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SOME UPPER WIND OBSERVATIONS FOR THE TROPICAL INDIAN OCEAN

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Summary.—Three short series of upper wind soundings, some of them exceeding 80,000 feet, were made in February and April 1956 from two ships in different parts of the Indian Ocean. The results indicate conditions in broad agreement with those established for the central Pacific.

Introduction.—While upper wind observations in low latitudes have undergone a substantial increase in recent years this has mainly benefited land areas. The basic importance of oceanic data is however illustrated by the manner in which special observations at the Marshall Islands in the central Pacific brought about a revolution in many accepted views of the tropical circulation.[1] This has created an urgent need for the validity of the new concepts to be tested in other ocean regions, especially in the Indian Ocean with its complicated monsoonal régimes, and for that purpose even short series of upper wind observations may be of some help.

The data to be presented in this note were obtained from ships travelling on the routes shown in Figure 1. The first series covers part of a traverse along the meridian 75°E. from 16°S. to the equator and was obtained at the end of February 1956 during an oceanographic survey by the French Antarctic Expedition ship *Norsel* of 650 tons. The two other series of upper wind observations were made in support of single-station forecasts from the aircraft carrier H.M.A.S. *Melbourne* (19,650 tons) in April of the same year during a passage from Aden to Colombo and hence to Fremantle. The methods used reflect the facilities available on the two ships and are outlined in the next section.

Methods.—The *Norsel* winds were observed by means of a prismatic shipboard theodolite and 35-gramme balloons. The motion of the small empty ship at first created great difficulties with the angle of roll continually exceeding the range of the theodolite's gimbal suspension. However, by accident it was found that a great improvement resulted from eliminating the gimbal altogether and taking readings whenever the balloon happened to be in the field of vision. The prismatic arrangement ensures that the correct angle of elevation is obtained as long as the balloon image falls on (or preferably in practice just

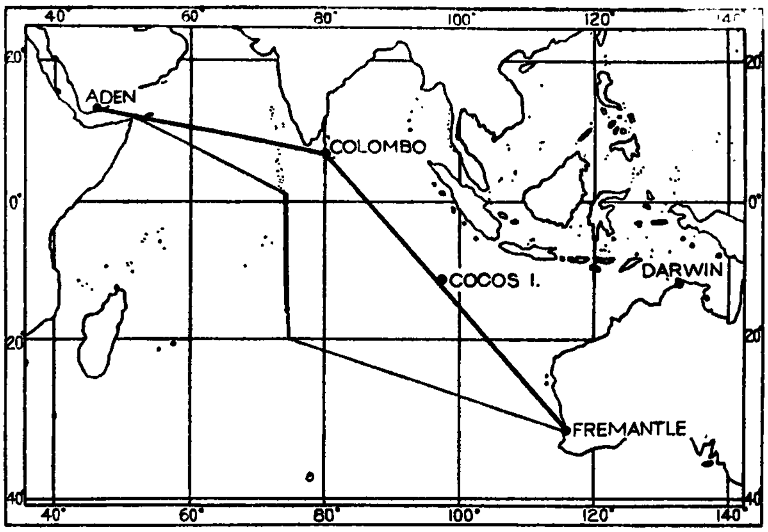

FIGURE 1—ROUTES COVERED BY UPPER WIND OBSERVATIONS (HEAVY LINES)

below) the horizon. It was then easy to find the balloon even after spells of violent rolling or after it had been obscured for some time by clouds or obstructions, and flights of up to 50-minutes duration proved possible for a single observer after the change in method. The evaluation, including the subtraction of the ship's travel, was made graphically with an assumed rate of ascent of 180 metres per minute, subsequently confirmed by a double theodolite flight in Australia.

For the other two series the radar installations of the aircraft carrier *Melbourne* were used. The ship's motion in this case was fully eliminated by aerials stabilized in elevation and azimuth. The target at first consisted of nylon–metal mesh over the 100-gramme balloons. The comparatively low heights achieved with this arrangement suggested, however, that the mesh tended to rub holes into the balloons. As an alternative therefore the mesh was suspended below the balloons and spread out by 12-inch crosses of light alloy rods. This gave strong signals at all heights and raised the average maximum height from 40,000 to 60,000 feet. Somewhat greater altitudes were reached with a few larger balloons provided by the courtesy of the meteorologists at Ratmalana, Ceylon, and Guildford, Western Australia.

During each flight the evaluation of the radar winds was made graphically on a plotting table which automatically eliminated the ship's travel. This arrangement took care of unexpected course changes and also permitted such changes occasionally to be made purposely in order to facilitate the launching of the balloon or to improve the field of vision of one of the aerials.

Discussion.—The results of the upper wind measurements are shown in Figures 2, 3 and 5. The abscissa in each diagram primarily represents time (increasing to the right) but also latitude and (Figures 3 and 5 only) longitude. This implies a compounding of time and space variations with consequent difficulties for the interpretation. In aid of the latter incidental information such as characteristic convectional cloud types and centred 24-hour pressure tendencies have been included in the diagrams, and data from land stations will also be used.

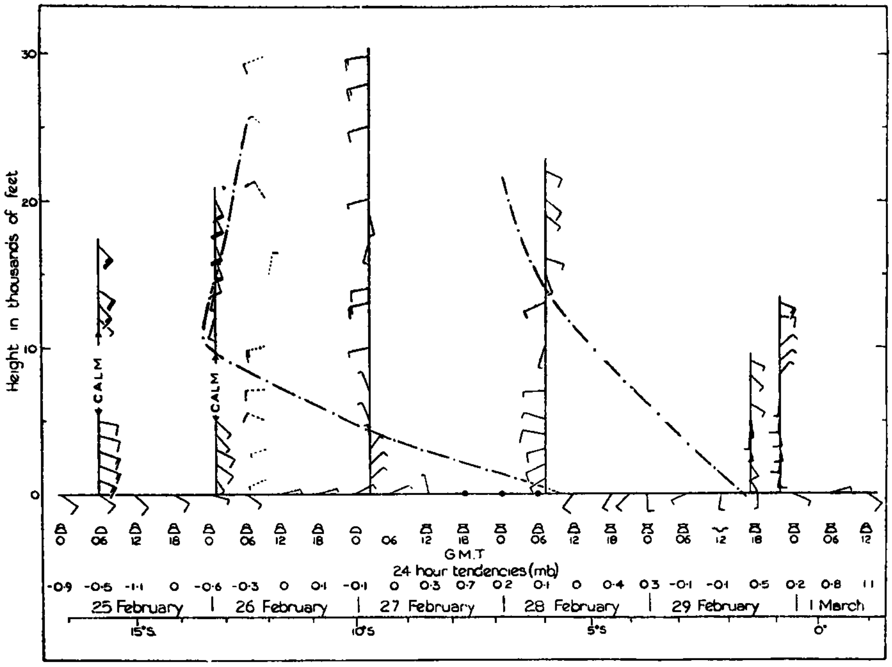

FIGURE 2—UPPER WINDS OBSERVED BY THEODOLITE FROM M.V. "NORSEL" IN LONGITUDE 75°E., 25 FEBRUARY–1 MARCH 1956

Dash–dot lines separate easterlies and westerlies. Broken arrows give winds at Cocos Island at 0800 G.M.T. on 26 February 1956.

The section along 75°E. (Figure 2) showed in latitude 16°S. south-east winds at all levels up to the maximum altitude of 17,000 feet, but also a layer of light and variable winds marked as "calm" in the diagram. A similar layer recurred in 13°S. with light south-westerlies in its upper portion. The next flight, made in 10°S., showed westerlies from 5,000 to at least 30,000 feet. A little further on, north of a zone of calms and heavy showers from cumulonimbus cloud, south-westerlies appeared at the surface where they persisted from 6°S. to 2°S. The wind soundings are not sufficiently close in time to prove conclusively that the base of the upper easterlies descended in this region, as suggested by the flight in latitude 6°S. They indicate clearly, however, that the westerlies had vanished near 2°S. shortly before another zone of heavy rain was encountered just north of the equator.

For the interpretation of Figure 2 it is of interest that north of that second rain area the surface wind at first returned to the south-east before backing gradually to north-east as the *Norsel* proceeded towards Aden (Figure 1). According to the *Indian Daily Weather Report* the same sequence of surface winds was encountered also by the only other ship nearby at the time, the *Vanloon.* Together with the pressure tendencies, the surface winds in Figure 2 suggest the existence then of two cyclonic eddies centred roughly on the precipitation regions in latitudes 7°S. and 1°N. and giving rise to the surface westerlies in between.

The explanation of low-level equatorial westerlies along such lines was first formulated on the basis of detailed streamline analyses for the central and western Pacific by Palmer.[1] Until then, these westerlies, discovered in 1893 by

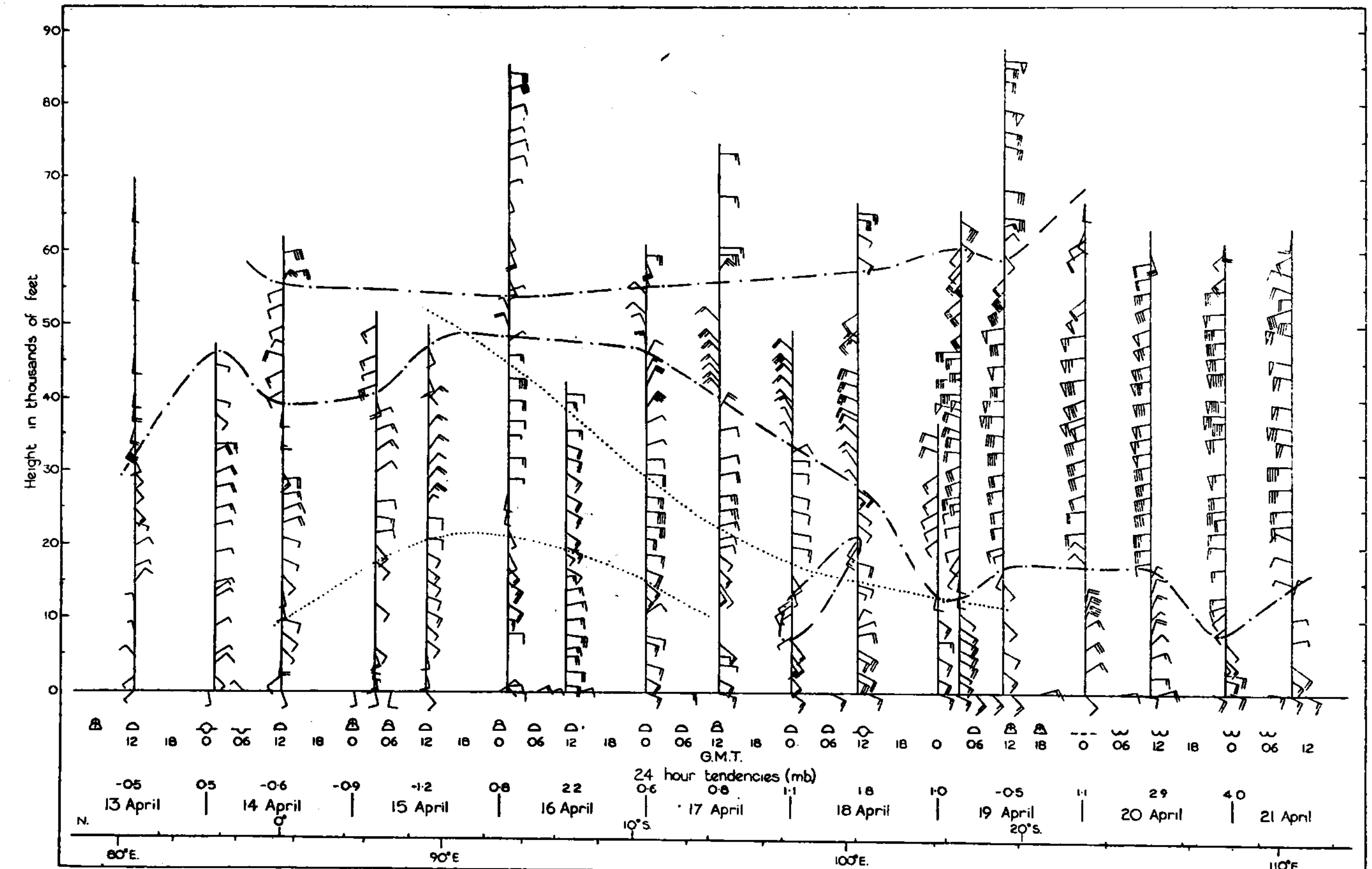

FIGURE 3—UPPER WINDS OBSERVED BY RADAR FROM H.M.A.S. "MELBOURNE" BETWEEN COLOMBO AND FREMANTLE, 13–21 APRIL 1956

Dash–dot lines separate easterlies and westerlies. Dotted lines give boundaries between easterlies and westerlies in the mean cross-section for April 1953.[9]

Meinardus[2] and discussed in great detail recently by Flohn,[3,4] had been regarded as part of a quasi-steady current extending through a large part of the tropics including the Indian Ocean for which this view appears to be still the accepted one today.[5] A mechanism capable of producing such a current was suggested by Fletcher[6] in the form of radiational cooling from the tops of the cumulonimbus clouds usually flanking the equatorial westerlies at the surface.

The present data hardly warrant a fuller discussion of these controversial questions but it is at least of some interest that, apart from suggesting cyclonic circulations at the surface, Figure 2 should show westerlies at moderate heights already well south of the first belt of cumulonimbus cloud. Additional evidence of eddy flow is provided by the winds at Cocos Island where throughout the summer conditions appear to alternate between easterlies and westerlies. The latter are exemplified by the sounding made at Cocos at the time the *Norsel*, some 1,100 miles to the west, crossed the latitude of the island; these winds are indicated by thin arrows in Figure 2. While they consisted of westerlies up to 35,000 feet it is characteristic that both the previous and the two following days were marked by easterlies up to 5,000 feet. A full analysis of the new radar-wind data for this station would be of considerable interest.

With monsoonal influences at their weakest in April an approximation to undisturbed oceanic conditions might be expected for the other section through the equatorial zone, from Colombo to Fremantle (Figure 3). These flights were made approximately six weeks after those of Figure 2, and their regular spacing brings out clearly the gradual descent of the base of the polar westerlies with latitude. A distortion near 20°S. was caused by a weak disturbance with interesting features which have been discussed elsewhere.[7] In low latitudes the easterlies extended almost throughout the height range explored but vestiges of westerlies remained in evidence near 50,000 feet. In the neighbourhood of the equator these might be identified with the "Berson westerlies",[8] differing in nature from the polar westerlies further north and south. The present data are inadequate for a firm distinction of this sort but it is at any rate suggested by the virtual disappearance of the high-level westerlies in 6°S. which may even have been complete a little nearer the equator. Thus Figure 3 would show all the elements of the cross-section for the central Pacific given by Palmer[8] (for the highest levels, compare below).

The agreement is enhanced by the almost complete absence of low-level westerlies in Figure 3. This represents no problem on the eddy hypothesis provided it can be shown from other data that the passage of the *Melbourne* coincided with one of the brief periods of comparatively prominent easterlies. Such an interpretation is supported by the dotted lines in Figure 3 which give the boundaries between easterlies and westerlies in a mean cross-section along 110°E. for April 1953.[9] There the easterlies formed a fairly narrow band between the high-level polar and low-level equatorial westerlies and became dominant only north of 6°S. The strength of the mean easterlies for April 1953 was comparable to that observed from the *Melbourne* in April 1956 whereas the mean westerlies of April 1953 were much weaker than those shown between 10°S. and 20°S. in Figure 3.

However, the latter certainly did not even approximate to steady conditions. This is demonstrated by Figure 4 which shows schematically the major features of the upper winds above Cocos Island and Darwin together with those of Figure 3. It is obvious from Figure 4 that the descent of the westerlies and their acceleration to velocities of the order of 80 to 90 knots between 17 and 20 April largely reflected a *local* change affecting at the same time both Cocos Island and Darwin. The westerlies at these stations persisted well beyond the time covered in Figure 4; furthermore, around the same time (27 April) deep easterlies made their first appearance for the year at Aden. All this suggests that the second half of the cross-section in Figure 3 may have been affected by a sudden seasonal change in the global pattern of the upper circulation, of the type described by Radok and Grant.[10]

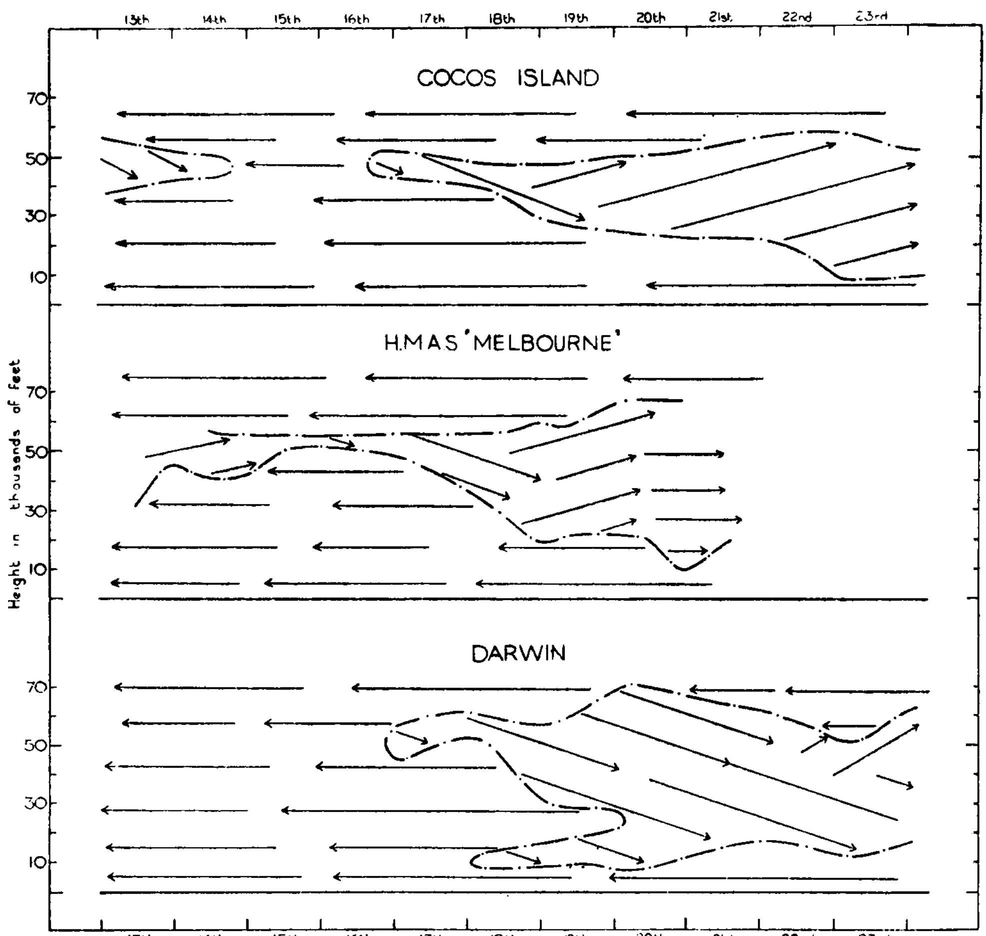

FIGURE 4—SCHEMATIC REPRESENTATION OF THE MAIN UPPER CURRENTS OBSERVED ABOVE COCOS ISLAND, H.M.A.S. "MELBOURNE" AND DARWIN, 13–23 APRIL 1956

While in the second series no clear separation of time and space changes was possible the remaining upper winds, observed earlier in April 1956 between Aden and Colombo (Figure 5), could be fitted into the larger synoptic flow by means of published upper air data for Nicosia, Bahrain, Habbaniyah and the Indian upper air stations. 200-millibar charts constructed with these data for the period from 4 to 9 April (not reproduced here) showed a trough which moved across Aden from the west on 4 April and became stationary in longitude

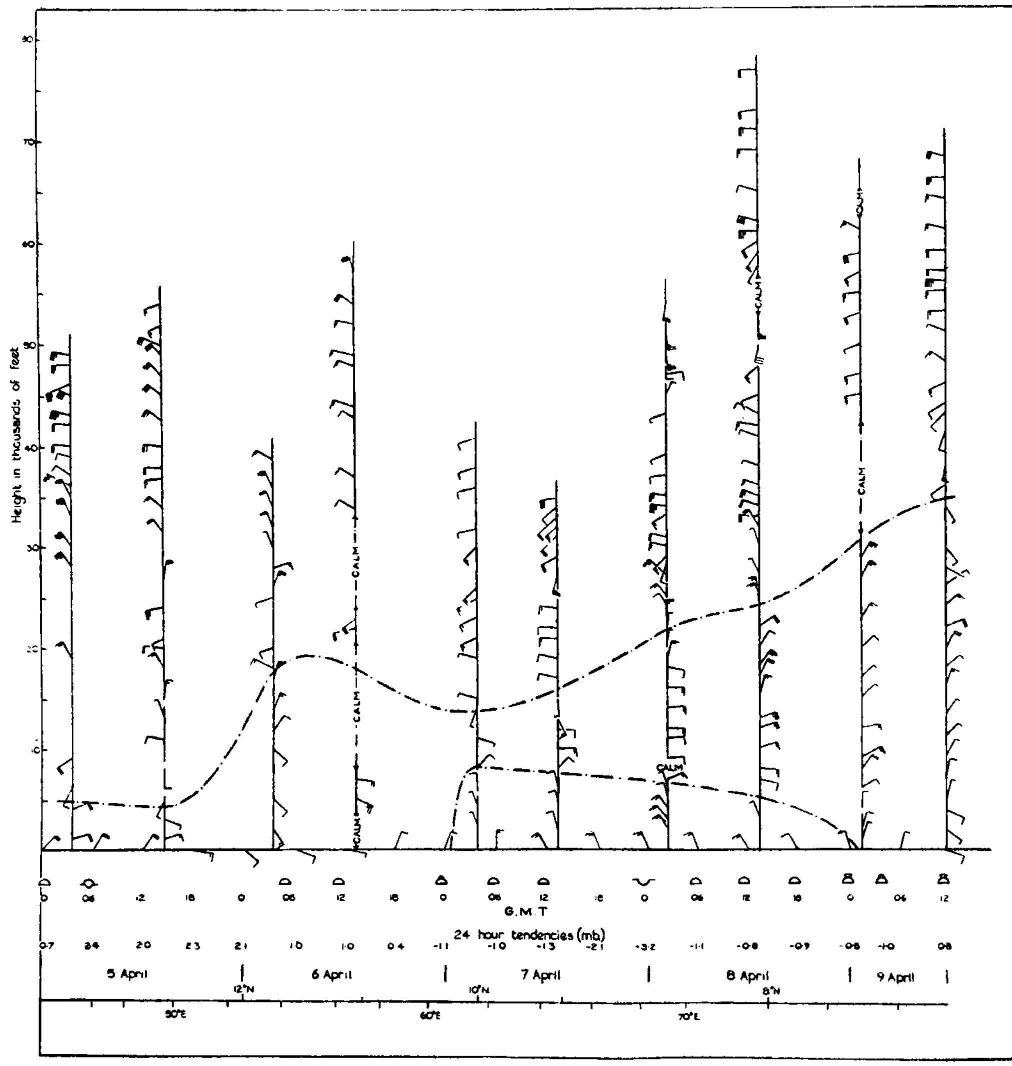

FIGURE 5—UPPER WINDS OBSERVED BY RADAR FROM H.M.A.S. "MELBOURNE" BETWEEN ADEN AND COLOMBO, 5–9 APRIL 1956

Dot–dash lines separate easterlies and westerlies.

60°E. for the remainder of the period. On the *Melbourne* the upper trough made itself felt late on 6 April by the backing of the winds in higher layers and by more developed convective cloud. The winds at lower levels, especially the unusually deep north-westerlies between 60°E. and 75°E., suggest that the trough was located over the eastern end of a surface cell of high pressure, and this is confirmed by the pressure tendencies. The three-dimensional structure thus may have resembled temporarily the subtropical anticyclone model of J. Bjerknes[11] which has been found valid generally for comparative latitudes in the central Pacific.[1]

Lastly, the winds at the highest levels reached deserve some comment. Figure 5 shows westerlies from 30,000 feet to 80,000 feet in 8°N. Turning to Figure 3 we note that near the equator the high-level winds became weak southerlies. The next high ascent in 6°S. showed easterlies from 55,000 feet to 85,000 feet. Similar conditions at the highest levels were indicated by the last high flight of the series in 20°S., with strong easterlies above 80,000 feet which may have marked the beginning of the "Krakatoa" winds.[12] Their southern limit on this occasion remains in doubt, but it may be added that a single flight made in 36°S. on 28 April when the *Melbourne* was in the great Australian Bight indicated westerlies at all levels up to 83,000 feet.

Conclusion.—Despite difficulties of interpretation inherent in observations from moving ships the upper winds from different parts of the tropical Indian Ocean here discussed appear to fit well into the picture of the tropical circulation developed for other ocean regions, notably the central Pacific.

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VISIBILITY AND SURFACE WIND AT MANCHESTER AIRPORT

By E. R. THOMAS

Manchester Airport (Ringway) is becoming increasingly important as an international airport and to assist in the preparation of terminal forecasts and flight schedule planning an investigation of the variation in visibility and surface wind has been undertaken recently.

Manchester Airport is situated in open country with the Pennines running north–south about ten miles to the east. To the south-west the land slopes gradually to the narrow, steep-sided valley of the River Bollin about a mile

TABLE I—PERCENTAGE FREQUENCY OF OCCASIONS WITH VISIBILITY WITHIN CERTAIN RANGES AT MANCHESTER AIRPORT 1947–51

Time	January			February			March			April		
	yards											
G.M.T.	≤220	≤1100	≤2200	≤220	≤1100	≤2200	≤220	≤1100	≤2200	≤220	≤1100	≤2200
	per cent											
0100	1·9	5·2	9·0	0·7	2·1	9·9	2·6	9·0	16·8	0·0	2·0	3·3
0200	1·9	3·2	9·0	0·7	2·8	8·5	1·9	10·3	16·8	0·0	0·7	3·3
0300	1·3	2·6	7·1	0·7	4·3	7·1	1·9	6·5	17·4	0·0	0·7	3·3
0400	0·6	2·6	5·8	2·1	4·3	8·5	2·6	3·9	19·4	0·0	0·7	4·0
0500	0·6	1·3	5·2	2·1	3·5	9·2	1·9	5·2	16·1	0·7	1·3	5·3
0600	0·6	1·3	5·2	2·1	4·3	9·9	2·6	7·7	18·7	1·3	3·3	6·0
0700	0·6	3·2	5·8	1·4	3·5	11·3	4·5	9·7	19·4	0·7	2·0	6·7
0800	2·6	5·8	12·9	1·4	5·0	10·6	5·2	9·0	18·1	0·7	1·3	3·3
0900	2·6	7·2	18·7	1·4	6·4	11·3	2·6	11·0	20·6	0·0	0·0	2·7
1000	3·2	8·4	17·4	2·1	6·4	12·8	1·3	5·8	18·7	0·0	0·0	0·0
1100	1·9	6·5	15·5	1·4	4·3	8·5	1·3	3·2	11·0	0·0	0·0	0·7
1200	1·3	4·5	13·5	2·1	2·8	4·3	0·0	2·6	5·2	0·0	0·0	0·7
1300	1·3	2·6	11·6	0·0	2·1	6·4	0·0	1·3	5·2	0·0	0·0	0·0
1400	1·3	2·6	11·0	0·0	2·1	4·3	0·0	0·6	6·5	0·0	0·0	0·0
1500	1·9	3·9	11·0	0·0	1·4	2·8	0·0	0·6	5·8	0·0	0·0	0·0
1600	1·3	3·2	11·6	0·0	0·7	5·7	0·0	0·6	5·8	0·0	0·0	0·0
1700	1·3	5·2	16·1	0·0	1·4	5·0	0·0	2·6	10·3	0·0	0·0	0·0
1800	0·6	4·5	16·8	0·0	3·5	9·2	0·0	1·9	14·2	0·0	0·0	0·7
1900	1·9	5·2	19·4	0·0	2·1	10·6	0·0	2·6	20·0	0·0	0·7	4·0
2000	1·9	8·4	18·1	0·0	2·8	10·6	0·0	2·6	19·4	0·0	0·7	5·3
2100	1·3	7·1	14·2	0·0	2·1	9·2	0·6	5·8	20·6	0·0	0·0	3·3
2200	1·3	7·7	12·9	0·7	3·5	8·5	1·3	9·7	21·3	0·0	0·7	2·7
2300	1·9	7·7	14·2	0·0	2·1	8·5	1·9	9·7	20·6	0·0	1·3	2·7
2400	2·6	5·2	9·7	0·0	2·1	9·2	3·2	9·7	18·7	0·0	0·7	2·7

Time	May			June			July			August		
	yards											
G.M.T.	≤220	≤1100	≤2200	≤220	≤1100	≤2200	≤220	≤1100	≤2200	≤220	≤1100	≤2200
	per cent											
0100	0·0	1·3	5·8	0·7	2·0	2·7	0·0	0·0	1·3	1·3	1·9	2·6
0200	0·6	0·6	7·1	0·7	3·3	4·0	0·0	0·6	2·6	1·9	3·9	5·8
0300	0·6	1·3	7·7	1·3	4·0	6·7	0·0	1·3	2·6	1·9	3·9	6·5
0400	1·3	3·2	13·5	2·0	4·7	11·3	0·6	0·6	5·2	1·3	3·9	8·4
0500	1·3	2·6	11·0	4·0	6·7	10·7	0·6	1·9	5·2	1·9	3·9	11·0
0600	0·6	3·2	12·9	2·0	4·7	10·7	1·9	1·9	5·8	0·6	3·2	9·7
0700	0·6	1·9	10·3	1·3	2·0	8·0	1·9	1·9	3·2	0·6	3·2	10·3
0800	0·0	0·6	7·7	0·0	0·7	6·0	0·6	0·6	1·9	0·0	1·9	8·4
0900	0·0	0·0	2·6	0·0	0·0	2·7	0·0	0·6	0·6	0·0	0·0	4·5
1000	0·0	0·0	2·6	0·0	0·0	0·0	0·0	0·0	0·6	0·0	0·0	1·3
1100	0·0	0·0	1·3	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	1·3
1200	0·0	0·0	1·9	0·0	0·0	0·7	0·0	0·0	0·0	0·0	0·0	0·6
1300	0·0	0·0	0·6	0·0	0·0	0·0	0·0	0·0	0·6	0·0	0·0	0·0
1400	0·0	0·0	0·6	0·0	0·0	0·7	0·0	0·0	1·3	0·0	0·0	0·0
1500	0·0	0·0	0·6	0·0	0·0	0·0	0·0	0·0	0·6	0·0	0·0	0·0
1600	0·0	0·0	0·6	0·0	0·0	0·0	0·0	0·0	0·6	0·0	0·0	0·0
1700	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·6	0·0	0·0	0·0
1800	0·0	0·0	1·3	0·0	0·0	0·0	0·0	0·0	0·6	0·0	0·0	0·0
1900	0·0	0·0	2·6	0·0	0·0	0·0	0·0	0·0	0·6	0·0	0·6	0·6
2000	0·6	0·6	4·5	0·0	0·0	0·0	0·0	0·0	0·6	0·6	0·6	2·6
2100	0·6	0·6	6·5	0·0	0·0	0·7	0·0	0·6	1·9	0·0	2·6	2·6
2200	0·0	0·6	3·9	0·0	0·0	0·0	0·0	0·6	0·6	1·3	2·6	2·6
2300	0·0	1·3	5·2	0·0	0·0	0·0	0·0	0·6	1·9	0·0	1·9	2·6
2400	0·0	1·3	5·8	0·0	0·7	1·3	0·0	0·0	1·3	0·6	0·6	0·6

TABLE I—PERCENTAGE FREQUENCY OF OCCASIONS WITH VISIBILITY WITHIN CERTAIN RANGES AT MANCHESTER AIRPORT 1947–51 (CONT.)

Time	September			October			November			December		
						yards						
G.M.T.	≤220	≤1100	≤2200	≤220	≤1100	≤2200	≤220	≤1100	≤2200	≤220	≤1100	≤2200
						per cent						
0100	2·7	4·7	8·0	4·5	9·7	15·5	6·7	12·0	16·0	2·6	9·7	16·8
0200	2·7	5·3	9·3	5·2	10·3	14·2	6·0	12·7	15·3	3·9	7·7	16·1
0300	3·3	4·7	9·3	2·6	10·3	12·3	8·7	14·0	18·0	3·9	6·5	15·5
0400	3·3	5·3	9·3	4·5	10·3	15·5	8·0	13·3	16·0	3·2	7·7	14·2
0500	4·7	6·0	9·3	4·5	9·0	14·2	6·7	12·0	14·7	3·2	9·0	13·5
0600	3·3	5·3	11·3	5·2	11·6	16·8	5·3	10·0	14·0	3·9	6·5	11·6
0700	3·3	4·7	9·3	6·5	13·5	20·6	5·3	12·0	15·3	4·5	6·5	9·0
0800	1·3	5·3	8·0	6·5	12·9	21·9	7·3	12·0	18·7	4·5	7·1	14·8
0900	1·3	2·7	5·3	3·2	7·1	15·5	5·3	10·7	24·7	2·6	8·4	18·1
1000	0·0	2·7	3·3	1·9	7·1	12·3	4·7	10·7	23·3	2·6	6·5	20·0
1100	0·0	0·7	4·0	0·6	4·5	10·3	5·3	10·0	20·0	2·6	9·0	18·7
1200	0·0	0·0	2·7	0·6	2·6	9·0	4·0	8·0	17·3	1·9	7·1	15·5
1300	0·0	0·0	2·0	0·6	2·6	7·1	2·0	8·0	15·3	1·9	7·7	15·5
1400	0·0	0·7	0·7	0·0	1·9	4·5	1·3	4·7	14·7	0·6	7·1	13·5
1500	0·0	0·7	0·7	0·0	1·9	3·2	0·7	6·0	16·7	0·6	9·0	16·1
1600	0·0	0·7	0·7	0·0	1·3	5·2	0·7	9·3	21·3	1·3	8·4	19·4
1700	0·0	0·7	0·7	0·6	1·9	9·7	1·3	10·7	26·0	1·3	9·0	21·9
1800	0·0	0·7	2·7	0·0	3·9	18·1	2·0	10·0	22·7	1·3	9·0	16·8
1900	0·0	1·3	7·3	0·0	5·8	16·8	2·0	12·0	22·0	1·3	7·7	16·1
2000	0·0	1·3	7·3	1·3	5·8	19·4	3·3	15·3	20·7	1·9	7·7	20·6
2100	0·0	2·7	8·1	2·6	9·0	17·4	5·3	14·0	23·3	3·2	11·6	19·4
2200	0·7	2·0	9·3	2·6	8·4	17·4	5·3	14·1	23·3	3·2	10·3	19·4
2300	0·7	2·7	9·3	3·2	9·0	16·1	4·0	15·3	20·0	1·9	9·7	16·1
2400	2·0	2·7	8·7	3·9	8·4	14·8	4·0	14·1	19·3	2·6	10·3	16·8

away. Manchester is six miles to the north, though recent industrial and housing estates have spread to the north-eastern perimeter of the airfield, and the main smoke drift which affects the airfield is with winds between north-north-west and north-east.

The five-year period 1947 to 1951 was selected for the investigation, and from the daily registers the number of hourly occasions when the visibility was 220 yards or less, 1100 yards or less and 2200 yards or less were extracted, occasions of precipitation being excluded. The results are shown in Table I giving the number of hourly occasions of visibility in the varying ranges for each month.

Most of the variations in the pattern, which is typical of a station affected by industrial smoke, can be explained by length of day, turbulent mixing after sunrise, dispersal of fog due to insolation and so on. Further reasons are needed to explain the following interesting features in the pattern:

(i) The marked frequency of poor visibilities in March and from October to December compared with the comparative freedom from thick fog which occurs in January and February, except for the after-dawn effect.

(ii) The double maximum which occurs in the lower visibility range in November—the greatest number of thick fogs occurring about 0300 G.M.T. with a secondary peak shortly after sunrise.

(iii) The greater frequency of thick fog about dawn in June and July compared with the months of April, May and August.

(iv) The comparative freedom from thick fog before 2000 G.M.T.

During the months of January and February the grass minimum temperatures are at their lowest and some of the moisture which would otherwise be available for fog formation is deposited as frost and is not made available again as water vapour until after sunrise. These two months more than any other months, are affected by a katabatic wind produced by the Pennines, which rise to about 2,000 feet 10 miles to the east of the airfield. This wind blows between north-east and south-east and has a pronounced effect on the time of formation and the frequency of fog at Manchester. For example, the annual mean number of hours of thick fog at Manchester is 119 hours while the value for London Airport and Northolt is 228 hours; again thick fog rarely persists all day at Manchester (twice in five years) while at London Airport thick fog tends to persist throughout the day.[1]

Thick water fogs form in the valley of the River Bollin and drift over the airfield on the predominantly southerly surface winds, and the early morning maximum during June and July is due to advection of overspill fog from this valley.

Most thick fogs are water fogs, though smoke itself with a light northerly wind under a low-level inversion does reduce visibility to 600 to 800 yards, and the visibility in the clearing skies after the passage of a cold front at dusk with a slack northerly gradient in its rear can deteriorate to thick fog limits in a few moments due to the combined effects of Lancashire smoke, abundant surface moisture and radiative cooling.

In general, the effect of smoke is most noticeable in the visibility ranges above the fog limit, though advection of smoke naturally reduces the visibility in fog. Thick fogs with southerly winds are twenty times more frequent than with the smokier northerly winds. Domestic smoke from the recent extensive housing and industrial estates immediately to the north of the airfield will no doubt have a marked effect on the visibility in the future with light winds from the north-north-east.

Surface wind and visibility.—To examine the relationship between surface wind and visibility, details of surface wind speed and direction for all occasions (excluding those when there was precipitation at the time) during the period 1947 to 1951 when visibility was 2200 yards or less were extracted from the hourly observations in the daily registers.

Visibilities of 2200 yards or less were rarely reported with wind speeds greater than 12 miles per hour, so the investigation was confined to occasions when surface wind speed was 12 miles per hour or less.

Monthly wind roses for sixteen compass points were produced (Figure 1) for wind speeds of 12 miles per hour or less. The winds are predominantly southerly; this is due largely to the channelling effect between the Pennines to the east and the Welsh hills to the west.

During January to March the wind frequency increases from between north-east and east, part of this is due to the katabatic effect referred to earlier. Also during April to July there is a noticeable increase in the frequency of winds between west and north-west, part of which is due to the sea-breeze effect from the Irish Sea though the number of well defined sea-breezes at Manchester is small. The number of calm winds reported during February is small compared with the other winter months and this may account in part for the low fog frequency during this month.

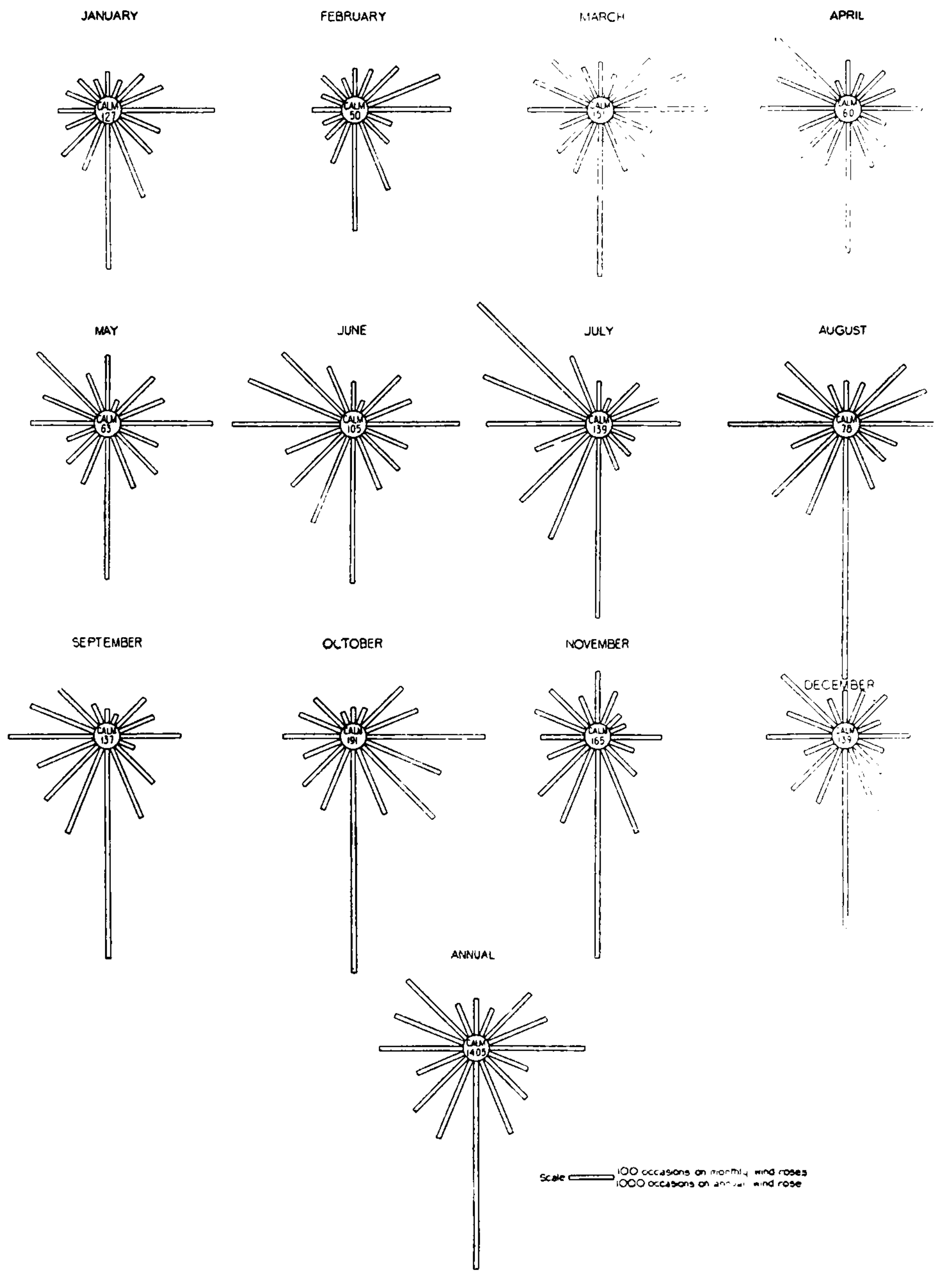

FIGURE 1—WIND ROSES FOR THE PERIOD 1947–51 (INCLUSIVE) AT MANCHESTER AIRPORT FOR WIND SPEEDS 0–12 M.P.H. (BEAUFORT FORCES 0–3) USING HOURLY OBSERVATIONS

The numbers of calms are written within the centre circles.

The frequency of visibility in the three ranges (220 yards or less, 1100 yards or less and 2200 yards or less) for each of the sixteen compass points, was expressed as a percentage and the results are shown month by month in the form of roses (Figure 2).

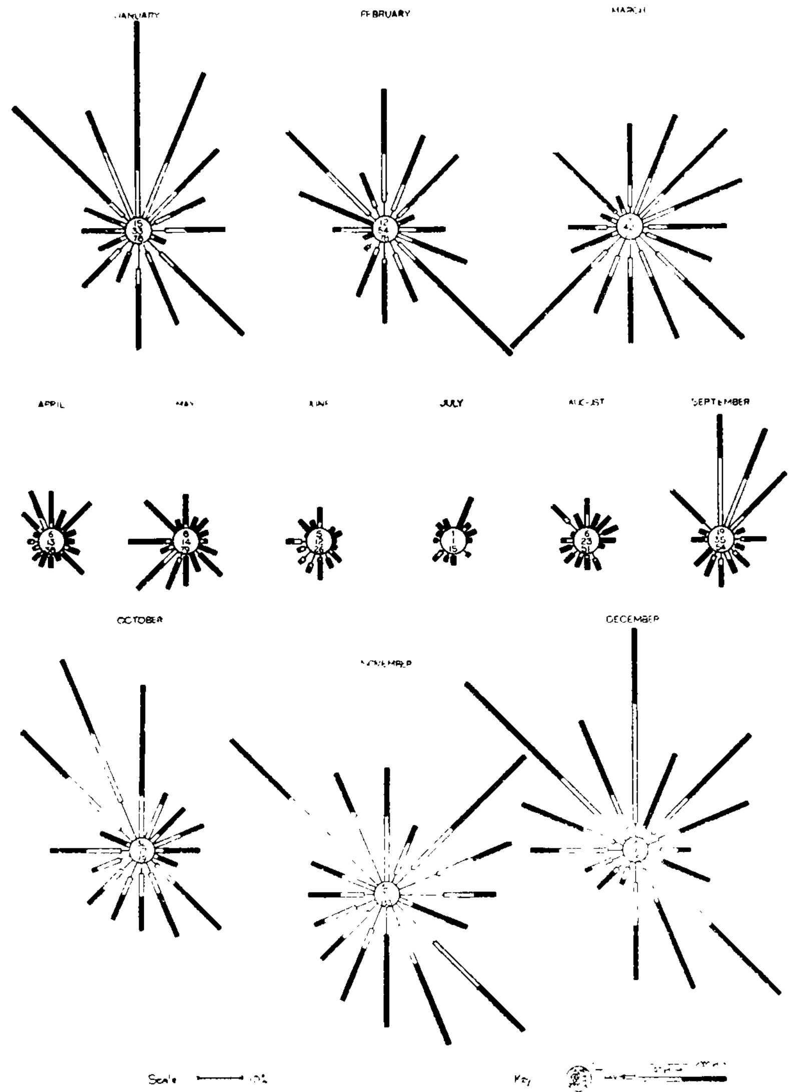

FIGURE 2—PERCENTAGE FREQUENCY OF VISIBILITY WITHIN SELECTED RANGES FOR VARYING WIND DIRECTIONS

The values for calm winds are within the centre circles.

These show that most thick fogs occur with southerly winds (including the maximum in June and July referred to earlier) and the diagrams also show the smoke effect, that is in the visibility range 1100 to 2200 yards, the main smoke sources being Lancashire to the north and the Potteries and Midlands to the south-south-east.

REFERENCE

1. DAVIS, N. E.; Fog at London Airport. *Met Mag., London*, **80**, 1951, p. 12.

TEMPERATURE GRADIENT AT BLACKPOOL

By R. E. BOOTH

Early in 1956, the directors of the Blackpool Tower Company proposed, for publicity purposes, that regular temperature readings should be taken at the top of their Tower, some 400 feet above Blackpool Promenade. The plan was to erect a screen containing four thermometers at the highest point on the Tower to which the public is admitted and to display a board at the Tower entrance showing the temperature at the top. On a hot summer's day it would be stated as being so many degrees cooler on top. It was also proposed that a few of the wooden louvers in the door of the screen should be replaced by perspex so that the public could see the thermometers inside, but this suggestion was dropped later.

The Tower Company offered to make the readings available to the Meteorological Office. The offer was accepted and arrangements made for a member of the Meteorological Office staff to advise on the siting of the Bilham Screen. It was eventually erected near the south-west corner of the 420-foot level of the Tower, overhanging the main structure, bracketed to withstand wind speeds of up to 100 knots and with the door facing north-north-east (see photograph facing p. 113). Readings of the dry- and wet-bulb temperatures were made four times a day by members of the Tower staff and telephoned to the Meteorological Office, Squires Gate, where the records were tabulated. No arrangements were made for taking observations at ground level.

The meteorological station at Squires Gate is nearly three miles south of Blackpool Tower and about half a mile from the coast. It seems probable, therefore, that although temperatures taken at the foot of the Tower would be very different from those taken at ground level at the open site at Squires Gate, there would be little difference in the air at 420 feet above the two sites. In the following comparison it is assumed that air conditions at this height at Squires Gate are represented by readings taken at Blackpool Tower. The two sets of readings will be referred to as "ground" and "Tower" respectively.

TABLE I—MEAN MONTHLY TEMPERATURE ON BLACKPOOL TOWER AND AT SQUIRES GATE

	0900 G.M.T.			1200 G.M.T.			1500 G.M.T.		
	Blackpool Tower	Squires Gate	difference	Blackpool Tower	Squires Gate	difference	Blackpool Tower	Squires Gate	difference
1956				*degrees Fahrenheit*					
July	57·7	60·4	−2·7	59·0	62·8	−3·8	60·4	63·5	−3·1
Aug.	54·7	56·6	−1·9	56·0	58·9	−2·9	56·3	60·0	−3·7
Sept.	56·3	57·8	−1·5	59·0	61·5	−2·5	60·0	62·0	−2·0
Oct.	49·9	50·1	−0·2	51·6	53·5	−1·9	51·6	53·7	−2·1
Nov.	44·2	43·7	+0·5	44·8	47·2	−2·4	45·1	46·9	−1·8
Dec.	44·2	42·6	+1·6	44·3	43·8	+0·5	44·5	43·7	+0·8
1957									
Jan.	42·7	41·7	+1·0	42·8	43·9	−1·1	43·1	41·9	+1·2

Table I gives the monthly average dry-bulb temperature at 0900, 1200 and 1500 G.M.T. for each of the seven months July 1956 to January 1957. The readings are reasonably complete for these hours over this period, but for various reasons the 1800 G.M.T. readings and those of the maximum and minimum thermometers are not suitable for analysis. In general the table shows a lapse rate of temperature between the "ground" and "Tower" sites which is greatest during the summer months and greater at midday and in the afternoon than in the morning. A gradual decrease in this lapse rate occurs during the autumn, which is most pronounced at the 0900 G.M.T. observation, leading to an inversion which during 1956 was first evident in November at 0900 G.M.T. There is an inversion of temperature which was greatest during the morning at all three observational hours during December. The fall of temperature of 3·8°F. between "ground" and "Tower" sites in July may be compared with a dry adiabatic decrease of approximately 2·3°F. over this height and a wet adiabatic lapse rate of about half that amount.

TABLE II—MEAN MONTHLY DIFFERENCE BETWEEN TEMPERATURES AT THE SURFACE AND AT THE TOPS OF THE TOWERS AT LEAFIELD, RYE AND BLACKPOOL

	0900 G.M.T.			1200 G.M.T.			1500 G.M.T.		
	Leafield	Rye	Blackpool	Leafield	Rye	Blackpool	Leafield	Rye	Blackpool
					degrees Fahrenheit				
July	−2·6	−2·3	−2·7	−3·2	−2·9	−3·8	−2·6	−2·4	−3·1
Aug.	−2·5	−2·7	−1·9	−3·1	−3·5	−2·9	−2·2	−2·8	−3·7
Sept.	−1·7	−1·8	−1·5	−2·8	−2·7	−2·5	−2·1	−2·1	−2·0
Oct.	−0·9	+0·2	−0·2	−2·1	−2·1	−1·9	−1·3	−1·3	−2·1
Nov.	+0·4	+0·8	+0·5	−1·2	−1·0	−2·4	−0·9	−0·2	−1·8
Dec.	+0·9	+1·7	+1·6	−0·7	−0·6	+0·5	−0·7	−0·1	+0·8
Jan.	+0·8	+1·3	+1·0	−0·8	−0·8	−1·1	−0·4	−0·3	+1·2

Surface temperature is measured at 4 feet above ground level. The heights of the towers are Leafield 288 feet, Rye 350 feet, Blackpool 418 feet

Table II compares the mean monthly difference in temperature between the two sites at Blackpool with temperature gradients measured over comparable heights at Leafield[1] and Rye.[2] The figures give the difference in temperature between 4 feet and 288 feet in the case of Leafield, 350 feet at Rye and 418 feet at Blackpool. Temperatures at Leafield were measured by platinum resistance thermometers and the table is based on means over a five-year period; Rye temperatures, which were measured by nickel resistance thermometers are based on three-year means while those at Blackpool refer to only one year. The exposures of the three stations are very different. Leafield is an inland station, not very far from Oxford, about 70 miles from the south coast and even further from the sea in other directions. Blackpool occupies a position on the north-west coast very exposed to winds from between south-west and north-west, while Rye, although near the south-east coast, is rather further from the sea, and more sheltered, than Blackpool.

Although the figures are not directly comparable, they show that the differences are rather similar in the three cases. Leafield and Rye show the same kind of temperature lapse during July, August and September as noted at Blackpool and the magnitude of the lapse, as at Blackpool, tends to decrease towards the autumn, the decrease during the morning being the most pronounced. There is an inversion of temperature at all three places during November, December and January at 0900 G.M.T., but at 1500 G.M.T. the inversion occurs only at Blackpool during December and January.

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1. JOHNSON, N. K. and HEYWOOD, G. S. P.; An investigation of the lapse rate of temperature in the lowest hundred metres of the atmosphere. *Geophys. Mem., London,* **9**, No. 77, 1938.

2. BEST, A. C., KNIGHTING, E., PEDLOW, R. H. and STORMONTH, K.; Temperature and humidity gradients in the first 100 m. over south-east England. *Geophys. Mem., London,* **11**, No. 89, 1952.

NEW METEOROLOGICAL OFFICE HEADQUARTERS, BRACKNELL, BERKSHIRE

Since the outbreak of the Second World War the Meteorological Office has worked under the handicap of a dispersed headquarters. The Office now has three main centres, in London, Harrow and Dunstable. Following the report of the Committee under Lord Brabazon it was decided in 1957 to bring this unhappy state of affairs to an end by the provision of a headquarters office block, adequate to meet the demands of a rapidly growing service, at the new town of Bracknell, Berkshire.

Bracknell has many advantages as the site of the Meteorological Office Headquarters. It is situated in pleasant open country and has excellent rail and road communications with London, Reading and Windsor. Equally important, it will have adequate housing, educational and shopping facilities for the staff and their families.

The photographs (between pp. 112–113) which accompany this account are of a model constructed by the Ministry of Works, who have prepared the following description of the architectural features of the buildings.

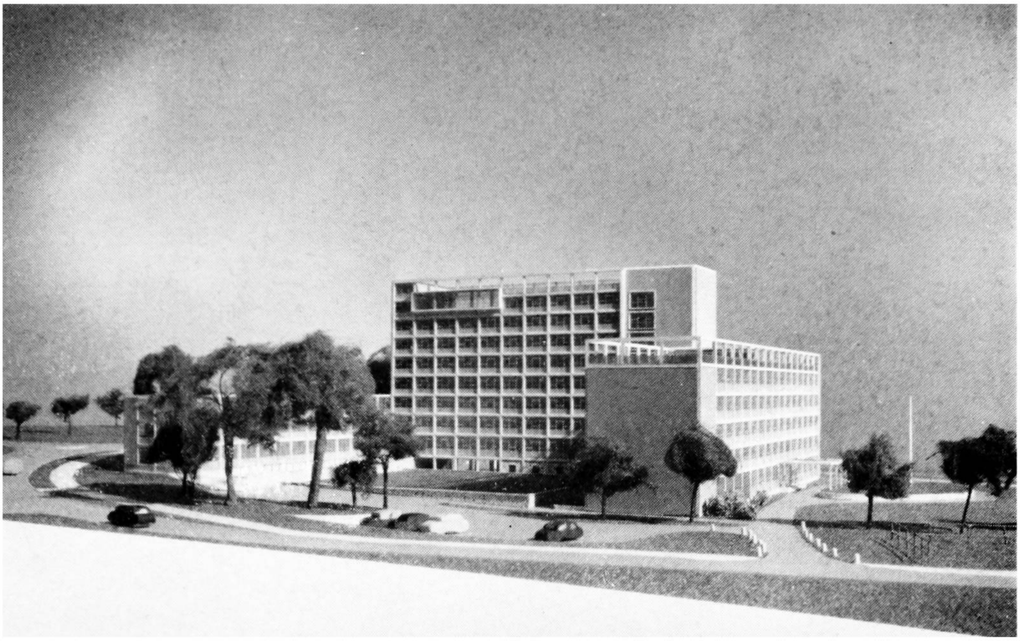
The site—which has been acquired from the Bracknell Development Corporation—occupies a prominent position above the new town on the road approaches from London, Windsor and Maidenhead.

The building is planned as three distinct but interconnected blocks, grouped round a central grassed court. Block I, a five-storey building, will house the directing and administrative staffs and the national Meteorological Library. At the top there will be dining-rooms designed in the form of a penthouse leading on to the flat roof. Block II, three floors, will provide staff rooms, laboratories, wind-tunnels and work-rooms for the Physical Research activities of the Office, as well as housing the Punched-Card Installation. The third, and tallest, block will rise for eight storeys and accommodate the forecasting and forecasting research staffs with their electronic computer, as well as providing for the Training School and Her Majesty's Stationery Office's specialized printing plant.

Reinforced concrete construction is used throughout, the exposed framework being of white Portland-Stone aggregate composition. Elevational treatment is simple, expressing as truthfully as possible the constructional framework. The architects have relied for effect mainly upon the massing of units, made possible by the contrasting block heights. Besides contributing to the architectural interests of the group, the eight-storey central block makes economical use of the limited site and so leaves greater space for possible future extensions. Coloured panels will be introduced below the full-width windows, contrasting with the golden-brown brickwork of flank walls and lift tower.

To preserve as far as possible an unbroken skyline, the concrete framework is taken above roof level on Blocks I and III to form an open "screen"; behind these, such excrescences as tank rooms, instruments or functional test rigs can be accommodated without detriment to the general effect.

It is not proposed to erect fences around the site; the buildings will stand free and unobstructed amid the surrounding lawns and trees. They will thus be seen to full effect on all sides.



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View from the south.

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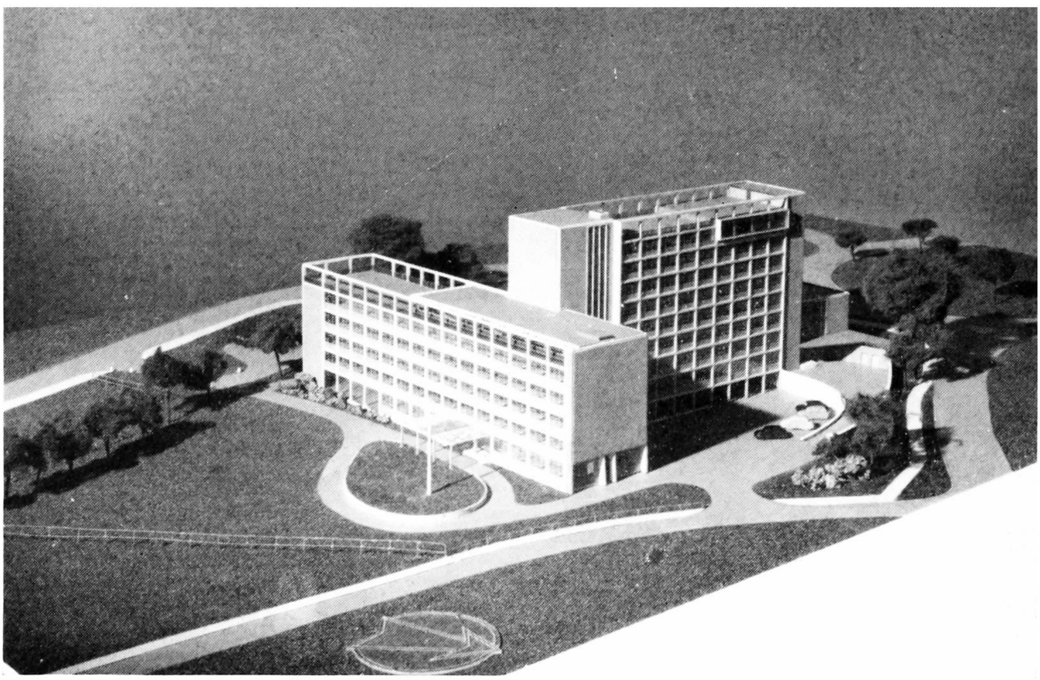
View from the north-west.

MODEL OF THE NEW METEOROLOGICAL OFFICE HEADQUARTERS, BRACKNELL BERKSHIRE

(see p. 112)



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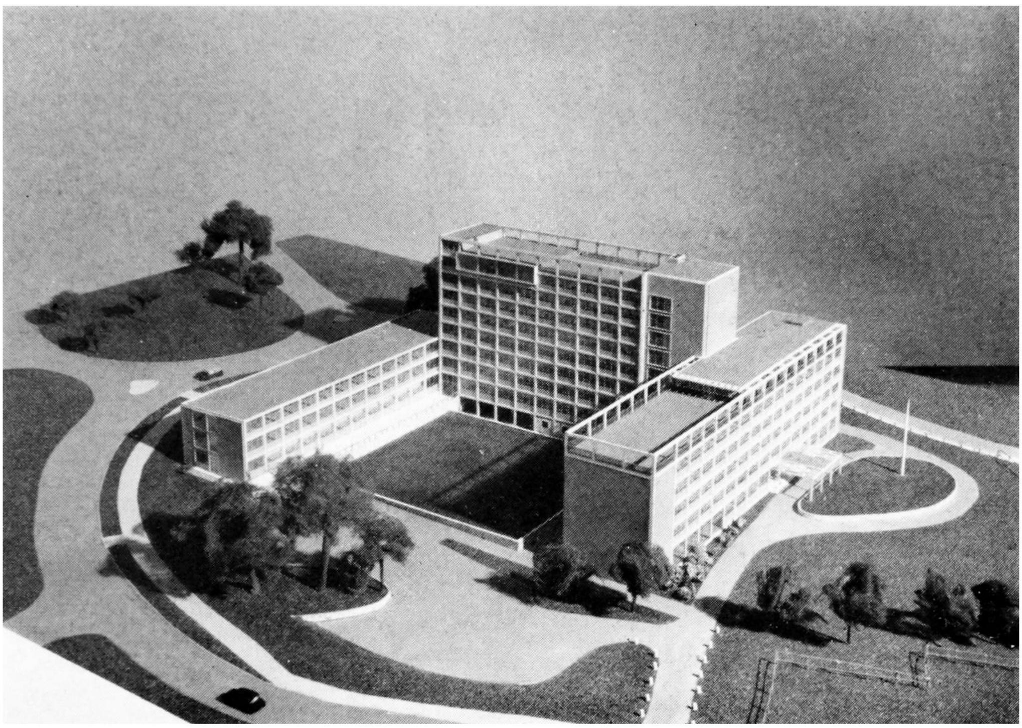
View from the east.

MODEL OF THE NEW METEOROLOGICAL OFFICE HEADQUARTERS, BRACKNELL BERKSHIRE

(see p. 112)



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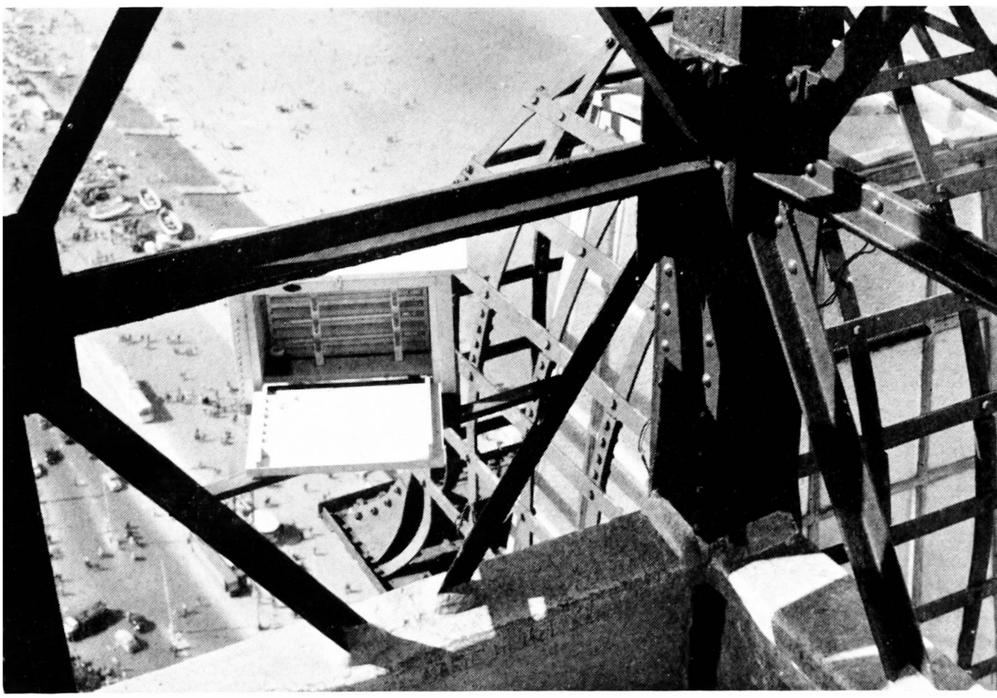
View from the south.

MODEL OF THE NEW METEOROLOGICAL OFFICE HEADQUARTERS, BRACKNELL
BERKSHIRE

(see p. 112)

To face p. 113]



The Evening Gazette, Blackpool

THERMOMETER SCREEN ON BLACKPOOL TOWER

(see p. 110)

It is expected that building will begin in July, 1959. The structure should be ready for occupation in stages between January and July, 1961.

The designs were prepared in the Chief Architect's Division of the Ministry Of Works (Architects, H. A. Snow, A.R.I.B.A., and K. H. Choate, A.R.I.B.A., Structural Engineer, F. Walley, M.SC., A.M.I.C.E.), the Chief Engineer's Division (Engineer, A. M. Palmer, B.SC., A.M.I.H.V.E.) being responsible for mechanical and electrical services.

METEOROLOGICAL OFFICE DISCUSSION

Tropical Meteorology

The subject for the Monday Discussion on 15 December 1958 was "Tropical meteorology". Dr. A. C. Best was in the Chair and the opening speakers were Mr. P. F. Emery and Mr. P. Graystone.

Mr. Emery opened by speaking of the sparse observational network of South-East Asia and the slowness with which data are received there by comparison with North-West Europe. He went on to discuss the relationship between wind and pressure gradient in tropical and equatorial regions and pointed out that the observed wind bears an indeterminate relationship to the pressure gradient within some 10 degrees latitude of the equator; outside this region the isobaric pattern bears at least a qualitative relationship to the wind flow. He suggested several methods of wind field analysis in the tropics aimed at determining divergence patterns, and advocated the drawing of isobars on surface charts to obtain a general idea of the flow pattern outside the equatorial belt.

Mr. Emery next spoke of the correlation of the divergence pattern on the 1,500–2,000-foot streamline chart with the distribution of weather, but added that local influences on low-level winds make the assessment of divergence difficult at low levels. He also mentioned that pressure tendencies were small by comparison with semi-diurnal effects and could not be used to draw isallobars over a large region; 24-hour pressure differences were of more value for this purpose.

Turning to the diurnal weather cycle, he said that it was normal to have early morning fog and stratus inland which, although it lifts and disperses through insolation, transforms itself quickly into large amounts of convective cloud. As shown on a slide of mean tephigrams for Singapore, the air is seen to be conditionally unstable and very moist to great heights so that showers and thunderstorms are commonplace. Where low-level convergence assists convection the shower activity is increased, and where divergence is occuring showers are less pronounced; the effect of orography on weather distribution is considered to be more important than the sign of the divergence however.

Speaking of the increased interest in high levels of the troposphere, Mr. Emery suggested that there are normally large amounts of cirrus cloud in equatorial regions although the mechanism maintaining this cloud over the open sea is obscure. He then mentioned the occurrence of clear-air turbulence associated with strong vertical wind shear, and the difficulty of determining the lateral and longitudinal extent of strong wind belts due to lack of high-level wind reports.

He made reference to fronts entering the tropics, losing their temperature contrast by passage over uniformly warm sea and by subsidence, but remaining as shear-lines which may persist for several days moving slowly equatorward. He also referred to reports of icing at temperatures below −40°C., at which temperature liquid water droplets are supposed to freeze spontaneously.

The last part of Mr. Emery's discourse dealt with the problem of upper wind forecasting. Pointing out that the instantaneous flow pattern could not be used to predict the future flow pattern, he quoted Durst's stretch-vector correlation coefficients[1] for the tropics showing that statistical forecasts based on spatial or temporal regression relationships were of little use except for short distances and periods of time. He next suggested that the extrapolation of "trends" might be used to produce spot winds assuming that periodicity could be established. In Malaya, this method is not effective as no detectable periodicity appears to exist in the upper wind patterns. The forecasting of upper winds from prontours is invalid in equatorial regions because a relationship between contours and wind has not been established; in any event the radar wind-finding network is inadequate to construct useful contour or thickness charts.

In conclusion, Mr. Emery called for more radar wind-finding stations in equatorial regions and pilot-balloon reports from all main reporting stations at main synoptic hours at least up to 2,000 feet.

Mr. Graystone discussed the meteorological observations made during the past two years in the central Pacific. These comprised a continuous record at Christmas Island, with a small, but quite dense, meteorological network—the first of its kind in purely equatorial regions—operating for comparatively short spells. Though of interest in several fields, it was the synoptic aspect that was considered most useful.

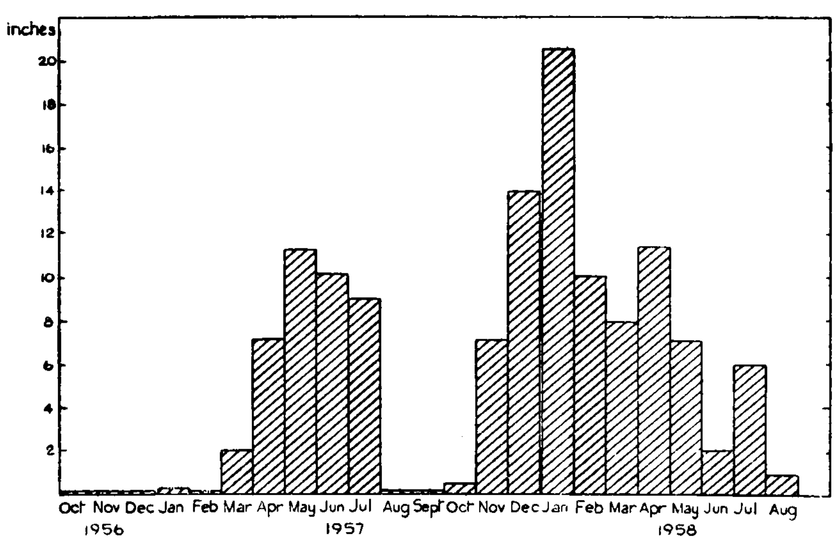


FIGURE I—MONTHLY RAINFALL FOR CHRISTMAS ISLAND

Christmas Island is in an oceanic region, free from orographic effects, where the trade winds blow with almost 100 per cent regularity. Nevertheless the climate is far from settled. The rainfall records for the past two years (Figure 1) show large monthly and seasonal variations, with a remarkable disparity between the first six months and the corresponding period a year later. This irregularity, also found in earlier records, becomes more comprehensible when related to the average rainfall in the central Pacific, which shows a dry zone centred just south of the equator, with belts of maximum rainfall a few degrees north and south.

The "normal" settled type of weather was discussed; it was characterized by uniform wind, cloud and weather over wide areas. The low-level wind pattern was slightly divergent, favouring subsidence while the low sea surface temperatures near the equator in the eastern Pacific were reflected in lower humidities and increased stability. Light showers fell frequently from very shallow cumuli, often with tops 4,000 feet or less. With large cumuli, correspondingly heavier showers occurred, the tops being well below the freezing level.

A zone of unsettled weather to the north was soon located, some activity being reported almost every day between 5°N. and 10°N. Low-level reconnaissance flights through this zone showed clear-cut convergence in the lower layers between east to east-south-east winds to the south and strong east-north-east trades to the north. Though frequently affecting Christmas Island there was only one occasion when this zone was centred to the south of the island. Intensity varied considerably, from moderate convection with cloud tops

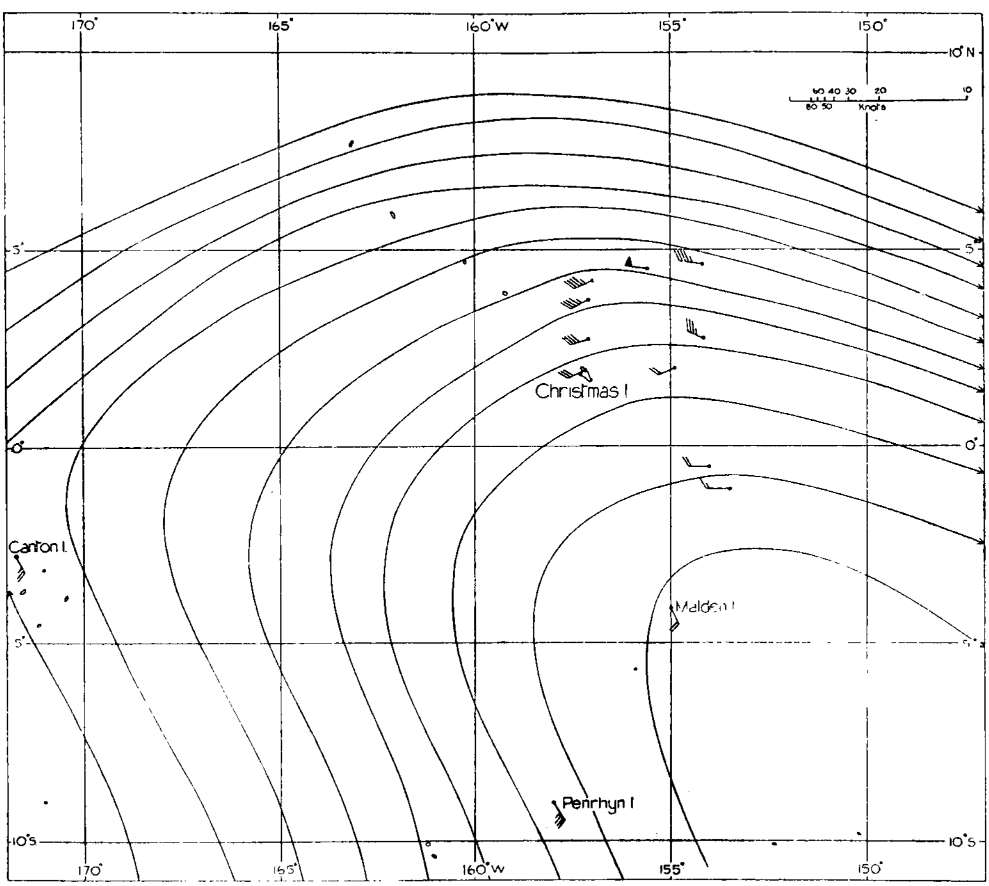


FIGURE 2—40,000-FOOT WINDS FOR 1700–2400 G.M.T., 12 APRIL 1957

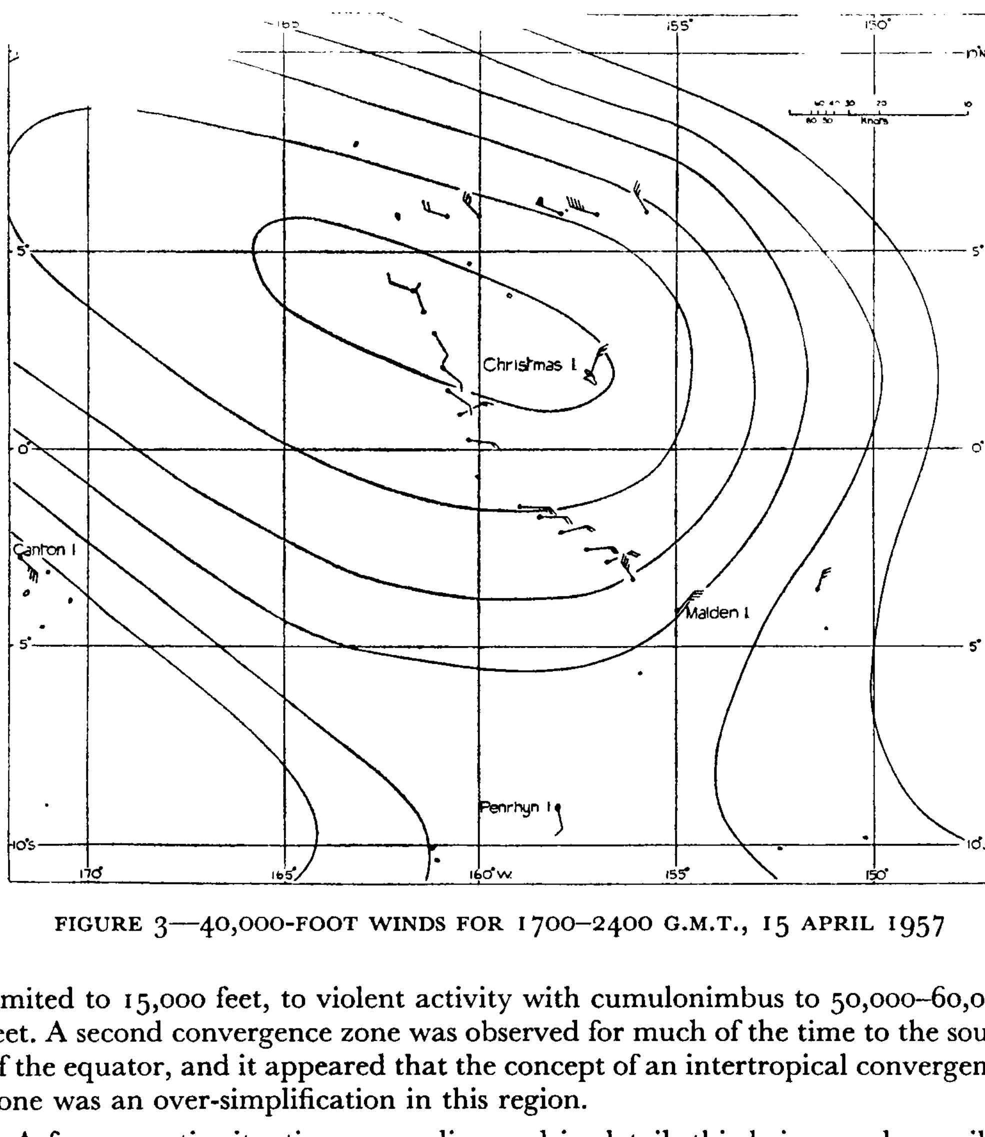


FIGURE 3—40,000-FOOT WINDS FOR 1700–2400 G.M.T., 15 APRIL 1957

limited to 15,000 feet, to violent activity with cumulonimbus to 50,000–60,000 feet. A second convergence zone was observed for much of the time to the south of the equator, and it appeared that the concept of an intertropical convergence zone was an over-simplification in this region.

A few synoptic situations were discussed in detail, this being made possible by the reports from reconnaissance aircraft; these included jet aircraft equipped with Doppler apparatus for wind finding. The detailed upper-level charts drawn from these wind reports revealed a variety of patterns, with an occasional closed circulation. Such circulations were nearly always secondary transient phenomena but a few retained their identity for some time. A sequence was shown illustrating the formation of a deep southern hemisphere trough at 40,000 feet, leading to a closed cyclonic circulation which crossed the equator and appeared as a short-lived clockwise circulation in the northern hemisphere. The early and final stages are shown in Figures 2 and 3. Of the few well authenticated circulations observed, all appeared to originate as cyclonic vortices and none maintained its existence for any length of time in the other hemisphere, a fact in good accord with theoretical considerations.

Developments aloft were often independent of those at low levels, and indeed of weather in general, but one outstanding case was noted of a sudden widespread outbreak of heavy rain apparently associated with marked divergence at 40,000 feet. Valuable information was collected on wind structure in the stratosphere.

Winds above the tropopause at Christmas Island were summarized for the two-year period (Figure 4), the diagram showing zonal components using 10-day means. Noteworthy are the absence of any annual cycle and the presence of very large shear values. What about the QBO? It's there but not apparently recognized

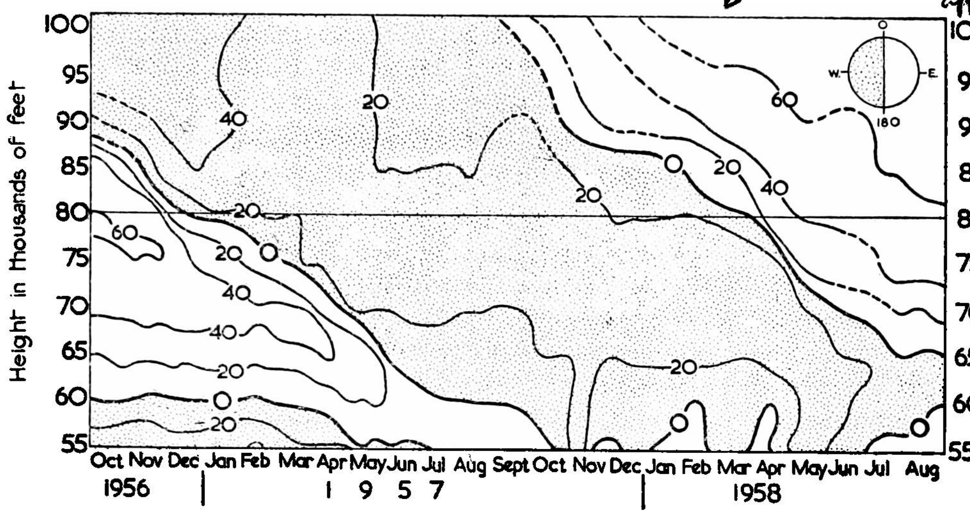


FIGURE 4—ZONAL COMPONENTS OF WINDS ABOVE THE TROPOPAUSE AT CHRISTMAS ISLAND USING 10-DAY MEANS

Turning to more general problems of equatorial forecasting, Mr. Graystone discussed methods of observation and chart analysis. The orthodox surface chart has a diminished value, and there is a requirement for regular 2,000-foot wind reports to replace pressure observations. No existing method of wind analysis is wholly satisfactory. The non-divergent method as illustrated in Figures 2 and 3 gives the best representation of vectors in two dimensions, but is time-consuming and is often inferior at low levels where divergent regions can often be identified and the streamline–isotach method of the Palmer school, now widely used in the tropics, is often superior. The latter too has the virtue of ease of construction; on the other hand attempts to indicate convergent and divergent regions may be misleading, while this technique tends to exaggerate minor features at the expense of the major wind current.

As far as forecasting was concerned, Mr. Graystone considered shortage of information to be the main handicap. Technically the stumbling-block was lack of any real understanding of the behaviour of wind near the equator, while difficulties arose also from the vast amounts of energy latent in the atmosphere so that the scales were often finely poised between settled and stormy weather.

Mr. Freeman showed several cloud photographs taken in the Christmas Island region. Features of note were a tendency for cloud to lie in lanes along the wind and the typical lean of trade wind cumuli, while one unusual photograph showed an area of large cumuli isolated among general small cumuli.

Mr. Rao, opening the general discussion, doubted the value of searching for areas of convergence and divergence, which if real should already show corresponding weather. He also asked whether upper troughs and ridges in the extratropical flow could be followed near the equator. Mr. Graystone thought this was so in the tropics generally, but not on the whole in equatorial regions.

Mr. Willis spoke of his attempts to predict wind at Christmas Island by identifying cycles in the local flow, suggesting a moving wave pattern. His results were encouraging at first, though less so recently.

Mr. Walker, Director of the Ghana Meteorological Service, cautioned against the practice of drawing too definite conclusions from a brief acquaintance with tropical meteorology. Long experience showed that textbook situations occurred no more frequently than in temperate latitudes. Fundamental problems remained to be solved and there was no guarantee that an improved upper air network, for instance, would improve forecasting significantly. Humidity was a factor whose importance could not be over-emphasized.

Dr. James spoke of the diurnal variation of convective cloud at Christmas Island. During the day a line of continuous shallow cumuli, apparently fixed in position, extended downwind from the north-east point of the island, with a horizontal depth of 3,000–4,000 feet. Tops seemed to be some way below the inversion level of 850 millibars as predicted theoretically by Malkus.[2] During the evening as the sheet began to break up, some tops reached or exceeded this level, while the line of cumuli tended to drift northwards across the wind. The height increase could be attributed to a fall in surface temperature, making inoperative the Malkus restriction on cloud top, and to long-wave radiation from cloud exceeding the solar radiation absorbed. *Mr. Clark* thought the lateral movement of the cloud could be a simple sea-breeze effect.

In a lively discussion, several speakers referred to problems in a wide variety of tropical regions. A distinction was made between the problems of equatorial meteorology, on which the opening speakers had concentrated, and those of the tropics in general.

Mr. Beynon discussed the West Indies region, referring in particular to tropical storms and their formation in easterly waves. He drew attention to Riehl's method of forecasting their motion.

Mr. Murray referred to tropical Arabia, where rainfall was infrequent and its prediction of prime importance; analysis of the depth of the moist layer was an important tool. Easterly waves were of secondary importance to troughs in the westerlies.

Mr. Hunt spoke of the Seychelles region. He had been able to follow what appeared to be frontal zones moving across the equator from the southern hemisphere.

Mr. Barrientos mentioned the Philippines, noting a tendency for tropical storms to recurve in this area. Malayan problems were raised by two speakers; the sea-breeze was considered an important factor in thunderstorm formation, though Sumatra squalls could develop at any time of day.

Mr. Wallington commented generally to the effect that experience acquired in one tropical region could not necessarily be transplanted to another—each had its own problems. Also, was it justifiable to attempt to join up limited zones of convergence into a global intertropical convergence zone?

The problem of the intertropical convergence zone was also raised by other speakers. *Mr. Sharp* had found that the zone had a double structure over the Indian Ocean, with westerlies separating the trade winds. *Mr. Harding* considered, however, that the northern convergence zone over the central Pacific could be considered as a true intertropical convergence zone, that in the southern hemisphere being a more localized feature.

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1. DURST, C. S.; Variation of wind with time and distance. *Geophys. Mem., London,* **12,** No. 93, 1954.
2. MALKUS, J. S.; The effects of a large island upon the trade-wind air stream. *Quart. J. R. met. Soc., London,* **81,** 1955, p. 538.

NOTES AND NEWS

Halo complex, 2 March 1954

The brilliant halo complex seen over England, Wales and parts of Scotland on 2 March 1954 was reported in the *Meteorological Magazine* and in *Weather.*[1, 2]

We are now indebted to Miss C. M. Botley for the reference to a report in *L'Astronomie*[3] of an identical observation during the morning of the same day at a point in the French Alps (Agnières-en-Dévoluy, Hautes Alpes, about 35 miles south of Grenoble.) The tangent arcs to the 22° and 46° haloes formed two magnificent ellipses about the sun. This is the only observation of this complex to be reported from the continent of Europe. A trough with a cold front extended from the Netherlands to south-west France preventing any view of the sky over the area between south-east England and south-east France.

REFERENCES

1. London, Meteorological Office; Halo complex, March 2, 1954. *Met Mag., London,* **83,** 1954, p. 186.
2. London, Royal Meteorological Society; The halo display of 2 March 1954. *Weather, London,* **9,** 1954, p. 206.
3. Paris, Société Astronomique de France; Communications écrites. *Astronomie, Paris,* **68,** 1954, p. 195.

Corrigenda

In the index for 1958 of the *Meteorological Magazine,* included in the December number, the review of *The physics of clouds* by B. J. Mason was attributed to H. H. Lamb instead of B. C. V. Oddie, and the review by H. H. Lamb of *Physikalisch-statistiche Regeln als Grundlagen für Wetter-and Witterungsvorhersagen* by F. Baur was omitted. (p. 346)

REVIEWS

Atmosphärische Elektrizität, Teil I: Grundlagen, Ionen, Leitfähigkeit (Probleme der kosmischen Physik Band 29). By H. Israël. 6 in. × 9¼ in., pp. ix + 370, *illus.,* Akademische Verlagsgesellschaft, Geest und Portig K.-G., Leipzig, 1957. Price: *DM* 42.

Dr. Israël writes from a long experience and an encyclopaedic knowledge of his subject and this not inconsiderable work is but the first of two volumes on Atmospheric Electricity. The second is to be entitled "Felder, Ladungen, Ströme".

The choice of topics and, still more, the allotment of space are a little surprising and it is perhaps worth indicating in some detail the contents of the volume. After a brief introduction (15 pages) on the history of the subject there follows a long second chapter (74 pages) on the fundamental physics of ionic conduction in gases, without particular reference to the atmosphere; it includes a section on gas discharges, written by H. Dolezalek. The chapter is well written and covers a wide field but is necessarily rather condensed; it includes some quite elementary physics.

There follows a curious little chapter (15 pages) in which the reader is introduced to the main subject of the book by the device of allowing a hypothetical fully trained experimental and theoretical physicist, provided with all necessary facilities, to rediscover for himself the main facts concerning the electrical effects in the atmosphere, effects of whose existence he was apparently unaware. He makes very rapid progress although, curiously, half a page has to be devoted to explaining Poisson's equation to him! This chapter is well done on the whole; the author is at pains to emphasize that the electrical state of the atmosphere is the result of a balance between two opposing processes, the vertical separation of electrical charges by thunderstorms and the neutralisation of charges by the vertical conduction current of fair-weather regions. He proceeds however to make, dogmatically and without real explanation, the surprising statement that the answer to the classical problem of the maintenance of the earth's negative electric charge is that the earth has no net negative charge! It is by no means obvious that a balance of currents into the earth by very different mechanisms necessitates a zero net charge, nor is there any conclusive observational evidence for such a conclusion.

After this interlude of easy reading we are plunged in Chapter IV (134 pages) into a detailed study of the conductivity of the atmosphere and its causes, the climax of the volume. Here are discussed the principles of methods of measurement and the detailed theory of conduction, ionic equilibrium, atmospheric radioactivity, etc. This detailed compilation will be invaluable to a specialist in this very complex and technical field and he will wish to ponder it at length.

There follows a useful chapter on techniques of measurement by Dolezalek and Israël (in the main reprinted from Linke's Taschenbuch), a series of tables, mathematical, meteorological and physical (for example radioactive constants) and a vast bibliography of over 800 papers.

This is a book which every serious worker in the field will wish to have on his shelves or, at least, in the library down the corridor. This first volume is primarily concerned with what is normally thought of as fair-weather atmospheric electricity although its author is at pains to emphasize the limitations of what can be deduced from observations on quiet days only. He pleads indeed for what he calls a synoptic and climatological approach to atmospheric electricity and makes an attempt to show what he means by this. Nevertheless the main Chapter IV is concerned primarily, at any rate when the discussion is quantitative, with a fine-weather atmosphere or even with an idealized model of the atmosphere.

One may take leave to doubt whether it is practicable or desirable to combine in a single volume a long and detailed discussion of a technical subject, really suitable only for a specialist reader, with other chapters which assume no previous knowledge of the field and are by comparison very condensed, with a summary of all the fundamental physics and mathematical and other tables the reader is likely to need.

The book is attractively produced, although not entirely without misprints. It is clearly printed and has numerous excellent diagrams and its author is with rare exceptions a reliable guide. The second volume will be awaited with great interest. T. W. WORMELL

Dynamical and physical meteorology. By G. J. Haltiner and F. L. Martin. $9\frac{1}{2}$ in. $\times$ $6\frac{1}{2}$ in., pp. xi + 470, *illus.*, McGraw-Hill Book Company, Inc., New York, Toronto, London, 1957. Price: 75*s.*

Doctors Haltiner and Martin are instructors in meteorology at the United States Naval Postgraduate School, Monterey, California and this book is presumably the outcome of their experience in teaching meteorology at post-graduate level. The text is largely concerned with the dynamical aspects of meteorology and only those parts of physical meteorology which are relevant to the dynamics are dealt with. This means the omission of much that is of considerable interest: for example, nothing of the physics of clouds, thunderstorms or radar is mentioned here, but this is not a loss since to have included all these topics would have meant a much larger book and the pedagogical theme would have been obscured.

The book opens with a very short chapter on vectors and the authors are to be congratulated upon avoiding over-elaboration here; the amount of vector calculus used in meteorology is quite small and largely consists of writing down physical facts in mathematical form and not of manipulation. The next four chapters deal with thermodynamics and problems of stability. The text here is clear and short although the notation is occasionally puzzling; there is a curly delta, indicating an infinitesimal, which it is impossible to use in script and such symbols are best avoided. The treatment of moist air is well done and, although the student will have to go elsewhere for theories of precipitation, there are references to the necessary papers.

Chapters 6 to 9 deal with radiation. The first of these develops the basic definitions and laws without much discussion, so that it reads rather like a mathematical exercise and indeed throughout these chapters the condensation gives a note-like form to the text. Incoming solar radiation is discussed in a clear simple way and the chapter on atmospheric radiation leads to a discussion of the use of radiation charts, such as have been produced by Elsasser and Robinson, enabling the student to realize that radiational fluxes can be assessed quantitatively and not only qualitatively. This is a welcome inclusion. The discussion of night minimum temperatures follows the usual pattern and there is not sufficient warning that the physical characteristics of the air and ground cannot be determined accurately enough to use the various mathematical formulae. Chapter 10 closes the physical content of the book with a treatment of the heat balance in the atmosphere, showing the necessity for the breakdown of zonal motion. These chapters on the physics of the atmosphere provide a skeleton outline which will need a good deal of supplementary reading, especially on the physical side.

The remainder of the book is devoted to the dynamics of the atmosphere and the authors seem more at home here than in the physical part. The vector calculus of Chapter 1 is used throughout and to great advantage over the Cartesian scheme. The equations of motion are well treated in several different co-ordinate systems and there are a few remarks upon mapping on a horizontal surface which do not usually get into meteorological texts and which are important when calculations are made from a synoptic chart. The equations are applied to horizontal frictionless flow leading to the ideas of geostrophic and gradient flow, and to the variation of wind in the vertical. A good point here is the introduction of both pressure and potential temperature as a co-ordinate. For a clear straightforward account of these basic ideas it would be hard to improve on these chapters.

There are three chapters on atmospheric turbulence. The first deals with viscous flow and the Reynolds' stresses and gives the various forms that have been suggested for the wind profile in the surface layers. Here the contracted style leads to a little confusion. The unwary might suppose that equations (14–5) are applicable to a compressible fluid, especially in view of the note following the derivation of equations (14–12); near the foot of page 220 no mention is made of the scale of motions in which the horizontal accelerations may be neglected; the computation of surface roughness for an aerodynamically smooth surface is incorrect, perhaps a typographical error. The theories of diffusion are treated in a straightforward manner, illustrated by numerical examples, and the reader who has worked his way through these chapters will be sufficiently well-versed to read Sutton's treatise.

Two chapters on kinematics follow which are largely formal and then a miscellaneous chapter dealing with divergence, vertical motion and the corresponding pressure tendency equations. More of the observational results which require to be explained would have been welcome here, with a more critical appreciation of the recent work: it is, perhaps, noticeable that the pages upon which little or no mathematical symbolism appears are the most interesting. The remainder of the book, excepting for a chapter on the general circulation, is devoted to the more modern developments in dynamical meteorology leading up to numerical prediction. On the whole these are very good chapters, although one might quarrel with detail, such as the introduction of circulation and solenoids which does not add to the classification. Is there a vortex-tube term in the vorticity equation? The physical explanation of the presence of this term, obtained by considering the velocities of neighbouring air parcels passing through a pressure surface with different vertical velocities in the presence of a vertical wind shear, is so simple that it seems a pity to ignore it and tie on a sophisticated label; this is an example of the mathematical, rather than the physical, approach. Perturbation theory is treated in some detail and this is to be commended since it often indicates the class of motions that are likely to appear without calling for too much computation. The bases of numerical prediction of large-scale synoptic motions are carefully laid and there is a good description of how numerical methods are used in the barotropic and simple baroclinic models to produce forecasts; these chapters lay a good foundation for moving on to original papers.

Thus, the book gives an account of theoretical meteorology as applied to motions on a synoptic scale. Although the mathematics is relatively simple the approach is mathematical rather than physical. There is nothing of synoptic meteorology here and the reader must have as a background ideas and observations which call for an explanation; there is very little mention of the scale of motions and so that, for example, as far as the text is concerned fronts might well be a local phenomenon. Occasionally there is a lack of critical evaluation, or perhaps not sufficient warning is given that results should be treated with reserve.

Despite these few criticisms, which are important in their way, this is a very good book and is very suitable for those who have taken a degree in mathematics or physics and are entering meteorology. It should become a standard text at this level and no library can afford to be without it. Students and teachers will wish to own it, and it is not expensive.

There are a few blemishes in the text due to faulty proof reading. The diagrams on the whole are clear, informative and well drawn; an exception is Figure 7–1. The references are mainly to recent work; when referring to a book the authors should indicate the page or at least the chapter.

E. KNIGHTING

The threshold of space. The proceedings of the Conference on Chemical Aeronomy, edited by M. Zelikoff, sponsored by Geophysics Research Directorate, Air Force Cambridge Research Center, Air Research and Development Command, Cambridge, Mass. 25–28 June 1956. Co-ordinated by Wentworth Institute, $7\frac{1}{2}$ in. × 10 in., pp. xi + 342, *illus.*, published by Simposium Publications Division, Pergamon Press, London, 1957. Price £5 5*s*.

This book is a report of a Conference on Chemical Aeronomy sponsored by the Geophysics Research Directorate of the United States Air Force Cambridge (Mass.) Research Center, from 25–28 June 1956. It is a report in what one may fairly call the New Pergamon manner—beautifully printed and bound, lavishly illustrated, enormously detailed, enormously expensive, and bearing a dramatic title which gives absolutely no hint as to the subject.

The report is divided into four sections. The first deals with photochemical processes occurring in the atmosphere and in particular with "photochemical and chemiluminescent processes occurring in the airglow and aurora"—in other words with "chemical aeronomy". The second and third sections are devoted to the tools of the trade—the second to spectroscopy and laboratory studies of photochemical processes, the third to the use of rockets. Part IV deals with "phenomena produced by hypersonic flight", and looks at first sight as if it had strayed into the wrong book: but there is a connexion. The shock wave which accompanies a projectile at hypersonic speeds is a region of very high pressure and temperature, and both radiation and molecular dissociation must be taken into account in order to estimate its reactions on the projectile. Thus the problems of chemical aeronomy and of hypersonic ballistics have a good deal in common and employ similar experimental methods.

To the ordinary earth-bound meteorologist the papers are of very variable interest. Most of Part II and some of Part I are barely comprehensible except to the student of molecular spectroscopy; but there are several excellent and easily understood reviews of the chemistry of the upper air in Part I, among which the first, entitled "Chemistry of an oxygen–nitrogen atmosphere" by Barth and Caplan, is particularly lucid. The last article in this section "The atmosphere and the cloud layer of Venus" by Gerard P. Kuiper is fascinating in itself, and has an unusual sequel. Venus is covered by cloud but it is somewhat yellow in colour and has other optical properties which show that it is either not a water cloud at all or, more likely, is water mixed with some other material. A group of specialists got together after this meeting to discuss the nature of this other material, and concluded that it might consist of carbon suboxide C_3O_2 which, it seems, is formed from a mixture of carbon dioxide and carbon monoxide by the action of ultraviolet light, and polymerises to form a fine yellow powder! Not even the most adventurous writer of science fiction ever thought of an odder atmosphere than this.

But Part III is the most consistently entertaining part of the book. Rockets are not only an exciting development in themselves, but they have been employed throughout their brief history in an exceptionally imaginative way. All the six papers of this section are worthy of this fine tradition. The first three describe elegant researches based on the traditional semi-spectroscopic method as used in rockets—the measurement of the intensity of radiation in suitable wavebands selected by filters: while the last three described researches in which substantial volumes of the upper air were modified by introducing suitable materials (sodium, nitric oxide) and the resultant changes studied from the ground.

Part IV is likewise interesting and fairly easy to read but is concerned with a particular branch of engineering and has only a rather remote connexion with meteorology.

Whether such elaborate conference reports as this are justifiable is doubtful. Scientific literature appears so rapidly that most of us have to select with some care the items on which we expend either reading time or money, and from either point of view, reports such as this are a poor investment. They are useless as textbooks because they are of necessity mere collections of separate essays. They are useless as source books, for the articles are almost all either reviews of work already published, or previews of work which is not yet ready for publication. Possibly the intention is to give an account of the present state of the subject—the ways in which the leading workers are thinking and moving; but if that is the purpose, it would surely have been better served by a shorter and cheaper report, published a year earlier. Still, it makes entertaining reading for those who have the time. B. C. V. ODDIE

OFFICIAL PUBLICATION

The following publication has recently been issued:—

PROFESSIONAL NOTES

No. 126—*A synoptic study of anomalies of surface air temperature over the Atlantic half of the Northern Hemisphere.* By J. M. Craddock, M.A. and C. A. S. Lowndes.

The preparation is described of a series of charts covering the Atlantic half of the Northern Hemisphere giving the five-day mean temperature anomaly for 73 non-overlapping periods covering the year 1 May 1955 to 30 April 1956. The more important features seen during the year are described, and their relationship to the patterns found on contemporaneous series of five-day mean charts of pressure at mean sea level and of daily charts of the 1000–500-millibar thickness.

The possible application of the temperature anomaly charts in long-range forecasting is discussed.

METEOROLOGICAL OFFICE NEWS

Retirements.—The Director-General records his appreciation of the services of:

Mr. A. D. Mills, Senior Assistant (Scientific), who retired on 25 February 1959. He joined the Office in January 1928 as a locally entered clerk in the Middle East after service first in the King's Own Yorkshire Light Infantry and then in the Meteorological Section, Royal Engineers from 1918–19 and with the Royal Air Force from July 1922 to January 1928. Apart from a period from 1948 to 1951 at an aviation outstation in the United Kingdom, he has served continuously in the Middle East. From 1955 until his retirement he served in Cyprus.

Mr. W. A. S. Prior, Senior Assistant (Scientific), who retired on 13 February 1959. After service with the Royal Field Artillery in the First World War he was employed in the Ministry of Pensions. He joined the Office in May 1926 as a Grade III Clerk. Apart from short periods at Croydon and Holyhead all his service has been spent at Headquarters in the Forecast Division. From 1939 until his retirement he served in the London Forecast Office. Mr. Prior has accepted a temporary appointment in the Meteorological Office.

WEATHER OF DECEMBER 1958

Northern Hemisphere

In association with a pronounced southward extension of the Canadian upper trough, the North Atlantic circulation had a southward displacement. Mean pressures were below normal over Europe and anomalies reached −10 millibars over Biscay and northern Spain. A large area of unusually high pressure extended over Greenland, Iceland, and all parts of the Arctic, anomalies being comparable in magnitude with those over Europe. There were further positive anomalies over North America where mean pressure ranged from near average in Mexico to 7 millibars above average in northern Canada. The Siberian high was nearly normal in position and intensity but had a very strong ridge extending north-east from the centre with a secondary centre situated at about 65°N. 140°W. A southward displacement of the Aleutian low, which was slightly deeper than usual, and an abnormally weak North Pacific high resulted in negative pressure anomalies up to − 8 millibars over much of the North Pacific.

Mean temperatures were 1° to 3°C. above average in Europe, apart from most of Britain and Scandinavia, as a result of increased cyclonicity and more southerly advection than usual. Negative temperature anomalies occurred over Scandinavia and in the north coastal regions of Asia, reaching −9°C. in parts of north-west Russia. Over most of the remainder of Asia temperatures were above normal, anomalies being small in India and Japan but as large as +7°C. at and near Irkutsk.

In North America it was approximately 2°C. warmer than usual over and to the west of the Rockies, and also in the Canadian Arctic, but in eastern parts of both the United States and Canada it was a cold month. The anomalies were only about −1°C. in southern states of America but they were − 5° and − 6°C. near the Great Lakes and along the St. Lawrence, where ice conditions were exceptionally severe.

Rainfall totals were near or above average nearly everywhere in Europe. They were more than three times the normal at many stations in Spain and Portugal where severe flooding was reported. Drought in countries at the eastern end of the Mediterranean persisted throughout December, the situation being particularly serious in Israel where there had been a deficiency of rain for many months. Over Asia precipitation amounts were variable and in many areas not clearly related to the pressure distribution. In North America it was generally a drier month than usual, although some stations on the eastern slopes of the Rockies and also in British Columbia received up to twice the average.

WEATHER OF JANUARY 1959

Great Britain and Northern Ireland

Cold northerly winds persisted over much of the country from the 2nd to the 13th and then, after a short period of quiet, foggy weather, several disturbances moved north-east across the British Isles between the 17th and 23rd giving mostly cold weather in the north and mild weather in the south. The last week of the month was anticyclonic, cold, foggy and very dry.

New Year's Day was mild generally with strong westerly winds and outbreaks of moderate to heavy rain, as a complex depression moved rapidly across Scotland. Weather soon became colder in Scotland and cold northerly winds behind the depression spread over the whole of the British Isles the following day accompanied by showers of rain, sleet or snow and occasional thunderstorms. Minor waves on a warm front brought milder air to the southern counties of England on the 5th and 6th and there were prolonged falls of rain or snow in many districts south of a line Mersey–Humber. In the north, however, frost persisted extensively all day; at Dalwhinnie temperature on the 6th failed to rise above 18°F. The following day there was widespread snow as the cold northerly winds spread back again over the whole country, but falls were not large. During the next three days weather became progressively drier and colder and temperatures at many places in south and east England remained below freezing point; 27°F. was not exceeded at Driffield on the 10th. On the 11th and 12th a depression from eastern Europe moved southwards from Scandinavia into the North Sea and associated troughs moved southwards over the British Isles, bringing snow to all districts. On the 11th wind reached gale force over most of Scotland, gales being severe in the north-east where, at Lerwick, a gust of 79 knots was recorded, but the following day winds moderated and weather became less cold, although frost was widespread at first.

On the 13th pressure became almost uniform over the country, and in these quiet conditions fog developed widely during the day, thickening at night. The fog persisted for about four days in many places. In the foggy areas temperature remained low; it did not exceed 25°F. at Renfrew throughout the 14th and 15th, or 24°F. at Birmingham during the 16th.

Fresh south-westerly winds, associated with a deep depression about 400 miles to the south-west of Iceland, brought widespread rain on the 17th and a general rise in temperature which remained above freezing the following night for the first time for over two weeks. During the next three days a depression remained almost stationary off the west of Ireland. There was rain over much of the country and it was particularly heavy in parts of Scotland where about 1½ inches fell at both Stornoway and Cape Wrath in 12 hours on the 18th. Several disturbances moved north-east across the British Isles between the 17th and 22nd giving mostly cold weather in the north and milder weather in the south of the country. On the 21st south-westerly winds were confined to southern England where afternoon temperatures rose to about 50°F. but over much of Scotland they were less than 40°F. and in the Shetlands 10°F. lower still. The next day cold northerly winds spread over the remainder of the British Isles bringing rain to most districts and local sleet and snow to parts of the North and Midlands.

Pressure rose rapidly over the country on the 24th and 25th as an anticyclone from Greenland moved south-east, reaching the continent on the 26th. Patchy, though persistent, fog formed in the Mersey area and in Lancashire on the 25th and during the remainder of the month there was a good deal of fog which became very dense and widespread on the 28th and 29th.

Sunshine amounts were outstanding for January, several stations reporting more than double their usual amount of sunshine for the month. At Stonyhurst it was the sunniest January since 1881 and places as far apart as Thorney Island and Leuchars had over 100 hours. Mean temperature was below average over the whole country; at Ross-on-Wye and Hampstead it was the coldest January since the cold winter of 1947. Rainfall was 109 per cent of the average in England and Wales, 76 per cent in Scotland and only 66 per cent in Northern Ireland. Less than 25 per cent of the average occurred locally in south-west Scotland and less than half the average occurred over much of Scotland south of a line from the Isle of Rhenn to Arbroath. The English Lake District also recorded less than half the average amount. Values exceeded 150 per cent over an area extending from Dorset to the Wash, and in northern Sutherland twice the average was exceeded.

Ground conditions continued to impede outside farm work; all cultivations were behind and only on the lighter soils was ploughing possible. However, greater day-length, together with increased sunshine, produced good improvements in glass-house crops which helped to compensate for the increased fuel costs caused by the cold weather. The severe frosts checked spring greens and caused some damage to winter cauliflowers.

WEATHER OF FEBRUARY 1959

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 ...	66	14	+0·5	14	−10	90
Scotland	61	0	+1·1	43	− 5	106
Northern Ireland ...	56	18	+2·1	38	− 9	95

*1916-1950 †1921-1950

RAINFALL OF FEBRUARY 1959

Great Britain and Northern Ireland

County	Station	In.	*Per cent of Av.	County	Station	In.	*Per cent of Av.
London	Camden Square Gdns.	·06	4	*Pemb.*	Maenclochog, Ddolwen B.	·82	17
Kent	Dover	·02	1	*Cards.*	Aberporth	·43	14
,,	Edenbridge, Falconhurst	·06	2	*Radnor*	Llandrindod Wells ...	·38	12
Sussex	Compton, Compton Ho.	·12	4	*Mont.*	Lake Vyrnwy	·81	14
,,	Worthing, Beach Ho. Pk.	·03	1	*Mer.*	Blaenau Festiniog ...	4·63	48
Hants.	St. Catherine's L'thouse	·27	13	,,	Aberdovey	1·31	40
,,	Southampton, East Pk.	·17	7	*Carn.*	Llandudno	·15	7
,,	South Farnborough ...	·14	7	*Angl.*	Llanerchymedd ...	1·03	37
Herts.	Harpenden, Rothamsted	·05	3	*I. Man*	Douglas, Borough Cem.	1·43	46
Bucks.	Slough, Upton ...	·11	6	*Wigtown*	Newton Stewart ...	1·71	49
Oxford	Oxford, Radcliffe ...	·08	4	*Dumf.*	Dumfries, Crichton R.I.	1·11	39
N'hants.	Wellingboro' Swanspool	·06	4	,,	Eskdalemuir Obsy. ...	2·05	45
Essex	Southend W.W. ...	·08	6	*Roxb.*	Crailing...	·58	33
Suffolk	Ipswich, Belstead Hall	·17	11	*Peebles*	Stobo Castle	1·02	37
,,	Lowestoft Sec. School	·17	11	*Berwick*	Marchmont House ...	·55	25
,,	Bury St. Ed., Westley H.	·18	11	*E. Loth.*	N. Berwick	·32	22
Norfolk	Sandringham Ho. Gdns.	·20	10	*Midl'n.*	Edinburgh, Blackf'd H.	·69	41
Dorset	Creech Grange... ...	·64	23	*Lanark*	Hamilton W.W., T'nhill	1·36	48
,,	Beaminster, East St. ...	·39	13	*Ayr*	Prestwick	1·56	66
Devon	Teignmouth, Den Gdns.	·27	10	,,	Glen Afton, Ayr San. ...	...	...
,,	Ilfracombe	·22	8	*Renfrew*	Greenock, Prospect Hill	2·43	48
,,	Princetown	·59	9	*Bute*	Rothesay, Ardencraig...	...	...
Cornwall	Bude	·62	25	*Argyll*	Morven, Drimnin ...	2·36	52
,,	Penzance	·40	11	,,	Ardrishaig, Canal Office	2·03	38
,,	St. Austell	·61	15	,,	Inveraray Castle ...	4·45	62
,,	Scilly, St. Marys ...	·23	8	,,	Islay, Eallabus ...	1·33	35
Somerset	Bath	·21	9	,,	Tiree	1·19	38
,,	Taunton	·16	8	*Kinross*	Loch Leven Sluice ...	1·03	38
Glos.	Cirencester	·16	7	*Fife*	Leuchars Airfield ...	·22	13
Salop	Church Stretton ...	·30	11	*Perth*	Loch Dhu	3·44	49
,,	Shrewsbury, Monkmore	·20	12	,,	Crieff, Strathearn Hyd.	1·10	36
Worcs.	Worcester, Red Hill ...	...	...	,,	Pitlochry, Fincastle ...	·74	27
Warwick	Birmingham, Edgbaston	·19	9	*Angus*	Montrose Hospital ...	·21	11
Leics.	Thornton Reservoir ...	·04	2	*Aberd.*	Braemar	·39	14
Lincs.	Cranwell Airfield ...	·37	22	,,	Dyce, Craibstone ...	·32	14
,,	Skegness, Marine Gdns.	·17	11	,,	New Deer School House	·56	24
Notts.	Mansfield, Carr Bank...	·18	9	*Moray*	Gordon Castle	·37	20
Derby	Buxton, Terrace Slopes	·77	19	*Inverness*	Loch Ness, Garthbeg ...	1·65	50
Ches.	Bidston Observatory ...	·48	25	,,	Fort William	6·20	87
,,	Manchester, Airport ...	·41	17	,,	Skye, Duntulm... ...	3·00	76
Lancs.	Stonyhurst College ...	·78	21	,,	Benbecula	1·77	59
,,	Squires Gate	·37	17	R. & C.	Fearn, Geanies ...	·35	27
Yorks.	Wakefield, Clarence Pk.	·07	3	,,	Inverbroom, Glackour...	3·06	65
,,	Hull, Pearson Park ...	·22	12	,,	Loch Duich, Ratagan...	5·66	89
,,	Felixkirk, Mt. St. John...	·56	28	,,	Achnashellach	4·76	70
,,	York Museum	·27	16	,,	Stornoway	2·12	79
,,	Scarborough	·41	23	*Caith.*	Wick Airfield	·33	17
,,	Middlesbrough... ...	·57	36	*Shetland*	Lerwick Observatory ...	1·24	37
,,	Baldersdale, Hury Res.	·56	18	*Ferm.*	Belleek	1·33	40
Nor'l'd	Newcastle, Leazes Pk....	·57	32	*Armagh*	Armagh Observatory ...	1·01	45
,,	Bellingham, High Green	·78	30	*Down*	Seaforde	1·08	38
,,	Lilburn Tower Gdns. ...	·27	12	*Antrim*	Aldergrove Airfield ...	1·23	51
Cumb.	Geltsdale, Derwent Island	1·07	44	,,	Ballymena, Harryville...	1·19	41
,,	Keswick, High Hill ...	1·31	30	*L'derry*	Garvagh, Moneydig ...	·74	26
,,	Ravenglass, The Grove	1·45	50	,,	Londonderry, Creggan	·94	30
Mon.	A'gavenney, Plâs Derwen	·35	10	*Tyrone*	Omagh, Edenfel ...	1·52	48
Glam.	Cardiff, Penylan ...	·45	15				

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