M.O. 641 AIR MINISTRY

METEOROLOGICAL OFFICE

# THE METEOROLOGICAL MAGAZINE

VOL. 87, No. 1,036, OCTOBER 1958

## SOME NOTES ON OPTICAL PHENOMENA IN ANTARCTICA

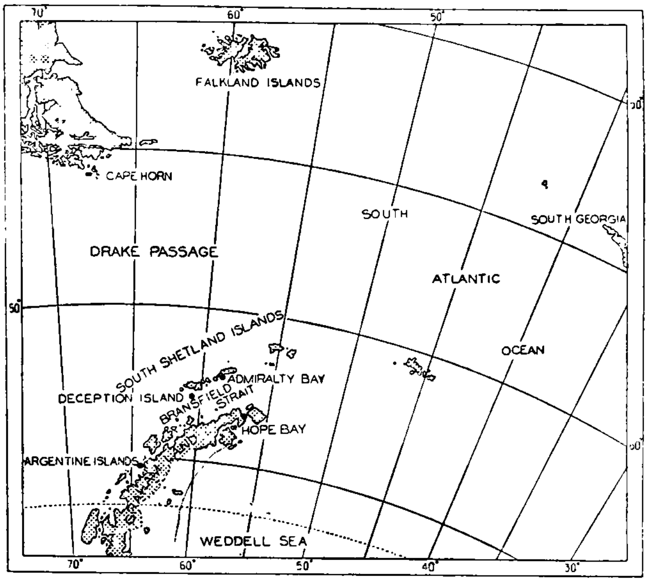
By D. J. GEORGE, F.R.G.S.

**Introduction.**—The following notes were made while serving with the Falkland Islands Dependencies Survey at bases in the South Shetland Islands, to the west and north-west of the Grahamland peninsula. In the Antarctic, meteorologists are ideally situated for observing meteorological optical effects, which are in many cases rare and present an inspiring spectacle to those lucky enough to see them. The region is a natural laboratory for observing examples of the optical laws, owing to the favourable conditions which prevail—the low temperatures experienced and the frequent occurrence of ice crystals near the ground, the lack of industrial pollution and the consequent clarity of the atmosphere, the large temperature differences between air and land and sea surfaces, and careful observers to observe and record the phenomena.

Most of the phenomena were observed at Deception Island (62° 59′S. 60° 34′W.) and Admiralty Bay (62° 03′S. 58° 24′W.) some 80–90 miles from the tip of the Grahamland peninsula, but some were observed when travelling down the west coast of Grahamland as far as 65°S. on the R.R.S. *John Biscoe*.

For most of the year the area is under the influence of the depressions which pass in a general south-west to north-east direction along the Drake Passage, but the more extreme continental weather prevails from May or June to November, when the adjacent seas freeze over. The majority of the ice crystal phenomena were observed during those months. The air temperature varies between approximately +45°F. and −30°F. in the South Shetlands, whilst the sea temperature varies by a few degrees around 30°F. Topography and the occurrence of orographic cloud favoured the observation of some phenomena and, in the case of Deception Island, the volcanic nature of the island contributed to the formation of local effects.

**Methods of observation.**—At the base a pilot balloon theodolite was available for accurate measurement of angular distances, but for quick routine use a measuring stick was made, consisting of a T-shaped piece of 2 × 2 centimetre wood, with the leg 57·3 centimetres long. The crossbar had marks made and panel pins inserted at centimetre intervals so that, when one end was held to the eye, each centimetre on the crosspiece represented one degree.




FALKLAND ISLANDS AND GRAHAMLAND.

For rough measurement in the field, the distance between the thumb and little finger of an outstretched hand was assumed to subtend an angle of 22 degrees. Angular distances were marked on an outstretched ski stick or ice axe haft in pencil, for later checking by theodolite at the base.

For photographing phenomena, a panchromatic film (Ilford F.P.3. or Pan -F in good lighting, and H.P.3. in poor light or for night photography) was used, with a 5X orange filter for solar phenomena. Polaroid spectacles of the type used to eliminate snow glare were very useful for observing bright effects.

**Rainbows, ulloa's rings (fogbows), and brocken spectre.**—In summer and early winter, when the precipitation was often wholly liquid, rainbows and secondary bows were seen.

In the winter of 1953 at Deception Island, it was possible for an observer, on the Mount Pond ridge (1,200 ft.), to stand with his back to the sun and see an enlarged shadow of himself, with a corona round the shadow of his head, thrown on a bank of orographic stratus a few hundred feet thick which often formed on the island.

During the winters of 1953 and 1954, after the sea ice had formed, banks of cloud which were classed as stratus or stratocumulus in accordance with the F.I.D.S. practice of classifying clouds by appearance, would cause the formation of fogbows centred at 180 degrees to the sun. (Previous observers on earlier expeditions have classified such clouds as "Cirrus at low heights", "Ice crystal fog", and "Ice needle fog".) These clouds appeared to be composed of a mixture of water droplets and ice crystals, the evidence for this being that in the cloud soft rime would form, and precipitated crystals would drift in the light air from the cloud bank causing haloes and fogbows to appear simultaneously. These fogbows were usually white, but on one occasion at Deception Island on a cloud bank about 200 yards away from an observer, a fogbow was visible with faint red, orange and yellow coloration, the elevation of the centre of the arch being 34 degrees.

At Admiralty Bay in August 1954, during a period of anticyclonic weather, fogbows were observed throughout the day for several days, the elevation of the centres of the arches varying between 28 and 38 degrees. The true radii of the bows would be larger than this as the theodolite was levelled at the height of the observer's eye, whereas the centre of the bow would be in line with the observer's eye and the sun, the sun being at an approximate elevation of 12 degrees at midday at that time of year.

Broadbear[1] mentions that the 38-degree radius bows observed at the Argentine Islands were presumably caused by refraction through ice crystals. If these bows were formed in cloud composed of a mixture of ice crystals and water droplets, as is possible at temperatures considerably below 32°F.[2,3] and indicated in actual cases by the formation of soft rime and the occurrence of haloes, then the bows could be caused by refraction and reflection of the light ray in the water droplets, similar to a rainbow, rather than by reflection in ice crystals. The size of the droplets and the elevation of the sun may account for the varying radii of the bows observed.

**Mirages.**—At Deception Island two types of mirage were observed, one of the inferior type and one of the superior type.

During the summer the snow-line receded to about 100 feet above sea level, exposing a coastal belt composed of black volcanic ash of a low albedo. During a calm fine day the surface would be heated by the sun, resulting in an abnormal lapse rate near the ground. Objects at the opposite side of the island could be seen shimmering and occasionally disappearing, apparently obscured by a smooth water surface. Similar mirages at Admiralty Bay were caused by air of a temperature ten or fifteen degrees below freezing overlying air warmed by the sea at a temperature of about 30 degrees. Icebergs could be seen drifting in the Bransfield Strait apparently elevated above the horizon by half a degree.

A superior mirage was observed from the Mount Pond ridge at Deception Island in midwinter, 1953. The plateau of Grahamland, 4,000–5,000 feet high and about 90 miles away, would normally in good visibility be visible quite low on the horizon. When suitable conditions prevailed the plateau would loom above the horizon and when viewed through binoculars would have an unnatural appearance due to refraction. The mirage was probably caused by cold air from the snow-covered land and growing pack ice cover being overlain with warmer air from the sea areas to the north.

Surveyors have found difficulty in using optical instruments in conditions of abnormal refraction. Sir Douglas Mawson in his report on meteorological optics on the British Antarctic Expedition of 1907–1909[4] mentions that it was impossible to make theodolite observations between 1 a.m. and 6 a.m. on the summer journey to the South Magnetic Pole, owing to extreme refraction caused by the katabatic flow of cold air from the plateau mingling with the warmer air over the sea ice.

It is of interest to note here that normally in conditions of unlimited visibility the coast of Grahamland would appear white or slightly yellowish from Deception Island, but on several occasions where air had travelled round an anticyclone from over the southern half of South America and southwards over the Drake Passage, the plateau appeared brownish through the polluted air although the visibility would still be classed as excellent for statistical purposes.

Dust would probably be collected over the dry Patagonian steppe, some 1,400 miles to the north, and industrial pollution over the northern half of Argentina, some 1,800 miles away.

**Coronae.**—Lunar coronae caused by diffraction through cloud droplets were observed on many nights because of the high frequency of occurrence of orographic cloud. The radii of the coronae varied between 2½ and 10 degrees, depending on the height of the cloud and the size of the cloud droplets. Sometimes two coronae would been seen, formed in two layers of thin cloud. Often the range of colours would be repeated. A yellowish aureole was sometimes visible round the moon although no cloud could be discerned. Some observers used the evidence of an aureole as confirming the presence of thin cirrus, but the aureole may have been formed in mother of pearl cloud. Solar coronae were occasionally observed.

**Iridescent clouds.**—Irisation of high stratocumulus, altocumulus and cirrus edges was often seen, usually within 25 to 30 degrees of the sun and less frequently within a few degrees of a full moon. The coloration was delicate, following the contours of the cloud.

A good example of iridescence over a wide area of cloud occurred at Admiralty Bay on 3 July 1954. The coloration was first observed at 1135 Zone time within 45 degrees of the sun and was of a moderate to bright red, green and light blue shade persisting till sunset. At 1430 Zone time a patch of coloration appeared opposite the sun. Measurements were made at 1500 Zone time—the coloration round the sun extended from 268 to 050 degrees (true) in an arch form between elevation 17 and 25 degrees. Opposite the sun the patch extended from 099 to 117 degrees between elevation 18 and 20 degrees. The cloud over the period was 6/8 Ci., Cs. and Cc. estimated to be at 17,000 feet with 2/8–3/8 Sc. at 1,500 feet. A nephoscope observation at 1100 Zone time gave the wind at the cirrus height as 240 degrees 20 radians per hour. The cloud was orientated in polar bands from 240 to 060 degrees. A small depression had passed in the morning, the barometer rising and cloud breaking in the rear of a cold front just before 1100 Zone time.

**Haloes, parhelic circles, arcs of contact, parhelia and paraselenae, sun and moon pillars.**—These refraction and reflection phenomena were observed in cirrostratus sheets ahead of depressions but the more spectacular types occurred in winter when ice crystals formed near the surface. Various combinations were observed, depending on the shape of the crystal and its orientation in relation to the light source.

At Deception Island in July and August 1953 brilliant haloes of 22½ degrees, arcs of contact, parhelia and crosses (sun pillar above and below the sun with part of the parhelic circle) were observed in microscopic crystals (sometimes called "diamond dust"), which appeared to be precipitated from a bank of stratus-like cloud which formed at a few hundred feet over the island. A 46-degree lunar halo was observed twice in such conditions, the halo appearing between the observer and the hillside.

On several occasions in an apparently clear sky with a light north-west air, brilliant haloes, parhelia, upper arcs of contact and sun pillars were formed by microscopic crystals which drifted from the north-west and which could only be seen when viewed against the sun, when they glittered. It is believed that in this case the crystals originated from the steam which rose from patches of open water near the shores (similar to Arctic sea-smoke). In the sunken crater of the volcano which formed the harbour at Deception Island were warm areas, which heated the water near the beaches sufficiently to remain ice free all the winter, whilst the rest of the harbour was covered in bay ice. (The steaming beaches were warmed to 90–140° F., whilst the sea water was around 28°F. and the air temperature −7°F.) The temperature difference was probably sufficient to cause the formation of microscopic crystals from the vapour.

At Admiralty Bay between 10 and 14 August, and again on 24–26 August 1954, an anticyclone was centred over the north-west of the Weddell Sea, giving pressures of 1000–1012 millibars at the base, temperatures between −15°F. and −26°F. and clear skies. Haloes and associated phenomena were of daily occurrence over this period, caused by crystals precipitated from thin banks of stratified cloud on the sea ice or on the 2,000 foot plateau.

A fine sun pillar was observed at 1125 Zone time on 25 August from the summit of Flagstaff (1,000 feet) in ice crystals which drifted from a bank of cloud on the plateau, the visibility in the crystals being reduced to 700 yards at times. An analysis of the snow crystals, using the International Snow Classification, showed them to be 60 per cent stellar crystals, 0·5 millimetres in diameter, with equal percentages of the remainder being irregular microscopic particles and small hexagonal plates, some of which were double and connected by short columns.

The photograph, Plate I, was taken at 1125 Zone time and shows part of the glittering white pillar which extended from 5 degrees above to over 46 degrees below the sun. A faint 22½ degree halo was visible. The pillar was of a brilliant whiteness and had a bright spot (possibly the lower arc of contact of the 46 degree halo) at 46 degrees below the sun. The individual crystals forming the pillar could be seen glittering and appear in the lower part of the pillar in the photograph as bright streaks. The bright spot can be seen as a circular bright area probably due to halation effects. Simultaneously at the base near sea level a fogbow, 22½ degree halo, sun pillar, partial parhelic circle and a circumzenithal arc were visible. The circumzenithal arc, which showed very pure red, orange, yellow-green and blue colours, was convex to the sun and 48 degrees above it. The ends extended from bearing 351 degrees to 059 degrees from true north.

A circumzenithal arc, formed with a bright 22½ degree halo and parhelia, was observed in crystals drifting from a bank of cloud at 1,800 feet at 1330 Zone time on 7 September 1954 at Admiralty Bay. The arc was bright and showed red, orange, green and blue coloration, being at an elevation of 45 degrees above the sun which was 20 degrees above the horizon. The arc was about a third of a circle.

Plate III shows a typical 22½ degree halo, parhelic circle, sun pillar and parhelia observed from Hope Bay, Grahamland, during the 1954 winter and photographed by Dr. W. Turner. The crystals causing the phenomenon probably drifted from the bank of low stratified cloud over the sea ice in the background.

Sun and moon pillars are often reported with beams of light above the luminary, but less frequently with the beam below. Murray[5] reported that on the British Antarctic Expedition of 1907–09, pillars were observed above the sun only. This may be due to the low elevation of the sun or to the particular type of crystal causing the reflection. Flat plates and stellar crystals were observed in 1953 and 1954 with rime-like growths on one side. If this type of crystal were falling in still air with its principal axis vertical, the reflection from the upper side would be broken up by the rime-like growths resulting in the upper pillar only being visible.

**Sunrise and sunset coloration.**—Coloration of the sky in clear conditions with unlimited visibility was observed frequently during the winter of 1954. As the sun was setting an arch appeared in the eastern sky, which grew darker as the sun lowered. The colours slate blue, purple, red, pink, orange and greenish blue were noted upwards from the eastern horizon, merging into one another. The arch grew in elevation to about 40 degrees before darkness commenced. Similar coloration was observed at sunrise in the western sky.

**Alpine glow.**—This phenomenon was observed during the 1953 and 1954 winters but the best examples were seen in latitude 65°S., from on board the R.R.S. *John Biscoe* when lying off the Argentine Islands in March 1954. The 4,000–5,000 foot plateau of Grahamland lay north to south about ten miles to the east and, long after the observer at sea level was in shadow at sunset, the glaciers and snow fields of Grahamland would be illuminated a deepening rose colour. The only cloud at the time was a small amount of high cloud from the edge of a depression far to the north.

**Conclusion.**—Standards of observing varied greatly between individuals, stations and from year to year, thus making a comparable frequency analysis of optical phenomena over the period impracticable. Descriptions of the snow crystal types were commenced at the F.I.D.S. bases in 1953 and with long-term records it may be possible to correlate optical effect with snow crystal type, cloud structure and synoptic situation.

**Acknowledgment.**—I am grateful to the Falkland Islands Dependencies Survey and Scientific Bureau for permission to publish this article and for the loan of Plates II and III.

REFERENCES

1. BROADBEAR, N. R.; Notes on observing at Argentine Islands, Grahamland in 1950 and 1951. Appendix IV to Meteorology of the Falkland Islands and Dependencies, 1944–50 by J. Pepper, London, 1954.
2. DOBSON, G. M. B.; Ice in the atmosphere. *Quart. J. R. met. Soc., London*, **75**, 1949, p. 117.
3. LUDLAM, F. H.; The forms of ice clouds. *Quart. J. R. met. Soc., London*, **74**, 1948, p.39.
4. MAWSON, D.; Meteorological optics. Appendix to "The heart of the Antarctic", by E. H. Shackleton, London, 1909.
5. MURRAY, J.; Additional notes on meteorological optics. Appendix to "The heart of the Antarctic", by E. H. Shackleton, London, 1909.

## VARIATION OF PRESSURE AT GIBRALTAR

By G. W. HURST, B.Sc.

**Introduction.**—Pressure records exist for many years at Gibraltar and analysis has been made of both seasonal changes and diurnal variation. Several interesting points emerged.

**Seasonal change in average pressure.**—There are observations for over a century until 1929 for South Bastion (50 feet), 1930–36 for Alameda Gardens (90 feet), 1937–46 for Windmill Hill Flats (400 feet) and 1947 onwards for North Front (10 feet). Examination of the older records showed that there was a marked change in corrections applied after September 1912 (in consequence of an inspection of the station, observations at which were performed by R.A.M.C. personnel). The error had been about 2 millibars and earlier records have therefore been held to be unreliable particularly as times of reading were varied at frequent intervals. The period from 1913 has however been taken as homogeneous, as all stations were within 1½ miles of South Bastion and none was higher than 400 feet above mean sea level; in fact, apart from the ten years 1937–46, the stations were within 1½ miles of each other and less than 100 feet above mean sea level. Average monthly values have been taken for the period 1913–56 (converting from inches to millibars before 1936) and a comparison has been made of these with corresponding North Front figures for the 10 years 1947–56. This is shown in Table I.

TABLE I.—AVERAGE MONTHLY AND SEASONAL PRESSURE READINGS (IN MILLIBARS) AT GIBRALTAR 1913–56

| | All stations (1913–56) | | | North Front (1947–56) | | |
|---|---|---|---|---|---|---|
| Period | Mean | Standard Deviation | 50% range of mean | Mean | Standard Deviation | 50% range of mean |
| Jan. | 1020·91 | 3·62 | 1020·54–21·28 | 1019·8 | 1·70 | 1019·4–20·2 |
| Feb. | 1019·29 | 3·70 | 1018·91–19·67 | 1018·5 | 4·49 | 1017·5–19·5 |
| Mar. | 1017·23 | 3·30 | 1016·89–17·57 | 1017·2 | 3·67 | 1016·4–18·0 |
| Apr. | 1016·03 | 2·01 | 1015·83–16·23 | 1016·6 | 2·53 | 1016·1–17·1 |
| May | 1016·10 | 1·62 | 1015·94–16·26 | 1016·0 | 1·62 | 1015·7–16·3 |
| June | 1016·78 | 1·23 | 1016·66–16·90 | 1016·8 | 1·24 | 1016·5–17·1 |
| July | 1016·29 | ·88 | 1016·20–16·38 | 1016·0 | ·77 | 1015·8–16·2 |
| Aug. | 1015·66 | 1·28 | 1015·53–15·79 | 1015·2 | ·91 | 1015·0–15·4 |
| Sept. | 1016·69 | 1·02 | 1016·59–16·79 | 1016·9 | ·81 | 1016·7–17·1 |
| Oct. | 1017·07 | 1·83 | 1016·88–17·26 | 1018·0 | 1·69 | 1017·6–18·4 |
| Nov. | 1017·82 | 2·69 | 1017·55–18·09 | 1018·9 | 2·09 | 1018·5–19·3 |
| Dec. | 1020·19 | 2·84 | 1019·90–20·48 | 1020·2 | 2·13 | 1019·7–20·7 |
| Winter | 1020·13 | 2·15 | 1019·91–20·35 | 1019·5 | 1·59 | 1019·2–19·8 |
| Spring | 1016·46 | 1·45 | 1016·31–16·61 | 1016·6 | ·87 | 1016·4–16·8 |
| Summer | 1016·25 | ·78 | 1016·17–16·33 | 1016·0 | ·50 | 1015·9–16·1 |
| Autumn | 1017·19 | ·82 | 1017·11–17·27 | 1017·9 | 1·25 | 1017·6–18·2 |
| Year | 1017·51 | ·82 | 1017·43–17·59 | 1017·51 | ·65 | 1017·4–17·6 |

Data for all stations have been taken to two places of decimals but the shorter period for North Front does not justify this. Average figures for both sets are shown in Figure 1, together with lines indicating values which will contain 90 per cent of the mean monthly pressures. It is immediately evident that the mean North Front values in nearly all cases fall within the 90 per cent range, and only in October is the North Front average appreciably different from that over the longer period. The difference is still such however as to suggest no significant departure for the month. It is clear therefore that North Front is fairly representative of the Rock as a whole, though it does happen that pressure in autumn 1947–56 was rather above average and that in winter correspondingly rather below.

Three points stand out from Figure 1: the considerably higher average pressure in winter than summer, the much greater variability of average monthly pressure in winter and the secondary maximum pressure in June. Average pressure would be expected to be lower in summer, as a feature of the Gibraltar summer is the slack pressure gradient in the area: more or less col conditions, with low pressure over the heated land masses of Iberia to the north and Morocco and the Sahara to the south. No depressions as such are effective in this part of the year and variation of pressure is therefore restricted. In winter, there is little or no thermal heating effect and pressure tends to build up slightly

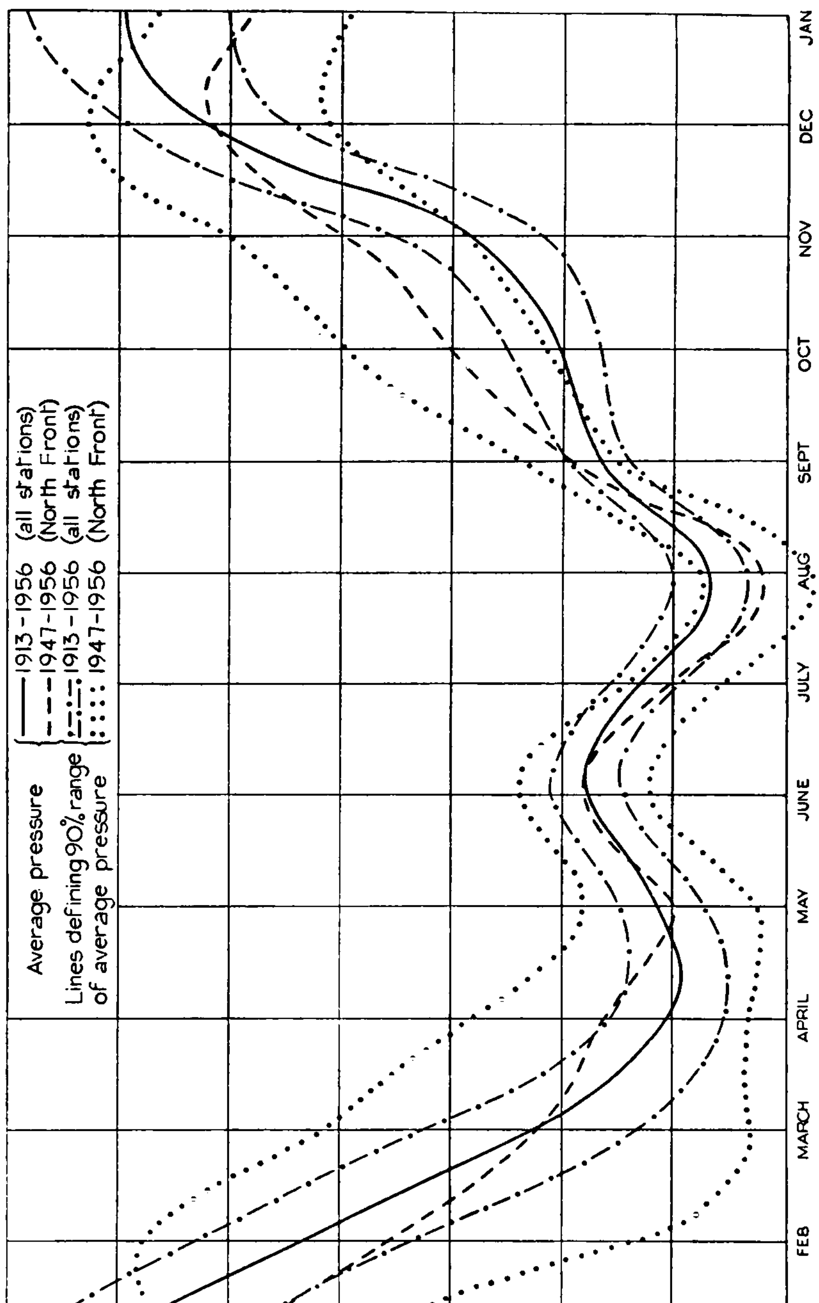



FIGURE I—ANNUAL VARIATION OF PRESSURE AT GIBRALTAR

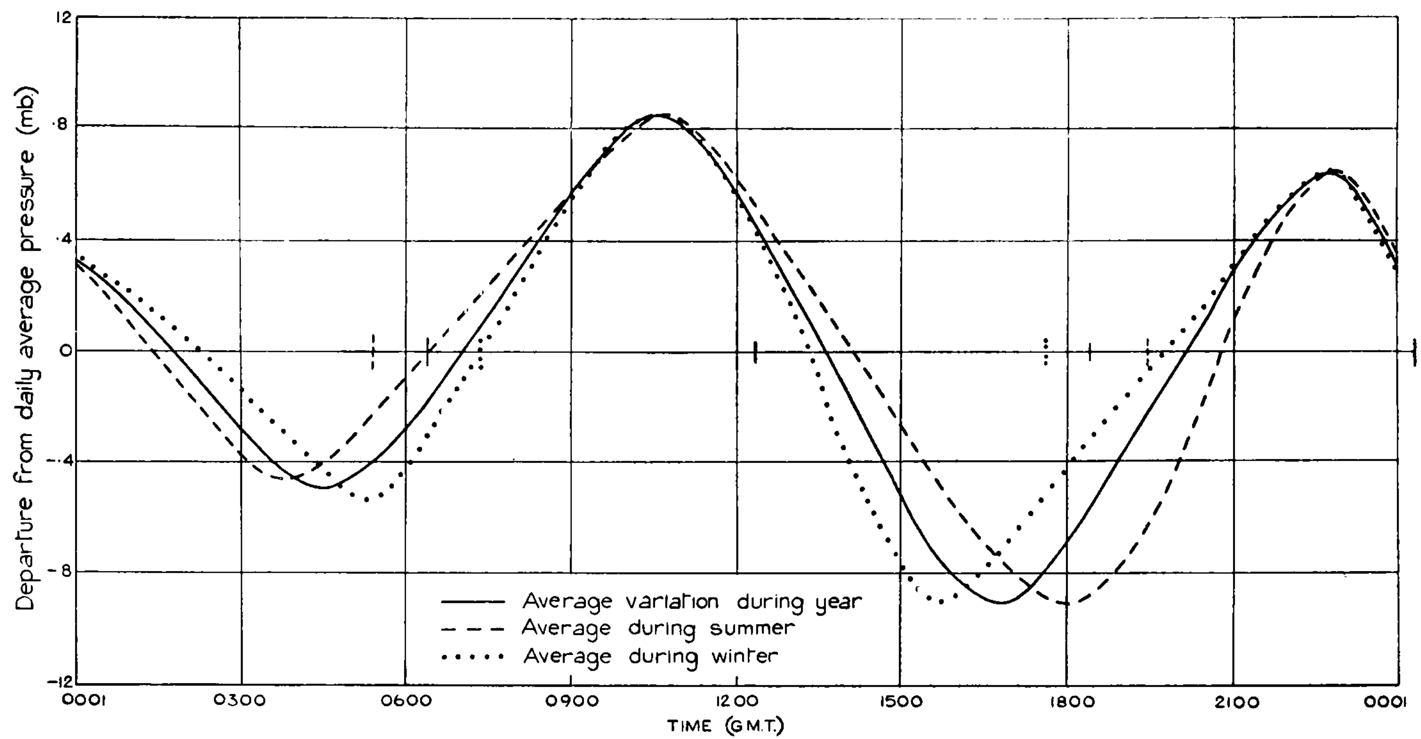



FIGURE 2—DIURNAL VARIATION OF PRESSURE AT GIBRALTAR (NORTH FRONT) 1952–56.

Local times of sunrise, sunset, midday and midnight are shown.

to the north or more frequently to the south. Occasional active depressions move across the Straits (usually from west to east) so that variation in pressure must be far higher. The secondary maximum in June is rather interesting. This is the time of the start of the levanter season at Gibraltar, with really high temperatures occurring in the north Africa area. This is not thought to be the main factor in this change, however. Gibraltar, at 36°N. 5°W., lies in the subtropical summer high pressure zone and with no interference due to the land heating effects discussed, the average pressure would show a maximum in summer. Pressures for two typical Azores stations[1] from March to September are given in Table II.

TABLE II.—AVERAGE PRESSURE (IN MILLIBARS) AT AZORES STATIONS DURING SUMMER HALF OF YEAR

| Station | March | April | May | June | July | August | September |
|---|---|---|---|---|---|---|---|
| Horta (25 year period) | 1021 | 1021 | 1021 | 1024 | 1025 | 1023 | 1022 |
| Ponta Delgada (45 year period) | 1020 | 1021 | 1021 | 1023 | 1024 | 1023 | 1021 |

The subtropical high obviously gains in intensity between May and June and, taking this as a common tendency for the latitude, the increase of pressure in June is readily explained, as the increase due to the anticyclonic build-up is rather greater than the seasonal fall due to continental heating. The fall of pressure at Gibraltar is continued in July and August, when the anticyclone is no longer intensifying appreciably. This effect of a secondary summer maximum is reflected in other stations in south-west Spain and north-west Africa in similar latitudes. It is interesting to note that pressure in summer at Gibraltar is almost 10 millibars lower than over ocean areas at the same latitudes.

**Seasonal changes—extreme values.**—Monthly and seasonal data have been examined for variation in extreme pressures during the period 1947–56 for North Front. Analysis of seasonal and annual values is given in Table III.

TABLE III.—EXTREME SEASONAL PRESSURES (IN MILLIBARS) AT NORTH FRONT 1947–56

| Period | Average | Standard Deviation | Extreme Recorded | Values expected to be exceeded once in 10 years | Values expected to be exceeded once in 100 years |
|---|---|---|---|---|---|
| | | (a) Highest values | | | |
| Winter | 1033·3 | 2·41 | 1037·4 | 1036·4 | 1038·9 |
| Spring | 1029·3 | 3·67 | 1036·0 | 1034·0 | 1037·8 |
| Summer | 1023·2 | ·85 | 1024·9 | 1024·3 | 1025·2 |
| Autumn | 1028·2 | 2·42 | 1032·6 | 1031·3 | 1033·8 |
| Year | 1033·7 | 2·43 | 1037·4 | 1036·8 | 1039·4 |
| | | (b) Lowest values | | | |
| Winter | 996·8 | 3·84 | 990·6 | 992·8 | 987·9 |
| Spring | 1002·1 | 3·73 | 993·3 | 996·3 | 993·4 |
| Summer | 1008·7 | 2·06 | 1003·9 | 1006·1 | 1003·9 |
| Autumn | 1003·1 | 7·17 | 986·4 | 993·9 | 986·4 |
| Year | 995·5 | 4·27 | 986·4 | 990·0 | 985·6 |

The range of possible pressure extremes is naturally far higher in winter than in summer: the range for a typical winter is 36·5 millibars and in summer 14·5 millibars; extremes over 10 years would differ by at least 47·3 and 19·3 millibars respectively. The only slight anomalies in Table III are the high values of the standard deviation for the autumn minimum, due to an exceptionally low pressure recorded on 30 November 1947 and the lowness of the absolute minima for all seasons except winter. Most of the anomalously low values arising in spring and autumn occur as isolated values within a few days of the winter season; those of summer occur mostly at the begining and end.

Considering the settled season as the conventional summer, but omitting unduly high or low readings in the first four days of June and the last four of August, readings corresponding to entries in Table III would be:

*Settled season.*

(a) Highest values.
Average 1023·0 millibars, standard deviation 0·76 millibars.
Highest recorded 1024·1 millibars.
Value expected to be exceeded once in 10 years 1024·0 millibars.
Value expected to be exceeded once in 100 years 1024·8 millibars.

(b) Lowest values.
Average 1009·7 millibars, standard deviation 1·31 millibars.
Lowest recorded 1007·8 millibars.
Value expected to be exceeded once in 10 years 1008·0 millibars.
Value expected to be exceeded once in 100 years 1006·7 millibars.

The unsettled season consists of the conventional winter together with about half November and March, and includes all extremes in the 10 years 1947–56 except 994·9 millibars on 10 November 1951 (1·6 millibars lower than the February reading) and 1035·0 millibars on 5 April 1947 (2·4 millibars higher than the December pressure).

It is therefore seen that in high summer pressure values outside the range 1006/1025 occur only about once a century, whereas in winter limits are 985/1039, giving a range in the settled season of 19 millibars and in the unsettled 54 millibars. Agreement is fairly close with data for South Bastion and Windmill Hill,[1] where the actual summer range over the 17 year period 1922–38 was 1006/1026 and that of winter 990/1038. The rather higher summer value of 1026 millibars (1025·7 millibars on 10 June 1923) appeared very exceptional as no other reading in the period exceeded 1024·1 millibars. Most of the higher pressure readings occur during surface easterlies, with ridge conditions over southern Spain.

**Diurnal variation of pressure.**—Diurnal variation can be observed on barograms throughout the year with ease, even at 36°N., and is the main feature in summer. Data for North Front were extracted on a three-hourly basis for the period 1952–56, backed by hourly data for two typical months in summer and winter. Data were also extracted for the period 1947–52 for minor synoptic hours only (a period when tabulated data for the other hours were not readily available), and also for similar hours for Windmill Hill observations (reduced to sea level); both confirmed that there was no important error in considering the shorter period only as representative. The diurnal variation from the average pressure is shown in Figure 2 for the seasons winter and summer and for the year as a whole. Also are marked local times of sunrise and set, and midday and midnight.

The maxima occur rather under two hours before midday and midnight (local time), but an interesting feature is that there is virtually no variation throughout the year in amplitude, which is +·85 at 1015 and +·65 at 2220 local time. This compares, for example, with a morning maximum variation between ·60 millibars in summer and 1·05 millibars in winter at the Cape of Good Hope (almost symmetrically placed to Gibraltar in the southern hemisphere at 34°S. 18°E.) and almost one millibar difference at Calcutta at 22°N. The average morning maximum at Good Hope of ·83 millibars is almost identical with Gibraltar. The evening maximum pressure is only ·50 millibars at Good Hope and the average summer maximum at this time is ·30 millibars higher than that in winter. (Data from Shaw.[2])

Minima at Gibraltar are more or less typical, with the greater in the evening, —·90 millibars through the year. There is a slight yearly difference in the morning minimum (average —·52 millibars), though much less than at Good Hope. The average annual diurnal range is 1·75 millibars compared with 1·55 millibars at Good Hope, and the mean amplitudes are ·73 and ·67 millibars respectively. This amplitude of ·73 millibars is rather higher than the figure of ·66 millibars which would be expected for the latitude (Simpson[3]). A final point is that the winter minima occur about 2 hours before sunrise and set, but the period is only about $1\frac{1}{2}$ hours in summer; the average over the year is about $1\frac{3}{4}$ hours.

A natural deduction from the three hourly departures from normal is an assessment of the contributions to the tendency at the various synoptic hours. These are shown in Table IV.

TABLE IV.—MEAN CONTRIBUTION OF DIURNAL VARIATION TO BAROMETRIC TENDENCIES (IN MILLIBARS) AT GIBRALTAR

Time G.M.T.

| Period | 00–03 | 03–06 | 06–09 | 09–12 | 12–15 | 15–18 | 18–21 | 21–00 |
|---|---|---|---|---|---|---|---|---|
| Winter | —·4 | —·3 | +1·0 | | —1·3 | +·3 | + ·7 | |
| Spring | —·8 | | + ·8 | | —1·0 | —·2 | +1·1 | |
| Summer | —·7 | +·3 | + ·7 | +·1 | — ·9 | —·6 | +1·0 | +·2 |
| Autumn | —·6 | | +1·1 | —·2 | —1·2 | +·1 | + ·9 | —·1 |

The effect of diurnal variation is almost negligible for charts at the major synoptic hours, except possibly in summer at 1800 G.M.T. with an average value of —·6 millibars (as high as —·7 millibars in July); at no other time or season is it greater than ·3 millibars. Characteristics tend to be of the rising then falling type at 0001 and 1200 G.M.T., and vice versa at 0600 and 1800 G.M.T. Diurnal variation contribution to intermediate tendencies, however, is mainly of the order of a millibar except at 0300 G.M.T., when the range is —·4 to —·8 millibars. Table IV can be used with little error for any low level coastal station in the vicinity (for example Port Lyautey, Tangier, etc.), but tendencies resulting from diurnal changes inland over heated Spain and Morocco are of course much more irregular and variable and, in particular, values well over a millibar can occur inland during the period 0900/1800 G.M.T.

## REFERENCES

1. London, Meteorological Office; Weather in home waters and the north-eastern Atlantic. Vol. II, Part 1, The Atlantic from the Azores to the African coast with an appendix on Gibraltar, London, 2nd edition, 1944, pp. 148, 150, 230.
2. SHAW, SIR NAPIER; Manual of Meteorology. Vol. II. London, 1928, pp. 224–229.
3. SIMPSON, SIR GEORGE; The twelve-hourly barometer oscillation. *Quart. J. R. met. Soc., London,* **44**, 1918, p.9.

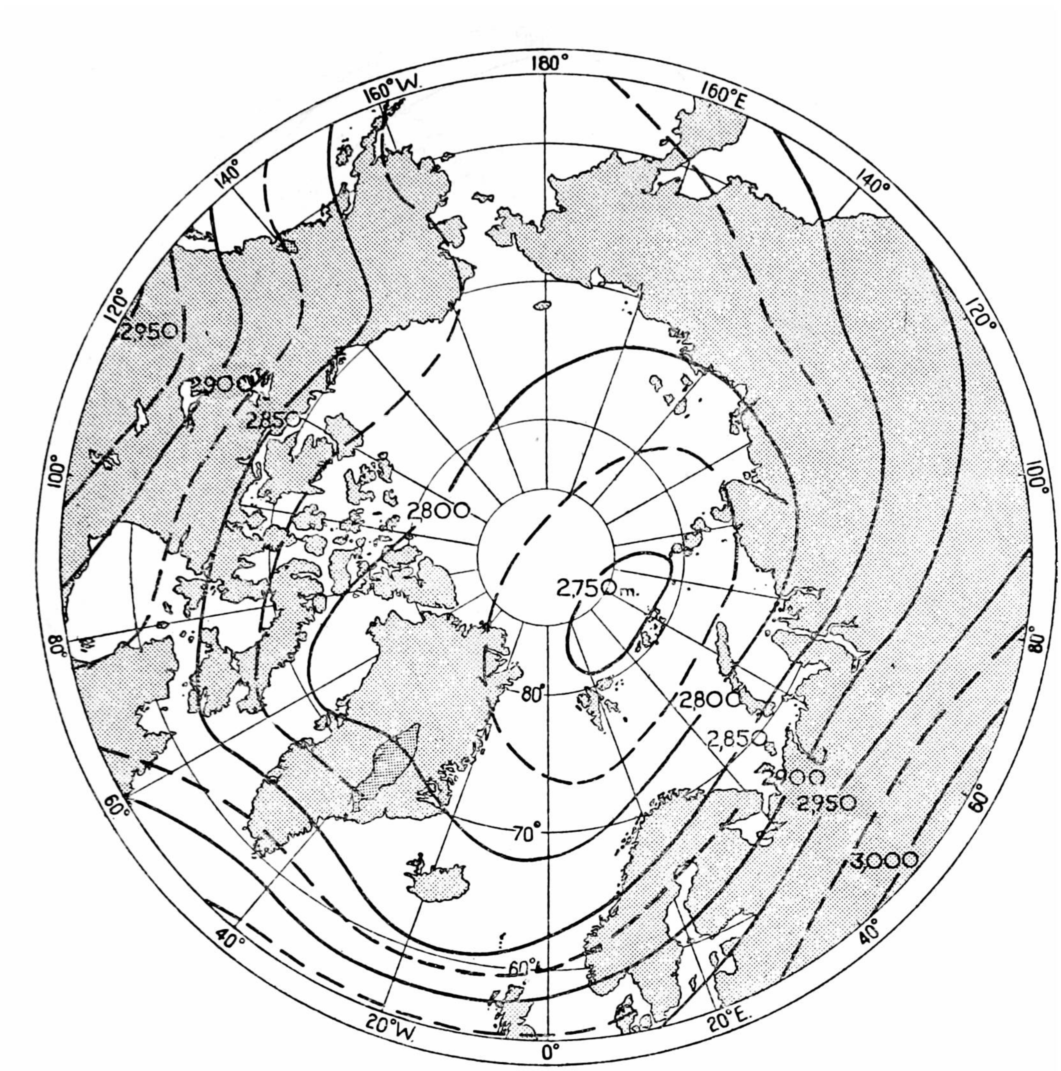



FIGURE I—AVERAGE 700-MB. CONTOURS FOR APRIL 1949–53

# AVERAGE HEIGHT OF THE STANDARD ISOBARIC SURFACES OVER THE NORTH POLAR REGIONS IN APRIL AND OCTOBER

By H. HEASTIE, M.Sc.

**Introduction.**—The revision of *Geophysical Memoirs No.* 85—*Upper winds over the world*—has been started by constructing circumpolar charts of the height of the standard isobaric surfaces, as explained in a previous article.[1] In that article some of the charts for January were shown and a further article[2] showed some of the corresponding charts for July. This part of the revision of the memoir has been completed by the construction of circumpolar charts for April and October[3] and this article presents, with a brief description, some of these charts.

**Data.**—Data for the same period, 1949–53, were used; sources are listed elsewhere.[4]

**Method of constructing the charts.**—The method used was similar to that described previously.[1] Again the data from Siberia were very sparse

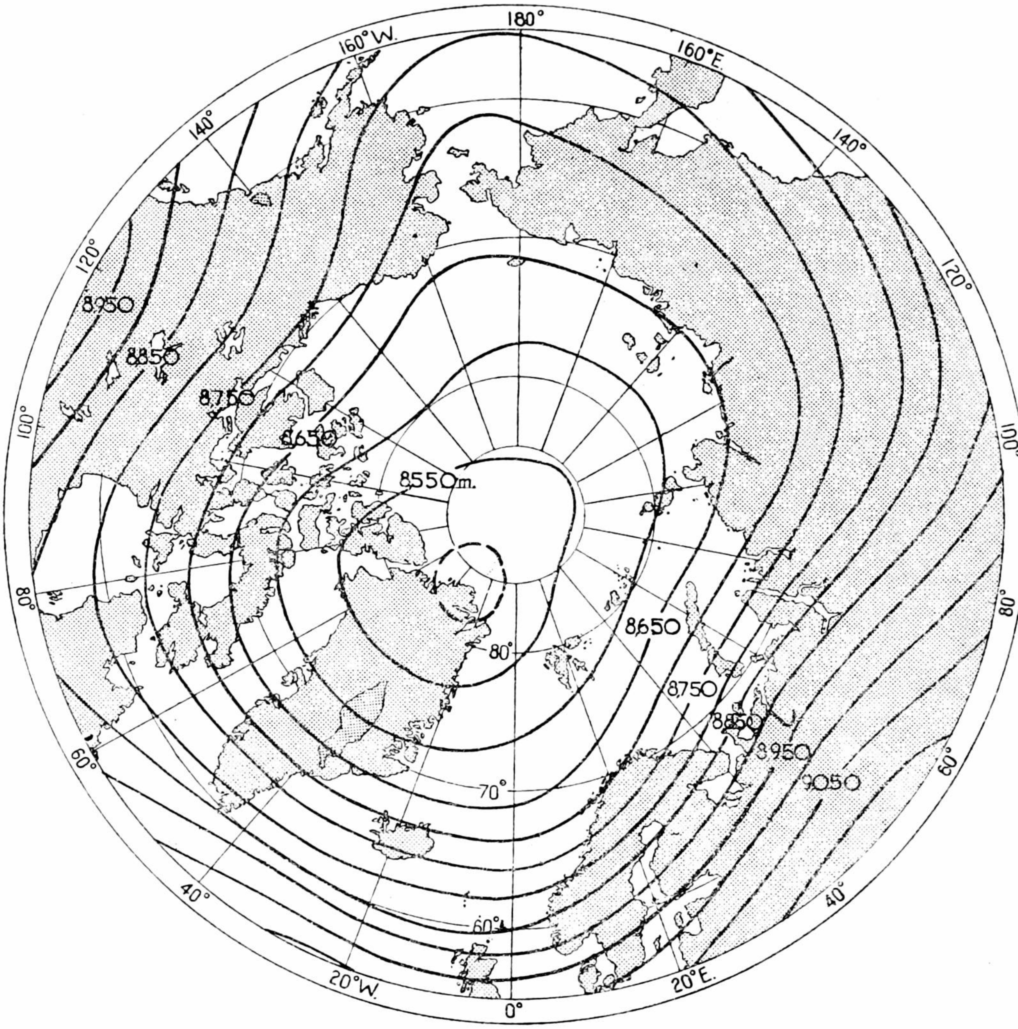



FIGURE 2—AVERAGE 300-MB. CONTOURS FOR APRIL 1949–53

both in April and October and the charts were drawn up to the 300-millibar level by means of the correlation method described in an earlier article.[2]

It was not possible to use data from night-time ascents only and the effect of solar radiation could not be eliminated entirely. 0300 G.M.T. data were used generally, but 1500 G.M.T. data were available from the Aleutian and Alaskan stations and were used when the 0300 G.M.T. ascents were made in daylight. At 0300 G.M.T., daylight covers most of the U.S.S.R. in April and all of Siberia in October, and no Russian data for 1500 G.M.T. were available. Guterman[5] discusses the radiation correction of the comb radiosonde used in the U.S.S.R. and suggests that for solar elevations below 15° the error is negligible. For solar elevations of 50°–60° he quotes figures which would imply errors of 3–4 metres in the 500–300-millibar thickness and 30–35 metres in the 300–100-millibar thickness. However, no Russian data above 300 millibars were available and use was made of the temperature lapses from a memoir on upper air temperature.[6] In the preparation of this memoir data at both 0300 G.M.T. and 1500 G.M.T. were used

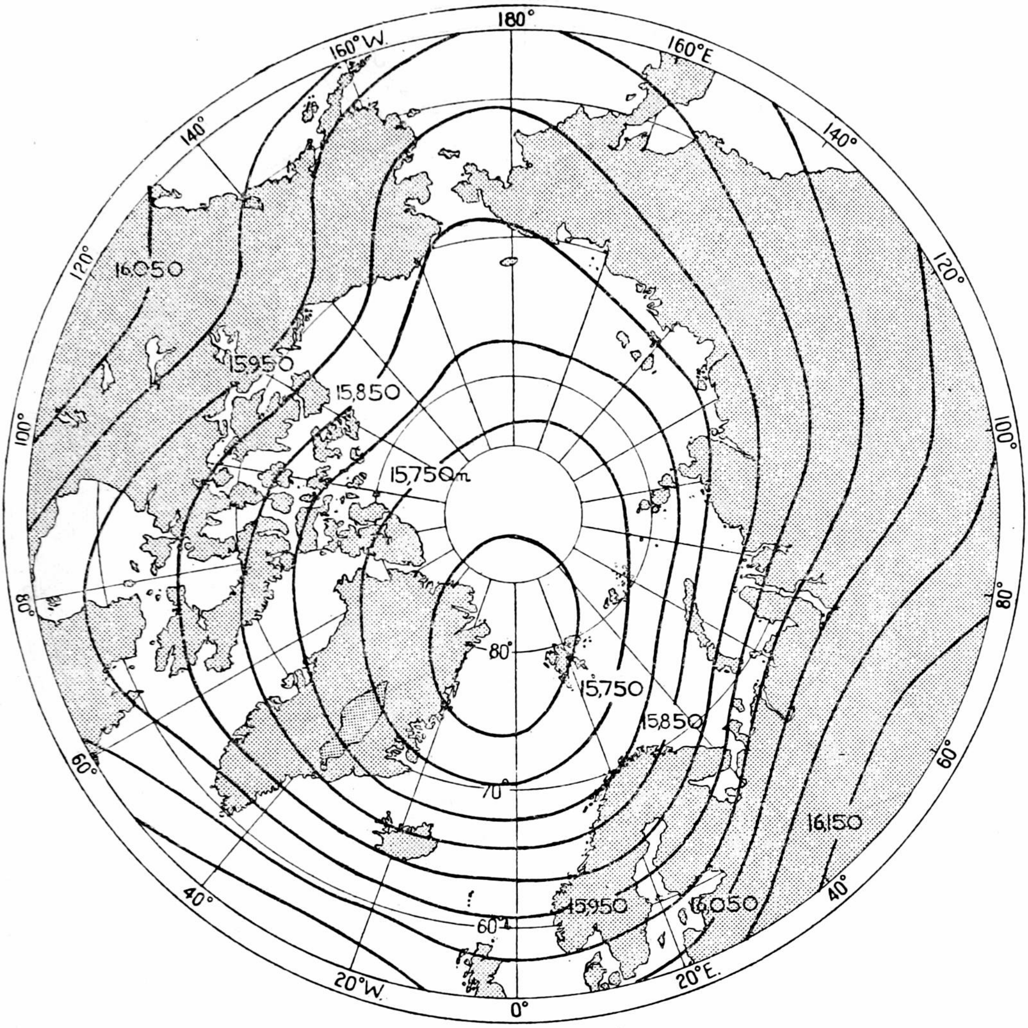



FIGURE 3—AVERAGE 100-MB. CONTOURS FOR APRIL 1949–53

and, it is reasonable to suppose, any error due to radiation halved in consequence. Further, the maximum elevation of the sun for the area and period considered is 10° or more below that to which the radiation corrections quoted are applicable. It was assumed, therefore, that the maximum error due to radiation was less than 20 metres at 100 millibars. As, however, the variation of radiation correction with solar elevation was unknown, no attempt was made to assess the actual error.

**The charts.**—The April charts show two interesting differences from those for the other mid-season months. The first concerns the centre of the main circulation. In January, July and October, at all levels above 700 millibars, this centre lies between 75° and 90°W. and 67° and 87°N. i.e. within a relatively narrow sector of northern Canada and the Canadian Arctic. In April, at 700 millibars (Figure 1), it lies to the north of Franz Josef Land at 84°N., 50°E. At 300 millibars (Figure 2) it lies to the north of Greenland (84°N., 35°W.) and, at 100 millibars (Figure 3) between Greenland and Spitsbergen (82°N., 10°W.). It is possible to attribute the centre at 700 millibars to the persistence of a

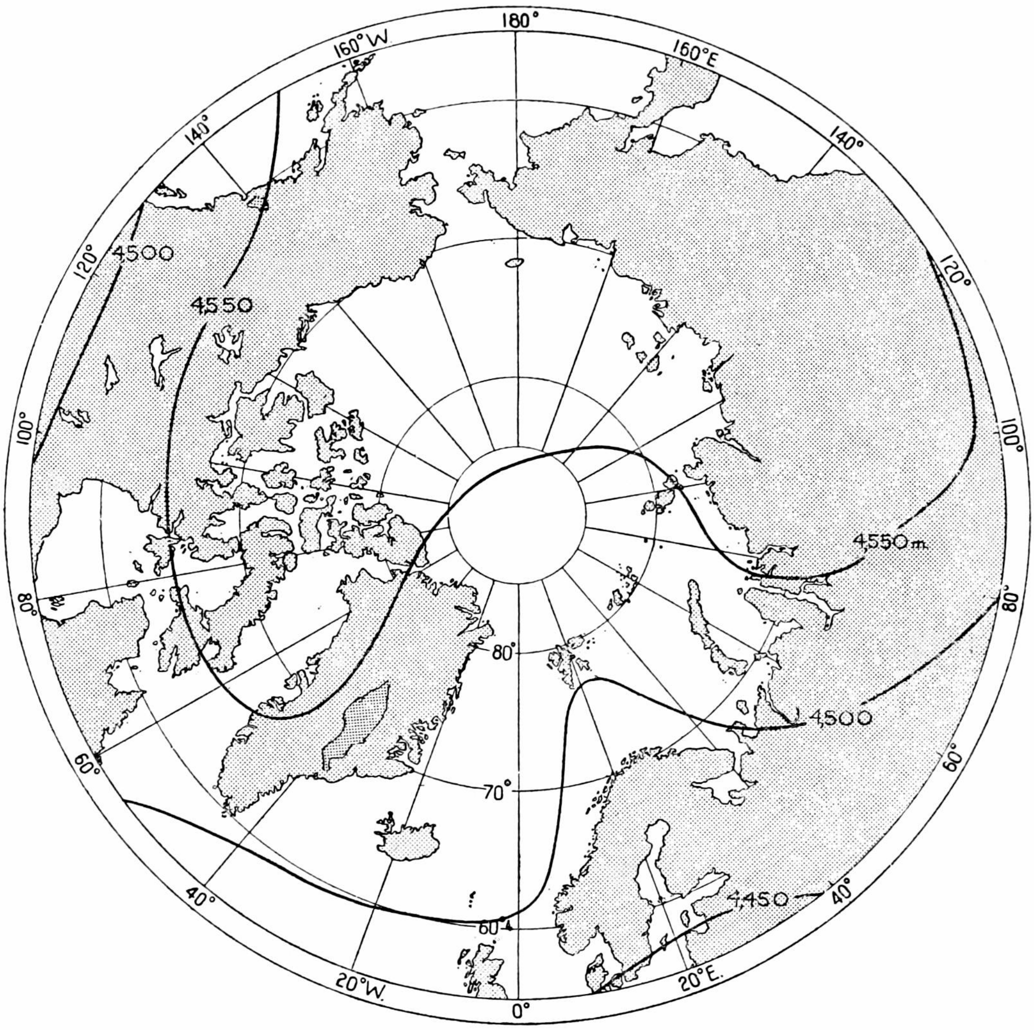



FIGURE 4—AVERAGE 200–100-MB. THICKNESS FOR APRIL 1949–53

secondary centre at about 80°N., 70°E. on the 700 millibar chart for January.[4] Changes from a winter to a summer régime take place very rapidly in the spring and not necessarily at the same time in different regions of the chart (though detailed evidence from the Russian Arctic is lacking) and it is doubtful whether the April or any other monthly chart represents a true "mid-season" circulation pattern. The second peculiarity of the April charts is a departure from the normal association between features of the tropopause pressure and stratospheric thickness patterns shown generally on the charts for the other three months. This occurs at about 20°E. where the tropopause pressure chart[6] shows a marked ridge which is almost immediately below troughs in the thickness charts 300–200 millibars and 200–100 millibars (Figure 4) i.e. relatively low stratospheric temperature above a relatively low tropopause. These thickness patterns are consistent with the patterns shown on the relevant average temperature charts.[6] In this area fairly adequate data were available and this peculiarity is believed to be real.

Both the April and October charts show a westerly circulation at all levels with main troughs at 60–80°W., and 160–180°N., though there appears to be a

[*To face p.* 304

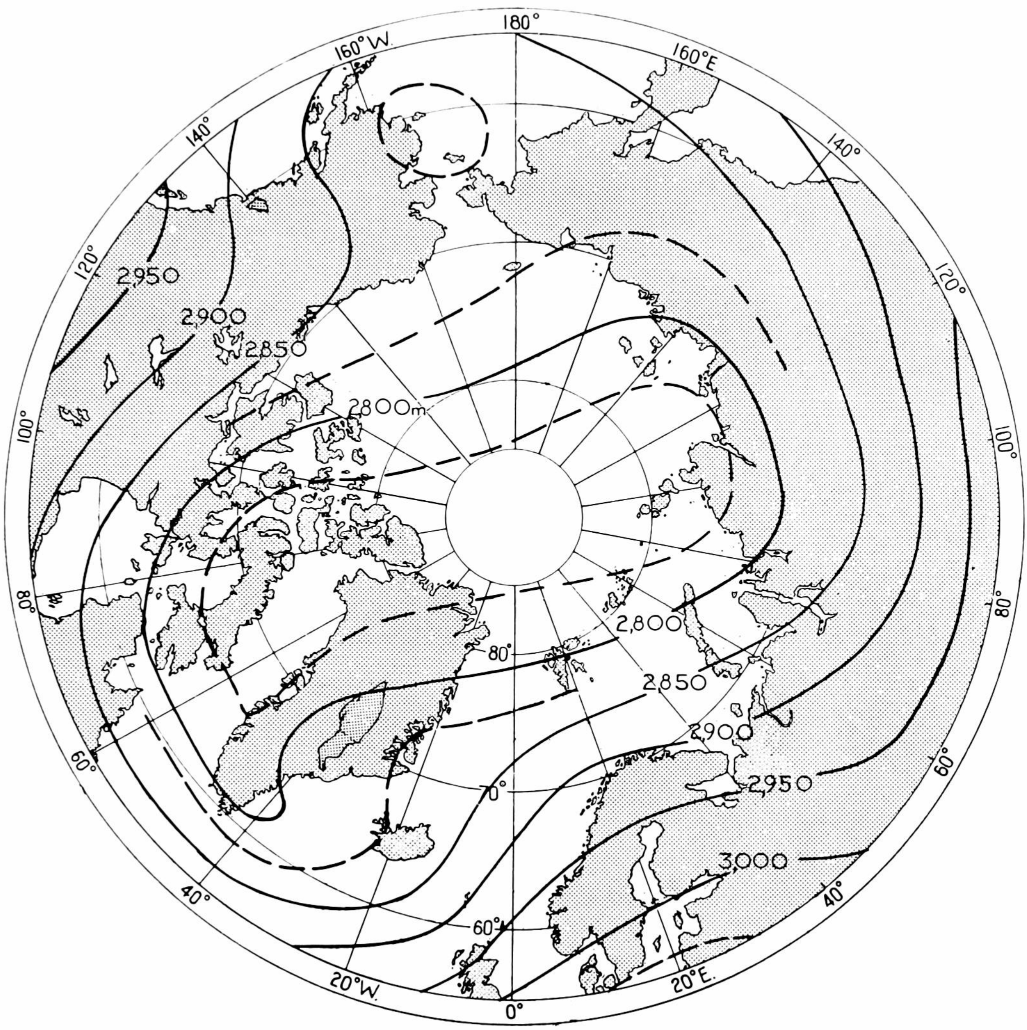



FIGURE 5—AVERAGE 700-MB. CONTOURS FOR OCTOBER 1949-53

*Falkland Islands Dependencies Survey* *Photograph by D. J. George*

PLATE I—SUN PILLAR AT ADMIRALTY BAY, ANTARCTICA, ON 25 AUGUST 1954

(see p. 293)

*Falkland Islands Dependencies Survey* *Photograph by G. Brookfield*

PLATE II—PARHELIA AT HOPE BAY, GRAHAMLAND, 1954

(see p. 293)

To face p. 305]

Falkland Islands Dependencies Survey

Photograph by Dr. W. Turner

PLATE III—PARTIAL $22\frac{1}{2}$ DEGREE HALO, PARHELIA AND CROSS AT HOPE BAY, GRAHAMLAND, 1954

(see p. 293)

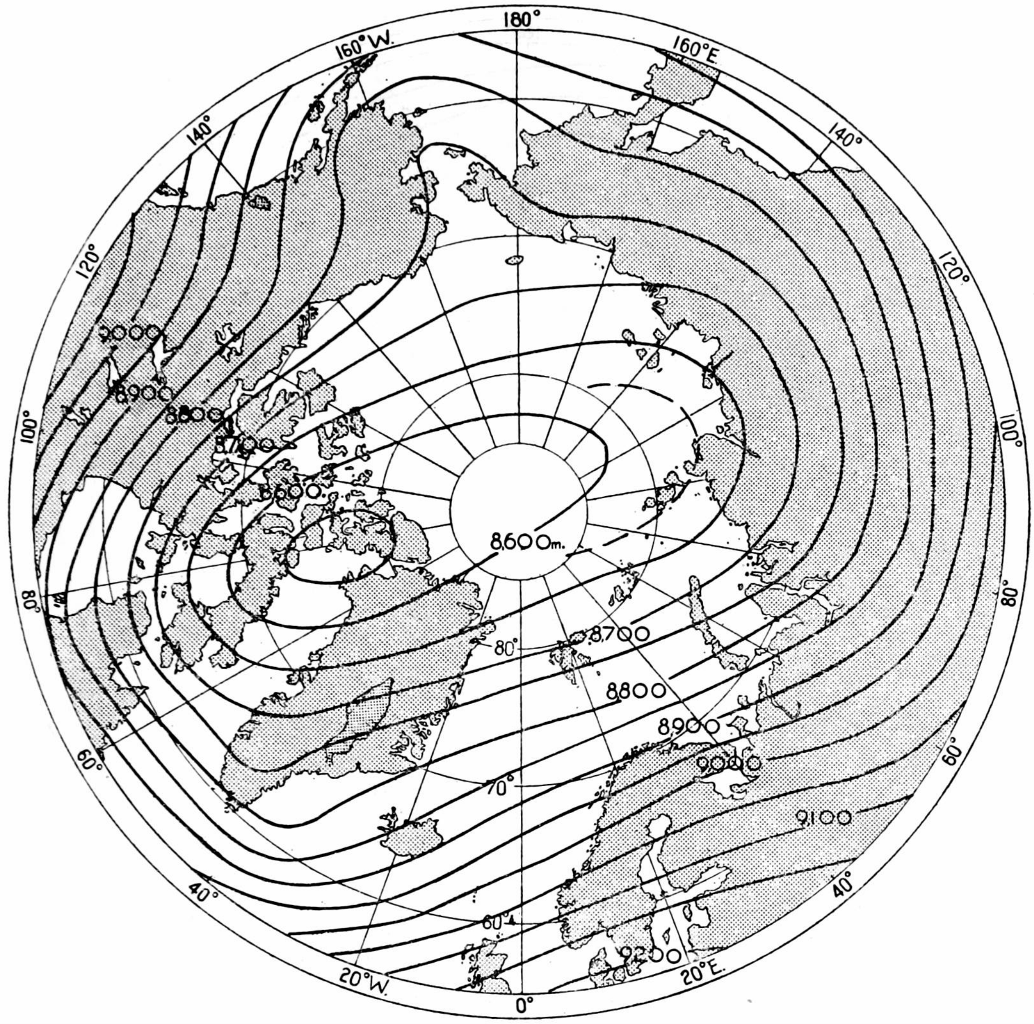



FIGURE 6—AVERAGE 300-MB. CONTOURS FOR OCTOBER 1949–53

weak secondary circulation at 700 millibars in the Bering Sea in October (Figure 5). The main centre of the circulation lies between Franz Josef Land and north-east Greenland in April (Figures 1, 2, 3) and over Ellesmere Island in October (Figures 5, 6, 7). The April charts show a further main trough about 0°W. and a rather indeterminate trough over Siberia, while in October there are troughs between Iceland and Greenland and over western Siberia.

The stratospheric thickness charts for both months are extremely flat and the pattern rather nondescript. This might be expected from the corresponding charts for January and July. In January the 200–150-millibar and the 150–100-millibar thickness charts[4] both show a mainly cyclonic circulation centred near the pole while in July the 200–100-millibar thickness chart[2] shows an anticyclonic circulation centred on the pole. For the two shown here (Figures 4, 8) the corresponding thermal wind is everywhere less than 10 knots and in large areas less than 5 knots. Relatively high values of thickness are shown over Siberia and northern Canada corresponding to the two main centres of low tropopause.[6] In April the thickness values are, on average, some 50 metres greater than in

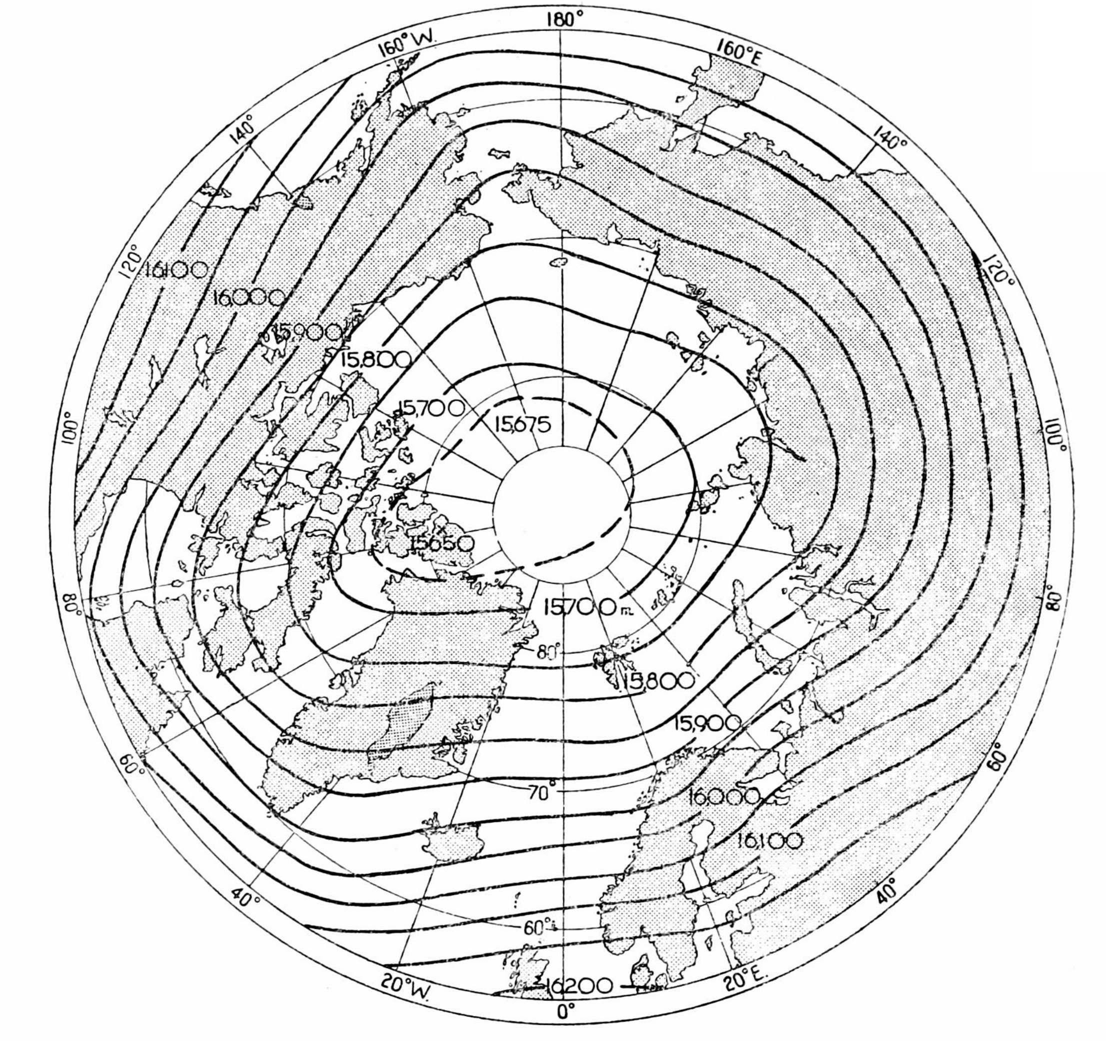



FIGURE 7—AVERAGE 100-MB. CONTOURS FOR OCTOBER 1949–53

October. This implies that the layer 200–100 millibars in the stratosphere is approximately 2·5°C. warmer in April than in October and is in good agreement with the tropopause pressure charts,[6] which show the pressure at the tropopause to be, on average, about 20 millibars higher in April than in October. In the central North Atlantic the thickness and the tropopause pressure are approximately the same in both months.

REFERENCES

1. HEASTIE, H.; Average height of the standard isobaric surfaces over the North Polar regions in January. *Met. Mag., London,* **85,** 1956, p. 368.
2. HEASTIE, H.; Average height of the standard isobaric surfaces over the North Polar regions in July. *Met. Mag., London,* **86,** 1957, p. 198.
3. HEASTIE, H.; Average height of the standard isobaric surfaces over the area from the North Pole to 55°N. in April and October. *Met. Res. Pap., London,* No. 1020, 1956.
4. HEASTIE, H.; Average height of the standard isobaric surfaces over the area from the North Pole to 55°N. in January. *Met. Res. Pap., London,* No. 918, 1955.
5. GUTERMAN, I. G.; Radiation error of the comb radiosonde. *Met. Hydr., Leningrad,* No. 5, 1955, p. 49.
6. GOLDIE, N., MOORE, J. G., and AUSTIN, E. E.; Upper air temperature over the world. *Geophys. Mem., London,* No. 101, 1958.

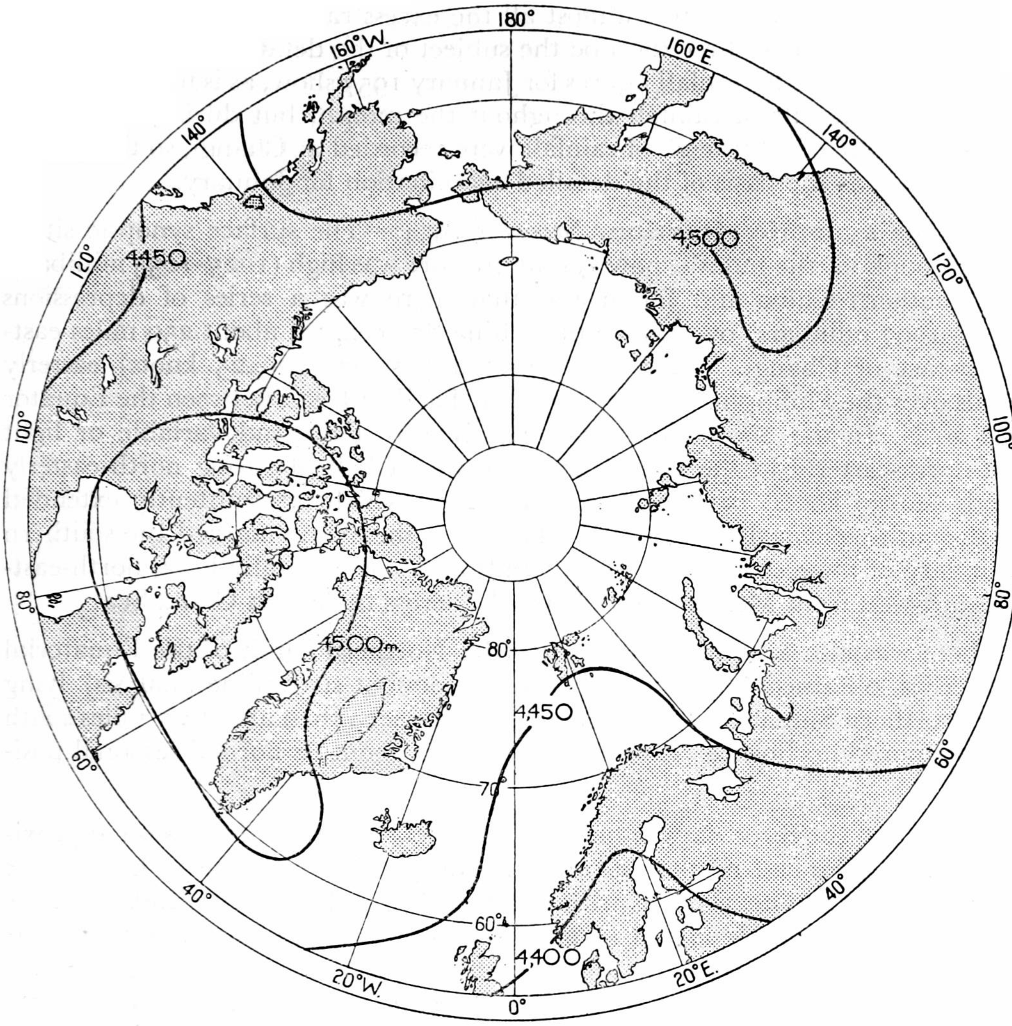



FIGURE 8—AVERAGE 200–100-MB. THICKNESS FOR OCTOBER 1949–53

## COMPARISON OF MONTHS GIVING EXTREMES OF RAINFALL DURING NORTH-EAST MONSOON AT CHANGI, SINGAPORE ISLAND

By K. BRYANT

December 1954 was an extremely wet month at Changi[1], Singapore Island, the recorded rainfall of 35·91 inches being three and a half times the 54-year mean for December (10·22 inches). January 1957 on the other hand was very dry, the recorded rainfall at Changi being 1·93 inches, approximately one fifth of the 54-year January mean (10·61 inches).

Singapore is covered by the North-east Monsoon in December and January, and it was thought that examination and comparison of these two very different months in the same monsoonal flow might indicate the synoptic situations associated with such extremes of rainfall in this area.

A review of the daily rainfall figures for December 1954 shows that there were three extremely wet days namely the 9th (12·66 inches), the 13th (3·85 inches) and the 16th (6·69 inches) and that these three days accounted for two thirds of the month's rainfall (this was almost all the excess rainfall). It was considered reasonable that these three days be the subject of the detailed examination for December. The daily rainfall figures for January 1957 show, as is to be expected, only small amounts of rainfall throughout the month, but during the period 19th–28th only odd "traces" of rainfall were recorded at Changi, so this period was selected as the basis of the detailed examination for January.

**Surface synoptic situation.** *December* 1954.—The surface synoptic situation throughout the month showed that pressure was high (1025–1035 millibars) over southern China and Japan and that there was a series of depressions (1006–1007 millibars) over the South China Sea centred about 250 miles east-north-east of Changi. There were unusually strong (20–25 knots) easterly winds over the Philippines and the western Pacific Ocean between the Equator and 20°N. In the South China Sea winds were light and variable or light east-north-easterly in the south but there was a belt of strong north-easterly winds (20–30 knots) between 5°N. and 12°N. which intermittently extended south-south-westwards to southern Malaya. A shear line marked the southern boundary of these strong north-east winds and was generally lying north-east-to south-west from Mersing to 8°N. 110°E. across the South China Sea.

There was also a convergence zone (the Northern Limit of the Equatorial Westerlies, obtained from the 1,000 and 3,000-foot streamline analysis) lying from northern Sumatra along the Straits of Malacca then about 25 miles south of Singapore into Borneo (see Figure 1): this is about its normal seasonal position.

On each of the three days in question it appears that the depression approximately 250 miles east-north-east of Changi deepened during the 12 hours prior to the moderate to heavy rains with the stronger north-easterly winds from the north of the South China Sea surging south-south-westwards. The shear line became more intense and moved southwards merging with the convergence zone at a "triple point" (described as the meeting point of two or more convergence zones) shown at A in Figure 1. The depression then filled slowly and appeared to move away north-eastwards, the shear line becoming weaker and withdrawing northwards. There was an extensive surface trough from central Australia across Java to Burma containing several small depressions.

Throughout the remainder of the month there was either a shear line or convergence zone (obtained from the 1,000 and 3,000-foot streamline analysis) within 50 miles of Singapore and minor fluctuations in these features gave nearly the normal rainfall for the remainder of the month. The mean pressure for December 1954 at Changi was 0·5–1·0 millibars below the 9-year mean for Changi at all hours, but this is within the standard deviation of 1·6 millibars.

*January* 1957.—During the period 19–28 January 1957 there was no shear line or convergence zone (obtained from the 1,000 and 3,000-foot streamline analysis) within 90 miles of Singapore Island on any of the days. The pressure distribution over Malaya and the South China Sea was flat with a tendency towards slight ridging from the north. A depression near the Cocos Islands on the 19th gradually deepened to become a tropical storm (990 millibars) centred at 11°S. 96°E. by the 28th (see Figure 3). The mean pressure for January 1957 at Changi was within 0·1 millibars of the 9-year Changi mean at all hours.

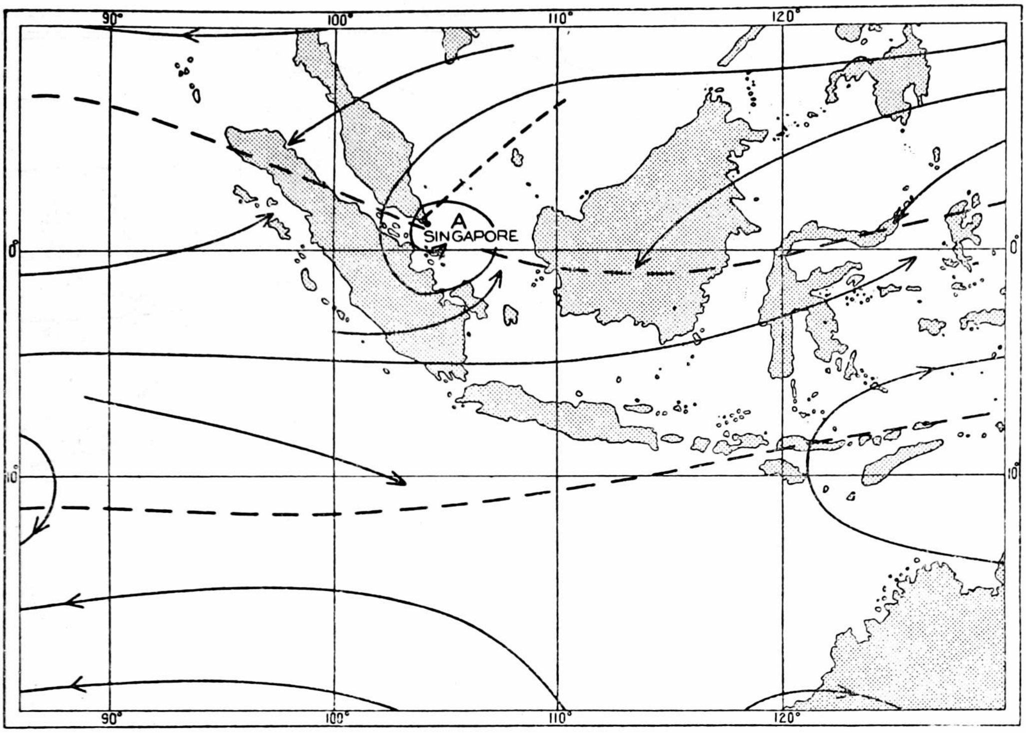



FIGURE 1—3,000-FOOT STREAMLINES FOR 1200 G.M.T., 9 DECEMBER 1954

— — — Northern and Southern Limit of the Equatorial Westerlies

- - - - - - Shear line

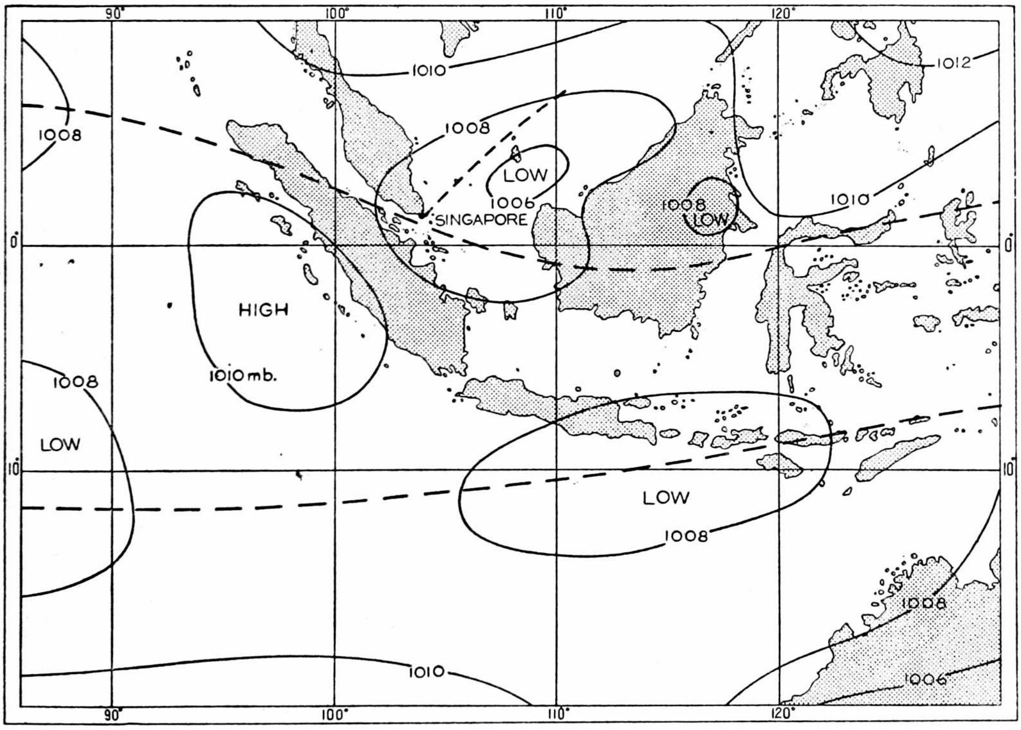



FIGURE 2—MEAN SEA LEVEL PRESSURE FOR 1200 G.M.T., 9 DECEMBER 1954

— — — Northern and Southern Limit of the Equatorial Westerlies

- - - - - - Shear line

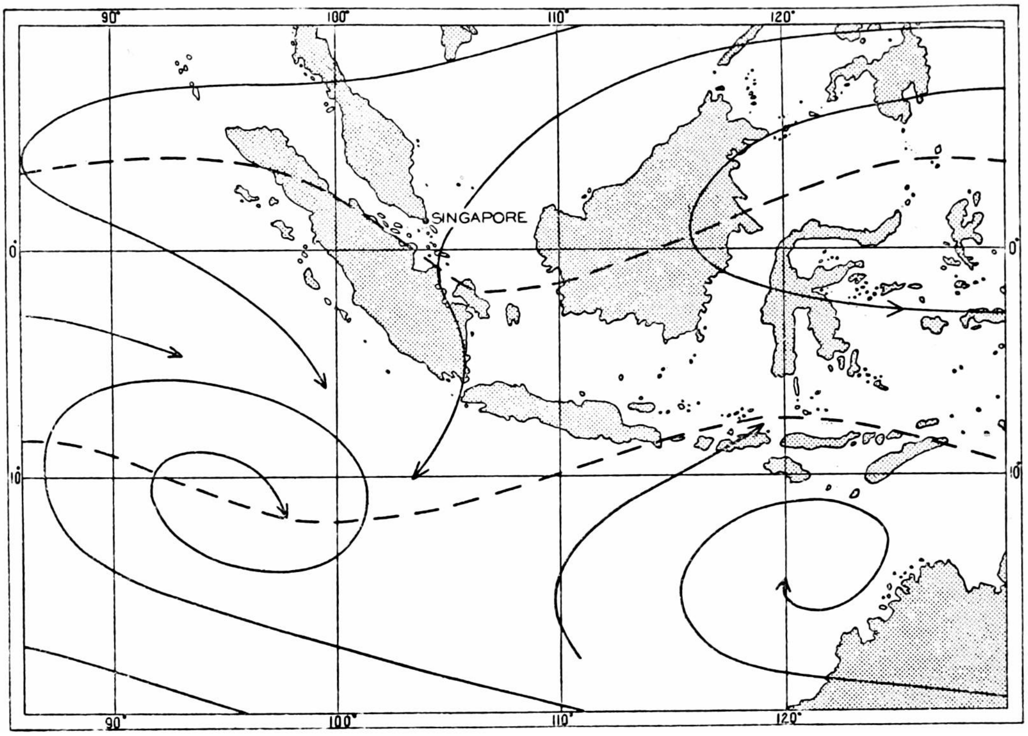



FIGURE 3—3,000-FOOT STREAMLINES FOR 0001 G.M.T., 27 JANUARY 1957

— — — Northern and Southern Limit of the Equatorial Westerlies

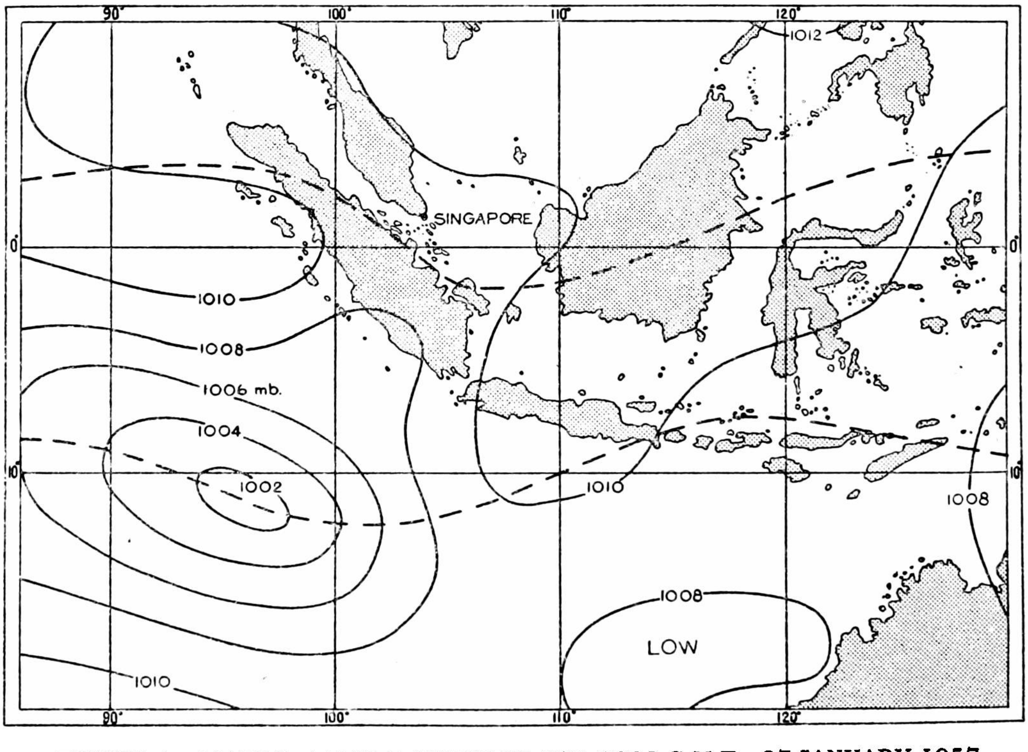



FIGURE 4—MEAN SEA LEVEL PRESSURE FOR 0001 G.M.T., 27 JANUARY 1957

— — — Northern and Southern Limit of the Equatorial Westerlies

**Streamline analysis.**—Streamline analysis for the three very wet days in December was treated subjectively owing to the lack of wind observations in South Malaya due to rain and low cloud and also to the fact that the radar wind-finding equipment was unserviceable. It appears that the depression over the South China Sea together with the high pressure over China and Japan strengthened the north-easterly flow at 1,000 and 3,000 feet over the northern part of the South China Sea and along the east coast of Malaya. The shear line became more marked and moved slowly southwards, as the depression gradually deepened, eventually merging with the convergence zone. The steady 10–15 knot north-easterlies or easterlies from 3,000 –10,000 feet over the South China Sea showed little change throughout the days in question, but there was convergence at all levels within 25 miles of Singapore.

In January 1957 with full wind information available it was apparent that the 10–15 knot north-easterly flow at 1,000 and 3,000 feet was sweeping straight across Singapore Island and that low level convergence was taking place about 100–150 miles south of Singapore Island. The upper level charts to 10,000 feet showed very variable north-east to east winds with indefinite shear over Malaya but they did not show consistent convergence to all levels for any position in the area.

**Divergence charts.**—Divergence charts ($\partial u/\partial x + \partial v/\partial y$), after Forsdyke[2], at 3,000 feet were drawn for 8 and 9 December 1954 and for 24 January 1957. The charts for 8 December showed an area of divergence over the South China Sea and a very rapid change over southern Malaya to a centre of convergence over eastern central Sumatra and the Straits of Malacca. Wind data for 9 December was sparse (as previously explained) but the charts treated subjectively gave indication of an eastward movement of this centre of convergence.

The chart for 24 January showed an extensive area of divergence over Thailand, Viet Nam and most of the South China Sea and an area of convergence near to the Cocos Islands but no marked change or centre of convergence near to Malaya.

**Conclusions.**—It is suggested that the essential factors in the development of the "rain area" over Singapore Island in December 1954 were:-

(*a*) The high pressure over South China and the development of the depressions in the south of the South China Sea (possibly lee depressions created by the stronger than normal easterly flow over Borneo) which helped increase the speed shear to the north-east of Malaya.

(*b*) The shape of the east coast of Malaya (with associated hill ranges) south of Trengganu, which may increase cyclonic curvature of the strong north-easterly flow towards the Equator.

(*c*) The extensive trough from Burma to Australia possibly assisting the development of depressions in the South China Sea.

(*d*) The merging of the shear line and convergence zone at the "triple point" over the east of Singapore Island. This feature is in many respects similar to the conditions which some authors[3] consider to be the start of typhoons. In this instance the position was too near the Equator for the rotary circulation of a tropical storm to develop, but the weather with heavy cloud and rain was similar to that of a typhoon. It is interesting to note that with such active convergence taking place no reports of lightning or thunder were made on

Singapore Island during the three wet days in December; this also is in line with the more stable conditions found in mature typhoons.

In January 1957 the deepening depression near the Cocos Islands was a major factor in drawing the "Northern Limit" south of its seasonal position and this led to the straight north-easterly monsoonal flow across Singapore, with little or no rain in the east and only scattered slight showers over the west of the island, but with no active convergence in the area.

Thus although the two months being considered were in the same monsoonal season, it is suggested that external pressure systems can materially affect the seasonal position of convergence zones and lead to totally different weather in the north-easterly monsoon season from year to year at Singapore.

REFERENCES

1. BOTHWELL, F.; Heavy rainfall at Changi, Singapore. *Met. Mag., London,* **84,** 1955, p.156.
2. FORSDYKE, A. G.; Weather Forecasts in Tropical Regions, *Geophys. Mem., London,* No. 82, 1949.
3. Report of Tropical Cyclone Conference, Brisbane, Australia, 1955, pp.18, 105, 106.

## METEOROLOGICAL RESEARCH COMMITTEE

The meeting held on 28 November 1957 was devoted mainly to consideration of the progress reports from the three Subcommittees for the period March to August 1957. It was noted that the entire field of technique for upper air sounding by radio-sonde and radar procedure was under review. Among other items of interest were the results obtained in the application of numerical prediction (machine computation) to a small deepening depression, the promising nature of an analogue method for forecasting the general character of weather a month ahead (based on mean monthly temperature anomaly pattern in the preceeding month), and significant results on the composition of fogs obtained by optical investigations.

### Instrument Subcommittee

At the meeting held on 4 December 1957, the Subcommittee reviewed the progress reported on items of instrument development for the period March to August 1957. Mention was made of the progress with a frost point hygrometer —using polarized light—for indicating values of frost point down to −100°C.; the development of an automatic frequency recorder system for use in conjunction with the standard radio-sonde; and the results of further comparisons between the height of cloud base as indicated by the modulated beam searchlight and the standard cloud searchlight.

Three papers dealing with aircraft measurements of meteorological elements were considered. It was gratifying to note from M.R.P. 1043 that flight tests by the Meteorological Research Flight of a conical-head thermometer (made according to the specification of M.R.P. 960) had shown the speed correction coefficient of the instrument to be sensibly constant with height up to 40,000 feet. The next paper, M.R.P. 1070, presented information on the accuracy of determination of the wind velocity by the use of a Marconi radio navigational system (Doppler principle) installed in a jet aircraft of the Meteorological Research Flight. This technique is likely to have important meteorological applications. The diagram, described in M.R.P. 1071, for obtaining the true air temperature from the temperature indicated by an aircraft thermometer removes the need to use more or less complicated tables for this purpose, and might form the basis of an instrument for the purpose.

ABSTRACTS

HINKEL, C. H.; Report on flight tests of a prototype conical-head aircraft thermometer. *Met. Res. Pap., London.* No. 1043, 1957.

Flight test results are given for an aircraft thermometer in the shape of a cone of 10° semi-angle. The recovery factor of the thermometer is shown to be sensibly constant. An increase in the scatter of the data at high altitudes is noted and discussed with reference to similar data for a standard flat-plate thermometer mounted on the same aircraft. It is suggested that this increased scatter is caused by inaccuracies in the measurement of altitude and airspeed and not by the thermometer.

MURGATROYD, R. J., and HELLIWELL, N. C.; The measurement of wind at altitude by airborne instruments. *Met. Res. Pap., London,* No. 1070, 1957.

A Marconi Doppler navigational equipment has been installed in a Canberra aircraft of the Meteorological Research Flight. It can be used for the instantaneous measurements of wind in flight by comparison of the vectors of groundspeed and airspeed. Tests were made to investigate the accuracy of winds obtained by this method by flying different geometrical patterns and also by direct comparison with wind measurements obtained from the Crawley radiosonde-radarwind ascents. It was concluded that, providing suitable corrections can be made for any slight misalignment of the aerial system of the navigational equipment and for errors in the airspeed found from the aircraft's airspeed indicator, the wind can be measured in flight with an accuracy of $\pm 5$ knots. If special attention is not paid to these possible sources of error, the wind error may be 10 knots or more.

DURBIN, W. G.; A diagram for obtaining true air temperatures from indicated air temperatures for aircraft resistance thermometers. *Met. Res. Pap., London,* No. 1071, 1957.

Air temperatures measured by aircraft thermometers must be corrected for kinetic heating effects. A graphical method is presented which enables these corrections to be derived readily from readings of indicated temperature, height and airspeed at any given value of the thermometer recovery factor. Compressibility effects are taken into account, but any instrumental corrections must be made before using the diagram. It is claimed that by its use, corrections can be obtained very rapidly and conveniently with about the same accuracy as calculations using a slide rule.

## Physical Subcommittee

The five papers discussed at the meeting on 12 December 1957 are typical of the range of investigations with which this Subcommittee is concerned. M.R.P. 1062 was noted as a valuable contribution to the intricate problem of estimating the spectrum of atmospheric turbulence from series of fine-scale simultaneous measurements of fluctuations of wind and temperature, with special reference to the effect of the length or duration of the series. Discussion on the further study of convection-diffusion processes below a stable layer presented in M.R.P. 1073 (a sequel to M.R.P. 1048 considered at the meeting on 9 May 1957) suggested that the formal results obtained by the theoretical treatment of idealized models indicated the need for more detailed study of the physical mechanisms operating and could therefore influence the nature and interpretation of field experiments. For several years it has been fairly generally believed that widespread (often densely packed) radar echoes, not associated with precipitation, are due to meteorological causes, for example intense localized gradients of air temperature and humidity. M.R.P. 1068, however, advances evidence that at least on many occasions these echoes ("angels") are caused by flocks of birds in migratory or similar flight. The Subcommittee accepted this conclusion as applying to the occasions cited in the paper, but did not exclude the possibility of the occurrence of angel echoes as a result of back scatter from the ground in certain atmospheric structures. It was noted that M.R.P. 1068 would be of much interest to ornithologists. Consideration of the data reported in M.R.P. 1069 on the vertical variation of the concentration of condensation nuclei, as determined by a Pollak photo-electric condensation nucleus counter installed in an aircraft of the Meteorological Research Flight, pointed to the desirability of obtaining similar information in maritime air masses well away from sources of pollution. The Subcommittee welcomed the highly interesting paper M.R.P. 1074 which describes early significant results obtained by optical methods (light-scattering and infra-red transmission) of determining the composition of fogs at Kew Observatory. It is proposed to examine whether at places less subject to pollution the contribution made by very small droplets to the opacity of thick fog is as important as at Kew.

ABSTRACTS

CHARNOCK, H. and ROBINSON, G. D.; Spectral estimates from subdivided meteorological series. *Met. Res. Pap., London*, No. 1062, 1957.

The relation $$\frac{1}{2}\frac{\partial^2}{\partial s^2}\left\{s^2\,\Phi\,(s)\right\} = 1 - R_+(s)$$

between $\Phi(s)$, the average fraction of the coverance contained in a subseries of $s$ terms and $R_+(s)$, the even part of the correlogram, is simply derived. Its use and practical limitations are illustrated by the analysis of an artificial series.

The form $\Phi(s) = s/(a+s)$ appears to be a suitable approximation for certain observed series involving vertical wind near the surface, and at heights up to 2,000 feet. The corresponding spectrum is discussed; it is asymptotic to the inverse square of frequency.

SMITH, F. B.; Convection-diffusion processes below a stable layer. Part II. *Met. Res. Pap., London*, No. 1073, 1957.

M.R.P. 1073 (an extension of M.R.P. 1048) deals with the dual effect of convection and normal turbulent diffusion on the dispersal of an emittant from a ground level crosswind line source into an atmosphere of finite depth. In the mathematical analysis, the diffusion coefficient $K(z) = kz^{-\alpha}$ represents the turbulent diffusion (cf. $K=k(H-z)$ in M.R.P. 1048). Approximate solutions for general $K(z)$ are indicated.

Free convection is represented directly. Entrainment into ascending convective motions is linked to the velocity of the compensating environmental subsidence, empirically defined as $v = \lambda z$. Uniformity of concentration throughout the layer, being hastened by convection, is achieved at distances downstream dependent on $k$, $\alpha$ and $\lambda$.

HARPER, W. G.; The origin of radar "angels". *Met. Res. Pap., London,* No. 1068, 1957.

The remarkable nature and intensity of bird migration is shown to be adequate in explaining radar "angels", which, as output powers have been increased, have come to present a hazard to airfield-control and military-type radars. With a telescope mounted on the aerial of a target-tracking radar large numbers of birds have been seen when the radar was tracking angels, and it was clear that the radar was following their flight. It would seem unnecessary to invoke any other mechanism to explain these phenomena and it is suggested that there is little prospect of entirely eliminating their effects from airfield control radars.

DAY, G. J.; Some airborne observations of condensation nucleus concentration. I. Variation in the vertical. *Met. Res. Pap., London,* No. 1069, 1957. Abstract not yet available.

STEWART, K. H.; Some observations on the composition of fogs. *Met. Res. Pap., London,* No. 1074, 1957.

Observations on the number and size of water drops in a fog were made with a cascade impactor and by two specially devised optical methods, one based on the measurement of the scattering of light at small forward angles, the other on the measurement of attenuation at different wavelengths, up to 10 microns.

Approximate size distributions are given for many fogs at Kew Observatory. The most striking feature is the preponderance of very small drops; drops of less than 3 microns diameter contribute at least half the opacity in all fogs and over 90 per cent of the opacity in fogs with visibility above 100 yards.

## REVIEW

*Climatology.* By W. G. Kendrew. $5\frac{1}{2}$ in. $\times$ $8\frac{3}{4}$ in., pp. xv + 400, *illus.* Clarendon Press. Oxford University Press, London. 2nd edition, 1957, Price: 42*s.* net.

Kendrew's "Climate" first appeared in 1930 and became a classic. After running through two editions and being reprinted, the work was largely re-written, appearing under the new title "Climatology" in 1949. This new edition includes further revisions of parts of the text and some additions, notably paragraphs on ozone in the upper atmosphere, jet streams and the upper westerlies, zonal index, blocking anticyclones, the Antarctic and micro-climates near the soil. There is also a brief appraisal of the probable role of numerical forecasting in the meteorological service. An index of place names has been added.

The efforts to keep the work up to date have been praiseworthy. It is still one of the best and most readable descriptive works for students, laymen and in-quirers. A real merit is the quotation of graphic descriptions, sometimes by travellers, of characteristic weather experiences in different parts of the world—a West Indian hurricane, a cold front in the Sahara, a hailstorm in Tibet (and many others). The photographic illustrations are well-chosen and beautiful.

The book begins with a nice summary of the fundamentals of the radiation and heat budget, which represent the energy supply of the atmospheric circulation. From that point on, however, the development is more disappointing for anyone who wants to understand the broad essentials of atmospheric movement which is the mechanics of climate. What actually follows is a very good text book on regional and descriptive climatology with some useful reference data, but the upper atmosphere is introduced (as explained in the preface) rather incidentally, for its relevance to air navigation and its "repercussions" on surface weather.

The new diagrams dealing with the jet stream, blocking anticyclones etc. are good, but the text tries to say too much in too short a space, sometimes producing a distorted view.

A number of the old diagrams (e.g. many pressure maps and figure 10 showing surface temperatures around Oxford on a radiation night) are marred by an oddly erratic isopleth interval. In the case of the pressure maps, this defect is more apparent than real, being the result of the dubious (but doubtless economically dictated) expedient of renumbering to the nearest whole millibar isobars which had been drawn to 1/10 inch for an earlier edition. These difficulties will be with us until the metrical system is fully and finally adopted.

The reader is made aware the "climate is always changing" but the discussion in terms of cycles is out of date. Suprisingly, in view of the admission of climatic change, the book treats it as needless to specify even approximately the datum periods of the tables and maps. This criticism, though logical, may be a little unfair, since we still await the day when specification of a consistent datum period is regarded as an essential standard practice in climatology. Yet, the distributions of different phenomena described may be inexplicable in physical terms unless they are all related to the same epoch with its characterstic patterns and intensity of atmospheric and ocean circulation.

In the Arctic and at the fringe of the arid zone in the tropics climatic figures are liable to be meaningless, unless the years in question are specified. This also applies to the table of frequencies of tropical cyclones on p.131, since the West Indian hurricanes have stepped up their frequency from 6 a year in the first decades of the century to a yearly average of 9 since 1933.

The short, carefully selected bibliography should surely have included a longer list of the excellent climatological atlases of different countries coming out in recent years—e.g. for China, Rumania and most of the German Länder. This represents an important current activity in climatology and more countries will be covered as time goes on. In the reviewer's opinion, Brooks's "The English climate" and "Climate in everyday life" should have been mentioned too.

The book is arranged in six parts: (1) insolation and temperature; (2) atmospheric pressure and winds, dealing with distributions and such implications as physiological effects of reduction of pressure with height and a world map of sailing ships tracks; (3) vapour in the atmosphere and its condensation, rain, cloud, sunshine and visibility, touching also upon atmospheric pollution; (4) mountain and plateau climates; (5) weather of the westerlies, anticyclones, depressions, frontal weather and spells; (6) a few specific types of climate. It can be recommended as one of the most useful, standard works in the field.

H. H. LAMB

## METEOROLOGICAL OFFICE NEWS

**Retirements.**—*Mr. S. P. Peters, C.B.E.*, Deputy Chief Scientific Officer, retired on 1 July 1958. He joined the Office as a Junior Professional Assistant in July 1923 and was posted to Cranwell. Early in 1925 he was transferred to the Airships Division at Headquarters and after some three months he was posted to Cardington. In 1932 he was transferred to Worthy Down and for a period in 1935 and 1936 he was in charge of the Meteorological Office School at South Kensington. From 1937 to 1946 he served successively at Foynes, Gloucester and Prestwick. In 1946 he was transferred to Headquarters to be Head of the Coastal Command Branch. From 1948 until his retirement he has been located at Dunstable, first in the Forecast Division and since 1953 as Deputy Director Forecasting and Central Services respectively. Mr. Peters served in the Meteorological Section of the Royal Engineers from 1918 to 1919. He was appointed a Commander of the Order of the British Empire in the Birthday Honours List of 1956. Mr. Peters has accepted a temporary appointment in the Meteorological Office.

*Mr. J. Wadsworth*, Senior Scientific Officer, retired on 18 July 1958. After service in the Meteorological Section of the Royal Engineers from 1917 to 1919 he joined the Office as a Junior Professional Assistant in the Forecast Division. In 1922 he was transferred to Malta and on his return in 1925 served in the Climatology and Forecast Divisions at Headquarters. In 1927 he was posted to the Middle East and after a period of one year he was transferred to Larkhill. In 1930 he left the Office to take up the post of Director of Apia Observatory, Western Samoa where he remained for eight years. He rejoined the Office in 1938 and has since served at Headquarters in the Climatology and Forecast Divisions and from 1948 until his retirement in the Special Investigations Division.

*Miss D. G. Lee*, Senior Experimental Officer, retired on 31 July 1958. She joined the Office in August 1918 as a Clerk Assistant in the Forecast Division where she remained until 1937 when she was transferred to the Climatology Division. From 1940 until her retirement she has served in the Administrative Division.

## WEATHER OF JUNE 1958

### Northern Hemisphere

As in May 1958, the depression track across the North Atlantic was unusually far south for the time of year. Mean pressures for the month were below normal over north-east Canada, much of the North Atlantic and Europe, excluding Scandinavia, and coastal regions of the Mediterranean. The greatest anomalies, of −5 millibars, occurred a little west of Ireland where a small area of low pressure was present on the mean chart. The polar anticyclone was centred near its normal position and was more extensive than usual, with a strong ridge over Siberia and another north of the British Isles.

The North Pacific high was a smaller feature than usual and the centre was displaced northwards. The most important departure from normal in the Pacific sector was the presence of a well marked Aleutian low, an unusual feature for June. Both the low pressure areas of Asia were deeper than normal and a belt of small negative anomalies extended from the eastern Mediterranean to central China.

Mean temperatures for the month were close to the average everywhere in Europe, there being slight negative anomalies in central and eastern Europe and slight positive ones elsewhere. Negative temperature anomalies were reported in the area east of the Rockies between 40°N. and 60° N., associated with a stronger northerly advection than usual there. Positive anomalies occurred in Alaska as a result of warm air advection from the south around the Aleutian low; further positive anomalies of +3°C. occurred west of the Rockies.

In central and western Europe rainfall totals were above normal; more than twice the usual amount was recorded at a number of stations in the British Isles and France. Precipitation totals were up to twice the normal over north-east Asia, but were near or below normal in other parts of that continent. The rainfall pattern over North America was very irregular.

## WEATHER OF JULY 1958
### Great Britain and Northern Ireland

After four days of cyclonic weather with pressure low to the south of the British Isles, the situation became weakly anticyclonic until the 13th of the month when a depression moved north-east across the country accompanied by widespread rain. Subsequently pressure distribution over the country was somewhat featureless though weakly cyclonic for some days, but from the 21st until the end of the month a sequence of depressions brought changeable weather to most of the country.

From the 1st–3rd a shallow depression was centred over the western English Channel and thundery rain belts moved slowly northwards across England and Wales, although over most of Scotland weather was sunny and warm; on the night of the 1st/2nd 1·3 inches and 1·7 inches of rain fell in 12 hours at Cardington and Shawbury respectively; in Scotland on the 3rd the exceptional temperature of 80°F. was recorded at Benbecula and on the 4th Renfrew reported 82°F. From the 6th–8th a ridge of high pressure moved across the country and weather was generally fine and warm during the day, but fog was fairly widespread at night; extensive fog over the Irish Sea and English Channel kept the adjacent coastal temperatures about 20°F. lower than at places further inland where, on the 8th, 80°F. was exceeded in many eastern districts and 83°F. was reached at places as far apart as Cardington, Finningley and Dyce. Although a weak cold front gave a little rain as it crossed the country on the 9th, the mainly dry weather continued for several days until rain, associated with a deep depression on the Atlantic, reached Cornwall and north-west England during the evening of the 11th, subsequently spreading to most areas except the extreme north of Scotland. The depression moved north-east across the Irish Sea during the early hours of the 13th reaching the northern North Sea by the evening and was accompanied by heavy falls of rain and strong winds. Except in northern Scotland and south-east England, most districts from 11th to 13th had a daily fall of ½ inch of rain or more and daily falls exceeded 1 inch in Northern Ireland and west Wales. Wind rose in gusts to 50 knots and more along the south coast.

From the 14th to 19th wind was rather light and variable over the British Isles and weather showery, with good sunny periods, and a steadily rising temperature; thunderstorms were reported from many places particularly from eastern districts on the 16th and 20th.

A succession of depressions approached the British Isles from the west and south-west during the last ten days of the month bringing generally unsettled weather. The first of these moved over the country on the 21st and the next skirted the south coast two days later. Another depression moved across Ireland and southern Scotland to the North Sea on the 25th and 26th, while the fourth and final depression of the series moved north-eastward from Southern Ireland to the northern North Sea about two days later. During this time there was heavy rain over most western districts, and in southern and eastern Scotland rainfall was heavy and prolonged and in places falls exceeded 2 inches in 24 hours. Flooding was reported from Glasgow and Perth. In parts of Scotland more than half the average rainfall for July was recorded in 12 hours on the 28th.

The month ended with three days of showery weather, heavy thunderstorms occurred locally particularly in southern Scotland; although there were good sunny periods. At Eskdalemuir 1·3 inches of rain fell in 12 hours on the 30th.

Rainfall was 112 per cent of the 1921–50 average in England and Wales, 126 per cent in Scotland and 121 per cent in Northern Ireland, where it was the wettest July since 1947. The combined rainfall for May, June and July over England and Wales was the highest recorded since 1924. Less than half the July average was recorded in the Hebrides and the extreme north-west of the Scottish mainland. Twice the average was exceeded in parts of Lincolnshire, Morayshire, around Edinburgh and in East Lothian. Thunderstorms occurred over the British Isles on the 1st–5th and 20th–23rd inclusive and on seven other days. July was a cool month generally with average temperatures generally near or a little below the normal. At Aberdeen two temperature records were broken; air temperature reached 83°F. on the 8th and fell to 35°F. on the 25th which were respectively the highest and lowest values recorded there since records began in 1925. Sunshine amounts were about normal at most inland stations but coastal stations showed a deficit.

The heavy rains during the month, besides causing severe floods in eastern districts, continued to interfere seriously with farm work. Crops were badly beaten down locally and the harvest in consequence will almost certainly be retarded and yields possibly low. Potato blight continued to be spread rapidly in the worst year of the century for this disease. The rain also reduced the promised bumper strawberry crop and cherries were affected to a lesser extent. The pea crop was reduced but most summer vegetables were in plentiful supply and prospects for winter vegetables were considered to be good.

## WEATHER OF AUGUST 1958

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 ... | 84 | 35 | −0·1 | 123 | +6 | 74 |
| Scotland ... ... | 77 | 34 | +0·3 | 112 | +2 | 89 |
| Northern Ireland ... | 70 | 39 | +0·1 | 123 | +3 | 80 |

*1916–1950 †1921–1950

# RAINFALL OF AUGUST 1958

## Great Britain and Northern Ireland

| County | Station | In. | *Per cent of Av. | County | Station | In. | *Per cent of Av. |
|---|---|---|---|---|---|---|---|
| *London* | Camden Square Gdns. | 3·92 | 170 | *Carm.* | Pontcrynfe | 3·52 | 72 |
| *Kent* | Dover | 3·11 | 139 | *Pemb.* | Maenclochog, Ddolwen B. | 6·67 | 132 |
| ,, | Edenbridge, Falconhurst | 3·66 | 125 | *Radnor* | Llandrindod Wells | 2·97 | 94 |
| *Sussex* | Compton, Compton Ho. | 5·51 | 179 | *Mont.* | Lake Vyrnwy | 3·66 | 72 |
| ,, | Worthing, Beach Ho. Pk. | 4·80 | 211 | *Mer.* | Blaenau Festiniog | 8·01 | 75 |
| *Hants.* | St. Catherine's L'thouse | 4·39 | 205 | ,, | Aberdovey | 4·12 | 98 |
| ,, | Southampton, East Pk. | 4·37 | 168 | *Carn.* | Llandudno | 1·80 | 71 |
| ,, | South Farnborough | 4·25 | 188 | *Angl.* | Llanerchymedd | 2·65 | 77 |
| *Herts.* | Harpenden, Rothamsted | 3·35 | 146 | *I. Man* | Douglas, Borough Cem. | 5·41 | 139 |
| *Bucks.* | Slough, Upton | 3·61 | 165 | *Wigtown* | Newton Stewart | 4·95 | 122 |
| *Oxford* | Oxford, Radcliffe | 2·65 | 117 | *Dumf.* | Dumfries, Crichton R.I. | 3·75 | 94 |
| *N'hants.* | Wellingboro' Swanspool | 2·67 | 116 | ,, | Eskdalemuir Obsy. | 6·05 | 110 |
| *Essex* | Southend W.W. | 3·71 | 190 | *Roxb.* | Crailing | 2·19 | 67 |
| *Suffolk* | Ipswich, Belstead Hall | 3·54 | 171 | *Peebles* | Stobo Castle | 3·68 | 104 |
| ,, | Lowestoft Sec. School | 2·32 | 108 | *Berwick* | Marchmont House | 4·10 | 125 |
| ,, | Bury St. Ed., Westley H. | 2·63 | 107 | *E. Loth.* | N. Berwick | 2·37 | 77 |
| *Norfolk* | Sandringham Ho. Gdns. | 2·39 | 99 | *Midl'n.* | Edinburgh, Blackf'd H. | 3·11 | 99 |
| *Dorset* | Creech Grange | 3·83 | 132 | *Lanark* | Hamilton W.W., T'nhill | 5·81 | 159 |
| ,, | Beaminster, East St. | 2·76 | 88 | *Ayr* | Prestwick | 4·00 | 131 |
| *Devon* | Teignmouth, Den Gdns. | 2·95 | 120 | ,, | Glen Afton, Ayr San. | 6·33 | 148 |
| ,, | Ilfracombe | 4·54 | 144 | *Renfrew* | Greenock, Prospect Hill | 5·07 | 110 |
| ,, | Princetown | 11·49 | 171 | *Bute* | Rothesay, Ardencraig | ... | ... |
| *Cornwall* | Bude | 6·65 | 236 | *Argyll* | Morven, Drimnin | 6·39 | 127 |
| ,, | Penzance | 5·78 | 196 | ,, | Ardrishaig, Canal Office | 7·79 | 142 |
| ,, | St. Austell | 7·58 | 211 | ,, | Inveraray Castle | 8·50 | 122 |
| ,, | Scilly, St. Mary | 4·61 | 183 | ,, | Islay, Eallabus | 4·41 | 104 |
| *Somerset* | Bath | 2·41 | 85 | ,, | Tiree | 3·12 | 86 |
| ,, | Taunton | 2·22 | 96 | *Kinross* | Lock Leven Sluice | 3·46 | 95 |
| *Glos.* | Cirencester | 2·81 | 91 | *Fife* | Leuchars Airfield | 2·59 | 97 |
| *Salop* | Church Stretton | 4·96 | 155 | *Perth* | Loch Dhu | 7·36 | 119 |
| ,, | Shrewsbury, Monkmore | 3·36 | 134 | ,, | Crieff, Strathearn Hyd. | 3·84 | 98 |
| *Worcs.* | Worcester, Red Hill | 2·47 | 112 | ,, | Pitlochry, Fincastle | 5·37 | 160 |
| *Warwick* | Birmingham, Edgbaston | 2·72 | 99 | *Angus* | Montrose Hospital | 4·76 | 170 |
| *Leics.* | Thornton Reservoir | 2·80 | 107 | *Aberd.* | Braemar | 3·20 | 104 |
| *Lincs.* | Cranwell Airfield | 2·11 | 97 | ,, | Dyce, Craibstone | 2·75 | 92 |
| ,, | Skegness, Marine Gdns. | 1·75 | 82 | ,, | New Deer School House | 3·70 | 120 |
| *Notts.* | Mansfield, Carr Bank | 2·56 | 102 | *Moray* | Gordon Castle | 4·26 | 137 |
| *Derby* | Buxton, Terrace Slopes | 3·37 | 81 | *Inverness* | Loch Ness, Garthbeg | 4·08 | 120 |
| *Ches.* | Bidston Observatory | 4·47 | 143 | ,, | Fort William | 5·39 | 90 |
| ,, | Manchester, Ringway | 5·09 | 160 | ,, | Skye, Duntulm | 3·62 | 82 |
| *Lancs.* | Stonyhurst College | 5·02 | 102 | ,, | Benbecula | 4·33 | 114 |
| ,, | Squires Gate | 3·98 | 114 | R. & C. | Fearn, Geanies | 3·33 | 134 |
| *Yorks.* | Wakefield, Clarence Pk. | 2·58 | 98 | ,, | Inverbroom, Glackour | 5·25 | 119 |
| ,, | Hull, Pearson Park | 2·20 | 85 | ,, | Loch Duich, Ratagan | 4·92 | 79 |
| ,, | Felixkirk, Mt. St. John | 3·88 | 128 | ,, | Achnashellach | 4·17 | 64 |
| ,, | York Museum | 2·33 | 91 | *Suth.* | Stornoway | 3·26 | 97 |
| ,, | Scarborough | 2·40 | 92 | *Caith.* | Lairg, Crask | ... | ... |
| ,, | Middlesbrough | 3·02 | 110 | ,, | Wick Airfield | 3·19 | 121 |
| ,, | Baldersdale, Hury Res. | 4·18 | 124 | *Shetland* | Lerwick Observatory | 3·45 | 125 |
| *Nor'l'd* | Newcastle, Leazes Pk. | 2·54 | 82 | *Ferm.* | Belleek | 5·14 | 108 |
| ,, | Bellingham, High Green | 3·32 | 97 | *Armagh* | Armagh Observatory | 3·89 | 115 |
| ,, | Lilburn Tower Gdns. | 3·29 | 104 | *Down* | Seaforde | 5·57 | 151 |
| *Cumb.* | Geltsdale | 4·26 | 100 | *Antrim* | Aldergrove Airfield | 2·79 | 85 |
| ,, | Keswick, High Hill | 6·73 | 133 | ,, | Ballymena, Harryville | 4·45 | 109 |
| ,, | Ravenglass, The Grove | 3·89 | 96 | *L'derry* | Garvagh, Moneydig | 4·96 | 124 |
| *Mon.* | A'gavenney, Plâs Derwen | 3·09 | 92 | ,, | Londonderry, Creggan | 4·53 | 105 |
| *Glam.* | Cardiff, Penylan | 5·69 | 147 | *Tyrone* | Omagh, Edenfel | 4·58 | 115 |

* 1916–1950

Printed in Great Britain under the authority of Her Majesty's Stationery Office
By Geo. Gibbons Ltd., Leicester

Wt-18. K16.