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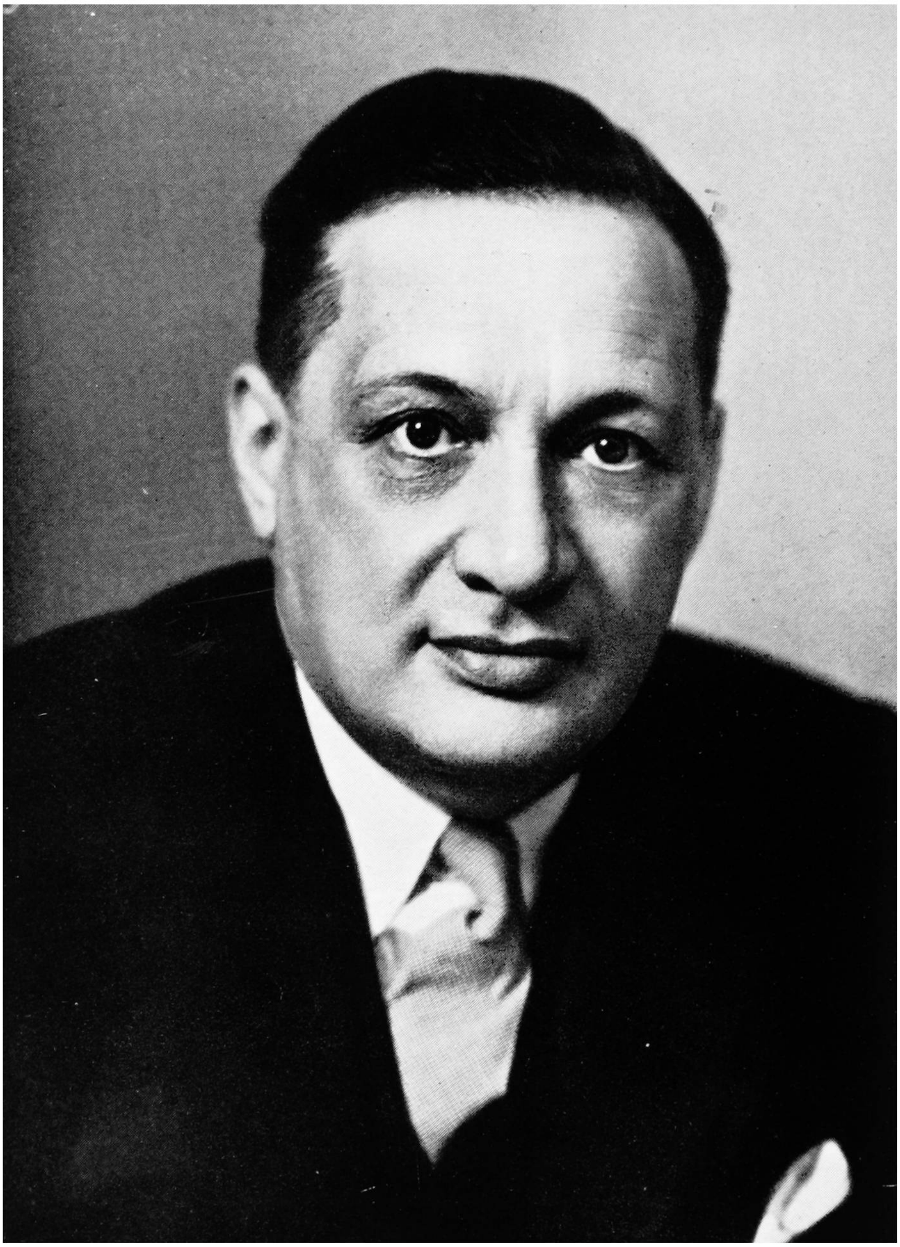

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DR. O. G. SUTTON, C.B.E., F.R.S.

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Dr. O. G. SUTTON

Dr. O. G. Sutton, C.B.E., D.Sc.(Wales), B.Sc.(Oxon), F.R.S., took up his duties as Director of the Meteorological Office on September 1, 1953, in succession to Sir Nelson Johnson.

Dr. Sutton is well known as an expert of world-wide fame in the dynamics of the lower atmosphere. He graduated with honours in mathematics at the University College of Wales, Aberystwyth, and later took the degree of B.Sc. Oxford as a scholar of Jesus College. He was a mathematical lecturer at Aberystwyth from 1926 to 1928, and then joined the Meteorological Office as a Junior Professional Assistant. After service at Shoeburyness he was seconded in 1929 to the War Office for service at the meteorological office attached to the Chemical Defence Experimental Establishment, Porton.

This position gave full scope for Dr. Sutton's mathematical ability in the development of the theory of turbulence and its application to practical problems. Theoretical work at Porton before his arrival had been based solely on the concept of the coefficient of eddy diffusivity, the so-called "K" theory. Dr. Sutton's early work at Porton was the application of Prandtl's mixing length theory and Taylor's theory of diffusion by continuous movements to atmospheric diffusion. His paper on these matters, published in the *Proceedings of the Royal Society* as early as 1932, has become classical. During the years up to the outbreak of war he worked continuously on turbulence, and published numerous important papers on atmospheric diffusion, evaporation and the vertical variation of wind speed. In 1942 he was appointed Superintendent of Research in Chemical Defence at Porton, and from 1943 to 1945 was Superintendent of Tank Armament Research. He went to the Radar Research and Development Establishment in 1945 as Chief Superintendent, and in 1947 was appointed Bashforth Professor of Mathematical Physics in the Royal Military College of Science, Shrivenham, latterly becoming Dean of the College.

While occupying these posts outside the Meteorological Office Dr. Sutton continued his meteorological researches, published a number of important theoretical papers such as "Application to micrometeorology of the theory of turbulent flow over rough surfaces"* and "Stability of a fluid heated from below"†, and applied the theory of eddy diffusion to practical problems such as the dispersion of smoke from factory chimneys, in "The theoretical distribution of airborne pollution from factory chimneys"‡ and "Dispersion of hot gases

* *Quart. J.R. met. Soc., London,* **75**, 1949, p. 335.
† *Proc. roy. Soc., London,* A, **204**, 1950, p. 297.
‡ *Quart. J.R. met. Soc., London,* **73**, 1947, p. 426.

in the atmosphere"*. He has also written important general accounts of the meteorology of the "regions where life is most abundant" in his book "Atmospheric turbulence"†, in his article on "Atmospheric turbulence and diffusion" in the "Compendium of meteorology"‡, and, finally and most important, in the comprehensive textbook "Micrometeorology" §. His "The science of flight" || is a useful semi-popular book on aerodynamics.

Dr. Sutton, was elected a Fellow of the Royal Society in 1949 and appointed C.B.E. in 1950. He was Scientific Adviser to the Army Council in 1951, is Chairman of the Atmospheric Pollution Research Committee, and has recently been elected President of the Royal Meteorological Society for the period beginning October 1953. Before becoming Director he represented the Royal Society on the Meteorological Committee and was a personal member of the Meteorological Research Committee.

Dr. Sutton has a long experience and a very high reputation in scientific research and the administration of scientific departments. All readers of the Magazine will join in wishing him every success as Director of the Meteorological Office.

WIND DIRECTION AT NORTH FRONT, GIBRALTAR

By A. WARD

Introduction.—The nature of the air flow through the Straits of Gibraltar and the problems of forecasting surface winds at Gibraltar have received close attention from a number of investigators, notably R. S. Scorer and A. H. Gordon, and there is a considerable amount of published and unpublished information on the subject. This paper amends and brings up to date some of the earlier statistical data[1], and is based on the records of the pressure-tube anemograph at the Meteorological Office at North Front.

The site of the anemograph and the topography of the Rock and of the surrounding country are shown in Figs. 1 and 2. The northern face of the Rock rises precipitously to a maximum height of 1,400 ft. about 1,100 yd. distant from the anemograph in the direction 145°, and falls steadily to sea level about 900 yd. away in the direction 210°. As a result, there are often marked local variations in wind speed and direction over the airfield, and, on such occasions, the anemograph winds may be completely unrepresentative of the wind conditions along the greater part of the runway. These local variations are to be investigated in detail in the near future.

Apart from the general effect of the Rock, the exposure of the anemometer head is influenced by the building on which it is sited and by groups of buildings to the south-west and west. Prior to July 1951, the anemometer head was 29 ft. above ground level and 13 ft. above the buildings in the immediate vicinity, and it appears that for all wind directions, but in particular for those between 180° and 270°, the recorded wind speeds were too low; "effective heights" of 10 ft. for the quadrant between 180° and 270° and 16 ft. for the remaining sector were adopted . In July 1951, the anemometer head was raised to a height of 39 ft. above ground level and 23 ft. above the buildings in the immediate vicinity, and new "effective heights" of 22 ft. for the quadrant

* *J. Met., Lancaster, Pa.*, 7, 1950, p. 307.
† Atmospheric turbulence. London, 1949.
‡ Compendium of meteorology. Boston, Mass., 1951, p. 492.
§ Micrometeorology. London, 1953.
|| The science of flight. London, 1949.

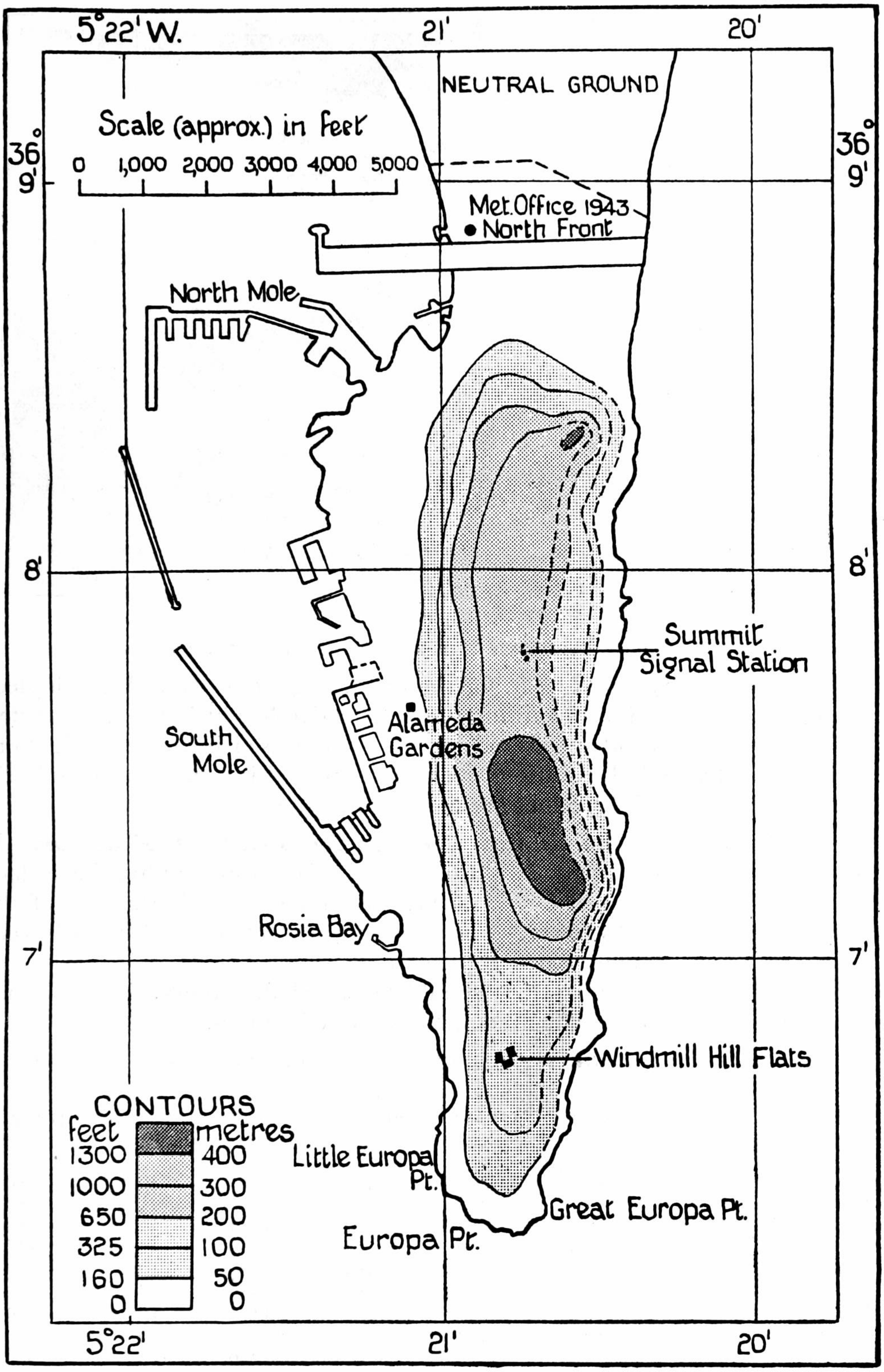

FIG. I—PLAN OF THE ROCK OF GIBRALTAR SHOWING THE SITE OF THE METEOROLOGICAL STATION AT NORTH FRONT

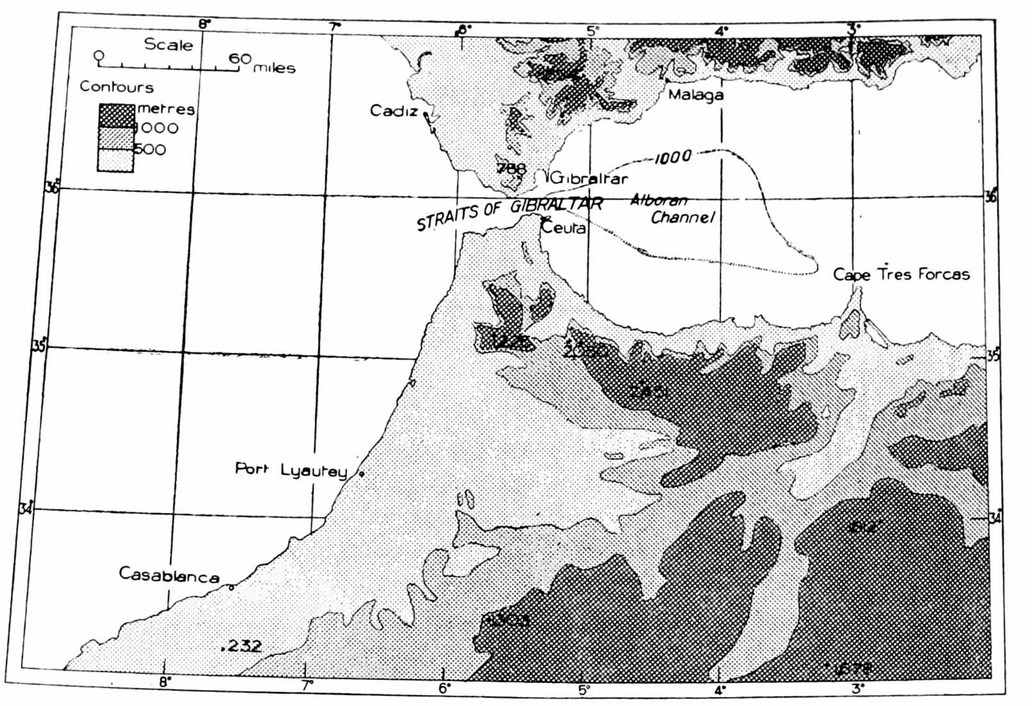

FIG. 2—TOPOGRAPHY OF THE REGION AROUND GIBRALTAR

between 180° and 270° and 33 ft. for the remaining sector were then adopted. In view of the uncertainty regarding these "effective heights", the uncorrected tabulated values of wind speed and direction were used in this investigation. On the basis of visual observations over a long period it is considered unlikely that the recorded wind directions are significantly affected by these buildings.

General nature of the air flow through the Straits of Gibraltar.—It is a well established fact that, as a direct result of the topography, the surface winds at Gibraltar are usually E. or W., and blow towards the end of the Straits where pressure is lower. The "steering" effect of the Straits is very well marked up to about 2,000 ft., and is even discernible at 5,000 ft., as illustrated in Tables I and II. It should be noted that the various columns in the tables do not all include an equal number of degrees.

TABLE I*—PERCENTAGE FREQUENCY OF SURFACE WIND DIRECTION AT NORTH FRONT

	60–120°	130–160°	170–190°	200–210°	220–230°	240–300°	310–50°
				per cent.			
January	26·1	0·5	1·2	3·7	10·5	49·3	8·9
February	28·3	0·7	2·4	7·4	12·1	45·2	3·9
March	44·6	0·7	1·3	4·2	10·4	32·5	6·2
April ...	47·9	0·8	2·3	3·9	7·0	32·3	5·6
May ...	26·2	0·8	2·1	5·0	12·4	47·8	5·5
June ...	45·2	0·6	1·7	6·1	10·9	28·6	7·0
July ...	46·7	0·4	3·6	8·2	11·5	19·7	9·9
August ...	37·3	0·3	4·2	9·9	15·8	20·7	11·9
September	44·9	0·4	3·5	6·3	12·0	23·8	9·0
October...	41·6	0·2	2·8	4·5	8·6	32·1	10·3
November	35·4	0·4	1·5	3·8	9·1	40·8	9·0
December	34·3	0·4	0·7	1·6	6·7	47·2	9·4
Year ...	37·3	0·6	2·2	5·4	10·7	36·0	7·8

*Table I is an extract from a paper by O. M. Ashford[2] and is based on tabulated records for the period 1947–51 inclusive.

TABLE II—PERCENTAGE FREQUENCY OF UPPER WIND DIRECTION AT NORTH FRONT

	360–50°	60–100°	110–120°	130–180°	190–230°	240–250°	260–300°	310–350°
				per cent.				
				At 5,000 ft. or 850 mb.				
January	13·4	19·0	7·8	4·9	7·1	7·5	22·0	18·3
April ...	9·9	17·9	15·7	8·0	6·5	7·6	18·7	15·6
July ...	2·9	13·4	13·7	18·4	19·1	10·1	17·0	5·4
October...	8·1	18·6	13·5	12·2	7·5	5·4	17·3	17·3
				At 2,000 ft. or 950 mb.				
January	2·9	30·0	9·2	3·7	6·6	5·9	29·6	12·3
April ...	3·7	39·2	6·3	2·2	3·3	3·7	31·3	10·1
July ...	2·8	42·5	6·4	2·8	2·5	1·8	30·6	10·7
October...	3·5	35·9	9·5	5·7	4·1	2·8	24·6	13·9

Table II is based on radar-wind data for three times daily at 0200, 0800 and 1400 G.M.T. over the period 1949–51 inclusive. The markedly increased frequency of winds from between 130° and 230° at 5,000 ft. in July reflects the change in the thermal pattern from winter to summer. During the winter months the frequent bursts of cold air southwards over France into the western Mediterranean result in a thermal gradient from west to east, a gradient which is reversed in summer by the intense heating over north Africa and Spain.

The theoretical and practical aspects of the air flow through the Straits have been discussed by Scorer[3,4] and Gordon[5], and the reader is referred to the original papers for a complete account . It will be sufficient to say here that a distinction must be made between occasions when convection is active up to or over mountain-top level and occasions of great stability. In the first case the interchange of momentum between the surface and upper layers results in a surface wind which closely follows the wind at about 2,000 ft., whereas in the second case the surface wind may differ appreciably from the wind at 2,000 ft. and is very noticeably directed towards the low-pressure end of the Straits.

Table I shows that, apart from E. and W. winds, the most frequent wind direction at North Front is between S. and SW. During the winter months strong south-westerly winds occur ahead of active cold fronts approaching Gibraltar from the west; the increased frequency of winds from this direction during the summer months reflects the influence of the southerly sea-breeze.

Changes of wind from west to east and from east to west.—On a large number of occasions the weather at Gibraltar is determined almost entirely by the direction of the surface wind. During the summer months a light easterly wind may advect low stratus and fog patches over the airfield[6], whereas a westerly wind is normally associated with fine clear weather, but with the attendant risk of a strong, southerly sea-breeze developing during the afternoon[7]. A correct forecast of a wind change, therefore, is often vital to the success of the whole forecast.

Table III shows, as a percentage frequency, the time of change of wind from W. to E. and from E. to W. and the average number of wind changes each season during the period 1947–51 inclusive. Occasions of calms have been classed as a continuation of the earlier régime.

The table illustrates the pronounced tendency for a wind change to E. to occur between sunrise and noon, and a change to W. to occur a few hours

TABLE III—TIME OF CHANGE OF SURFACE WIND AT NORTH FRONT

	0000 –0300	0300 –0600	0600 –0900	0900 –1200	1200 –1500	1500 –1800	1800 –2100	2100 –2400
				per cent. W. to E.				
Winter	6·8	3·9	13·6	38·0	13·6	8·7	8·7	6·8
Spring	8·6	3·8	21·0	23·8	12·4	7·6	10·5	12·4
Summer	12·5	7·0	25·0	18·8	14·1	7·8	7·0	7·8
Autumn	12·7	7·3	20·0	31·8	8·2	9·1	8·2	2·7
				E. to W.				
Winter	12·6	12·6	3·9	7·8	11·6	13·6	22·3	15·5
Spring	14·4	14·4	6·7	1·9	12·5	13·5	13·5	23·0
Summer	23·0	19·0	4·0	4·8	8·7	10·3	12·7	17·5
Autumn	12·6	12·6	19·9	8·1	5·4	14·4	15·3	11·7
				Average number of wind changes				
Winter	4·0	3·4	3·6	9·4	5·2	4·6	6·4	4·6
Spring	4·8	3·8	5·8	5·4	5·2	4·4	5·0	7·4
Summer	9·0	6·6	7·4	6·0	5·8	4·6	5·0	6·4
Autumn	5·6	4·4	8·8	8·8	3·0	5·2	5·2	3·2

after sunset. This distribution is commonly attributed to the effect of a very shallow, westerly katabatic wind which, on quiet nights, replaces any light easterly wind blowing at dusk, and reverts to a light easterly wind after dawn. It is unlikely, however, that the large number of wind changes to E. during the forenoon are entirely due to the reversal of a night katabatic wind, and it seems probable that external influences favour a wind change to E. at this time of day.

Another noteworthy feature of Table III is the marked increase in the number of wind changes to E. between midnight and 0300 in summer and autumn, an increase which is at complete variance with the idea of a dominant, westerly katabatic wind during the night. During the summer an unexpectedly large number of wind changes occur in this period, possibly the result of two effects of similar magnitude in opposition, i.e. the katabatic effect and some external effect favouring an easterly wind.

The problem is closely allied to that of the diurnal variation of wind speed during spells of easterly winds, discussed in the next section.

Diurnal variation of surface winds.—Table IV shows the percentage frequency of E. and W. winds and calms at stated hours during the period 1947–51 inclusive. In the table, winds from due N. have been included with E. winds and winds from due S. with W. winds.

The maximum frequency of westerly winds and minimum frequency of easterly winds during the night in all months reflects the influence of the westerly katabatic wind.

Westerly winds.—A distinction must be made between occasions when convection is active up to or over mountain-top level and occasions of great stability. In the former case, the solar heating during the day results in a transfer of momentum downwards, and the surface wind follows the wind at 2,000 ft., i.e. with the normal distribution of wind at 2,000 ft. the surface wind freshens and veers to westerly. Exceptions occur with light upper winds, i.e. winds of less than 15 kt., during the summer months when the sea-breeze effect is important and results in a southerly surface wind[7].

In the latter case, even with winds of 20 kt. at mountain-top level, the surface wind may remain light SW. to W. throughout the day, and frequently,

TABLE IV—SURFACE WIND DIRECTION AT NORTH FRONT AT STATED HOURS

	0000	0300	0600	0900	1200	1500	1800	2100
				per cent.				
January								
calm	5·8	7·8	8·4	6·4	2·6	..	4·5	6·4
E. wind	26·4	27·0	25·8	27·8	37·5	40·0	35·5	28·4
W. wind	67·8	65·0	65·7	65·7	60·0	60·0	60·0	65·0
April								
calm	4·7	6·7	5·3	2·0	..	0·7	..	1·3
E. wind	48·6	43·3	45·3	50·0	56·7	54·0	52·7	54·7
W. wind	46·6	50·0	49·3	48·0	43·3	45·3	47·3	44·0
July								
calm	7·1	10·3	1·9	1·9	..	..	0·7	4·5
E. wind	52·3	44·5	47·1	54·9	58·0	58·7	58·0	54·9
W. wind	40·6	45·1	51·0	43·3	42·0	41·3	41·3	40·6
October								
calm	9·0	8·4	6·4	3·2	..	..	2·6	6·4
E. wind	42·5	41·3	42·5	48·4	54·1	54·1	51·6	47·1
W. wind	48·4	50·3	51·0	48·4	45·8	45·8	45·8	46·5

in particular during the summer months, a strong southerly sea-breeze sets in during the forenoon and continues until early evening[7].

Easterly winds.—A light easterly wind by day shows a very marked tendency to become a calm or light westerly at night because of the effect of the westerly katabatic wind. However, Table III and the discussion in the preceding section show that, during summer and autumn, there is a slight tendency towards a change back to easterly between midnight and 0300 although this tendency is not apparent in Table IV.

The diurnal variation of wind speed during spells of easterly winds is unusual, and, as shown in Table V, during most of the year the maximum is reached during the forenoon with a pronounced minimum during the evening. The delayed maximum in July is attributed to a sea-breeze effect resulting in a freshening easterly wind during the afternoon. This effect has been discussed in an earlier paper[7], where it was also shown that the southerly sea breeze does not normally occur with an easterly gradient wind.

TABLE V*—DIURNAL VARIATION OF EASTERLY SURFACE WINDS AT NORTH FRONT EXPRESSED AS THE DIFFERENCE FROM THE MONTHLY MEAN

	Mean	Hour centred at 0030	0330	0630	0930	1230	1530	1830	2130
					knots				
January	20·3	−0·4	−0·1	+0·6	+1·6	+1·0	−0·3	−1·0	−1·2
April	18·8	−0·8	+0·1	+0·5	+2·6	+2·2	−0·2	−2·3	−2·4
July	13·2	−0·8	−0·5	−0·3	+1·8	+2·1	+1·1	−1·0	−2·5
October	14·3	+0·6	+0·3	−0·3	+1·3	+1·1	−0·1	−1·5	−1·6

*Table V is based on tabulated hourly values for days when the wind was easterly throughout the 24 hr. during the period 1947–51 inclusive.

Forecasters at Gibraltar have long been aware of the tendency for an easterly surface wind to freshen during the night, and this tendency is clearly illustrated in Table V. An explanation has been suggested by Scorer[4]. He argues that if the easterly wind decreases with height in the mixing layer—a common occurrence at Gibraltar—the transfer of momentum upwards from the surface layer will be decreased at night owing to increased stability, and the surface wind should therefore increase. This theory has been investigated statistically for the period 1947–51 inclusive, and the results are presented in Table VI.

TABLE VI—CHANGES IN STRENGTH OF EASTERLY WINDS WITH HEIGHT

	Easterly wind decreasing with height at 0200	Easterly wind increasing with height at 0200
	No. of occasions	
Surface easterly wind increased at night	33	55
Surface easterly wind decreased at night	5	38

The investigation was not entirely objective, since there were no ready means of ascertaining whether or not an increase or decrease of surface wind at night was due to external causes. In practice, it was assumed that the general situation had remained unchanged throughout the night if the radar winds, as given by the preceding 1400 observation, the 0200 observation in question, and the succeeding 0800 observation, varied by less than 5 kt. The depth of the mixing layer was assumed to be the level of marked wind change shown by the 0200 observation; this was usually about 3,000 ft.

The results confirm that an easterly wind decreasing with height normally results in a freshening easterly surface wind at night, but also indicate that on a large number of occasions a freshening surface wind is associated with an increasing wind with height. In view of this, and the results of an earlier investigation by Skelton[8]—of which an extract is given in Table VII—based on the records from the anemometer at 1,310 ft. above sea level, at the summit of the Rock, it seems that the increase in wind speed may be general throughout the mixing layer.

TABLE VII—DIURNAL VARIATION OF EASTERLY WINDS AT THE SUMMIT OF THE ROCK

	0100	0200	0300	0400	0500	0600	0700	0800	0900	1000	1100	1200
	knots											
Difference from mean value	+0·9	+0·9	+1·0	+1·1	+1·2	+1·1	+1·0	+1·0	+0·9	+0·9	+0·5	+0·2

	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	2400
	knots											
Difference from mean value	−0·1	−0·4	−0·9	−1·3	−1·6	−1·5	−1·2	−1·1	−0·9	−0·7	−0·3	−0·1

It will be noticed that, at the summit of the Rock, the maximum and minimum values are reached some 4–6 hr. earlier than on the surface; no satisfactory explanation of this effect can be suggested.

Although the explanation for a freshening easterly wind at night suggested by Scorer must apply to a certain extent, it cannot now be accepted as complete. A further contributory factor may be the diurnal pressure changes in the vicinity of Gibraltar, and these will be discussed in the next section.

Diurnal pressure variations in the vicinity of Gibraltar.—In the experience of forecasters at Gibraltar, a wind change at North Front often occurs soon after the reversal in sign of the pressure difference between Malaga and Casablanca, i.e. easterly winds being associated with a positive difference and westerly winds with a negative difference. A knowledge of the diurnal pressure variations at these stations is therefore important for forecasting surface-wind changes at North Front, and the results of an investigation based on data extracted from the working charts at Gibraltar are presented in Table VIII. The period covered is 1950–52 inclusive, except for January where it is 1951–53 inclusive. A number of observations were missing from the Gibraltar charts, and the investigation was eventually restricted to days for which observations were available at all of the eight synoptic hours; the minimum number of such days was 47. The diurnal pressure variations at Gibraltar, based on observations during 1950–52 inclusive, are included for comparison.

TABLE VIII—DIURNAL VARIATION OF PRESSURE AT MALAGA, GIBRALTAR AND CASABLANCA EXPRESSED AS THE DIFFERENCE FROM THE MONTHLY MEAN

	Station	Mean	0000	0300	0600	0900	1200	1500	1800	2100
			millibars							
January	Malaga	1021·48	+0·45	+0·22	−0·27	+0·57	+0·49	−0·86	−0·58	−0·02
	Gibraltar	1020·27	+0·19	−0·12	−0·38	+0·67	+0·57	−0·84	−0·36	+0·27
	Casablanca	1021·17	+0·17	−0·17	−0·51	+0·73	+0·69	−0·83	−0·35	+0·28
	Malaga — Casablanca		+0·28	+0·39	+0·24	−0·16	−0·20	−0·03	−0·23	−0·30
April	Malaga	1017·14	+0·38	+0·02	−0·20	+0·58	+0·33	−0·58	−0·81	+0·26
	Gibraltar	1016·23	+0·40	−0·47	−0·34	+0·44	+0·52	−0·43	−0·63	+0·48
	Casablanca	1016·92	+0·41	−0·53	−0·40	+0·48	+0·44	−0·49	−0·47	+0·59
	Malaga — Casablanca		−0·03	+0·55	+0·20	+0·10	−0·11	−0·09	−0·34	−0·33
July	Malaga	1017·19	+0·69	−0·06	−0·03	+0·53	+0·65	−0·14	−1·30	−0·36
	Gibraltar	1015·91	+0·39	−0·30	0·00	+0·64	+0·66	−0·28	−1·03	−0·06
	Casablanca	1016·77	+0·62	−0·34	−0·22	+0·40	+0·34	−0·50	−0·71	+0·38
	Malaga — Casablanca		+0·07	+0·28	+0·19	+0·13	+0·31	+0·36	−0·59	−0·74
October	Malaga	1018·63	+0·19	−0·36	−0·31	+0·74	+0·49	−0·61	−0·50	+0·37
	Gibraltar	1017·41	+0·20	−0·49	−0·43	+0·73	+0·53	−0·66	−0·39	+0·49
	Casablanca	1017·66	+0·36	−0·42	−0·39	+0·71	+0·43	−0·82	−0·54	+0·47
	Malaga — Casablanca		−0·17	+0·06	+0·08	+0·03	+0·06	+0·21	+0·04	−0·10

Some interesting features of the diurnal changes emerge. In January and April, the evening pressure rise takes place earlier at Casablanca than at Malaga; one would expect the westward-moving pressure wave to produce rising pressure earlier at Malaga. In all seasons, the pressure rise at 2100 is noticeably greater at Casablanca than at Malaga.

The difference, Malaga — Casablanca, shows a minimum between 1800 and midnight and a maximum around 0300 in January and April and around 1500 in July and October. The diurnal variation of the difference has a pattern similar to that of the diurnal variation of the speed of easterly winds shown in Table V, and the minima appear to be very closely related. The complete break-down of the geostrophic relationship in the Straits, where the low-level flow is dominated by the accelerational terms in the equations of motion[4], makes it difficult to assess the effect of the pressure differences on the wind velocity at Gibraltar; but it is clear that the net pressure rise at Malaga between 2100 and 0300, a rise which is particularly well marked in July, will result in an addition to any existing wind of an isallobaric wind component from the north-east.

Conclusions.—Marked changes of wind may occur at North Front without any apparent change in the general pressure distribution. A wind change to E. occurs preferentially during the forenoon and a change to W. preferentially after dusk, and, in the main, this distribution may be attributed to the effect of a westerly katabatic wind frequently replacing a light easterly wind blowing at dusk and reverting to a light easterly after dawn.

The marked increase in the number of wind changes to E. between midnight and 0300 in summer and autumn, and the tendency for a freshening easterly wind after 2100, require some further explanation. It now seems probable that these effects are due to the diurnal pressure variations in the vicinity of Gibraltar, which favour a maximum westerly wind between 1800 and midnight and a maximum easterly wind at about 0300 in January and April and at about 1500 in July and October. The tendency for a maximum easterly wind at about 0300 in January and April is not reflected in the frequency tables of wind direction at North Front, and is probably over-compensated by a stronger katabatic flow during these months.

It is not at all clear why such marked differences in the diurnal pressure variation between Malaga and Casablanca should arise, but it is possible that the pressure variation at Malaga is greatly influenced by a pronounced anabatic and katabatic flow in the mountainous coastal regions bordering the Alboran Channel.

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ELECTRONIC COMPUTATION OF THE FIELD OF ATMOSPHERIC DEVELOPMENT

By F. H. BUSHBY, B.Sc. and M. K. HINDS, B.Sc.

Introduction.—For some years upper air charts have been used increasingly in forecasting, and it is important to know as much as possible about the relationship of upper air patterns to surface developments. Sutcliffe[1], in his formula expressing cyclonic and anticyclonic development in terms of rates of change of vorticity and the vertical shear of the horizontal wind, made an important contribution to this subject. In recent years forecasters have been using ideas based qualitatively on this theory (Sutcliffe and Forsdyke[2]), but until now all methods applying the formula quantitatively have proved too lengthy to be of practical use. However, with the advent of modern electronic computing machinery the calculations necessary to produce a chart of Sutcliffe's expression for development can be carried out within a few minutes, and it was considered desirable to study the practical value of such charts.

In the present article an outline is given of a method of evaluating the field of development using an electronic computing machine. One development chart is described in relation to the relevant synoptic situation, and some general observations are made on the results of twelve such computations which have been described in detail by Bushby and Hinds[3].

Method of Computation.—Sutcliffe[1] has shown that, subject to various approximations, the relative divergence between two pressure levels p_0 and p_1 is given by

$$l\,(\mathrm{div}_p\,\mathbf{V}_1 - \mathrm{div}_p\,\mathbf{V}_0) = -\mathbf{V}'.\,\mathrm{grad}_p\,(l + \zeta_0 + \zeta_1) \quad \ldots\ldots (1)$$

where l is the Coriolis parameter, $\mathbf{V}_0$, $\mathbf{V}_1$, ζ_0 and ζ_1 are the horizontal wind velocities and the vertical components of vorticity at the pressure levels p_0 and p_1, $\mathbf{V}'$ is the vertical wind shear $\mathbf{V}_1 - \mathbf{V}_0$, and the suffix p represents differentiation in an isobaric surface with respect to orthogonal curvilinear distance co-ordinates on the sphere.

It has been shown by Sutcliffe[4] that the left-hand side of equation (1) can be interpreted in terms of vertical motion, and hence in terms of cyclonic and anticyclonic development. If $p_0 > p_1$ then the left-hand side of equation (1) is positive for ascending motion and negative for descending motion.

The equation is particularly valuable because the horizontal divergence which appears on the left-hand side cannot be estimated from geostrophic winds, and even when the most dense network of actual wind observations is available, the values of divergence which can be obtained are inadequate to give a satisfactory estimate of the difference of divergence between two levels. It is, however, permissible to substitute geostrophic values in the right-hand side of equation (1), and it is then practicable, using finite difference methods, to calculate its value over a network of points.

The values of p_0 and p_1 used in the computation were 1000 mb. and 500 mb., and the development term was evaluated at a network of 12×8 points covering most of the north-east Atlantic and western Europe (see Fig. 1). When an electronic computing machine is used for this computation it is necessary to feed into the machine the values of the 500-mb. height and 1000–500-mb. thickness at the points of a 16×12 grid, these being read directly from the working charts. It is also necessary to feed into the machine a programme of orders instructing it how to do the computation, together with the value of $\sin\phi$ (where ϕ is the latitude) for each grid point. The programme and the $\sin\phi$'s are of course the same for each computation, and only need to be prepared once. Both data and programme are fed into the machine on punched tape similar to that used by teleprinters. The answers are printed on a teleprinter attached to the machine.

For each computation the machine took 3 min. to read in the programme and data, 1 min. to perform the calculations and $1\frac{1}{2}$ min. to print the results, making a total of $5\frac{1}{2}$ min. machine time. It is necessary to allow a certain time for reading data off charts, punching data tapes and plotting the answer, but it is estimated that a development chart could be produced in about 1 hr. from the time the initial charts were ready. This compares very favourably with the 4–5 hr. that would be needed if a Sawyer-Matthewman[5] scale were used, the most efficient method of hand computation.

Results.—The development chart computed for 1500 G.M.T. March 14, 1949 is shown in Fig. 1, and Figs. 2, 3 and 4 give a series of three synoptic charts at 12-hr. intervals. Anticyclonic development areas are shown as positive and cyclonic development areas as negative. These may be directly associated with vertical motion but only indirectly with surface pressure changes.

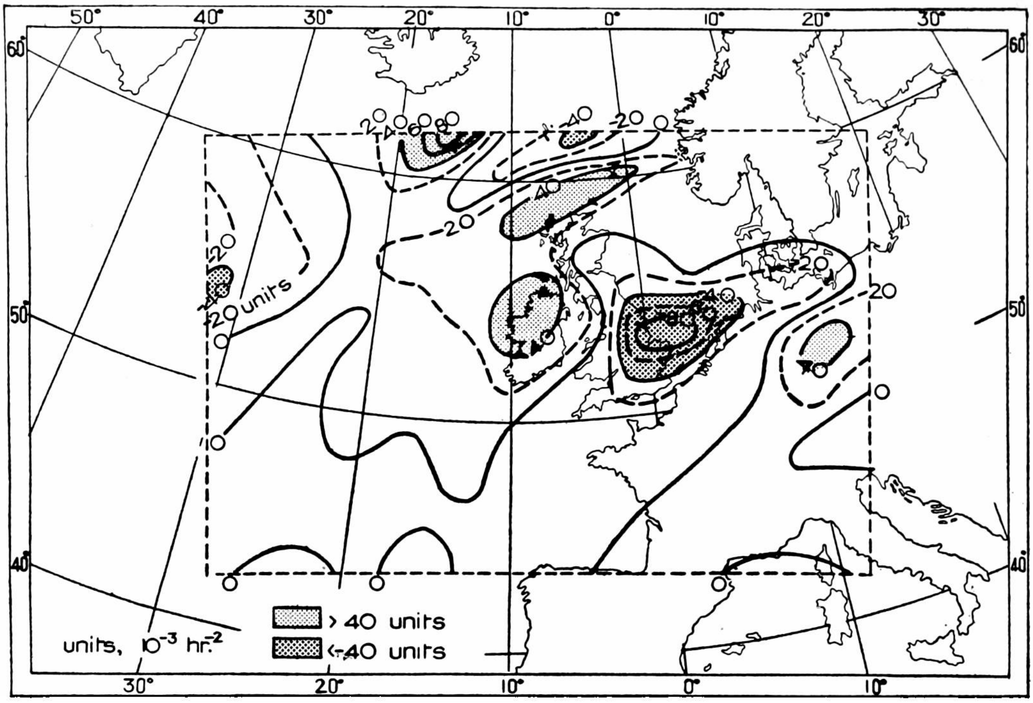

FIG. 1—DEVELOPMENT CHART, 1500 G.M.T., MARCH 14, 1949

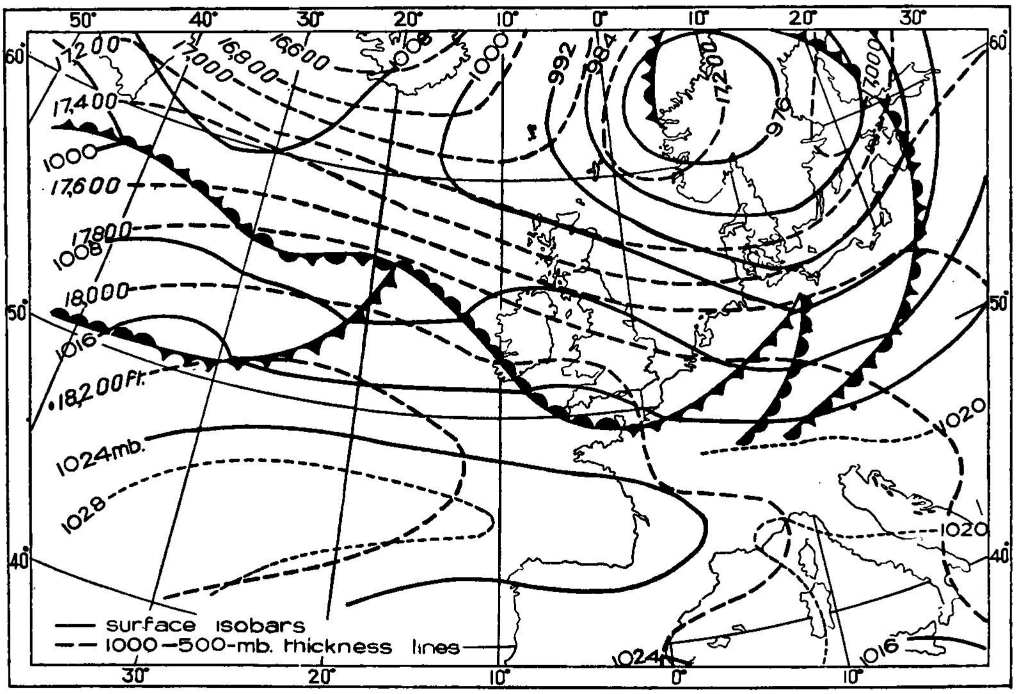

FIG. 2—SYNOPTIC CHART, 0300 G.M.T., MARCH 14, 1949

Fig. 1 in conjunction with Fig. 3 indicates the eastward motion of the main troughs and ridges in the latitude of the British Isles as maximum anticyclonic development areas occur to the east of the main ridges and cyclonic development areas occur to the east of the main troughs. Corresponding movements did in fact occur. A negative area between the Faeroes and Lerwick and a marked

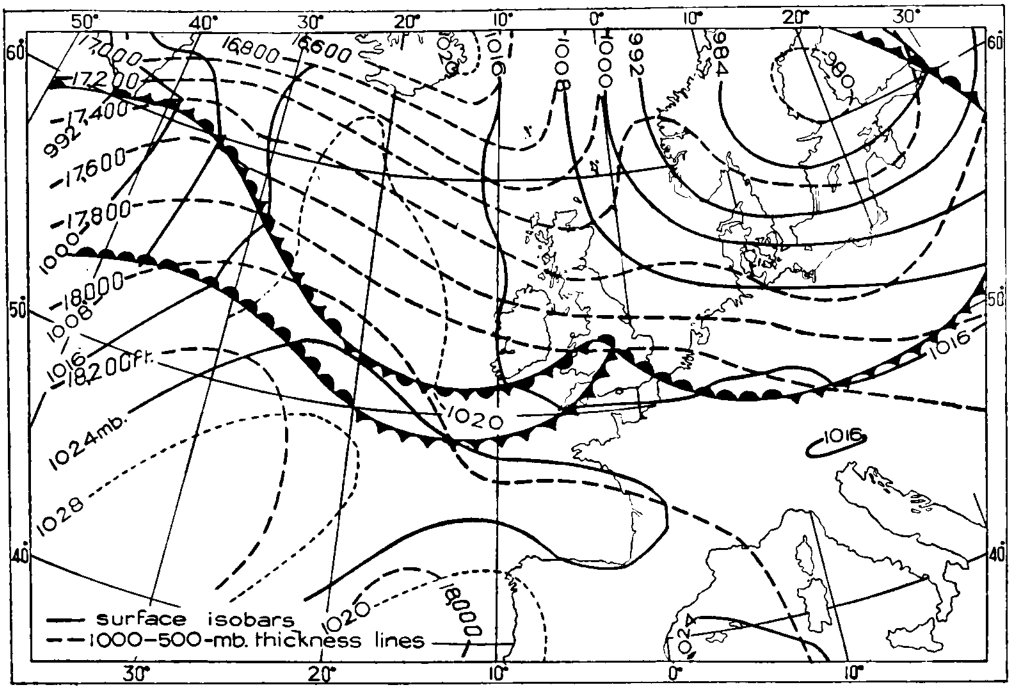

FIG. 3—SYNOPTIC CHART, 1500 G.M.T., MARCH 14, 1949

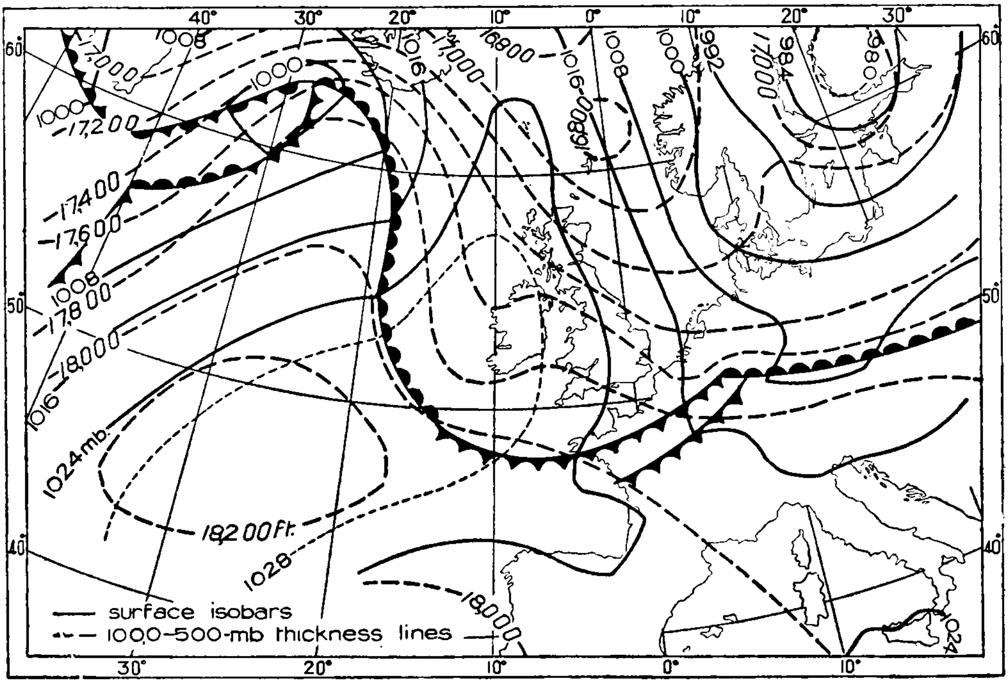

FIG. 4—SYNOPTIC CHART, 0300 G.M.T., MARCH 15, 1949

positive area slightly further west are in agreement with the formation of a cut-off cold pool to the north of Lerwick and the strengthening of the surface-pressure ridge at 10°W. Another feature of note is the negative area about 55–60°N. 30°W. A quite well marked surface trough had appeared in this region by 0300 G.M.T. March 15, with a break-away depression at 63°N. 30°W. just outside the area for which the computation was made.

Development charts were also produced for eleven other occasions so that their usefulness in various synoptic situations could be judged.

All development areas numerically greater than 40 units (10^{-3} hr.$^{-2}$) have been classified as follows, according to their value to the forecaster:—

A $\equiv$ useful guidance.
B $\equiv$ not particularly useful, but not misleading.
C $\equiv$ misleading.

The B classification has been used mainly for those development areas which were greater than 40 units but which were overshadowed by other development areas. Although this is a very subjective classification it gives some idea of the usefulness of development charts, and a summary of the results is shown in Table I.

TABLE I—NUMBER OF CASES IN EACH CLASS

A	B	C
41	36	13

There were many more development areas in class A than class C, whilst most of those in class B might have been disregarded by forecasters with experience in the use of development charts.

The more intense features on the development charts were nearly always, though not invariably, connected with an appropriate change in the synoptic situation. There also appeared to be some connexion between rainfall and maximum cyclonic development areas, but there were occasions when rainfall forecasts based on the development charts would probably have been wrong.

Features of lesser intensity are difficult to assess. They may be irrelevant, having been arbitrarily brought into the computations, either as a result of difficulties of interpolation in reading data from the charts, or from slight inconsistencies in the analysis. Alternatively, these features may be real, and if development charts were used as an aid to forecasting one would have to decide whether they were significant as individual features or whether they were likely to be swamped by adjacent, more intense, developments.

Conclusions.—Given the necessary computing facilities it is now possible to have development charts computed in about an hour from the time the initial charts are ready. It seems probable that such charts would be useful to the forecaster, although it is difficult to assess their practical value without a test under working conditions. However, if electronic facilities are available, more elaborate calculations become possible with little increase in the time involved; better estimates of vertical motion are likely to be possible than those obtained simply from development charts and therefore the introduction of electronic computing machinery for the routine calculation of development charts seems somewhat premature.

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FOG INVESTIGATION AT WELLESBOURNE MOUNTFORD

By W. W. CLEAVER and R. A. S. RATCLIFFE, B.A.

An investigation has been made into the frequency of fog at Wellesbourne Mountford based on observations for the period September 1941 to January 1946. Wellesbourne Mountford is situated in the Avon Valley some 150 ft. above M.S.L.; it is almost surrounded by low hills of the order of 300 ft. high. It is 5 miles east of Stratford-on-Avon and 10 miles south-south-west of Leamington Spa. The area within about 20 miles radius is mainly rural, the greater Birmingham area lying some 20 miles to the north-north-west. The soil is clay.

Fig. 1 shows the diurnal variation of fog frequency. The basis of the diagram is a statistical analysis of all occasions when visibility was reported as less than 1,100 yd. (excluding those cases adjudged due to heavy precipitation). Observations were divided into 5-day periods. To smooth out irregularities, means over a 15-day period were taken. Throughout Fig. 1 the percentage frequency ascribed to each 5-day period is the mean over a 15-day period and is usually based on 75 observations in the 5-yr. period.

Of the several factors affecting the formation and persistence of fog at Wellesbourne Mountford, the following two appear to be important:—

(i) Slow drainage of cooled air into the Avon Valley from the low hills surrounding the station, this may be the most important single factor.

(ii) Clay soil which easily becomes waterlogged and is usually permanently wet from late September until March.

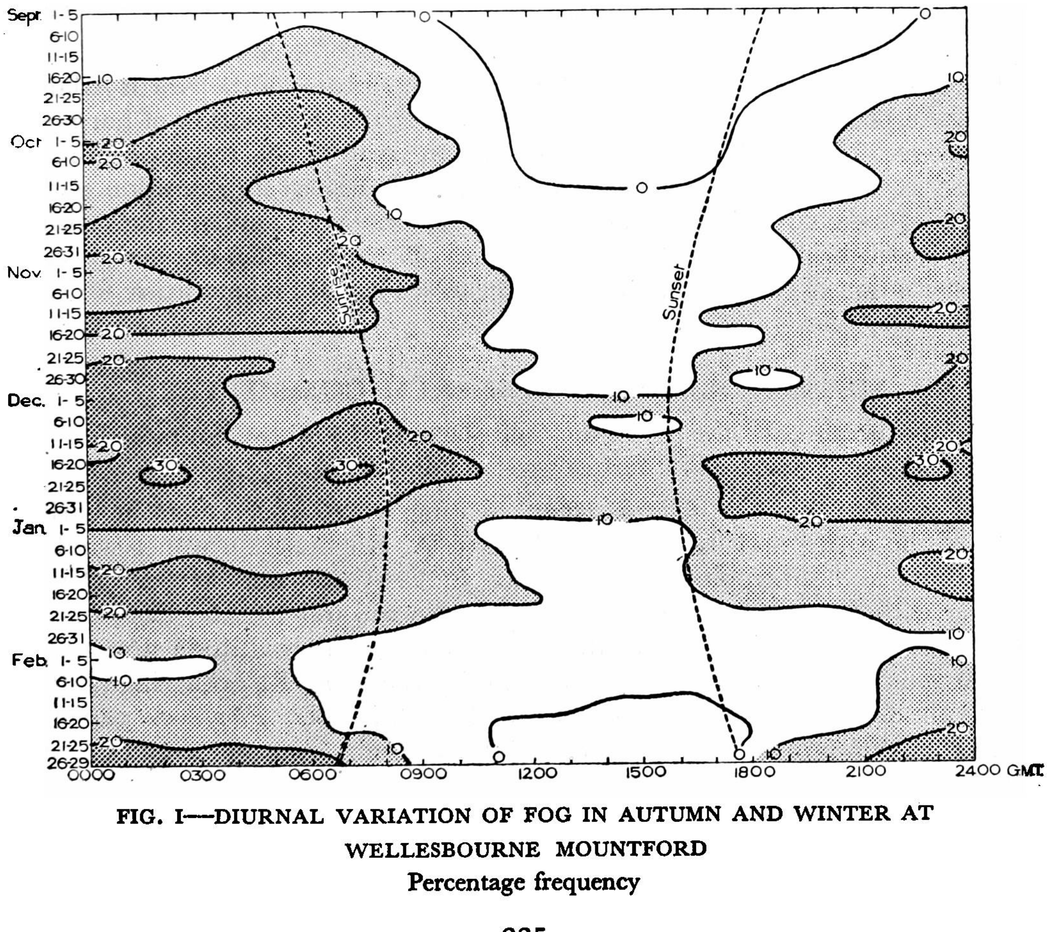

FIG. 1—DIURNAL VARIATION OF FOG IN AUTUMN AND WINTER AT WELLESBOURNE MOUNTFORD

Percentage frequency

The most interesting points in Fig. 1 are the differences between this diagram and a similar one prepared for London Airport[1]. The chief differences are:—

(i) Maximum frequency of fog at Wellesbourne Mountford always occurs immediately before sunrise, whereas London Airport has a maximum 2–3 hr. after sunrise in the winter months.

(ii) There is no minimum before sunrise in winter at Wellesbourne Mountford such as occurs at London Airport.

(iii) Higher general fog frequency at Wellesbourne Mountford.

Factors (i) and (ii) of the foregoing paragraph would appear to indicate that there is in general little smoke pollution at Wellesbourne Mountford. Fig. 1 is very akin to a similar type of diagram showing the frequency of mist at Mildenhall[2], another rural situation. Fig. 1 may well be typical of a country station uncomplicated by smoke pollution.

The high general fog frequency is therefore probably due to the valley situation and the saturated clay soil in the winter half of the year.

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OFFICIAL PUBLICATION

The following publication has recently been issued:—

GEOPHYSICAL MEMOIRS

No. 90.—Seasonal change of surface temperature of the North Atlantic Ocean. By T. H. Kirk, B.Sc.

The facts of the seasonal change of surface temperature of the North Atlantic Ocean are presented by means of charts showing the distribution of harmonic parameters. This method makes it possible to write down, by inspection, an analytic expression for the process of seasonal change at any position within the area of the charts. The influence of the various factors underlying seasonal change is also briefly discussed. A new series of charts is then derived to show the distribution of the rate of change of mean sea-surface temperature for each month of the year.

METEOROLOGICAL RESEARCH COMMITTEE

The 27th meeting of the Synoptic and Dynamical Sub-Committee of the Meteorological Research Committee was held on July 9, 1953.

The meeting was devoted to papers dealing with upper winds in various parts of the world and included one by Mr. A. Gilchrist[1] on upper winds in the tropics and subtropics, one by Miss E. E. Austin and Mr. D. Dewar[2] dealing with upper winds over the Mediterranean and Middle East, one by Mr. J. K. Bannon[3] dealing with the structure of the high-altitude strong wind belt in the Middle East in winter and one by Lieut. R. R. Fotheringham[4] on high-altitude winds over the ocean weather ship *Polar Front*. A paper by Mr. D. H. Johnson[5] on the accuracy of the 100-mb. contour height was also considered.

ABSTRACTS

1. GILCHRIST, A.; Upper winds in the tropics and subtropics. *Met. Res. Pap., London*, No. 795. S.C. II/141, 1953.

With a view to revision of "Upper winds over the world" charts showing mean winds (40°N.–40°S.) for January, April, July and October at 300, 200, 150 and 100 mb. are given, based on rawind observations and geostrophic winds mostly for 1951. Cross-sections of mean zonal winds and potential temperature are given for 80°W., 45°E., 140°E. and 165°E. All charts show a subtropical westerly jet, about 30°N. in winter, further north in summer; structure is shown for individual days. Nearer equator is a system of easterlies.

2. AUSTIN, E. E. and DEWAR, D.; Upper winds over the Mediterranean and Middle East. *Met. Res. Pap., London,* No. 811, S.C. II/148, 1953.
Monthly vector resultant winds, standard vector deviations and scalar mean velocities 1948–50 for 8 British stations between Gibraltar, Habbaniya and Nairobi, 850–100 mb., are shown in tables and plotted. A number of points are brought out, including a subtropical jet in winter.

3. BANNON, J. K.; Note on the structure of the high-altitude strong wind belt in the Middle East in winter. *Met. Res. Pap., London,* No. 821, S.C. II/155, 1953.
Upper winds and temperatures at Habbaniya and Bahrein 400–60 mb. were plotted twice daily for January 1951 (example shown January 12–14) and a mean cross-section drawn for 45°E. Position of belt of strongest winds (between lower and upper tropopauses) was estimated. The 100-kt. isokinetic is about 700 miles wide; level of maximum wind falls southwards.

4. FOTHERINGHAM, R. R.; High-altitude winds at O.W.S. *Polar Front. Met. Res. Pap., London,* No. 812, S.C. II/149, 1953.
Upper wind velocities in 66°N. 2°E., June 1948–April 1952, are plotted to show seasonal frequencies at 19,600–64,000 ft. above various speeds (80–160 kt.). There is a marked maximum at 25,000–30,000 ft. and a decrease in summer compared with other seasons. Directions are mainly westerly. Results are compared with Larkhill and Lerwick.

5. JOHNSON, D. H.; The accuracy of 100-mb. contour heights. *Met. Res. Pap., London,* No. 800, S.C. II/144, 1953.
Observed winds at 100 mb. over British Isles are reasonably accurate, and discrepancies with slope of 100-mb. levels are due to errors in the latter. Comparisons give standard error in height measurement of 100-mb. surface as 145 ft.

The 25th meeting of the Physical Sub-Committee of the Meteorological Research Committee was held on July 10.

At this meeting Dr. G. D. Robinson[1] presented a report dealing with some examples of the energy spectrum of turbulence in the atmosphere near the ground and Mr. N. E. Rider[2] described some work in which he continued an earlier investigation into the eddy diffusion of momentum, water vapour and heat in the lowest two metres of the atmosphere. A laboratory investigation into the temperature decay law of a naturally convected air stream with distance from its source of heat was described by Dr. W. Railston[3]. An experiment in the measurement of wind shear in the free atmosphere by taking a sequence of photographs of a vertical smoke trail laid by an aircraft was reported by Mr. I. J. W. Pothecary and Mr. R. J. Murgatroyd[4]. Recently the Meteorological Research Flight, in collaboration with the Clarendon Laboratory at Oxford, have made measurements of the vertical distribution of atmospheric ozone at heights up to 12 Km. A report of the preliminary measurements was presented by Dr. R. H. Kay[5] of the Clarendon Laboratory.

ABSTRACTS

1. ROBINSON, G. D.; Some examples of the energy spectrum of turbulence in the atmosphere near the ground. *Met. Res. Pap., London,* No. 808, S.C. III/151, 1953.
A number of hot-wire records of air speed, 150 cm. above ground at Kew Observatory, including large positive and negative temperature gradients were analysed by autocorrelation of readings at intervals of $\frac{1}{5}$ or $\frac{1}{4}$ sec. The three components of turbulent motion were equal (isotropic turbulence) at frequencies of 3 c./sec. to limit of observation at 8 c./sec., and energy varied as inverse square of frequency, in accord with Kolmogoroff. Horizontal components were equal above 1·5 c./sec. The local rate of viscous dissipation appeared to balance the local rate of working of Reynolds stress.

2. RIDER, N.E.; The eddy diffusion of momentum, water vapour and heat near the ground. *Met. Res. Pap., London,* No. 809, S.C. III/152, 1953.

Vertical profiles of wind, temperature and humidity 15–200 cm. above short grass at Cardington, with rate of evaporation, aerodynamic surface drag and components of heat balance, are tabulated. Eddy diffusivities of momentum, water vapour and heat are calculated. It is found that wind speed and temperature profiles always, and humidity generally, had the same form. In adiabatic conditions (Ri small) the established laboratory law for surface drag holds with $k = 0{\cdot}41$ and $Z_0 = 0{\cdot}3$ cm. In unstable conditions E. L. Deacon's generalized wind-profile law holds; in stable conditions the equations of C. G. Rossby and R. B. Montgomery, or of B. Holzman, hold. It is found that diffusivities for momentum and vapour are given by identical parameters and are equal in all conditions, but that of heat is sometimes larger.

3. RAILSTON, W.; The temperature decay law of a naturally convected air stream with distance from its source of heat. *Met. Res. Pap., London,* No. 818, S.C. III/155, 1953.

In air rising from an electrically heated 3½-cm. gauze square, temperatures were measured by thermistor at points 5–70 cm. above gauze. Rising air stream was observed by a very sensitive Schlieren system to exclude draughts. Mean temperature distribution across rising jet, corrected for radiation, was represented by

$$91{\cdot}3\ Q^{0{\cdot}675}\ Z_0^{-1{\cdot}52}$$

where Q = heat output in watts and Z_0 = height above theoretical equivalent point source. An expression was also derived for width of rising jet. Both these agreed closely with theoretical formulae due to O. G. Sutton.

4. POTHECARY, I. J. W. and MURGATROYD, R. J.; The use of aircraft to measure wind shear by observation of vertical smoke trails. *Met. Res. Pap., London,* No. 810, S.C. III/153, 1953.

Describes trails of a smoke generator falling vertically from an aircraft, producing a trail 5,000 ft. long which is observed and photographed from a second aircraft. Examples are shown and analysed, and improvements suggested.

5. KAY, R. H. (Clarendon Laboratory, Oxford); An interim report on the measurement of the vertical distribution of atmospheric ozone by a chemical method to heights of 12 Km. from aircraft. *Met. Res. Pap., London,* No. 817, S.C. III/154, 1953.

Measurements of ozone by oxidation of potassium iodide (Ehmert's method) on 13 flights are described. Amounts below 12 Km. (0·001–0·002 cm./Km.) averaged 8 per cent. of total O_3. No regular discontinuity was found at tropopause. Results compare well with Umkehr method.

The 28th meeting of the Synoptic and Dynamical Sub-Committee of the Meteorological Research Committee was held on July 22, 1953.

At this meeting the Committee discussed a paper by Mr. J. S. Sawyer and Mr. F. E. Dinsdale[1] on cloud in relation to active warm fronts, and a paper by Mr. D. H. Johnson and Miss Sylvia Daniels[2] on rainfall in relation to the jet stream. Two interesting papers analysing observations made by the Meteorological Research Flight were also considered. The first by Mr. J. S. Sawyer[3] discussed the free atmosphere in the vicinity of fronts and the second by Mr. R. Murray[4] discussed the upper troposphere and lower stratosphere near jet streams. The problem of standing waves and dangerous flying conditions near mountains was also considered.

ABSTRACTS

1. SAWYER, J. S. and DINSDALE, F. E.; Cloud in relation to active warm fronts near Bircham Newton during the period April 1942 to April 1946. *Met. Res. Pap., London,* No. 799, S.C. II/143, 1953.

Clouds observed by airplane were classified and analysed statistically. Results confirm that cloud increases towards front. There is some increase with increasing frontal slope and with decreasing pressure thickness of frontal zone. Cloud is mainly in warm air more than 200 miles from front, but extends down through frontal zone nearer the surface front. Positive relations were found with speed difference between surface and upper wind normal to surface front and with speed differences of warm air and surface front.

2. JOHNSON, D. H. and DANIELS, S.; Rainfall in relation to the jet stream. *Met. Res. Pap., London,* No. 803, S.C. II/145, 1953.

Rainfall in British Isles was tabulated against position in regard to axis, entrance, centre and exit of jet streams. Means per hour: entrance, left of axis 0·9 mm., right 1·8 mm.; centre, left 2·4, right 2·3; exit, left 4·6, right 2·3. Amounts within 50 miles of axis generally small. The preponderance of rainfall to right of confluence and left of diffluence implies mean cross-axis vertical circulations with ascent beneath the right entrance and left exit, and descent beneath left entrance and right exit, in accord with dynamical theory.

3. SAWYER, J. S.; The free atmosphere in the vicinity of fronts—analysis of observations by the Meteorological Research Flight, 1950–52. *Met. Res. Pap., London,* No. 807, S.C. II/147, 1953.
Analyses 23 flights to study structure of fronts, with temperature and frost-point profiles, synoptic situations and cross-sections. Discussion deals with thermal, humidity and cloud structure and turbulence (not especially great except in convective clouds), illustrated by frequency histograms. Results showed the great complexity of frontal regions. Fronts are associated with a sloping baroclinic zone; about half the temperature contrast lies within a width of 100–200 miles. Irregularities of temperature of 1–5°F. are associated with condensation, precipitation and evaporation. Main frontal cloud usually forms in warm air and extends into transition zone.

4. MURRAY, R.; The upper troposphere and lower stratosphere near jet streams: an examination of observations made by the Meteorological Research Flight, Farnborough. *Met. Res. Pap., London,* No. 813, S.C. II/150, 1953.
From 20 special flights near jet stream and synoptic studies it is found that: (i) mean temperature gradient was 3°F./100 n. miles, and structure agreed with that normally given by vertical sections; (ii) frost point was variable; average relative humidity at jet-stream level was 50 per cent. 300 miles to right of axis (looking down wind) and 10 per cent. 300 miles to left; (iii) layer cloud occurred to right of axis but not to left or above, consistent with ascent in troposphere on high-pressure side and descent on low-pressure side; (iv) tropopause on low-pressure side is sometimes disrupted. Occurrence of clear-air turbulence is also discussed.

INSTITUTE OF NAVIGATION

At the meeting of the Institute of Navigation held on June 26, 1953, papers were read by Mr. D. G. Harley on "Equivalent tailwinds Shannon–Gander on actual and forecast charts" and by Mr. C. S. Durst on "The accuracy of wind forecasts for aviation".

Mr. Harley described the results of a comparison between forecasts prepared at the meteorological office, London Airport, of tailwinds for west-bound flights across the Atlantic Ocean to Gander along the great circle route and subsequent estimates of the same winds from the isobaric contour charts drawn up for a time during the currency of the forecast. The forecast charts are composite charts so that the time of validity varies along the route. The time interval between the taking of the observations on which the forecast is based and the period of validity also varies along the route; it is about 20–24 hr. at the mid point. The work was done for the 700-mb. and 500-mb. levels for the period April 1949 to May 1953. The forecasts were made in the conventional manner by drawing predicted contour charts and measuring geostrophic winds on them. Seasonal means of the equivalent tailwinds were given for each year. These means showed a considerable variation from year to year, but on the whole the monthly means at 700 mb. were about −28 kt. (i.e. headwind) in winter, the season of strongest winds, and −12 kt. in spring, the season of lightest mean winds; corresponding values at 500 mb. were −40 kt. in winter and −17 kt. in spring. The standard deviations were about half the means except in spring when they approximated to the mean values. Extreme values were, at 700 mb. −68 kt. and +29 kt. and at 500 mb. −124 kt. and +35 kt. Comparison of these estimated actual winds with those forecast and of those forecast with the winds found by the aircraft is very difficult for several reasons. However, subject to some uncertainty, the mean seasonal differences between forecast tailwinds and values subsequently estimated are less than 2 kt. in absolute magnitude at both levels with standard deviations of from 6 to 13 kt. The differences satisfy the normal law of errors. A curve of the percentage frequencies of errors less than specified amounts showed that only 5 per cent. of the differences in winter, the worst season, exceeded 25 kt. at 500 mb. or 18 kt. at 700 mb., and it was pointed out that many large errors were associated with headwinds too strong for a direct crossing to be attempted. Appreciable errors are often associated with the timing of new developments. Finally, Mr. Harley compared the errors found with those to be expected from other methods. It appeared that the conventional forecasting methods over the North Atlantic route gave standard errors about 1 kt. less than those to be expected from a regression equation technique and nearly 2 kt. less than those to be expected from using "actuals" as forecasts.

The main theme of Mr. Durst's paper was the accuracy of forecasts of upper winds issued to pilots shortly before departure, with illustrations from the forecasts for flights of Comet aircraft at 40,000 ft. between London and Rome. Special attention was directed to the accuracy necessary in forecasting upper winds in relation to the accuracy of navigation in flying at great heights. Mr. Durst pointed out that the standard error of forecasts by conventional contour analysis of winds at 40,000 ft. was about 15 kt. at one point and rather less for a mean wind over a distance. In equatorial regions between about latitude 20°N. and 20°S. the contour technique could not be used, and measured winds provided the only reliable information. The high cost of upper air observing stations makes it essential for them to be situated where their observations will be most useful. A major factor is the variability of wind which, represented by the standard deviation of departures from the mean, has been charted in *Geophysical Memoirs* No. 85. The variation of wind in any given period and the errors of forecasting are proportional to the standard deviation. Mr. Durst then described the results of a check of the accuracy of the assessment of the tailwind at 40,000 ft. on the route from London to Rome, of the accuracy of forecasts, and the accuracy of winds found from aircraft navigation. The forecasts were based mainly on observations made about 12 hr. before the flight and were issued 2 hr. before the take-off. Comparison of assessments of the actual wind made independently from the same data gave a root-mean-square difference of 7·5 kt. between the two assessors. From this it is concluded that the error of a single assessment is between 5 and 6 kt. The root-mean-square difference between the forecast equivalent headwinds and the actual winds as subsequently assessed from the chart came to between 12 and 14 kt., which, allowing for assessment errors, gives a standard forecast error of 11 kt. The differences between forecast equivalent headwinds and those found by the aircraft however are as large as 20 kt., which suggests the standard error in "found" headwinds is of the order of 15–18 kt., a value somewhat larger than the standard error in the forecast winds. On the other hand another analysis by H. Keeling had given a standard error in headwinds calculated from flight data of only 8 kt. and of forecast winds of 15–18 kt.

In the final part of his paper Mr. Durst discussed the accuracy of wind forecasts over air routes in different parts of the world from known standard deviations of upper winds and gave advice on the location of upper air observing stations for maximum benefit in air-route forecasting. It emerged amongst other things, that if only one observing station can be provided it should be placed in the centre of the route, and would then be more useful than two stations, one at each end and none in between. The relation between the radius of action of homing aids and the accuracy of wind information was also described in detail. A major point raised in the paper is the accuracy of wind forecasts desirable in relation to the accuracy of navigation, for, if the latter is appreciably less than the former, expensive efforts to increase the accuracy of the wind forecasts are difficult to justify. Much of the discussion dealt with the accuracy of navigation. On the meteorological side Dr. Sutcliffe pointed out that, apart from immediate application in aerial navigation, upper air observations were essential for progress in dynamical understanding of the atmosphere. Publication of the full papers in the Institute's Journal for January 1954 will be awaited with much interest.

LETTERS TO THE EDITOR

Heavy Storm at Changi

A violent thunderstorm occurred at Changi during the afternoon of April 20, 1953, when 149 mm. of rain fell between 1350 and 1520 zone time (G.M.T. + 7). Of two hyetograms which are available, the one from the standard tilting-siphon recorder is undecipherable, but the other, from a standard recorder restricted to measure at 1/5 the normal rate, is well marked and easily analysed. The trace (Fig. 1) shows that the rate of fall was remarkably steady over a period of 40 min. at very nearly 150 mm./hr.

During the storm frequent lightning flashes were observed between cloud and earth, with heavy thunderclaps. The main fuse in the power supply to the cup generator anemometer was burnt out, and a soldered joint in the junction box at the cable terminal was broken down. It is not believed that the anemometer received a direct lightning stroke. The damage is thought to have been caused by induced currents produced by a very near discharge. A number of the staff were watching the anemometer when, simultaneously with a lightning flash and a deafening thunderclap, considerable sparking was seen at the rectifier and other electrical parts.

During the storm the surface wind was variable in direction and between 8 and 17 kt. in speed. The maximum gust observed was 27 kt. at 1506. Visibility was reduced to 100 yd. between 1430 and 1500.

The local nature of the storm is shown by the following total rainfall figures (0700–0700) for stations on Singapore Island for April 20.

	mm.
Changi	149
Kallang (12 miles west of Changi)	5
Seletar (10 miles west-north-west of Changi)	1
Tengah (25 miles west of Changi)	30

At 0700 on April 20 a line of convergence, at least up to 12,000 ft., was lying north-west to south-east across the Malayan Peninsula and extended to the east of Singapore Island, separating the westerly air stream over the Indian Ocean from the Pacific easterlies, the two streams gradually curving to become north-west and north-east, respectively. The eastern coastal stations of Malaya were reporting easterly winds. No significant change had taken place by 1300, but by 1900 the convergence line at the surface had moved south-westwards to be lying along the western seaboard of Malaya and Singapore Island. Easterly winds up to 2,000 ft. had spread in over south Malaya, although at 3,000 ft. and above the stream was still west to north-west. Both air streams

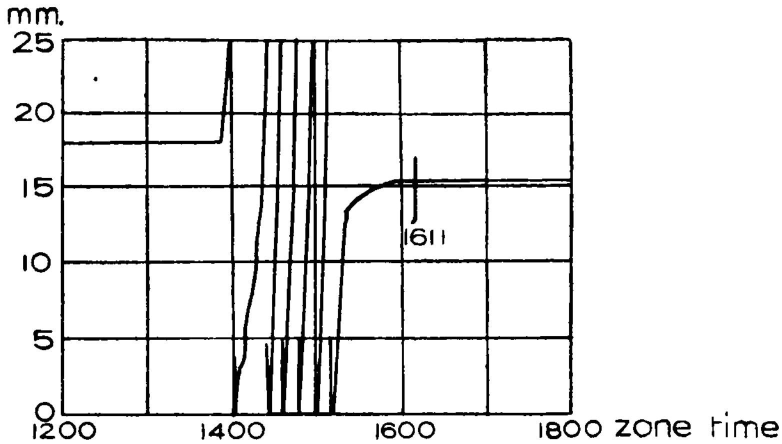


FIG. 1—HYETOGRAM FROM CHANGI, APRIL 20, 1953

being conditionally unstable, the immediate cause of the occurrence seems to be found in the impulse provided by the onset of the easterly sea-breeze over the extreme south-east of Malaya. By 1600 the surface wind at Changi had become light and variable.

This local occurrence is not considered to be a rare one for this region by any means. The main interest attached to it lies in that, being so severely local in its effect, it should have taken place exactly over a location equipped with recording instruments.

Changi, Singapore, April 20, 1953 W. G. PALMER

Unusually vigorous cumulonimbus cloud over southern England

Between 1645 and 1655 G.M.T. on July 1, 1953, reports were received by the meteorological office at Farnborough from pilots of four experimental aircraft of a cumulonimbus cloud top reaching to at least 40,000 ft. in a position about 20 miles east of Farnborough. All these pilots indicated that the speed of development of the cloud had been exceptional in their experience, which was in all cases considerable. The report of Sqd.-Ldr A. W. Bedford, an observer of considerable reliability, is of particular interest.

Sqd.-Ldr Bedford approached the cloud at 29,000 ft. trimmed for level flight, and during his traverse of the cloud was thrown up to 38,500 ft. in a time estimated to be between half-a-minute and a minute. During the traverse conditions were turbulent and visibility "comparatively good". There was no airframe icing though there were indications that the pitot head had iced up inside despite use of the pitot-head heater. On leaving the area the top had reached 42,000 ft.

After his traverse Sqd.-Ldr Bedford descended to cloud base in the Leatherhead area, and observed heavy rain and lightning beneath the cloud. He reports that there were dark, ragged fragments of cloud beneath the main mass being lifted into the cloud in a powerful vortex motion.

The meteorological office at Croydon reported at this time that a funnel-shaped cloud extended from the base of this cloud, 5,000 ft., to within 800 ft. of the ground, and that forked lightning discharges were frequent from the sides of the funnel cloud. This condition persisted for about 5–10 min.

Farnborough approach radar had the cloud under observation between about 1630 and 1720, and reported that the top of the echo was generally about 40,000 ft., and that the original single cumulonimbus was developing into a large, L-shaped complex having a general westerly motion of 15–18 kt.

The meteorological radar station at East Hill, Dunstable, reported that the tops of the echo were at 43,000 ft. and that the echo tops grew at a rate of 2,000 ft./min.

On this day the afternoon radio-sonde ascent from Crawley, West Sussex, showed a general tropopause level of 37,000 ft., so that it appears that this cloud penetrated into the stratosphere. However, recent work by Dr. James[1] of the Meteorological Research Flight and earlier work by Mr. D. R. Grant[2] have indicated pools of cold air lying over the tops of convective cloud, the temperature differential having a maximum value of 5–6°F. at low levels. In the case in question a pool 15–20°F. colder than the surrounding air would be necessary to raise the tropopause locally to 43,000 ft. Since the vigour of development was so great it is possible, however, that there may have been the usual pool 5–6°F. colder than the surrounding air raising the local tropopause to about 39,000 ft., and that the cloud did in fact overshoot into the stratosphere.

Other points worthy of note arise from Sqd.-Ldr Bedford's observations. First, if his assessment of the time of traverse is correct he encountered a mean up-draught of about 150 ft./sec. It is, of course, extremely difficult to estimate time intervals in such circumstances, so that if a reasonable lateral dimension is assumed of 10 miles for the cloud at the mean height of traverse, a time of traverse is reached of about 2 min. from his known indicated airspeed. Thus a probable value of about 80 ft./sec. is obtained for the mean up-draught. Even this value is very high since Byers and Braham[3] quote a maximum up-draught speed of 84 ft./sec. for the Project Thunderstorm flights. Further, they report that only 2 per cent. of up-draughts encountered during this series of flights caused displacements greater than 3,000 ft., and on only two cases was the displacement greater than 5,000 ft. The values obtained above for the up-draughts encountered by Sqd.-Ldr Bedford are dependent, of course, on that assumed for the lateral dimension of the cloud, but it is considered that the latter was probably a maximum value since Farnborough approach radar reported the echo dimensions to be 5 by 4 miles at the height of traverse.

Secondly, if in fact the pitot head did ice up there must have been super-cooled cloud droplets present at least at 29,000 ft., i.e. at a temperature of about −30°F., an unusually low figure which must presumably be associated with the unusual vigour of the up-draught.

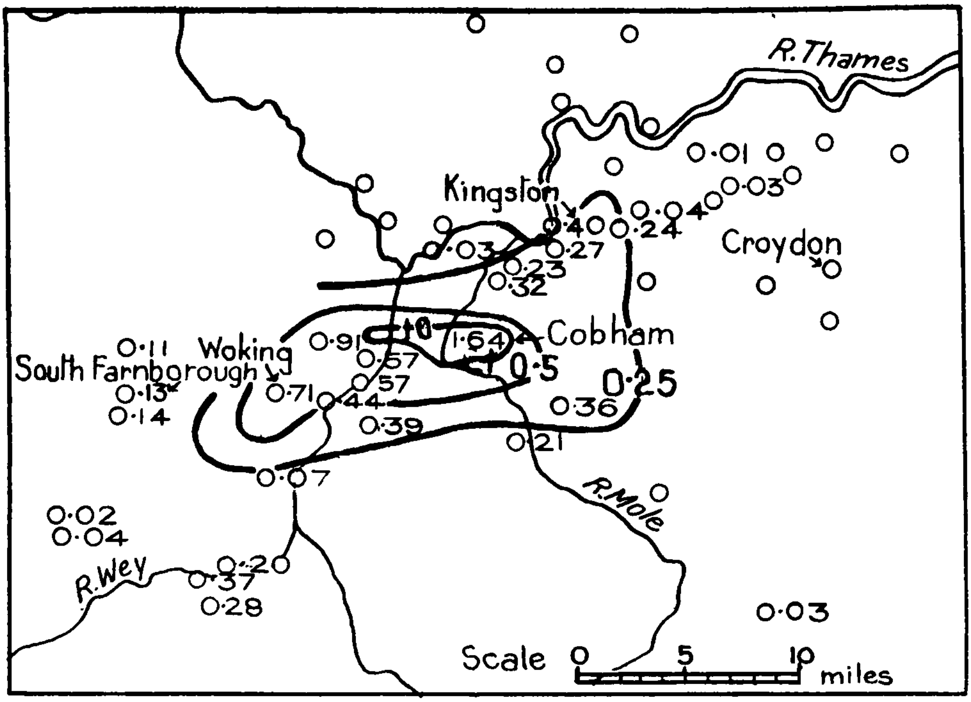
G. J. DAY

Farnborough, July 25, 1953.

REFERENCES

1. JAMES, D. G.; Typescript. Meteorological Office, London, 1953.
2. GRANT, D. R.; Fluctuations of temperature in clear air as recorded by an ultra-rapid thermometer. *Met. Res. Pap., London,* No. 658, 1951.
3. BYERS, H. R. and BRAHAM, R. R.; The thunderstorm, *Washington D.C.,* 1949.

[Thunderstorms with very heavy rain in places occurred over north Surrey on the afternoon of July 1. For most of the following information we are indebted to the Chief Engineer, Surrey County Council. The largest reported amounts of rain were 1·64 in. at Cobham Sewage Works and 0·71 in. at Goldsworth Road, Woking. Autographic rain-gauges maintained by the County Council showed that 0·24 in. fell at Raynes Park in 6 min. (1620–1626), 0·44 in. at Woking in 30 min. (1627–1703) and 0·40 in. at Kingston in 12 min.



Rainfall amounts given in inches

FIG. 1—RAINFALL DISTRIBUTION OVER NORTH SURREY, JULY 1, 1953

(1633–1645). The rainfall distribution is shown in Fig. 1. Mr. G. Nicholson of Stanley Road, Teddington, Middlesex, writes to the British Rainfall Organization that the first sign of a thunderstorm was a towering cumulus over Tolworth, Surrey, at 1445 G.M.T. Torrential rain fell in the Kingston area for about 12 min. at 1640, flooding roads. The edge of the rain area was very sharp: heavy rain fell at Atbara Road, Teddington, but 30 yd. north it was completely dry. At South Farnborough 0·13 in. (3·4 mm.) fell between 1815 and 1851 G.M.T.; the maximum rate of fall indicated by the Meteorological Office rate-of-rainfall recorder was 0·69 in./hr. (17·5 mm./hr.).—Ed., *M.M.*]

NOTES AND NEWS

Thunderstorms of June 26, 1953

Thunderstorms which gave very heavy rain and hail at many places broke out during the late morning and afternoon of June 26, 1953, over much of England, Wales and southern Scotland. The day will be remembered for the number of falls ranking as "very rare", "remarkable" or "noteworthy" which were reported from Renfrew to south Wales and Essex.

A weak ridge of high pressure extended north-east from the Azores to north-west of Scotland and a shallow complex area of low pressure covered the Continent. Surface winds over the British Isles were light to moderate from N.–NE. Over the western half of the British Isles the upper winds backed with height to between W. and S. and rose to about 18 kt. at a height varying at 1400 G.M.T. from 18,000 ft. over Liverpool to 8,000 ft. over Aldergrove. A weak quasi-stationary front extending south from Iceland moved slowly east across Ireland during the day. The lapse rate over Liverpool at 1400 equalled or exceeded the saturated adiabatic value between about 900 mb. (3,500 ft.)

and 500 mb. (18,900 ft.) and again from 400 mb. (24,300 ft.) to the tropopause at 250 mb. (34,600 ft.). The morning was sunny and surface temperatures exceeded 75°F. at most inland stations by midday. This temperature was high enough for it to be possible for convection currents to develop from the lower layers up to the tropopause. The ascent was doubtless helped by some convergence between the northerly and south-westerly air streams.

Floods occurred in many districts. The rain was particularly heavy in the Lake District and over south-west Scotland. At Eskdalemuir 3·15 in. of rain fell in 30 min. between 1333 and 1403 and 3·54 in. in the longer period of 55 min. These falls, which are well within the "very rare" category—unlikely to occur more than once in 160 yr. at the same place—have never been exceeded for amount amongst measurements for 55 min. or less as recorded in *British Rainfall* during the past 80 yr., but there have been instances of greater intensity of fall over shorter periods, such as 1·25 in. in 5 min. at Preston on August 10, 1893, and 1·88 in. at Ferriby Sluice, Lincolnshire, in 15 min. on September 14, 1943.

The account of the storm at Eskdalemuir has been extracted from information provided by Mr. Ian Grant of the Observatory staff to whom we are also indebted for the photographs at the end of this number of the Magazine.

The hills round the Observatory were quickly covered with an inch or so of water, and mountain streams were turned into raging torrents. Some stone walls were knocked down by the first rush of water and several bridges over the River Esk were broken. The Esk Valley was flooded under 6 ft. of water. Considering the intensity of the fall—equivalent to nearly a gallon of water per second on a patch 10 yd. square—there was surprisingly little damage though it should be pointed out that the moor is uncultivated and virtually uninhabited.

The total rainfall for the day was 4 in. at the Observatory, 3 in. at Eskdalemuir village (3 miles south of the Observatory), 2 in. at Ettrick (10 miles north of the Observatory) and 3·3 in. in the Daer Valley, south Lanarkshire (17 miles west-north-west of the Observatory).

At Eskdalemuir Observatory the early morning had been fine and exceptionally warm (69°F. at 0800), but subsequently altocumulus cloud increased to about half cover. Towards noon cumulus began developing rapidly—3 oktas of large cumulus at 1100 and 6 oktas of cumulonimbus at 1200. The actual timing of the rain can be given accurately as the recording rain-gauge was time marked both before and after the heaviest downpour. Distant thunder was heard about 1130 G.M.T., and the storm moved steadily nearer. Heavy rain began quite suddenly at 1222 and continued for 35 min.; then it died away and stopped altogether at 1302, by which time 0·29 in. had fallen; this was probably enough to saturate the ground, which tends to be rather boggy in all but the driest weather. Thunder and lightning continued, and after 27 min. heavy rain began again at 1329; by 1333 it had reached or surpassed tropical intensity, and this violent downpour continued for a further 30 min., in which time 3·15 in. was recorded. After 1403 the rain steadily decreased in intensity.

During the heaviest rain (which was accompanied by some hail) it was almost impossible to stand out-of-doors. The wind was gusty, 20–30 kt. (maximum gust 49 kt.), visibility was down to 200 yd. or less, and the air was filled with spray. If a door was opened even a few inches, this spray drifted in and saturated everything in a matter of seconds, while outside a raincoat was no protection. At about 1345 the observer, Mr. Hogg, ran out to the Stevenson screen to read the thermometers; he was out less than a minute, but in this time he was soaked to the skin, even though he was wearing a waterproof coat.

By 1340 the ground was covered with approximately an inch of water, and streams and rivulets were beginning to form; five minutes later three inches of water was running across the instrument enclosure (this was part of a "river" carrying water away from the higher ground 150 yd. to the north-north-west). Flooding in the Observatory grounds was at its worst by about 1400; the position then is shown in the accompanying diagram. The Observatory, which is at the top of a small hill 800 ft. above sea level and about 120 ft. above the Esk Valley, is surrounded by a stone wall enclosing approximately 12½ acres. It seems fair to assume that flooding in the grounds was caused entirely by rain which fell within this area; the "rivers" originated in the north-western half which is fairly flat, and ran towards the main gate which is in the south-east corner and some 30 ft. lower.

After 1403 the rain continued fairly heavy till 1412 (0·20 in. in 9 min.), but by 1430 it had decreased to moderate (rainfall 1412 to 1522, 0·25 in. in 70 min.); however water continued to run off the grounds till 1530 or later. But the worst was over by then, and by 1600 even the level of water in the valley was falling.

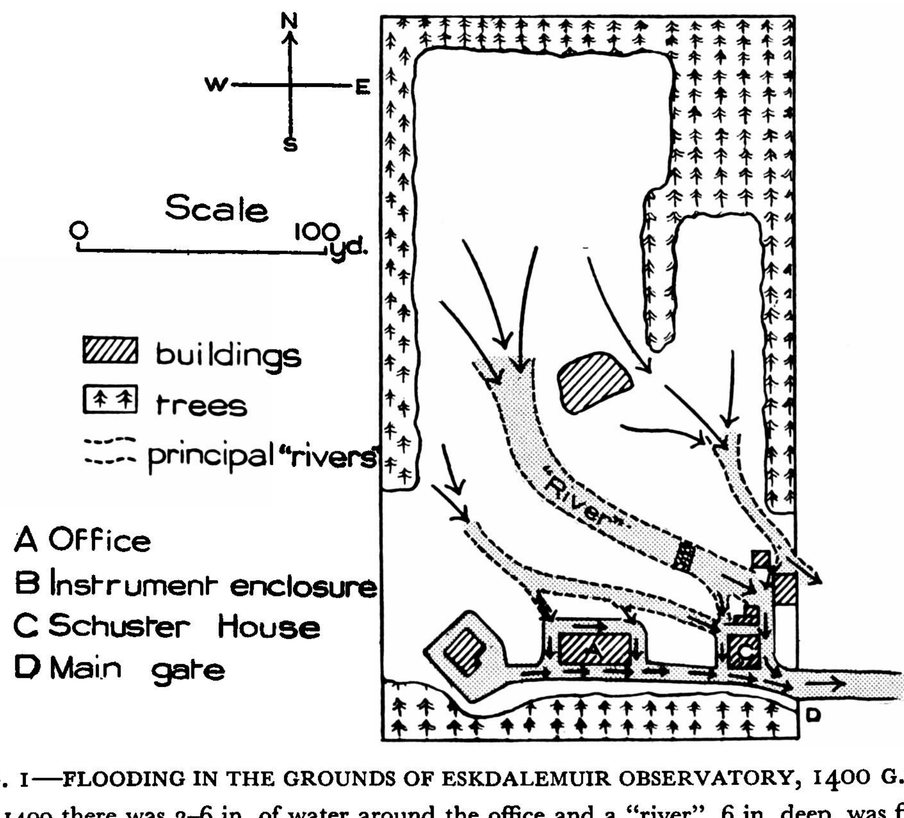


FIG. 1—FLOODING IN THE GROUNDS OF ESKDALEMUIR OBSERVATORY, 1400 G.M.T.

At 1400 there was 3–6 in. of water around the office and a "river", 6 in. deep, was flowing across the instrument enclosure. On the west side of Schuster House the water was 6 in. deep while on the east side the main "river" 6–12 in. in depth flowed rapidly. At the main gate the water reached 12 in. in depth. The grounds generally were under 2 in. of water.

Four other falls were reported for the 26th which rank as "very rare": 2·84 in. in 55 min. at Holehird in the Troutbeck Valley, Windermere; 1·72 in. in 15 min. at Nelson, Lancashire—a rate of 6·88 in./hr.; 2·09 in. in 39 min. at Langley, Trentbank Reservoir, Upper Mersey, Cheshire; 2·10 in. in 35 min. at Langham Waterworks, near Colchester.

At Troutbeck a wall of water 7 ft. high was reported to have come down the bed of a small stream and a man was drowned. Very intense rain was also observed at the north-west end of Lake Vyrnwy where bridges and roads were carried away. No direct rainfall observations are available for the storm period, but the Chief Engineer to the Liverpool Waterworks has estimated a fall of 3·00 in. in 90 min. near the centre of the storm, of which 2·00 in. probably fell in 30 min.

REVIEW

The theory of homogeneous turbulence. By G. K. Batchelor. 8¾ in. × 5¾ in., pp. xi + 197. *Illus.*, Cambridge University Press, Cambridge, 1953. Price: 25*s.* net.

Much of the recent work on turbulence is scattered in many different journals which are not always easy to assemble together, particularly for a meteorologist who is on an outstation. Dr. Batchelor has performed a real service in gathering the main results of recent research into a connected account in one volume.

The book is divided roughly into two parts: the first part, chapters II to V being mainly mathematical and the remaining chapters, VI to VIII, being much more physical in outlook. There is an introductory chapter defining homogeneous turbulence, and introducing the basic equations that are to be used. Homogeneous turbulence, as its name suggests, is turbulence in which the mean properties of the random motion are independent of position; this largely means that the experimentally measured properties of the random motion are independent of position, for an instrument usually measures a mean property. The basic equations of the flow, the equations of continuity and Navier-Stokes, are familiar to all meteorologists; the main difference is that most often the meteorologist is concerned with much larger-scale motions, so that his equations include the effect of the earth's rotation and neglect the viscosity effect. However, in much of the book the Navier-Stokes equations are in the background, acting mainly as a check on the size of the phenomena which are investigated.

In chapters II to V the author sets up a mathematical model and investigates the consequences. First he defines what he means by "average", a point which has sometimes not been stressed sufficiently in work on atmospheric turbulence and which is of importance in interpreting experimental results in the light of theory. The main tools used are Cartesian tensors and Fourier transforms; the main results concern correlations and the distribution of energy over the spectrum of eddy size. Chapter II deserves close study before proceeding to the kinematics of the motion in chapters III and IV. The conditions of homogeneity restrict and simplify the form of the tensors which arise in the theory; in particular axisymmetric and isotropic turbulence are defined, and isotropic turbulence considered in detail. The definition of isotropic turbulence is mathematical (a considerable restriction on the form of the tensors which arise) and leads to predictions; experimental evidence provides non-negative rather than positive proof of the existence of isotropic turbulence. The evidence is mainly drawn from wind-tunnel experiments, but it is clear that isotropic turbulence is not confined to such experiments. Chapter V deals with the decay of turbulence; it is not as formidable as it looks, and contains much of interest to the meteorologist in the flow of energy in turbulent motion and its final dissipation.

The remaining chapters contain much more physical argument. Bearing in mind the author's article in the *Quarterly Journal of the Royal Meteorological Society** meteorologists will want to study chapter VI, which is concerned with Kolmogoroff's theory of similarity. There are roughly two parts of the turbulent motion contained by the smaller eddies, one which dissipates the energy by viscous processes and one in which negligible dissipation occurs, so that the transfer of energy is largely caused by inertia forces. The latter will be the more important to the meteorologist who will want to examine the various hypotheses that are discussed. The author is very careful to differentiate between what follows from the theory which he has set up in the previous chapters and what is newly imported, and does not ride any particular hobby-horse. Chapter VII deals with the eddies which contain the principal part of the energy, and, being largely independent of the foregoing theory, provides a valuable survey of the experimental work which has led to a knowledge of the distribution of energy and its dependence upon initial conditions. Since it is found generally in wind-tunnel experiments that the turbulence settles down very quickly to a statistical state with about 80 per cent. of the total energy distributed approximately independently of the initial conditions, it seems that something of this sort may occur in atmospheric turbulence, so that the meteorologist will want to examine this chapter. The hypotheses advanced in explanation are examined carefully. The final chapter on the probability distributions continues the review of experimental work, and the results resemble those concerning the correlations of temperature and wind with much larger scales of distance and time in the atmosphere.

These few remarks can only give too brief an idea of the scope of the book and its appeal to meteorologists. It is not written with any chosen applications in view, but there is much of deep interest for us here and also much that is enlightening. Many of the problems concerning turbulence in the atmosphere are concerned with transfer or diffusion; the author excludes such problems in this book. We can only hope that he will provide another companion volume dealing with turbulent diffusion.

The book itself is intensively written so that it will require much study. It will not do to borrow a copy for a short time and it is not particularly expensive. The publisher's name is a guarantee of beautiful printing and display, and there are only a few trivial misprints, e.g. on pp. 37, 38 and 86, and surely a mis-statement concerning the exponential term in 5.4.4.

E. KNIGHTING

RETIREMENT

Mr. John Crichton retired from Eskdalemuir Observatory in July. It is natural to speak of him retiring from the Observatory because more than half of his 34 years in the service of the Meteorological Office have been spent at the two observatories Lerwick and Eskdalemuir, and for the past 14 years he had been continuously at Eskdalemuir. To visitors to Eskdalemuir and to large numbers of Office staff who, at some time, have been stationed there it

*BATCHELOR, G. K.; The application of the similarity theory of turbulence to atmospheric diffusion. *Quart. J. R. met. Soc., London*, **76**, 1950, p. 133.

must be difficult to think of the place without John Crichton as Superintendent. Civil servants are sometimes accused of being moulded into a standard pattern, but no one can be imagined further removed from the comic paper caricature of the civil servant than Crichton. In dress, in blunt speech and in rugged independent thought he conformed to no conventional type.

He joined the Meteorological Office after service during the 1914–18 war in the "Met" sections of the R.N.V.R. and the R.F.C., chiefly at airship stations. In 1921 he was selected to be the officer-in-charge of the new magnetic observatory in the Shetlands near Lerwick, and he worked literally like a navvy in establishing the work there. Observatory work was his absorbing interest, but he worked at times in the Forecast Division and at Edinburgh.

In 1939 while stationed in the Forecast Division he suffered the amputation of a foot, the result of his diabetic complaint. He refused to be crippled by this, and on the outbreak of war was posted again to Eskdalemuir where he led a very active physical and mental life until the amputation of his other foot early this year caused him to seek retirement. To this second cruel blow he is dauntlessly accommodating himself, driving a car and very actively engaged in setting up a new home in Kirkcudbright. All who have served with him will wish him and Mrs. Crichton much happiness in their new surroundings.

NEWS IN BRIEF

The L. G. Groves Memorial Prize for Meteorology has been awarded this year to Mr. R. F. Jones, B.A., Principal Scientific Officer, Meteorological Office, East Hill, who has made a special study of the employment of radar technique for examining the internal structure of cumulonimbus clouds. Simultaneous measurements of vertical acceleration by aircraft flying through the cloud have also provided a more detailed knowledge of the conditions to be expected by pilots than was previously available. Mr. Jones has also made a study of the turbulence which occurs in the upper atmosphere outside clouds, and he has been able to show that some at least of the occasions of occurrence of such turbulence can be explained in terms of the irregularity of temperature and humidity distributions. These results have a direct application to the safety and comfort of high-speed flying.

The L. G. Groves Memorial Award for Meteorological Air Observers has been awarded to Sergeant G. N. Franklin (3127399) Royal Air Force, for meritorious work and devotion to duty with No. 202 Squadron. He trained as a meteorological air observer in January 1951, and since then he has flown consistently at Gibraltar and Aldergrove, completing no less than 87 meteorological sorties involving 1,130 flying hours. He has also for some time carried out the duties of Squadron Meteorological Air Observer Leader remarkably well, gaining by his example of keen interest and enthusiasm the respect and admiration of the whole Squadron.

METEOROLOGICAL OFFICE NEWS

Ocean weather ships.—The ship's company of *Weather Observer* celebrated her 50th voyage as an ocean weather ship at a dinner and dance in Greenock on September 3, 1953. *Weather Observer* was formerly H.M. Flower Class Corvette *Marguerite*; she was launched in July 1940, and was engaged on convoy escort duties in the North Atlantic and other theatres during the last war. She was the first of the British ocean weather ships to put to sea and she sailed her first voyage to station JULIETT on August 1, 1947. At the dinner there was a good attendance of staff from all departments of the ship with their lady guests. At the head table, in addition to Captain Sobey and his wife, were seated four who had served continuously in the ship for the 50 voyages; Mr. Gascoyne, Chief Steward; Messrs. Dunning and Sharland, Radio Mechanics and Mr. Clifton, Bo'sun. The fifth veteran (Mr. Lambert, Radio Overseer) was unavoidably absent. Cmdr Frankcom, Marine Superintendent, was the guest of honour. Mr. Gaskin (Meteorological Assistant) was master of ceremonies and under his guidance the party was an enormous success.

Academic successes.—To the lists published in the October number should be added:—

Intermediate B.Sc.: pure and applied mathematics, physics, J. W. Simpson.

General Certificate of Education (Advanced Level): applied mathematics, physics, E. A. Southey.

Horticultural show.—Belated congratulations are offered to successful competitors at the Air Ministry Horticultural Society's Summer Show held at Adastral House on July 7 last: to Miss H. G. Chivers, who obtained the special prize for the fruit section, to Messrs. H. A. Scotney and L. S. Clarkson for flower and vegetable exhibits, and to Mr. Ben G. Brame for winning the Banksian Medal of the Royal Horticultural Society for the second time in three years.

Retirements.—Mr. W. J. Grassick, who has been Senior Meteorological Officer at Watnall since April 1945, retired on September 30 on the completion of 33 years' service. At an informal gathering at Watnall he was presented with a standard reading lamp and a travelling clock subscribed for by many of his colleagues. Mr. Grassick has accepted a temporary appointment in the Meteorological Office and is now at the Air Traffic Control Centre, Preston.

Mr. S. T. A. Mirrlees also retired on September 30: a note on his career in the Office will be published later.

Christmas party.—It is the intention of the Social and Sports Committee to hold a staff Christmas Party again this year. Tuesday, December 15, is the date fixed and the venue the same as last year—Air Ministry Refreshment Club, Adastral House.

WEATHER OF SEPTEMBER 1953

Mean pressure was below normal over a large area including most of the United States, Greenland, Iceland, the North Atlantic and north-west Europe; the deficit of pressure was generally 1–3 mb. but reached 5 mb. in the region between Greenland and Iceland, where the mean pressure was 1002 mb. Over south-east Europe and the Mediterranean, mean pressure was a little above normal, generally about 1 mb. The mean pressure in the Azores was 1021 mb.

Mean temperature over most of the United States and Europe was above normal to the extent of 2–3°F. The means varied from 45° to 55°F. in Scandinavia, 55° to 65°F. in west Europe, 70° to 75°F. in the Mediterranean region and 80° to 90°F. in north Africa.

In the British Isles the changeable weather of late August persisted during the first few days of September. A fair spell set in on the 5th and lasted until the 14th. The remainder of the month was mainly unsettled and there was a notable gale on the 21st. Mean temperature exceeded the average in northern districts and was about or slightly below the average in the south. Rainfall was mostly above average but there was a deficit over eastern England and locally in the north of Scotland. Sunshine considerably exceeded the average in southern and eastern England but was below the average in Scotland and Ireland.

In the opening days a depression off west Scotland moved north-east, while associated troughs of low pressure crossed the British Isles. Rain fell in the north and west on the 1st and throughout the country on the following night, and showery weather with sunny periods prevailed on the 2nd and 3rd. Subsequently a ridge moved slowly east over the British Isles and increased in intensity, the highest pressure being found over Germany by the 6th. Fine weather set in in the south-east on the 5th and soon became general; temperature reached 80°F. locally in England and Wales on the 6th and 8th and there were local maxima of 75°F. or somewhat higher in both Scotland and Ireland during this spell; 78°F. at Dyce near Aberdeen on the 7th and 8th was the highest temperature registered there in September since records began in 1941. On the 8th the anticyclone over the Continent declined and a north-westerly type became established as another anticyclone built up on the Atlantic. Temperature fell on the 9th but the fine weather persisted apart from slight rain chiefly in the west and north. On the 12th to 13th the anticyclone moved north-east to Scandinavia. The fine weather was brought to an end in the south-west on the 14th and elsewhere on the 15th as a trough moved slowly north-east across the country bringing rain to most districts. A spell of thundery weather ensued from the 16th to the 18th. On the 19th a depression to the north-west of Ireland moved east-north-east across Scotland giving general rain, heavy locally, and a gale in south-west Cornwall. On the 21st an exceptionally deep depression, which was formerly a tropical cyclone in the Bermuda area, approached north-west Ireland and moved across southern Scotland giving widespread gales, severe locally, and heavy rain or showers in places (3·09 in. at Patterdale, Westmorland, 2·90 in. at Watendlath Farm, Cumberland, 2·65 in. at Challacombe, Devon, and 2·18 in. at Lake Vyrnwy, Montgomeryshire). Pressure at Claremorris, north-west Ireland, fell to 957 mb. at 0700, the lowest pressure on record in the British Isles in September. This disturbance was followed by a secondary depression which moved east across southern England during the night of the 22nd and then turned north-east to the North Sea giving a gale in south-west England and more heavy rain. Subsequently the depression filled up and a weak ridge formed over southern England giving a spell of fair weather, with widespread morning fog in the south, though some rain occurred in northern districts. An unsettled westerly type of weather prevailed during the last few days with considerable rain at times in the west and north, particularly on the 30th (3·57 in. at Fort William (Teviot), 3·16 in. at Inveraray, Argyllshire, 2·73 in. at Llechwedd Quarries, Merionethshire, and 2·59 in. at Windermere Nurseries, Westmorland), but there were long sunny periods on the 28th.

The general character of the weather is shown by the following provisional figures:—

	AIR TEMPERATURE			RAINFALL		SUNSHINE
	Highest	Lowest	Difference from average daily mean	Percentage of average	No. of days difference from average	Percentage of average
	°F.	°F.	°F.	%		%
England and Wales ...	81	32	+0·3	125	0	111
Scotland	79	31	+2·0	139	+1	92
Northern Ireland ...	76	41	+2·4	115	+3	81

RAINFALL OF SEPTEMBER 1953

Great Britain and Northern Ireland

County	Station	In.	Per cent. of Av.	County	Station	In.	Per cent. of Av.
London	Camden Square	1·78	98	*Glam.*	Cardiff, Penylan	4·61	151
Kent	Dover	2·99	129	*Pemb.*	Tenby, The Priory	3·84	122
,,	Edenbridge, Falconhurst	4·02	177	*Radnor*	Tyrmynydd	6·23	161
Sussex	Compton, Compton Ho.	3·16	113	*Mont.*	Lake Vyrnwy	7·36	204
,,	Worthing, Beach Ho. Pk.	3·95	185	*Mer.*	Blaenau Festiniog	12·48	158
Hants.	Ventnor Cemetery	3·34	131	,,	Aberdovey	5·74	179
,,	Southampton, East Pk.	3·46	159	*Carn.*	Llandudno	4·07	191
,,	South Farnborough	1·97	103	*Angl.*	Llanerchymedd	4·62	157
Herts.	Royston, Therfield Rec.	2·25	120	*I. Man*	Douglas, Borough Cem.	5·71	175
Bucks.	Slough, Upton	1·60	91	*Wigtown*	Newton Stewart	6·76	198
Oxford	Oxford, Radcliffe	1·85	108	*Dumf.*	Dumfries, Crichton R.I.	5·17	191
N'hants.	Wellingboro' Swanspool	1·12	62	,,	Eskdalemuir Obsy.	5·74	155
Essex	Shoeburyness	1·86	111	*Roxb.*	Crailing	3·17	155
,,	Dovercourt	1·28	72	*Peebles*	Stobo Castle	3·47	138
Suffolk	Lowestoft Sec. School	1·61	82	*Berwick*	Marchmont House	2·46	102
,,	Bury St. Ed., Westley H.	1·38	69	*E. Loth.*	North Berwick Res.	2·21	106
Norfolk	Sandringham Ho. Gdns.	1·45	70	*Midl'n.*	Edinburgh, Blackf'd. H.	2·64	129
Wilts.	Aldbourne	3·31	165	*Lanark*	Hamilton W. W., T'nhill	2·79	104
Dorset	Creech Grange	2·98	109	*Ayr*	Colmonell, Knockdolian	6·30	182
,,	Beaminster, East St.	3·14	123	,,	Glen Afton, Ayr San.	7·29	187
Devon	Teignmouth, Den Gdns.	3·02	154	*Renfrew*	Greenock, Prospect Hill	7·16	159
,,	Taunton (Vivary Park)	2·63	124	*Bute*	Rothesay, Ardencraig	5·59	138
,,	Ilfracombe	5·54	206	*Argyll*	Morven (Drimnin)	6·69	118
,,	Okehampton	5·09	182	,,	Poltalloch	8·73	191
Cornwall	Bude, School House	3·49	141	,,	Inveraray Castle	11·07	172
,,	Penzance, Morrab Gdns.	4·10	140	,,	Islay, Eallabus	6·94	166
,,	St. Austell	4·10	129	,,	Tiree	5·63	152
,,	Scilly, Tresco Abbey	2·59	101	*Kinross*	Loch Leven Sluice	4·52	176
Glos.	Cirencester	3·01	137	*Fife*	Leuchars Airfield	2·11	109
Salop	Church Stretton	2·77	131	*Perth*	Loch Dhu	9·03	158
,,	Shrewsbury, Monksmore	2·44	150	,,	Crieff, Strathearn Hyd.	4·10	143
Worcs.	Malvern, Free Library	2·49	129	,,	Pitlochry, Fincastle	4·22	168
Warwick	Birmingham, Edgbaston	2·33	130	*Angus*	Montrose, Sunnyside	2·64	133
Leics.	Thornton Reservoir	1·53	85	*Aberd.*	Braemar	3·06	122
Lincs.	Boston, Skirbeck	1·13	64	,,	Dyce, Craibstone	4·23	175
,,	Skegness, Marine Gdns.	1·22	67	,,	New Deer School House	3·06	121
Notts.	Mansfield, Carr Bank	1·23	67	*Moray*	Gordon Castle	2·92	117
Derby	Buxton, Terrace Slopes	3·37	104	*Nairn*	Nairn, Achareidh	2·07	98
Ches.	Bidston Observatory	3·01	125	*Inverness*	Loch Ness, Garthbeg	3·66	118
,,	Manchester, Ringway	2·45	108	,,	Glenquoich	10·67	123
Lancs.	Stonyhurst College	5·83	153	,,	Fort William, Teviot	10·58	166
,,	Squires Gate	3·92	145	,,	Skye, Broadford	8·45	122
Yorks.	Wakefield, Clarence Pk.	1·29	81	,,	Skye, Duntuilm	3·88	84
,,	Hull, Pearson Park	0·68	39	*R. & C.*	Tain (Mayfield)	2·00	87
,,	Felixkirk, Mt. St. John	1·85	102	,,	Inverbroom, Glackour	5·70	129
,,	York Museum	1·19	73	,,	Achnashellach	8·05	117
,,	Scarborough	0·84	47	*Suth.*	Lochinver, Bank Ho.	4·91	141
,,	Middlesbrough	1·27	77	*Caith.*	Wick Airfield	2·09	84
,,	Baldersdale, Hury Res.	2·72	106	*Shetland*	Lerwick Observatory	3·32	110
Norl'd.	Newcastle, Leazes Pk.	1·82	92	*Ferm.*	Crom Castle	3·72	133
,,	Bellingham, High Green	3·74	156	*Armagh*	Armagh Observatory	2·97	121
,,	Lilburn Tower Gdns.	2·66	113	*Down*	Seaforde	2·78	101
Cumb.	Geltsdale	4·11	147	*Antrim*	Aldergrove Airfield	2·40	97
,,	Keswick, High Hill	8·95	212	,,	Ballymena, Harryville	3·60	116
,,	Ravenglass, The Grove	5·64	167	*L'derry*	Garvagh, Moneydig	3·47	117
Mon.	A'gavenny, Plâs Derwen	4·68	183	,,	Londonderry, Creggan	3·85	117
Glam.	Ystalyfera, Wern House	7·23	165	*Tyrone*	Omagh, Edenfel	3·65	120

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Flood water in the Observatory grounds. Water, pouring off higher ground less than 200 yd. away, turned some steps at the back of Schuster House into a miniature waterfall. At the foot of the steps the water was 4–6 in. deep. Fifteen minutes earlier the volume of water pouring over the steps was so great that the "waterfall" effect was lost.

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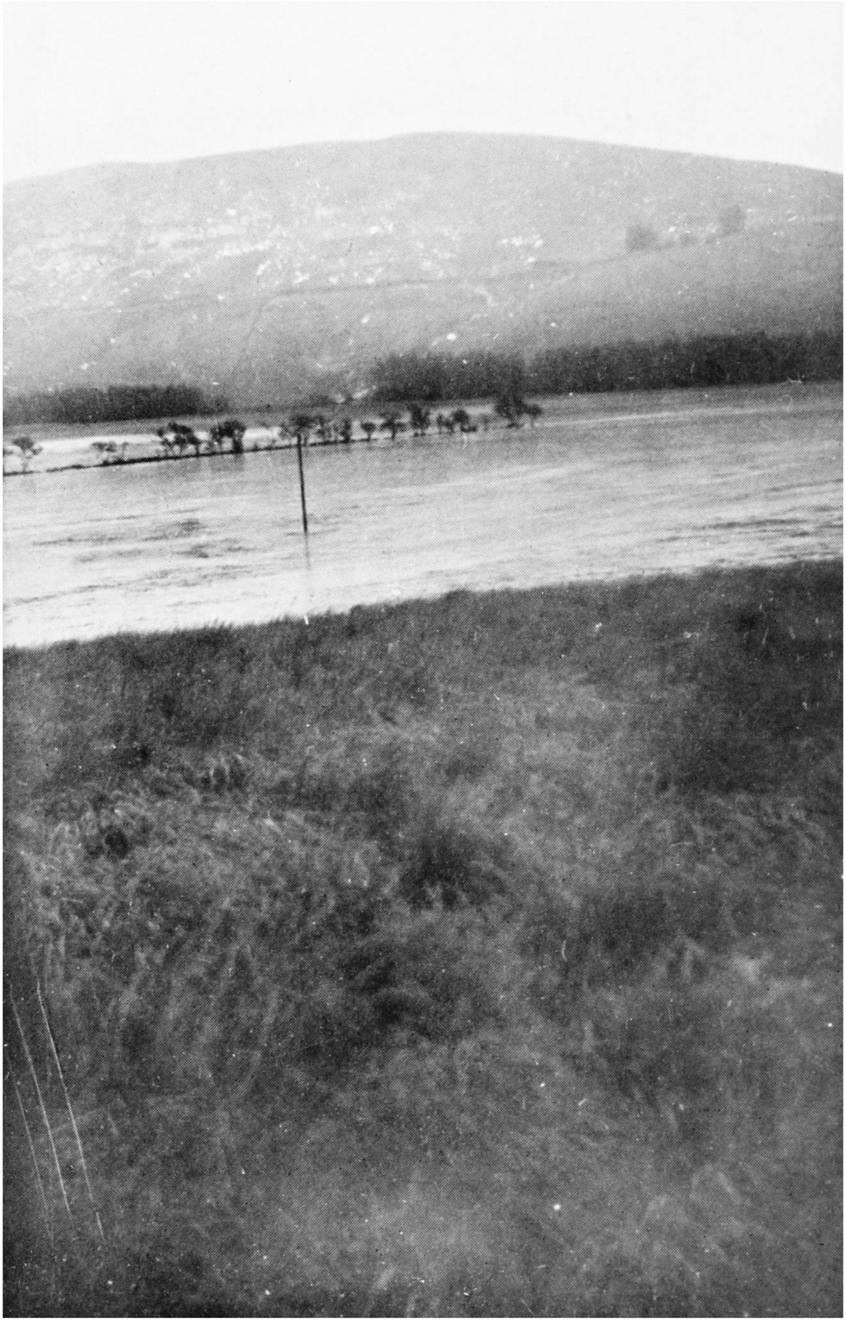
The River Esk a few days after the storm—depth about 12 in. During the storm it rose 10–15 ft. in 10 min., flooding the valley almost without warning. The reinforced-concrete bridge a mile south of Davington on the private road to Dumfedling (pictured above) was broken in two by the force of the flood water.

THE STORM OF JUNE 26, 1953, AT ESKDALEMUIR

(see p. 344)



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THE ESK VALLEY SEEN FROM THE OBSERVATORY HILL, 1615, JUNE 26, 1953

The whole valley was still flooded, but the water level was dropping. The white patches on Dumfedling Hill in the background are drifts of hailstones; 90 min. earlier the hillside presented a peculiar mottled-white appearance—hail and flood water combined. At 1400 the hail was 2 in. deep with drifts up to 12 in.; 24 hr. later some drifts still remained.

(see p. 344)