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AN INDEX OF DRIVING RAIN

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Summary.—Two maps are presented, one showing the variation of an index of driving rain over the British Isles, the other showing how the index varies with direction. The method of preparing the maps from data of rainfall and wind speed is described.

Introduction.—When rain is carried along at an angle to the vertical by wind, so that it impinges on vertical surfaces, some of it will be absorbed if the surface is porous, or driven into cracks between units which are impervious. Damage to buildings, to their decorations and even to their contents from rainwater which is driven onto a wall in this manner is of common occurrence. Not only does the rainwater absorbed by the structure cause direct damage, but also by increasing the thermal conductivity of the materials it tends to lower the temperature at the inner face and so increase the risk of condensation there. Greater heat-losses because of the higher thermal conductivity either reduce the comfort of the occupants or increase costs because the losses must be made good by burning more fuel.

Such wind-driven rain is called "driving rain" and it is useful to have some measure of its severity. It is common knowledge that the problem of penetration of buildings by rain is more acute in some parts of the country than in others; in some parts special precautions may need to be taken, precautions which would be unnecessary in other places. It may therefore be possible to save money in areas which are not liable to have severe driving rain by using simpler methods of construction than those needed elsewhere, or by using materials which would not be suitable in more exposed regions. Clearly then, there is a need for a map of the country showing how the severity of driving rain varies from place to place.

In 1956–57 measurements were made on buildings in Glasgow, using specially developed raingauges for measuring the amount of rainwater driven onto a vertical surface[1]. Comparison of the catch in one of these gauges was made with the rainfall and wind at Renfrew, about three miles to the north-west of the building. For this purpose, each hourly amount of rain on the horizontal (i.e. the normal rainfall on the ground) was multiplied by the corresponding component of the wind speed resolved normal to the surface of the wall in which the gauge was set. In this particular case the wall faced 220° true. The daily sums of these products were compared with the corresponding catches of the gauge in the wall, and were found to be proportional to these catches.

It seemed clear as a first approximation that we could use the product of the rainfall on the ground and the mean wind speed while rain was falling, as an index of driving rain. Thus an average map showing the distribution of driving rain over the country might be constructed by combining a map of average rainfall with one showing the average wind speed during rain. Unfortunately a map of average wind speed during rain does not exist and such information is available for only a few places. Table I gives values for three widely separated stations, based on hourly observations over the ten years 1946–55, and suggests that the ratio of mean wind speed during rain to that for all hours does not vary greatly. It seems reasonable therefore to assume that

TABLE I—MEAN WIND SPEED DURING RAIN (TEN-YEAR MEANS, 1946–55) FROM HOURLY DATA

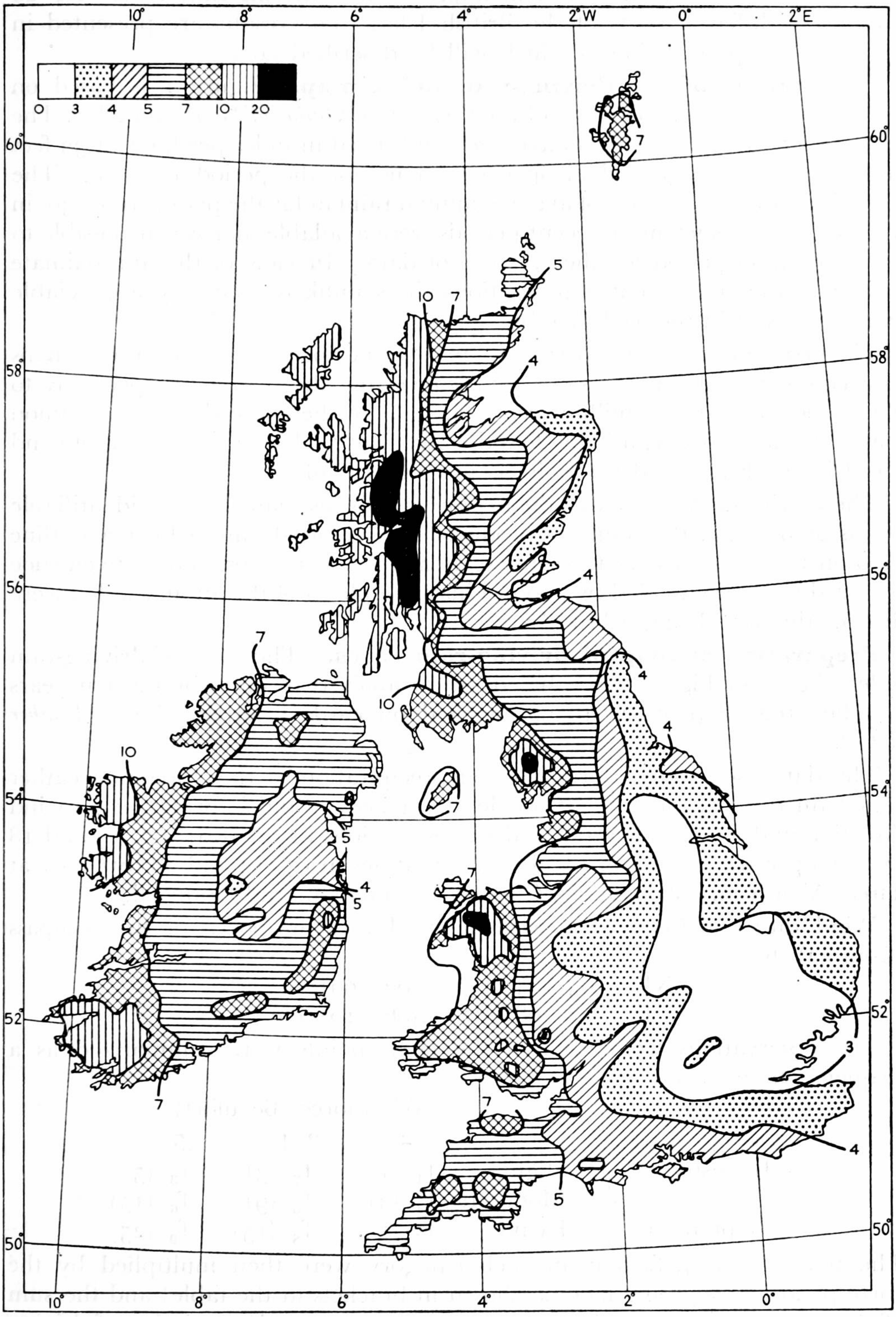
Station	Wind speed during rain	Wind speed at all hours	Ratio
	mph	*mph*	
Croydon	11.5	8.9	1.29
Holyhead (Valley)	16.9	14.1	1.20
Renfrew	12.2	8.7	1.40

All speeds are reduced to the standard height of 33 ft.

this ratio is more or less constant and to construct a driving-rain map using maps of average annual rainfall and of average annual wind speed. Such a map is shown in Figure 1 and it is considered unlikely that the picture it presents is significantly distorted by the assumption that mean wind speed during rain bears a constant ratio to overall mean wind speed. The method of construction of the map is described below.

A map of driving rain for Norway has been constructed by Hoppestad[2], using daily observations of rainfall and the corresponding wind speeds, but in view of the fact that many of the wind data he used were subjective estimates, it is unlikely that the final result is any more accurate than that presented here.

Figure 1 gives in effect a driving-rain index for a vertical surface which is always facing the wind. For our purpose it is also necessary to know if the index is always highest for the direction facing the prevailing wind, or whether severe driving rain can occur with other directions of wind. The data readily available for this purpose were limited. Once again the only detailed data available were hourly instrumental observations of rainfall and wind at Croydon, Holyhead and Renfrew, during 1946–55, which had been analysed as part of a preliminary investigation of the driving-rain problem a few years ago. The full results of this analysis cannot be presented in the limited space available here, because they involve three variables—rainfall amount, wind speed and wind direction, but some of them are presented in Tables II, III and IV on an annual basis. The bottom line in each table gives the percentage of the total driving-rain index (sum of products of frequency, times mean wind speed, times mean rainfall amount) from eight ranges of wind direction. These figures indicate that the direction of maximum index is not necessarily that of the prevailing wind. At both Croydon and Holyhead, for example, the maximum index occurs with south winds while the prevailing winds are from south-west; at Renfrew the maximum index occurs with south-west winds and the prevailing wind is westerly. In order to obtain a better picture of the variations of driving-rain index with wind direction over the country a further



(Units m² sec⁻¹ yr⁻¹)

FIGURE I—ANNUAL DRIVING-RAIN INDEX FOR THE BRITISH ISLES analysis was undertaken to obtain approximate "driving-rain roses" for 20 stations in different parts of the British Isles. The results are presented in Figure 2, the preparation of which will be described later.

Preparation of the driving-rain index map.—Figure 1 is based on the two maps on pp. 20 and 72 of the *Climatological atlas of the British Isles*[3]. The first of these shows isopleths of average wind speed in miles per hour at 33 feet (10 metres) above ground in open situations, for the period 1926–40. The second map shows isohyets of average annual rainfall for the period 1901–30, in inches. No maps for more recent periods were available, nor was it possible to use a common period for the two sets of data. In view of the approximate nature of the subsequent computations, it is unlikely that any appreciable extra error was introduced thereby.

The first step was to prepare annual mean wind speed and total rainfall maps to a common scale, at the same time converting the readings respectively to metres per second and millimetres. These were then traced onto a common map, on tracing paper, it being found convenient to draw the isopleths of wind speed in black ink, and the isohyets in coloured inks.

The driving-rain index was then computed for as many readily identifiable points as possible, the resulting products being plotted onto a further outline map on tracing paper, to the same scale as the other maps. For convenience the products were divided by 1000. Finally isopleths of the annual index were drawn, the units being $m^2\ sec^{-1}\ yr^{-1}$.

Preparation of map of driving-rain roses.—The roses of driving-rain index shown in Figure 2 are based on an analysis of data for the ten years October 1929–September 1939, punched on cards from the *Daily Weather Report.*

The data used were information on precipitation in the "present weather code" (in the categories slight, moderate or heavy) and information on wind direction and force. They referred to observations made at 01, 07, 13 and 18 GMT at 14 of the 20 stations, and to observations at 07, 13 and 18 GMT only at Tiree, Aberdeen, Eskdalemuir, Chester, Birmingham and Cranwell.

Wind direction frequencies were reduced to eight points of the compass (from 32) thus:

$$NE = 03+04+05+\tfrac{1}{2}(02+06)$$
$$E = 07+08+09+\tfrac{1}{2}(06+10), \text{ etc.}$$

The observations from each of the eight points were summarized as a frequency table, as follows:

		Wind force (Beaufort) 1–2	3–4	5
Intensity of precipitation	Slight	f_1 (1)	f_2 (3)	f_3 (5)
	Moderate	f_4 (3)	f_5 (9)	f_6 (15)
	Heavy	f_7 (5)	f_8 (15)	f_9 (25)

The frequencies f_1, f_2, etc. in each category were then multiplied by the corresponding weighting factors (shown in brackets in the table) and the sum of the products was considered to represent an approximate index of driving rain, the weighting factors being very roughly proportional to the product of mean rate of rainfall and the mean wind speed for the group concerned.

In each rose the length of each vector indicates the percentage of the total index for the station from that direction.

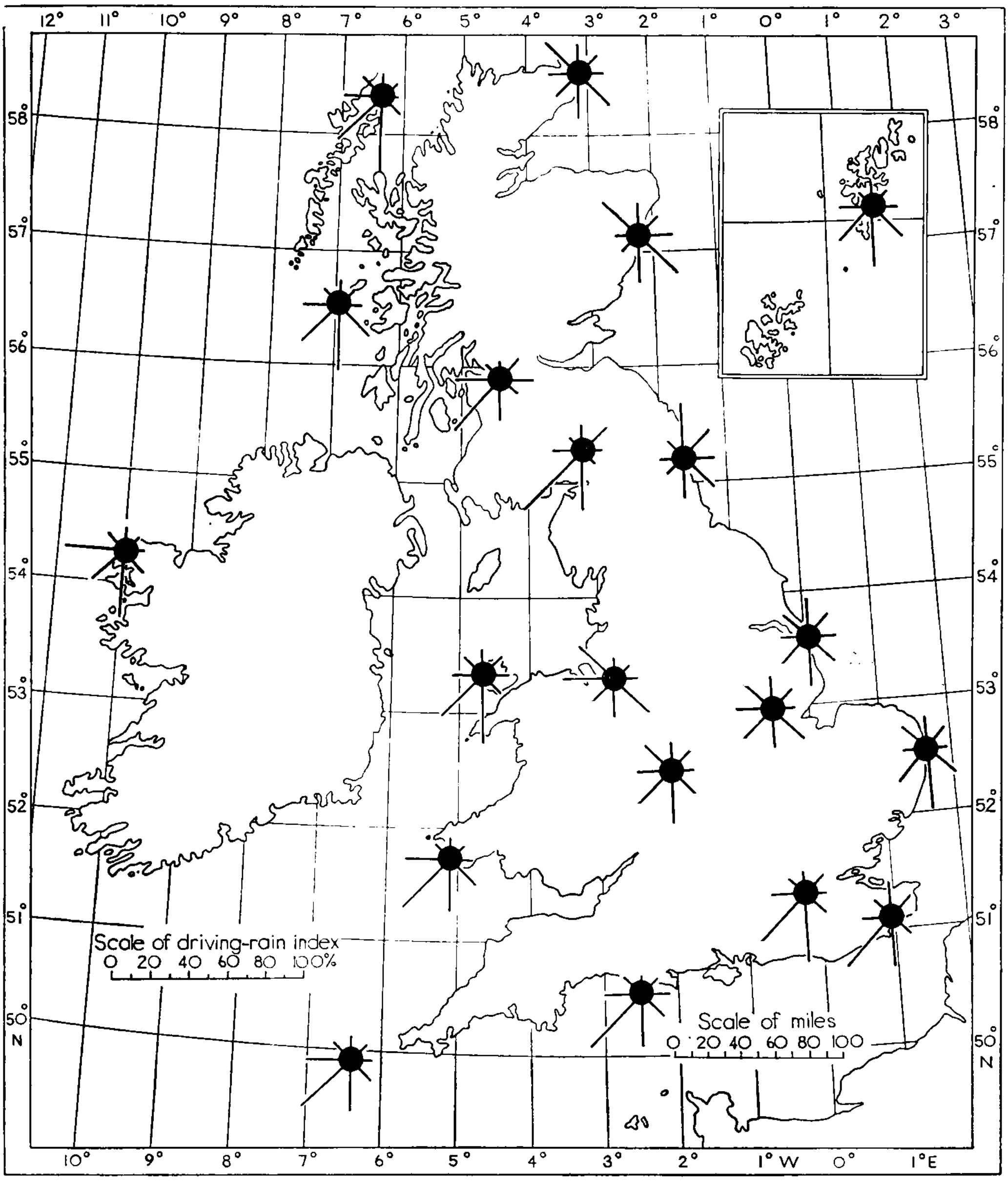


FIGURE 2—ANNUAL RELATIVE DRIVING-RAIN INDEX FROM EACH OF EIGHT WIND DIRECTIONS FOR 20 STATIONS

The length of each vector shows the percentage of total index for the station from that direction.

Discussion.—The "driving-rain index" presented in Figure 1 above is a figure proportional to the total amount of rain which would be driven on a vertical surface always facing the wind. The assumption is made that the mean wind speed while rain is falling is the same as, or some constant proportion of, the annual mean wind speed. Further, it is assumed, in effect, that for a given wind speed the spectrum of raindrop sizes is always the same, so that the mean angle of incidence of the raindrops is constant. In fact, the spectrum varies considerably from rainstorm to rainstorm and so does the angle of incidence of the drops. However, as has already been remarked, it is probably sufficient for our purpose to assume that the product of total rainfall amount and overall mean wind speed can be used as a driving-rain index. This index should give a measure of the relative severity of the driving-rain problem in different parts of the country.

There are obvious limitations to this simple index. Firstly, it gives no information on the effect of direction of the wind. This can only be obtained by an analysis of the wind speed and direction at times when rain is falling. Secondly, the map is based on averages, while it is likely that the most serious rain penetration occurs on a few occasions of strong winds with prolonged rainfall. It is thought, however, that the relative severities under worst conditions in the different parts of the country would be much the same as under mean conditions. Finally, it must be emphasized that a small-scale map such as this cannot show the local variations of exposure which must be very significant. The map of mean wind speed used in the preparation of the index refers to winds in open situations—but not, for example, on isolated hills, on cliff tops or in mountainous areas. The rainfall map takes account of variations due to the large-scale topography, but not of the effects of local features. In open country, quite a small hill experiences appreciably stronger winds and greater rainfall than the level country around it, with a corresponding increase in the driving-rain index. These local variations, especially of mean wind speed, must be taken into account when using the map.

It has been suggested that the increase in severity of exposure experienced by high buildings, as compared with low ones at the same place, is greater than the change in severity between different parts of the country. The map shows a range of index of about 10:1. It is unlikely that the range between say 300 feet and 30 feet on a building in an open situation much exceeds 2:1, except perhaps at the corners and at copings.

TABLE II—FREQUENCY SUMMARIES OF HOURLY WIND SPEED AND HOURLY RAINFALL AMOUNTS AT CROYDON IN TEN YEARS (1946–55)

Rainfall *mm*	Calm	1–4	5–9	10–14	15–19	20–24	25–29	30–34	35–39	40–44	Total
	Speed in miles per hour *frequencies*										
0.1– 0.9	173	545	1607	1637	1235	813	250	85	14		6359
1.0– 1.9	13	93	283	328	266	178	68	31	7	2	1269
2.0– 2.9	6	29	90	84	114	80	24	11	2		440
3.0– 3.9	2	23	42	38	35	19	17	7	2		185
4.0– 4.9	1	7	14	11	25	14	2	5	2		81
5.0– 5.9	1	6	11	8	11	5	5	2	1		50
6.0– 6.9		3	4	1	1	3			1		13
7.0– 7.9	1	2	3	3	1	2	1				13
8.0– 8.9			2	1	1	2					6
9.0– 9.9			1	1		1					3
10.0–10.9				1							1
11.0–11.9											
12.0–12.9		1									1
23.0–23.9			1		1						2
26.0–26.9						1					1
Total	197	709	2058	2113	1690	1118	367	141	29	2	8424

	NE	E	SE	S	SW	W	NW	N
Percentage of total driving-rain index	6	6	8	31	30	11	4	4

Total driving-rain index $= 4.7 m^2 sec^{-1} yr^{-1}$

TABLE III—FREQUENCY SUMMARIES OF HOURLY WIND SPEED AND HOURLY RAINFALL AMOUNTS AT HOLYHEAD IN TEN YEARS (1946–55)

Rainfall *mm*	Calm	1–4	5–9	10–14	15–19	20–24	25–29	30–34	35–39	40–44	45–49	50–54	55–59	60–64	Total
	Speed in miles per hour — *frequencies*														
0.1– 0.9	141	394	944	1399	1762	1631	819	380	179	45	15	6		1	7716
1.0– 1.9	21	69	211	323	376	423	185	95	50	8	4	1			1766
2.0– 2.9	7	24	71	143	119	123	71	37	27	3					625
3.0– 3.9	4	8	24	50	48	56	26	17	7	3					243
4.0– 4.9	1	7	16	14	32	21	6	7	1						105
5.0– 5.9	4	5	6	3	12	10	3	6	1						50
6.0– 6.9			3	5	8	4	1	1		1					23
7.0– 7.9		1	2	1	5	4	2								15
8.0– 8.9				1											1
9.0– 9.9					1	1									2
Total	178	508	1277	1939	2363	2273	1113	543	265	60	19	7		1	10,546

	NE	E	SE	S	SW	W	NW	N
Percentage of total driving-rain index	5	6	8	33	25	11	7	5

Total driving-rain index $= 7.7$ m^2 sec^{-1} yr^{-1}

TABLE IV—FREQUENCY SUMMARIES OF HOURLY WIND SPEED AND HOURLY RAINFALL AMOUNTS AT RENFREW IN TEN YEARS (1946–55)

Rainfall *mm*	Calm	1–4	5–9	10–14	15–19	20–24	25–29	30–34	35–39	40–44	45–49	50–54	Total
	Speed in miles per hour — *frequencies*												
0.1– 0.9	462	986	2279	2129	1748	1190	372	129	38	8		1	9342
1.0– 1.9	74	207	482	417	360	316	130	52	16	4			2058
2.0– 2.9	25	79	168	130	120	64	30	14	4	1			635
3.0– 3.9	12	28	50	41	29	32	21	7	5	1			226
4.0– 4.9	2	6	25	32	18	13	6	1	2				105
5.0– 5.9		5	12	5	5	4	2						33
6.0– 6.9		1	7	2	5	4	4						23
7.0– 7.9	1	3	9	2	1								16
8.0– 8.9			2	1									3
9.0– 9.9	1		1										2
10.0–10.9													
11.0–11.9						1							1
12.0–12.9	1	1											2
13.0–13.9		1											1
16.0–16.9					1								1
18.0–18.9			1										1
32.0–32.9				1									1
Total	578	1317	3036	2760	2287	1624	565	203	65	14		1	12,450

	NE	E	SE	S	SW	W	NW	N
Percentage of total driving-rain index	9	10	5	15	34	22	4	1

Total driving-rain index $= 6.3$ m^2 sec^{-1} yr^{-1}

Tables II, III and IV give detailed frequencies of occurrence of hourly rainfall amounts associated with various ranges of wind speed at Croydon, Holyhead and Renfrew in the ten-year period 1946–55. The corresponding average annual driving-rain indices for each station have been computed and are 4.7, 7.7 and 6.3 m^{2}sec^{-1}yr^{-1} respectively. These values are in reasonably good agreement with the values interpolated from Figure 1 and this provides welcome supporting evidence of the validity of Figure 1. The agreement is a little better if the computed values are "corrected" by dividing by the appropriate ratios of mean wind speed during rain to that for all hours, when they become 3.6, 6.5 and 4.5 respectively.

It was hoped that the total indices obtained when calculating the driving-rain roses in Figure 2 would provide comparative data on driving-rain intensity at the various stations, but the ratios of the indices of Croydon, Holyhead and Renfrew derived by this approximate method were not in very good agreement with those derived independently from hourly instrumental observations of rainfall and wind at these three stations over the years 1946–55 inclusive.

Also the total index for some stations was clearly affected by the subjective nature of the observations on which it was based, both precipitation intensity and (at some stations in 1929–38) wind force being estimated. Thus the ratios of the total indices at Renfrew and Holyhead to that at Croydon were 1.35 and 1.33, whereas using the much more accurate hourly instrumental data for 1946–55 they were 1.36 and 1.60. Also the ratios of Gorleston, Portland Bill and Scilly to Croydon came out as 0.85, 1.82 and 1.36. It was reasonable to expect that Portland Bill would have an overall index somewhat lower than that for Scilly, which in turn would certainly be no greater than that for Holyhead, while there was no obvious reason why Gorleston on the east coast should have a lower index than Croydon (see also Figure 1). The figures obtained thus suggest overestimation at Portland Bill and underestimation at Scilly and Gorleston.

It was concluded that the 1929–38 data could not be trusted to give a fair comparison between stations, but that for any one station they would give useful information on the relative intensity of driving rain from different wind directions over a long period. This was confirmed by comparing the direction distributions obtained for Croydon, Holyhead and Renfrew with those obtained from hourly instrumental observations for these three stations, see Tables II, III and IV. The agreement is reasonably good. It is for this reason that the data in Figure 2 are presented only in the form of relative indices for each station. However, the driving-rain roses show clearly that on east coasts we may expect severe driving rain from directions between north through east to south, the worst direction at any particular place depending on the topography. Indeed, at no east coast station is the south-west side of a building the worst for driving rain—on a coast facing north-east a wall facing north may have the worst exposure, although inland or in the west this is the most sheltered direction.

Acknowledgements.—The work described here has been a co-operative effort, most of the work towards the preparation of the driving-rain map having been carried out by the Building Research Station as part of the programme of the Building Research Board. That involved in the preparation of Tables I to IV and the map of driving-rain roses has been done in the Meteorological Office.

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TROPOSPHERIC HEATING OVER THE NORTH ATLANTIC

By G. B. TUCKER, Ph.D.

Introduction.—Atmospheric systems on the meteorological scale are thermally driven. Therefore if dynamical and quantitative studies are to include the driving mechanism, an accurate specification of the areas of non-adiabatic heating and cooling is necessary on both the synoptic and climatological time scales. Clapp[1] in a synthesis of some published studies of the normal heat budget of the lower troposphere shows that the approach to heat sources and sinks can be made via the "thermodynamic energy equation" method or via the "heat-balance" method.

The heat-balance method is represented by the equation

$$\frac{\overline{dq}}{dt} = \frac{1}{m}\left[\overline{Lr} + \overline{R} + \overline{H}\right] \quad \ldots (1)$$

where q is the amount of heat per unit mass, m the mass of the column of air of unit cross-section, L the latent heat of condensation, r the rate of precipitation, R the net heating in the column due to radiation, and H the rate of gain of sensible heat by exchange from the earth's surface. All three terms within the brackets present individual problems, and it is with this approach that the remainder of the paper will be concerned.

Recently four publications have appeared which enable an assessment to be made of $\overline{dq/dt}$ via equation (1) on a mean monthly basis over the North Atlantic. First, a new version of a marine atlas[2] enables a recomputation of $\overline{H}$, and these values can then be compared with individual monthly estimates made by Shellard[3] at ocean weather stations "I" and "J". The third paper[4] provides a new method of calculating rainfall over the North Atlantic Ocean; this suggests that previous estimates were too high and provides revised figures for North Atlantic weather ships. Finally Möller[5] has shown that although net radiative cooling cannot be associated in any simple way with synoptic parameters, climatological values of the net radiative cooling throughout the troposphere (up to 300 mb) vary little from place to place. His figures suggest that a reasonable annual variation can apply to the whole of the Atlantic Ocean north of the tropics.

The information contained in these papers has been combined to obtain the mean monthly heating rate in the troposphere over the North Atlantic weather ships.

Sensible heat transfer between ocean and atmosphere.—It is considered permissible in climatology (e.g. Jacobs[6]) to represent the upward flux of sensible heat between ocean and atmosphere $(\overline{H})$ as

$$\overline{H} = B.E.L_w$$

where the "Bowen ratio"

$$B = 0.49 \frac{(T_w - T_a)}{(e_w - e_a)}$$

e being vapour pressure, L the latent heat of vaporization, T temperature (°C), and the subscripts w and a refer to the surface layers of water and air. The difficulty lies in estimating the evaporation, E. The method usually adopted is given by the relation

$$E = k(e_w - e_a)\, V_a$$

where V_a is the wind speed and k is a constant obtained by using an oceanographic energy balance method (e.g. Privett[7]). No other climatological method has been established and therefore this one is used in the present analysis. Shellard's[3] adaption of this has been used; it is

$$H = 0.0019\, L_w\, V_a\, (T_w - T_a)$$

where V is measured in knots, temperatures are now in °F,

$$L_w = 605 - 0.29\, T_w.$$

The mean monthly surface air temperature, T_a, and the mean scalar wind speed, V_a, have been obtained from the "Climatological and oceanographic

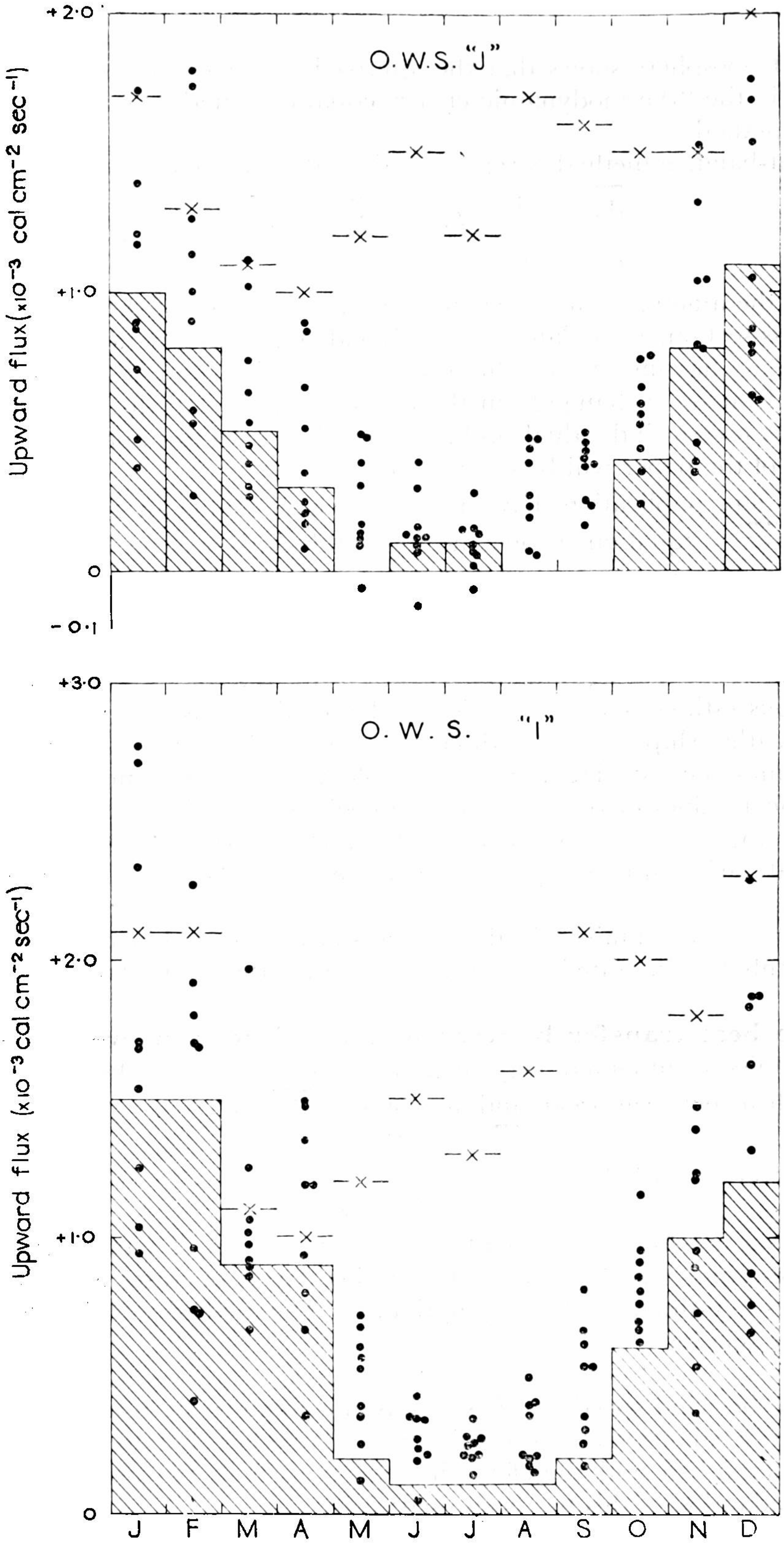

FIGURE I—UPWARD FLUX OF SENSIBLE HEAT AT THE SURFACE FOR O.W.S. "J" AND O.W.S. "I"

Shellard's[8] monthly values from 1948–56
–×– normal of latent heat liberated by condensation (precipitation)
normal values using marine chart data[8] are given in histogram form

atlas for mariners"[2], V_a being computed from the wind-rose statistics given in this publication. Unfortunately sea surface temperatures are given only for every other month, and therefore a different source of data had to be used for these statistics[8]. However, a comparison of sea surface temperature charts for the six months in which they appear in both publications shows them to be very similar, and the errors involved in using a different set of charts must be very small. All values were extracted for the standard ocean weather ship positions.

In order to check the values of H obtained from these climatological charts, the results for stations "I" and "J" are compared with monthly values obtained by Shellard[3]. Shellard used the ocean weather station surface data from 1948 to 1956 to obtain monthly values of H; all his values are plotted in Figure 1. The climatological values of H as now computed are plotted on the same diagrams in the form of a histogram and it can be seen that for most months they fall well within the scatter of the individual monthly values. There appears to be sufficient similarity for the climatological values to be accepted.

Latent heat released by condensation.—Condensation above the weather ships was assumed to be represented by precipitation. Mean monthly precipitation values for the five years 1952–57[4] were used to compute $\overline{Lr}$ in equation (1). L at condensation level is taken as 593 cal gm^{-1}. Values for "I" and "J" are plotted for comparison with $\overline{H}$ in Figure 1.

Net radiative heating.—Möller[5] has shown that variations in cloudiness and humidity in the upper troposphere are mainly responsible for variations in the radiation balance; surface parameters appear unimportant. He has

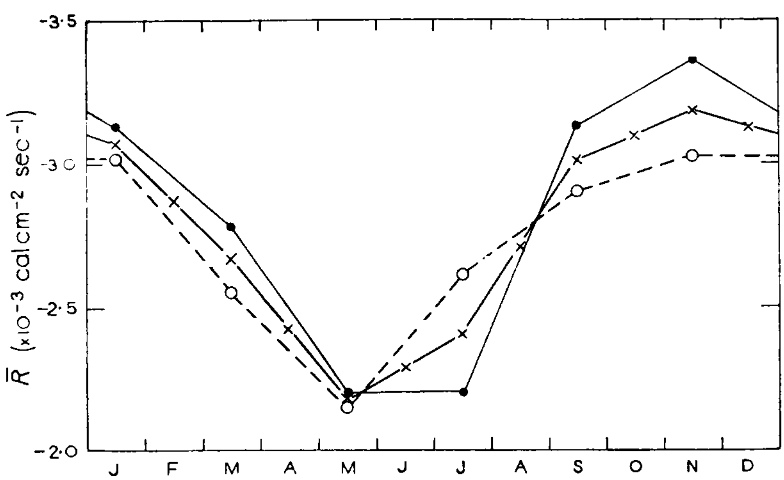

FIGURE 2—NET RADIATIVE HEATING $(\overline{R})$ IN THE NORTH ATLANTIC TROPOSPHERE (after Moller[5])

• north of 50° N o south of 50° N
× average monthly values inferred from these data

computed mean monthly values for alternate months of the net radiative heating of the troposphere up to 300 mb at several locations. The overall figures for the northern and southern parts of the North Atlantic Ocean are reproduced in Figure 2. The values for the two parts of the Ocean were not considered sufficiently different to be used independently; accordingly, average

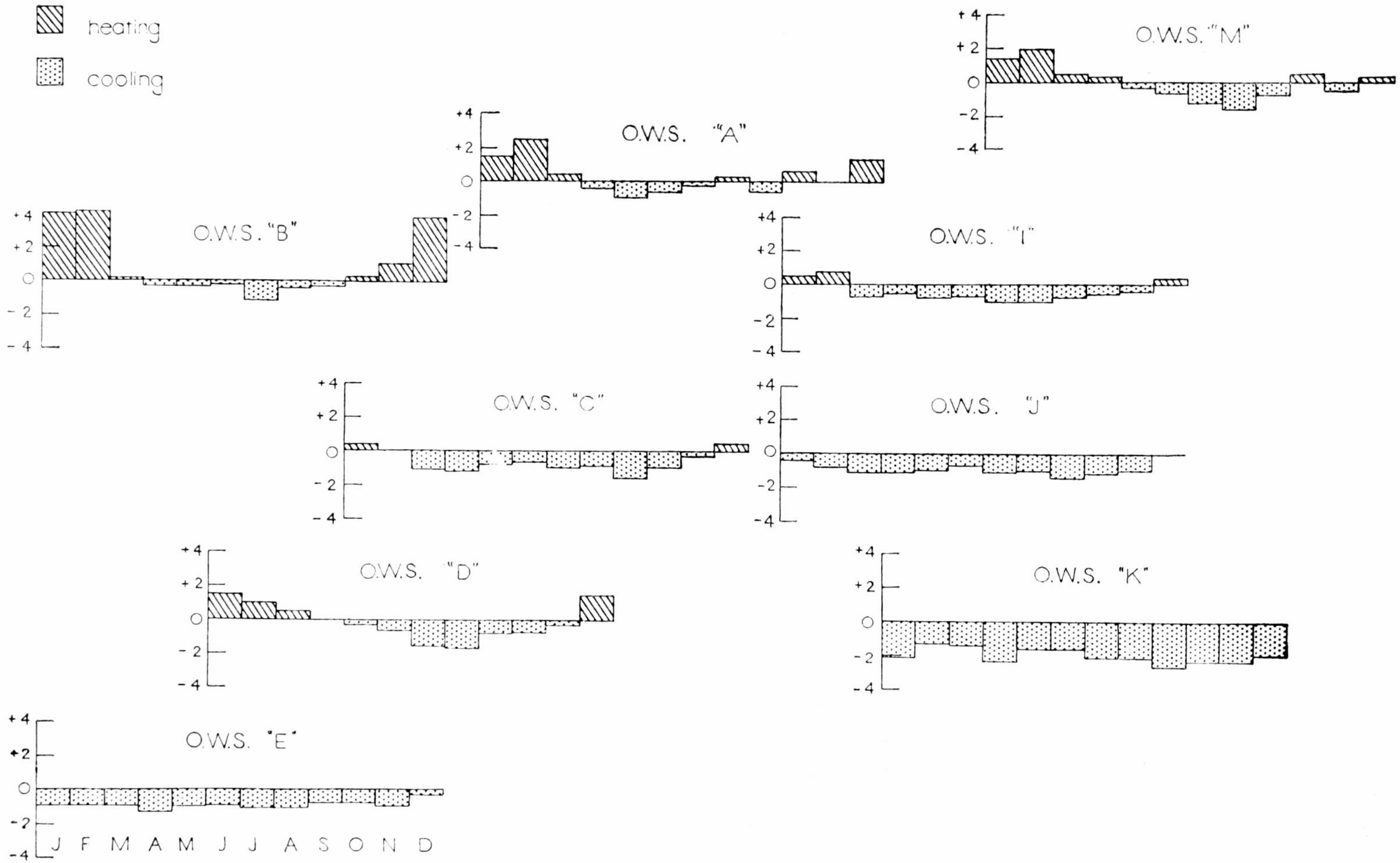

FIGURE 3—MEAN MONTHLY RATE OF HEATING IN THE TROPOSPHERE OVER THE NORTH ATLANTIC
Units: 10^{-3} cal cm^{-2} sec^{-1}

values with linear interpolation for the missing months were used in this analysis. The same value of $\bar{R}$ was therefore applied to all weather ships in any one month.

Results.—The resulting mean monthly values of tropospheric heating over the North Atlantic weather ships are presented in diagrammatic form in Figure 3. The approximations involved in their derivation preclude any inferences from the details of the curves. The most obvious results are however:

(i) Net heating occurs only over the northern and western parts of the North Atlantic, and only in the winter half-year.

(ii) Heating and cooling are of the same order of magnitude everywhere, $\sim 1 \times 10^{-3}$ cal cm^{-2} sec^{-1}.

(iii) when plotted on a chart, a feature of every month is that the isopleths tend to be oriented in a south-west to north-east direction with the areas of greatest heating (or lowest cooling) being in the north and west. This is in general agreement with Clapp's[1] synthesis of the heat-balance results of other workers but there are two important differences. These differences are shown in Figure 4 which is a reproduction (using the units of this study) of the North Atlantic portion of Clapp's chart of normal winter heating derived via the heat-balance method.

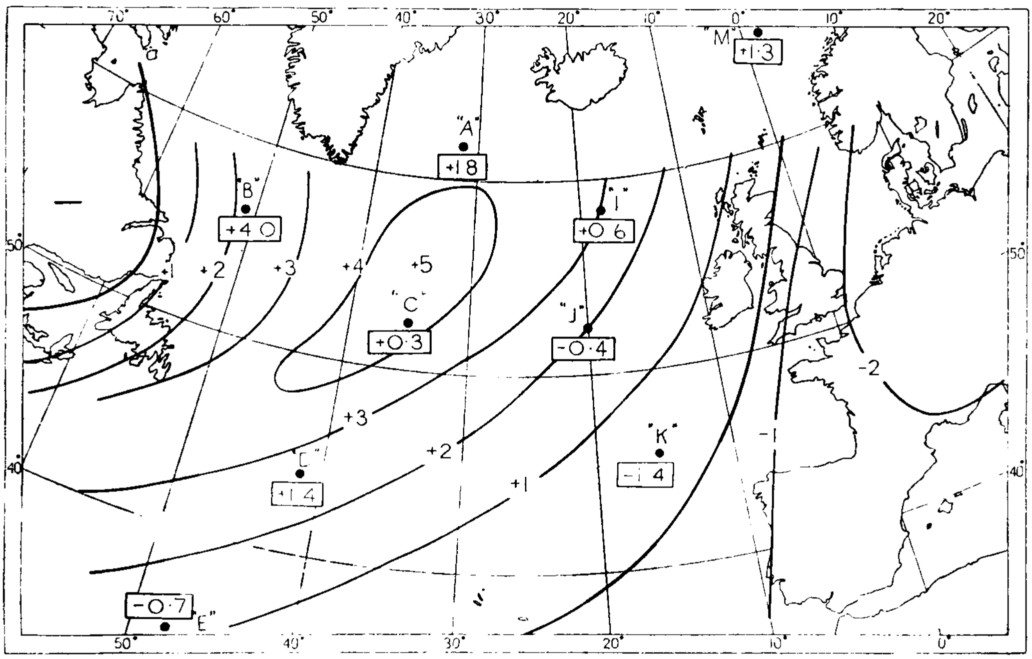

FIGURE 4—CLAPP'S SYNTHESIS OF HEAT-BALANCE METHOD CHARTS FOR NORMAL WINTER HEATING

Units: 10^{-3} cal cm^{-2} sec^{-1}. Values in boxes are those obtained in this investigation.

The mean of the December, January and February values calculated here have been superimposed upon this chart; they show much less heating over the central Ocean, and a shift of the maximum heating to the vicinity of station "B". Both these results reflect the findings of the precipitation analysis[4] which showed less rainfall than previously supposed and a maximum over "B". However, the general conformity between the results reported here, and those described by Clapp for winter give some measure of confidence to the annual variations illustrated in Figure 3.

(iv) A further result suggested by this analysis concerns the relative importance of the three terms in the year-to-year variation of $\overline{dq/dt}$.

Values of the coefficient of variation $\left(\frac{\text{standard deviation}}{\text{mean}} \times 100\right)$ of monthly rainfall have recently been produced for about 100 British Isles rainfall stations by the Meteorological Office Climatological Services Branch These figures show that the coefficient is roughly 50 per cent for both highland and lowland stations, and does not depend on rainfall amount. This suggests that the figure of 50 per cent may also apply over the North Atlantic. Applying this value to the figures for latent heat released by condensation given in Figure 1, we obtain values of the standard deviation of monthly latent heat liberated at ocean weather stations "I" and "J" of between 0.5×10^{-3} and 1.2×10^{-3} cal cm^{-2} sec^{-1}, the lowest values being in the spring. Compared with the standard deviation of upward flux of heat from the surface which can be inferred from the scatter of Shellard's points on Figure 1, the latent heat variations are slightly larger in winter and spring but much larger in summer and autumn. Möller's work on the net radiative cooling suggests that the year-to-year variation of this quantity is very small. We are left with the conclusion that year-to-year variations in the value of $\overline{dq/dt}$ are likely to be associated primarily with variations in rainfall—the variations in the other terms being generally smaller, and much smaller in summer and autumn.

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SURFACE WINDS OVER IRELAND ON SATURDAY, 16 SEPTEMBER 1961

By K. WOODLEY

Introduction.—During Saturday, 16 September 1961 a small and vigorous depression passed north-north-east close to the western seaboard of Ireland, bringing severe gales. Historically the depression could be traced back to the hurricane "Debbie", and at the time it was incorrectly so called in some press reports and elsewhere. Figure 1 gives the surface synoptic situation at 1200 GMT, 16 September 1961. The isobars are drawn at four-millibar intervals. The positions of the centre of the depression at six-hourly intervals between 0001 GMT, 16 September and 0001 GMT, 17 September are also shown.

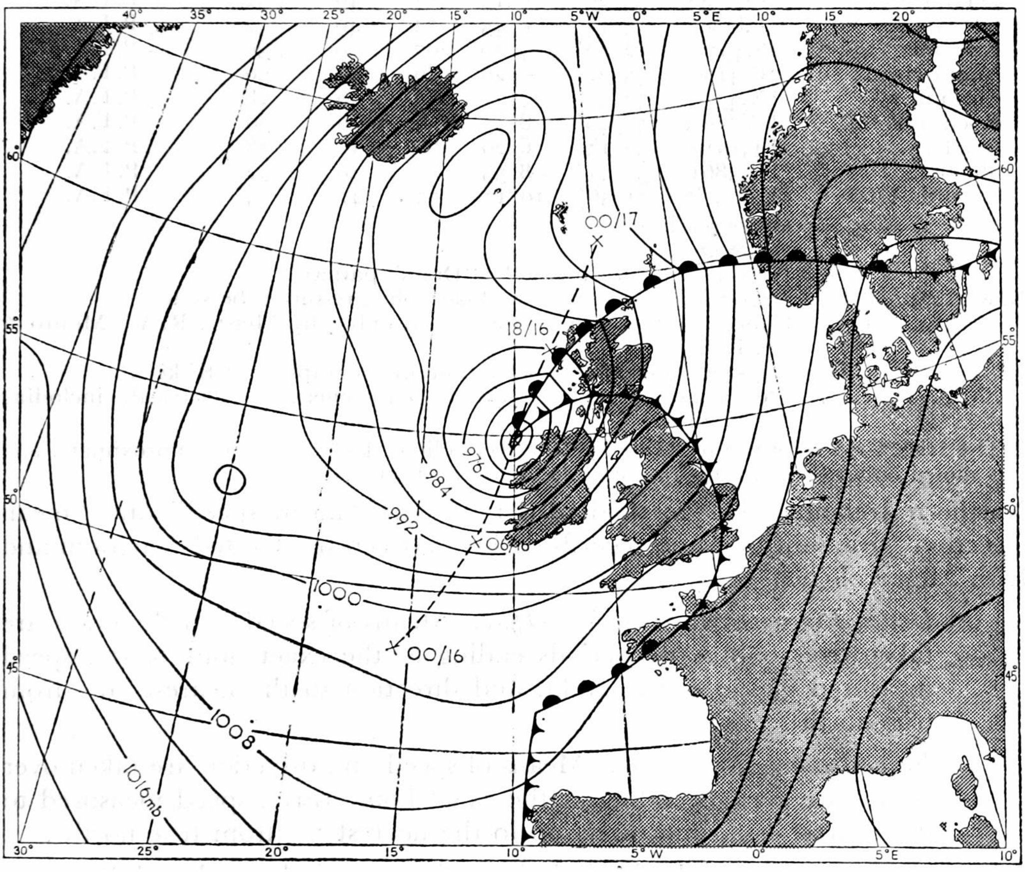


FIGURE 1—SURFACE SYNOPTIC SITUATION FOR 1200 GMT, 16 SEPTEMBER 1961

Wind data recorded.—Details of wind direction and speed were recorded on anemographs at 18 locations in Ireland and, in addition, observations at each hour of wind speed and direction from a cup-generator anemometer were available for most of the day from an auxiliary station. Details of the anemographs and their respective sites are given in Table I.

Hourly wind data.—Table II gives the hour-by-hour direction and speed of the wind during the day at stations in and adjacent to the six counties of

TABLE I—ANEMOGRAPH SITE DETAILS

Station	Irish Grid*	Lat.	Long.	Site a.s.l.	Height Head a.g.	Effective height	Type of instrument
		north	west	ft	ft	ft	
Northern Ireland							
Aldergrove	IJ.145801	54°39′	6°13′	216	65	55	P.T.A.
Ballykelly	IC.624235	55°04′	7°01′	2	50	35	P.T.A.
Belfast Harbour	IJ.362769	54°37′	5°53′	10	47	—	N. & Z. An. (P.T.)
Coolkeeragh	IC.483223	55°02′	7°15′	0	42	—	Munro C.G.
Nutts Corner	IJ.196776	54°38′	6°09′	314	31	31	MO.elect.(C.G.)
Kilkeel	IJ.315140	54°04′	5°57′	60	40	—	C.G. (not an anemograph)
Republic of Ireland							
Belmullet	IF.6932	54°14′	10°00′	29	40	30	P.T.A.
Birr	IN.0706	53°06′	7°54′	232	40	30	P.T.A.
Claremorris	IM.3574	53°42′	8°59′	225	40	28	P.T.A.
Clones	IH.5026	54°11′	7°14′	289	40	28	P.T.A.
Dublin Airport	IO.2744	53°26′	6°15′	213	40	32	P.T.A.
Glenamoy	IF.8833	54°14′	9°43′	73	40	32	P.T.A.
Kilkenny	IS.4957	52°40′	7°16′	207	40	30	P.T.A.
Malin Head	IC.4158	55°22′	7°20′	80	40	30	P.T.A.
Mullingar	IN.4353	53°31′	7°21′	357	40	28	P.T.A.
Roche's Point	IW.8361	51°48′	8°15′	133	40	30	P.T.A.
Rosslare	IT.1312	52°15′	6°20′	78	40	28	P.T.A.
Shannon Airport	IR.3861	52°41′	8°55′	25	40	32	P.T.A.
Valentia Obsy.	IV.4378	51°56′	10°15′	55	41	33	P.T.A.

a.s.l. = above sea level
a.g. = above ground
P.T.A. = Pressure-tube anemograph ("Dines" pattern)
N. & Z. An. (P.T.) = Negretti & Zambra anemobiagraph (pressure-tube system)
Munro C.G. = Cup-generator anemograph (speed only), by Messrs. R. W. Munro & Co. Ltd.
C.G. = Cup-generator anemometer (not anemograph)—at Kilkeel.
MO.elect.C.G. = Meteorological Office pattern, cup-generator, electrical, including direction.

* The Irish Grid reference of stations in the Republic of Ireland is very approximate, and is shown only to the two figures "easting" and "northing".

Northern Ireland. The method of determining "mean speed" and "mean direction" from anemograph records differs between the United Kingdom and Irish Meteorological Services:

(*a*) *United Kingdom Meteorological Office.* Means of speed and direction are taken over 60-minute periods ending at the exact hour (GMT), speed measured to the nearest 1 kt, and direction to the nearest 10° (from true north);

(*b*) *Irish Meteorological Service.* Means of speed and direction are taken over 10-minute periods ending at the exact hour (GMT), speed measured to the nearest 1 kt, and direction to the nearest 5° (from true north).

In addition to the standard tabulations of mean wind speed and direction, Table II also shows:

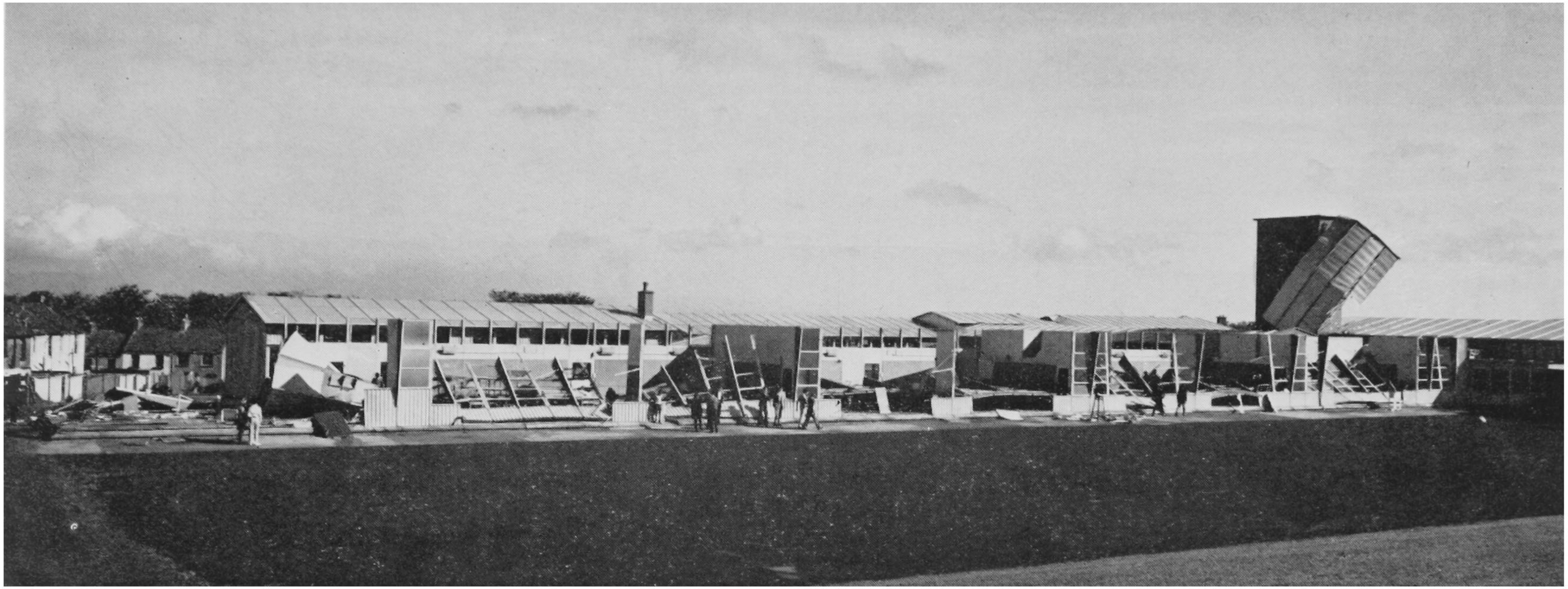
(*a*) the maximum gust (to the nearest 1 kt) in each of the 60-minute periods ending at the exact hour,

(*b*) the highest mean wind speed recorded over *any* 10 *minutes* during the day,

(*c*) the highest mean wind speed over *any* 60 *minutes* during the day.

The maximum gust can be obtained from the hour-by-hour entries.

General assessment.—In an attempt to present an overall picture for Ireland, isotachs of maximum gust and of maximum mean wind speed over any



By courtesy of City Surveyor, Londonderry

PLATE I—DAMAGE TO A LONDONDERRY SCHOOL ON 16 SEPTEMBER 1961

(see p. 191)

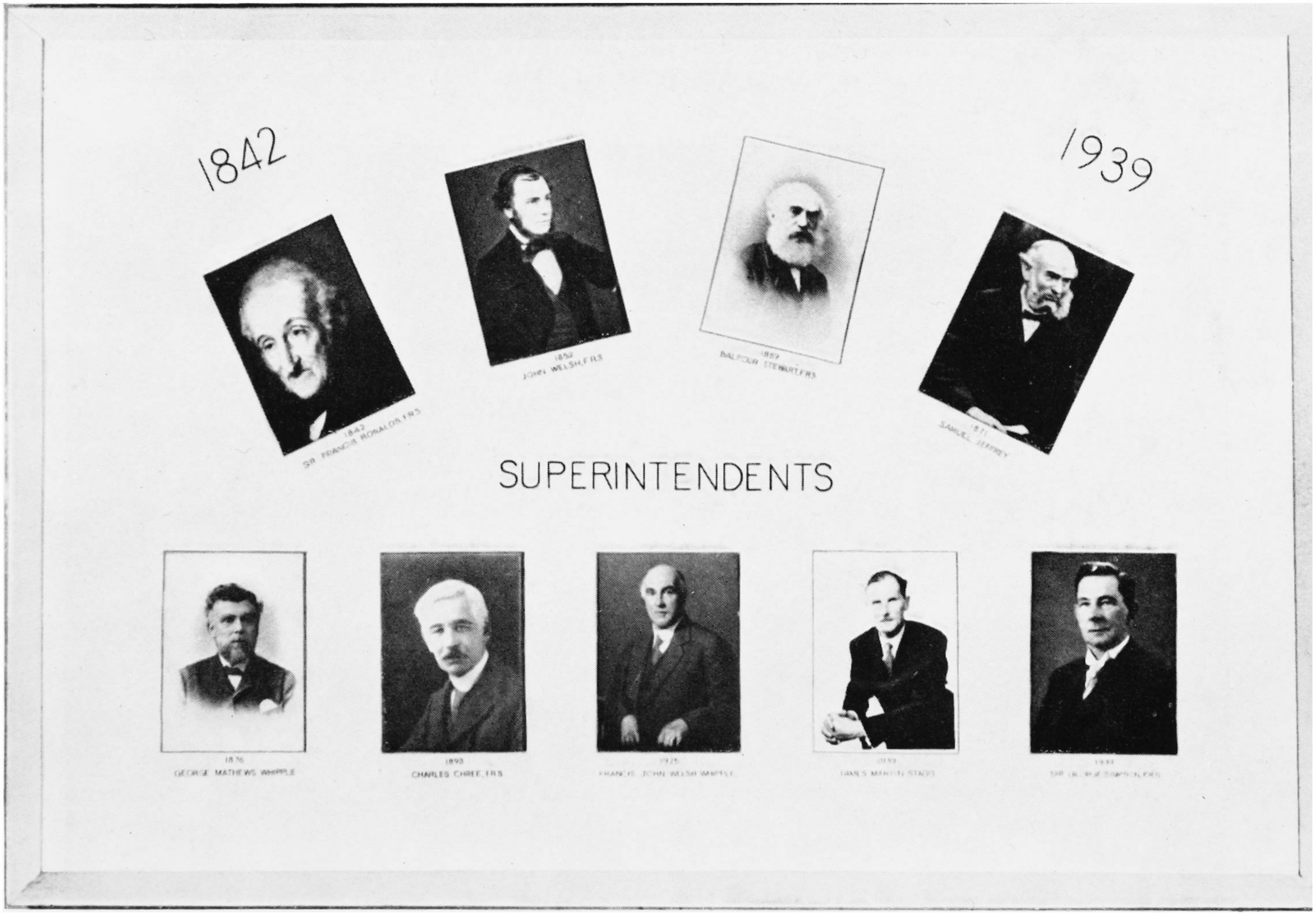
Photograph by W. H. Jack

PLATE II—WIND DAMAGE TO SITKA SPRUCE (30 YEARS OLD) IN BARONSCOURT FOREST, CO. TYRONE, AFTER GALE OF 16 SEPTEMBER 1961

(see p. 191)

Photograph by W. H. Jack

PLATE III—CLOSE-UP OF DAMAGE TO SITKA SPRUCE (34 YEARS OLD) IN BARONSCOURT FOREST, CO. TYRONE, AFTER GALE OF 16 SEPTEMBER 1961
(see p. 191)



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KEW OBSERVATORY SUPERINTENDENTS, 1842–1939

Top: 1842, Sir Francis Ronalds, F.R.S.; 1852, John Welsh, F.R.S.; 1859, Balfour Stewart, F.R.S.; 1871 Samuel Jeffery.

Bottom: 1876, George Mathews Whipple; 1893, Charles Chree, F.R.S.; 1925, Francis John Welsh Whipple; 1939, James Martin Stagg; 1939, Sir George Simpson, F.R.S.
(see p. 200)

TABLE II—HOURLY WIND DATA, 16 SEPTEMBER 1961

	Aldergrove			Ballykelly			Belfast Harbour			Coolkeeragh		Nutts Corner			Kilkeel			Clones			Malin Head		
	$\bar{d}_{60}$	$\overline{\ }_{60}$	V_G	$\bar{d}_{60}$	$\bar{v}_{60}$	V_G	$\bar{d}_{60}$	$\bar{v}_{60}$	V_G	$\bar{v}_{60}$	V_G	$\bar{d}_{60}$	$\bar{v}_{60}$	V_G	d	v	V_G	$\bar{d}_{10}$	$\bar{v}_{10}$	V_G	$\bar{d}_{10}$	$\bar{v}_{10}$	V_G
0100	110°	10	18	040°	1	5	—	0	0	—	—	150°	13	18	160°	22	—	080°	6	14	130°	7	13
0200	140°	15	25	030°	5	9	190°	3	18	7	13	160°	15	24	180°	25	—	160°	16	24	090°	9	14
0300	150°	19	30	020°	2	9	180°	14	27	10	16	170°	17	29	—	—	—	150°	18	33	065°	16	22
0400	150°	20	32	—	0	2	180°	16	30	10	17	170°	17	28	—	—	—	140°	14	27	075°	16	26
0500	150°	19	35	140°	7	21	180°	14	26	6	11	170°	17	29	—	—	—	135°	18	28	090°	14	25
0600	140°	19	31	130°	12	25	180°	18	36	5	10	160°	18	27	—	—	—	115°	12	33	110°	18	26
0700	130°	19	37	140°	18	42	160°	12	23	9	16	150°	21	37	160°	26	—	125°	14	22	130°	20	26
0800	140°	25	42	130°	18	29	150°	17	27	10	22	160°	23	39	160°	24	—	130°	16	27	130°	25	41
0900	140°	25	39	140°	22	40	170°	22	35	13	27	160°	23	35	160°	30	—	150°	25	41	130°	20	33
1000	150°	33	52	140°	26	45	170°	26	43	14	29	170°	32	49	180°	32	—	160°	34	50	140°	22	—
1100	160°	37	60	160°	29	53	180°	28	46	27	60	180°	32	47	180°	38	—	180°	37	77	165°	30	49
1200	170°	42	63	170°	35	75	190°	30	53	30	65	190°	35	61	200°	40	62	190°	42	79	180°	57	89
1300	170°	44	69	180°	44	89	200°	33	53	30	69	200°	39	66	200°	44	65	195°	47	87	185°	60	92
1400	180°	49	75	190°	51	82	200°	37	61	37	83	200°	39	69	200°	48	65	200°	39	84	200°	63	96
1500	190°	49	73	190°	50	86	220°	40	63	40	91	210°	38	63	200°	50	70	205°	39	77	200°	62	96
1600	190°	49	76	200°	46	92	220°	39	57	43	83	210°	37	61	200°	55	75	215°	38	72	205°	61	98
1700	200°	43	67	210°	43	75	220°	37	52	42	81	(220°	33)	60	230°	50	70	220°	34	63	220°	52	94
1800	200°	39	61	220°	40	68	220°	32	57	37	70	230°	26	43	230°	45	—	220°	28	57	230°	51	79
1900	210°	34	55	220°	31	56	230°	30	43	31	56	230°	24	48	230°	40	—	220°	25	47	245°	34	73
2000	200°	28	47	220°	26	49	240°	26	38	27	42	230°	20	40	230°	28	—	205°	18	38	240°	35	53
2100	200°	22	42	210°	19	34	230°	20	34	—	—	220°	17	30	250°	25	—	205°	19	32	230°	29	50
2200	200°	23	36	210°	21	36	230°	16	28	—	—	220°	14	25	230°	22	—	210°	15	31	225°	25	43
2300	190°	20	32	210°	18	37	220°	14	23	21	36	220°	14	24	200°	24	—	200°	14	24	230°	21	36
2400	190°	17	29	210°	19	31	220°	12	23	20	35	210°	12	19	—	—	—	200°	17	27	225°	22	37
VV_{60}		49			51			42		45			40			—			47			64	
VV_{10}		51			52			47		49			44			—			50			66	

$\bar{d}_{60}$ mean direction over 60 minutes (degrees from true north)
$\bar{d}_{10}$ mean direction over 10 minutes (degrees from true north)
d direction observed over a few minutes (degrees from true north)
v speed observed over a few minutes (knots)
V_G maximum gust in 60-minute period (knots)

$\bar{v}_{60}$ mean speed over 60 minutes (knots)
$\bar{v}_{10}$ mean speed over 10 minutes (knots)
VV_{60} maximum mean speed over any 60 minutes (knots)
VV_{10} maximum mean speed over any 10 minutes (knots)

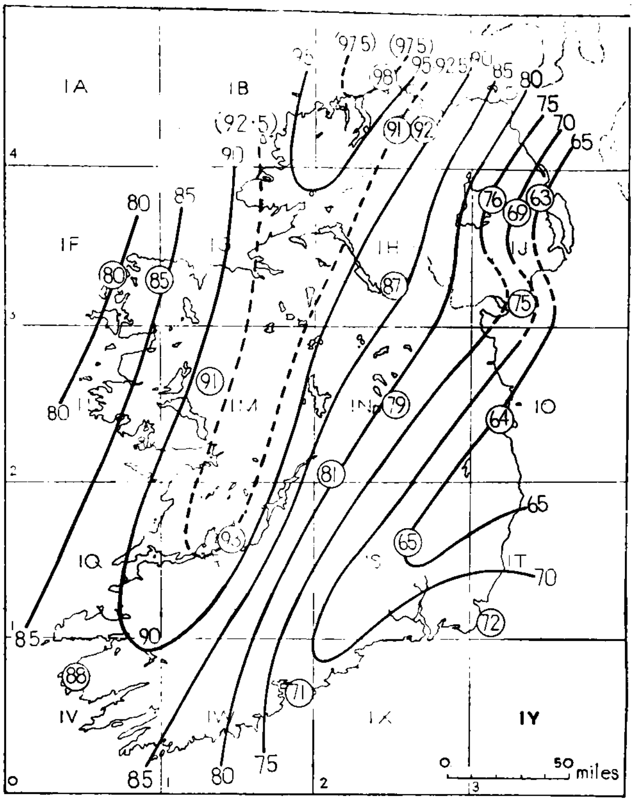

FIGURE 2—ACTUAL MAXIMUM GUST (IN KNOTS) RECORDED BY ANEMOGRAPHS, 16 SEPTEMBER 1961

The value for Kilkeel [75] was from eye observations of a cup generator anemometer indicating wind speed on a dial: no chart record is available.

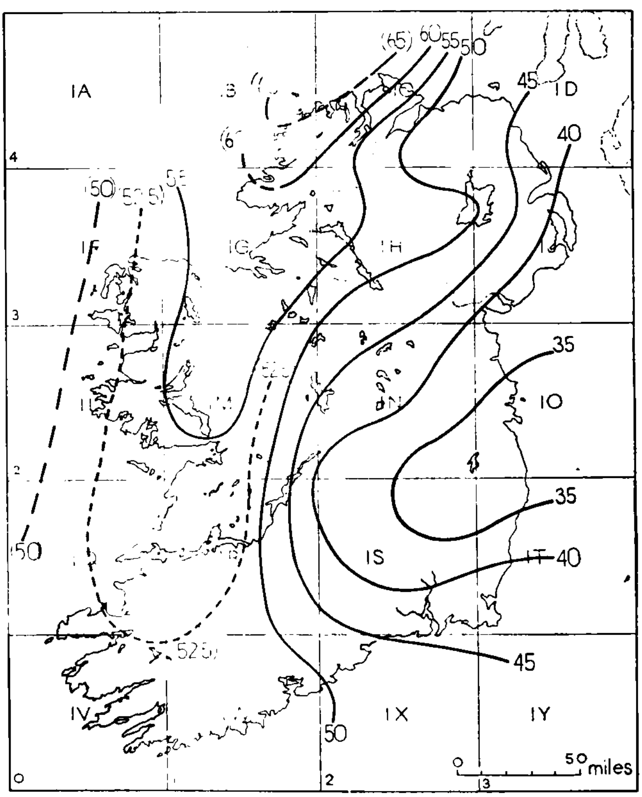

FIGURE 3—MAXIMUM MEAN WIND SPEED OVER ANY 60-MINUTE PERIOD, 16 SEPTEMBER 1961

60 minutes have been drawn: Figure 2 shows the isotachs of the maximum gust as recorded by the anemographs at each of the 19 stations—the speed of the gust (in knots) being plotted within a circle representing the station, and Figure 3 shows the isotachs of maximum mean wind speed over a period of any 60 minutes.

It will be seen that the highest wind speeds were recorded in a band, running south-south-west to north-north-east between Valentia and Malin Head, with the strongest winds at the northern end. (Lighter winds, as indicated by the data from Belmullet and Glenmoy on the coast of Co. Mayo, were experienced very near to the centre of the depression). The isotachs are dotted over southern Co. Down because the eye observations of the dials at Kilkeel cannot be treated in the same manner as data recorded on charts.

On the reliability of Figure 2 it is considered that the amount of basic data shown and their mutual consistency are such that Figure 2 can be taken to give a reasonable approximation to the true picture. Its interpretation for any given locality is subject to the remarks given below.

In the conditions prevailing at the time, the possibility of the maximum gust being close to the maximum gradient wind was considered to be worthy of examination. The isobaric charts at three-hourly intervals, drawn using some pressure data not available at the time due to communications breakdown, were examined at nine suitably chosen points over Ireland and the maximum geostrophic wind noted. The probable maximum gradient wind speed was computed and plotted for the nine points, and from these values isotachs were drawn (Figure 4). It will be seen that over much of Ireland the

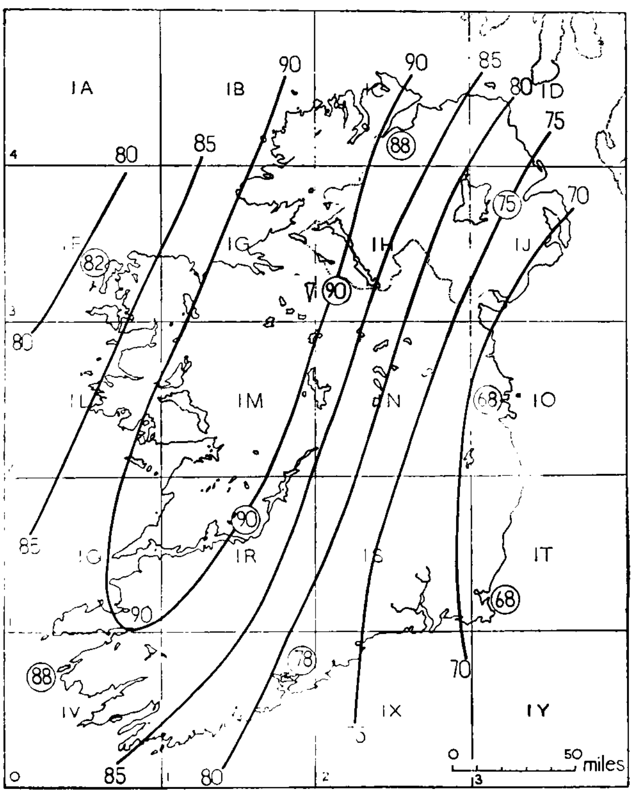

FIGURE 4—COMPUTED MAXIMUM GRADIENT WIND SPEED (IN KNOTS), 16 SEPTEMBER 1961

relationship between Figure 4 and Figure 2 is very close. This comparison between Figures 2 and 4 is interesting and suggests that estimates of the maximum gust likely to be experienced in such conditions at sites not subject to the limitations below could possibly be made from synoptic charts, if anemograph data are not available.

Limitations.—In utilizing the data in this paper, particularly if interpolation from the maps (Figures 2 or 3) is carried out, it should be appreciated that local topography could appreciably affect maximum wind speeds. None of the anemographs are at a very high altitude above sea level, so that the isotachs must be considered as being applicable only to relatively low-level areas. In addition, hills, particularly marked ranges of hills at right angles to the wind direction, would reduce wind speed for a distance on their leeward side. Conversely, valleys running parallel with the wind direction could be subject to "funnelling" effects, producing increased speeds. In built-up areas the general turbulence and eddies around buildings would affect the flow of wind, and the values given in this report cannot be considered as being representative. Generally speaking, however, mean wind speeds in built-up areas would have been appreciably lower than those indicated in Figure 3 whilst maximum gust speeds may not have fallen far short of those indicated in Figure 2 (i.e. the gustiness factor in built-up areas would be greater). It should be noted that the anemographs whose data were used for this paper were exposed to the wind under as near standard conditions as practicable (see site details, Table I).

In drawing Figure 3, the values as recorded at Coolkeeragh and Nutts Corner have largely been ignored because they are too low to fit the general pattern. This apparent anomaly is being investigated further.

Damage.—Press reports, etc., of the damage done by the winds on this occasion were numerous. The disruption of electricity and telephone services and the blocking of roads by fallen trees was widespread. The seas around Ireland were extremely rough and shipping was confined to harbour along the north and west coasts. The Spanish trawler *Andreas* ran aground in Bantry Bay and the coaster *Ulster Sportsman* in the Foyle Estuary. Serious domestic damage was reported in towns in the centre and west of Northern Ireland.

In Londonderry, in the north, a relatively new school was severely damaged, blocks being blown down (see Plate I, facing p. 192). In the Lagan Valley, near Moira, a new building was demolished. Cereal crops, which had only in part been harvested, were severely damaged, and it was reported that some 10,000 acres lost about two-thirds of the grain, another 10,000 acres lost about half, and about 20,000 acres lost about one-third. This was estimated to represent about £1,000,000 loss on the cereal crop.

Damage to forests was widespread in the areas of greatest wind speed. A survey carried out by the Department of Geography, Queen's University of Belfast[1], of all forests in Ireland, revealed the extent of the damage. Figure 5 shows the extent of wind damage in forestry plantations on this date. A certain amount of care needs to be taken in interpreting this map as, for example, the extent of the damage at any particular forest must be dependent upon the state of growth. For example, extremely young trees escaped serious damage. In this diagram the crosses represent slight or no damage and include forests comprising young plantations. The size of the other black dots is related to the percentage area of the total forest which was damaged and these figures must also be considered as giving only a general indication, for the total forest area may include young, unaffected trees. The worst hit forest was at Baronscourt (near Newtownstewart, Co. Tyrone) where almost one-quarter of the trees

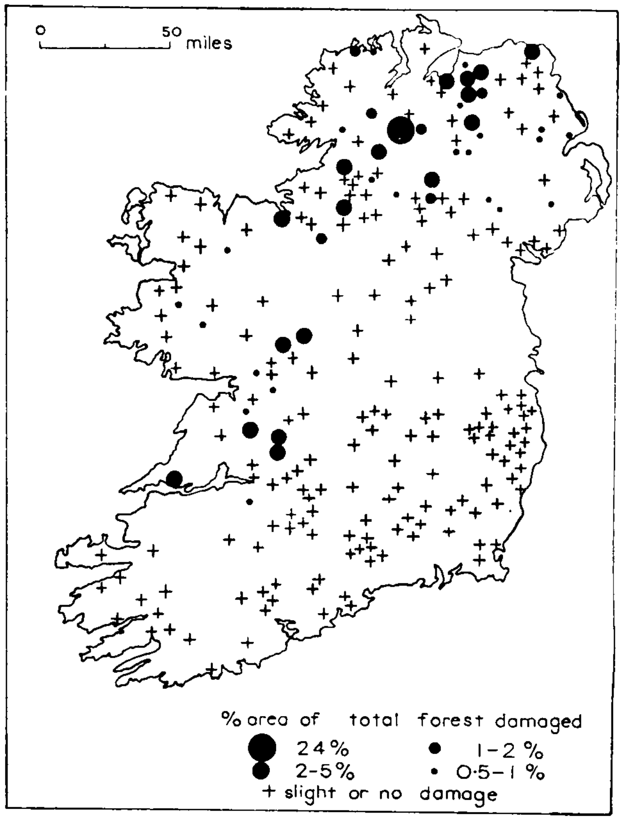

FIGURE 5—WIND DAMAGE IN FORESTRY PLANTATIONS, 16 SEPTEMBER 1961

were either uprooted or were broken off some feet above ground level (see Plates II and III between pp. 192–193). Generally speaking, trees of heights between 20 and 50 feet were damaged, conifers in the 30–40-foot height range being particularly hard hit.

Acknowledgements.—I would like to acknowledge the assistance given by:

(*a*) The Director of the Meteorological Service of the Republic of Ireland, in making available specially tabulated data and copies of certain anemograms which have been used in this paper,

(*b*) Messrs. Carbide Industries Ltd., for the use of their Coolkeeragh record,

(*c*) The General Manager, Belfast Harbour Commission, for the use of the Belfast Harbour anemograph record, and

(*d*) Mr. N. Stephens of Queen's University, for permission to reproduce Figure 5.

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THIRD SESSION OF THE WORLD METEOROLOGICAL ORGANIZATION COMMISSION FOR INSTRUMENTS AND METHODS OF OBSERVATION

By C. H. HINKEL, B.Sc.

At the invitation of the Government of India, the Commission for Instruments and Methods of Observation (CIMO) of the World Meteorological Organization (WMO) held its third session in the Vigyan Bhawan, New Delhi, from 29 January to 16 February 1962. The session was attended by delegates from 31 countries, and a number of international organizations also sent observers.

The opening ceremony was preceded by the presentation of the International Meteorological Organization Prize to Dr. K. S. Ramanathan (India) for his outstanding work in the field of solar radiation. This prize, which was presented by the Secretary-General of WMO, Mr. D. A. Davies, is awarded every two years for the most noteworthy contribution to international meteorology.

In his address Mr. Davies welcomed the delegations of new member states and said that it was most encouraging to see that the new countries were willing to play their full part as members of the WMO.

The session was opened by Mr. Ahmed Mohiuddin, Deputy Minister for Civil Aviation in the Ministry of Transport and Communication, Government of India, who spoke of the role played by the Commission in the field of meteorological instrumentation. He hoped that the third session would provide further stimulation to developmental work in this field.

In his presidential address M. A. Perlat (France) outlined the main objectives of the Commission and drew attention to the large agenda to be covered by the session. He also referred to the large gaps in the present network of observing stations some of which he hoped would be filled by automatic weather stations and he further hoped that in the future these deficiences might be remedied by the use of artificial satellite observations. M. Perlat concluded by thanking the Government of India for making it possible for the Commission to hold its third session at New Delhi.

With these formalities completed the Commission settled down to work by setting up the necessary Committees. Two working Committees were established which met every day to discuss the various agenda items and reported their findings back to the plenary sessions of which six were held. One Committee under the Chairmanship of Mr. V. D. Rockney (U.S.A.) dealt mainly with technical matters and the other under Mr. A. L. Maidens (U.K.) considered items of an organizational and administrative nature. Both chairmen kept their respective Committees hard at work and to such good effect that, in spite of the large agenda, the final plenary session was able to be held a day ahead of schedule. In addition there was the usual co-ordination Committee, a nominations Committee for the election of new officers, and a Committee for the nomination of members of working groups.

A detailed description of the full agenda discussed during the session and the outcome of these discussions would require too much space and only a few of the more important items will be mentioned. More complete information will be available in the "Abridged Final Report of the Third Session of the Commission for Instruments and Methods of Observation", to be published by WMO.

The item which occupied most time was the "WMO Guide to International Meteorological Instrument and Observing Practice". This is one of a series of handbooks issued by WMO to provide advice and guidance to Members, especially those with newly-formed services in developing countries. The form and presentation of the subject matter of the various chapters was considered and it was agreed that a standard format to which all chapters would conform should be developed. Draft material for the complete revision of the chapters on radiation and meteorological instruments and observations on aerodromes, submitted by the respective working groups, was approved. Material for a third chapter on hydrometeorological instruments was, after considerable discussion, referred back with amendments to the Commission for Hydrometeorology for their consideration. A number of alterations and revisions were approved and Members were recommended to submit proposed changes and suggestions direct to the Secretary-General who could act as co-ordinator and take the necessary action without delay.

Examination of the WMO Technical Regulations was also carried out and a number of recommendations made, among them a proposal by the United Kingdom delegation that the regulations relating to pressure measurements on land were too restrictive and by allowing only the use of a mercury barometer for this purpose stifled development. An amendment to the appropriate regulation to include the use of other types of instrument of equal accuracy (such as an aneroid barometer) but retaining the mercury barometer as the comparison standard, was included in the recommendations on this item.

Upper air measurements formed another large agenda item and the comparison of radiosondes gave rise to lengthy discussion. The Commission finally decided that Members should be encouraged to develop a reference sonde to assist in this work, and that they should also continue to carry out comparison bilaterally and multilaterally although a number of delegates felt that in view of the failure of the previous trials no useful purpose would be served by holding more. To stimulate research in this field the Executive Committee should be asked when awarding the IMO Prize to take account of major developments in meteorological instruments. The current world-wide shortage of adequate frequency bands for users of all types of radio equipment means that the meteorologist finds himself being gradually squeezed out of his existing frequency allocations. The Commission recommended that any reduction in facilities should be strongly resisted and that vigorous efforts to maintain the present *status quo*, at least, should be pressed at both national and international levels.

Satellite and rocket meteorology provided some discussion and Members were encouraged to collaborate in satellite projects and urged to put forward suggestions for the type of observations required as well as the instruments to be used. It was the general opinion, however, that developments in these fields were taking place so rapidly that it was too early for any attempt at standardization or to set up any working groups.

The future of the Commission itself was also debated. Previous sessions had been divided concerning its usefulness but the Executive Committee of WMO had ruled that CIMO must be maintained with limited terms of reference. After much discussion it was considered that CIMO should be responsible for those aspects of instruments and methods of observation which are the concern of more than one technical commission. Responsibility for a particular requirement by a single commission should rest with that commission which could, however, request CIMO's assistance. CIMO should also study developments in instrumental fields for possible meteorological application and promote interchange of information between members. A recommendation was drawn up on these lines.

At the end of the session the election of new officers took place. Dr. L. S. Mathur (India) was elected president to succeed M. Perlat who has held that office for the last eight years, and Mr. A. Hauer (Netherlands) was elected vice-president.

Three periods during the session were set aside for scientific discussions. Fourteen papers were read covering a wide variety of instrumental problems, such as evaporation, the uses of radar, automatic weather stations, upper air measurements, to name only a few. Social activities included a reception and a dinner given by Ministers of the Government of India, and a visit to the Indian Meteorological Department's Headquarters where the delegates were able to see the Department's fine workshops and equipment. In addition two most enjoyable and interesting tours were organized by the Indian Meteorological Department; one of them to places of historic interest in and around Delhi, while the other was a visit to Agra, over 120 miles away, where the delegates were able to see the famous Taj Mahal.

The success of the meeting was due not only to the fine co-operation of all the delegates, but also to the excellent work of the WMO Secretariat represented by Messrs. O. M. Ashford and K. T. McLeod. The Executive Secretary Mr. P. K. Das and all his staff also deserve mention for the way in which they kept the documentation right up to date. The interpretation throughout the session was extremely good. The Indian Government are to be congratulated upon the excellence of all the facilities provided. Thanks on behalf of all the delegates must be offered to them and to Mr. Krishna Rao and his staff in the Indian Meteorological Department for their helpfulness and generosity as hosts during the stay in New Delhi.

NOTES AND NEWS

Kew Observatory—a new feature

In July 1954, Mr. G. A. Whipple unveiled in the Superintendent's room at Kew Observatory, the main tablet, presented by his father, the late Mr. R. S. Whipple, giving the list of King's Observers and Superintendents from the time the Observatory was founded by George III in 1769 up to 1939, as well as the second tablet in memory of Robert Beckley. An account of the ceremony is given in the *Meteorological Magazine*[1].

Recently a collection of photographs has been assembled and placed opposite the stone tablets. There exists at Kew Observatory a small framed silhouette of the first King's Observer, Dr. Stephen Charles Triboudet Demainbray, which was presented by his great grandson Major-General G. Rigaud in 1881, as is recorded on the back in the latter's writing. No pictorial record has, however, so far as is known, survived of his son, Stephen George Francis Triboudet Demainbray who was King's Observer at Kew for 58 years, but as he did not die until 1854, at the age of 95, it is possible that a photograph may exist.

At the time of the present search photographs of six of the nine Superintendents, listed on the tablet, were available; the missing three were those of Sir Francis Ronalds, Samuel Jeffery and Dr. J. M. Stagg. The book "Catalogue of books and papers relating to electricity, magnetism, the electric telegraph etc., including the Ronalds Library" edited by A. J. Frost, 1880, stated that Sir Francis Ronalds had left his library to the Society of Telegraph Engineers and a telephone call to the Librarian to the successor to this Society—the Institute of Electrical Engineers—revealed that not only was an oil painting of Sir Francis Ronalds available, but a photograph had been taken of this by the Post Office in 1938; the Post Office readily supplied a copy of this photograph.

A search amongst old documents in the basement at Kew was rewarding in that a staff photograph marked "about 1870" showed an obvious grouping about a central figure; next to him was the unmistakable figure of a young G. M. Whipple who was then chief assistant and was later (in 1876) to become Superintendent. This central figure has been taken to be Samuel Jeffery and the photographic reproduction branch of the Air Ministry skilfully produced a suitable photograph eliminating the heavy watch chains on the waistcoats at the back of the group. Dr. Stagg could trace no photograph of himself taken in the relevant period, but kindly provided a copy of that taken in 1961 at the end of his term as President of the Royal Meteorological Society.

The group of photographs as thus assembled is shown in the photograph facing p. 193. Six of the nine photographs show Superintendents as they were during their term of office, the other three (Sir Francis Ronalds, Balfour Stewart and James Martin Stagg) show them later in life.

The silhouette of Dr. Demainbray and a small photograph of Robert Beckley are also kept in the Superintendent's room at Kew Observatory. There is also an interesting photograph of John Welsh showing him ready for a balloon ascent in July 1852; this photograph was taken from a group which included J. Gassiot and Sir Edward Sabine[2].

L. J.

REFERENCES

1. London, Meteorological Office; Memorial tablets at Kew Observatory. *Met. Mag., London,* **83,** 1954, p. 321.

2. SHAW, SIR NAPIER; An episode in the history of Kew Observatory. *Met. Mag., London,* **61,** 1926, p.125.

British Council course on meteorology, 1–13 April 1962

As part of its effort to encourage an appreciation of Britain abroad, the British Council organizes each year a number of courses on scientific subjects for overseas workers in the subjects, the object being to present a survey of recent developments and current practice with particular reference to British contributions and methods. It was as the result of a suggestion by Sir Cyril Hinshelwood, while he was President of the Royal Society, that the Council decided to include a course in meteorology in its 1962 programme. It will be recalled that Sir Cyril laid the foundation stone of the new Meteorological Office Headquarters building in Bracknell on 28 October 1959. The Director-General of the Meteorological Office was approached by the Council for help and advice as a result of which a suitable programme was prepared.

The course was designed for meteorologists of some standing; in the words of the advertising brochure produced by the British Council it was intended "primarily for senior members of the staff of meteorological services, but applications from senior research workers in a university or equivalent academic institution will also be considered." The total number of members was kept small to form a group in which communication would be easy and discussion free. In the event, the course attracted meteorologists from Austria, Finland, Germany, Greece, Hong Kong, Hungary, Iceland, Sweden, Switzerland and the United States of America, all of whom had long experience and proved ability in their profession. The standard of discussion aroused by the lectures was always high. It is perhaps surprising that such a large proportion of the course members came from European countries where meteorological services are already well established rather than from the developing countries but possibly the length of the course (two weeks) was too short to justify travel from distant places.

The course aimed to present a coherent picture of the present state of meteorology in this country. It was hoped that the programme achieved a balance between 'research' and 'services' topics which would assure the continuous interest of course members, bearing in mind their different backgrounds. It was inevitable that the bulk of the lectures and visits would concern the activities of the Meteorological Office. Indeed, most of the course was held within the Headquarters Building at Bracknell. However, the participation of members of the staff of Imperial College and of Rothamsted Experimental Station was most important in achieving a full account of meteorological work in this country, and contributed greatly to the ultimate success of the course.

The opening address was given by Sir Graham Sutton, the Director-General on Monday, 2 April. Sir Graham sketched the philosophy behind present developments within the Meteorological Office. He particularly emphasized three trends: first, the gradual replacement of the individual experience of forecasters by dynamical methods as the basis of weather forecasting in this country; second, the extension upwards into the high stratosphere of the region being examined synoptically by meteorologists; and third, the planned growth of the non-aviation services provided by the Meteorological Office. Evidence of these trends was to be apparent in much that was heard and seen by the course members in the succeeding two weeks.

A number of the lectures bore directly on the problems of weather forecasting. There were visits to the Central Forecast Office and to London Airport and lectures on the jet stream, the use of electronic computers to produce prognostic charts, objective forecasting by statistical techniques, mesometeorology and mountain waves. Related topics dealt with were the development of meteorological instruments and the handling of meteorological data. Non-aviation services were covered in another lecture and in a visit to the London Weather Centre. The problems of the general circulation and of long-range forecasting were explained in several notable lectures, and the work of the Meteorological Office in this field was seen in the Climatological Research Branch.

On the physical research side, the course learned about the meteorology of the stratosphere and in particular about the experiments of the High Atmosphere Research Branch. They were able to see this branch and some of the instruments now being made. The physics of clouds was dealt with in lectures and in visits to the Imperial College Experimental Station at Silwood Park, Ascot and to the Meteorological Research Flight at Farnborough. Kew was visited to see the work on radiation, while the final two days (when the course members stayed in Cambridge) were devoted respectively to turbulence topics and to agricultural meteorology. The Meteorological Office Experimental Station at Graveley was seen on 12 April and Rothamsted on the last day.

It appeared that all concerned considered the venture highly successful; the British Council reception at the White Hart Hotel, Windsor on Tuesday, 10 April for those who helped with or took part in the course was a happy occasion. Meteorologists have cause to be grateful to the British Council and in particular to Mr. G. L. Hitchcock, O.B.E., Director of Courses and Miss U. K. Bell, the Course Officer, for organizing a course which has fostered good international relations within their profession.

A. GILCHRIST

METEOROLOGICAL OFFICE DISCUSSION

Meteorological satellites

The last Monday Discussion of the season was held at the Royal Society of Arts on 19 March 1962. The meeting opened with the showing of a general instructional film entitled "The inconstant air". Mr. C. J. Boyden then gave an account of a recent visit to an International Meteorological Satellite Workshop which was held at Washington.

Mr. Boyden described the TIROS satellites, four of which have been launched since April 1960. All are in orbit 400–500 miles above the earth's surface and circle the earth in about 100 minutes but, as expected, the useful life of each has been only a few months because of deterioration of some part of the complex mechanism. A TIROS satellite operates on power provided by solar batteries. It takes cloud photographs on command from a ground station in a sequence of 32 pictures at 30-second intervals, and transmits them on request. Continuous recording of radiation measurements in several wavebands is also made and can be stored for one orbit. A limitation on the acquisition of data is imposed by the location of the read-out stations, and a drawback of TIROS is that it maintains an attitude which is more or less fixed in space, so for much of the time the cameras are not pointed towards the earth. Nevertheless over 70,000 photographs have been received so far and an enormous amount of radiation data has yet to be analysed.

The interpretation of cloud photographs is a complex process taking several hours, involving not only the recognition of cloud detail but the accurate location of the longitude–latitude grid. The results are transmitted both by facsimile and in code in the form of a nephanalysis, which depicts cloud boundaries and the broad types and amounts of cloud. Its usefulness to the forecaster is considerable in areas of the world where observations from the ground are sparse.

With satellite meteorology still in its infancy there is every promise of great advances both in the scope of observations and in the vehicle itself. Already the radiation readings provide estimates of cloud top temperature and thus an indication of its height. Three more TIROS satellites will be put into orbit and in the meantime the first NIMBUS will be launched. This will follow a polar orbit and face the earth at all times. Next will come AEROS, which at 22,300 miles from the earth will remain above a fixed point on the equator, its cameras continuously covering a hemisphere.

Most of the audience had not had the opportunity of using nephanalyses in forecasting, but the subsequent discussion showed the keen interest in the potentialities of satellites and an appreciation of the remarkable technical achievements already made.

REVIEWS

Mesures en Météorologie, by A. Perlat and M. Petit. 9½ in. × 6¼ in., pp. 393, *illus.*, Gauthier-Villars (Service Publicité) 55 quai des Grands-Augustins, Paris (VI^{e}), 1961. Price: 55 N.F.

M. Perlat, having been President of the World Meteorological Organization Commission for Instruments and Methods of Observation for about eight years, is well known internationally as an authority on the subject of this book. His co-author, M. Petit, also is well known for his published work on the techniques of upper air measurements. The aim of their book is the study of the general conditions and requirements for the measurement of the various meteorological quantities, the methods in use and the factors involved in reducing the basic data to the required form for synoptic and climatological use. The treatment is generally on the theoretical side and concentrates on general principles rather than on the practical details of instrumentation; the theory and the principles, however, are illustrated by descriptions of typical instruments in which they are employed. Not unnaturally, many of the instruments described are of French design.

The book opens with a chapter on the performance and errors of measuring instruments, including a clear account of the theory of response time. Roughly half of the book is concerned with methods used in surface observations of pressure, temperature, radiation, humidity, wind, visibility, cloud and precipitation. The other half of the book is devoted mainly to radiosonde and radar methods of upper air measurement and includes a chapter on captive balloon and kite techniques, but the special requirements for aircraft measurements are not considered. Sferics measurements are covered and the book concludes with a chapter on meteorological observing stations, both manned and automatic.

In one or two of the descriptions of equipment the information is too brief to be of much use to the reader. For example, a few lines are given to a French prototype "station parlante", an automatic station which can be called up by telephone at any time and will give in plain language the weather observations at the time of the call, but the book gives no information about the design. On the other hand, in discussing the layout of meteorological observing stations the authors go to the unusual length of recommending lawn-like plants, other than grass, which they consider suitable for the plots on which the instruments are exposed. They are very enthusiastic about Lotus corniculatus (Bird's-foot trefoil) and, for stations near the sea, Armeria maritima (thrift). It would be interesting to know if these recommendations are acceptable internationally.

Relatively few references to original sources of information are given in the book and the reviewer was a little surprised to find that in the section on dew-point hygrometry no mention is made of the Dobson–Brewer instrument or, in the description of differential barographs, of the Shaw–Dines microbarograph. The book concludes with a detailed list of contents but an alphabetical index would have been more useful. As a very clear and interesting exposition of the theory and general principles of meteorological measurements the book is strongly recommended.

F. J. SCRASE

Meteorological factors influencing the transport and removal of radioactive debris, WMO Technical Note No. 43. Ed. by Dr. W. Bleeker. 11 in. x 8½ in., pp. xii + 171, illus., World Meteorological Organization, Geneva, Switzerland, 1961. Price: Sw. fr. 8.—.

The major part of the radioactive fission products created by high-yield thermonuclear tests enters the stratosphere and is brought down to the earth's. surface gradually over a period of months or years. The full effect of the tests is, therefore, not immediately felt at the surface, and in order to make a reasonable assessment of the hazards to man arising from certain isotopes, it is necessary not only to make measurements of the deposition occurring at a given time, but also to be able to predict the rate of fallout in the future. In order to see whether any basis could be found for forecasting future world-wide fallout, a comprehensive survey of the problem was made during the seventh session of the United Nations Scientific Committee on the Effects of Atomic Radiation held in January 1960. A number of meteorologists attended the meetings and gave papers on various aspects of the problem, and a selection of the papers has now been published in the WMO "Technical Note" under review. A few papers which merely presented data, or which had appeared elsewhere in the literature, have been omitted.

The opening paper is a fairly detailed summary by Dr. L. Machta (United States Weather Bureau) of the available information on the meteorological aspects of world-wide fallout. He begins by indicating briefly the difference between "close-in" and "world-wide" fallout, the latter being divided into "tropospheric" and "stratospheric" fallout. The rest of the paper is concerned only with the world-wide stratospheric component of fallout, and contains sections dealing with the physical and chemical properties of the particles, with the observed distribution of fallout in soil, in rain and in air near the ground and aloft, with the transport and diffusion of the radioactive debris in the stratosphere, through the tropopause and in the troposphere, and with the processes which lead to the removal of the particles from the atmosphere. This survey formed the background for the remaining papers, and is in itself a good and useful account of the subject. The only major fault is an almost complete neglect of the work, carried out by N. G. Stewart, D. H. Peirson, R. N. Crooks and others at the Atomic Energy Research Establishment (A.E.R.E.), Harwell, on the world-wide distribution of fission products in rain and on the variation of activity with height in air over the United Kingdom. This work had added considerably to our knowledge in this field, and is worth a good deal more than the passing mention given to it by Machta.

The three papers which follow deal respectively with the sampling of radioactive debris in air near ground level along the 80° W meridian, stratospheric sampling using balloons to carry filters well into the stratosphere, and tropospheric and lower stratospheric sampling by means of aircraft. These papers contain a good deal of information and, although there is some doubt about the early balloon data, there is much here to interest the meteorologist. Professor Bleeker then discusses the tropospheric circulation and the way in which it influences the distribution of fallout. The meteorologist will be familiar with the substance of this paper, but he may be interested to see how quickly a radioactive cloud in the troposphere may at times be dispersed over a wide area. The next paper, by Professor H. A. Panofsky, is an interesting summary of the properties of the lower stratosphere, taken to be the layer between the tropopause and 100,000 feet. While recent work has not led to great changes in our ideas on the overall picture of the stratospheric circulation—it appears that weak reflections of the tropospheric flow are often evident at heights greater than suggested in this paper—more can now be said about the "sudden warming" phenomenon.

Dr. A. W. Brewer follows with a paper on the transfer of ozone from the stratosphere to the troposphere. Ozone is of interest in this context in that it is formed in roughly the height region into which the debris from high-yield tests is deposited. The model of a meridional circulation put forward by Brewer in 1949 to explain the observed distribution of water vapour, helium and, later, ozone in the stratosphere, seems to explain many of the observed features of the distribution of radioactive debris. Returning to the troposphere, Professor Bleeker gives an illustration of the activity changes on the passage of a double cold front over north-west Europe shortly after a nuclear test. Monsieur L. Facy goes on to describe a number of mechanisms which might contribute to the removal of radioactive particles from the atmosphere and their deposition on the surface. Not all of these mechanisms are equally effective: recent laboratory work by Goldsmith (to be published) indicates that the transport along the vapour pressure gradient is not an important factor in the scavenging of particles by cloud droplets.

Dr. M. Hinzpeter has attempted to derive information on the coagulation, fractionation and "residence time" of the fission product particles in the atmosphere. He deduces that the sub-micron radioactive particles coagulate with the larger neutral dust particles in the lowest layers of the atmosphere, since the two show very similar diurnal, weekly and seasonal variations. The second part of the paper attempts to show that time and space variations in the relative proportions of strontium–90 and caesium–137 are a result of the coagulation of the smaller caesium with the larger strontium particles. The argument is rather tentative, and is based on a number of assumptions, some of which are rather doubtful. As Machta has said in the first paper, there appears to be no evidence that such fractionation does occur. The third part is an attempt to derive a minimum "residence time" for nuclear weapon debris in the stratosphere.

Finally, Machta gives a brief summary of the results of the discussions and an epilogue which presents significant data on atmospheric radioactivity gathered up to about March 1961 and which includes new data on rhodium–102, released at above 30 kilometres over the central Pacific in August 1958 and on beryllium–7 and lead–210, two naturally occurring isotopes.

The general impression gained from a study of this "Technical Note" is that a vast body of data has been accumulated, often with great difficulty and at no little expense. The data are difficult to interpret, and the wide variety of "residence times" quoted is ample evidence of this. It is clear, however, that the rate of removal of fission products from the stratosphere is strongly dependent upon the latitude and height of injection, and that it varies with season and from year to year. Debris injected into the lower stratosphere in arctic regions, for example, is almost completely removed within a year, while there is now evidence that an appreciable fraction of the debris injected at 30 kilometres or so over the tropical Pacific in 1954, 1956 and 1958 is still present in the stratosphere. It appears that the problem of forecasting future world-wide fallout has not yet been completely solved.

J. CRABTREE

OBITUARY

Leonard Joseph Dwyer—The news of the death, after a short illness, of Mr. L. J. Dwyer on 16 May 1962 came as a very great shock to all who knew him. Born in 1907, he had been Director of the Bureau of Meteorology in Melbourne since 1955, and was a member of the Executive Committee of the World Meteorological Organization. In the Second World War, as a squadron leader in the Royal Australian Air Force, he was engaged in forecasting for operations in the Pacific area.

The Director-General writes:

"I knew Len Dwyer intimately as a fellow member of the Executive Committee, W.M.O. His breezy, forthright personality and massive commonsense, coupled with a deep knowledge of the requirements of operational meteorology, made him an outstanding member and he will be sadly missed. During our years of joint service on the E.C., I never knew him depressed or worried, and he won many friends. After working hours he was always the best of company.

"Len Dwyer will be remembered as one of the men who have helped to make the profession of meteorology unique in its world-wide friendships. Like many others, I mourn not only the loss of a fine public servant but a close and valued friend. The annual meetings at Geneva will not seem the same without him."

METEOROLOGICAL OFFICE NEWS

The Meteorological Office Football Club (Bracknell) has now completed its first season and can look back upon this with a feeling of satisfaction. A team was entered in Division II of the Ascot and District League and finished third in the competition. Of the 24 league games played, 14 were won, 2 drawn and 8 lost. Seventy-three league goals were scored and 63 conceded. Various cup competitions were also entered (without success) and the full playing record is: Played 31; won 16; drawn 2; lost 13; goals for 94; goals against 89. The chief goal-scorers were E. Ashby (M.O.14) and P. Underwood (M.O.5c)—20 each, R. Archard (M.O.3)—13, M. Crisford (White Waltham) and R. Hardy (M.O.18)—10 each.

The club is now looking forward to next season and the Secretary (J. R. Green, M.O.10b) would be pleased to hear from prospective new players or non-playing members. Staff serving at Heathrow, Farnborough, Odiham and other Offices near Bracknell might be interested to know that membership of the club is not limited to those serving at Headquarters. Training sessions in preparation for next season will commence during July.