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JET STREAMS OVER NORTH AFRICA AND THE CENTRAL MEDITERRANEAN IN JANUARY AND FEBRUARY, 1954

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Summary.—Most studies of jet streams in the subtropical zone have only been made possible by statistical treatments of many cases, based upon observation sequences at single widely-scattered stations. This paper is largely devoted to the description of one jet-stream situation of outstanding intensity over the Mediterranean and north Africa—a sector which has not hitherto been dealt with in this connexion—where the network of high-level observations made possible a synoptic study.

The resulting analysis establishes the occurrence, over the Mediterranean and north-Africa region between October 1953 and April 1954, of occasional maximum winds somewhat in excess of 200 kt. It also suggests lateral movements of various maxima in the upper westerlies from both south and north, which, because of the strong shears commonly occurring, lead to very large and rapid variations of upper-wind speed along the east–west air routes over the Mediterranean.

Introduction.—Several times during the winter 1953/4 north Africa north of 20°–25°N. and much of the Mediterranean were covered by a belt of strong high-level winds of very great breadth and intensity. The reported wind speeds somewhat exceeded the highest values of the six previous winters since the radio-sonde and radar-wind network had been developed in that part of the world. Several observing stations in the Malta Flight Information Region reported winds of 180 to 220 kt. and some stations purported to show much higher values. Between whiles there were lulls in the circulation, sometimes lasting ten days or more, when no winds of more than 80 to 90 kt. appeared to exist at any height anywhere in this sector. Little or nothing was known about the manner of formation of the strong-wind belt over north Africa, though it was doubtless part of the same system as the better known winter jet stream over south-west Asia and possibly an earlier phase of it.

The period which best lent itself to close study of the jet stream was January 1–10, 1954. Throughout these days the broad features of the situation were so nearly constant that one could use all the observational data of the ten days to amplify and cross-check one another. This checking for internal consistency was a vital part of the investigation. The region has one of the richest networks of observing stations in the subtropical zone, but these are operated by many different nations using different radio-sonde instruments. Moreover radio transmission errors and clerical mistakes produce some wind reports that are unbelievable and others that can only be accepted after careful scrutiny. The period was one of outstandingly strong winds aloft, though possibly not quite the strongest of the 1953/4 winter.

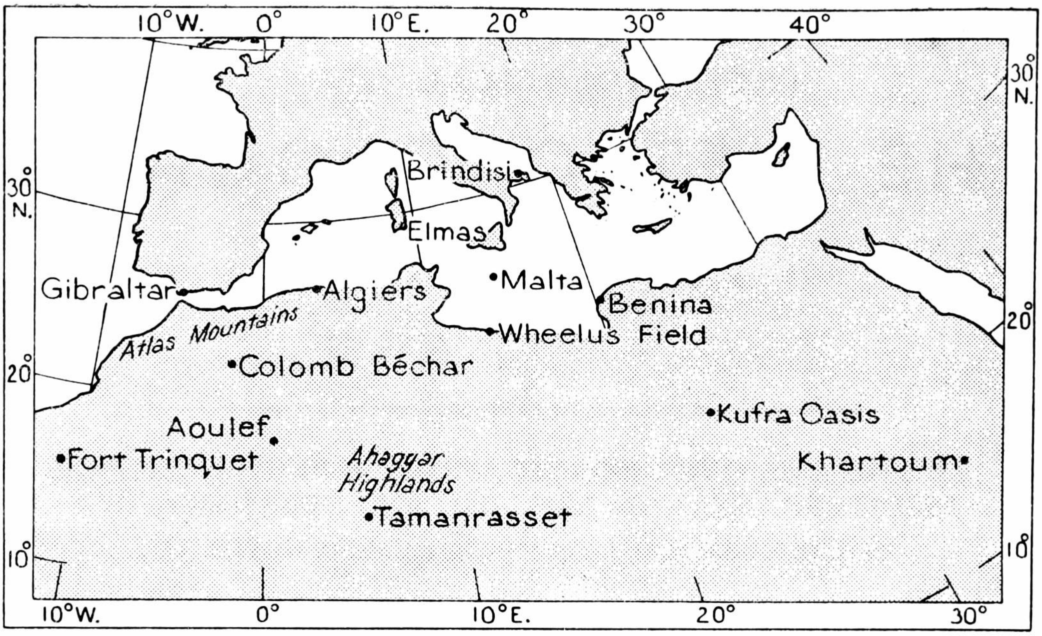

FIG. 1—MAP TO SHOW STATION POSITIONS AND PLACE NAMES

The observations.—The stations at which regular upper air observations were made in the region considered are shown in Fig. 1. Normally, even in this sector, the gap in the network of high-level observing stations south of the line Algiers–Tripoli–Benina–Cairo is a great obstacle to examining subtropical jet streams[1].

Wheelus Field, Tripoli, made four ascents daily; Elmas, Malta and Benina, Benghazi, made two daily; the other places made only one ascent a day. Not all the ascents reached the 200-mb. level. Over the western part of north Africa there were useful additional radio-sonde observations made once a day at Aoulef, 27°04′N., 1°08′E., Colomb Béchar, 31°51′N., 20°3′W. and Fort Trinquet, 25°14′N., 11°35′W., but these data were not regularly received. Khartoum lies south of the strong westerly régime aloft, even in mid-winter. The Tamanrasset and Kufra ascents were made with pilot ballons, which, however, penetrated above the maximum-wind level on some occasions.

In the case here examined the subtropical jet stream, which at first lay over the desert about 25°N. in the west and 30°N. over Egypt, moved northwards and emerged over the Mediterranean radio-sonde network, between Malta and the Libyan coast from January 4–6.

Several different analysis methods were used and their results compared for consistency; the statistics for each station were also independently examined, in order to achieve an acceptable comparability of the upper-wind observations reported from places where different instruments and techniques were in use. The observations of *Canberra* and *Comet* aircraft were also used.

The early January period, general survey.—From January 1–10, 1954, north Africa, north of 20°–25°N., and most of the Mediterranean south of 35°–40°N. were continuously covered by a broad belt of very strong high-level winds about 250°–270°. The temperate-zone westerlies farther north were

TABLE I—WIND SPEEDS AT DISTANCES FROM THE AXIS OF THE STRONG-WIND BAND OVER NORTH AFRICA AT 300 MB., JANUARY 1–10, 1954

Wind directions are between 240° and 280°

Distances in nautical miles (± 50)

	Time	North of axis				South of axis						
		500 Elmas	400 Brindisi Algiers*	200 Malta	0 Benina Wheelus Field†	200 Aoulef	300	400 Tamanrasset	500 Kufra	600	700	1,000
	G.M.T.				*knots*							
January 1, 1954	0200	27	30	53	81 85†	...	...	...	...	...	...	...
	1400	33	15	37	96 105†	...	...	...	120 at 27,000 ft.	...	...	...
January 2 1954	0200	19	5	77	123 82†	...	...	70‡	...	...	...	...
	1400	47	10	94	119 148†	...	...	...	...	...	...	...
January 3, 1954	0200	52	15	104	159 168†	...	...	...	...	...	...	...
	1400	27	35 83*	131	144 178†	*114*	120‡	48 at 0900 G.M.T.	...	...	...	...
January 4, 1954	0200	23	30	149	149 194†	...	...	...	...	...	...	...
	1400	...	...	132	138	...	...	45	84	...	...	...
January 5, 1954	0200	78	65 110*	123 at 30,000 ft.	132	...	130‡	...	...	60‡	...	...
	1400	73	...	135	138	*133*	...	...	...	...	...	...
January 6, 1954	0200	98 at 28,000 ft.	...	106	131 166†	...	...	...	...	...	...	...
	1400	85	53	88	128 112†	*103*	75‡	...	...	50‡	...	...
January 7, 1954	0200	51 at 26,000 ft.	...	111	139	...	...	...	...	...	...	...
	1400	51	41	84	157 174†	*56*	...	52	72	...	...	*29*
January 8, 1954	0200	54	35	84	154 110†	...	...	...	...	...	...	...
	1400	26	47	93	125	*79*	...	...	108	...	...	...
January 9, 1954	0200	35	...	76 at 30,000 ft.	117 170†	...	110‡	...	...	80‡	...	...
	1400	21	...	58	119 115†	*105*	...	...	125	...	...	*17 at* Niamey 13½°N., 2½°E.
January 10, 1954	0200	27	9	54	161 140†	...	...	...	...	...	...	...
	1400	...	40	56	141†	*97*	120‡	...	...	...	70‡	...

Values in italics denote winds reported by stations somewhat outside the limits of longitude at 5° and 25°E., but nevertheless belonging to the same wind system.

* The values for Algiers are indicated by an asterisk. † The values for Wheelus Field are indicated by a dagger.

‡ Denotes winds reported by Comet aircraft in flight between 10° and 13°E.

TABLE II—WIND SPEEDS AT DISTANCES FROM THE AXIS OF THE STRONG-WIND BAND OVER NORTH AFRICA AT 200 MB., JANUARY 1–10, 1954

Wind directions are between 240° and 280°

	Time	Distances in nautical miles (± 50) North of axis				South of axis	
		500 Elmas	400 Brindisi Algiers*	200 Malta	0 Benina Wheelus Field†	200 Aoulef	500 Kufra
	G.M.T.				*knots*		
January 1, 1954	0200	...	...	57	89 93†	...	...
	1400	...	...	57	75 99†	...	...
January 2, 1954	0200	25	...	74	119 120†	...	...
	1400	36	34	90	153 138†	...	...
January 3, 1954	0200	45	...	92	190	...	...
	1400	54	61 78*	117	...	*169*	...
January 4, 1954	0200	70	...	180	...	...	...
	1400	...	80	129	...	...	...
January 5, 1954	0200	96	115*	99 at 40,000 ft.	...	...	...
	1400	117	...	137	...	*141*	...
January 6, 1954	0200	...	...	131	154 at 250 mb. 186† at 36,000 ft.	...	...
	1400	56	67	98	160 at 250 mb. 175†	...	...
January 7, 1954	0200	...	...	103	158 at 37,000 ft.	...	...
	1400	79	...	89	148 at 250 mb.	*111*	78 at 38,000 ft.
January 8, 1954	0200	64	...	86	136†	...	...
	1400	...	...	89	153 at 50,000 ft.	*93*	145 at 37,000 ft.
January 9, 1954	0200	40	...	77 at 40,000 ft.	147 158† at 250 mb.	...	...
	1400	41	...	68	123 at 250 mb. 110†	...	...
January 10, 1954	0200	...	...	85	183 at 250 mb. 40†	...	...
	1400	...	...	81	146†	*174*	...

Values in italics denote winds reported by stations somewhat outside the limits of longitude at 5° and 25°E., but nevertheless belonging to the same wind system.

* The values for Algiers are indicated by an asterisk. † The values for Wheelus Field are indicated by a dagger.

blocked by a quasi-stationary anticyclone, about 1040 mb., in the neighbourhood of the British Isles and eastern Atlantic. Cold air of Arctic origin flooded into the Mediterranean, yielding the heaviest snows for many years in Austria and north Italy, the heaviest snow for 25 years in Milan.

About the same time over north Africa south of the strongest high-level winds, higher temperatures occurred up to the 300–200-mb. layer than for a month or two past. The warmth seems only explainable by advection of warm air from farther south over Africa. Dynamical warming is unlikely to have been at work below the level of maximum wind at the right-hand side of the strong stream in a region within a few hundred miles of the confluence[2] and remote from the exit.

Tables I and II give the wind speeds reported at 300 and 200 mb. respectively at various stations arranged according to their distance on either side of the axis of the strong-wind belt in about 5°–25°E.

The situation culminated with the strongest winds occurring near the Libyan coast in 32°–33°N. The evidence suggests only rather slight variation in intensity of the main velocity maximum during the ten days. Benina and Wheelus Field were near the axis of the upper-wind system throughout the period January 1–10, 1954, and observed the strongest winds of all. Only on the 1st and on the 9th and 10th were the greatest wind speeds farther south, at the mid-desert stations, Aoulef and Kufra.

Gaps in the central column in Table II are in many cases due to balloons being lost before the 200-mb. level was reached at both Wheelus and Benina, owing to the very strength of the wind. This may be presumed to mean that some of the greatest velocities were missed.

Table III summarizes the average wind speeds reported in Tables I and II during the seven days January 2–8, excluding the occasional instances of winds outside the range 240° to 280°. These cases occurred only on the fringes of the system.

TABLE III—AVERAGE WIND SPEEDS FOR CERTAIN STATIONS FOR JANUARY 2–8, 1954

	Elmas	Brindisi	Malta	Wheelus Field	Benina	Aoulef	Taman-rasset	Kufra
				knots				
300 mb.	56·1	28·3	108·9	150·9	137·9	97·0	48·3	88·0
				Number of ascents				
	12	4	14	7	14	5	3	3
				knots				
200 mb.	64·2	60·5	109·5	151·0	154·5	128·5	...	111·5
				Number of ascents				
	10	4	14	5	8	4	0	2

This table gives a general indication of the structure of the strong-wind belt during the seven days. It confirms the position of the axis of the system close to Wheelus Field and Benina. No importance is attached to the lower wind speeds consistently reported at Brindisi and Tamanrasset than at the stations (Elmas and Kufra) farther out from the axis of the strong-wind belt on either flank. Only a small number of ascents were available for these stations. Moreover topographical effects may be involved.

Table IV shows the strongest winds in the Meteorological Office records for the six years 1948–53 at various stations in the Mediterranean and south-west Asia. The information in this table made it possible to reject with some confidence the frequent winds over 250 kt., and occasionally well over 300 kt., reported by one foreign station during this sequence, shortly before the balloon was lost near the top of the ascents, i.e. at low angles of elevation.

TABLE IV—STRONGEST WINDS REPORTED 1948 TO FEBRUARY 1954

	300 mb.	270 mb.	256 mb.	239 mb.	227 mb.	207 mb.	202 mb.	200 mb.	195 mb.	153 mb.
					knots					
					1948–1953					
Malta ...	144	...	167	...	...	...	...	155	...	...
Benina ...	155	...	...	189	...	...	...	169	...	...
Nicosia ...	160	...	...	...	...	...	...	181	...	225
Habbaniya	172	...	...	...	183	183	...	171	...	...
Bahrain...	150	...	...	...	...	...	...	155	171	...
					January 1954					
Malta ...	...	...	...	...	...	...	...	180	...	...
Benina ...	...	...	...	...	...	...	190	...	...	...
					February 1954					
Malta ...	...	222	...	...	...	...	...	...	...	...

Estimation of maximum wind speeds during the sequence January 1–10, 1954.—To get a closer estimate of the probable maximum speeds attained during the sequence analyzed, the number of reports in 20-kt. intervals amongst the accepted ascents were studied. These are set forth in Table V.

TABLE V—FREQUENCY OF UPPER WIND SPEEDS IN VARIOUS RANGES OBSERVED AT THE MAIN UPPER AIR STATIONS, JANUARY 1–10, 1954

	Wind speed in knots								No. of balloons lost before maximum was reached*
	69	70–89	90–109	110–129	130–149	150–169	170–189	190–209	
300 mb.	*Number of occasions*								
Benina ...	0	1	1	6	7	4	0	0	
Wheelus Field	0	0	1	5	1	2	3	0	
Malta ...	5	5	4	1	5	0	0	0	
All Stations in Table I ...	24	12	12	16	14	6	3	0	
200 mb.									
Benina ...	0	2	0	2	2	5	1	1†	
Wheelus Field	0	0	2	2	3	1	2	0	
Malta ...	4	6	4	3	2	0	1	0	
All stations in Table I ...	13	13	8	10	9	7	5	1	
Any level	(*Known values of the maximum wind.*)								
Benina ...	0	1	1	1	1	6	0	0	5
Wheelus Field	0	0	2	1	3	1	2	0	3
Malta ...	3	3	6	2	5	0	0	0	1
All stations in Tables I and II	12	8	11	9	10	8	2	0	9

* Maximum was certainly > 180 kt. and probably > 190 kt.

† This one case at Benina was a reading of 190 kt. a little below the 200-mb. level. The balloon was lost at 202 mb. and the observers considered the 200 mb. wind was probably a little over 200 kt.

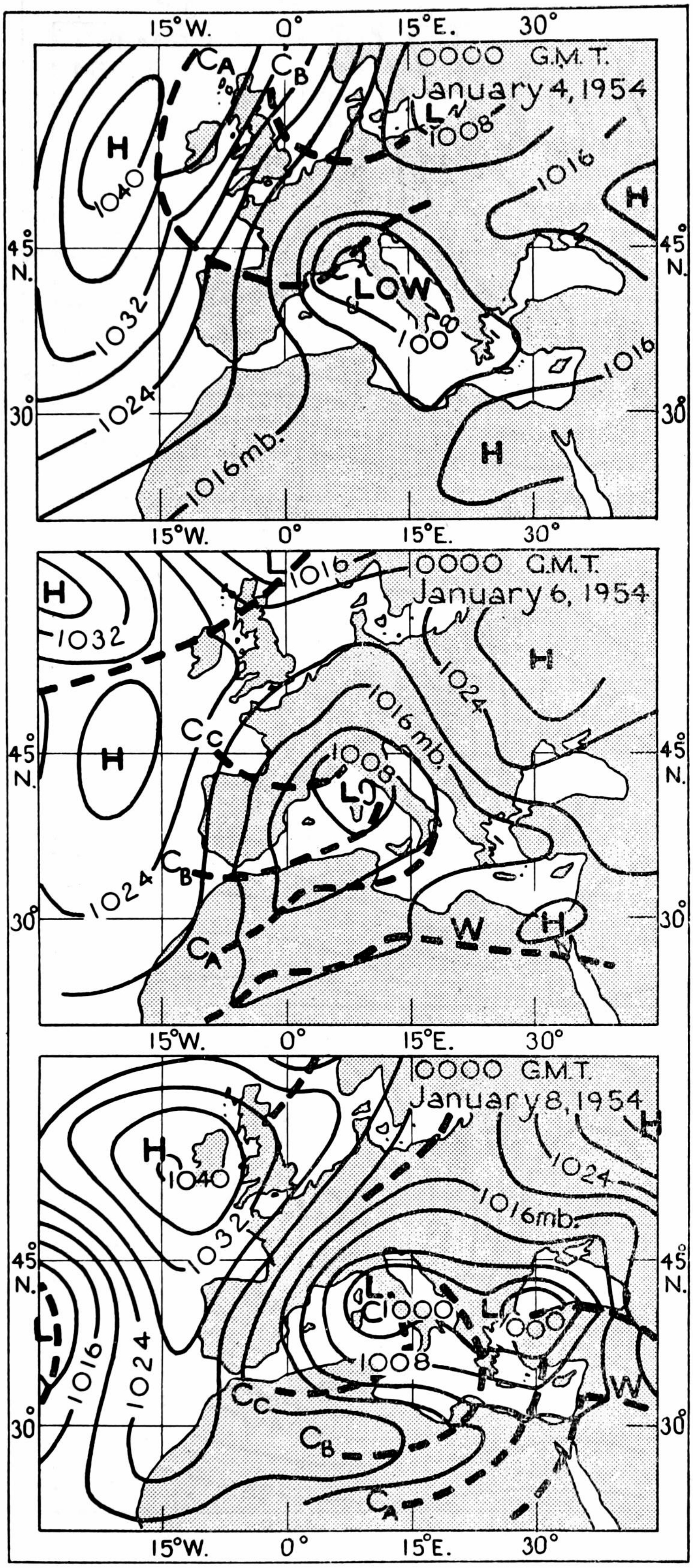

FIG. 2—MEAN-SEA-LEVEL SYNOPTIC MAPS

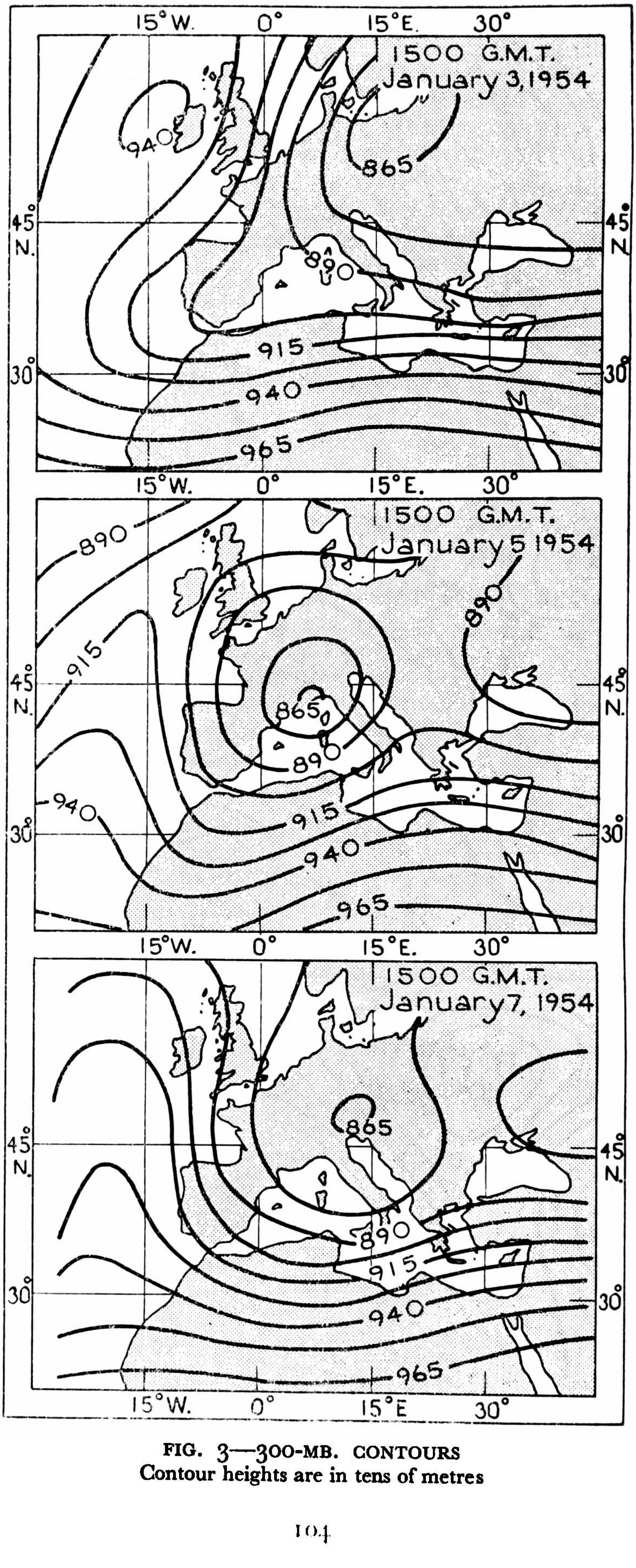

FIG. 3—300-MB. CONTOURS
Contour heights are in tens of metres

It seems legitimate to conclude from this table that the absolute maximum wind speeds reached in this jet stream, which was unlikely to be just over one of the observing stations at the time of ascent, were:—

at 300 mb. 190 ± 10 kt. (Malta about 160 kt.)
at 200 mb. 205 ± 10 kt. (Malta about 180 kt.)
at any level 220 ± 15 kt. (Malta 180–190 kt.)

Methods of analysis used.—The data accepted after the sifting processes described were analyzed in four different ways:

(i) "Horizontal" charts at mean sea level 700, 500, 300, 200 and 100 mb., here illustrated by three surface charts (Fig. 2) and three charts at 300 mb. (Fig. 3). It happened that the most satisfactory surface charts were the midnight ones, whereas the best upper-air charts were at 1500 G.M.T. Those reproduced here have been chosen to correspond with each other as nearly as the 9-hr. time interval allows.

(ii) Plotted graphs showing changes of wind speed with time over the ten days at all possible stations at the 200 and 300-mb. levels. This process permitted some reasonable attempts at interpolation where observation values were missing.

(iii) Time cross-sections were next drawn, making use of all available observed values and the graphs (ii) above, to show the changing wind speeds at all heights over Elmas, Malta and Benina. The time cross-section over Malta, for which most data were available, is shown in Fig. 4 and serves to illustrate the main stages of the sequence.

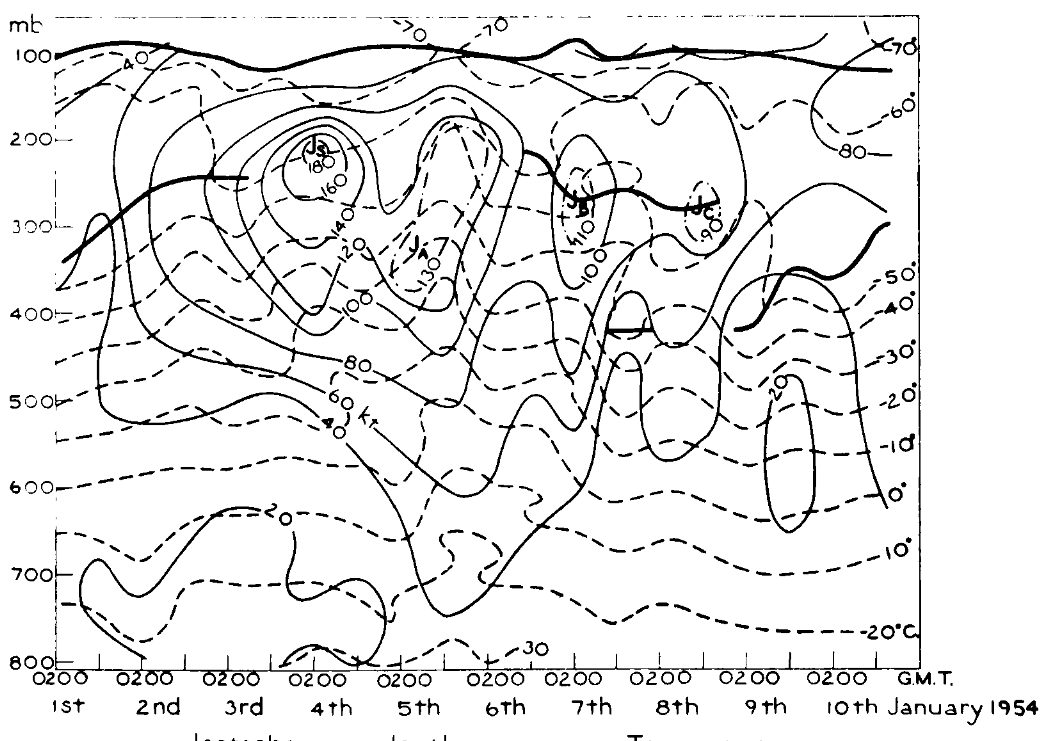

FIG. 4—TIME CROSS-SECTION OVER MALTA JANUARY 1–10, 1954

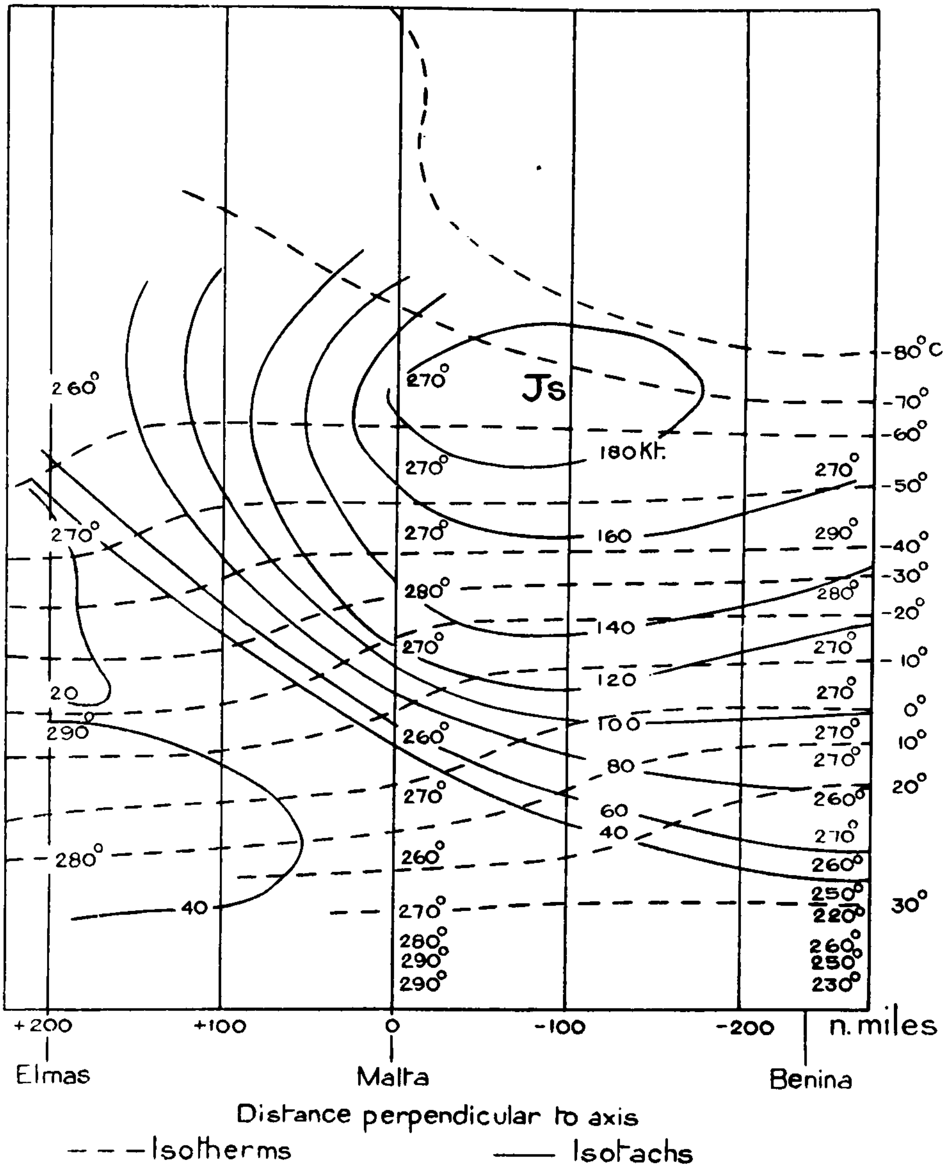

FIG. 5—VERTICAL CROSS-SECTION 0300 G.M.T. JANUARY 4, 1954
270° etc.: Observed wind directions in degrees from true north

(iv) Space cross-sections, drawn twice daily, for the 0200 and 1400 G.M.T. radio-sonde ascents, along the two axes Elmas–Malta–Benina and Aoulef–Wheelus–Malta–Brindisi.

Two cross-sections along the Elmas–Benina axis at 0200–0300 G.M.T. on January 4 and 6, have been chosen for reproduction here as Figs. 5 and 6 because they have the fullest data and show interesting phases of the development.

Results.—The essential features which emerged from the upper-wind analysis were as follows:

(i) At the desert stations, Aoulef, 27°04′N., 1°08′E., and Kufra Oasis 24°13′N., 23°20′E., also as reported by *Comet* aircraft over the Sahara on the north–south route between Tripoli and Kano, the high-level winds were strongest early and late in the period January 1–10, 1954 and they

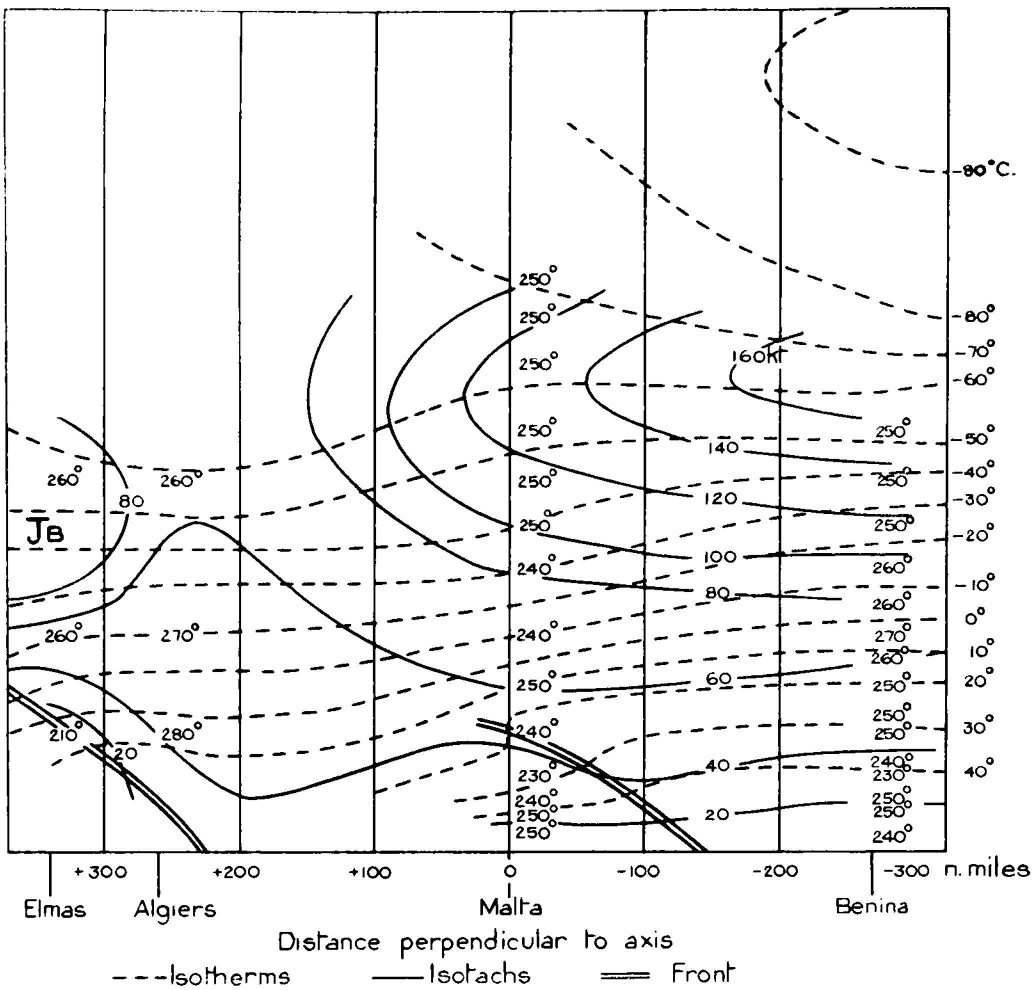

FIG. 6—VERTICAL CROSS-SECTION 0300 G.M.T. JANUARY 6, 1954
250° etc.: Observed wind directions in degrees from true north.

were then stronger over the desert with maxima over 170 kt., than anywhere else in this sector of the northern hemisphere. In the middle of the period the winds over places in 24° to 28°N. were much lighter, under 100 kt. at all heights, the minimum occurring on January 6 or 7.

(ii) At the Libyan coast, Wheelus Field and Benina, both about 32°N., the upper winds were under 100 kt. on the 1st, but quickly rose to an outstanding maximum of the order of 200 kt. by the 3rd–4th, high speeds being more or less sustained thereafter.

(iii) At the more northerly stations in the central Mediterranean the upper wind speeds were quite low at first, but gradually rose to several peaks in the middle of the period, between the 4th and 8th, and then fell off generally to light to moderate speeds by the 9th–10th. This broad trend is inverse to that at the desert stations, (i) above, apart from the complexity represented by several successive maxima with some decrease of wind between the northern stations: at Malta, Fig. 4, the first maximum was the strongest and at the highest level, about 200 mb., showing in these respects most resemblance to the maxima at the more southerly groups of stations.

(iv) The cross-sections leave little room for doubt that a jet stream J_S on Fig. 5, moved north out of Africa, passing over Benina on the 3rd, approached Malta on the 4th and then withdrew south-eastwards re-crossing Benina on the afternoon of the 6th. The northward movement was associated with temporary warming of the lower troposphere over north Africa and an accompanying northward advance of the high tropical tropopause as far as Malta. On Fig. 5, which represents the maximum movement to the north of this subtropical jet stream, the core is judged to be about 50 to 100 nautical miles south of Malta, a position far north of the normal January position of the subtropical jet[3].

(v) A further important feature of the subtropical jet stream as it approached Malta, cf. Fig. 5, was the sloping zone of tremendous shear underneath and somewhat north of the jet, which could not be associated with any front or frontal surface that had come from the north during the period studied. This sloping zone of shear may well have had some connexion with the warm front, marked W on Fig. 2, found moving north over the central Sahara.

(vi) The cross-section for the afternoon of the 4th, which is not reproduced, for the first time showed a second jet stream, rather over 80 kt. near the 400-mb. level, near Elmas, associated with the cold front C_A, Fig. 2, which swept south over Malta early on the 5th. The lower level of the wind maximum in itself probably marks this system out as having recently come from higher latitudes—quite apart from its obvious association with the cold front. This system passed over Malta, where it produced a second wind maximum, about 135 kt., at 350 mb. on the morning of the 5th, J_A on Fig. 4, with a subsequent increase in the main stream at higher levels. From the Elmas–Benina cross-sections J_A appears to have become virtually absorbed already in a single broad maximum with J_S by the afternoon of the 5th.

(vii) A second polar-front jet stream from the north, accompanying the second cold front, C_B, appears on the morning of the 6th near Elmas as J_B on Fig. 6, with maximum winds at about the 350-mb. level. This jet also continued to move south, though more slowly than J_A and was still traceable as a separate entity on the afternoon of the 6th. It was responsible for a third maximum of winds aloft over Malta >110 kt. near the 300 mb. level on the morning of the 7th, but may already have become part of the main broad core of strong upper winds near the north African coast: wind was 158 kt. at 37,000 ft. over Benina at that time. The cold front C_B had passed Elmas at 1200 G.M.T. on the 5th, but was retarded by development of minor waves along it before passing Malta at 0200 G.M.T. on the 7th, and Benina at 1800 the same evening.

(viii) A third cold front from the north, C_C, much less significant in the thermal field than C_A or C_B, passed rather quickly south-eastwards across the central Mediterranean between the afternoon of the 7th and the morning of the 9th. There were signs of another maximum of upper winds, about 80 kt., appearing over Elmas late on the 7th and approaching 100 kt. at 250 mb. over Malta, J_C on Fig. 4, at 1500 G.M.T. on the 8th. In this case, too, absorption into the main system seems to have occurred by the time the polar-front jet reached Malta, or soon after.

(ix) These systems from the north brought the low polar tropopause with them. In a tropopause funnel on the afternoon of the 7th, this polar tropopause descended to about 425 mb. near Malta.

(x) At various times during this coalescence of jet streams in early January the belt of westerly winds over 100 kt. at 300 mb. was more than 600 nautical miles in width from north of Malta to mid-Sahara. The same belt may have exceeded 750 nautical miles at 200 mb. These figures should be compared with the greatest known widths elsewhere, i.e. 600 nautical miles at 250 mb. over the Norwegian Sea on November 29, 1951 and a mean width for January over Iraq of 690 nautical miles[4]. Clearly there were several stages at which, for a time, two or more separate maxima lay side by side within the strong-wind belt of January 1–10, 1954, over the central Mediterranean, the main maximum being always the southernmost one, which was also rather higher up than the polar-front jet streams until the moment of their absorption.

(xi) Violent turbulence was reported in clear air along the northern flank of the strongest wind, but evidence is insufficient to say whether this turbulence is always there or whether it is confined to the northern side. There were no reports of turbulence from the southern side of the strongest wind stream, in spite of regular post-flight summaries received throughout the winter 1953/4 from the *Comet* air line, Tripoli–Kano, Nigeria.

(xii) The anticyclonic shear at the right of the main jet stream over north Africa between January 1 and 10, 1954 was of the same order of magnitude as the cyclonic shear to the left; in some cases the anticyclonic shear appears to have been the greater of the two. This is believed to be very rare with polar-front jet streams in middle latitudes. We have, as yet, no means of gauging whether it is a usual feature of jet streams in the Mediterranean and north Africa.

(xiii) The magnitude of the anticyclonic shear also attracted notice as it clearly approached and possibly exceeded the Coriolis parameter. To check this a careful search was made for occasions when measurements of the shear could be based directly on reliable observations.

The following pairs of observations giving outstanding values of the anticyclonic shear were the only ones during early January 1954 for which measurements might reasonably be significant: even so, the stations were not abreast of each other at the same point of the main-stream.

Case 1—January 3, 1954, 1400 G.M.T. at 300 mb.

	Mean latitude	Wind speed	Direction
Wheelus Field	32½°N.	178 kt.	270°
Benina	32½°N.	144 kt.	278°

The Wheelus velocity report is considered likely to be an over-estimate by a matter of 10–20 kt. Even so the anticyclonic shear implied is 14 to 24, say 20 kt., in 50 nautical miles, since Benina lay that much to the right of the streamline through Wheelus. The implied shear is $-0 \cdot 4$ hr.$^{-1}$.

Case 2—January 4, 1954, 1400 G.M.T. at 300 mb.

	Mean latitude	Wind speed	Direction
Benina	28°N.	138 kt.	266°
Tamanrasset	28°N.	45 kt.	250°

In this case both the observed velocities are accepted, but Tamanrasset winds may be reduced even at 300 mb. by the mountains just to the east and north-east. The implied shear is $-0\cdot2$ hr.$^{-1}$.

Case 3—January 7, 1954, 1400 G.M.T. at 300 mb.

	Mean latitude	Wind speed	Direction
Benina	28°N.	157 kt.	247°
Tamanrasset	28°N.	52 kt.	250°

The implied shear is $-0\cdot2$ hr.$^{-1}$.

In none of these cases were the stations near enough abreast of each other, relative to the jet stream, for confident assertion of the actual shear values. It remains true that the mean shear over distances of 100 to 400 miles on the right of the jet axis at the level of the wind maximum ran very close to, or exceeded, the Coriolis parameter* in all these cases. Consequently either the critical value must have been locally exceeded somewhere or the shear was remarkably uniform over hundreds of miles. The jet stream was nearly straight in all these cases, any curvature existing being slight and anticyclonic.

(xiv) A further case during the following month is very interesting.—February 8, 1954, 0300 G.M.T.

	Mean latitude	Malta		Benina	
		Wind speed	Direction	Wind speed	Direction
mb.	°N.	kt.	°	kt.	°
500	34	55	259	105	260
400	34	113	252	119	270
300	34	198	260	138	265
270	34	222	250	142	270
250	34	207	260	145	271
200	34	167	258	159	270

All these observations were accepted. This was a situation with a very intense jet moving laterally quite quickly across the area. By the afternoon radio-sonde ascents at 1400 G.M.T. February 8, the 300-mb. wind at Benina had risen to 185 kt. and at Malta had dropped to 90 kt., a decrease of 108 kt. in 12 hr. at the 300-mb. level over Malta. Great anticyclonic shear is implied between Malta and Benina, at levels between 300 and 200 mb. only, on the morning ascents. The implied shear values are:—

300 mb.	$-0\cdot2$ hr.$^{-1}$
270 mb.	$-0\cdot3$ hr.$^{-1}$
250 mb.	$-0\cdot2$ hr.$^{-1}$

A Canberra aircraft flying between Tunis and Tripoli on February 8, later in the day at 1300 G.M.T., reported severe turbulence in clear air at 25,000 ft. and down to 21,500 ft., but this aircraft at the time in question was immediately north of the jet stream in the region of great cyclonic shear, the average shear Benina–Malta at 1400 G.M.T. being $+0\cdot34$ hr.$^{-1}$.

(xv) In the case of January 1–10, 1954 the formation of a cold trough over the western Sahara went almost hand in hand with, or was closely

* The values of the Coriolis parameter in these latitudes are:

25°N.	30°N.	35°N.	40°N.
0·22	0·26	0·30	0·34 hr.$^{-1}$.

followed by, ridging immediately to the east, which brought the main subtropical jet stream north out of Libya to lie over the central Mediterranean for two days or so.

This type of development constitutes a major forecasting problem for the safety of jet aircraft on east to west flights over the Mediterranean. The high-level westerly winds have been observed to increase and decrease by as much as 100 kt. in 12 hr. over Malta, when the jet stream moves north or south and when it intensifies. Aircraft flying from Cyprus to Malta have been troubled by rapid increases of head winds of this order at 35,000–45,000 ft. The experience emphasizes the importance of jet-stream warnings to all aircraft on such courses and of regular, careful mapping of the winds up to 200 mb. in this part of the world.

(xvi) The structure of all the westerly jet streams in 25°–35°N. here examined appears in many ways similar to the jet streams in higher latitudes including, remarkably enough, a plausible association of each maximum with a frontal surface and sloping zone of strong shear below the jet. In this instance the zone of strong shear sloping downwards to the south underneath the subtropical jet stream when this lay over the Mediterranean was continuous down to the 600–700-mb. layer near the north African coast, see Fig. 5, and possibly still lower over the desert to the south, where there was a warm front. In other respects, however, the situation with two jet streams occasionally merging into one and with the subtropical jet stream the stronger and higher up of the two shows obvious resemblances to the winter jet streams over the Pacific Ocean sector as investigated by Hoyle[5]; though much of the detail is likely to be peculiar to each sector with its own geography.

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A WIND-VANE FOR RECORDING OR INDICATING MEAN WIND DIRECTION

By G. E. W. HARTLEY, M.A.

When wind direction is recorded, the usual procedure is to record the actual movements of a pivoted wind vane; and the record so obtained shows all the fluctuations of wind direction which the vane is capable of following. Unless the exposure of the vane is exceptionally open, the record will usually cover a fairly wide band of direction, and the mean direction is obtained from this by inserting a line which is as nearly as can be judged always at the centre of the band.

In wind measurements taken at the site of the proposed Severn Bridge, and near the Forth Bridge, where wind inclination to the horizontal was recorded as well as normal wind direction, it was found that the record of wind inclination even with a quick chart speed was a broad band in which it was practically impossible to insert a mean line; and an elaborate damping system developed by Admiralty for a wind resolver was used to extract the mean direction record. This system worked well, but is expensive and complicated and has a number of places where adjustment may be required. In the vane to be described an attempt is made to have the damping built into the vane, so that the movements of the vane spindle show the mean wind direction. The vane employs a system which has frequently been used before in various forms; a vane-type windmill carries a worm on its spindle, which engages with a fixed worm-wheel; when the windmill is turned by the wind, it rotates about the axis of the fixed worm-wheel until it reaches a position where the wind no longer causes it to turn.

The portion of the vane which carries the windmill turns the direction shaft or spindle. This sytem has been used in the Beckley anemometer and in the windmill-type d.c. generator anemometers used by the Admiralty, and was also used in the rotating-cap windmill, formerly used for grinding corn and pumping water. The objection to the system is that as the vane approaches true wind direction the force causing it to approach decreases rapidly; so that in light winds the vane may stop at an appreciable angle short of the true wind direction. In some applications, this does not matter; but for accurate recording of wind direction it does.

The methods adopted to try to overcome this defect in the instrument to be described are

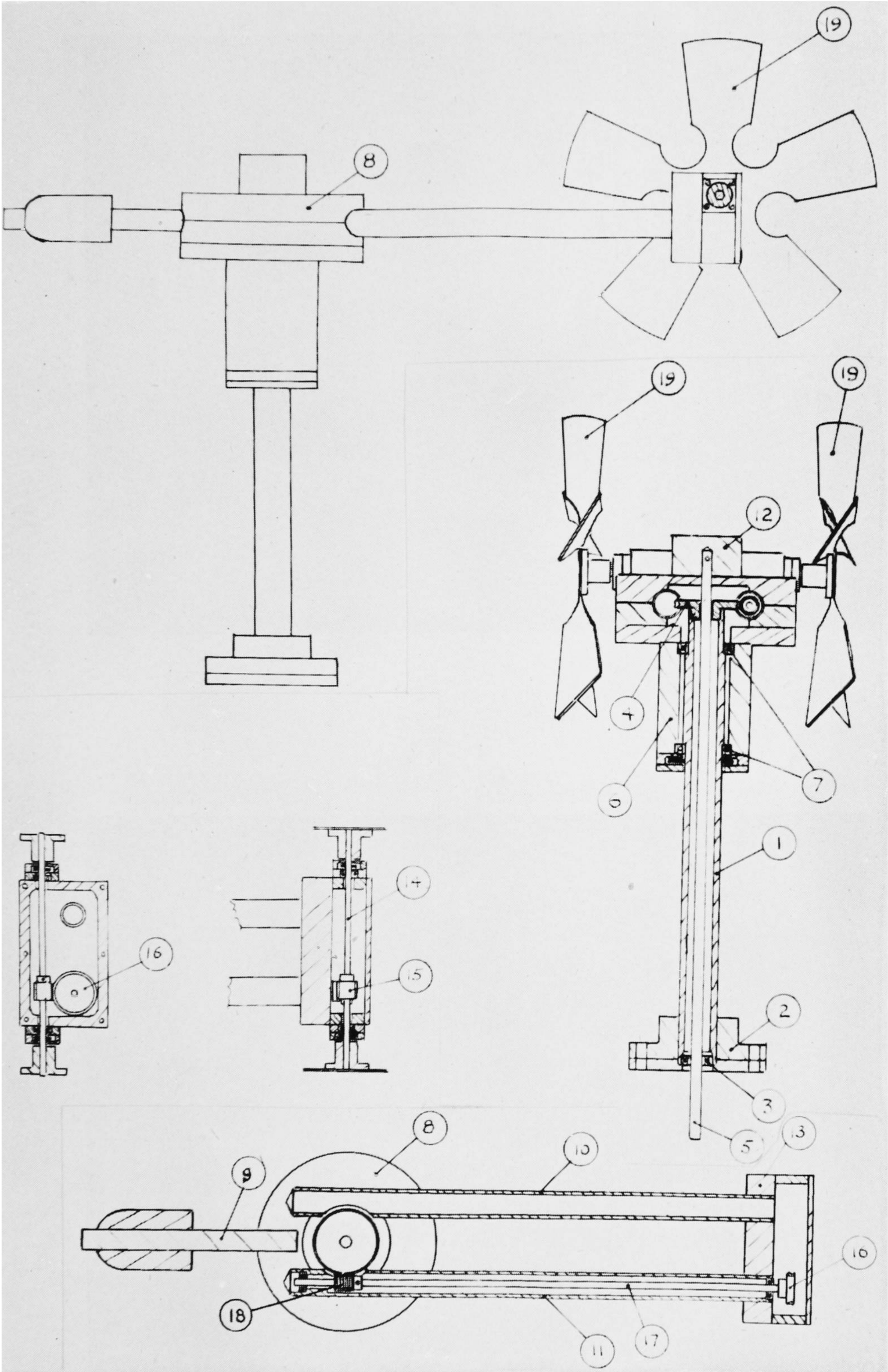
(i) to place the rotating windmill some distance out in front of the direction-shaft axis, so that it will be shielded as little as possible by the centre portion of the vane,

(ii) to mount all rotating parts in well protected and freely running ball-bearings,

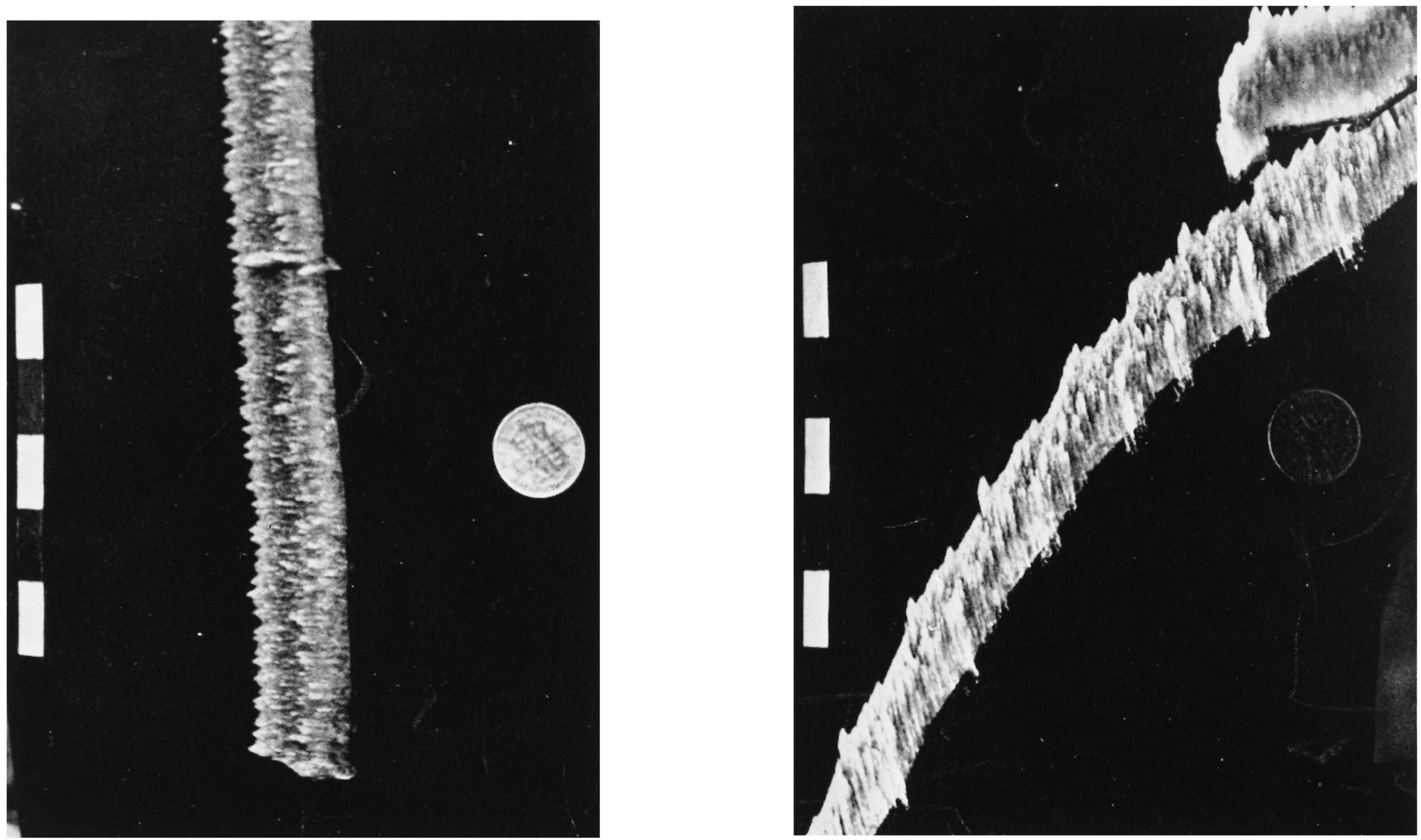
(iii) to make the worm-gear ratio as low as conveniently possible so that the windmill is doing very little work,

(iv) to balance the rotating portion as accurately as possible, and incidentally to arrange it so that it may rotate about a horizontal axis, if required, to record vertical inclination of the wind.

The vane is shown in the photograph opposite. A vertical tube (1) has at its lower end a flange (2) and a housing for a ball-bearing (3). Fixed to its upper end is a fixed worm-wheel (4) in the centre of which is a clearance hole through which passes the direction-transmitting spindle (5). The part of the vane which rotates in the wind consists of a sleeve (6) carried on ball-bearings (7) outside the centre tube (1) and having at its upper end a split cylindrical block (8) which when clamped up grips a balance weight (9) and two tubes (10) and (11). A boss (12) holds the upper end of the spindle (5). At the other end of the tubes (10) and (11) is a rectangular housing (13) which carries the windmill spindle (14) in ball-bearings suitably weather protected; and a worm (15) on the spindle engages with a worm-wheel (16) at one end of another spindle (17) carried inside the tube (11). On this spindle is a worm (18) which engages with the fixed worm-wheel (4). The spindle (14) carries at its ends two 5-bladed fans (19) 7 in. in diameter whose blades are bent in the same sense, at 40° to the plane at right angles to the axis. When caused to rotate by the wind, these windmills, through two stages of worm-gear reduction, 40 : 1 and 60 : 1, cause the whole of the rotating portion (6, 8, 10, 13 etc.) to turn round



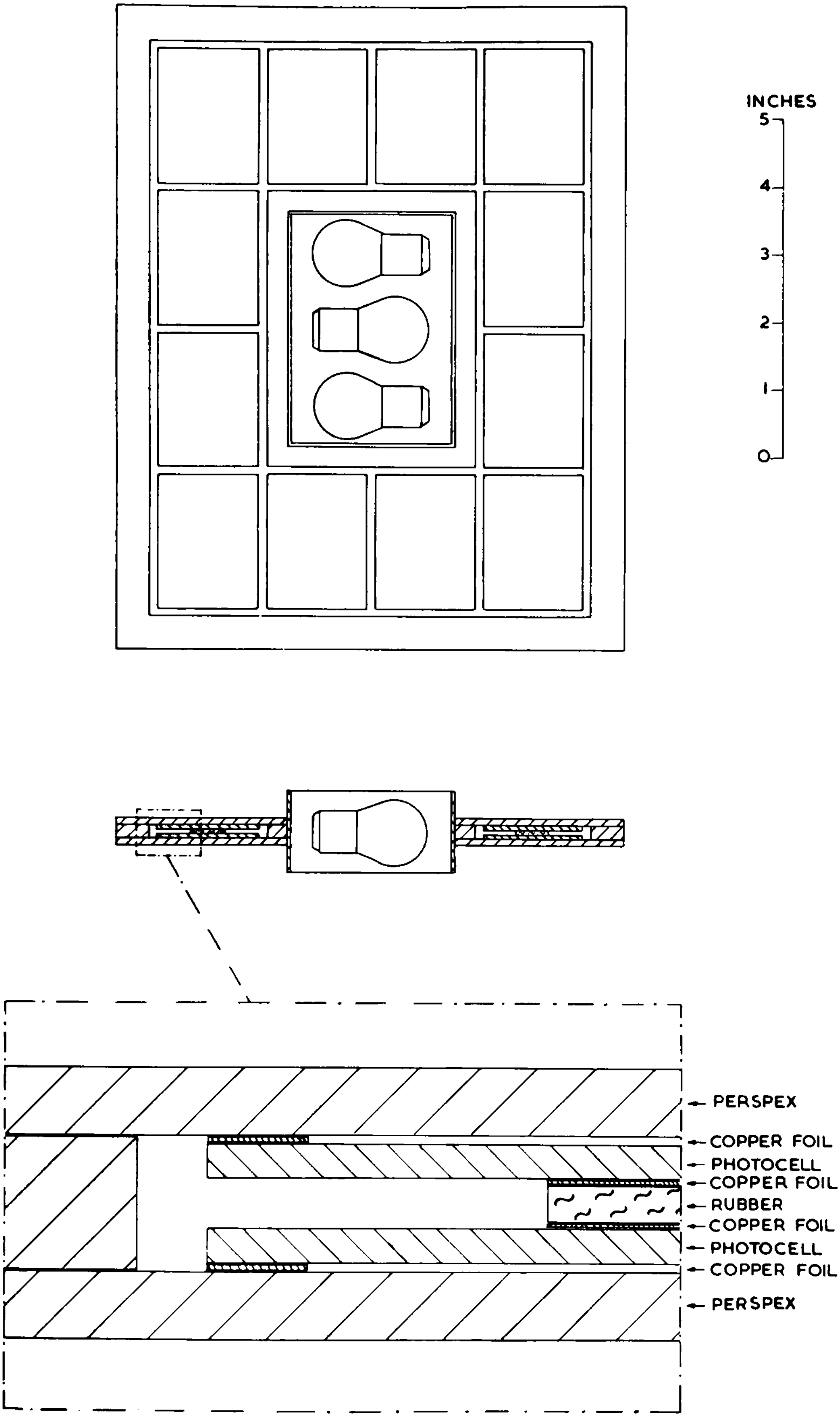
WIND VANE FOR RECORDING OR INDICATING MEAN WIND DIRECTION



Reproduced by courtesy of W. G. Pendleton

RIME AT TERNHILL, DECEMBER 21, 1956

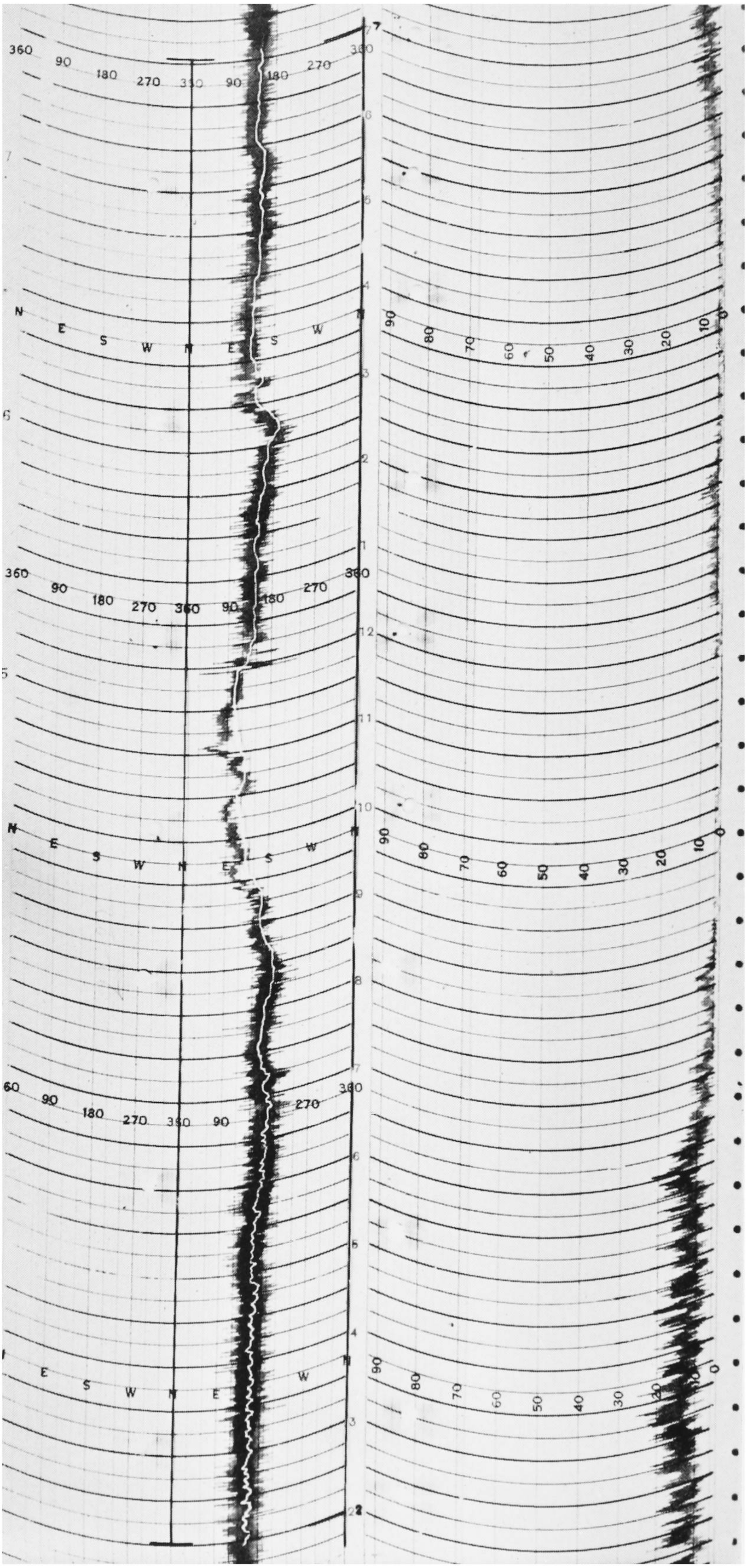
A one-inch scale and a half-crown piece are shown for comparison



FOG DENSITY INDICATOR

(see p. 117)

To face p. 113]



TYPICAL RECORD SHOWING MEAN WIND DIRECTION SUPERIMPOSED ON AN INSTANTANEOUS WIND-DIRECTION RECORD the fixed tube (1) until they are in such a position that the wind no longer causes them to rotate. This turning of the rotating portion also causes the spindle (5) to turn; and this is used to operate the direction-recording or transmitting device. All ball bearings are protected where necessary by means of oil soaked felt washers in housings outside the ball-bearings. The direction of rotation of fans relative to worms is such that the fans turn towards the direction of the wind, i.e. the balance weight is down stream.

Wind-tunnel tests.—The vane was set by hand at about 45° from true wind direction, and the time taken to reach 0° (or as near as possible) from 30°, in 5° intervals and from either side of 0°. The results are shown in Table I.

TABLE I—ACCURACY OF THE RECORDING WIND VANE

Wind speed	Vane movement	Displacement from true wind direction 25°	20°	15°	10°	5½°	5°	2°	1½°	1°	0°
kt.	From					*Time in seconds*					
30	E. to N.	4	9	15	24	...	36	...	...	...	65
	W. to N.	4	9	15	23	...	36	...	...	...	65
	From										
20	E. to N.	5	12	22	33	...	55	...	...	110	...
	W. to N.	6	14	25	38	...	62	100	...	...	...
	From										
10	E. to N.	11	25	42	64	...	105	...	190	...	...
	W. to N.	12	26	42	65	...	103	150	...	...	...
	From										
5	E. to N.	25	60	120	200	300	...	...	...	...	...
	W. to N.	23	55	95	150	...	190	...	...	...	...

These tests indicate that at speeds above 10 kt. the vane will show true direction to not worse than ±2°, though at 10 kt. it may take about 3 min. to do so. At speeds below 10 kt. the accuracy falls and the time increases.

Tests in natural winds.—The direction spindle of the vane was coupled to a Magslip transmitter, carried in a weather-proof housing below the vane, and the vane set up on the 40-ft. tower on the roof of the Meteorological Office at Harrow. The receiving Magslip operated a single-pen Meteorological-Office pattern direction recorder.

A Mk IIIb "In-line" pattern wind-vane connected to another recorder and mounted on a 34-ft. tower also on the roof of the Meteorological Office at Harrow, was used to provide a normal record for comparison. Both vanes were held to the same known direction, while the recorders were set to read that direction, with a probable error of ±3°.

A typical record is shown in the photograph opposite; the record of mean wind direction has been superimposed on the instantaneous wind-direction record taken from an electrical anemograph. This was done by tracing the mean wind record in white ink on a transparent sheet and photographing the electrical anemograph chart with the transparent sheet on top. It will be seen that when the wind speed is over 10 kt., between the hour lines 2–7 on the left-hand side of the chart, the mean trace lies near the centre of the instantaneous trace; but where the wind speed falls below 5 kt. between the hour lines 9–11.30, the mean trace does not follow the instantaneous trace.

It may be possible, by making the distance between the rotating fans and the vertical axis of the vane greater, to make the vane more sensitive at low wind speeds; but in its present form the vane will provide useful information on mean wind direction except at the lowest wind speeds. Trials of the vane to record vertical inclination of the wind have so far been limited to wind-tunnel tests; the performance is the same as with the vane axis vertical. To use the vane in this way in natural winds it would have to be mounted on another vane which would hold the windmill vane into wind, the procedure hence producing some complications.

Suggested uses.—

(i) In remote sites, where inking presents a difficulty, the fact that only a mean line is drawn will reduce considerably the amount of ink needed; so that with a simple cam recorder, and a glass pen and reservoir of the type used in the Meteorological Office Impulse Recorder, a week's, or even a fortnight's run should be possible; by using a silver pointer as a pen, and a metallized paper chart, a run of four weeks should be obtained with a suitable clock.

(ii) In cases where the wind flow is very turbulent, e.g. over crops, near the ground, where an ordinary vane would frequently box the compass, and give a trace covering 360°, from which it would be very difficult to extract the mean direction.

AURORAL DISPLAY OBSERVED FROM UNUSUALLY LOW GEOMAGNETIC LATITUDES

By B. McINNES, B.Sc.

Summary.—The interest of auroral observations from low geomagnetic latitudes is described. Observations of the auroral display of September 8, 1956 are reported, with brief details of some related effects.

Introduction.—Auroral displays occur most frequently in two rings of about 20° radius, centred on the north and south geomagnetic poles; these rings are known as the auroral zones. There is, however, frequent movement of the centres of auroral activity from these two mean positions, displays appearing overhead at places both inside and outside the zones. The frequency of observation falls off rapidly with decreasing geomagnetic latitude of the observer till at 45° it is less than one night per year on the average, according to available records.

Interest in low latitude observations.—There has recently been an increase of interest, fostered specially by Prof. S. Chapman, in the observation of those displays which move unusually far out from the auroral zones so that they become visible from low geomagnetic latitudes. The area between geomagnetic latitudes 45° north and south has been called the minauroral belt by Chapman. He has recently suggested that the chance of seeing an auroral display from this belt may be decidedly greater than past records indicate[1, 2]. The following notes of such an occurrence are published here not only for their intrinsic interest but also to support an appeal for further observations of this particular display and to encourage the careful watch by suitably placed observers that will yield more of these valuable minauroral observations.

Auroral observations.—An observation of the aurora on September 8, 1956 has been reported from a ship in geomagnetic latitude 43°S. The ship was at 31°40′S., 113°45′E., on her way from Fremantle to Durban when the aurora was first seen at 1435 universal time. The geomagnetic co-ordinates of this position are 43°S., 184°E. The observer was Mr. J. English, First Officer of the s.s. *Orion*. The display continued to be seen till nearly 1600 universal time. At 1435, which was just after moonset, an auroral glow was observed over the southern horizon. Rays appeared in the south-east and slowly wheeled across the sky towards the west, diffusing and becoming deep red. As the deep red faded in the south-west, a fresh set of rays sprang up in the east and developed as before. The auroral light reached 20° altitude.

The observation is confirmed and expanded by another report from a ship in an even lower geomagnetic latitude. This report evidently concerns a peak of activity of the display described above, since the aurora was seen only during the ten minutes 1446 to 1456 universal time. The ship was the M.V. *Port Phillip*, on a voyage from Fremantle to Cape Town, and the observers were Mr. J. E. Toghill, Second Officer and Mr. G. F. Brandon, Fourth Officer. The position was 29°22′S., 65°37′E., which has geomagnetic coordinates 37°S., 129°E. During the ten minutes mentioned, auroral light appeared in the southern sky between 20° each side of due south and up to 40° elevation, its colour changing from dull crimson to bright red and then back through crimson to extinction.

The sunset line, which was about an hour west of the second ship when the ten-minutes peak of activity was observed from it, passed across the British Isles at about 1830 universal time. Aurora was observed from Kirkwall, Orkney, geomagnetic latitude 62°N. at 2100 universal time and from Malin Head, Co. Donegal, Ireland, geomagnetic latitude 59°N., at 2200 universal time. Other reports of aurora seen later in the evening came from other observers in Scotland, but none of these was south of geomagnetic latitude 60°N.

A bright rayed arc was reported by an aircraft over the North Atlantic, flying in geomagnetic latitude 63°, at 0400 universal time on September 9; this remained visible till 0800.

Further observations.—It is hoped that there may be more reports of this display to come from other ships that were in the Indian Ocean or in the Pacific between Australia and the Hawaiian Islands at the time. The display was almost certainly seen from Australia and attempts are being made to collect the observations made there.

Geomagnetic disturbance.—The three-hour-range planetary indices of geomagnetic disturbance show a world wide magnetic storm at the time of the display, as follows:—

	0–3 hr.	3–6 hr.	6–9 hr.	9–12 hr.	12–15 hr.	15–18 hr.	18–21 hr.	21–24 hr.
	indices of geomagnetic disturbance							
Sept. 7	3_o	2+	3−	2_o	2_o	2_o	1+	1+
Sept. 8	1_o	1_o	4−	5+	8+	8_o	6_o	3+
Sept. 9	3−	3−	4+	4+	4−	3−	4_o	3+

These indices, which have 28 possible values, from 0_o to 9_o, are derived from measurements of the variations of the magnetic elements at magnetic observatories all over the world. The original records are continuous traces called magnetograms.

Fig. 1 is based on the magnetograms made at Lerwick Geophysical Observatory on September 8, 1956. Lerwick is at 63°N. geomagnetic latitude. During the peak ten minutes of the display there were unusually steep changes of the elements: during 1447 to 1450, D increased by over 700γ; during 1448 to

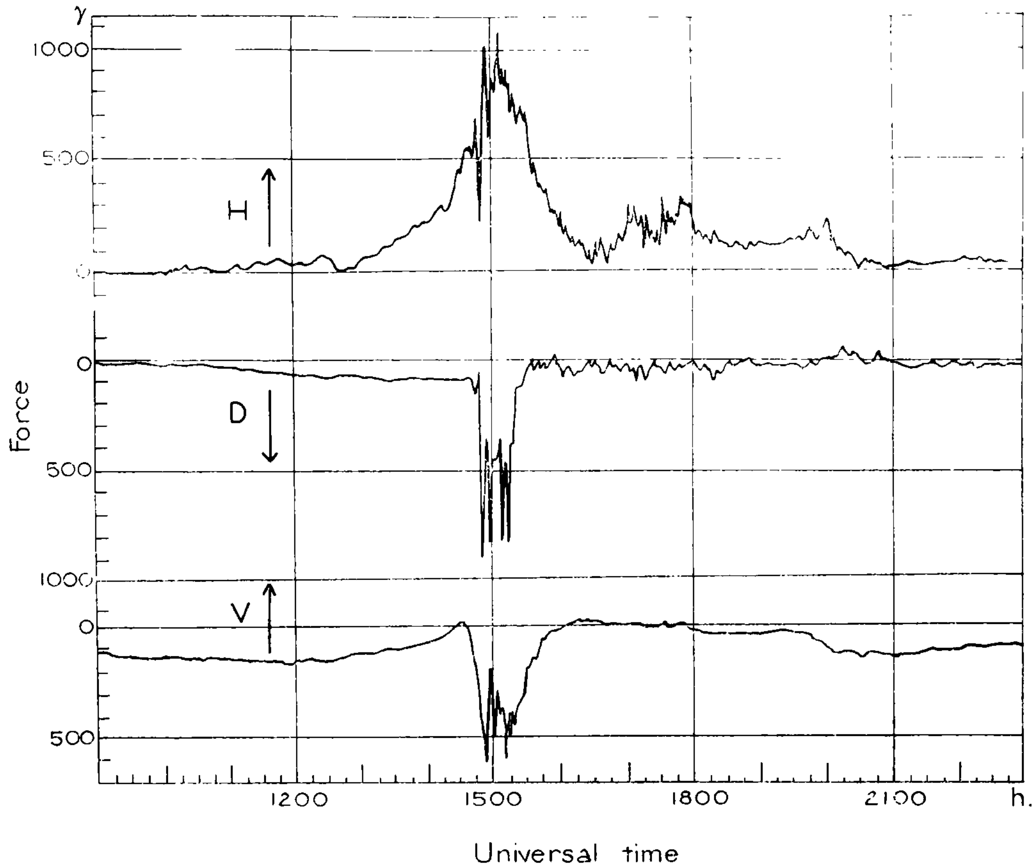


FIG. 1—VARIATION OF H, D AND V AT LERWICK GEOPHYSICAL OBSERVATORY ON SEPTEMBER 8, 1956

The direction of increase of each element is indicated by an arrow.

1454, H increased by about 800γ. The magnetogram made at Hermanus Magnetic Observatory in South Africa, at 34°S. geomagnetic latitude shows similar sudden changes. The details of the relationship between the auroral display and the geomagnetic disturbance are of considerable interest; the importance of accurate timing of the auroral observations is obvious.

Radio echoes.—The transmitter of the rotating aerial equipment at the University of Manchester's Experimental Station, Jodrell Bank, geomagnetic latitude 56°N., was unfortunately switched off from 1218 till 1500 universal time on September 8. But thereafter the following observations were made.

1500 strong echoes from about geomagnetic latitude 59°N. over an azimuth angle of ±30°; very intense at 500-Km. range at 20° east of geomagnetic north.

1510 intense echoes east of geomagnetic north continuing; westerly echoes die out.

1515 echoes less intense.

1520 echoes disappear for a minute.

1525 weak echoes east of magnetic north continuing.

1537 all echoes disappear after gradual decrease in intensity.

Radio star scintillation.—Another effect which gives information about ionospheric disturbances connected with aurora is the fluctuation of the signal received from the Cassiopeia radio source: this signal is continuously observed at Jodrell Bank, the measure used averaging between 1 and 2 during a normal day. The hourly values for September 8 were as follows:

10–11 hr.	11–12 hr.	12–13 hr.	13–14 hr.	14–15 hr.	15–16 hr.	16–17 hr.	17–18 hr.	18–19 hr.
3	3	4	5	7	7	4	4	3

Solar activity.—Since auroral displays follow solar-flare activity by about 18 to 30 hr., the state of the sun's surface during September 7 is of interest. A sun-spot with an area of 2,250 millionths of the sun's visible hemisphere on September 6 was crossing the disc during September 5–18. Some flare activity connected with this large spot was observed during the period of interest but insufficient information is available at present to decide the precise relationship between this and the display.

Acknowledgements.—Thanks are due to the ships' officers for the observations which started this study, and to the Director of the Irish Meteorological Service for auroral observations from meteorological stations in Ireland. The radio echo and radio-star-scintillation data were kindly supplied by Mr. C. D. Watkins of Manchester University, with the permission of Prof. A. C. B. Lovell. The sun-spot information came from the Royal Greenwich Observatory, by kind permission of the Astronomer Royal. A reproduction of the magnetogram made at Hermanus Magnetic Observatory on September 8 was kindly supplied by the Officer in Charge.

Appeal.—Further relevant data will be welcomed by the writer at the Balfour Stewart Auroral Laboratory, University Natural Philosophy Department, Drummond Street, Edinburgh 8. In particular, it is hoped that more observations of the auroral displays in both the southern and the northern hemispheres during the 12 hr. or so following on 1400 universal time on September 8 will be forthcoming.

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A FOG-DENSITY INDICATOR

By J. R. BIBBY, B.A.

In 1950 the Ministry of Civil Aviation asked the Meteorological Office for some means of measuring the depth of a fog layer, and preferably also the variation of visibility with height up to at least 500 ft. The most practicable method appeared to be to measure the scattering of light in the air by an instrument carried on a tethered balloon.

At first it was hoped to make an instrument which could be used in daylight as well as darkness. A model was made, using a series of baffles to exclude daylight, but it proved too heavy for the 500-gm. balloons it was proposed to use. Also it appeared that there would always be doubt whether the air inside was representative of that outside. A much simpler instrument was therefore designed for use in darkness only. Its dimensions are approximately 24 × 20 × 3 cm., and weight, without batteries, about 750 gm.

Description.—A simplified drawing of the instrument is shown in the photograph in the centre of this magazine. A "sandwich" is formed from two sheets of perspex, each with a rectangular hole in the centre. Between them, 24 selenium barrier-layer photo-electric cells are arranged in a double layer facing outwards, with a strip of rubber separating the two layers, and strips of copper foil making connexion with the cells. The inner and outer edges of the sheets are then cemented together with strips of perspex, and the whole made waterproof with a solution of perspex in chloroform. A pair of leads is fitted to allow electrical connexion to the photo-electric cells, which are all in parallel. In the central hole are placed three 6 v., 12 w. filament lamps. No lamp holders are used for lack of space, the lamps being fixed in a wire frame with soldered electrical connexions. Around the lamp is a metal strip, just wide enough to prevent any light reaching the photo-electric cells directly.

Provided the instrument is mounted so that there are no objects within about 50 ft. of it, except in its own plane, and there is no fog or mist, no light from the lamp can reach the photo-electric cells, and the current from the cells is very low, less than $0 \cdot 2 \mu$ amp. If fog is present, however, light from the lamps is reflected by the fog particles and a current is generated by the photo-electric cells. This current should be roughly proportional to the scattering coefficient of the air, i.e. inversely proportional to the visibility.

Method of Use.—As stated above, it can only be used in darkness, and must be mounted well away from any other object, which implies, for best results, at least 50 ft. above the ground. Normally it is fixed at one edge to the flying cable of a tethered balloon, at least 20 ft. below the balloon. A battery to supply the lamps (6 amp. at 6 v.) must also be carried, though for restricted heights a transformer fed by a length of mains cable could possibly be used. In any case some means of switching the lamps on and off is needed, not only to reduce the drain on the battery, but also to be able to allow for any photo-electric cell current generated by moonlight or other external lights. If a remotely controlled switch presents difficulties, an automatic switch controlled by clockwork, or a heated bimetal system, can be used to switch the lamps on for, perhaps 5 sec. every 30 sec. The photo-electric cell current is carried by a pair of wires to a galvanometer on the ground. The wires can be quite light but should be very well insulated in view of the small current they carry, and the damp conditions in which they are used. The galvanometer should have a full-scale deflection of about 5 μ amp. and its resistance should be not more than a few hundred ohms. A mirror galvanometer is therefore necessary.

Results obtained.—Calibration was carried out at Cardington by mounting the fog-density indicator at the top of a 60-ft. tower and comparing its readings with those of a photo-electric visibility meter operating over a 150-yd. path at the same height. As expected, the photo-electric cell current was found to be inversely proportional to the visibility, the approximate relationship being:

Current $\times$ visibility $=$ 300 μ amp. yd.

For comparison, the following approximate figures may be quoted:

Current in clear air $= 0 \cdot 2$ μ amp. or less

Extra current due to moonlight $= 0 \cdot 5$ μ amp.

Extra current if instrument is mounted only 7 ft. above the ground $= 3$ μ amp.

After calibration the instrument has been used for investigation of fog structure at Cardington, mounted on the cable of the barrage balloon used for "Balthum" ascents. It has been chiefly useful in finding the height of the base or top of a clearly defined layer of cloud or fog. Some indication is also given of the variation of visibility with height, but sampling errors are to be expected as most of the light reaching the photo-electric cells comes from the fog within about 50 cm. of them. It has not been used to give routine information for aviation, as originally envisaged, chiefly because of the difficulty of operating a large tethered balloon on an airfield.

OFFICIAL PUBLICATIONS

The following publications have recently been issued:—

The Annual Report of the Director of the Meteorological Office, presented by the Meteorological Committee to the Secretary of State for Air, for the year April 1, 1955 to March 31, 1956.

This Report is an account of the year's activities of the Meteorological Office as the State Meteorological Service. It appears this year with a new cover of modern design, and the contents have been prepared largely as continuous narratives replacing the numerous brief paragraphs of earlier Reports. Illustrations showing some of the more interesting aspects of the work of the Meteorological Office are included for the first time.

Meteorological services have been provided for civil and military aviation, for shipping and directly for the general public by telephone, television, radio and through the Press, and indirectly by special forecasts for electricity and gas undertakings, farmers and River Board and Road Engineers. Information regarding climate at home and abroad has been supplied to meet many enquiries connected with industry, commerce, agriculture, public utilities and shipping. An interesting development was the completion, in collaboration with the General Post Office, of arrangements to provide in the London area an automatic dialling telephone service for the issue of forecasts to the public. The Report also records the installation, in London, of a radar storm-warning set, to test its usefulness for short-period but very precise forecasts of rainfall.

The Meteorological Research Programme again covered a very wide field. Increased effort and staff were devoted to the study of numerical forecasting—the process whereby forecast pressure maps are produced by calculation—and approval was obtained for the installation of an advanced type of electronic computor for this work and other problems involving long and complex calculations. Work continued on a long series of carefully controlled trials on the possibility of increasing rainfall by cloud seeding. In addition, the Meteorological Research Flight has continued its high-altitude research and much effort has been directed at the problems which result from the increasing heights at which aircraft now operate.

The Meteorological Office has continued to take a leading part in international meteorology, not only through the World Meteorological Organization, but by exchange with and secondment of staff to other countries. The Report includes financial and staff details, and indicates both the continuing shortage of scientific staff and the difficulties still produced by the high rate of turnover of Assistants.

Weather map, 4th edition.

The "Weather map" has been a Meteorological Office "best seller" ever since it was first published as a 5 in. × 6 in. paper-covered pamphlet at 4d. a copy forty years ago. It was rewritten in 1930 to take account of the great strides which had been made in synoptic meteorology during the intervening years, and some further alterations were made for the 3rd edition in 1939.

Changes both in practice and emphasis in weather forecasting have since become so pronounced that it has been necessary to rewrite large parts of the book for this latest edition. The causes of our most frequently experienced weather phenomena have been given greater attention than formerly; a new set of weather maps plotted in the up-to-date manner and showing typical pressure distributions has been included, and modern forecasting techniques are described.

This 4th edition of the "Weather map" is a reasonably comprehensive introduction to weather forecasting, as described by the new sub-title and on that account it should appeal to many whose curiosity about weather forecasting may have been stimulated by the daily presentation of weather maps on television screens, and to teachers and pupils in secondary schools.

M.O.593. *Meteorology for Mariners.*

Meteorology for Mariners has been prepared in the Marine Division of the Meteorological Office to meet the specific need of an up-to-date book on this subject for ships' officers.

It is a companion volume to *The Marine Observer's Handbook* and aims to present the elementary theory of modern meteorology and the basic climatology of the oceans in a straightforward manner for the benefit of seamen and to show how this knowledge can be used by ships' officers in the course of their duties. Included in the book is a section on Oceanography, as it is a subject allied to meteorology, and because it forms part of the syllabus for the Extra Master's

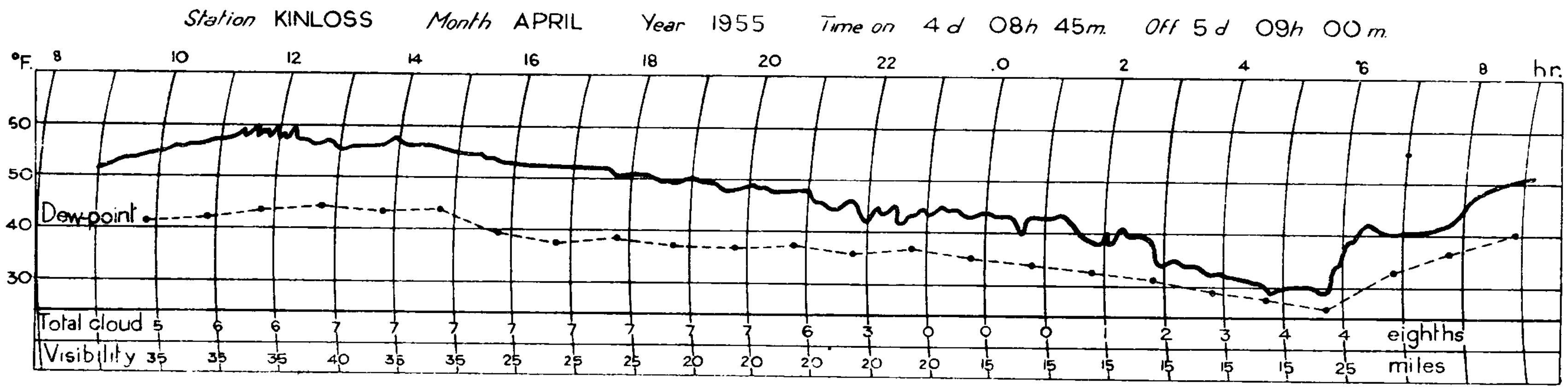


FIG. 1—THERMOGRAM SHOWING AMOUNT OF CLOUD AND VISIBILITY FOR KINLOSS, APRIL 4–5, 1953

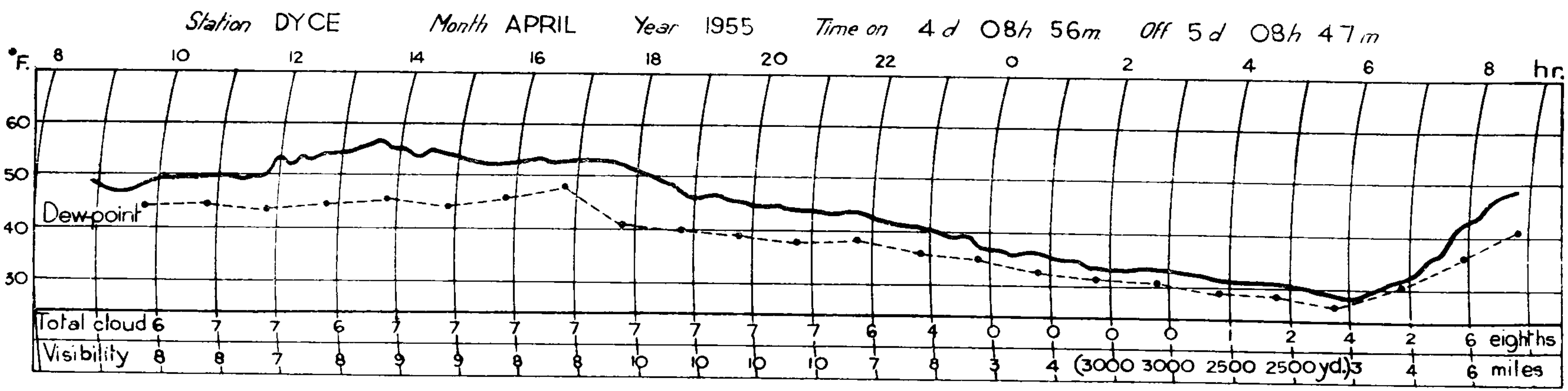


FIG. 2—THERMOGRAM SHOWING AMOUNT OF CLOUD AND VISIBILITY FOR DYCE, APRIL 4–5, 1953

Examination. All candidates for the Ministry of Transport and Civil Aviation masters' and mates' examinations will find the meteorological section of the syllabus covered in this book.

The book will be of value to yachtsmen and anyone interested in weather at sea as well as to the professional seaman.

NOTES AND NEWS

An example of freedom from fog, and an unexpected frost, at Kinloss and Dyce

On April 4, 1955, an occlusion passed Kinloss at 1200 G.M.T. and Dyce at 1400 G.M.T. At 1500 G.M.T. the temperature at Kinloss was 55°F., with a dew-point of 44°F., the gradient wind was 20 kt. from south-west and the surface wind 15 kt. Kinloss observed 3 oktas or less of low cloud and 7 oktas total cloud until 2000 G.M.T.; the cloud then began to break and had dispersed completely by 2300 G.M.T. The gradient wind slackened during the night to become 10 kt. by midnight, the surface wind falling calm.

With a dew-point of 44°F. at 1500 G.M.T. it might be expected that radiation would lead to fog formation and that thereafter temperature would fall only slowly. In fact the temperature at Kinloss fell unsteadily during the night, the minimum temperature being 28°F. (see Fig. 1). The dew-point remained fairly constant from 1700 to 2300 G.M.T. and then fell steadily to a minimum of 26°F. Saunders's investigations into night cooling under clear skies in southern England show a discontinuity in the rate of cooling which in early April occurs at about 2000 G.M.T., but no such discontinuity is apparent at Kinloss on this occasion, perhaps because of the cloud changes that were taking place. The lowest visibility reported was 15 miles.

At Dyce also the temperature fell progressively to a minimum of 28°F., and the dew-point fell fairly steadily from 1800 G.M.T. to reach a minumim of 26°F. (see Fig. 1). Visibility decreased to 3,000 yd. at 0200 G.M.T. and to a minimum of 2,500 yd. at 0400 G.M.T. In this case there is a suggestion of a Saunders's discontinuity at 1900 G.M.T. Mackenzie's formula for minimum temperatures at Dyce, $T = \frac{1}{2}(T_1 + D) - C$, where T_1 and D are the maximum temperature and the corresponding dew-point, respectively, and C a constant depending on wind and cloud, gives a minimum value of 36°F. for this night, assuming the wind to be calm and the sky free from cloud.

The hydrolapse at 1400 G.M.T. was 15·3 mg. per Kg., per mb. at Leuchars and 16·0 mg. per Kg., per mb. at Stornoway. Swinbank's diagrams[1], using these values of hydrolapse and a wind-shear value of 10 kt., give a forecast of no fog but apply to south-east and north-east England in October and November and might not be applicable to north Scotland in April. Briggs's method[2] gives a potential dew-point of 37°F. and 32°F. respectively for Leuchars and Stornoway. However, temperature fell to 28°F. at both Kinloss and Dyce without fog formation.

The north-east of Scotland is known to be comparatively free from radiation fog, largely because the atmosphere is clean and the air from the south-west is dried by subsidence. In the present case it seems likely that the absence of fog was due to an abnormally low number of condensation nuclei.

W. G. RITCHIE

REFERENCES

1. SWINBANK, W. C.; Prediction diagrams for radiation fog. *Prof. Notes, met. Off., London*, **6**, No. 100, 1949.

2. BRIGGS, J.; Notes on the temperature at which radiation fog forms. *Met. Mag., London*, **79**, 1950, p. 343.

Weather charts by radio

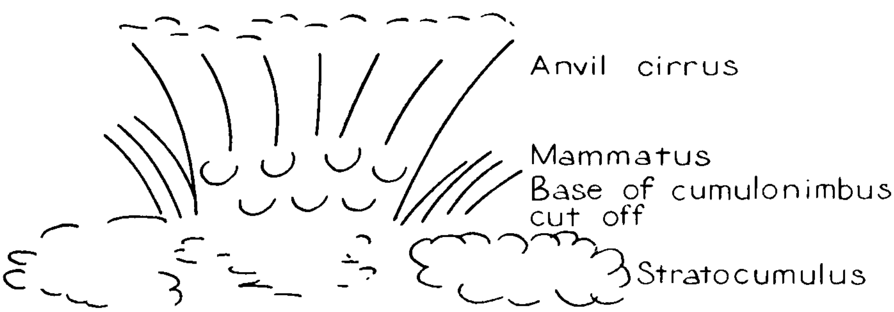
A Mufax Chart Recorder, for displaying facsimile-picture transmissions of weather charts, is now on exhibition in the Science Museum.

The recorder, which has been lent by the makers, Muirhead & Co. Ltd., reproduces a whole chart in thirty-five minutes or less depending on the speed setting, and, throughout the recording, the progressively growing chart is visible on a flat platen.

The exhibit can be shown in operation and will normally be used to record the transmissions broadcast from the Central Forecast Office at 1210 G.M.T. and 1650 G.M.T. The recorder will remain on exhibition for a period of about six months. Hours of opening:—Weekdays, 10 a.m. to 6 p.m.; Sundays, 2.30 to 6 p.m. Admission free.

Unusual cloud formation

The sketch and following notes have been received from Mr. W. J. Bruce.



"On Saturday August 25, 1956, at 1840 G.M.T. this cloud formation was seen at London Airport.

The cloud gave the appearance of 'mammatus' formed from anvil cirrus. The base of the cumulonimbus had been sheared off leaving the anvil top and stratification was rapidly taking place. At 1800 G.M.T. a filling depression was centred over northern England and an unstable westerly air stream covered the area. Showers, frequent at times, with local thunderstorms had occurred during the afternoon".

Funnel cloud off Ramsgate on August 5, 1956

We are indebted to Mr. R. T. Nicholas of 609 High Road, Tottenham, London, N.17, for the following description of the formation of a funnel cloud at the base of a cumulonimbus cloud off Ramsgate at 1210 G.M.T. on August 5, 1956.

"As I looked at the cloud (Fig. 1*a*) I saw a rounded bulge (Fig. 1*b*) appear at the base of it. The bulge developed quite quickly into a triangle as black and well defined as the main body above it. The triangle grew until it looked rather like a parsnip with the tail swinging to the right and then returning to the vertical (Fig. 1*c*). Suddenly the tail lengthened and, after swinging upwards towards the black cloud in a regular loop (Fig. 1*d*), darted away to the right (Fig. 1*e*). During this process the loop flattened out slightly

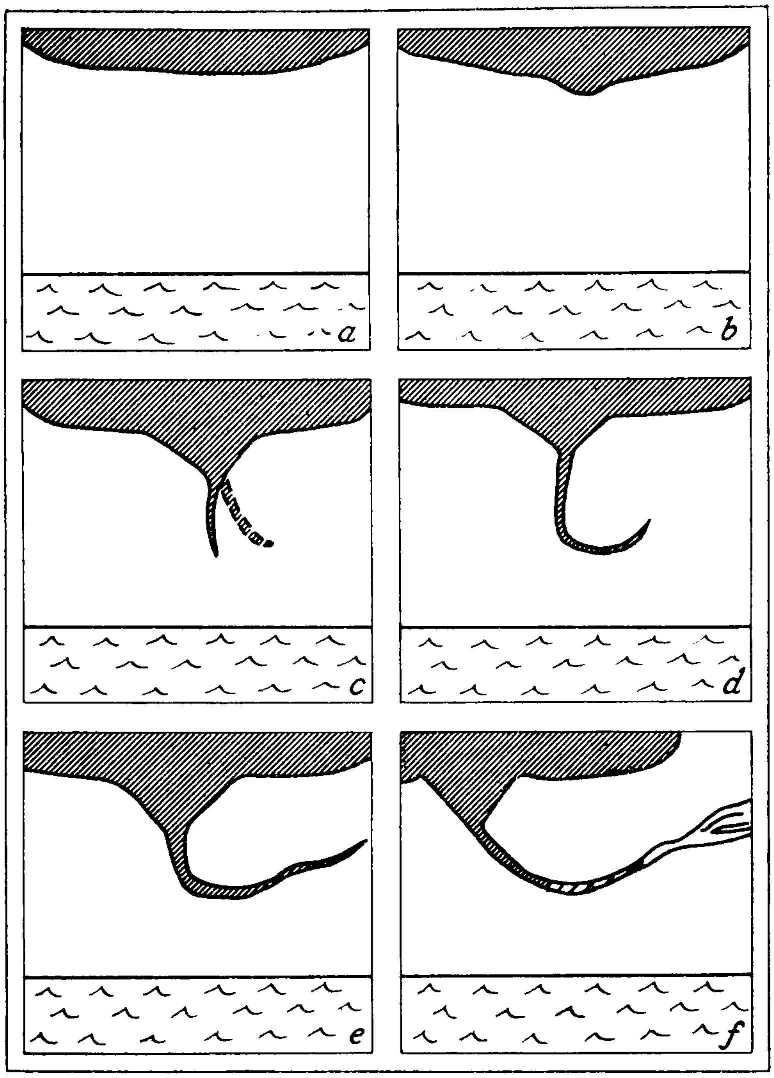


FIG. I

and the tail lightened in colour from a grey to near transparency. The extreme end seemed to feather out like a frayed rope (Fig. 1*f*) and the tail flailed round for a short time. At about 1220 G.M.T., as the cloud began to move away in a westerly direction, the tail descended slightly but remained roughly horizontal."

On August 5, 1956 large cumulus and cumulonimbus clouds developed quickly over south-east England and thunderstorms occurred before midday. At 1200 G.M.T. an extensive polar depression was centred over south-west England. At about 1500 G.M.T. the value of the 1000–500-mb. thickness reached the minimum recorded for August during the five-year period 1949–53.

REVIEW

Introduction to dynamic meteorology. By H. F. Panofsky. 9 in. × 6 in., pp. viii + 243, *Illus*., Pennsylvania State University, 1956. Price: $3.50.

Since the end of the Second World War a great deal of progress has been made in numerical forecasting. This has been both due to the advent of high-speed electronic computing machines and to a greater understanding of the mathematics and physics of dynamic meteorology. Numerous papers have been published on numerical forecasting and associated topics, and it is therefore very gratifying to find a textbook which contains an introduction to this subject.

This book is intended for two groups of people, forecasters who are well acquainted with problems of practical meteorology and who would like to review dynamic meteorology with special emphasis on the physical basis of numerical forecasting, and college students. It is very well written for that purpose and it assumes no prior knowledge of mathematics and physics beyond Intermediate B.Sc. It is therefore rather elementary for the specialists; indeed some college students will find the first chapter superfluous. However, a large amount of material is collected together in a convenient form for reference, and it may well be that even specialists in this field would find the book useful for reference purposes.

The book is divided into seven chapters and there are three appendices. There is also a very adequate index. Derivations are generally not given in detail and this makes for easy reading. Nevertheless, derivations of the vector form of the equation of motion and of the equation of continuity are given in one of the appendices. Diagrams are frequently used to illustrate points which the beginner may find difficult. The author does give wherever possible a physical interpretation of the mathematics and this is another reason why the non-specialist will find this book easy to understand.

The first chapter is intended only for readers whose knowledge of mathematics and physics is elementary. It explains many basic mathematical concepts, such as derivatives, integrals and vector notation. It also explains some basic meteorological concepts such as divergence, circulation and vorticity.

Although many people who read the book will omit Chapter 1, I think this chapter makes the book of value. This is primarily a book intended for the beginner, and a chapter on fundamental mathematical and physical ideas makes it very easy for the beginner in dynamical meteorology to understand the ideas which follow.

The two chapters dealing with the fundamental meteorological equations and simple manipulations of those equations are clearly set out. The derivations of the vector equation of motion and of the equation of continuity are not given in these chapters but are given in one of the appendices. A summary of the seven scalar equations in hydrodynamic form is given at the end of Chapter 2 and this is a useful feature for reference purposes. The Sutcliffe development ideas are explained, but the development equation is not derived. Constant absolute-vorticity trajectories and the Rossby wave formula are also dealt with.

The use of perturbation theory to obtain approximate solutions to non-linear equations is dealt with adequately. The properties of some important waves derived by perturbation theory are given. The absence of mathematical derivations does make this chapter easily readable; the results quoted can be derived quite straightforwardly if the reader so desires.

The chapter on dynamic forecasting is excellent. The first part of this chapter is devoted to the various techniques used in work on numerical prediction, while the second part describes the use of these techniques in specific models. The final two chapters are on turbulence and the general circulation.

I recommend this book as being very useful to the beginner in numerical forecasting and as being possibly useful to the more advanced worker in the field for reference purposes. It should be remembered that it is an elementary treatise on the subject, but that is what is intended and I think it very worth while.

F. H. BUSHBY

HONOUR

Dr. R. C. Sutcliffe, Deputy Director (Research) of the Meteorological Office, was elected a Fellow of the Royal Society on March 21, 1957.

METEOROLOGICAL OFFICE NEWS

Academic successes.—In addition to the list published in the March number the following members have also been successful in their examinations:

General Certificate of Education (Advanced Level): J. B. McNeill and A. B. Turner.

Meteorological "THUM" ascents.—On February 27, 1957 the 2,000th routine THUM ascent was made by Spitfire aircraft flown by the civilian contractors Messrs. Short and Harland. This daily ascent, which is normally performed over Worcester, was first undertaken by Messrs. Short and Harland on May 1, 1951. Spitfire aircraft supplied by the Royal Air Force Home Command are used for these flights. Despite the fact that this type of aircraft dates from the Second World War, the ascents have been made with very high regularity. A most satisfactory standard of meteorological observing has been maintained throughout, very largely as a result of the enthusiasm of Flt Lt J. Formby, R.A.F.R.O., who has been associated with the flight from the start. The Spitfire aircraft are shortly to be replaced by twin-engined Mosquito aircraft.

Ocean Weather Ships.—The following are extracts from the Radio Observer's report of Voyage 73 of the *Weather Watcher:*

"*Communications.*—While on station (Ocean Station 'India') difficulty was experienced on several occasions in establishing communications with Dunstable during the change from daylight to dark, although changes of frequency were made to try to overcome the difficulties. Long periods of squalls of rain, hail, snow and sleet did not help matters. One period of complete radio fadeout was experienced on January 21–22 between 1600 and 0300 approximately. As often happens this fadeout coincided with an unusually brilliant display of aurora.

Aircraft.—A total of 188 aircraft contacted the ship during the period on station. Meteorological information was provided for 178 of these and 173 radar fixes were given. Included in the above was a Canberra aircraft equipped only with VH/F; besides giving this aircraft the usual Weather Ship services, i.e. upper winds, radar fixes, continuous M/F beacon operation, etc. the ship acted as a link in relaying from Iceland meteorological information in that area including landing forecasts, etc. The pilot expressed his thanks for the ship's help and co-operation."

R.A.F.V.R. (Meteorological Section).—*Awards.*—It was announced in Air Ministry Orders dated February 13, 1957 that the undermentioned officers in the Meteorological Section of the Royal Air Force Volunteer Reserve had been granted the Air Efficiency Award. We offer them our congratulations.

Flight Lieutenants

E. Atkins	M. J. Merrick
H. W. Bitton	J. J. Parker
E. Chambers	A. A. Penny
C. G. Hawes	D. C. Pool
R. E. Hearn	R. S. Sowter
D. J. Hinds	D. V. Tamblin
F. M. Laughton	J. W. Thomas
A. Lonsdale	G. S. Wallace-Williams

Flying Officer W. J. R. Price.

In addition Flt Lt D. J. Hinds has been awarded a clasp to the Award.

WEATHER OF FEBRUARY 1957

The "Icelandic" depression was again much deeper than normal but unlike the preceding months of this winter the lowest monthly mean pressure in February (990 mb. at 55°N., 30°W.) was much displaced, actually well to the south-east of the normal position near Cape Farewell. In consequence, pressures were 14 mb. below normal over a considerable area (50°–55°N., 20°–30°W.). This situation gave a continuance of the mild, prevailing south-westerly winds over Europe but in many other parts of the northern hemisphere there was a radical change from the weather of the earlier part of the winter.

The Siberian high, which became weakened in January, recovered to well above normal intensity and the great extension of this system over the Arctic which had been a feature of December also reappeared in February. Pressures were 17 mb. or more above normal over much of northern and north-eastern Siberia, where the highest monthly mean pressure was about 1044 mb.

Mean temperatures in Europe for February were almost everywhere above normal, the excesses being greatest (3°–4°C.) in France and central Europe, least in Britain and northern Scandinavia, where a few stations on the north-west fringe were very slightly below normal. Unlike December and January, the month was less cold than normal in the Mediterranean and over most of the United States and eastern Canada. The lowest surface temperatures in February 1957 were over a wide area of north-east Asia, where the month was colder than average (greatest known anomaly −12°C.).

The month gave much above normal precipitation in many areas of great extent: the Plains States and western Gulf of Mexico, most of north-west Canada east of the Rockies, northern Iceland and east Greenland, also Labrador, all Europe between the Alps and Lapland, also northern Egypt and Mesopotamia. The whole Mediterranean, however, had a dry month, also most of India.

In the British Isles the first half of the month was changeable but mild with considerable rain at times. The third week was rather cold with light northerly winds, but weather became changeable again from the 21st to 24th. The last three or four days of the month were sunny and mild.

During the first few days winds were mainly south-westerly and weather unusually mild with occasional rain in most districts; afternoon temperatures exceeded 50°F. from the south coast to south-west Scotland and reached 57°F. at Mildenhall on the 1st and 4th. A vigorous depression skirted the western coasts of Ireland and Scotland on the 4th and 5th giving considerable rain and widespread gales; gusts of over 90 kt. were recorded in the Hebrides, while in western Ireland extensive damage occurred in Galway as the River Corrib overflowed its banks and flood-water in the city centre was 4–6 ft. deep. On the 7th a narrow warm sector moved across the country giving heavy rain in the west and south-west; many stations in Breconshire and Monmouthshire recorded more than 2 in. in 24 hr. A similar system on the 11th brought a renewal of heavy rain in southern England and by this time rainfall at many places had exceeded the February normal. There was considerable flooding in the Thames valley. On the 14th winds veered to the north over the British Isles and there were frequent snow showers in Scotland and northern England with keen or hard frost at night, temperature falling below 24°F, at many places. During the next few days snow showers extended as far south as the Midlands. At Leicester there was an unusual fall over a small area on the night of the 18th–19th as a small polar depression near the Scilly Isles moved eastwards; snow lay over 8 in. deep in and to the east of the city and 4–8 in. deep over most of Leicestershire, but ground remained largely clear of any but a light covering of snow in the surrounding counties. On the 21st mild south-westerly winds brought rain to southern England and two days later mild Atlantic air spread to the whole country preceded by widespread rain and some snow. By the 25th temperatures in England and Wales again exceeded 50°F. at many places and 57°F. was reached at Hurn. There was a general rise of pressure over the British Isles on the 26th and southerly winds spread to the whole country giving generally fine sunny weather until the end of the month.

It was the wettest February in England and Wales since 1951. More than 150 per cent. of the average rainfall was recorded generally south-east of a line Bristol Channel to the Wash; more than twice the average fell over most of Kent and Sussex. Temperature was about average in Scotland, but well above the average in England and Wales. At Kew it was the first February since 1946 with mean temperature more than the 1921–50 average. The mild weather has brought most crops well forward and the premature bud burst on some top and bush fruits is causing concern. A spell of hard weather during the next month would cause a serious set-back. Ground conditions are mostly very wet and even waterlogged in places: ground must dry out before any real progress can be made with spring ploughing and cultivating.

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 ...	59	3	+1·9	153	+3	118
Scotland	57	9	+0·5	103	−1	125
Northern Ireland ...	54	20	−0·3	92	+1	148

RAINFALL OF FEBRUARY 1957

Great Britain and Northern Ireland

County	Station	In.	Per cent. of Av.	County	Station	In.	Per cent. of Av.
London	Camden Square ...	3·11	186	*Glam.*	Cardiff, Penylan ...	5·31	181
Kent	Dover	4·54	236	*Pemb.*	Tenby	4·30	148
,,	Edenbridge, Falconhurst	5·14	233	*Radnor*	Tyrmynydd	7·50	143
Sussex	Compton, Compton Ho.	6·10	231	*Mont.*	Lake Vyrnwy	5·36	118
,,	Worthing, Beach Ho. Pk.	4·26	215	*Mer.*	Blaenau Festiniog ...	5·77	70
Hants.	St. Catherine's L'thouse	3·78	186	,,	Aberdovey	3·21	107
,,	Southampton (East Pk.)	4·03	175	*Carn.*	Llandudno	2·21	113
,,	South Farnborough ...	3·52	187	*Angl.*	Llanerchymedd ...	4·16	165
Herts.	Harpenden, Rothamsted	3·04	159	*I. Man*	Douglas, Borough Cem.	4·26	134
Bucks.	Slough, Upton	2·89	170	*Wigtown*	Newton Stewart ...	2·97	79
Oxford	Oxford, Radcliffe ...	2·83	173	*Dumf.*	Dumfries, Crichton R.I.	4·61	141
N'hants.	Wellingboro' Swanspool	2·20	137	,,	Eskdalemuir Obsy. ...	5·32	107
Essex	Southend, W. W. ...	1·95	144	*Roxb.*	Crailing...	2·48	134
Suffolk	Felixstowe	2·05	163	*Peebles*	Stobo Castle	3·36	122
,,	Lowestoft Sec. School ...	2·24	160	*Berwick*	Marchmont House ...	3·23	155
,,	Bury St. Ed., Westley H.	2·27	151	*E. Loth.*	North Berwick Gas Wks.	3·16	203
Norfolk	Sandringham Ho. Gdns.	3·38	205	*Midl'n.*	Edinburgh, Blackf'd. H.	2·31	139
Wilts.	Aldbourne	4·21	186	*Lanark*	Hamilton W. W., T'nhill	2·80	97
Dorset	Creech Grange... ...	4·37	153	*Ayr*	Prestwick	2·13	89
,,	Beaminster, East St. ...	5·35	177	,,	Glen Afton, Ayr San. ...	5·59	127
Devon	Teignmouth, Den Gdns.	5·71	215	*Renfrew*	Greenock, Prospect Hill	4·30	81
,,	Ilfracombe	5·26	190	*Bute*	Rothesay, Ardencraig ...	3·56	89
,,	Princetown	12·21	162	*Argyll*	Morven, Drimnin ...	4·49	85
Cornwall	Bude	3·71	148	,,	Poltalloch	4·11	95
,,	Penzance	5·35	160	,,	Inveraray Castle ...	4·58	68
,,	St. Austell	5·94	155	,,	Islay, Eallabus... ...	3·60	86
,,	Scilly, Tresco Abbey ...	3·97	142	,,	Tiree	3·21	93
Somerset	Taunton	3·99	192	*Kinross*	Loch Leven Sluice ...	3·53	125
Glos.	Cirencester	4·07	174	*Fife*	Leuchars Airfield ...	3·37	193
Salop	Church Stretton ...	2·71	116	*Perth*	Loch Dhu	6·85	92
,,	Shrewsbury, Monkmore	1·82	116	,,	Crieff, Strathearn Hyd.	3·92	111
Worcs.	Malvern, Free Library...	2·78	154	,,	Pitlochry, Fincastle ...	3·56	121
Warwick	Birmingham, Edgbaston	2·93	158	*Angus*	Montrose Hospital ...	2·57	140
Leics.	Thornton Reservoir ...	2·64	158	*Aberd.*	Braemar	2·93	103
Lincs.	Boston, Skirbeck ...	3·28	224	,,	Dyce, Craibstone ...	2·26	99
,,	Skegness, Marine Gdns.	2·81	184	,,	New Deer School House	1·65	77
Notts.	Mansfield, Carr Bank ...	2·73	141	*Moray*	Gordon Castle	1·46	76
Derby	Buxton, Terrace Slopes	3·58	95	*Nairn*	Nairn Achareidh ...	1·52	94
Ches.	Bidston Observatory ...	1·74	104	*Inverness*	Loch Ness, Garthbeg ...	3·62	105
,,	Manchester, Ringway...	1·89	100	,,	Loch Hourn, Kinl'hourn	8·09	81
Lancs.	Stonyhurst College ...	2·98	89	,,	Fort William, Teviot ...	5·46	73
,,	Squires Gate	2·52	119	,,	Skye, Broadford ...	0·00	000
Yorks.	Wakefield, Clarence Pk.	2·33	136	,,	Skye, Duntulm... ...	3·79	82
,,	Hull, Pearson Park ...	1·94	117	*R. & C.*	Tain, Mayfield... ...	1·76	77
,,	Felixkirk, Mt. St. John...	2·34	138	,,	Inverbroom, Glackour...	4·25	83
,,	York Museum	2·48	164	,,	Achnashellach	5·91	86
,,	Scarborough	2·08	124	*Suth.*	Lochinver, Bank Ho. ...	2·96	74
,,	Middlesbrough... ...	1·76	136	*Caith.*	Wick Airfield	1·20	53
,,	Baldersdale, Hury Res.	3·06	105	*Shtland*	Lerwick Observatory ...	4·37	138
Norl'd.	Newcastle, Leazes Pk....	1·91	125	*Ferm.*	Crom Castle	2·65	90
,,	Bellingham, High Green	3·55	140	*Armagh*	Armagh Observatory ...	2·02	91
,,	Lilburn Tower Gdns. ...	3·74	188	*Down*	Seaforde	4·18	137
Cumb.	Geltsdale	3·02	116	*Antrim*	Aldergrove Airfield ...	1·56	65
,,	Keswick, High Hill ...	5·29	107	,,	Ballymena, Harryville...	2·36	73
,,	Ravenglass, The Grove	3·59	117	*L'derry*	Garvagh, Moneydig ...	3·06	98
Mon.	A'gavenny, Plâs Derwen	6·27	179	,,	Londonderry, Creggan	2·08	65
Glam.	Ystalyfera, Wern House	7·49	146	*Tyrone*	Omagh, Edenfel ...	3·41	114

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