stage has not been reached.

*Systematic errors in rainfall data.*—Virtually all important errors of types (ii) to (vii) (page 99) can be detected during month-by-month quality control, whether by subjective methods or by computer, given sufficient refinement of the tests. The same is not necessarily true of systematic errors which usually depend for their detection on the availability of data covering a long period of months, or preferably years, and an adequate knowledge of the variation, with altitude and other factors, of average rainfall in the neighbourhood of the station. Some of the quality-control tests themselves depend on an adequate knowledge of the spatial distribution of average rainfall. In order to minimize the influence of undetected systematic errors in quality-control tests, whilst making full use of existing trustworthy knowledge of average rainfall, a procedure has been adopted of allocating to every single station a value of average rainfall according to a threefold classification:

Class A. Stations with virtually complete trustworthy data throughout the standard period to which the annual averages refer—averages very reliable.

Class B. Stations without such complete data throughout the standard period, but with sufficient data for a standard-period average to be estimated with fair confidence.

Class C. Stations for which the standard-period average is no better than a very provisional estimate, subject to review and probably revision.

For station in classes A and B the emergence of systematic errors would be a new departure which would be readily detected and investigated at an early stage. For stations in class C it would necessarily require a fairly long process of review and reassessment before any decision could be made on the possible presence of systematic errors, or alternatively the transfer of such a station to class B. A special watch should be kept on results for class C stations during quality-control procedures.

## Appendix I

### EXAMPLES OF DAILY RAINFALL DATA AS RECEIVED, WITH SUGGESTED AMENDMENTS

*Example (a)* Probably a mistake in copying (error type\* (iii)).

Station	327022	327138	<u>327153</u>	328159	328572	Suggested amendment 327153
Date						
Feb. 22	—	—	—	—	—	
23	0.18	0.10	0.18	0.17	0.17	
24	0.58	0.68	0.58	0.36	0.30	
25	0.24	0.25	0.30	0.24	0.36	
26	0.31	0.35	0.31	0.26	0.31	
27	0.62	0.54	0.59	0.57	0.57	
28	—	—	0.61	tr	0.01	0.01
Mar. 1	—	—	—	—	—	

\*Error types are listed on page 99.

*Example (b)* Observations not very accurately made (type (iii)), recorded against incorrect dates (type (vi)) with accumulations (type (v)), one indicated, one not.

Station	311001	312780	<u>313158</u>	313317	313324	Possible amendment 313158
Date						
July 10	—	—	—	—	—	—
11	0.19	0.16	—	0.03	0.03	0.25
12	0.14	0.29	—	0.20	0.16	0.45
13	0.02	0.12	0.70	0.14	0.15	0.10
14	0.65	0.44	0.10	0.35	0.28	0.40
15	0.35	0.32	0.40	0.32	0.33	0.35
16	0.15	0.06	—	0.20	0.18	0.15
17	—	—	0.50	—	—	—
8-day total	1.50	1.39	1.70	1.24	1.13	1.70

It is doubtful if the amendment to 313158 is worth making. Throughout the whole year every daily entry except two had either 0 or 5 in the second decimal place, and most readings, including several accumulations, seemed to be very crude approximations. The possible amendment shown is very rough and based on the suggestions that the set of readings for 10–17 July should first be thrown back one day, with 0.70 now on the 12th, as an accumulation, not indicated, and 0.50 now on the 16th as an indicated two-day accumulation.

*Example (c)* Indicated accumulation (type (v)), no other fault.

Station	586983	590690	<u>592488</u>	592764	592849	593510	Suggested apportionment 592488
Date							
Apr. 12	0.31	0.56	0.53	0.34	0.24	0.33	
13	0.45	0.34	0.40	0.59	0.57	0.26	
14	1.72	3.35	2.78	1.24	1.18	1.36	
15	0.13	0.12	0.05	0.08	0.05	0.02	
16	0.20	0.35	0.83	0.14	0.12	0.11	0.17
17	0.81	0.63		0.74	0.68	0.52	0.62
18	0.11	—		0.06	0.03	tr	0.04
19	—	—	—	—	—	—	

*Example (d)* One observation recorded against incorrect date (type (vi)).

Station	253174	253749	254432	<u>254651</u>	254820	255554	Suggested amendment 254651
Date							
May 25	—	—	0.02	—	0.01	tr	
26	0.02	tr	0.01	0.02	0.02	0.01	
27	0.40	0.29	0.75	—	0.41	0.30	0.72
28	—	—	—	0.72	—	tr	—
29	0.16	0.12	0.16	0.18	0.19	0.08	
30	—	—	—	—	tr	—	

Station 254820. Amounts have been moved forward by one day, for this group of readings.

Station 255554. Amounts have been thrown back by one day, for the whole year.

*Example (e)* A small group of observations recorded against incorrect dates (type (vi)), one reading queried as very probably excessive (type (ii) or (iii)).

Station	337038	<u>337291</u>	338132	338940	339296	340174	Suggested amendment 337291
Date							
June 10	—	—	—	—	—	—	
11	—	—	—	—	—	—	
12	—	1.15	0.40	0.37	0.08	0.22	1.15 too big?
13	1.20	1.27	0.83	0.96	1.53	1.28	
14	—	—	—	—	—	0.02	
15	—	0.02	0.02	0.01	0.01	0.01	readings 15th–18th to be moved forward one day
16	0.07	0.24	0.01	0.02	—	—	
17	0.34	0.25	0.27	0.24	0.24	0.21	
18	0.26	0.18	0.14	0.04	0.07	0.10	
19	0.36	—	0.12	0.18	0.17	0.26	
20	0.03	—	—	—	—	—	
21	—	—	—	—	tr	—	

551.501.45:551.577.21:311.214

## ERRORS IN THE TRADITIONAL METHOD OF COMPUTING GENERAL VALUES OF MONTHLY AND ANNUAL RAINFALL OVER LARGE AREAS

By R. P. WALDO LEWIS, M.A., M.Sc. and B. GOLDING

From 1923 until recently it has been the practice in the rainfall section of the Meteorological Office to compute monthly general (or areal mean) values of rainfall over areas such as England, Wales, England and Wales, and Scotland, by the following method:

A network of stations with reliable monthly averages for the standard period in use (1881–1915, or 1916–1950) is chosen, so that the stations are distributed

over the area in question as evenly as possible. The rainfall at each station for the month under consideration is expressed as a percentage of its monthly average, and a mean percentage over the area is found by meaning the individual percentages over all stations in the area. This mean percentage is then applied to a previously computed average general value of rainfall over the area (also referred to the standard period) in order to give the desired general areal value for the month in inches. The reason for adopting this method is that variations of monthly percentages from point to point are much smaller than the variations of the actual rainfall. The method is not exact, however, and an expression for the error introduced may be derived as follows.

Let the rainfall for a particular month at a point  $(x, y)$  within the area be  $r$ , a function of  $x, y$ .

Let the average over the standard period for that month at  $(x, y)$  be  $\rho$ , also a function of  $x, y$ .

Let  $\phi \equiv r/\rho$ , so that  $100 \phi$  is the monthly percentage at  $(x, y)$ .

Let  $R$  be the true general value of the rainfall over the area, and  $R'$  the value yielded by the 'percentage method.'

Then  $R = A^{-1} \iint r dx dy = A^{-1} \iint \rho \phi dx dy$  . . . . (1)  
 where the double integral is taken over the whole area, and  $A$  is the magnitude of the area. Also  $R' = A^{-1} \iint \phi dx dy A^{-1} \iint \rho dx dy = \bar{\phi} \bar{\rho}$   
 where  $\bar{\phi} \equiv A^{-1} \iint \phi dx dy$  and  $\bar{\rho} \equiv A^{-1} \iint \rho dx dy$ .

Then  $R = A^{-1} \iint (\rho - \bar{\rho} + \bar{\rho}) (\phi - \bar{\phi} + \bar{\phi}) dx dy$   
 $= A^{-1} \iint \{ \bar{\rho} \bar{\phi} + \bar{\phi} (\rho - \bar{\rho}) + \bar{\rho} (\phi - \bar{\phi}) + (\rho - \bar{\rho}) (\phi - \bar{\phi}) \} dx dy$   
 $= R' + A^{-1} \iint (\rho - \bar{\rho}) (\phi - \bar{\phi}) dx dy$  . . . . (2)  
 since  $\iint \bar{\rho} \bar{\phi} dx dy = \bar{\rho} \bar{\phi} \iint dx dy = A \bar{\rho} \bar{\phi}$   
 and  $\iint (\rho - \bar{\rho}) dx dy = 0 = \iint (\phi - \bar{\phi}) dx dy$ .

Thus the error of the percentage method is equal to

$$R' - R = -A^{-1} \iint (\rho - \bar{\rho}) (\phi - \bar{\phi}) dx dy. \quad . . . . (3)$$

This expression is a sort of 'areal covariance' between percentage values and average values, taken over the area under consideration and will thus not be systematically different from zero. In individual months however, its value may differ appreciably from zero, particularly when the overall patterns of average and percentage—considered regardless of sign—bear a marked resemblance to one another. An example would be furnished by the association of small percentages in the Lake District and Pennines with large percentages in south-east England since these two areas have high and low average rainfall respectively.

To determine the error in an estimate of a value it is of course necessary to determine the true value. The best way to determine the true value of  $R$  for say England and Wales is to plot isohyetal maps of England and Wales for each month and obtain  $R$  by planimetering, an immensely laborious task unsuitable for mechanization. However, it is possible to split up a large area into a large number of smaller areas, each of which is so small that the variation of percentage over it is trivial and the error  $R' - R$  is thus also trivial. The percentage method is then applied to each of the small areas, and the total rainfall over the large area is found as the sum of the total rainfalls over all the small areas:

this will yield an estimate of  $R$  that is not perhaps the best possible, but one that can be expected to be much nearer the truth than the original  $R'$ .

The existence of estimates of average monthly rainfall over each county of England and Wales\* made it possible to carry out calculations using the county as the basic small area. For each county (or in some cases for a small group of counties), several rainfall stations having averages for the standard period 1881–1915 were chosen so that the percentage value of the rainfall over the county could be estimated as the mean of the percentage values at the individual stations. (Lack of suitable stations in some localities was overcome by grouping certain counties together). The areas into which England and Wales were divided together with the positions of the rainfall stations used, are shown on the map (Figure 1). Certain stations were used to provide estimates of percentage for more than one county.

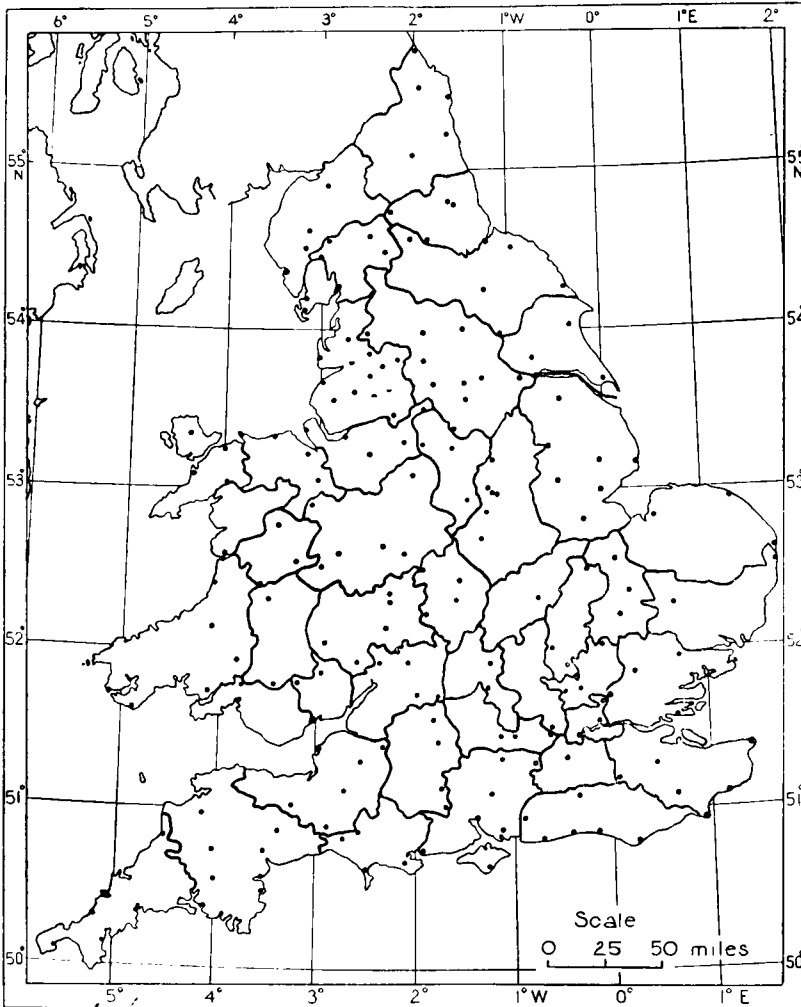


FIGURE 1—AREAS USED IN CALCULATION OF GENERAL (OR AREAL MEAN) RAINFALL WITH POSITIONS OF RAINFALL STATIONS USED

\*London, Meteorological Office. Average monthly and annual rainfall over each county of England and Wales. *Brit. Rainf.*, 1950, London, 1952, p. 215.

For each month, county by county, the estimates of monthly percentage were multiplied by the appropriate monthly average of rainfall, and the resulting county rainfall totals were combined into monthly totals for Wales, England, and England and Wales. These calculations were performed on the Meteorological Office electronic computer METEOR.

There are two sources of discrepancy between the monthly rainfall figures produced by this new method and those previously published in *British Rainfall*. Firstly, there is the discrepancy due to the method of calculation, which is what we wish to determine. Secondly, there is a discrepancy because the integrated individual county monthly averages are not exactly the same as the general monthly and annual averages of rainfall over large areas used in Section 8 of *British Rainfall*.

This latter discrepancy is shown up by Table I in which the columns labelled A are the areal rainfall averages used in Section 8 of *British Rainfall*, and those labelled B are the areal rainfall averages calculated from the individual county averages. In order therefore to ensure that the areal averages used in the two methods are comparable and thus to allow a fair comparison between the estimates produced by the new method and those previously published, the former were multiplied by an appropriate factor, different for each month and large area, deduced from the figures in the table; for example, the computer estimates for Wales for March were multiplied by 3.82/4.08.

TABLE I—TWO SETS OF AREAL AVERAGES OF MONTHLY AND ANNUAL RAINFALL

Month	England		Wales		England and Wales	
	A	B	A	B	A	B
				<i>inches</i>		
January	2.69	2.59	4.72	4.84	2.99	2.90
February	2.34	2.25	3.94	3.99	2.57	2.49
March	2.47	2.39	3.82	4.08	2.67	2.62
April	1.98	1.95	2.96	3.02	2.12	2.10
May	2.19	2.17	2.95	3.04	2.30	2.29
June	2.33	2.32	3.05	3.13	2.44	2.43
July	2.75	2.69	3.60	3.70	2.87	2.83
August	3.11	3.03	4.71	4.86	3.35	3.28
September	2.37	2.30	3.51	3.59	2.54	2.48
October	3.69	3.55	5.63	5.71	3.97	3.85
November	3.19	3.06	5.25	5.35	3.49	3.38
December	3.56	3.42	6.00	6.16	3.92	3.79
Year	32.67	31.72	50.14	51.47	35.23	34.44

A = areal rainfall averages used in Section 8 of *British Rainfall*,

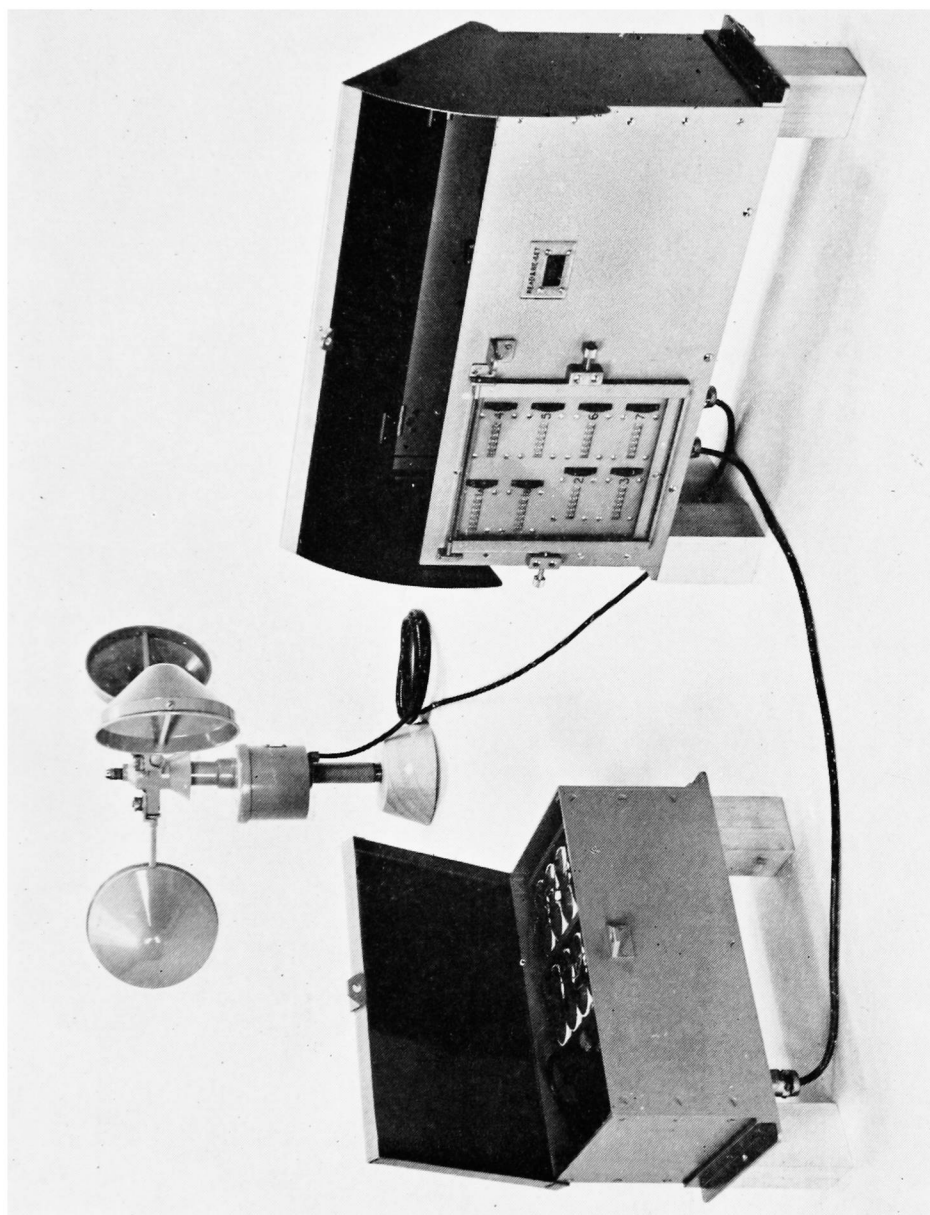
B = areal rainfall averages calculated from the individual county averages.

If the monthly estimates produced by the new method just described are subtracted from the old previously published estimates, the resulting differences may reasonably be regarded as good approximations to the errors in the old estimates.

Table II shows the frequency distribution of these errors during all months of the decade 1941–50 for England and Wales as a whole and for Wales. It is clear that over England and Wales the errors were usually very small. Scrutiny of the detailed monthly figures (not given here) showed that sizable percentage errors were due to errors of  $\pm 0.1$  inch in months of low rainfall, e.g. 0.1 inch in 0.7 inch amounting to 14 per cent.

Over England by itself errors were also small but for the much smaller area of Wales the errors are seen to be larger. In one dry month the new method gave

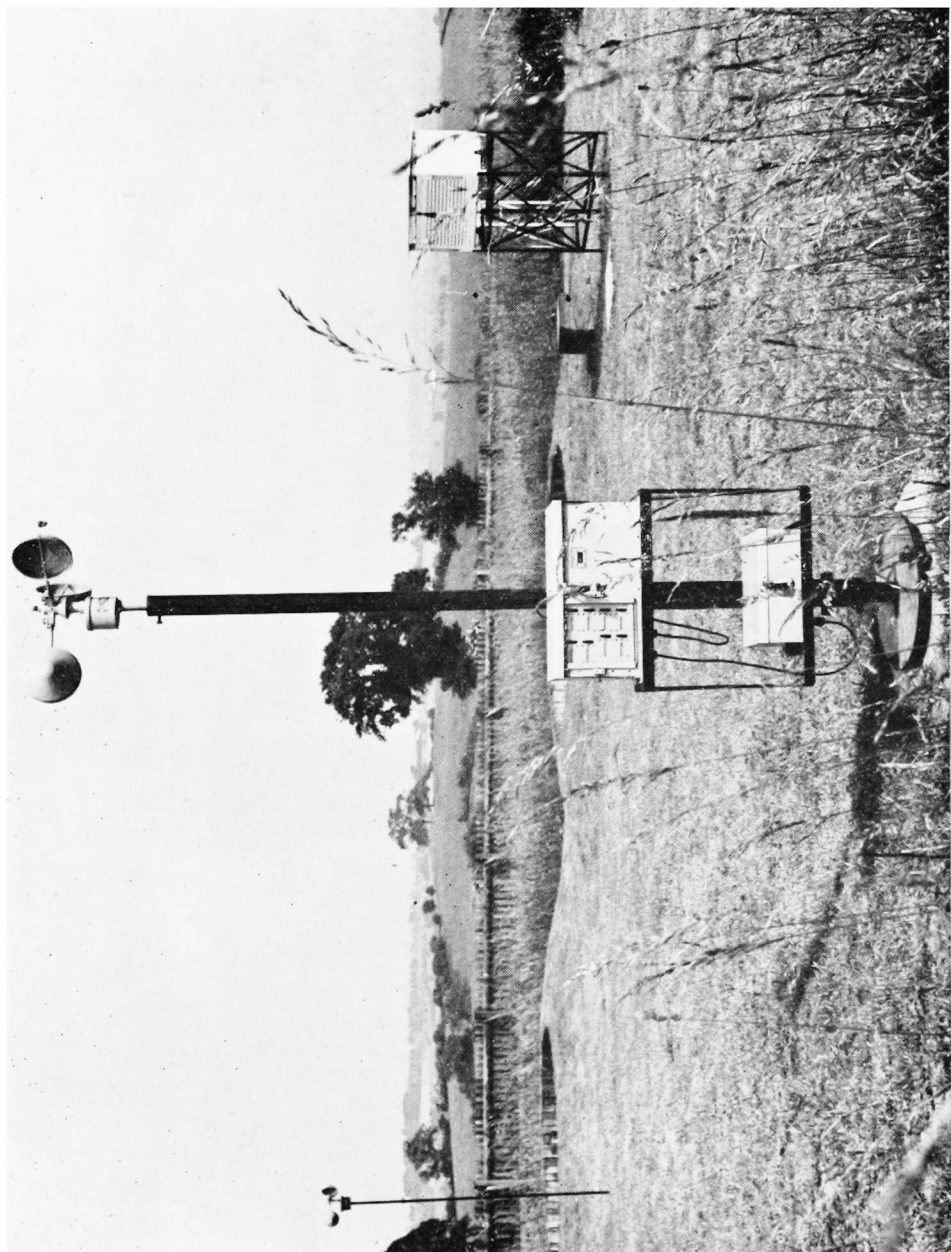




*Crown copyright*

PLATE 1—RECORDING ANEMOMETER DESIGNED BY THE HYDRAULICS RESEARCH  
STATION, WALLINGFORD

The equipment consists of battery box (left), anemometer, and recorder (right) (see page 114).  
The anemometer cups are mounted 2 metres above ground.



*Crown copyright*

PLATE II—RECORDING ANEMOMETER DESIGNED BY THE HYDRAULICS RESEARCH  
STATION, WALLINGFORD, INSTALLED ON A CATCHMENT SITE

See page 114.



*Photograph by R. K. Pilsbury*

PLATE III—A STRIKING DISPLAY OF MAMMA BENEATH CUMULONIMBUS TO THE SOUTH OF BRACKNELL AT ABOUT 1400 GMT ON 23 OCTOBER 1964

Showers were visible at the time to the south and west with cumulonimbus in all quadrants of the sky.

To face p. 113



*Crown copyright*

PLATE IV—WEATHER PRESENTATION BY MR. NORMAN ELLIS ON BBC TELEVISION

TABLE II—DISTRIBUTION OF DIFFERENCES BETWEEN OLD AND NEW ESTIMATES OF MONTHLY GENERAL RAINFALL 1941-50

Old estimate minus new estimate <i>inches</i>	England and Wales <i>number of occasions</i>	Wales	Old estimate minus new estimate <i>inches</i>	England and Wales <i>number of occasions</i>	Wales
-0.6		1	+0.2	8	13
-0.5		2	+0.3		7
-0.4		7	+0.4		5
-0.3		1	+0.5		0
-0.2	11	10	+0.6		0
-0.1	32	24	+0.7		0
0.0	53	23	+0.8		2
+0.1	16	25	Total	120	120

0.7 inch whereas the old estimate was 0.4 inch, an error of over 40 per cent. The main reason for the contrast between Wales and England is as follows: over a medium-sized area such as Wales there can easily be appreciable variations of percentage leading to appreciable values of the ‘areal covariance’; this is especially true when, as in Wales, the area includes big variations in average rainfall. Over a much bigger area, such as England, local contributions to the areal covariance may be just as large but they will on the whole tend to cancel each other out. It follows that the old method will tend to give larger errors for medium-sized than for either very small or very big areas. A secondary reason for the contrast is that the number of stations used for determining the mean percentage over Wales in the old method was rather small.

Errors in the estimates of annual totals over England and Wales ranged fairly evenly from -0.6 inch to +0.5 inch, that is, up to approximately 2 per cent; over Wales however errors in annual totals ranged from -1.3 inch to +2.0 inch, that is, up to about 4 per cent. Even over Wales, however, 8 out of the 10 years had errors of 0.6 inch or less.

The conclusion to be drawn from the work described above seems to be that the great majority of the previously published monthly and annual general values of rainfall over England, Wales, and England and Wales are as accurate as can reasonably be hoped for, but that the old-established method of computing them gives rise to substantial errors often enough to make a change of method desirable in all future work. (Such a change of method has in fact now been introduced into the rainfall section largely as a result of this investigation.)

We wish to express our thanks to Mr. P. B. Sarson who wrote the computer programme.

551.508.54

A WEEKLY RECORDING ANEMOMETER

By M. T. H. KEY

Hydraulics Research Station, Wallingford, Berkshire

**Introduction.**—The Hydrological Research Unit (HRU), Wallingford, is conducting water-balance investigations on experimental catchments in certain parts of England and Wales. Climatological stations have to be operated at isolated sites which can be visited only once a week.

An anemometer of the cup counter type was required to record the daily total run of the wind for a seven-day period without attention, to be independent of outside electrical supply and to be able to withstand the adverse climatic conditions of exposed positions.

A standard instrument to fulfil the seven-day recording requirement was not available, but a suitable recording anemometer (Plate I) has been designed and manufactured at the Hydraulics Research Station (HRS). The instrument has been in use on one of the catchment sites since March 1964 having previously been tested on the HRU climatological site at Wallingford since October 1963. A photograph of the complete installation on a catchment site is shown in Plate II. A comprehensive note<sup>1</sup> has been prepared to guide observers on the installation and on the weekly readings.

**Principles of operation and general description.**—The instrument was designed for use with a commercial contact anemometer providing an electrical closed circuit for each tenth of a mile run of the wind. Each daily total is recorded on one of eight counters; a clock and cam-operated micro-switch system connects the anemometer to the counters at 24-hour intervals. Every week, when the installation is visited, seven counters are read and reset to zero, the one actually operative at the time being ignored until the next visit.

The counters are battery operated. Battery life is expected to be at least 200,000 counts or 20,000 miles run of wind. A battery tester has been made for use by the observer when he visits the installation.

The three units of the equipment, comprising anemometer, recorder and battery box, are mounted on a 1 $\frac{3}{4}$ -inch diameter scaffold pole, the anemometer cups being 2 metres above the ground. The mounting frame for the recorder and battery box is arranged to swivel on the mast so that it can be rotated to the leeward side, and then, when the recorder box is opened for winding the clock or adjustment of the time dial, the cowled lid will shield the mechanism from driving rain. The counters are protected by a movable perspex flap which closes on a rubber sealing strip and which also serves as a rain shield when it is raised for resetting the counters.

The instrument may also be used to obtain mean wind speed in the manner prescribed for the cup counter anemometer Mk II.<sup>2</sup>

**Acknowledgments.**—The work described in this paper was carried out as part of the research programme of the Hydraulics Research Board and this note is published by permission of the Director of Hydraulics Research.

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551.501.8:061.3

### **1964 WORLD CONFERENCE ON RADIO METEOROLOGY, INCORPORATING THE 11TH WEATHER RADAR CONFERENCE, BOULDER, COLORADO**

This conference, held from 14 to 18 September 1964, was sponsored by the Inter-Union Committee on Radio Meteorology of the International Scientific Radio Union (URSI) and the International Union of Geodesy and Geophysics (UGGI), the American Meteorological Society, the U.S. Weather Bureau, and the Central Radio Propagation Laboratory of the U.S. National Bureau of Standards in whose laboratories at Boulder it met. It was remarkable not only



for the length of its title and list of sponsors but also for its organization and procedure. The organizing committee invited papers on a number of chosen subjects; contributors were required to forward their manuscript in a specified format about four months before the date of the conference. These papers were printed by a photographic process in a paper-backed volume of some 500 pages, and the volume was in the hands of all those who had registered to attend the conference about a month before it convened. At the conference papers were not presented by the authors in the usual way. Each session was in the hands of a Chairman and a 'lead speaker.' The latter introduced the subject of the session, and was supposed to refer to all the papers and indicate their content and interrelation. The Chairman then called for discussion of the papers in turn. One or two lead speakers dwelt unnecessarily on their own work, and one or two authors evaded the Chairman's eye and slipped in a hurried presentation under the guise of comment, but on the whole the method was successful, with informed discussion of the content of the more interesting papers and of the general state of the subject. The success of this procedure implies a high degree of discipline from contributors, an unusually hard-working group of organizers, and a sponsoring Institute with considerable resources in facilities and finance. The conference volume will be a valuable addition to any library during the year or two which will elapse before the high proportion of its content which is worth preserving finds its way, in more polished and final form, into the journals and textbooks.

Four sessions were devoted to the meteorology of radio-propagation—'Radio climatology,' 'Meteorological effects on propagation,' 'Radio-refractive index measurements' and 'Tropospheric propagation, super-refraction, and scatter propagation.' The subjects were rather arbitrarily differentiated and the papers put forward no really new ideas, but in some cases brought a new degree of precision to the subject. Perhaps the most interesting new observations were those on fine-scale variation of refractive index, made mainly at Cardington and communicated by J. A. Lane of the Radio Research Station.<sup>1</sup>

The session on 'Anomalous echoes and angels' led to very lively discussion but, not surprisingly, to no general agreement. Few were able to accept wholeheartedly D. Atlas's picture of the leading edge of an ascending thermal acting in much the same way as a well-figured spherical metallic reflector, but equally few were convinced by less precisely specified alternative explanations involving birds and insects.

The papers on rainfall measurement by radar were concerned not with the usefulness of the technique—that was not questioned—but with ways of assessing and improving its accuracy. A paper on precipitation measurement by Weather Bureau radars, for example, concluded that present methods led to an average underestimate of about 20 per cent on an area basis, with errors up to a factor of two either way in individual cases. There were many papers on drop-size distribution, which of course determines the relation between rainfall rate and echo intensity. Measurements with the Malvern Doppler radar, presented by P. G. F. Caton, made a weighty contribution to this problem.

A session on 'Scattering and attenuation—tropospheric and terrain noise radiation' contained rather a mixture of papers, as one or two on precipitation attenuation at 3 cm were caught up with the majority which were either on generalized scattering problems or on atmospheric transmission in the 1-mm to 3-cm region. On the whole the papers were educative rather than original,

introducing to radio scientists concepts which have long been familiar to students of atmospheric radiation. D. Diermendjian extended his Mie-theory work to the 1-mm to 10-cm range, and B. M. Hermann reported on a 'simple' problem in multiple scattering. Microwave spectra and atmospheric transmission functions were mentioned. Possibilities of temperature-structure measurements from satellites using microwave spectroscopy were discussed by self-styled optimists and pessimists. The great advantages of microwave over infra-red spectroscopy are the extraordinarily high resolution attainable and the sensitivity of available detectors, so long as the wavelength is not too short for true radio techniques.

The last session, on lasers, opened with an extraordinary lead speech by Professor Franken of Michigan State University, which was at once a comic turn of great distinction, a summary of the properties of available lasers in the context of atmospheric sounding and an estimate of likely technical developments. The actual work reported to the meeting was disappointing in amount and content, the most substantial part having already been published.<sup>2,3</sup> Professor Franken is himself involved in the search for clear-air turbulence (CAT) by the use of laser methods, a search which has had some Press publicity. It transpired that the basis of the work was a belief that CAT might be connected with the mixing of two air masses of different aerosol content, the difference being detectable by optical back-scatter. Professor Franken himself discounted the possibility of more sophisticated Doppler laser techniques.

There was, of course, some social activity, the most memorable being an afternoon spent walking in a sprinkling of new snow in the high Rockies. Boulder itself is likely to become a centre for meteorologists, as the new home of the National Center for Atmospheric Research is now being built there, to an imaginative design, on a site of quite exceptional natural beauty. While it is hoped that the increasing urban sprawl of the town of Boulder itself can be contained, the great scientific opportunities opening up in such remarkable surroundings for the young student of our science are considered with envy.

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G. D. ROBINSON

551.510.42

## METEOROLOGICAL OFFICE DISCUSSION

### Atmospheric pollution

The Monday discussion held on 26 October 1964, opened by Dr. A. G. Forsdyke, covered those aspects of air pollution which are dealt with in the Special Investigations Branch (Met.O.9). These arise from particular inquiries which the branch is called upon to answer, and they draw upon the results of fundamental research, though the research itself is done in other branches of the Office and elsewhere.

Atmospheric pollution by smoke has been a nuisance in large towns for a very long time, the earliest record dating from 1273 when there were appeals to the governing authorities to ban the burning of coal at such industrial premises as then existed in London. But the first effective legislative action was not



taken until 1863 when there was set up the Alkali Inspectorate, a body which still exercises control over noxious emissions from industrial plant. Government sponsored research began in 1917, and today is carried on chiefly at the Warren Spring Laboratory at Stevenage. An important part of the work of the Laboratory is the organization of a country-wide network of stations which regularly measure and report atmospheric pollution. The serious consequences of heavy pollution were brought home by the disastrous London smog of December 1952, which led to the setting up of the Beaver Committee and the subsequent passing of the Clean Air Act, 1956. This Act empowered local authorities to designate 'Smokeless Zones' and encouraged the use of smokeless fuels and more efficient burning appliances. The result has been a gratifying decrease in smokiness over the past eight years, particularly in London. The main troublesome pollutant is now sulphur dioxide ( $\text{SO}_2$ ). Neither this gas nor the sulphur from which it is derived can be economically removed from the raw fuel or the chimney effluents. Reduction of the concentration of  $\text{SO}_2$  to below harmful levels is therefore dependent upon dispersal and dilution of the effluent in the atmosphere. In big industrial plant and power stations this is achieved by building high stacks and discharging the effluent at high speed and high temperature.

Following these introductory remarks the speaker outlined the theoretical background relating to atmospheric diffusion and turbulence. This is the basis for calculation of concentration of a pollutant in the atmosphere at any point affected by a particular source such as a power station chimney. The working formula is that proposed by Pasquill.\*

There followed a description in some detail of the application of the formula in a particular inquiry dealt with in Met.O.9. This involved the calculation of  $\text{SO}_2$  concentration at various floor levels of proposed tower-block flats between  $\frac{1}{2}$  and  $1\frac{1}{2}$  miles from an electrical power station with tall stacks emitting up to 10 tons of  $\text{SO}_2$  per hour. The calculated concentration at the upper floors was above the limit of tolerance and, partly for this reason, the scheme was not proceeded with.

As a further example of a practical problem in air pollution a method was outlined for the forecasting of high  $\text{SO}_2$  pollution levels in the City of London. Daily values of  $\text{SO}_2$  concentration measured at St. Bartholomew's Hospital were tabulated for the five winters 1958/59 to 1962/63. These were related to the minimum night temperature at London (Heathrow) Airport ( $T_n$  °C) and the largest temperature 'inversion' ( $\Delta T$  °C) calculated as the difference between the highest temperature below 900 mb on the Crawley midnight tephigram, and  $T_n$ . It was found that provided the cloud amount at London (Heathrow) Airport remained small and the wind light throughout the period, smog (defined as  $\text{SO}_2$  concentration  $\geq 1000$  microgrammes per cubic metre) was likely if

$$2 \Delta T - T_n \geq 12.$$

In the subsequent discussion Mr. E. N. Lawrence described the routine methods of measuring  $\text{SO}_2$  pollution. Dr. F. Pasquill commented on the physical foundation and the conditions of applicability of his formula on which, at present, the calculation of pollution is based in practice.

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\*PASQUILL, F.; The estimation of the dispersion of windborne material. *Met. Mag., London*, **90**, 1961, p. 33.

## A COLLOQUIUM ON TELEVISION WEATHER FORECASTING

Mr. Robert T. Freeman, Chief Meteorologist WKY Radio and Television, Oklahoma City, was the chief speaker at a colloquium on television weather forecasting held at the Imperial College of Science and Technology, London, on 17 November 1964.

Mr. Freeman commenced by pointing out that the weather in Oklahoma is rather more settled than in this country and the winters are not very severe. Forecasts are normally only required for short periods, and in the summer months they usually consist of forecasting severe storms such as thunderstorms, hail and tornadoes. These storms can be very destructive even though they may have a relatively short lifetime. An individual storm may last only about half an hour, though a number of them forming an area of storms can continue for up to 10 to 12 hours. Rapid notification of the development of storms to the public is essential so that the optimum use can be made of the information. As the forecasting of such storms can be literally a matter of life and death it would seem that the qualifications of the forecasters must be of the highest order. However, in the United States many stations employ weather men who are not professional meteorologists. Television weather men are becoming the public image of the profession, and the aim should be for them to possess the highest possible qualifications. As a result, a system of seals of approval has been instituted by the American Meteorological Society.\* Some television stations take weather forecasting very seriously indeed and have helped to educate people to the problems involved, but not all stations employ forecasters possessing the seal of approval. The only station in Oklahoma State to do so is WKY Oklahoma City.

Mr. Freeman showed a film depicting the weather set-up at WKY Radio and Television Station Oklahoma City. The weather office is close to the television studio and a full set of meteorological instruments is maintained. The readings of the instruments are displayed in the weather office and this display is duplicated in the television studio so that it can be televised. A weather radar set is also provided, with two scanners, one of which is on a high tower 11 miles away. The radar has ranges of 250, 160, 80 and 25 nautical miles. The radar set is in the weather office and the display is also duplicated in the studio, so, here again, the cameras can be trained on the radar picture whilst the presentation is taking place. There is also a switch in the studio by means of which the weather man can change the range of the radar whilst he is actually doing the presentation. By means of an 'overlay' of the State, it is possible to show viewers the areas in which storms are occurring, and this display can also be photographed to be shown at a later time. The company provides a news car which can be used by the weather section to search for and track storms or tornadoes. The film includes dramatic pictures of an approaching tornado seen against the skyline of Oklahoma City and pictures of the news car dashing off to investigate. Reports also come in by telephone from the public, and all these reports are plotted, future movements of the storms are estimated, and the information is relayed to the public. This is done by means of special bulletins, and the company gives the meteorologist authority to interrupt programmes at any time if it is necessary to issue weather warnings. The decision to issue a

\*JEHN, K. H.; Radio and television weathercasting—the seal of approval program after five years. *Bull. Amer. met. Soc., Boston, Mass.*, **45**, 1964, p. 489.

warning rests entirely with the television meteorologist, but he acts in close liaison with the Weather Bureau forecasters at the nearby airfield. In the summer months in Oklahoma, many people leave their television sets switched on all day. If a weather warning is to be issued, the company broadcasts what is known as a 'BEEPER' and this draws the attention of the public to the fact that a weather warning is about to be issued.

In his concluding remarks Mr. Freeman said that Television Station Oklahoma City (WKY) has a coverage over a radius of about 150 to 160 nautical miles. This is obtained through the use of 'community antennae' which in this country would be known as booster stations. These are operated in the United States on a commercial basis, the community in a small radius around the station paying a small fee to the commercial company to obtain a picture at least as good as that obtained in Oklahoma City itself. Finally, once a warning has been issued it is absolutely mandatory for the weather man to provide the public with further information about the movement and development of the storm. If the storm weakens and decays, the public must be told so and not left 'hanging in mid-air'.

Dr. Ludlam opened the discussion by pointing out that the occasional great severity of local weather in Oklahoma gives Mr. Freeman a distinct advantage. The weather is very seldom as severe in this country. Mr. Freeman tells people what the weather is. Couldn't we have more of this here? It would be interesting to know, as well, how much time Mr. Freeman gets on television. Mr. Freeman replied that he has three 5-minute periods during the morning, a 10-minute period at noon, 10 minutes at six o'clock and 10 minutes at 10 p.m., making a total of 45 minutes a day. So much interest is shown in weather in Oklahoma that commercial interests fall over each other to buy television weather time for commercial advertising. They know full well that there will be a large viewing public at the normal weather presentation times. The weather, therefore, becomes a 'saleable product.' In reply to another question Mr. Freeman stated that apart from himself he has one full-time and one part-time assistant, but he is now looking for somebody else to work full-time.

Mr. Foord, one of the weather men on British Broadcasting Corporation (BBC) Television, wanted to know something about the technical details of Mr. Freeman's presentation. Did he forecast for the entire state? How long preparation beforehand did he have? What charts were used, and how did he draw them? Mr. Foord pointed out that although many people were interested in the day's weather, time to explain this was essential and the BBC only allowed 3 minutes for the full United Kingdom forecast. Mr. Freeman expressed horror at having only 3 minutes a day, saying it certainly would not be sufficient for him. He forecasts for the whole of the state of Oklahoma and has hourly surface charts plotted, and also does 850, 700 and 500 millibar analyses. He feels that it is essential to have 4 hours of preparation for a 10-minute show, and if he cannot be on duty in time to get the 4 hours he will ask his assistant to stay behind and do the broadcast instead. He makes use of a four-sided drum on which he can draw with a felt pen and paint. The maps he uses in his presentation are: a synoptic map of Oklahoma State; a map of maximum and minimum temperatures for the State; a map of the State showing the present weather situation; and two United States maps, one showing cloud cover, and the other showing representative temperatures around the country. On this last map he draws in the surface isotherms whilst he is actually doing the presentation.

Mr. Hunt of Anglia Television said that the set-up in the United States is obviously different from that in the United Kingdom. Probably the main difference is the time aspect. Even on independent television in this country there is the problem of the national network presentations. This means that it is difficult for a regional company to insert weather forecasts or warnings; but there are signs of the beginnings of elasticity in that 'promotion periods' can be used in an emergency. These are periods between programmes for which no television advertising has been allotted and the time would normally be used for 'trailing' other programmes. If the weather situation warrants it, the company will allow Mr. Hunt to make use of one or more of these promotion periods.

Professor Sheppard, Head of the Meteorology Department at Imperial College, spoke next. He was severely critical of the methods of weather presentation on television in this country at the present moment. Isobaric charts are definitely not the answer. He felt sure that the time has come when the BBC and Independent Television, if they were approached, would probably be ready to be impressed by new methods of presentation.

An animated discussion ensued on this point until, finally, Mr. Harding, Assistant Director (General Services) at the Meteorological Office, put the case for the Meteorological Office and the BBC. Admittedly the time allotted to weather forecasts on television is very limited, but the BBC is fully alive to the interest taken in the weather by people in this country and allocates about 100 minutes a day to weather bulletins on the various sound radio channels. Experience has shown that lengthy forecast bulletins encourage padding of the forecast with inessential material which results in consequent confusion to a majority of viewers and listeners. Mainly at the instigation of the BBC, individual bulletins are shorter now than they were a few years ago; this encourages clear concise forecasts. Mr. Harding was convinced that this was good policy. The BBC and the Meteorological Office have the problem of catering for those who are only interested in knowing whether it is going to rain tomorrow and would be happy with, for example, a mere simple caption chart on television, and, at the other end of the scale, for those specialist viewers such as farmers and sailors who are so very dependent on weather. The latter are extremely interested in synoptic developments, can interpret weather charts and are much more understanding of the reasons why a forecast may have gone wrong; their numbers are growing daily.

Dr. Ludlam then closed the discussion by thanking Mr. Freeman for his very interesting talk and also thanking everyone who had taken part. He regretted that there was no time left for a further film to be shown, but pointed out that the fact that he had been obliged to forcefully close the discussion showed what a lively interest had been taken in the subject.

N. ELLIS

### **METEOROLOGICAL OFFICE NEWS**

Dr. G. B. Tucker, a Principal Scientific Officer in the Dynamical Climatology Branch of the Office (Met.O.20), is widely known for his researches and numerous papers concerning the general circulation of the atmosphere. He has recently accepted an appointment as Assistant Director (Research and Development) in the Commonwealth Bureau of Meteorology, Australia, and will be leaving the Office in early April to take up his appointment.

We extend to him our best wishes for his success in his new and important post.

## NOTES AND NEWS

### Services to the agricultural community

At a colloquium given in the lecture theatre at the Headquarters of the Meteorological Office, Bracknell, on 24 November 1964, Mr. G. W. Hurst described the services provided by the Meteorological Office for the agricultural community. Extracts from the lecture and the discussion which followed are given below.

**Introduction.**—The Agricultural Branch exists to meet the needs of agriculture, horticulture and forestry in the United Kingdom although problems occasionally arise in other fields. However, most of the work of the Branch deals with agriculture in the broadest sense and there are few progressive agricultural organizations in the U.K. with whom there is not at least occasional contact. The most important link between the Office and agriculture is through the National Agricultural Advisory Service (NAAS) which operates under the Ministry of Agriculture, Fisheries and Food in England and Wales. NAAS has eight divisional headquarters and there are meteorological offices at three of them—Bristol, Cambridge and Leeds. Meteorological representation is desirable in principle at all the centres to complement the activities of other specialists—in entomology, pathology, husbandry, etc.—who are qualified to answer most enquiries which are submitted to the centres through county advisers. Some research is done at several of the centres but most research is carried out at the main institutes such as Rothamsted, Wellesbourne, East Malling, etc. In Scotland and Northern Ireland where NAAS does not operate, the universities and research institutes disseminate scientific and specialized knowledge to the farming community.

There are about 90 agro-meteorological stations in the U.K. and their main function is to provide information suitable for meteorological work in scientific agriculture, and a further 50 establishments, including for example research laboratories, have been actively in touch with the Branch.

**Routine services.**—These can be divided into straightforward work, such as extraction of data, and work based on research.

Under the first of these headings are the weekly summaries of weather during the past week which are sent to NAAS and some other bodies. The circulation is about 300. Half of the summaries are prepared at Bracknell with the co-operation of Met.O.3 (Climatological Services) and half by various regional stations, roughly for their own regions.

Routine services developed from research are mostly seasonal and chiefly for the summer months. Research on some problems has led to the establishment of very definite rules of behaviour and the formulation of warning schemes, for example potato blight and apple scab warnings.

*Potato blight.*—This is a fungoid disease, and work done by the Office in collaboration with research stations such as Rothamsted has established that high temperatures and high relative humidity are conducive to the build-up of the fungus on the haulms. It is particularly important to carry out preventive spraying before the first outbreak.

*Apple scab.*—The spores causing this disease are present on fallen infected leaves. Wet conditions, during and after rain for example, can discharge the spores, and relationships have been established between the discharge and the number of hours when the trees are wet, coupled with the temperature.

*Liverfluke*.—This is a serious disease of sheep. The life-history of the fluke is very involved partly because the fluke necessarily spend one stage of their life-cycle in a particular species of snail; moisture is important as in very dry weather the snail population is low and the egg hatch mortality of the fluke is high. Returns of rainfall, rain days and transpiration are made monthly to the Central Veterinary Laboratory, Weybridge, and these enable a decision to be made on the necessity for 'drenching' and the application of molluscicide. It is interesting to note that when the disease is prevalent the loss to the farming community could be of the order of a million pounds in the year so that even a saving of about 20 per cent due to good advice would represent a very real profit to the community.

*Potential transpiration*.—Monthly potential transpiration over the country has been related to sunshine, and relevant figures are issued monthly with the routine summaries and also to other interested people. These figures assist in scientific irrigation which is particularly important in horticulture.

**Non-routine services**.—These cover a wide field and although many of the problems are channelled through NAAS, some are received direct. Information supplied varies from relatively simple extraction of data to a considered professional opinion based on long experience, and sometimes experiments are specially mounted to meet the required need.

Problems which have been specially studied include: irrigation needs, which may only be of concern for two months of the growing season: shelter effects—here it is interesting to note that in the Isles of Scilly the horticultural activities are being planned on a scientific basis using ideas supplied by the Meteorological Office: land use: ventilation, for example for indoor crops: and animal comfort.

The problem of frost might involve the examination of an area with a view to planting an orchard, or a comparison of the freedom from frost in neighbouring areas.

An experiment at Manor Farm, Luddington in the west Midlands, illustrates how the problem might be tackled. Figure 1 shows the site which slopes down to the River Avon, a fall of about 60 feet; the weather station is shown at W.S. and additional thermometers were specially mounted at positions I to IV. Temperature comparisons are made in Figure 2 where the average minimum and the average weekly absolute minimum for the highest (176 feet) and lowest (120 feet) sites are shown for eight weeks following 31 March in 1950 and 1951. The estimated frequency of various degrees of frost in a 10-year period in May at the two sites is as follows:

Height of site feet	Temperature		
	≤ 32°F	≤ 30°F	≤ 28°F
	estimated frequency		
176	10.5	5	1
120	22.0	15	7

The difference between the sites is quite striking and in fact a proposed orchard was not extended down to the bottom of the slope.

**Research**.—During the 15 years that the Agricultural Branch has existed some problems have been solved satisfactorily enough for working rules to be laid down. Problems which have been actively studied during the last 2 years are as varied as and more numerous than those listed under non-routine services. Three examples will indicate the scope of the work.

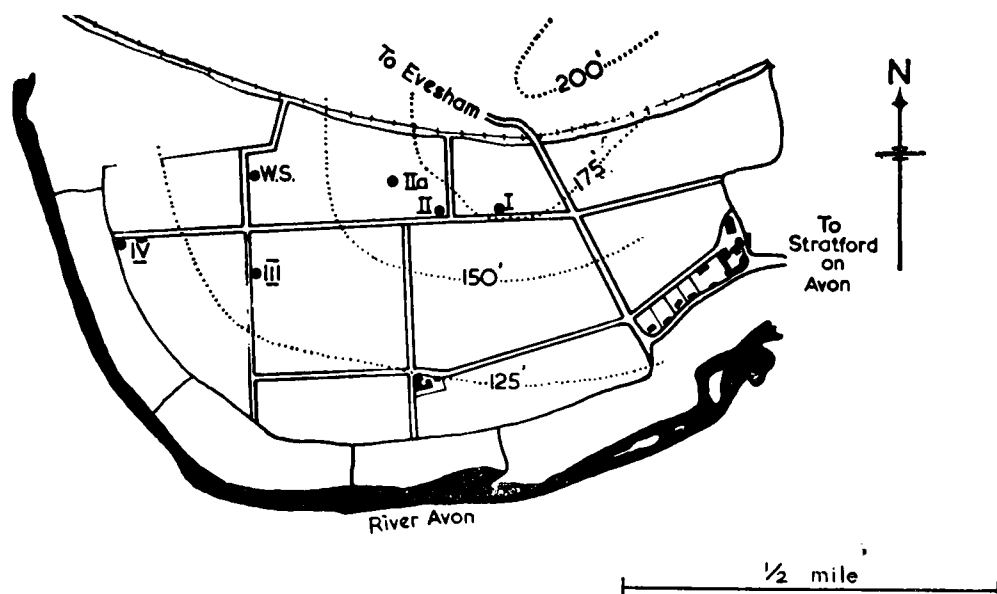


FIGURE 1—DISTRIBUTION OF THERMOMETERS AT MANOR FARM DURING A FROST INVESTIGATION IN 1950 AND 1951

W.S. is the weather station and additional thermometers were placed at positions I to IV. Contours are at intervals of 25 feet.

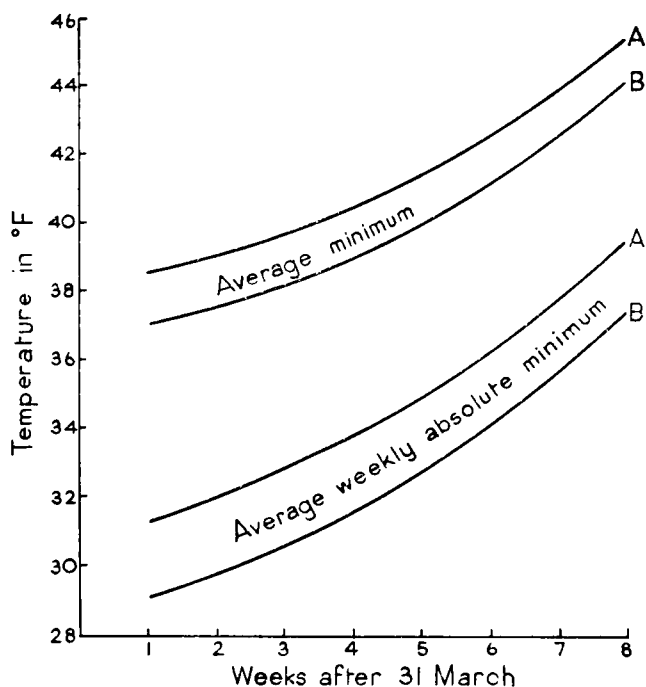


FIGURE 2—AVERAGE MINIMUM AND AVERAGE WEEKLY ABSOLUTE MINIMUM TEMPERATURE CURVES (SMOOTHED) FOR TWO SITES AT MANOR FARM FOR AN EIGHT-WEEK PERIOD FOLLOWING 31 MARCH IN 1950 AND 1951

Curves A are for site I at 176 feet and curves B are for site IV at 120 feet above MSL. (see Figure 1 for site positions.)

*Sugar-beet yellows.*—This disease has not been so prevalent in recent years; even so, for example, over 20 per cent of all beet plants were infected in 1961. The virus is vectored by an aphid (*Myzus persicae*) so various factors which might affect the population of this aphid early in the year were examined. It was found that correlation between incidence of the disease and rainfall and sunshine was low but the correlation was high between the temperature in February, March and April and subsequent yellows percentage. The temperature data considered were departures from average in eastern England—the main growing area for sugar beet—and the results are shown in Figure 3. The severity of an attack was assessed on a 5-point scale ranging from less than 5 per

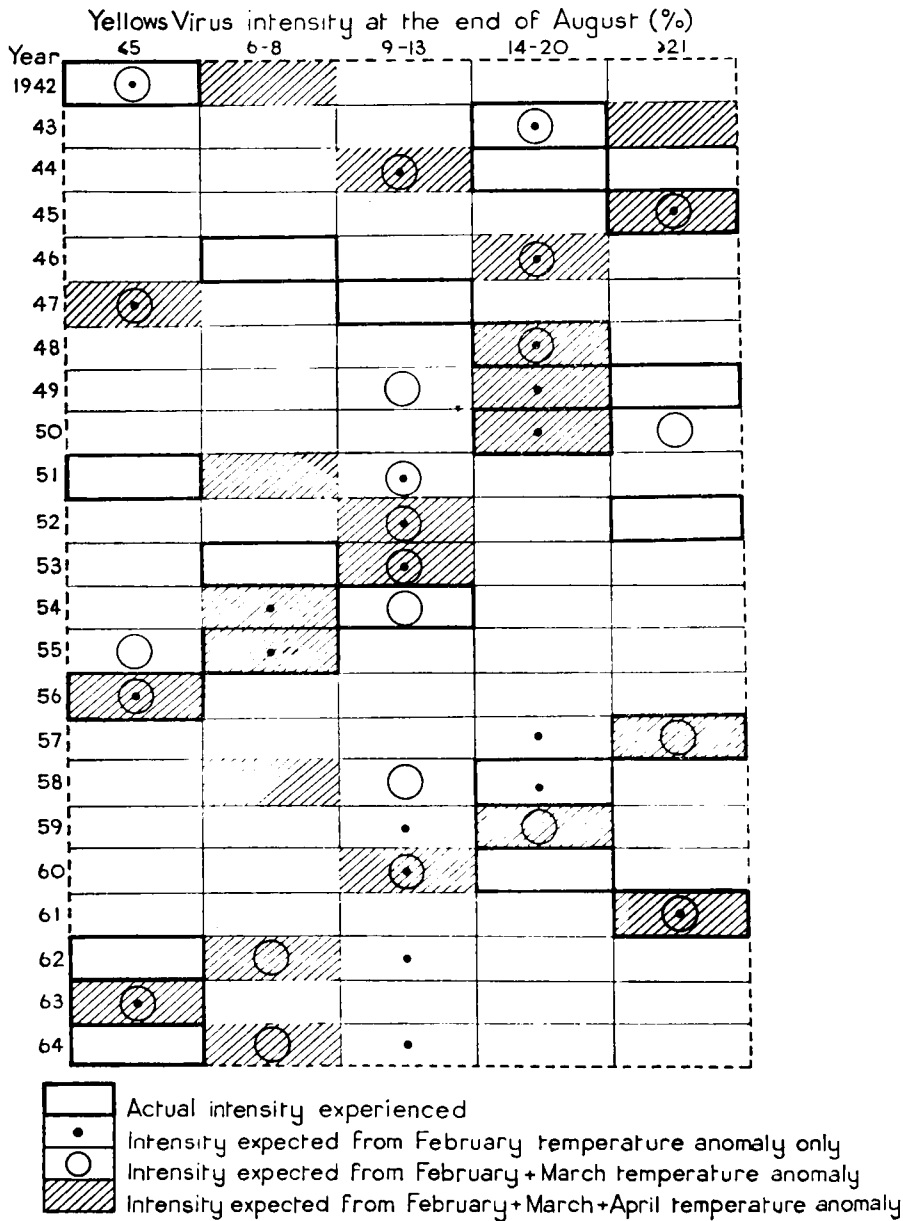


FIGURE 3—ACTUAL INTENSITY OF ATTACKS OF YELLOWS VIRUS IN THE PERIOD 1942-64 COMPARED WITH THE EXPECTED INTENSITY BASED ON TEMPERATURE ANOMALIES IN FEBRUARY, MARCH AND APRIL IN EACH YEAR



cent of yellows at the end of August in a good year to greater than 21 per cent in a bad year. Intensities expected were seldom seriously in error and in 1946, the only year in which temperature anomalies gave an incorrect expected intensity, the poor weather during May, June and July very considerably restricted the aphid numbers. The existence of the correlation of February temperature anomaly with subsequent disease is useful because during March a decision has to be made on spraying programmes for the summer. The loss of sugar from the beet can vary from 100,000 tons upwards to as much as 1,000,000 tons in one particular year—a financial loss of £5,000,000—so if the loss were reduced by 10 per cent by using good advice on the need for spraying this would represent a very real saving.

*Agricultural practices.*—Work has been done in relating agricultural practices in England and Wales to meteorological parameters such as effective transpiration in the summer half of the year. As an example, Figure 4 shows that far larger numbers of cattle exist in areas in the west where the effective transpiration is high than in the drier areas less suitable for grass in the east.

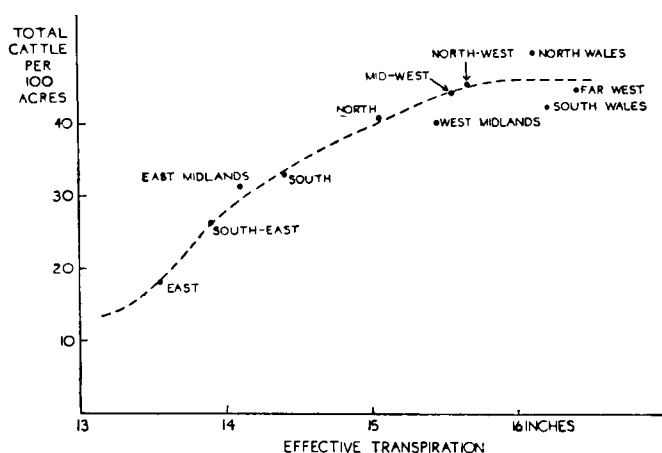


FIGURE 4—NUMBER OF CATTLE PER 100 ACRES COMPARED WITH THE EFFECTIVE TRANSPIRATION OF THE AREA

It has also been shown that the production of milk has been increasing in areas where the effective transpiration is high and decreasing where it is lower. In Figure 5 the arrows show how the percentage of national milk per unit area has changed in various counties between 1946 (blunt end of the arrow) and 1960 (pointed end of the arrow). The arrow is placed on the x-axis according to the average effective transpiration for the county. The curve has been drawn to show the 'target line' which the counties might reach. The few arrows going in the opposite direction from the expected, represent exceptional counties which may be affected by say nearness to London or communication difficulties.

Consideration of the type of crops grown compared with the soil moisture deficit at the end of August confirms the general pattern of deep-rooted crops in the dry areas and more shallow-rooted crops in the wet areas.\*

**Conclusions.**—Future work will to some extent depend on the customers' requirements, but some of the problems envisaged concern the rational and efficient use of the land in relation to meteorological factors, control of diseases

\*WALKER, J. M.; Distribution of crops with respect to mean potential soil moisture deficit at the end of August. *Met. Mag., London*, 94, 1965, p. 18.

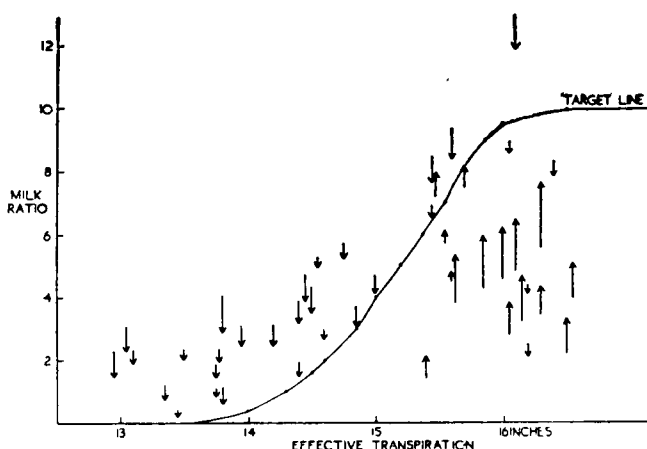


FIGURE 5—CHANGES IN PRODUCTION OF MILK PER UNIT AREA FOR THE VARIOUS COUNTIES DURING THE PERIOD 1946–60 COMPARED WITH THE EFFECTIVE TRANSPIRATION OF THE COUNTY

The blunt end of the arrow represents the position in 1946 and the pointed end the position in 1960. The 'target line' represents production figures which might be reached in time.

The milk ratio is the county production, expressed as a percentage of the total production, divided by the area of the county.

and pests, and, in the field of ventilation, the establishment of simple formulae which can be applied to the construction of animal houses, storage buildings etc. of a specific nature. In the realm of instrumentation, techniques and instruments introduced many years ago are still in use but the introduction of more sophisticated instruments including the automatic weather station can be foreseen.

**Discussion.**—During the lively discussion which followed, the use and meaning of grass minimum temperatures were questioned. The possibility was discussed of measuring ground temperatures over concrete rather than over grass. This would give considerably more uniform results. Soil temperatures usually fall to about halfway between the low grass minimum and the less low concrete minimum. Finding a satisfactory substitute for the grass minimum temperature would be of interest in the synoptic world as well as in agriculture.

Some discussion took place on the measurement of radiation and it was stated that a realistic network of stations giving reliable radiation measurements would be welcome.

Among other topics raised were interest in the spectrum of radiation, work for the Fisheries and the effects of air pollution.

G. W. HURST

### Retirement of M. André Viaut

In October 1964, M. André Viaut, Director of the National Meteorological Service of France, retired on reaching the statutory age limit of 65.

M. Viaut is well known to meteorologists everywhere and especially to the staff of the Meteorological Office. He began his career as a professional meteorologist in 1921 and after service in France and North Africa, was appointed Director in 1945. During this period his interests lay mainly in the application of meteorology to aviation, and it is pertinent here to mention his skill as a cloud photographer. As Director, he carried out the formidable task of organizing the French meteorological service, in the years that followed the liberation,

with skill and devotion. He was appointed successively Chevalier, Officier and finally, in 1956, Commandeur of the Légion d'Honneur.

For most of us, M. Viaut is best known for his remarkable work in the international field, especially with the International Civil Aviation Organization and the World Meteorological Organization (WMO). He was one of those who formed WMO from the old International Meteorological Organization and was a prominent figure at the 1947 Conference of Directors that drew up the Convention of WMO. He was a member of the Executive Committee from its inception and in 1955 he was elected President. In 1959 he was chosen for a second term.

Those of us who attended the sessions of Congress and of the Executive Committee during the eight years of his presidency know him as a tireless worker and skilled administrator. It was largely under his guidance that WMO grew to its present position and not the least of his achievements was the successful conclusion of the negotiations with the Canton of Geneva that gave the Organization its impressive Headquarters.

No account of M. Viaut's career would be complete without referring to the help given him in the many social responsibilities of the president's office by Mme Viaut. They will be greatly missed in the meetings at Geneva.

We wish M. and Mme Viaut a long and happy retirement.

O. G. SUTTON

### **Appointment of M. J. Bessemoulin**

We have been informed that M. J. Bessemoulin has been appointed Director of the French Météorologie Nationale in succession to M. A. Viaut, and he will also be Permanent Representative of France with the World Meteorological Organization.

We wish M. Bessemoulin every success in these appointments.

### **Italian Meteorological Service**

Maggior Generale Prof. Giorgio Fea succeeded Brig. Gen. Fernando Giasanti as Chief of the Italian Air Force Meteorological Service on 20 January 1965. We wish Maggior Generale Prof. Fea every success in his new appointment.

### **REVIEWS**

*Meteorological soundings in the upper atmosphere* by W. W. Kellogg. (WMO Tech. Note No. 60.) 10 $\frac{3}{4}$  in  $\times$  8 $\frac{1}{2}$  in, pp. x + 48, *illus.*, Geneva, World Meteorological Organization, 1964. Price: Sw. F. 8.

The authoritative and inexpensive WMO *Technical Notes* cover a wide range of subjects. *Technical Note* No. 60, recently published, claims to present "a brief and factual review of our current knowledge of the upper atmosphere, defined as the region above the level usually attained by sounding balloons (about 30 km) and below the level of satellites (about 150 km); and it then treats the various techniques for observing conditions in the upper atmosphere." It does just that. There are six sections. In the first, the major features of the upper atmosphere are described; in the second, ground-based techniques for investigating the upper atmosphere are outlined; and in the third, fourth and fifth the uses of small meteorological rockets, of large rockets, and of guns for probing the upper atmosphere are discussed. The final chapter summarizes what

observations are most needed in order to make progress in our understanding of this region. All this is done in 23 pages yet, as is to be expected from a document prepared by Dr. Kellogg, the note is easy and pleasant to read and there are, with one notable exception, no serious omissions and nothing with which I, at any rate, can find serious fault. The omission is that there is scarcely any mention of the value of satellites in observing the high atmosphere—a strange omission since it may only be by using satellites that the world-wide cover, the importance of which is stressed in the Note, can be obtained.

There are four pages of references so that it is easy for any reader to follow up any aspect in which he is particularly interested. There are also five appendices—three of which, occupying nearly as many pages as the Note itself, serve little useful purpose.

R. FRITH

### OBITUARIES

*Mr. Ben. G. Brame, M.B.E.*—It is with very deep regret that we heard of the death of Mr. Ben. G. Brame on 16 March 1965. A full appreciation of his many years of service in the Meteorological Office appeared in the April, 1956 issue of this magazine. Our deepest sympathy is extended to his widow in her sad loss.

*Mr. R. Graham.*—It was with great regret that his many friends in the Office learnt of the death of Mr. R. Graham on 25 November 1964.

'Robbie' joined the Office in 1920 as a Boy Clerk in M.O.3 which in those days included the Library as well as Climatological Services. In 1925 he moved to Renfrew and from there to Lerwick in 1928. On this occasion his stay in Lerwick was comparatively short, three years. For the next 15 years Robbie served at many outstations located throughout the United Kingdom from southern England to northern Scotland, and during this period he progressed from Boy Clerk to Assistant I and served for two and a half years as a Flight Lieutenant in the Royal Air Force Volunteer Reserve. After release from the RAFVR in 1945 he returned to forecasting duties serving at a number of stations in England and also in Italy and Habbaniya. In 1951 he entered the radiosonde field and moved to Lerwick where he stayed for the remainder of his career. Robbie had most of the qualities of an ideal officer-in-charge, always being cheerful and quite imperturbable and his work at an isolated station such as Lerwick made full use of his qualities. The long period of smooth efficient operation of the radiosonde unit at Lerwick under his guidance is a measure of his success. It was a 'happy' station and much of the credit for this was his. We extend our sympathies to his wife and family.

A.P.T.

*Mr. B. K. Benfield.*—We regret to announce the death of Mr. Brian Kenneth Benfield, Experimental Officer, while serving at El Adem. He was accidentally drowned at The Beach Club, Tobruk on 22 August 1964 at the early age of 29 years. During his six years within the Office he served at Little Rissington, Manchester and Liverpool Airports and at El Adem.

He impressed his colleagues by his quiet friendly nature and devotion to duty. His death is a sad loss to the Office. We extend our sympathy to his family.

W.C.D.