To face p. 257.

Photograph by W. Bird

PLATE I—SIR GRAHAM SUTTON, C.B.E., F.R.S.

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RETIREMENT OF SIR GRAHAM SUTTON, C.B.E., F.R.S.

In September 1953 we welcomed Dr. O. G. Sutton, as he then was, as Director of the Meteorological Office in succession to Sir Nelson Johnson. Now, twelve years and one month later, we bid him farewell on his retirement from the Office to take over wider responsibilities.

In 1953 he was best known to most of us for his research on the turbulent structure of the lower atmosphere, and as a scientist with an international reputation—a reputation gained as a result of work as a member of the Office staff. He was however also an experienced administrator in the scientific field. This was fortunate for the Meteorological Office, which was then on the threshold of a decade of great change. Prior to the Second World War there had been very little officially organized research within the Office. In a reorganization after the war Sir Nelson Johnson laid the foundations for a planned research side of the Office. The tempo of such changes is inevitably slow and to Sir Graham (he was knighted in 1955) fell the task of building on the foundations laid by his predecessor. On 30 September 1965 he leaves an organization with a strong and closely integrated structure combining services, research and administration. In this technological age it is widely held that the research worker should be in close contact with the practitioner who uses the results of research. In the Meteorological Office, with its facilities for interchange of men and ideas between the Services and Research Directorates, the contact could not be closer. It was Sir Graham also who brought about a long-standing hope of many of the staff for a unified headquarters to replace the old tripartite split between London, Harrow and Dunstable.

However, organization and staff are not sufficient without the material facilities and Sir Graham has ensured that the equipment made possible by technical advances has become available to the Meteorological Office. The electronic computer is certainly not the only example of such equipment but there is something particularly appropriate in the circumstance that the Director-General who was responsible for getting our first computer—primarily for research purposes—should also be with us long enough to see the installation of its successor, which is intended to carry out a large, routine task. However, it has not been only the research work of the Office which has concerned Sir Graham. The past decade has seen a big increase in the importance of the meteorological services for those parts of the community not concerned with aviation. A pattern has been laid which will allow expansion if this seems desirable in the interests of the community.

Sir Graham has been unstinting in his efforts in the international fields connected with the development of the science and practice of meteorology. For the twelve years from 1953 to 1965 he was a member of the Executive Committee of the World Meteorological Organization.

Since his appointment as head of the Meteorological Office a number of marks of recognition of his status as a scientist have been conferred on him, including Presidency of the Royal Meteorological Society from 1953 to 1955, the Symons Gold Medal in 1959, and the Presidential Gold Medal of the Society of Engineers in 1957. But his position as President of the Institution of Professional Civil Servants from 1957 to 1961 was indicative of a characteristic which naturally received less publicity than his scientific work, namely a great concern for the conditions of work for his staff.

During his last year as Director-General his wide experience has been called upon to assist in the task of forming the Natural Environment Research Council and during the past few months he has been chairman of that body as well as Director-General of the Meteorological Office. He leaves us to devote his time to this new organization. All who have served under him will wish him good luck in this wider field and feel glad that a meteorologist has been chosen for this important work.

A. C. BEST

RETIREMENT OF DR. R. C. SUTCLIFFE, C.B., O.B.E., F.R.S.

On 31 August Dr. R. C. Sutcliffe retired from the post of Director of Research of the Meteorological Office, thus completing 38 years work in the Office.

Although Dr. Sutcliffe was born in Wales in 1904 the family soon returned to their native Yorkshire and his early education was at the Whitcliffe Mount Grammar School, Cleckheaton. He went from there to the University of Leeds to read mathematics, and afterwards to the University College of North Wales, Bangor, where he gained his doctorate. In his Meteorological Office appointments he saw service at home and overseas (Malta) and during the war served first as a Squadron Leader, RAFVR in France from 1939 to 1940, then as Senior Meteorological Officer of the No. 3 Bomber Group of the RAF (1941–44) and finally as Chief Meteorological Officer for the RAF in Germany from 1944–46 with the rank of Group Captain. He has thus had an exceptionally wide range of experience and carried great responsibilities in his work as an operational meteorologist. No one knows better the difficulties (and delights) of forecasting, and his well-known *Meteorology for aviators* (1938) is evidence of his skill in this field.

It is, however, as a theoretical meteorologist that his name will live long in the history of meteorology. In the development of our science there are a handful of contributions—perhaps a dozen or so—that stand out as landmarks. Among these must be placed Dr. Sutcliffe's papers on development theory. They provide in part the basis for the powerful dynamical methods that have now led to the realization of mathematical forecasting, and the science of the atmosphere is forever indebted to the physical insight and mathematical skill that enabled him to utilize to such great advantage the experience gained in long hours at the forecasting bench.

His work has been recognized, not only in Britain, but elsewhere. He was elected to the Royal Society in 1957 and received from the Royal Meteorological

Society the Buchan Prize in 1950 and its highest award, the Symons Gold Medal, in 1955. In 1959 the Physical Society awarded him the Charles Chree Medal and in 1963 his career culminated in the award of the International Meteorological Organization Prize by the World Meteorological Organization. He has also acted as President of the Commission for Aerology of WMO (1957–61) and is now Chairman of its Advisory Committee.

Dr. Sutcliffe became the first Director of Research of the Meteorological Office in 1957. The concept of a fully-developed research side, which had been growing steadily since the formation of the Meteorological Research Committee in 1941, was not completely realized until 1956 when the Brabazon Committee recommended the creation of separate Directorates of Research and Services within the Office. To Dr. Sutcliffe fell the onerous task of building up what virtually amounted to an institute of meteorology within the framework of a governmental establishment. The success which has attended his efforts is now visible to all, but it is only those inside the Office who can realize how much we owe to his wisdom, drive and enthusiasm.

Reggie Sutcliffe, as he is invariably known to us, has always been immensely popular with his colleagues. To me, as Director-General, he has been not only a close friend but the wisest and most cheerful of counsellors. We wish him and his wife many serene years of well-earned retirement from the service to which he has added such lustre.

O. G. SUTTON

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A TEST OF KENNINGTON'S METHOD OF FORECASTING THE TIME OF CLEARANCE OF RADIATION FOG

By D. J. HEFFER

Basis of the investigation.—Kennington has described a method of forecasting the time of clearance of radiation fog.[1] To forecast the time of clearance it is necessary to forecast the clearance temperature and Kennington says that "one way of doing this is to take the surface temperature required to give a saturated adiabatic lapse rate to the top of the inversion". He then derives the time of clearance from an estimate of the amount of solar radiation required to raise the temperature from its dawn value to the clearance temperature.

He admits that at the time of writing he had been unable to test the method exhaustively and quotes preliminary tests on five particular occasions at Kew. The object of this paper is to report on a more comprehensive test based on the Cardington Balthum ascents. Special reports of wind and temperature are made at Cardington daily at about 0000, 0600, 1200 and 1800 GMT (and on occasions at intermediate hours) except on public holidays and on occasions of strong or gusty winds, or when thunderstorms are in the vicinity. Instruments are carried aloft by means of a tethered kite-balloon and readings are made at the surface, 9, 15, 21, 30, 45, 75 and 150 metres then every 75 metres up to 600 or 1200 metres, together with any special inversion points. Heights are usually converted to pressure in millibars for convenience of plotting on the standard tephigram.

The paper is in two parts. In the first the clearance time is derived directly from the 'dawn' ascents; this part of the paper shows the degree of accuracy which is likely to be attained by a forecaster who is fortunate enough to have a dawn ascent available. Most forecasters in the British Isles are, however, dependent on data from a midnight upper air ascent and the second part of the paper suggests how a midnight Balthum ascent may be modified to give an estimate of the fog top at dawn.

Test based on dawn ascents.—For the purpose of the test a period of the night with visibility less than 1100 yards with an average of $\leqslant 2/8$ low/medium cloud from onset to dispersal constitutes a radiation fog. All dates when there was radiation fog at any one of six stations in eastern England during the four years 1960–63 were listed and data were extracted for those on which a Balthum ascent was made at Cardington at 0600 GMT. This gave a total from the six stations of 401 reports of a period of radiation fog on 110 different dates. On occasions when clearance occurred before 0600 GMT it was possible to use an 0300 GMT ascent to find the forecast clearance time.

On all the Balthum ascents there was a clearly defined nose on the dew-point curve and this was taken to mark the fog top. (This does not mean necessarily that there was fog at Cardington as the formation of fog also depends on surface conditions.) In all cases the fog-top estimate was below the top of the inversion, and in many cases it was well below. It was therefore decided to take as the clearance temperature the surface temperature required to give a saturated adiabatic lapse rate to the top of the fog (not the top of the inversion as recommended by Kennington). This is in accord with the practice recommended by Barthram,[2] whose diagrams were used as the most convenient way of computing clearance times.

The six stations used in the original tests were Bedford, Bassingbourn, Wyton, Honington, Mildenhall and Watton. Details are given in Table I together with details of two other stations, Wittering and Cottesmore, which are mentioned later.

TABLE I—DETAILS OF STATIONS USED IN THE INVESTIGATION

Station	Height above mean sea level	Approximate distance from Cardington	Approximate bearing from Cardington	Number of reports
	feet	*nautical miles*	*degrees*	
Bedford	293	10	280	51
Bassingbourn	81	6	100	87
Wyton	135	17	010	97
Honington	175	35	070	51
Mildenhall	30	30	050	64
Watton	200	50	050	51
Wittering	275	32	350	Pilot scheme only
Cottesmore	460	39	350	

The results are shown in Figure 1 which includes all reports except 22 which gave forecast clearance temperatures below 0°C. (The cases with forecast clearance temperatures below 0°C had irregular clearance times. The forecasts were invariably too early and in a third of the cases the fog failed to clear that day. They were insufficient in number for detailed study with a view to finding a delay factor.) Forecast clearance times can be readily estimated to the nearest quarter of an hour; actual clearance times (H) observed at the stations are

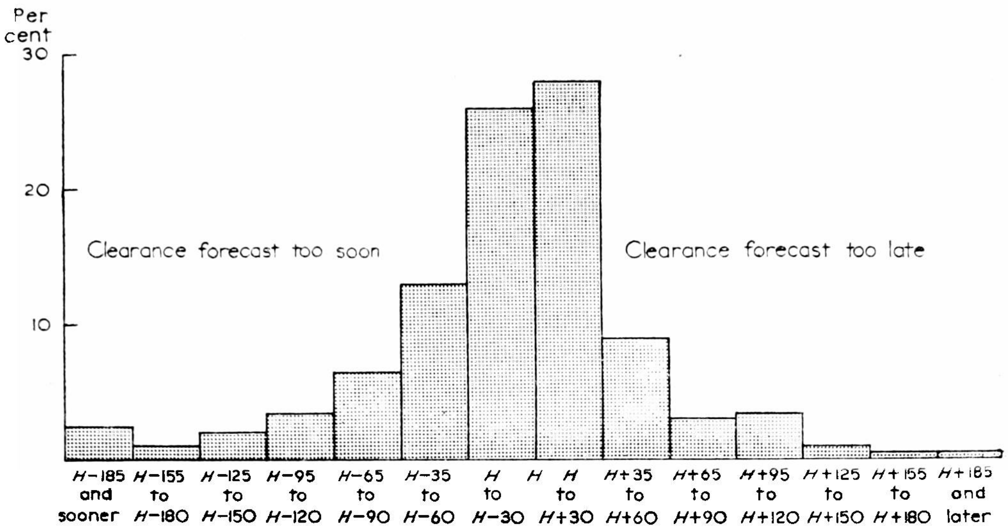

FIGURE 1—HISTOGRAM SHOWING PERCENTAGE DISTRIBUTION OF ERRORS IN FORECAST TIMES OF FOG CLEARANCE

When the forecast time of clearance corresponds with the actual time of clearance (H) the occasions are apportioned between the periods H to $H + 30$ minutes and H to $H - 30$.

normally correct to well within a quarter of an hour during daylight hours. Differences between forecast and actual clearance times are given to the nearest five minutes. Kennington's method gave the time of clearance to within ½ an hour on 54 per cent of occasions and to within 1 hour on 76 per cent of occasions. It made no great difference to these percentages whether two years were considered instead of four or whether the stations were considered individually or in a group. The test confirms Kennington's method as a most useful means of forecasting times of fog clearance when a reliable measurement of the height of the fog top is available. It also shows that the measurement can be used over a wide area of eastern England with fogs varying in thickness between 5 and 40 mb, and at stations with heights above mean sea level varying over quite a wide range. No adjustment to the height above sea level of the fog top as measured at Cardington is necessary.

The percentage of other instances when there were big forecast errors was not large but, as a big error could cause serious inconvenience to the user of the forecast, cases of large forecast errors have been examined individually. The first thing to note is that large errors generally apply to a particular place and not to the area as a whole. The biggest error (apart from those arising from temperatures below freezing) was a discrepancy of 4¼ hours at Bassingbourn on 26 November 1962, but at the neighbouring stations of Bedford and Wyton the forecast was correct to within ¾ hour. It is not possible to go into details of every discrepancy here but Kennington's method applies strictly to radiation fogs which form and disperse *in situ*, and in a number of cases the discrepancies could be attributed to a light drift from the fens; this was quite marked at Wyton and also to a lesser extent at Watton and Mildenhall. In a light north-easterly wind, fog at Bassingbourn tends to clear later than a general forecast for the area would suggest and the case of 26 November 1962 was an extreme example. Local peculiarities are well known to forecasters with long experience of particular stations and the influence of the fens on fog clearance has been discussed by Freeman.[3]

The contrast between Bedford and Wittering is interesting. Both stations are at roughly the same height above sea level. Bedford is on the flat top of a hill where radiation fog rests where it forms and 71 per cent of the forecasts were correct to within an hour; but Wittering is on the side of a hill where fog is liable to drift and only 45 per cent of forecasts in the pilot scheme were correct to within an hour. Only 50 per cent were correct to within an hour for Cottesmore, another station liable to topographical effects. Wittering and Cottesmore were omitted from the main test and used in a separate investigation.

In Table II, data for the six stations are analysed for each month to show for each hour the frequency of fog clearance expressed as a percentage of the total number of occasions of fog in each month. Thus, in June, a forecast clearance time of 0700 GMT would be correct to within ½ hour on 43 per cent of occasions.

TABLE II—DISTRIBUTION OF CLEARANCE TIMES OF RADIATION FOG

Time (GMT)	0430 to 0530	0530 to 0630	0630 to 0730	0730 to 0830	0830 to 0930	0930 to 1030	1030 to 1130	1130 to 1230	1230 to 1330	Did not clear	Number of reports
	percentage of total for each month										
January	3	3	3	3	6	16	37	10	3	16	31
February		3	10	22	16	10	26	13			31
March		6	24	19	17	17	11	3	3		46
April	4	35	19	15	23	4					26
May	43	16	16	9	16						12
June	14	29	43	14							14
July	17	41	17	8	17						12
August	34	21	18	27							33
September	4	12	24	18	21	17	4				66
October		8	11	12	31	19	10	8	1		75
November		6	6	26	29	20	13				28
December		4	4	8	8	11	14	8		43	27

Examination of midnight ascents.—The foregoing describes tests based on dawn ascents. It now remains to show how a midnight ascent may be used to give an estimate of the fog top at dawn.

Occasions when both a midnight and a 0600 GMT Balthum were available were examined in conjunction with synoptic charts and it was evident that in many cases which at first sight had been accepted as radiation fogs the difference between midnight and 0600 GMT profiles were due, at least in part, to advection. For this part of the investigation it was necessary to use data free, as far as possible, from advection effects and it was therefore decided to use only data for which the forecasts produced by the test method had been accurate to within an hour and for which scrutiny of synoptic charts gave no grounds for suspecting advection effects between midnight and 0600 GMT (such as the passage of minor fronts or a change of moisture content in the lower layers of the atmosphere associated with a shift of wind bringing moister air off the sea). In the four years 1958, 1959, 1961 and 1962, 122 examples of fog were examined for Wyton (the station chosen for this part of the investigation) and only 40 satisfied these conditions. These statistics are in themselves some measure of the frequency of occurrence of radiation fogs without advection effects.

Comparison of the midnight and 0600 GMT Balthums showed that the height of the top of the radiation inversion on the temperature curve was generally about 35 mb above the ground, though there were occasional wide variations from this value. Once formed, the nose on the dry-bulb temperature curve rarely rose by more than 5 mb in the six-hour period. The average rise was 2–3 mb and the average decrease in temperature at the nose was 1.5°C. This information forms the basis of the following rule for estimating the fog top at dawn from the midnight ascent:

(i) If the nose has already formed on the temperature curve, the level is raised by 5 mb and the temperature is decreased by 1.5°C and this point is joined to the night minimum temperature by a straight line on the tephigram. It is assumed that the dew-point curve changes little in the period from midnight to dawn. The point where the straight line and the dew-point curve intersect (point O in Figure 2) represents the fog top at dawn for use in Kennington's method.

(ii) If a nose has not yet formed on the temperature curve at midnight, the point 35 mb above the ground is joined to the night minimum surface temperature (i.e. without subtracting 1.5°C from the temperature) and the fog top estimated as before (point O in Figure 3).

To test this rule the assumption was made that it is possible to forecast accurately the night minimum temperature, and the observed night minimum temperatures at Wyton were used in the test. The figures given above show that radiation fogs with no advection occur on only about 33 per cent of foggy nights, which limits the application of the rule, but on those 40 occasions at Wyton which were used to test the rule, 23 forecasts (57 per cent) of the time of fog clearance were correct to within ½ hour and 35 forecasts (87 per cent) were correct to within one hour.

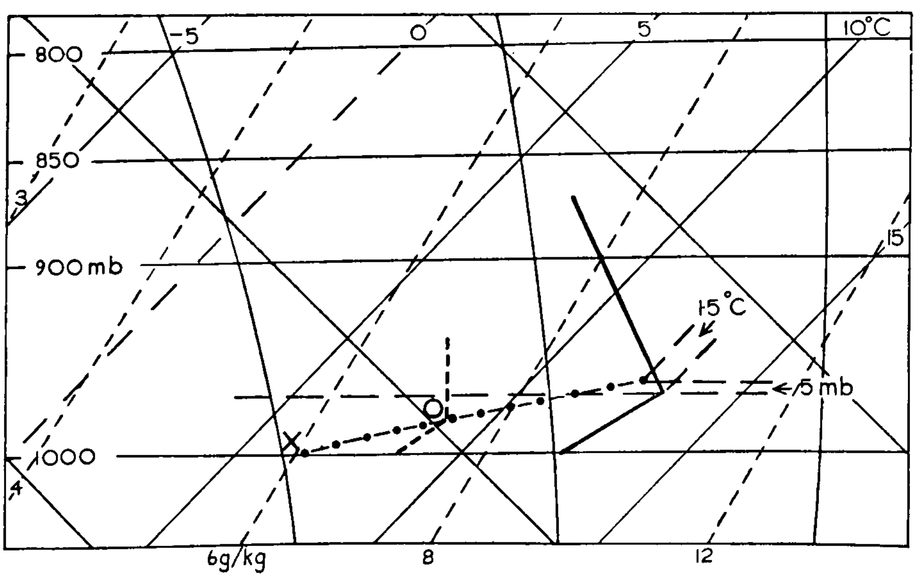

FIGURE 2—CONSTRUCTION FOR FOG-TOP ESTIMATE FROM A MIDNIGHT BALTHUM WHEN THE INVERSION NOSE HAS ALREADY FORMED

——Dry-bulb curve — — — Dew-point curve
•—•—• Construction for fog-top estimate. **O** Estimated fog top
X Night minimum temperature

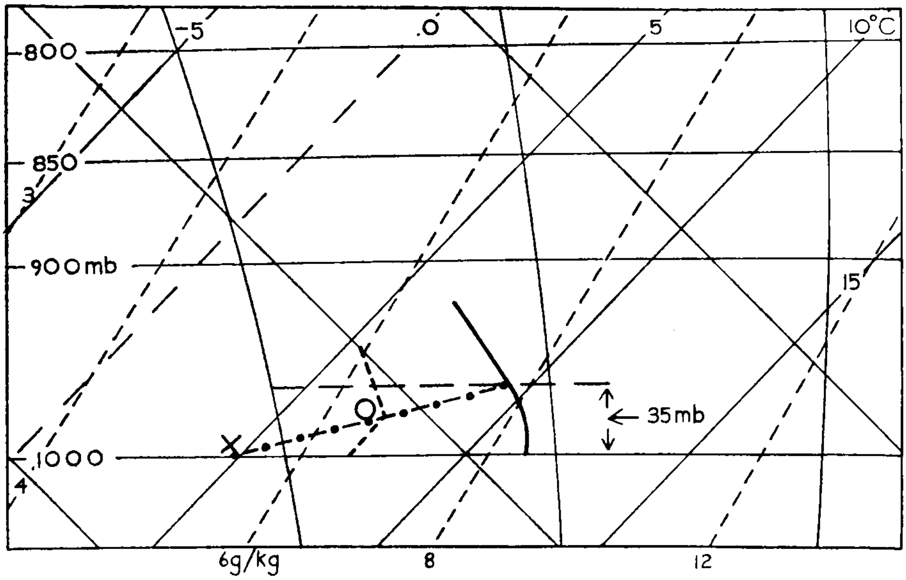

FIGURE 3—CONSTRUCTION FOR FOG-TOP ESTIMATE FROM A MIDNIGHT BALTHUM WHEN THE INVERSION NOSE HAS NOT YET FORMED

—— Dry-bulb curve   – – – Dew-point curve
•—•—• Construction for fog-top estimate   **O** Estimated fog top
X Night minimum temperature

When the dew-point curve was isothermal or still increasing with height at the point of intersection, the position of the fog top was not so clearly defined. The clearance times of the deeper fogs tended to be underestimated.

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551.509.324.2:551.509.542:551.524:77

THE FORECASTING OF SHOWER ACTIVITY IN AIRSTREAMS FROM THE NORTH-WEST QUARTER OVER SOUTH-EAST ENGLAND IN SUMMERTIME

By C. A. S. LOWNDES

Introduction.—The purpose of this investigation was to distinguish between synoptic situations when polar airstreams brought widespread showers to south-east England between 0900 and 2100 GMT and similar situations when the shower activity was slight. The investigation was restricted to airstreams which approached the British Isles from the north-west quarter. This restriction was achieved by including only those days when the surface isobars over England at midday showed a flow from between west and north-west inclusive and the polar front lay to the south of the British Isles or had cleared south-east England by 0600 GMT. Occasions were not included if a front was situated over south-east England between 0900 and 2100 GMT or if the precipitation was not mainly showery. The classification of the intensity of shower activity was based on reports from eight stations in south-east England in the months May to September during the 13-year period from 1952 to 1964. From 1962, the stations were Kew, London (Heathrow) Airport, Thorney Island, Hurn, Wattisham, Gorleston, Mildenhall and Cardington. For other years, one or two of these stations were not available and adjacent stations were substituted. From the Beaufort letters in the *Daily Weather Report* the total number of mentions of slight, moderate and heavy showers at the eight stations during the period 0900 to 2100 GMT was obtained for each day. From these figures, the intensity of shower activity was classified as follows:

A Widespread showers with a good proportion of moderate or heavy showers (8 or more mentions of showers; more than 25 per cent moderate or heavy showers).

B Widespread showers with few moderate or heavy showers (8 or more mentions of showers; 25 per cent or less of moderate or heavy showers).

C Few showers (less than 8 mentions of showers).

D No showers.

A note was made of thunder or hail reported between 0900 and 2100 GMT at any station in south-east England included in the *Daily Weather Report*. Surface reports were supplemented by sferic (atmospherics) observations during the same hours of the day.

The factors which were considered.—It is reasonable to associate the degree of shower activity primarily with the degree of instability of the lower troposphere as indicated by dry-bulb temperatures. Instability can be assessed in a simple fashion in various ways, of which seven were chosen for this investigation,* (1) the 1000–500 mb thickness anomaly, (2) the 1000–700 mb thickness anomaly, (3) the 700 mb temperature anomaly, (4) the Boyden instability index,[1] (5) the Rackliff instability index,[2] (6) the Jefferson instability index[3] and (7) the modified Jefferson instability index.[4]

The thickness anomalies are departures from a climatological normal of thickness values and are closely related to the general excess or deficiency of air temperature which in turn is related to the degree of instability resulting from surface heating. The anomaly of 700 mb temperature is a fair measure of the instability attainable between the ground and the freezing-level. The instability indices, which were all devised for thunderstorm forecasting, are measures of instability which dispense with climatic normals. Apart from the humidity measurements inherent in the Rackliff and Jefferson indices, humidities in the troposphere were not considered because the variations in space and with time are large and difficult to forecast and because a high relative humidity may be simply the consequence of the evaporation of raindrops from a shower and may not be representative of the airmass. However, it became clear that the level of surface pressure was a useful predictor in association with the temperature and thickness anomalies, probably because of the well-known association between high surface pressure and relatively dry air aloft.

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*For the years 1952 to 1955, solar radiation and lag corrections have been applied to the upper air temperatures and thicknesses to make them comparable with the data for 1956 to 1964 to which the corrections had already been applied.

Other factors considered included the position of the associated depression, surface troughs which moved across England, uniform cyclonic isobars over England and the effect of fast-moving warm fronts from the west.

Association with surface synoptic features.—

The position of the associated depression at midday.—Table I shows for each class of shower activity the number of occasions when the depression with which the polar air was associated was situated in a particular locality.

TABLE I—SHOWER ACTIVITY RELATED TO POSITION OF ASSOCIATED DEPRESSION AT MIDDAY (MAY–SEPTEMBER 1952–64)

Position of depression	Class of shower activity *A*	*B*	*C*	*D*
	number of occasions			
Arctic	0	0	1	3
Iceland	0	1	1	0
Norwegian Sea	5	1	14	10
Scandinavia	16	10	11	14
North of Scotland	6	5	6	5
Scotland	10	0	0	0
North Sea	17	5	6	2
Denmark	2	0	3	0
Germany	0	0	0	1
All areas	56	22	42	35

On all 10 occasions when the depression was situated over Scotland there were widespread showers over south-east England with a good proportion of moderate or heavy showers (class *A*). On 73 per cent of occasions when the depression was over the North Sea there were widespread showers (classes *A* and *B*). On 80 per cent of occasions when the depression was situated over the Norwegian Sea there were few showers or no showers (classes *C* and *D*). In general, the nearer the depression was to the British Isles, the more intense was the shower activity in south-east England. This suggests that the isobaric curvature and the level of surface pressure over the British Isles might be useful predictors.

The curvature of the surface isobars over England.—On many days of widespread showers, a surface trough moved eastwards or southwards across England. Of the troughs which moved eastwards, 70 per cent were major features with the trough axis some 600 to 1000 miles in length and 30 per cent were minor perturbations with the trough axis some 200 to 600 miles in length. Of the troughs which moved southwards, 30 per cent were major features and 70 per cent were minor perturbations. On other days of widespread showers there were uniform cyclonic surface isobars over England. Table II shows the number of these occasions for each class of shower activity.

TABLE II—SHOWER ACTIVITY RELATED TO THE CURVATURE OF THE SURFACE ISOBARS OVER ENGLAND (MAY–SEPTEMBER 1952–64)

	Class of shower activity *A*	*B*	*C*	*D*
	number of occasions			
Surface trough moved eastwards across England	25	7	4	2
Surface trough moved southwards across England	9	4	3	0
Uniform cyclonic isobars over England	9	3	3	1
Neither surface trough nor uniform cyclonic isobars	13	8	32	32
Total	56	22	42	35

On 58 per cent of occasions of widespread showers (classes *A* and *B*) a surface trough moved eastwards or southwards across England. Of the 27 days on which a major surface trough moved across England, all but one were associated with widespread showers and 21 (78 per cent) with thunder. Of the 27 days on which a minor perturbation moved across England, 19 (70 per cent) were associated with widespread showers and 10 (37 per cent) with thunder. Of the 16 days with uniform cyclonic isobars over England, 12 (75 per cent) were associated with widespread showers and 9 (56 per cent)with thunder. There were no occasions of widespread showers when the isobars over England were anticyclonic. On 83 per cent of occasions of few showers or no showers (classes *C* and *D*) there were neither surface troughs nor uniform cyclonic isobars. On 26 per cent of occasions of few showers or no showers, the isobars over England were anticyclonic.

Association with 700 mb temperature and surface pressure.—The following data were extracted for the period 1952–64:

(i) The 700 mb temperature anomaly at Crawley for 1200 GMT (1500 GMT before 1957); for 1952, Larkhill was used. The anomaly was based on the 5-day mean temperatures given in Table III.

(ii) The mean sea level pressure at Heathrow for 1200 GMT.

TABLE III—FIVE-DAY MEAN 700 MB TEMPERATURE AT CRAWLEY* IN °C

Period	Mean	Period	Mean	Period	Mean
1– 5 May	−6	30 June – 4 July	−1	29 Aug. – 2 Sept.	−1
6–10	−6	5– 9 July	0	3– 7 Sept.	−1
11–15	−5	10–14	0	8–12	−1
16–20	−5	15–19	0	13–17	−1
21–25	−4	20–24	0	18–22	−2
26–30	−4	25–29	0	23–27	−2
31 May – 4 June	−3	30 July – 3 Aug.	0	28 Sept. – 2 Oct.	−2
5– 9 June	−3	4– 8 Aug.	0		
10–14	−3	9–13	0		
15–19	−2	14–18	0		
20–24	−2	19–23	0		
25–29	−1	24–28	0		

*Obtained from 5-year monthly means[5] for the period 1951–55 (Larkhill 1951–52, Crawley 1953–55).

Rain showers.—A diagram was plotted (Figure 1) of the 700 mb temperature anomaly at Crawley against the mean sea level pressure at Heathrow. The various intensities of shower activity are indicated by symbols, class *A* by a black triangle, class *B* by an open triangle, class *C* by a dot and class *D* by a cross. The diagram can be divided into two areas as indicated. Of the occasions within area I, 87 per cent were associated with widespread showers (classes *A* and *B*) representing 91 per cent of all occasions of widespread showers. Of the occasions within area II, 90 per cent were associated with few showers or no showers (classes *C* and *D*) representing 86 per cent of all occasions of few showers or no showers. Assuming that the two predictors could be forecast and the diagram was used to forecast either widespread showers or few showers/no showers, a 'skill score' of 0.77 would be obtained. The skill score, *S*,[6] is defined by

$$S=\frac{\text{number of correct forecasts} - \text{number correct by chance}}{\text{total number of forecasts} - \text{number correct by chance}}$$

It ranges from 0 for no success to 1 for complete accuracy.

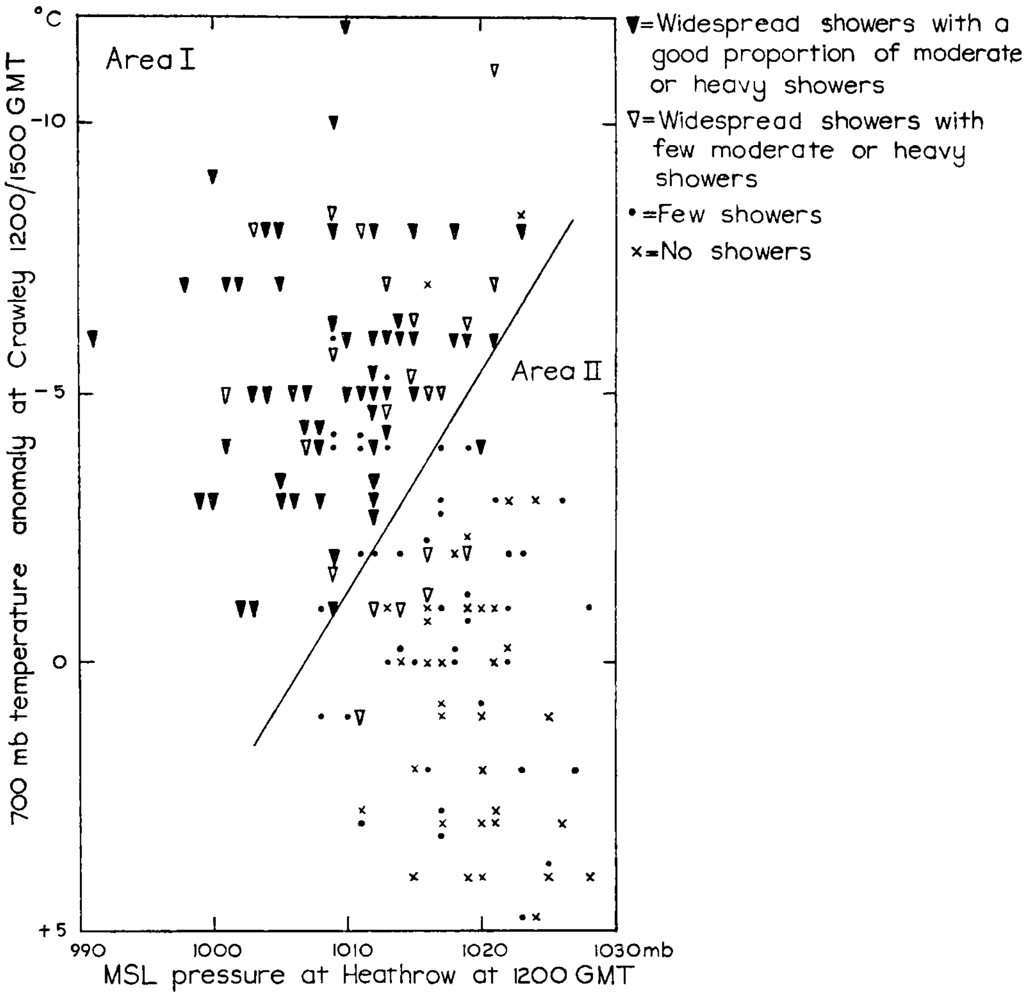

FIGURE I—SHOWER ACTIVITY IN SOUTH-EAST ENGLAND ASSOCIATED WITH SURFACE PRESSURE AND THE 700 MB TEMPERATURE ANOMALY

The line divides the diagram into area I containing most of the occasions of widespread showers and area II containing most of the occasions of few or no showers.

Rainfall amount.—A similar diagram (Figure 2) was plotted with symbols representing the average rainfall between 0900 and 2100 GMT for the eight stations in south-east England for each day examined. The diagram can be divided into the same two areas which were used in Figure 1. Of all occasions within area I, 90 per cent were associated with an average rainfall at the eight stations of 0.1 millimetres or more, representing 89 per cent of all occasions of 0.1 mm or more. Of the occasions within area II, 88 per cent were associated with less than 0.1 mm, representing 89 per cent of all occasions of less than 0.1 mm. If the diagram were used to indicate an average rainfall of either 0.1 mm or more or less than 0.1 mm, a skill score of 0.78 would be obtained.

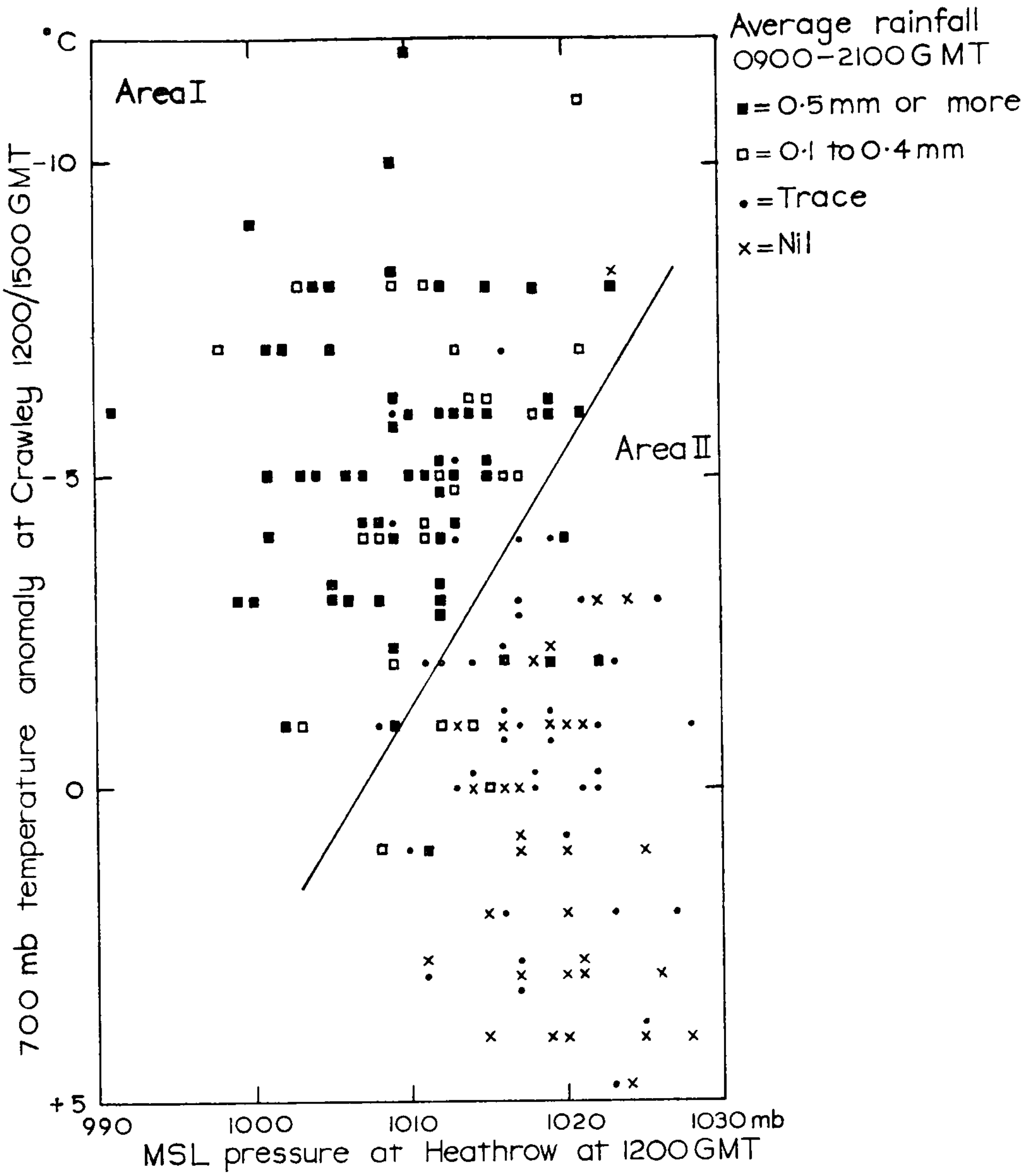

FIGURE 2—AVERAGE RAINFALL FOR EIGHT STATIONS IN SOUTH-EAST ENGLAND FOR EACH INDIVIDUAL DAY ASSOCIATED WITH SURFACE PRESSURE AND THE 700 MB TEMPERATURE ANOMALY

Areas I and II are the same areas as in Figure 1.

Of all occasions within area I, 66 per cent were associated with an average rainfall of 0.5 mm or more, representing 92 per cent of all occasions of 0.5 mm or more. Of the occasions within area II, 93 per cent were associated with less than 0.5 mm, representing 71 per cent of all occasions of less than 0.5 mm. If the diagram were used to indicate an average rainfall of either 0.5 mm or more or less than 0.5 mm, a skill score of 0.58 would be obtained.

Figure 3 shows the highest and lowest rainfall amounts plotted against the average amount for the eight stations in south-east England for each day examined. For an average value of up to 1 mm, the highest value is likely to be about four times the average and for average values of 2 mm or more, about three times the average. For an average value of up to 1.7 mm, the lowest value was nil or a trace and for an average value above 1.7 mm the lowest value varied between nil and 1 mm. It is clear that however widespread the showers, some places are likely to escape with little or no rain.

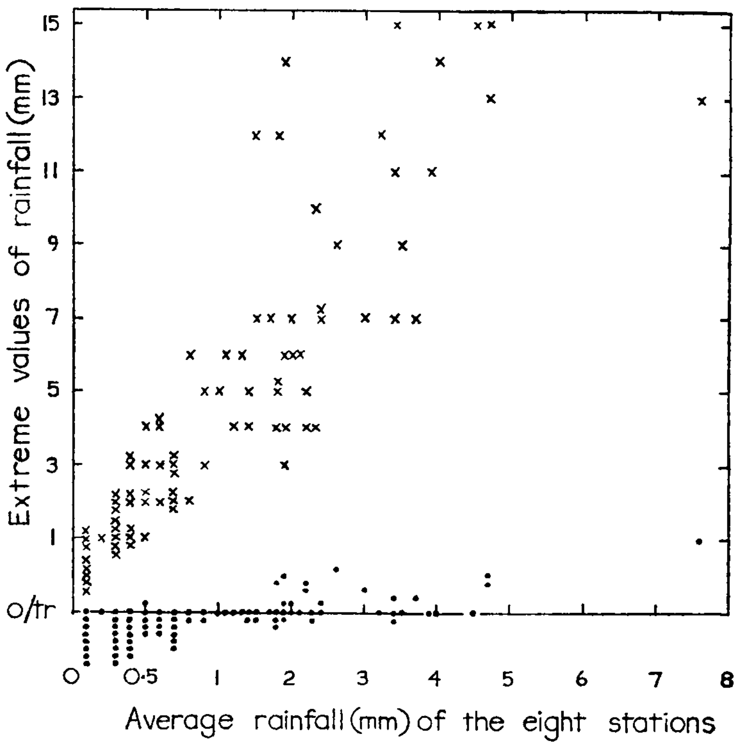

FIGURE 3—THE HIGHEST AND LOWEST RAINFALL AMOUNTS (0900–2100 GMT) ASSOCIATED WITH AVERAGE VALUES FOR EIGHT STATIONS IN SOUTH-EAST ENGLAND

x Highest individual values • Lowest individual values

For some values of the average rainfall the lowest amount was zero on several occasions and such occasions are plotted below the axis.

Thunder and hail.—A diagram was plotted (Figure 4) of the 700 mb temperature anomaly against mean sea level pressure with symbols representing thunder or hail. If no thunder or hail was reported, a cross was plotted. The diagram can again be divided into the same two areas. Of all occasions within area I, 72 per cent were associated with thunder, representing 89 per cent of all occasions of thunder and 35 per cent with hail, representing 97 per cent of all occasions of hail. Of the occasions within area II, 90 per cent were associated

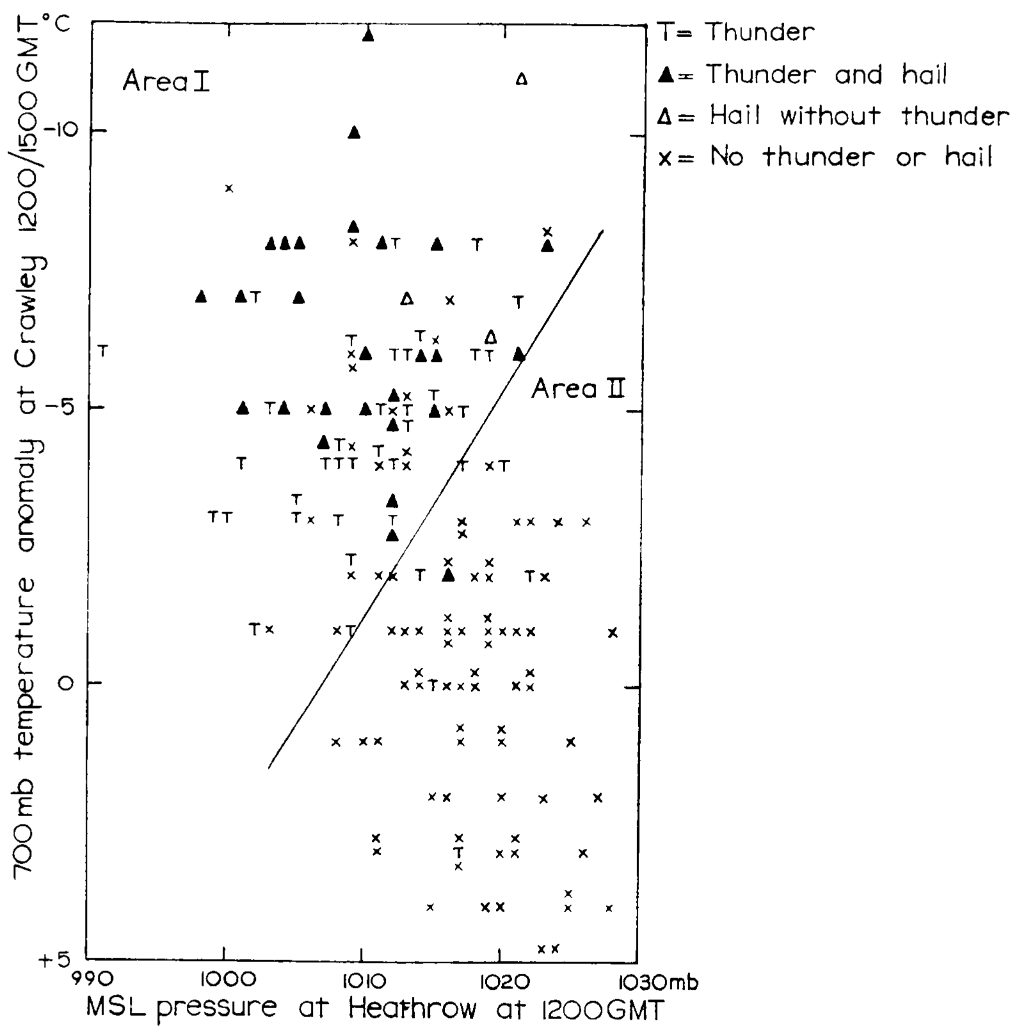

FIGURE 4—THUNDER AND HAIL IN SOUTH-EAST ENGLAND ASSOCIATED WITH SURFACE PRESSURE AND THE 700 MB TEMPERATURE ANOMALY

Areas I and II are the same areas as in Figure 1.

with 'no thunder', representing 74 per cent of all occasions of 'no thunder' and 99 per cent with 'no hail', representing 58 per cent of all occasions of 'no hail'. If the diagram were used to indicate thunder or 'no thunder', a skill score of 0.62 would be obtained. For an indication of hail or 'no hail', a skill score of 0.33 would be obtained.

Many of the occasions of thunder without hail occurred with relatively high 700 mb temperatures, suggesting that hail may have formed and melted before reaching the ground. Of all occasions of thunder, 41 per cent were accompanied by hail, but of the 15 occasions of thunder when the height of the freezing-level above the ground at Crawley was 207 decametres or more, only two were associated with hail. Mason[7] deduced that with the melting-level at 200 decametres, solid ice particles would need to be of initial radius greater than 2.5 mm and graupel pellets (density 0.3 g/cm³) at least twice as large in order to retain an unmelted core during the downward journey. If the height of the freezing-level above the ground could be forecast and hail were forecast only when the height was less than 207 decametres, the skill score would be improved from 0.33 to 0.36.

On all but two occasions, reports of thunder were associated with negative temperature anomalies. On all occasions of hail, the negative temperature anomaly was 2°C or more.

Sunshine.—A diagram was plotted (Figure 5) of the 700 mb anomaly against mean sea level pressure, with figure entries representing the average

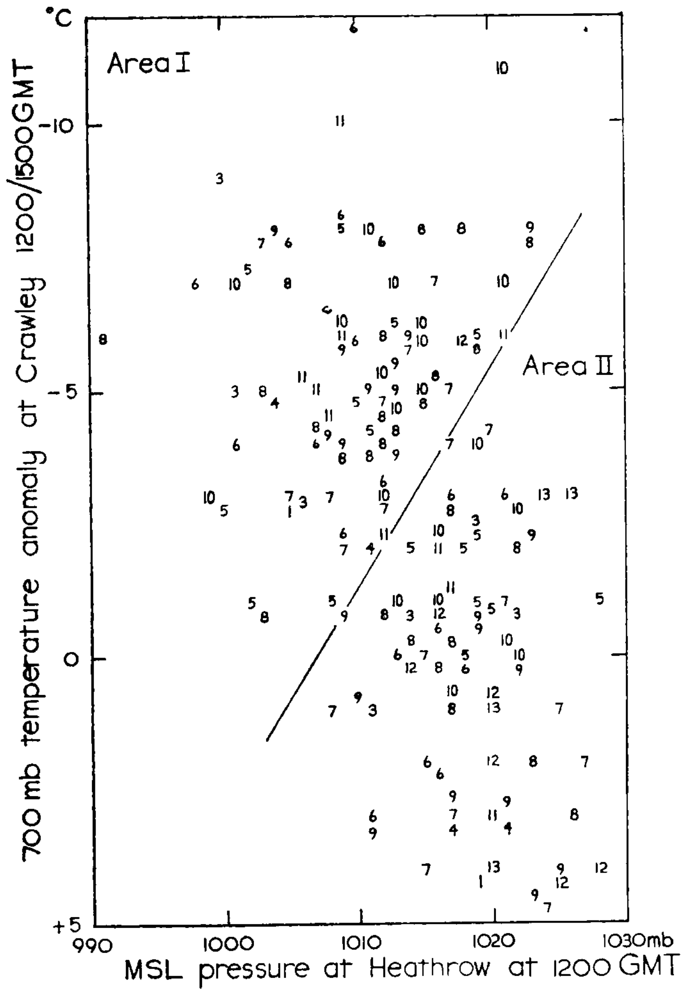

FIGURE 5—AVERAGE DURATION OF SUNSHINE FOR SEVEN STATIONS IN SOUTH-EAST ENGLAND FOR EACH INDIVIDUAL DAY ASSOCIATED WITH SURFACE PRESSURE AND THE 700 MB TEMPERATURE ANOMALY

Areas I and II are the same areas as in Figure 1.

duration of sunshine in hours for seven of the stations in south-east England for each day examined. If the diagram is divided into areas I and II, representing generally high and low shower activity respectively, the high and low values of sunshine duration appear to be scattered at random in both areas and there is no evidence of an association between the intensity of shower activity and the duration of sunshine. It is clear that a substantial amount of morning sunshine, as implied by the large total durations, is no bar to a showery afternoon.

Association with 1000–500 mb thickness and surface pressure.—The 1000–500 mb thickness anomaly at Crawley for 1200 GMT (1500 GMT before 1957) was extracted for the period 1952–64; for 1952 Larkhill was used. Anomalies were measured from the 5-day mean 1000–500 mb thickness values for Crawley given in Table IV.

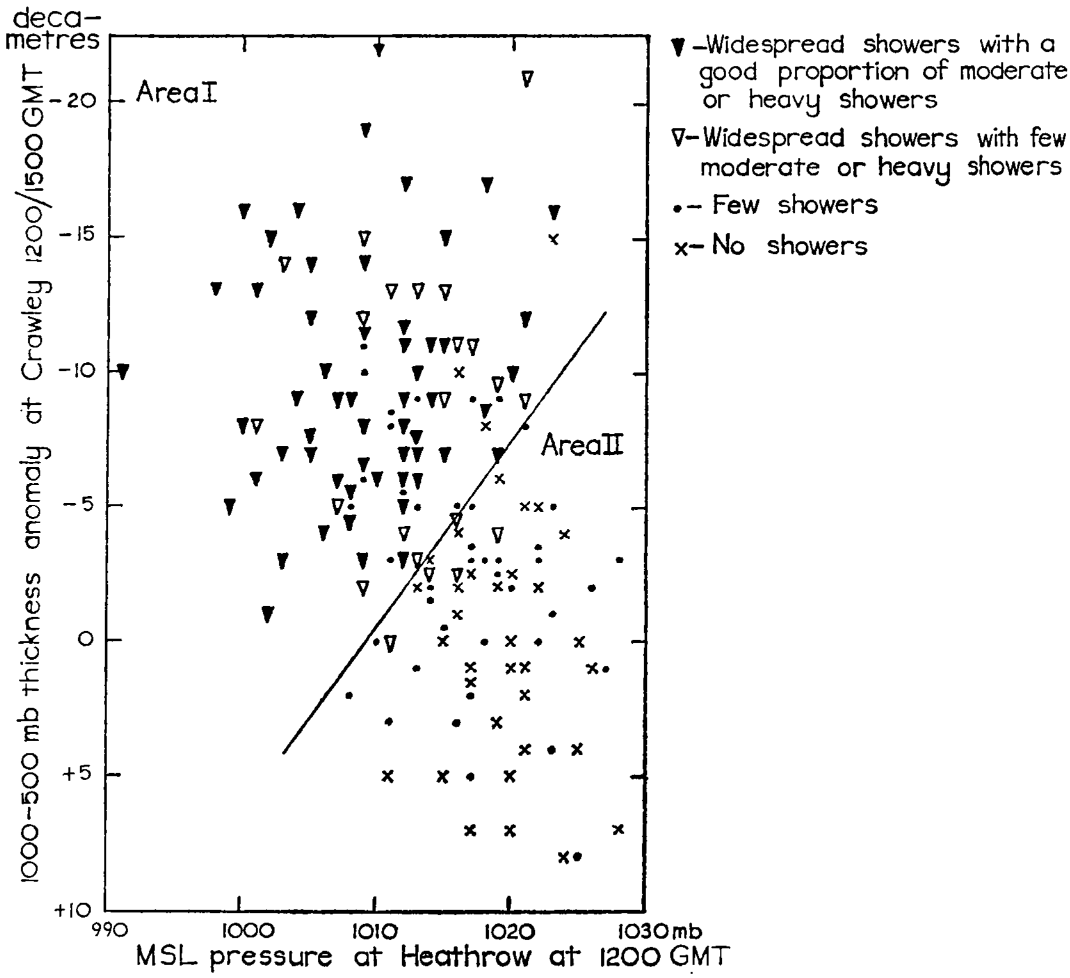

FIGURE 6—SHOWER ACTIVITY IN SOUTH-EAST ENGLAND ASSOCIATED WITH SURFACE PRESSURE AND THE 1000–500 MB THICKNESS ANOMALY

The line divides the diagram into area I containing most of the occasions of widespread showers and area II containing most of the occasions of few or no showers.

TABLE IV—FIVE-DAY MEAN 1000–500 MB THICKNESS AT CRAWLEY* IN DECAMETRES

Period	Mean	Period	Mean	Period	Mean
1– 5 May	543	30 June – 4 July	553	29 Aug. – 2 Sept.	554
6–10	544	5– 9 July	554	3– 7 Sept.	553
11–15	545	10–14	555	8–12	552
16–20	546	15–19	556	13–17	552
21–25	547	20–24	556	18–22	551
26–30	547	25–29	556	23–27	551
31 May – 4 June	548	30 July – 3 Aug.	556	28 Sept. – 2 Oct.	550
5– 9 June	549	4– 8 Aug.	556		
10–14	550	9–13	556		
15–19	551	14–18	556		
20–24	552	19–23	555		
25–29	553	24–28	555		

*Obtained from 5-year monthly means[5] for the period 1951–55 (Larkhill 1951–52, Crawley 1953–55).

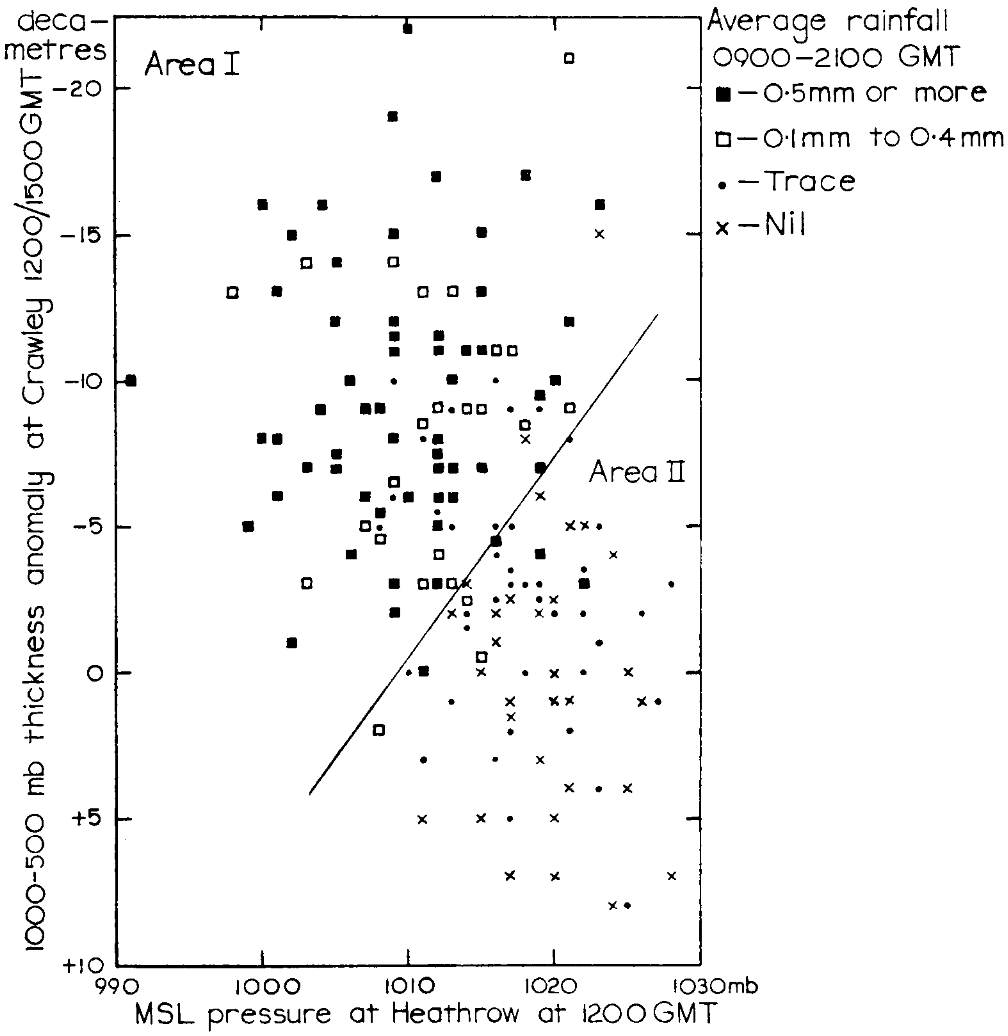

FIGURE 7—AVERAGE RAINFALL FOR EIGHT STATIONS IN SOUTH-EAST ENGLAND FOR EACH INDIVIDUAL DAY ASSOCIATED WITH SURFACE PRESSURE AND THE 1000–500 MB THICKNESS ANOMALY

Areas I and II are the same areas as in Figure 6.

Analyses were carried out with the 1000–500 mb thickness anomaly in place of the 700 mb temperature anomaly and statistics were extracted to construct Figures 6, 7 and 8. The corresponding skill scores are shown in Table V (page 279).

An analysis was also carried out with the 1000–700 mb thickness anomaly in place of the 700 mb temperature anomaly and similar statistics extracted. The corresponding skill scores are also shown in Table V.

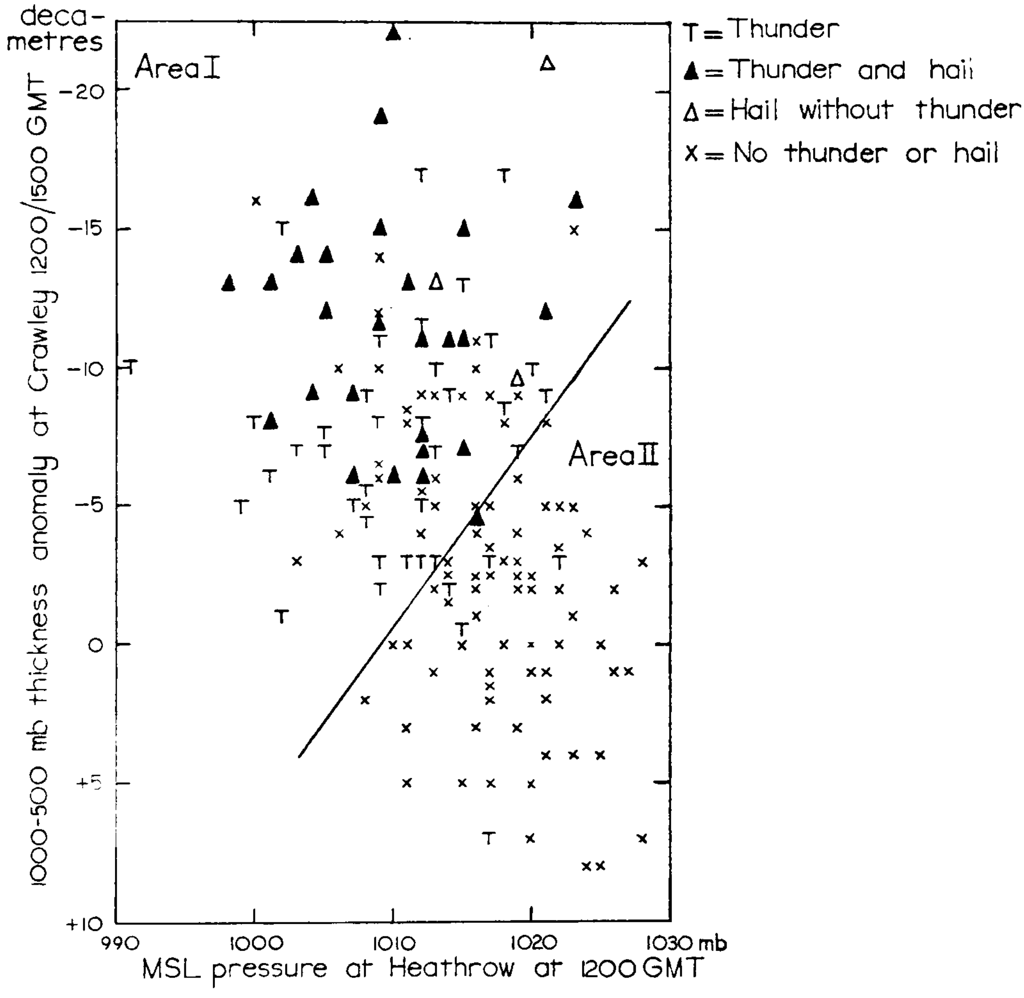

FIGURE 8—THUNDER AND HAIL IN SOUTH-EAST ENGLAND ASSOCIATED WITH SURFACE PRESSURE AND THE 1000–500 MB THICKNESS ANOMALY

Areas I and II are the same areas as in Figure 6.

Association with the Boyden instability index.—The instability index proposed by Boyden[1] was calculated for the Crawley 1200 GMT ascents (1500 GMT before 1957). For 1952, Larkhill was used. The formula for the index (I) was

$$I = Z - T - 200$$

where Z = 1000–700 mb thickness in decametres,
T = 700 mb temperature in °C.

Rain showers.—Figure 9 shows the distribution of the instability index and the frequency of days on which the various intensities of shower activity occurred. Of the occasions with an index of 94 or more, 79 per cent were associated with widespread showers (classes *A* and *B*), representing 87 per cent of all occasions of widespread showers. Of the occasions with an index of 93 or less, 85 per cent were associated with few showers or no showers (classes *C* and *D*), representing 77 per cent of all occasions of few showers or no showers. Assuming that the index could be forecast and was used to forecast either widespread showers or few showers/no showers, a skill score of 0.64 would be obtained.

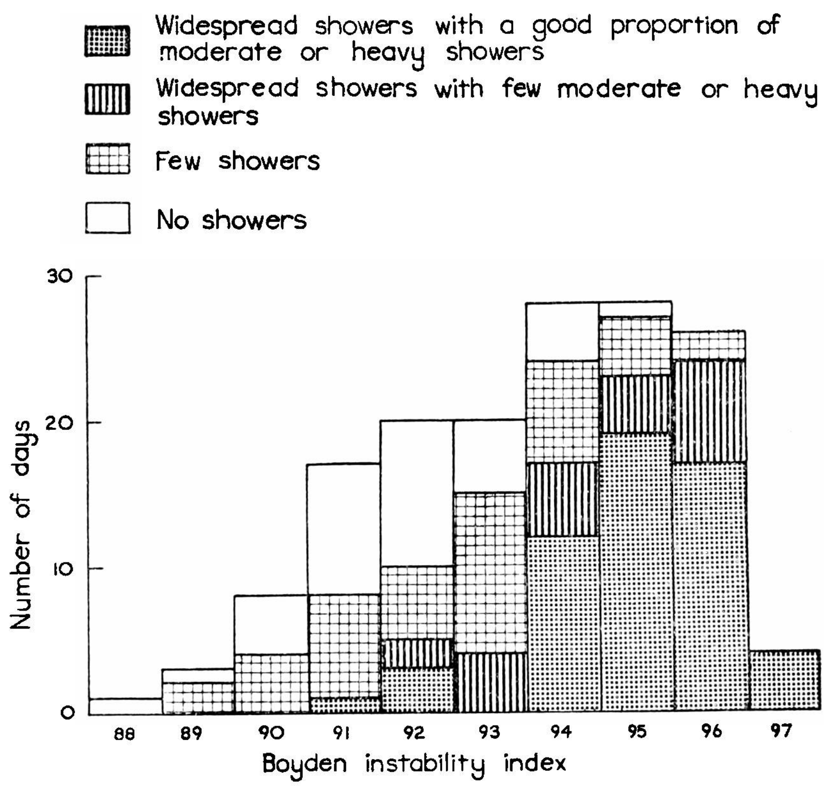

FIGURE 9—FREQUENCY OF DAYS WITH SHOWERS FOR EACH VALUE OF THE BOYDEN INSTABILITY INDEX

Rainfall amount.—Figure 10 shows the frequency of days on which various average rainfall amounts occurred. Of the occasions with an index of 94 or more, 85 per cent were associated with an average rainfall of 0.1 mm or more, representing 88 per cent of all occasions of 0.1 mm or more. Of the occasions with an index of 93 or less, 85 per cent were associated with less than 0.1 mm, representing 82 per cent of all occasions of less than 0.1 mm. If the index were used to indicate either 0.1 mm or more, or less than 0.1 mm, a skill score of 0.70 would be obtained.

Of the occasions with an index of 94 or more, 64 per cent were associated with 0.5 mm or more, representing 93 per cent of all occasions of 0.5 mm or more. Of the occasions with an index of 93 or less, 94 per cent were associated with less than 0.5 mm, representing 68 per cent of all occasions of less than 0.5 mm. If the index were used to indicate either 0.5 mm or more, or less than 0.5 mm,a skill score of 0.56 would be obtained.

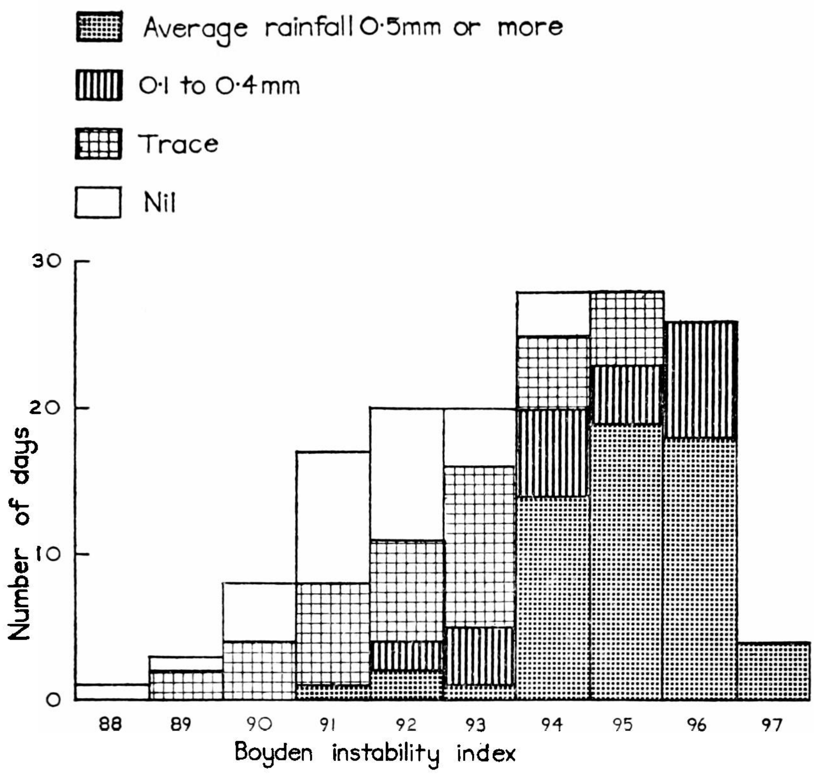

FIGURE 10—FREQUENCY OF DAYS WITH RAIN FOR EACH VALUE OF THE BOYDEN INSTABILITY INDEX

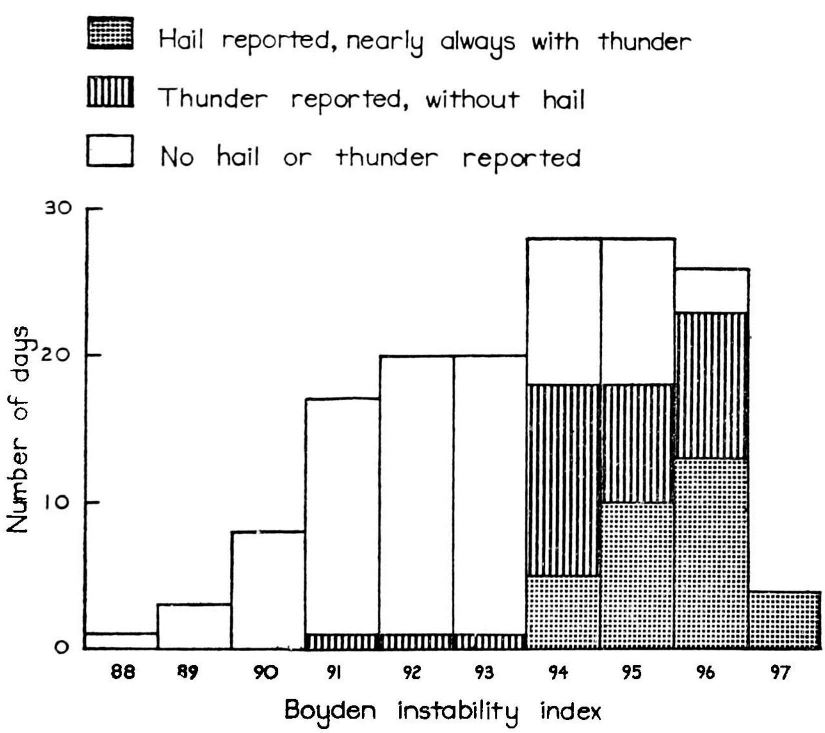

FIGURE 11—FREQUENCY OF DAYS WITH HAIL OR THUNDER FOR EACH VALUE OF THE BOYDEN INSTABILITY INDEX

Thunder and hail.—Figure 11 shows the frequency of days on which hail or thunder was reported. Of the occasions with an index of 94 or more, 73 per cent were associated with thunder, representing 96 per cent of all occasions of thunder and 35 per cent with hail, representing all occasions of hail. Of the occasions with an index of 93 or less, 96 per cent were associated with 'no thunder', representing 74 per cent of all occasions of 'no thunder' and 100 per cent with 'no hail' representing 55 per cent of all occasions of 'no hail'. If the index were used to indicate thunder or 'no thunder', a skill score of 0.67 would be obtained. For an indication of hail or 'no hail', a skill score of 0.32 would be obtained. If the height of the freezing-level above the ground could be forecast and hail was forecast only when the height was less than 207 decametres, the skill score would be improved from 0.32 to 0.38.

Using similar data for 1960 to 1962, but including all non-frontal situations, Boyden[1] found that 49 per cent of occasions with an index of 94 or more were associated with thunder compared with 73 per cent in the present investigation. The difference is clearly due to the relatively high probability of thunder in airstreams from the north-west quarter to which the present work is restricted.

Association with the Rackliff and Jefferson instability indices.—Analyses similar to that for the Boyden instability index were carried out for the Rackliff instability index,[2] the Jefferson instability index[3] and the modified Jefferson index.[4] The indices are defined as follows:

Rackliff index (ΔT) $= \theta_{w900} - T_{500}$
Jefferson index (T_J) $= 1.6\,\theta_{w900} - T_{500} - 11$
Modified Jefferson index (T_{mJ}) $= 1.6\,\theta_{w900} - T_{500} - \frac{1}{2}T_{d700} - 8$
where θ_{w900} = 900 mb wet-bulb potential temperature in °C,
T_{500} = 500 mb dry-bulb temperature in °C,
T_{d700} = dew-point depression at 700 mb in °C.

The corresponding skill scores and critical values of the indices are given in Table V.

The effect of warm fronts from the west.— On some occasions the midday ascent at Crawley was not representative of conditions later in the day owing to the arrival of overrunning warm air associated with the rapid approach of a warm front from the west, resulting in the damping down of shower activity. The seven dots and one cross within area I of Figure 2 represent occasions when the average rainfall from showers was only a trace or less. On four of these occasions, a warm front moved quickly eastwards, reaching 5°W by 2359 GMT and on one occasion a warm front reached 10°W. Of the 47 occasions during the 13 years when a warm front reached 10°W by 2359 GMT, 72 per cent were associated with an average rainfall of a trace or less. Of the 15 occasions when a warm front reached 5°W, 87 per cent were associated with a trace or less.

The relative usefulness of the predictors.— Assuming that the predictors can be forecast, their relative usefulness in forecasting showers activity, rainfall amount, thunder and hail can be assessed by a comparison of skill scores. Table V showes the skill scores obtained by the predictions already discussed and also for the 1000–700 mb thickness anomaly used with surface pressure.

TABLE V—A COMPARISON OF SKILL SCORES

Predictors	Shower activity	Rainfall (limit 0·1 mm)	Rainfall (limit 0·5 mm)	Thunder	Hail	Hail*
700 mb temperature anomaly and surface pressure	0·77	0·78	0·58	0·62	0·33	0·36
1000–500 mb thickness anomaly and surface pressure	0·73	0·74	0·53	0·56	0·28	0·31
1000–700 mb thickness anomaly and surface pressure	0·68	0·71	0·47	0·48	0·23	0·27
Boyden instability index	0·64	0·70	0·56	0·67	0·32	0·38
(critical values)	(93/94)	(93/94)	(93/94)	(93/94)	(93/94)	(93/94)
Rackliff instability index	0·69	0·73	0·64	0·62	0·45	0·49
(critical values)	(28/29)	(28/29)	(30/31)	(29/30)	(29/30)	(29/30)
Jefferson instability index	0·63	0·71	0·59	0·59	0·45	0·52
(critical values)	(22/23)	(22/23)	(25/26)	(25/26)	(25/26)	(25/26)
Modified Jefferson instability index	0·65	0·69	0·64	0·61	0·47	0·54
(critical values)	(20/21)	(20/21)	(22/23)	(24/25)	(24/25)	(24/25)

*Including freezing-level as a predictor.

The 700 mb temperature predictor gives the highest scores in general but not for forecasting hail. The instability indices and the 700 mb temperature predictor show similar degrees of success in forecasting the higher rainfall amounts and thunder. The 1000–700 mb thickness predictor is rather less successful than the 1000–500 mb thickness predictor. The highest scores for the forecasting of hail are obtained by the Rackliff, Jefferson and modified Jefferson indices. However, which predictor is to be preferred depends largely on which is easiest to forecast.

Conclusions.—This investigation was concerned with polar airstreams from the north-west quarter affecting south-east England in summertime and was restricted to days when no fronts were situated over south-east England. Widespread showers are likely if the associated depression is situated over Scotland or the North Sea at midday. Few showers are likely if the depression is over the Norwegian Sea or the Arctic. If the depression is situated to the north of Scotland or over Scandinavia, widespread showers are just as likely as few showers or no showers.

Widespread showers with thunder are likely if a major surface trough moves across England. Widespread showers are also likely if a minor perturbation moves across England or if the isobars are uniformly cyclonic. Few showers or no showers are likely if the isobars are anticyclonic. Few showers are likely if a warm front from the west is expected to reach 5°W by 2359 GMT.

An indication of the intensity of shower activity, rainfall amount and the likelihood of thunder or hail can be obtained from the midday values of (1) the 700 mb temperature anomaly at Crawley and the surface pressure at Heathrow, (2) the 1000–500 mb thickness anomaly at Crawley and the surface pressure at Heathrow, (3) the Boyden instability index, (4) the Rackliff instability index, (5) the Jefferson instability index and (6) the modified Jefferson instability index. The indication of hail can be improved by the use of the height of the freezing-level above the ground as a further predictor.

The relative usefulness of the predictors has been evaluated; which is to be preferred in forecasting depends largely on how successfully each can be forecast.

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551.508.77

A STANDARD HEATER FOR RECORDING RAIN-GAUGES

By A. L. MAIDENS

The provision of a source of heat within a rain-gauge can be intended either for the melting of hail or snow, or for ensuring continuity of operation of the gauge during occasions of frost. To achieve the former, the amount of heat necessary to thaw frozen precipitation can be considerable and is often beyond the means of the available energy which can be conveniently provided. Moreover it is debatable whether a rain-gauge is in fact the best means of obtaining a representative sample of snowfall.

Heat is also required within a recording rain-gauge to ensure that the recording mechanism is free to operate should rain occur during or immediately after a spell of frost, when the mechanism might otherwise be frozen. A limited amount of heat, suitably applied, will then suffice to ensure the immediate readiness of the gauge to record the first rainfall.

No standard form of heater has hitherto existed for Meteorological Office rain-gauges, although small 15- or 25-watt lamps have been provided for use where mains electrical supplies can be made available at the rain-gauge site. Alternatively it has been necessary to employ night-lights or similar forms of combustion heating. Outside the Office, various types of electrical heating have been individually designed, of which that described by Rodda* is of special interest.

In a new system which will shortly be available as a complete kit for incorporation within the Meteorological Office tilting-siphon rain recorder, the lamps are replaced by a robust and flexible heater strip, of almost unlimited operating life, which can be easily installed adjacent to the recording mechanism and float chamber. This heater operates on a 24-volt supply which can be provided either from the mains supply through a suitable transformer or from accumulators. This low voltage has been chosen on the grounds of safety.

The heater unit, which provides an output of 15 watts, is controlled by a thermostat. In this way the amount of power required to maintain the internal temperature at a value just above the freezing-point is kept to a minimum and there is no risk of overheating, with consequent evaporation losses.

As a further step towards power conservation, the complete kit includes easily attachable insulating material, tailored to cover the internal surfaces of the funnel, walls and base of the instrument compartment. In addition to

*RODDA, J. C. A note on the operation of rain-recorders during cold weather. *Met. Mag., London*, **92**, 1963, p. 335.

reducing heat losses, this insulation should itself reduce evaporation in summer. The kit will not only be available as a standard item of supply within the Meteorological Office but will be placed on the market for direct purchase.

An assembly has been tested in an ice chamber at the Meteorological Office, Bracknell. This environmental temperature averaged −10°C and surrounded the whole gauge, including those parts normally buried within the ground and hence protected to some degree from low temperatures. The test continued for one month during which time the internal temperature remained at between +1 and +4°C. Under these severe conditions the thermostat remained closed for the bulk of the time and electrical consumption was thus at the maximum level of 15 ampere-hours per day. At this rate, for continuous frost protection, a pair of small, car accumulators would require recharging at intervals of four days. Under more typical frosty conditions a much lower consumption could be anticipated but as the need for recharging will depend on the duration and severity of the frost and the heat losses due to wind, conditions will vary from site to site.

Although the present design is intended specifically for the Meteorological Office tilting-siphon rain recorder, only small changes in the shaping of the insulating material will be required to adapt the system to most other types of rain-gauges. The option of employing either mains supplies or accumulators should widen the circumstances under which electrical power may be conveniently employed for frost protection.

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METEOROLOGY AT THE 1965 WORLD GLIDING CHAMPIONSHIPS

By C. E. WALLINGTON

In May 1965, glider teams from 28 countries came to South Cerney, Gloucestershire, to compete in the 1965 World Gliding Championships. As weather is one of the most vital factors in a gliding championship a temporary meteorological office was set up at the airfield to provide a service for the organizers and the visiting teams.

The forecaster's most important job at a championship is to advise on the suitability of the weather for flying tasks which are set, if possible, on each day. These flying tasks are contests to see who can fly the furthest or fastest, although the accent nowadays is on racing rather than distance flying. A race may be to a distant goal or around a closed circuit (mostly triangular) the distance usually being between about 100 and 300 kilometres. Convective upcurrents commonly called 'thermals' are used by glider pilots to remain airborne and such convection need not be deep. A clear sky with light winds, little or no smoke haze and a low-level dry-adiabatic (or superadiabatic) layer from ground level to about 2000 feet or just over will usually provide enough thermals for top-class pilots to remain airborne for a long time, and if the depth of the convective layer extends to 4000 or 5000 feet these pilots can usually cover the distance around a course at average speeds of between 30 and 50 knots.

Gliders can fly at speeds up to between 100 and 120 knots, so provided that not too much time is used in climbing in thermals, a pilot can make appreciable headway into wind when necessary.

Early each morning the three forecasters at the championships concentrated their efforts on meso-scale analysis and prediction of cloud, temperature, visibility and wind structure over England and Wales. Normal routine observations are not enough for such analyses so reconnaissance and temperature sounding flights were carried out and assistants made frequent pilot-balloon observations.

As soon as the day's task was decided, details of the local and route forecasts were sketched on a set of blackboards and 160 copies of these forecasts were duplicated for pilots, team managers and the Press. The general briefing that followed was conducted in English, French and German with the help of experienced gliding forecasters from France and Germany (see Plate II).

On racing days the next duty of the organization was to launch the 86 competing pilots as quickly as possible when local conditions were just suitable, and as conditions were only marginally suitable on many days, the timing was critical. A fairly elaborate plan was put into effect. Two gliders, one with a forecaster on board, were flown continuously from mid-morning until conditions were suitable. The object of these flights was to test the characteristics of low-level turbulence and thermals and relate these to the local temperature sounding and surface temperature. Another forecaster remained in the office to keep a constant watch on the surface temperature changes, pilot-balloon observations and synoptic information, while the third forecaster liaised with the Championship Director at the launching point or made quick Chipmunk reconnaissance flights if necessary to view cloud structure further upwind than could be seen from the ground. These forecasters and the flying control organization were all linked together by 'walkie-talkie' radios. When conditions appeared to be suitable and safe the Director gave a signal for launching to start, whereupon all the gliders could be launched within 15 minutes. Although this procedure may appear elaborate, it was apparent that several contest days would have been lost or mismanaged without it.

Forecasting for a gliding championship brings the forecasters concerned into closer contact with the weather and the users of the meteorological service than is ever achieved in any other application of meteorology. Obligatory meso-scale analysis reveals coherent structures that are often missed in other types of forecasting duties; flight reconnaissance by forecasters adds a valuable dimension to their paper-work forecasting and, at South Cerney, foreign meteorologists who accompanied a number of teams and glider pilots (who amassed 2500 launches and flew 50,000 miles during the two-week contest period) were keen to discuss meteorology from morn till night.

METEOROLOGICAL OFFICE NEWS

Secretary, Meteorological Office

Mr. W. J. B. Crotch, Secretary of the Meteorological Office since April 1957 retired from established civil service on 30 June 1965 after a career which began in the academic world. He graduated with first class honours in English from London University (King's College) in 1922 and after some years of post-graduate work he joined the staff of the London School of Economics in 1927. There he remained, first as a lecturer and then as one of the administrative staff, until 1941 when he joined the Air Ministry as an Administrative Officer. His subsequent experience ranged over a wide area and included service in the Establishment, Finance and Secretarial Divisions, in Organization and Methods and in Civil Training as well as a year with the United States Army Air Force at the Headquarters of the 3rd Air Force, at Ruislip. He was promoted Assistant Secretary in 1955 and became the first Secretary of the Meteorological Office in April 1957.

At an informal gathering at Bracknell Headquarters in June a tribute to his work in the Office was paid by the Director-General who wished him well in his new unestablished appointment with the Navy Department at Bath.

The new Secretary of the Meteorological Office is Mr. B. M. Day. After commissioned service in the Royal Artillery from 1947 to 1948 Mr. Day graduated with honours from the London School of Economics in 1950. He joined the Air Ministry in the following year as an Assistant Principal and served in the Finance and Secretarial Divisions and as Private Secretary to the Air Member for Supply and Organization. In 1956 he was promoted to the grade of Principal and was seconded to the Cabinet Office for two years from 1959. During this period he was Secretary General of the Sierra Leone Constitutional Conference. On returning to the Air Ministry he served in the Central Finance Division and in 1963 he attended the Fourth Congress of the World Meteorological Organization as the financial adviser to the United Kingdom delegation. Mr. Day has now been promoted Assistant Secretary and we welcome him to his new appointment in the Meteorological Office.

NOTES AND NEWS

Meteorology in the University of Reading

On retirement from the Meteorological Office, Dr. R. C. Sutcliffe has become Professor of Meteorology in the University of Reading. This appointment marks the creation by the University of a new department which it is planned will undertake undergraduate and graduate teaching as well as research and will need to expand to a considerable size.

The proximity of the University to the Meteorological Office at Bracknell would point to a special relationship between the two institutions and Professor Sutcliffe has this circumstance much in mind. The *Meteorological Magazine* hopes soon to be able to publish a fuller account of this important new development in university meteorology.

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Address by Professor E. H. Palmén

At the invitation of the Director-General, a special lecture was given at Bracknell on 10 May 1965 by Professor E. H. Palmén of Finland. Although the first 25 years of his academic career were spent at the Finnish Institute of Marine Research, it is as a meteorologist that the Professor is perhaps better known internationally. Over the last 20 years his studies have ranged over such varied subjects as tropical hurricanes, evaporation and, of course, atmospheric meridional circulations and transfers. His choice of subject on this occasion was 'The atmospheric heat budget and general circulation'.

The atmospheric heat budget is often investigated from two different aspects: either by a consideration of the air currents and the way in which they redistribute quantities of heat, or by a consideration of the excesses (and deficits) of heating over the latitudes, from which can be deduced the heat flux required to maintain the observed temperature distribution.

Looking at the second of these two methods, the three ways in which significant heating of the atmosphere can be achieved are by a net radiation input, by heat exchange at the boundary interface and by the release of latent heat due to water state changes. An equivalent statement holds for the earth. London (1957) considered the radiative heating process for the combined earth–atmosphere system for both summer and winter. Assuming the net heating of the earth at these two solstices to be approximately zero he was able to derive estimates of the atmospheric meridional heat flux required to maintain the observed temperature distribution. He found, in addition to the need of a poleward flux of heat that an unrealistically large heat flux across the equator was also implied. Such an anomaly arises largely as a result of the invalid assumption that the earth's heat storage in winter and summer is small; it is known that the ocean temperatures in the northern hemisphere reach a minimum around 1 March and a maximum around 1 September. More than 60 per cent of the northern hemisphere surface is water-covered and it requires a 200-metre layer to cool through only 0·85°C during the three winter months for the cross-equator flux implied by London's results to be reduced to zero. This underlines the importance of the role played by the oceans in the heat budget of the atmosphere. To avoid the difficulty it is necessary to formulate a heat balance equation for the atmosphere alone; this requires knowledge of the heat transfer between earth and atmosphere. Budyko (1963) has derived mean values of this transfer which, together with estimates of atmospheric radiative heating and of latent-heat release, enable us to formulate a heat budget of the atmosphere, together with the associated heat flux.

Considering now the first aspect, estimates of the meridional heat flux can be made directly from available data. Three different atmospheric motions contribute significantly here—mean meridional circulation of the Hadley type, the semi-permanent standing waves and the synoptic-scale transient eddies. Many papers have been written on their respective roles in the transport of the relevant meteorological parameters and each of the three types of motion can be shown to play an important part in the redistribution of particular elements—the poleward transport of sensible heat being generally associated with the Hadley circulation in low latitudes while the standing-wave and transient eddy motions are the more influential in higher latitudes.

It is interesting to compare the implied flux of the heat excess/deficit estimates with the directly measured flux. Incorporation of Budyko's estimates into the former leads to a meridional heat flux picture which is quite similar to that derived by the latter method.

If we are to appreciate fully the heat budget and fluxes derived then it is necessary to consider also the manner in which vertical motions redistribute heat within the atmosphere. Near the equator the vertical limb of the Hadley circulation is seen to carry heat upwards, though vigorous small-scale convective activity is considered to be the major factor in diffusing heat from the surface.

Polewards of 30°N, winter convective activity is usually limited to the lower half of the troposphere and to the sea areas; cyclonic activity penetrates a greater depth of the atmosphere and though synoptic-scale eddies are not usually associated with downward transfer of heat, schematic vertical velocity fields in the disturbed westerly belt have been found to suggest a positive correlation between temperature and descending motion. From an appropriate vertical integration based on this positive correlation it is possible to derive the rate of conversion of potential energy to kinetic energy in the atmosphere; this is found to be of the order of four watts per square metre, a value which agrees well with independent estimates of the compensating frictional dissipation of kinetic energy.

To make such a comprehensive review of the problem of the atmospheric heat budget within the short time of a lecture was indeed an achievement, the appreciation of which was shown by the audience.

D. B. SHAW

REVIEW

Physics of the marine atmosphere by H. U. Roll. 9¼ in × 6¼ in, pp. viii+ 426, *illus.*, Academic Press Inc., 111 Fifth Avenue, New York 10003, 1965. Price: £5 7*s*. 6*d*.

In the preface Dr. Roll states "although a number of books exist that treat marine meteorology as an applied science I doubt whether there is any book available that considers the subject as a pure science," and accordingly sets out to fill one of the remaining gaps in meteorological literature.

In Part I the author, after considering whether there should be only one meteorology to deal with the atmosphere as a whole, argues that there is a sufficiently large number of meteorological phenomena which are closely related to, or dependent upon, the sea surface and which do not occur over the land, to warrant a separate treatment. In the present book the marine atmosphere is defined as that part of the atmosphere which has the sea surface as its lower boundary and which receives its peculiar characteristics from interaction with the sea, and the author restricts himself to the description of atmospheric processes of small and medium scale only, leaving discussion of large-scale phenomena over the oceans to be undertaken elsewhere.

In Part II the particular difficulties connected with meteorological measurements at sea, the bases and procedures which are available for executing such measurements, and the instruments and methods which are used for making routine measurements at sea are discussed.

Part III deals with the subject of atmospheric nuclei over the oceans, their concentration, size and chemical composition and their interrelation with meteorological elements and phenomena. A brief description of atmospheric electricity and radio-activity is included for the sake of completeness.

Part IV which discusses the flow characteristics of the marine atmosphere is probably the most valuable section in the book. This emphasizes the differences between flow over land and sea, and in particular highlights the difficulties experienced in dealing with flow over a surface generally distorted by a large variety of ocean waves, all different in size, shape and velocity as well as being subject to continuous and irregular changes, and which, with increasing wind speed, tends to disintegrate into sea spray and foam. After consideration of the essentials of the sea surface which may or may not be related to the wind structure, the author proceeds to a discussion of the wind field above and around the ocean waves, the effect upon the wind profile of thermal stratification over the sea, the mean stress at the sea surface, the drag coefficient, the variance of horizontal and vertical wind fluctuations, and the diurnal, annual and aperiodic variations of the wind.

Part V deals with the thermodynamic processes in the marine atmosphere resultiug from the fact that the temperature and moisture contents of the lower layers of the air over the sea are influenced by the sea surface. Factors affecting the sea surface temperature, horizontal variations of sea surface temperature, diurnal, annual and non-periodic variations of the sea surface temperature, and air effects on the temperature and moisture fields in the first few metres are discussed in some detail as are also the modification of cold or warm air masses moving over warm or cold seas.

This book which is the seventh in the International Geophysical series edited by J. Van Mieghem is mainly concerned with maritime boundary problems and with one exception the author has confined himself to a treatment of the marine atmosphere in the lowest 1500 metres above the sea. This exception, the discussion of oceanic cumulonimbus cloud in part V, appears to be somewhat out of place in the present monograph and although of interest should not in the opinion of the reviewer have been included.

Dr. Roll has performed a valuable service in gathering together into a connected and well-written account of the results of about 550 studies on marine meteorology, mostly written within the last decade, which up to now have been scattered in many different and sometimes non-meteorological journals in many countries. The production is excellent and the reviewer noticed no misprints.

R. FROST

HONOURS

The following awards were announced in the Birthday Honours List in June 1965:

C.B.E.

Mr. B. C. V. Oddie, Deputy Director (Central Services), Meteorological Office.

I.S.O.

Mr. C. W. G. Daking, Assistant Director (Defence and International), Meteorological Office.

M.B.E.

Mr. F. J. Parsons, Auxiliary Observer, Ross-on-Wye.

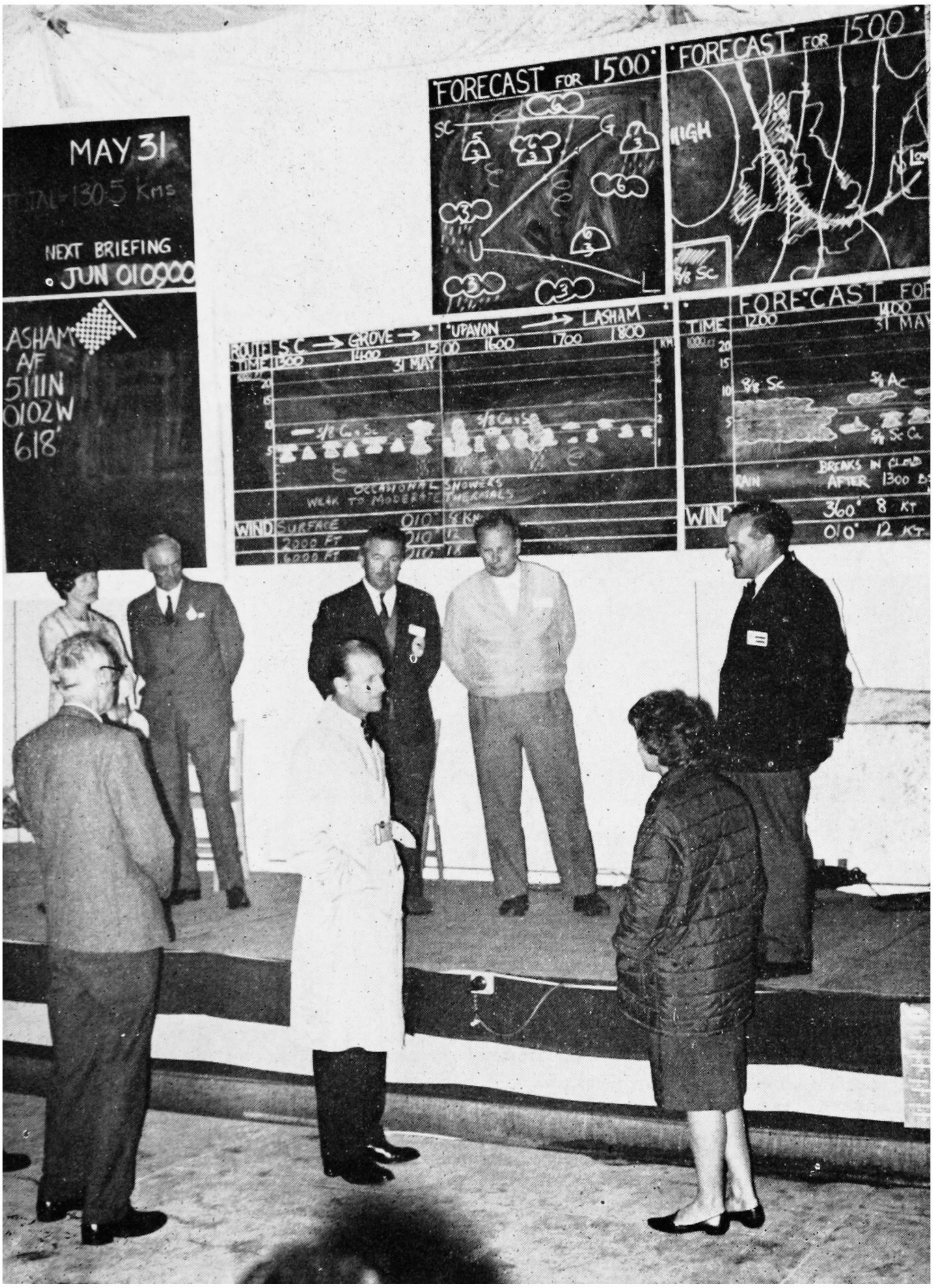
AWARD

We have great pleasure in recording that Mr. C. E. Wallington, Principal Scientific Officer and Superintendent of the Meteorological Office Porton, has recently been awarded the OSTIV Plaque for 1965. The President of the Organisation Scientifique et Technique Internationale du Vol à Voile (OSTIV), Mr. L. A. de Lange, presented the plaque at the opening ceremony of the Xth OSTIV Congress held at South Cerney on 4 June 1965, saying that it was in recognition of Mr. Wallington's services to gliding, including his textbook *Meteorology for glider pilots*, his researches into the sea-breeze front and his meteorological advice at many gliding meetings in various parts of the world since 1953.

This award is made for "the most noteworthy scientific contribution to soaring flight" and Mr. Wallington is the fourth recipient of the plaque since it was instituted in 1958.

CORRIGENDUM

Meteorological Magazine, February 1965, p. 37: line 30 for "ν is the frequency" read "$\nu/2\pi$ is the frequency"; line 37 for "underestimate of the calculated velocity" read "overestimate of the calculated velocity"—this is consistent with the view that it is unlikely that the disturbance was a stationary train of lee-waves.



Photograph by Sally Anne Thompson

PLATE II—DISCUSSION ON THE WEATHER SITUATION DURING THE WORLD GLIDING CHAMPIONSHIPS AT SOUTH CERNEY IN JUNE 1965

H.R.H. the Duke of Edinburgh discussing the weather with Mr. C. E. Wallington, Mr. Philip Wills (Chairman of the British Gliding Association) and Mrs. Ann Welch (Director of the Championships).

Special signs and symbols were used on the briefing boards to overcome the problem of briefing pilots of 28 nations (see page 281).

To face back cover

Photograph by H. H. Lamb

PLATE III—TORNADO DESTRUCTION OF TREES AT SHALFORD PARK, GUILDFORD, SURREY

The tree nearest the camera was twisted off by a tornado at 1600 GMT on 26 April, 1965. The next stump only 8 metres away, seen—barkless and discoloured by age—in front of the white building, was plainly a relic of a similar event some decades before. The park is largely river meadows beside the River Wey where it cuts through the east-west line of the North Downs (100–150 metres high); the park lies in the southern entrance to the gap whose steep sides are at this point scarcely 800 metres apart. It is a likely place for twisting motions to be imparted to many airstreams; though abundant surface roughness (in the shape of trees, woods and lesser hills) probably tends to destroy these motions before they have travelled far.

The photograph was taken the morning after the event. Twentieth century technology is against the preservation of evidence of this kind. Within 4 days—before the first bright day for photography—all trace of these tornadoes had been removed by bulldozer and the site cleared.