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METEOROLOGICAL FACTORS IN THE CENTRAL DESERT OF ICELAND

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In August and September 1956 the members of the British Schools Exploring Society's eighteenth expedition spent six weeks in central Iceland, during which time various scientific tasks were undertaken. On this occasion certain meteorological projects received special attention, and these have already been outlined in general terms.[1]

The expedition's main meteorological station, at point A in Figure 1, was located near the south-eastern corner of Langjökull in latitude 64° 26′ N., longitude 20° 15′W. Immediately to the north lay the Jarlhettur, a range of very steep-sided tuff and lava hills, whose general alignment was continued south-westwards through Lambahraun, Porolfsfell and Hognhöfdi. Stretching for some miles to the east, west and south was a desert of volcanic and glacial debris whose surface, diversified by innumerable minor hillocks of irregular shape, varied from sand to rock pavement. There was virtually no vegetation except for isolated patches of turf-covered loess which were very sparsely distributed in the north but more numerous in the south-east. These were being rapidly destroyed by wind action. Much of the desert surface was covered by bare loess, from which most of the surface soils of Iceland's farming regions have been derived.[2] Mixed with the loess were large numbers of morainic stones and boulders of all sizes, which were left littering the surface as a result of the blowing away of the finer material.

During the first week of August, many dust-storms of two distinct types were observed in this desert area. Under the influence of strong winds the finer particles of surface material were raised as sheets of dust and carried away.[3] In calmer weather with strong sunshine, individual dust devils of a few feet in diameter developed, sometimes beneath small cumulus clouds.[4] These dust devils increased in number during the warmest hours and frequently coalesced into a widespread mass of dust which, however, was still clearly convective in character. Although on a few occasions dust devils moved in close proximity to the main meteorological station, most of the dust-storms of both types were restricted to the southern part of the desert near Sandfell, in spite of the fact that there was enough fine material on the surface to give rise to them almost anywhere. Since the deposition of this dust is of the utmost importance in building

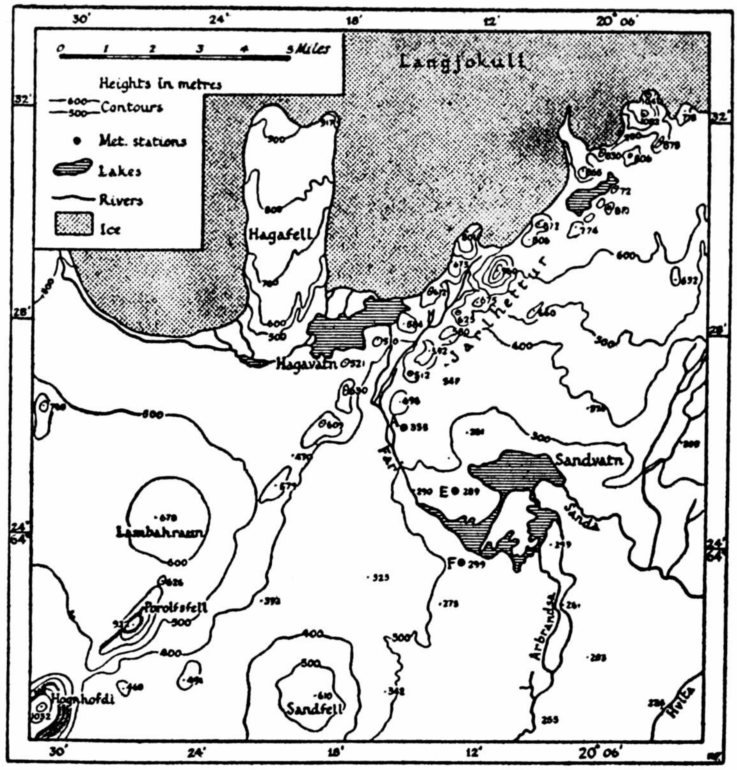

FIGURE I.—POSITIONS OF STATIONS

up the cultivated soils of Iceland[5] it was decided to combine an examination of the factors influencing the development of dust-storms with an investigation of such changes in meteorological conditions as might occur with increasing distance from the ice-cap. Two subsidiary stations were therefore established at points E and F in Figure 1, and at each of these, as well as at station A, observations of all elements were made every hour, both by day and by night, from 2100 G.M.T. on 26 August to 0900 G.M.T. on 1 September.

Station A was sited reasonably clear of the Jarlhettur range and exposure in all directions other than due north was excellent. Here a large Stevenson screen housed a thermograph and a hygrograph, in addition to the maximum, minimum, wet-bulb and dry-bulb thermometers. A shipboard screen, containing wet- and dry-bulb thermometers, was also erected to provide readings strictly comparable with those taken at the subsidiary stations which were equipped with screens of this type. A cup counter anemometer was erected 9 feet above the surface and wind speed at the time of each observation was measured by noting the change of figures in a one-minute period and converting into knots at 33 feet from prepared tables. Wind direction was indicated by a vane comprising a stout aluminium arm mounted on the bearings of a bicycle wheel. This too was fixed 9 feet above the surface and proved to be well balanced and steady but very sensitive. Pressures were read from an aneroid barometer, which had been checked against a mercury barometer at Reykjavik, and a barograph, both of which were housed in a tent. A sunshine recorder was erected on a low hillock, with a good exposure in all directions except when the sun was very low in the west.

The subsidiary stations E and F were established at distances of 2 and 3½ miles respectively to the south-south-east of station A on surfaces which, as was general elsewhere, were covered with loess and heavily littered with rounded stones. At each site a cup counter anemometer, erected and read as at station A, and a wind-direction flag were placed at the summit of a small hillock, but the other instruments were set up well clear of it.

A shipboard screen was mounted on bamboo poles about 4 feet above the surface, and this housed wet- and dry-bulb thermometers. Bent-stem thermometers were placed at depths of 4 and 8 inches and in an effort to obtain some rough indication of surface temperature, the bulb of an ordinary thermometer laid on the ground was covered with a thin layer of soil. Owing to the fine nature of this soil it was difficult to keep the bulb covered and it is highly probable that radiation effects were considerable. A somewhat more reliable indication of air temperatures near the ground was obtained from the readings of an Assmann psychrometer held at a height of one inch above the surface, but it is likely that these were lower than the true values, particularly during the warmest hours, owing to a tendency for the instrument to draw down air from higher levels.[6]

The 6-day period during which the meteorological party was concerned with this particular project was characterised by two contrasting weather types; a calm type with mainly northerly winds and clear skies during the first three days, and a cloudy type with much stronger south-westerly winds during the last three. One day has been selected from each of these types to illustrate the prevailing conditions.

0800 G.M.T. 28 August to 0700 G.M.T. 29 August.—The synoptic situation at 0600 G.M.T. on 28 August is shown in Figure 2 (*a*) which is based upon all available data. At 0800 G.M.T., upper winds at Keflavik were slightly east of north up to 7000 feet at speeds of about 10 knots and then became west of north, increasing to 15 knots. Throughout the 24-hour period under review, Iceland lay on the north-east fringe of a large anticyclone.

At station A a continuous record of pressure was obtained by means of a barograph which was periodically checked against an aneroid barometer. Tendencies from an assumed zero at 0900 G.M.T. are represented in Figure 3(*a*). In view of the prevailing synoptic situation, the pressure at station A at 0900 G.M.T. is likely to have been only slightly higher than that at Reykjavik. Thereafter the pressure at both Reykjavik and Akureyri fell slightly until 1500 G.M.T., but at station A the decline was much more rapid and pronounced. There the lowest pressure was recorded at 1300 G.M.T. and its value was 2·5 millibars below that registered at 0900 G.M.T. The pressure at station A was maintained at this comparatively low level until 1800 G.M.T., but by 2100 G.M.T. it had risen by 2·5 millibars. Thereafter the tendency graph for station A runs roughly parallel with those for the coastal stations.

Throughout 28 August there was uninterrupted sunshine at station A from 0715 to 1940 G.M.T. and no cloud whatsoever was reported from A, E or F until after sunset. During the morning there was no measurable wind at A or E, and at F only very light breezes of uncertain direction were experienced (Figure 3(*b*)). However, between 0800 and 1200 G.M.T., when temperatures were increasing rapidly (Figure 3(*c*)), there were considerable fluctuations in the absolute humidity values (Figure 3(*d*)), and it is particularly worthy of note that each of

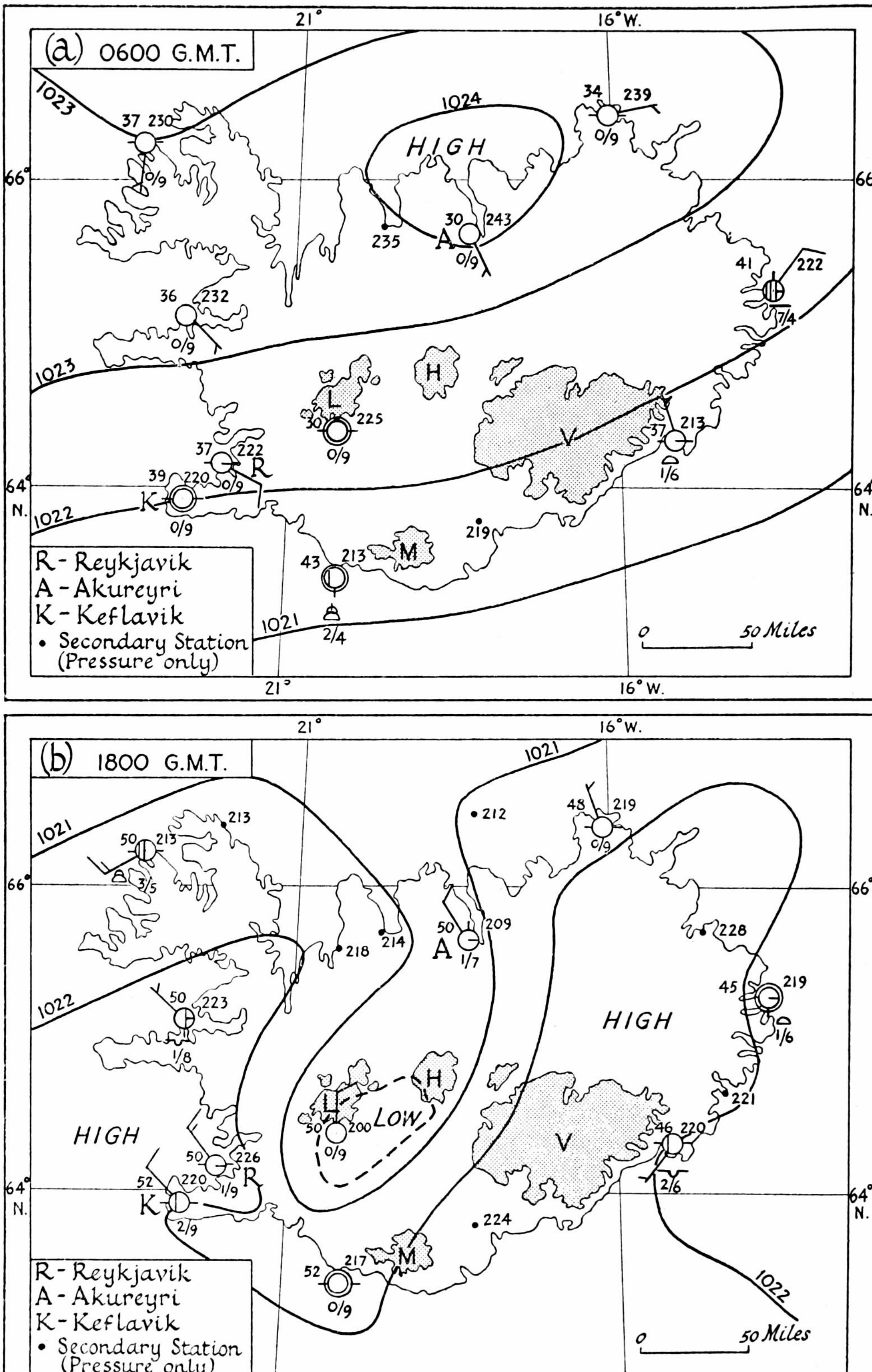

FIGURE 2.—SYNOPTIC SITUATIONS 28 AUGUST 1956

The four main ice-caps are indicated as follows:—L, Langjökull; V, Vatnajökull; H, Hofsjökull; M, Myrdalsjökull.

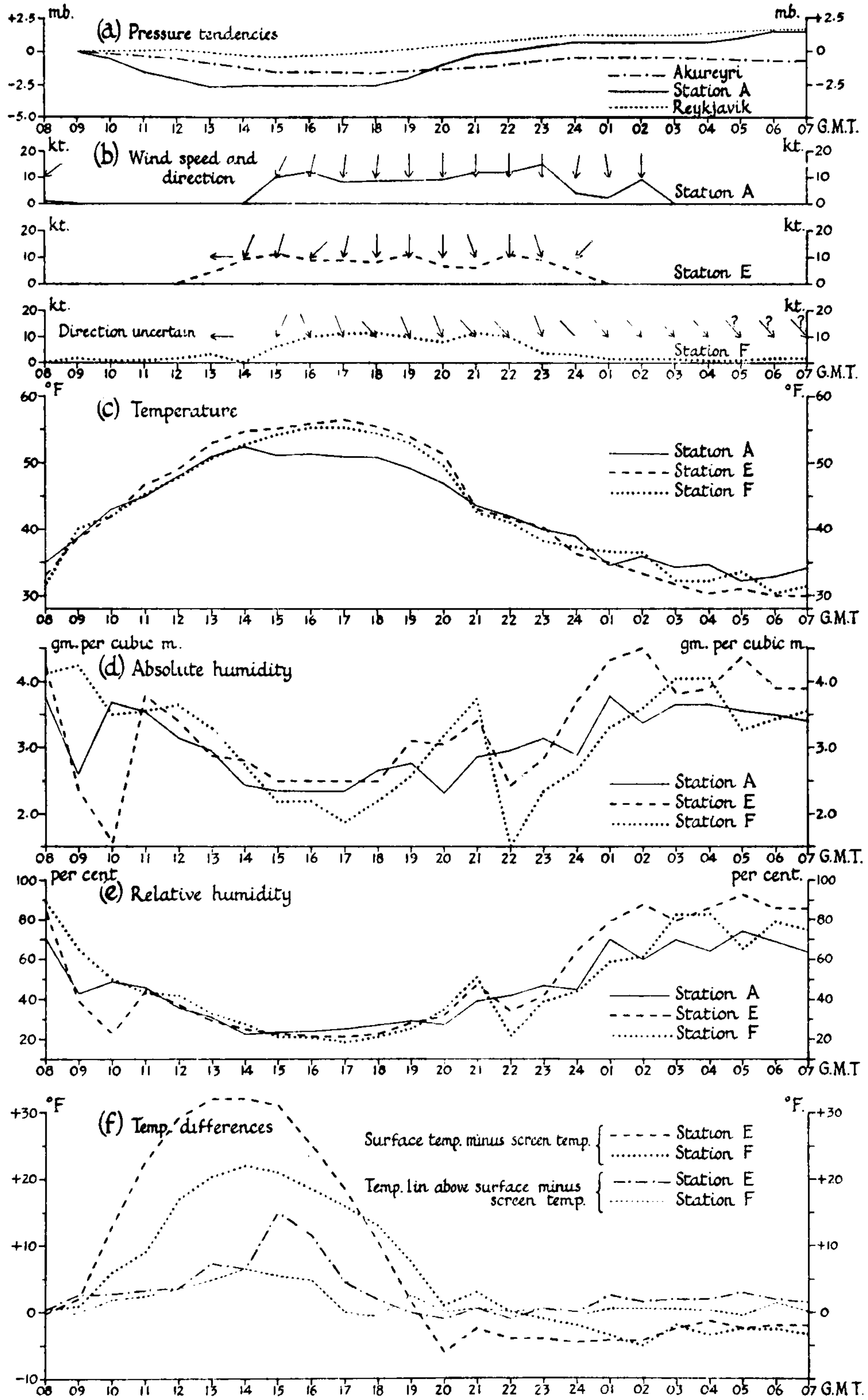

FIGURE 3.—HOURLY OBSERVATIONS 28–29 AUGUST 1956

these was first experienced at A, the station nearest to the ice-cap. Here the temperature reached a maximum for the day at 1400 G.M.T. In the succeeding hour the wind at station A rose from zero to a speed of 11 knots from the north-north-east, and this was accompanied by a fall in temperature which then remained virtually unchanged until 1800 G.M.T. Stations E and F also experienced this same wind, but at neither of these locations was there any decline in temperature. On the contrary, temperatures there rose to maxima at 1700 G.M.T., in spite of the fact that the winds at these stations, like that which produced the fall of temperature at station A, had undoubtedly come from the ice-cap. By 1800 G.M.T. absolute humidities at all stations were rising from the low values recorded during the warmest hours, but a temporary decline at station A at 2000 G.M.T. was followed two hours later by sharp falls at E and F. Thereafter absolute humidities rose but not without minor decreases, and that experienced at station A at 0200 G.M.T. coincided with a temporary increase in the strength of the northerly wind.

It would seem that these fluctuations in absolute humidity have a very close connection with a variation in the properties of winds blowing off the ice-cap. At each of the three stations the maximum wind was northerly and throughout the 24-hour period under review changes in absolute humidity values were first experienced at A, the station nearest to the ice-cap.

The relative humidity graphs (Figure 3(*e*)) are noteworthy for the low values attained in the middle and late afternoon, but the figure of 19 per cent recorded at station F at 1700 G.M.T. was by no means the only low figure obtained during the five-week period throughout which observations were continued at station A.

The fall in pressure at A during the late morning and early afternoon (Figure 3(*a*)) was also no isolated phenomenon. It was always most pronounced with clear skies and northerly winds, and may well indicate a general fall in pressure during the warmest hours over those extensive areas of bare sand and rock which lie between the main ice-caps.[7] It has previously been reported that these ice-caps, whose positions are indicated in Figures 2 and 4, set up a blocking action to northerly winds, and that small ridges of high pressure and troughs or even shallow cyclonic centres develop on their windward and leeward sides respectively.[8] Further evidence of this blocking action was provided by the members of a French expedition who, in the summer of 1954, made regular meteorological observations at Laugafell, some nine miles from the north-eastern edge of Hofsjökull. Their report states that on nearly 80 per cent of those 230 occasions when meteorological observations were made the wind blew due east or west; that is, in a direction parallel to the barrier provided by the northern slopes of Langjökull, Hofsjökull and Vatnajökull.[9]

An area of low pressure certainly developed on the leeward side of Langjökull during the late morning and afternoon of 28 August (Figure 2(*b*)), and this accounts for many of the fluctuations specified above. It would seem that the surface winds were blocked by Langjökull to the north, whilst over the desert intense insolation on the bare stony surface set up strong convection currents. Normally this large-scale raising of air would at once be compensated by surface currents, but since these were blocked an area of comparatively low pressure was established which increased in intensity with the surface temperature. The extent of this surface heating is indicated by the temperature differences shown in Figure 3 (*f*). As mentioned above, it is highly probable that the recorded values of surface temperature were strongly affected by radiation, but it is noteworthy that at each of the stations E and F the differences between the temperatures registered by an Assmann psychrometer at a height of 1 inch above the surface and those recorded in the shipboard screen show the same trend as the differences between the surface and screen values. It is particularly significant that at each of the two desert stations the maxima in these graphs of temperature differences occurred well before the time of the screen maximum. In fact, Figure 3 (*f*) indicates that the greatest turbulent activity on this particular day was between 1300 and 1500 G.M.T. It was at the beginning of this 2-hour period that the barograph at station A attained its maximum depression (Figure 3 (*a*)). At the same time mirages were seen over the desert to the south, and dust devils, which were observed over the southern part of the desert between 1200 and 1600 G.M.T., were reported to be particularly numerous in the neighbourhood of station F at 1345, 1400 and 1420 G.M.T. At 1300 G.M.T. very light breezes of uncertain direction were recorded at each of the two desert stations, but by 1500 G.M.T. all three stations were experiencing north-north-easterly winds which at A and E exceeded 10 knots.

In late July 1931, similar phenomena were observed near the north-west margin of Vatnajökull.[10] On that occasion thermometers were placed both above and below the surface, the temperature of which was then obtained by extrapolation. Results showed that over a period of five hot days the mean maximum temperature of the surface, very similar to that south of Langjökull, was 79°F., whereas that at a height of one metre was only 54°F. Thus the difference of 25°F. is one which is comparable with those shown in Figure 3 (*f*).On this earlier occasion mirages were seen in mid-morning, and dust devils, which attained a height of 400 metres above the surface, were also observed. As from that time, the north-east wind was replaced by a glacier wind from Vatnajökull which, without reaching any great strength, prevailed until a few hours before midnight.

Under the conditions prevailing on 28 August it seems probable that the lower pressure over the desert led to the establishment of a pressure gradient which eventually was sufficient to compensate for the blocking action of the ice-cap. Air which had passed over the ice-cap's summit was then drawn down as a Föhn wind, thus making good the loss by convection. The lower layers of this wind which had been in contact with the ice surface were cold and, in spite of adiabatic warming consequent upon their descent, their arrival soon after 1400 G.M.T. was marked by a fall in temperature at station A and a slight check in the temperature rise at station E. The upper layers of the Föhn wind, which had not been chilled by contact with the ice surface, were drawn down by turbulence over the central parts of the desert. There was thus no check in the rise of temperature at station F, but here the relative humidity at 1700 G.M.T. fell to 19 per cent. As convective activity decreased so did the descent of the Föhn wind's upper layers which it induced. The moister lower layers, which had been in contact with the melting surface of the ice-cap during the warmest hours of the day, now spread further southwards over the desert, thus causing a rapid increase in absolute humidity values at each of the three stations after 1700 G.M.T.

At 2100 G.M.T. there was a marked discontinuity in the rate of cooling at each of the three stations and this was followed throughout the night by minor fluctuations of temperature. These, together with the discontinuity and those more pronounced variations in absolute humidity which occurred throughout the night as well as in the late morning, were the consequence of meteorological events on the ice-cap. Such events were the subject of a separate study on other dates and the results obtained from this are to be reported in a later paper.

0800 G.M.T. 31 August to 0700 G.M.T. 1 September.—In the interval since the 24-hour period described above, an area of low pressure formed over the north-east coast of Greenland, and the anticyclone, which had induced northerly winds in the previous period, moved eastwards to a position almost due south of Iceland. The moist south-westerly winds associated with this change brought a remarkable reversal of conditions over the central desert.

At 0800 G.M.T. on 31 August the upper air ascent at Keflavik showed winds of average speed about 22 knots, which were south-westerly up to 3000 feet but almost westerly above 5000 feet. Moreover, between 4000 and 6000 feet there was a very marked layer of dry air. The synoptic situation at 0600 G.M.T. on this date is shown in Figure 4 (*a*), which is based upon all available information. It would seem that Langjökull, together with any weak anticyclonic circulation which may have been associated with it, was tending to divert air approaching from the south-west, whilst the wide but broken range of mountains, with highest points at about 1,100 metres, which runs south-westwards from Langjökull almost to the south coast had, together with the ice-cap, given rise to the formation of a ridge and trough on the windward and leeward sides respectively. On the western side of the trough, winds which were being diverted to the south of Langjökull had lost some of their moisture on the windward side of the mountains. However, on the eastern side of the trough, winds from the south coast were blowing parallel to the range of mountains without significant interruption. It would seem that the trough continued along the eastern side of Langjökull almost to the north coast, since the southerly winds at Akureyri, which would normally be attributed to the steering effects of local relief,[11] were also experienced by the expedition's long-march party, which was at this time half-way up the northern slope of Hofsjökull. At this latter location the southerly winds, which were estimated to exceed 20 knots, were accompanied by overcast skies.

Wind directions at each of the stations A, E and F fluctuated between west and south-south-west and there were periods duriug which the general wind speed of 10 knots increased to 20 knots (Figure 5 (*a*)). It is particularly noteworthy that whenever the wind veeredto a more westerly point, the absolute humidity values fell appreciably (Figure 5 (*b*)), whereas when it backed towards the south-south-west they increased. Moreover, the veering of the wind at stations E and F at 1100 G.M.T. and at all three stations at 1300 G.M.T., was accompanied not only by lower absolute humidity values but also by an increase in the rate of rise of temperature (Figure 5 (*c*)). In general, temperatures increased to maxima at 1500 G.M.T., and during the preceding hour station F experienced a very marked increase of temperature with an equally sharp decrease in absolute humidity. There was an extensive cloud cover of stratus throughout the 24-hour period, but following a veering of the wind slight breaks occurred, particularly between 1600 and 1800 G.M.T., (Figure 5 (*d*)), and these were accompanied by decreases in absolute humidity values. Furthermore, the sunshine recorder at station A showed a few isolated patches of sunshine

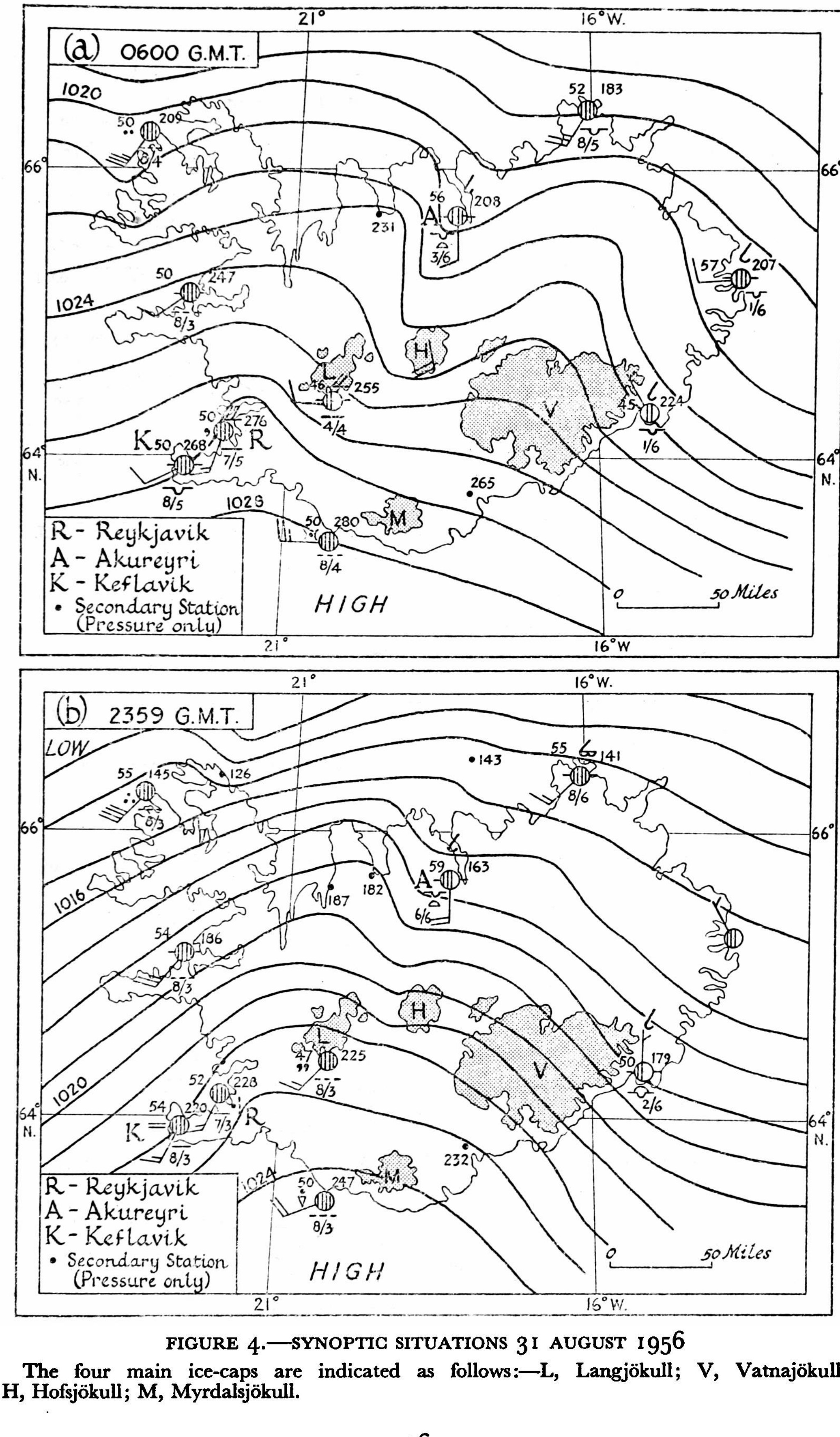

FIGURE 4.—SYNOPTIC SITUATIONS 31 AUGUST 1956

The four main ice-caps are indicated as follows:—L, Langjökull; V, Vatnajökull; H, Hofsjökull; M, Myrdalsjökull.

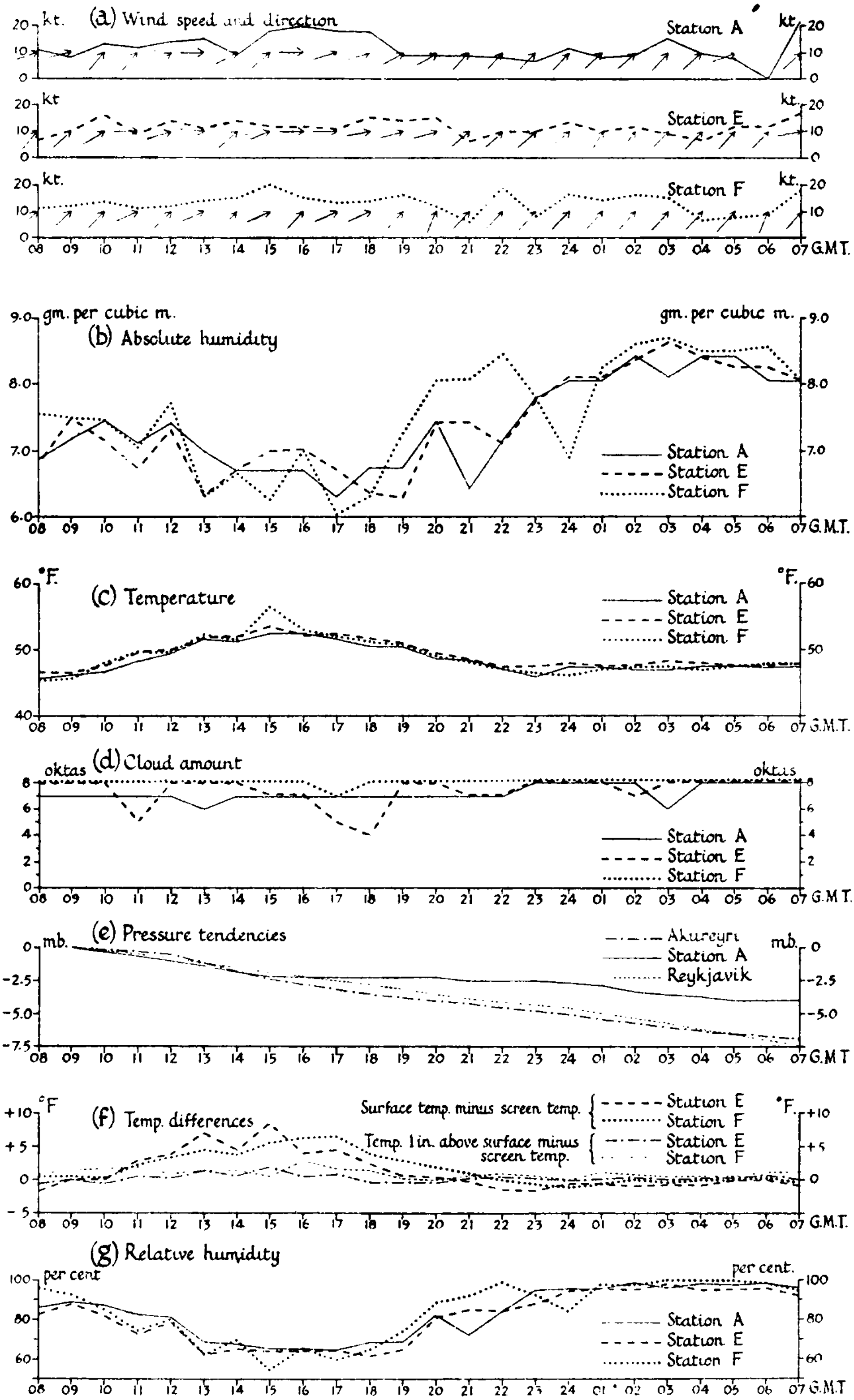

FIGURE 5.—HOURLY OBSERVATIONS 31 AUGUST–1 SEPTEMBER 1956

which coincided with the bursts of more westerly air. All these changes, which were initiated by a veering of the wind, are clearly indicative of Föhn conditions on the eastern side of the mountain range.

Although the three stations were affected by slight changes in the position of the local trough, this lay just to the east for much of the period between 1000 and 1900 G.M.T., and winds which were mainly from the more westerly points resulted in an over-all decrease in the absolute humidity values (Figure 5 (*b*)). However, by 1900 G.M.T. the winds at each of the three stations were beginning to back and thereafter absolute humidity values showed a general increase. The upper winds at Keflavik also showed this tendency, and by midnight a south-westerly airstream was established over the whole of south-west Iceland (Figure 4 (*b*)). Since the winds were now blowing parallel to the mountain range the cause of the local trough had disappeared, and in fact a ridge of relatively higher pressure was forming over the southern part of the central desert. It is significant that until 1500 G.M.T. pressure at station A decreased at the same rate as that at Reykjavik and Akureyri (Figure 5 (*e*)), but that thereafter it remained relatively static whilst that at the two coastal stations continued to decline.

Moreover, soon after the cessation of the Föhn effect, drizzle began to fall at each of the stations A, E and F. A meteorological observer with the expedition's long-march party reported conditions which suggested that the trough moved north from Hofsjökull during the late morning of 1 September.

The sharp falls in absolute humidity which occurred after 2100 G.M.T. and the slight increases of temperature which were recorded after 2200 G.M.T. appear to be connected, as on 28–29 August, with conditions on the ice-cap, since they are similar to those experienced with northerly winds. The fact that on this occasion the winds were south-westerly at 10 knots and that the most southerly station was the last to be affected constitutes a phenomenon of which a convincing explanation has yet to be found.

Under these conditions, with comparatively moist air, gusty winds and generally overcast skies, the temperature range (Figure 5 (*c*)) was very small compared with that of the previous period (Figure 3 (*c*)). Ground temperatures still showed a tendency to rise a few degrees above those recorded in the screen (Figure 5 (*f*)), but this effect was in no way comparable with that of the previous period (Figure 3 (*f*)). Dust-storms, however, were again very marked but there was now no sign of convective activity therein. On the contrary, whenever the wind speed exceeded 12 knots, dust was moved in dense sheets within a few feet of the ground, even though relative humidity was over 60 per cent throughout the period (Figure 5 (*g*)) and was over 80 per cent by 2000 G.M.T. when dust-storms were still being reported.

Conclusions.—Weather conditions typical of any particular air mass may be altered almost beyond recognition as a consequence of the effects produced by the ice-caps and the pronounced relief of Iceland. During the first of the above periods the weather was mainly influenced by the blocking action of Langjökull. Bright, dry conditions prevailed with very marked surface heating and convection, and a local area of low pressure was formed in the lee of the ice-cap. The ranges of air temperature (Figure 3 (*c*)) and relative humidity (Figure 3 (*e*)) were considerable and this probably had a marked effect on the weathering of rock on the desert surface.

Each of the three reporting stations was affected by winds which had passed over the ice-cap. However, those at station F, 6½ miles from the ice-cap, were Föhn winds, and true glacier winds were experienced only at station A, about 3 miles from its edge. During this period dust devils coalesced into large-scale convective dust-storms. These carried dust to great heights and this was deposited in other parts of Iceland or carried beyond its shores.

In the second period, however, the ice-cap played a much smaller part, although the trough formation was due very largely to its influence. Such troughs, which form as a result of the effects of relief upon air flow, may disappear entirely with a change in wind direction or possibly develop into fronts in the general circulation. Under the cloudy and windy conditions which now prevailed, the ranges of temperature and humidity were much smaller, but dust-storms still occurred on a large scale. These, however, were quite different to those which characterised the first period. When wind speeds exceeded 12 knots, dust was moved in dense sheets but only at a very restricted height, and it is probable that none of this material was carried far from its source.

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DIFFERENCES IN THE METEOROLOGY OF THE NORTHERN AND SOUTHERN POLAR REGIONS

By H. H. LAMB, M.A.

Read at the meeting of the International Association of Meteorology, International Union of Geodesy and Geophysics, Toronto, September 1957.

Summary.—Differences in the extent and arrangement of land, ocean and ice, and in the heat budget, introduce important differences of general atmospheric circulation as between Arctic and Antarctic. The southern upper westerlies are more powerful, more nearly circular in course and have less seasonal shift of latitude than their northern counterparts: in latitudes south of 40°S. the main trough and ridge are apparently positioned by thermal controls. At the surface the most striking difference is the penetration of deep, vigorous depressions in many sectors south of 67°S. in winter, so that little of Antarctica can be quite immune from the associated gales and blizzards. There should also be important differences between Northern and Southern Hemispheres in the response to small changes in the amount of incident radiation.

Introduction.—Meteorological differences arise of necessity from the very unlike geographical setting and the, partly consequential, differences of heat budget in north and south.

Shortage of observational data south of 40°S. has until recently compelled all workers on the synoptic weather analysis of the region to appeal to a greater or less extent to analogy with Northern Hemisphere experience. This has served well: for the differences are in the geographical framework and in the large-scale atmospheric flow patterns conditioned thereby, rather than in the meteorological processes observed.

Enough is now known of the prevailing mean-sea-level pressures and 500-millibar heights at the northern and southern flanks of the southern westerlies and from sample soundings within the westerlies to derive a useful first assessment of the strength and broad characteristics of the system. (The Pacific sector must unfortunately still be excluded from these remarks since data about the upper air circulation are still almost non-existent there.) From this it appears that the momentum of the southern circulation is so great that differences in the large-scale effects are by no means confined to the respective polar regions: in some ways the whole world is affected.

Geography.—The southern polar regions are occupied by the most elevated continent in the world whose area in relation to other great land masses is seen in Table 1. Antarctica's longest crossing, on the ninetieth meridian or from the coast of Queen Maud Land near Maudheim to the north coast of South Victoria Land, is about 2,400 nautical miles; from Little America across West Antarctica to the Weddell Sea is only about 1,200 miles.

TABLE I—AREAS OF MAIN LAND MASSES

	Millions of square (nautical) miles
Asia	13·0
Africa	8·7
North America	5·8
Central and South America	5·4
Antarctica	4·0 approx.
Europe	2·8
Australia	2·2
Greenland	0·6
Antarctica plus maximum extent of sea ice	10*

* Sir Napier Shaw's estimate[1] was 13·1 million square (nautical) miles. The new estimate of ten million is based on Mackintosh and Herdman's maps of the ice limits in the Southern Ocean.[2]

In spite of its general elevation of over 2,000 metres, Antarctica has regions which may be considered as fairly extensive lowland (for example, the Ross Ice Shelf—Rockefeller Plateau, the Filchner Ice Shelf south of the Weddell Sea, the Bellingshausen Sea ice and, probably, the hinterland of the eastern Wilkes Land coast). Unlike Greenland, Antarctica serves as the source of vast masses of deep cold air which are observed over the surrounding ocean.

The Southern Ocean rings the earth in 60°S., occupies most of the southern temperate zone and is generally 1,500–2,000 miles or more in width. It is invaded by no great meridional current of warm surface water to compare with the Gulf Stream (North Atlantic Drift) or the Kuro Shiwo (North Pacific Current). The more or less sharp water-current boundaries—the subtropical and Antarctic convergences—pursue a broadly zonal course, mostly near 40°S.

and 50–55°S.: only the Antarctic convergence, the boundary between Antarctic and intermediate water, has a decided north-eastward trend in one sector 80–35°W. between Drake Passage and a point north of South Georgia (that is, from about 62°S. to 48°S.).

By contrast, the central Arctic is a deep ocean with access to warm water of North Atlantic origin through the broad channel of the Norwegian Sea and Barents Sea. Nevertheless, the main ocean surface freezes in winter to form a continuous surface of ice and snow with the great continents which occupy most of the zone of westerlies 40–70°N.

The seasonal variation of extent of frozen surface is seen in Table II. Here the effect of Asia and North America in extending the frozen surface in winter and introducing a strongly heated surface to 70°N. in summer is clearly seen.

TABLE II—EXTENT OF SNOW AND ICE SURFACE

	Area in millions of square (nautical) miles	Equivalent latitude of limit
Antarctic		
Summer minimum (February–early March)	5·7	68°S.
Winter maximum (about September) ...	10 approx.	60°S.
Arctic		
Summer minimum (August–early September)	3·2 to 3·6	72–73°N.
Winter maximum (January–early February)	16 to 19	50°N.

Note:

1. Equivalent latitude of the limit is the position in which the boundary would lie if the frozen surface were circular and concentric with the Pole.
2. For the Antarctic, areas are measured from the normal limits of ice given by Mackintosh and Herdman.[2]
3. Arctic summer minimum areas are measured from charts published in the yearly volumes of *Isforholdene i de arktiske Have.*[3] The minimum area of northern ice, $3{\cdot}2 \times 10^6$ square nautical miles, refers to the optimum summers of the 1930's; the higher figure for the minimum occurred in the decade 1910–19 and probably also in more recent years.
4. Arctic winter maximum areas are measured from unpublished maps of the snow-and-ice limit. The northern winter ice- and snow-cover presents a non-circular form and the part south of 45°N. over the continents is generally impermanent, much of it thin snow easily removed by invading warm air, rain or sunshine. This leaves about 14×10^6 square nautical miles of well established snow- and ice-cover in January, corresponding to an equivalent latitude for the limit of 55°N.
5. A change of one degree of latitude in the mean position of the ice limit around the entire Southern Ocean at the time of the winter maximum would amount to about 8–10 per cent of the total extent of sea ice; a similar shift at the end of the melting season would amount to 30 per cent or more of the sea-ice belt, but would be less likely to occur because the present summer minimum normally eliminates the pack-ice belt in some eastern longitudes.

In midwinter part of the central Arctic about 75°N., 140°E.–140°W. partially isolated from the Pacific by high mountain chains* and beyond the limit of penetration of most Atlantic depressions following the favourite tracks towards the Barents and Kara Seas, is generally more remote from the main energy sources of cyclonic activity than anywhere in the Antarctic ever is. An exception to this statement may be represented by depressions deepening over the relatively warm open water in the one sector Denmark Strait–Barents Sea. Nowhere within 2,000 miles of the inner Arctic area specified do the gradient winds indicated by the mean 500-millibar pattern in winter exceed 20–25 knots; the region appears as an anticyclonic development area in relation to the nearest confluence in the 500-millibar flow over northern Canada: but at 60°S.

* The significance of mountain ranges, with extensive snow surfaces on the low ground beyond them, in blocking the advance of warm air was explored by the present author in an earlier paper.[5]

mean wind speeds over 40 knots are indicated, summer and winter, in most sectors. Upper winds observed over the South Pole International Geophysical Year station have been variable and at times quite strong, occasionally well over 100 knots at the maximum wind level, though more usually only 20 to 40 knots. (The maximum wind appears to be commonly at about 350 millibars.) The general run of depressions along the Antarctic fringe appear more vigorous in both summer and winter than in corresponding northern regions and gales are more frequent in the Antarctic than in the Arctic, whether we compare coastal or inland areas.

Radiation and heat budget.—The quantity of energy Q_s from solar radiation, which would fall on each square centimetre of horizontal surface *per diem* in the absence of the atmosphere, has its maximum value of about 1,150 gramme-calories at the South Pole about the December solstice. The corresponding value at the North Pole on 21 June is about 1,080 gramme-calories. There are secondary maxima at the solstices respectively of 1,060 near 48°S. and 1,000 near 48°N. At the equator the figure is between about 790 and 900 gramme-calories at all times of the year. (The figures are based on Milankovitch[6] but adjusted for reduction of the mean solar constant from 2 to 1·94 cal. cm.$^{-2}$ min.$^{-1}$. More recent estimates by Houghton[7] for the Northern Hemisphere based on the United States pyrheliometric measurements are in sufficient agreement.)

The over-all range of values of Q_s within each hemisphere is greatest at the equinoxes, but this over-all range is less important than the intensity of the zones of sharp gradient of net energy received, resulting from the modifying influence of such factors as cloudiness over the oceans and the high albedo of snow and ice.

Figure 1 is designed to show where, from radiation considerations, we should expect the main thermal gradients to be and where we actually find them in terms of 1000–500-millibar thickness. (The apparent discrepancies are no doubt mainly attributable to moisture effects—the density of water vapour and the redistribution of heat through liberation of latent heat of condensation—and to the effects of the circulation itself, but in the case of the Antarctic summer Simpson's radiation estimates here used seem to assume too low an albedo.)

Some fraction t of the incident solar energy actually reaches the earth's surface in the form of direct and diffuse radiation. This depends on the distance traversed through the atmosphere by the sun's rays and on the transmissivity of the atmosphere, affected by cloudiness, dust etc.

The balance of energy Q finally available for heating the earth's surface is given by

$$Q = t\,(1 - A)\,Q_s - Q_e$$

where A is the albedo of the surface and Q_e is the quantity of energy lost as outgoing terrestrial radiation. There are liable to be strong gradients of Q where A changes abruptly, for instance near the limit of the snow or ice surface.

Actually only a certain fraction b of Q is used in heating the surface, the remainder penetrating to some depth which is effectively very small on dry land but great in the oceans. Thus b changes abruptly at coastlines and produces further strong gradients of surface heating along the fringes of the continents.

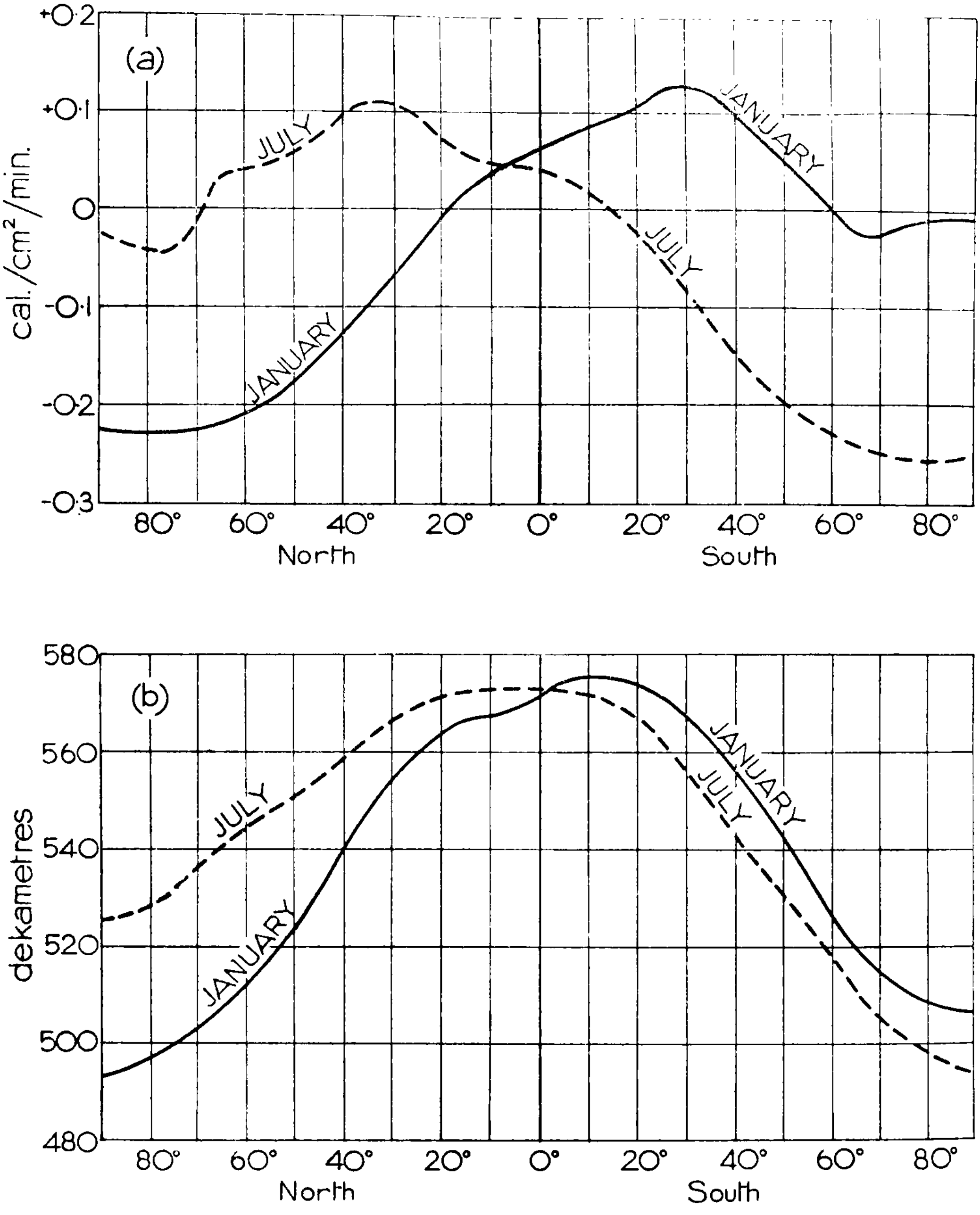
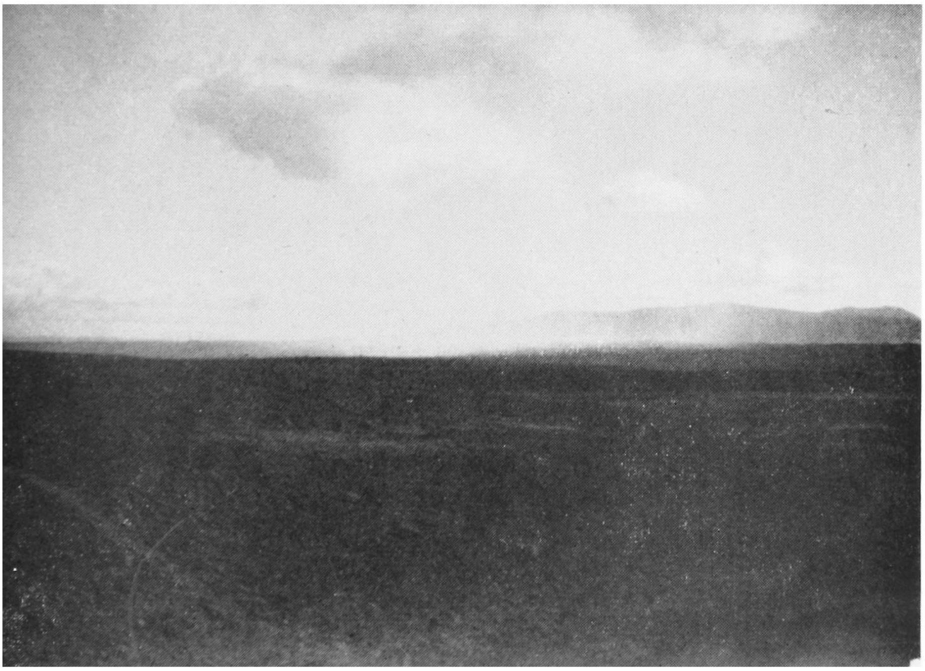


FIGURE 1.—LATITUDINAL DISTRIBUTION AND GRADIENT OF (*a*) INTENSITY OF NET RADIATION RECEIVED (AFTER SIMPSON) (*b*) 1000–500-MILLIBAR THICKNESS

Note: The main slope in middle latitudes is in each case slightly steeper in January than July. The thickness maxima are displaced towards the equatorial zone, also thickness values are high in relation to the net radiation receipt in the Southern Hemisphere in winter (moisture effects). The apparent discrepancy between the thickness and the radiation receipt in the Antarctic summer (January) is attributed to Simpson's underestimate of the albedo (0·65 for 0·8 to 0·9).

Photograph by F. G. Hannell

(*a*)



Photograph by F. G. Hannell

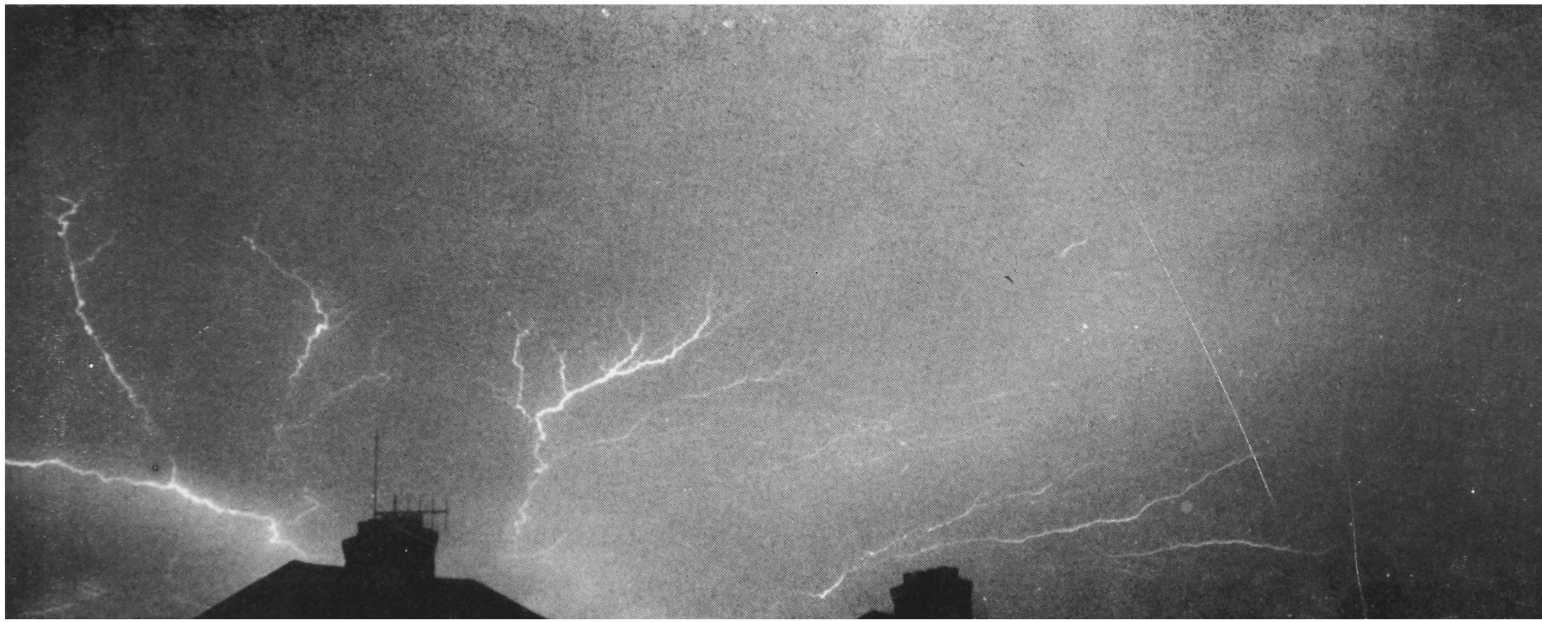
(*b*)

DUST-STORM ACTIVITY TO THE SOUTH OF STATION A ON 17 AUGUST 1956

(*a*) At 1530 G.M.T.: A single dust devil under cumulus cloud indicates the commencement of strong convective activity.

(*b*) At 1645 G.M.T.: Individual dust devils have coalesced into an area of general convection.

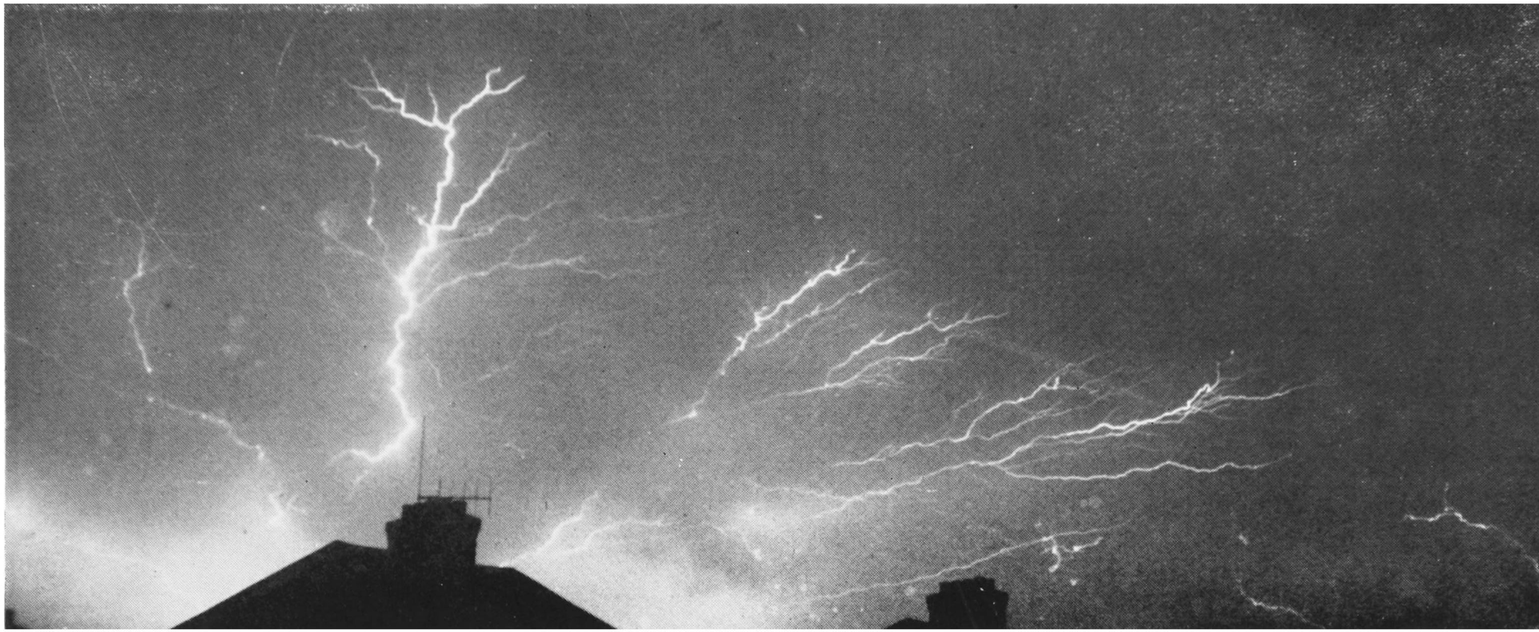
(see p. 353)



Photograph by T. Summers

LIGHTNING WITH UPWARD BRANCHING AT MILL HILL, LONDON, 5 SEPTEMBER 1958

(see p. 379)



Photograph by T. Summers

LIGHTNING WITH UPWARD BRANCHING AT MILL HILL, LONDON, 5 SEPTEMBER 1958

(see p. 379)

Photograph by D. W. Leddra

LIGHTNING FLASHES AT MOTTINGHAM, LONDON, 5 SEPTEMBER 1958
(see p. 379)

The albedo of the Antarctic snow surface appears to be between 0·8 and 0·9 at all times of the year,[8] and over the ice-cap the radiation balance is believed to be always negative.[9] By contrast, much of the Arctic snow and ice surfaces near sea level are modified by melting in summer; their albedo falls to between 0·64 and 0·7 at this season. At the extreme coast of Antarctica, and over a vastly greater proportion of the northern polar region, there are doubtless periods in summer of radiation gain. The average albedo for the whole earth is around 0·4.

Simpson[10] calculated realistic values of inward radiation received, $t(1 - A)Q_s$, for both clear sky and average cloudiness and also of Q_e and Q, to produce world maps. The curves (Figure 1) of difference between incoming and outgoing radiation averaged over each latitude, following Simpson, show the main gradient in middle latitudes; in the Northern Hemisphere this gradient is clearly steepest in winter, apart from the narrow zone of very steep summer gradient at about 70°N. corresponding to the heated land–Arctic ice boundary. In the Southern Hemisphere on balance there is not much difference between the summer and winter gradients of Q in middle latitudes: the strong gradient affects a broader range of latitudes in winter but between 45°S. and 60°S. near South America the gradient is decidedly strongest in summer. This gradient appears to be of the same order as that near the Atlantic coast of the Sahara and the Arctic coast of Asia or America in summer. In either hemisphere there is a latitude zone over which as a whole the gradient of Q is sharper in summer than in winter, respectively about 65–75°N. and 50–65°S. In both cases there is evidence of increased cyclonicity arising in or near the zone concerned in late summer–autumn, and over much of the zone 50–65°S. the mean tropospheric winds are probably rather stronger in late summer–autumn than in winter.[11]

Simpson's calculations suggest that the quantity of heat which must be made good per year by atmospheric and oceanic transport polewards across latitudes 30° to 40° is about 20 per cent, and across latitude 50° about 7 per cent, greater in the Southern than in the Northern Hemisphere. Oceanic transport contributes nothing south of 40°S., so Sverdrup estimated that the atmospheric contributions across the 40 and 50°S. parallels should be respectively 28–30 per cent and 7–8 per cent greater than those across the corresponding parallels in the Northern Hemisphere.[12] Since the steady meridional airstreams associated with stationary persistent blocking are rare in the Southern Hemisphere, it seems likely that the greater transport is mainly achieved by latent heat of condensation liberated in frontal processes over the Southern Ocean.

Meteorological consequences.

(*a*) *Upper air.*—1000–500-millibar thicknesses in summer and winter over the Arctic and Antarctic register the effects of the differing heat budgets.*

The Antarctic cold region is much more nearly circular than its northern counterpart, but it is centred somewhat away from the pole, in both summer and winter, near the true centre of the ice region at about 81–86°S., 50–70°E. In summer average 1000–500-millibar thicknesses are below 5,100 metres

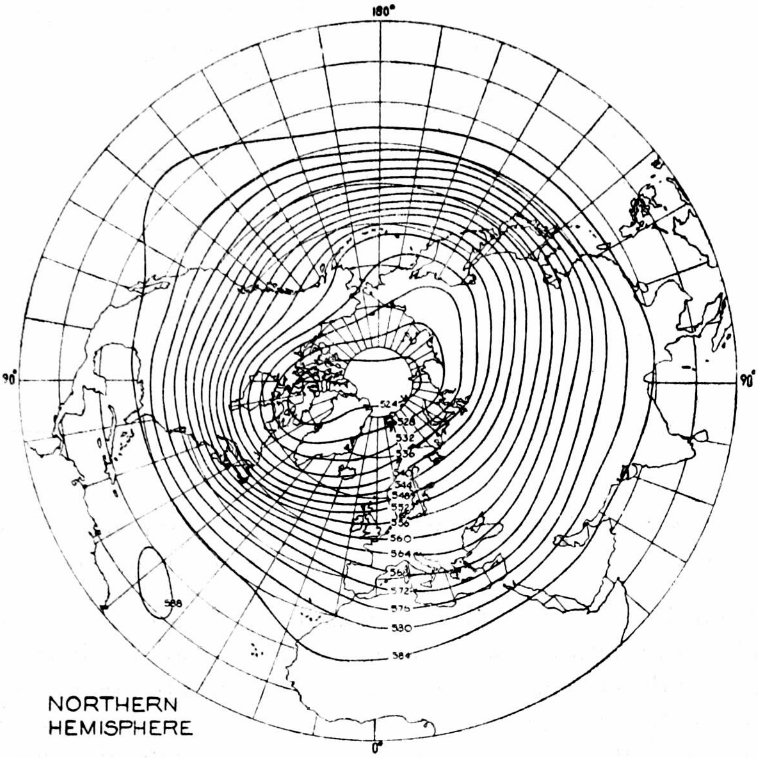
* Average upper air values and patterns over the far south referred to in this section have been derived from maps and data published in *Notos*, [13] except where otherwise stated. Corresponding Northern Hemisphere values are taken mostly from data computed in the Meteorological Office, London and partly published—an example is *Meteorological Reports* No. 13.[14] Earlier comparisons between the general circulation over the Northern and Southern Hemispheres by Gibbs[15] were based on much more restricted chart material.

over a roughly circular area 1,700–2,000 miles across, corresponding to maximum surface temperatures well below the freezing point all over the interior of Antarctica (−15°C. is the highest so far recorded on the South Polar Plateau—prior to the current International Geophysical Year expeditions. The highest reading at the South Pole in summer 1956–7 was −18°C.). Snow is the prevailing form of precipitation south of 60°S. even in summer, whereas rain is not uncommon near the North Pole between June and August[16] and actual minimum values of 1000–500-millibar thickness anywhere in the Arctic appear to be above 5,100 metres in July and August. By contrast, Antarctic winter values of 1000–500-millibar thickness appear to be slightly above the averages for the Canadian cold pole or north-east Siberia. At Maudheim (71°S., 11°W.)[17] observed temperatures at 500 millibars and below in the five late-winter months June–October were 1–3°C. higher, level for level, than in the corresponding months at Arctic Bay (73°N., 85°W.); but Maudheim was generally colder at all other levels and at all other times. The biggest disparity was in winter at 100 millibars and higher, where averages at Maudheim were in some cases below − 80°C. (at 50 millibars in July − 87°C.) and not below −58°C. at Arctic Bay. Summer temperatures above the 100-millibar level were closely alike in Arctic and Antarctic when latitude differences were allowed for.

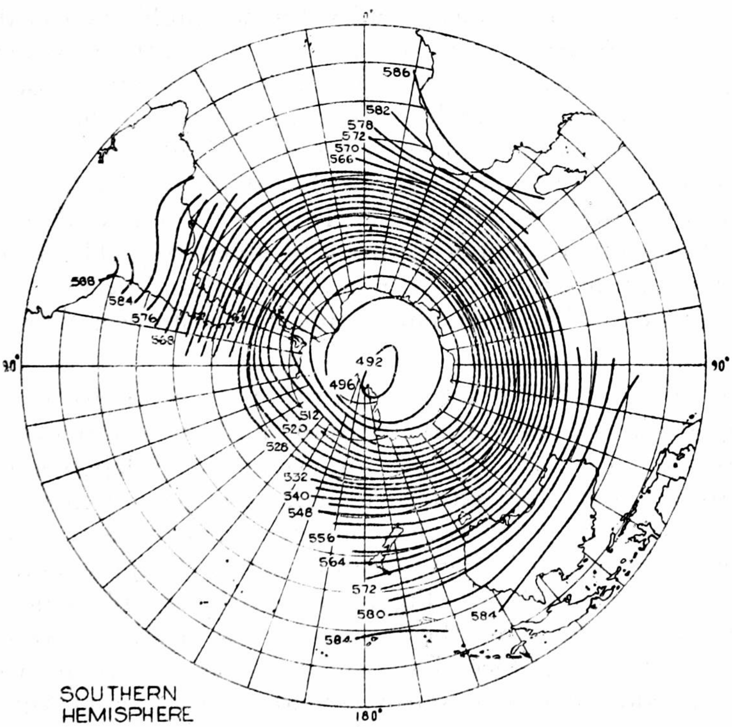
Surface temperatures probably fall below − 60°C. at times every winter over the inland ice of Antarctica at 67–90°S. (especially in the eastern sector between 50°E. and the Ross Ice Shelf, where owing to the general circulation near the surface the air habitually has had the longest run over the inland ice). The colder Antarctic stratosphere can reasonably be attributed to less upward radiation of heat from the ice surface and from clouds than takes place over the central Arctic pack-ice as suggested by Schumacher.[17] On the other hand the rather colder troposphere over the cold pole near 70°N. in winter probably means that the region concerned is more nearly immune from occasional advection of oceanic air than anywhere in the Antarctic.

Figure 2 shows the mean 500-millibar topography over the Northern and Southern Hemispheres. Unlike the northern pattern with its familiar troughs over north-east Canada and Asia, amounting almost to "twin" poles,† the southern circulation is nearly circular and the profiles along the 50°S. and 60°S. latitude circles shown in the subscript on Figure 2 are necessary to make clear where the mean troughs lie. In 50°S., and more clearly at 60°S., the main trough is in the Indian Ocean sector about 100–110°E., where it cannot be attributed to any orographic obstacle in the main flow. This trough appears most likely related to the quasi-permanent outflow of cold air from East Antarctica between 50°E. and 150°E. and possibly in the northern summer its amplitude may be increased by the Indian monsoon. The most noticeable warm ridge is about 150°E.–150°W. in the western Pacific, south of New Zealand. (A ridge pushing in from the north over Antarctica near the 140°W. meridian, east of the Ross Sea, has been reported by Rubin[18] to be a common feature of the first few months of daily charts at 500 millibars and higher levels

† Twin poles are very commonly present in the Arctic winter and may indeed be the usual condition. The minimum of 500-millibar height on the Asiatic side makes a less strong mark upon the average pattern at least partly because it is more variable in position than that on the Canadian side.



Average for the months January, April, July, October (1949–53).



Average for the year (1952–54 approx.).

FIGURE 2.—MEAN HEIGHT IN DEKAMETRES OF THE 500-MILLIBAR SURFACE

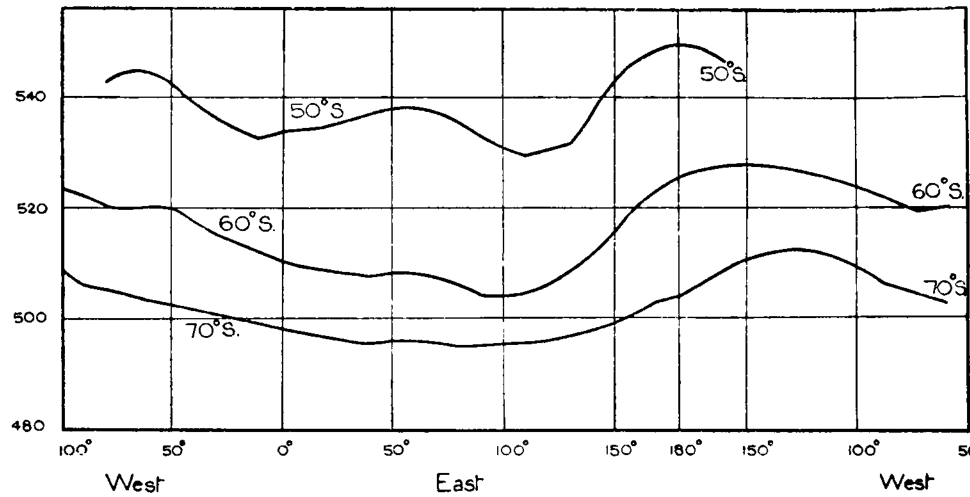
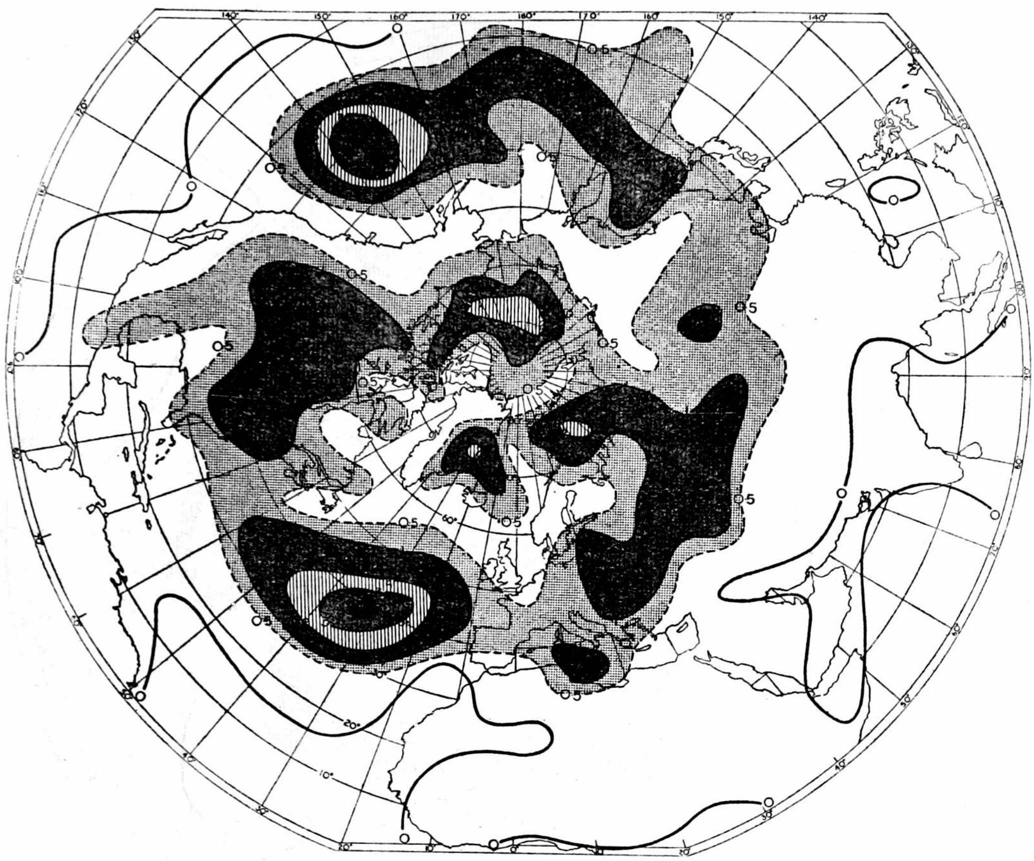


FIGURE 2.—MEAN HEIGHT IN DEKAMETRES OF THE 500-MILLIBAR SURFACE (*cont.*)
Yearly mean profiles in the Southern Hemisphere to show trough and ridge positions.

analyzed from International Geophysical Year Antarctic aerological observations.) The mean latitude of the strongest flow at 500 millibars shifts only a few degrees with the changing seasons, ranging for instance between about 50°S. and 58°S. at 70°E.[19] The position is about eight degrees north of the ice limit and the seasonal shift is identical with that of the ice limit, also eight degrees.

Calculation based upon the best available estimates of average upper winds indicates that the southern circumpolar westerlies carry much more momentum than any other wind system in the world. The overweight is primarily located in the lower troposphere from mean sea level to 500 millibars over the Southern Ocean in 40°–60°S. At levels up to 500 millibars the southern westerlies appear to be the most powerful wind system in the world at all seasons. Tentative integration of the westerly angular momentum between the 1000- and 100-millibar levels in either hemisphere between latitudes 0° and 70° suggests ratios of Southern to Northern Hemisphere of about 1·5 for the momentum of the westerlies over the year as a whole. In the northern summer the ratio is about 4; in the northern winter it drops to about 0·7. The ratios of linear westerly momentum are rather higher in each case and average nearly 2 over the year as a whole. (These estimates omit the Pacific sector between 170°E. and 70°W.)

(*b*) *Surface connexions*.—The unbroken ring of the Southern Ocean and the permanently strong thermal gradient from north to south over it make it almost impossible for even the biggest anticyclones and depressions to create a sufficiently distorted thermal pattern to maintain the system stationary over the ocean south of 40°S. Whole regions of the Southern Ocean, especially in the southern part of the broad Indian Ocean trough, are almost entirely avoided by the centres of anticyclones (Figure 3). Elsewhere blocking patterns do appear from time to time, but the systems are usually soon swept away by a renewal of the westerlies. Occasional linkages, when a ridge from the subtropical high pressure belt temporarily extends over a part of Antarctica, may be important in rejuvenating the polar anticyclones usually centred over East Antarctica near 80°S., 40°–90°E.; but there is no southern equivalent of either the persistent meridional airstreams associated with blocking anti-



(*a*) Northern Hemisphere, summer, 1952–54

FIGURE 3.—DISTRIBUTION OF ANTICYCLONE CENTRES

Unit: Percentage frequency of daily occurrencies per 100,000 square kilometres.

cyclones in 50°–70°N. or the persistent winter ridge of high pressure linking the anticyclones of the Azores region across Europe and central Asia with north-east Siberia and the Arctic ice north of Alaska.

The three regions most favourable for anticyclones over the ocean south of 40°S. are

(i) between Australia and 140–160°W. in association with the upper ridge already noted,

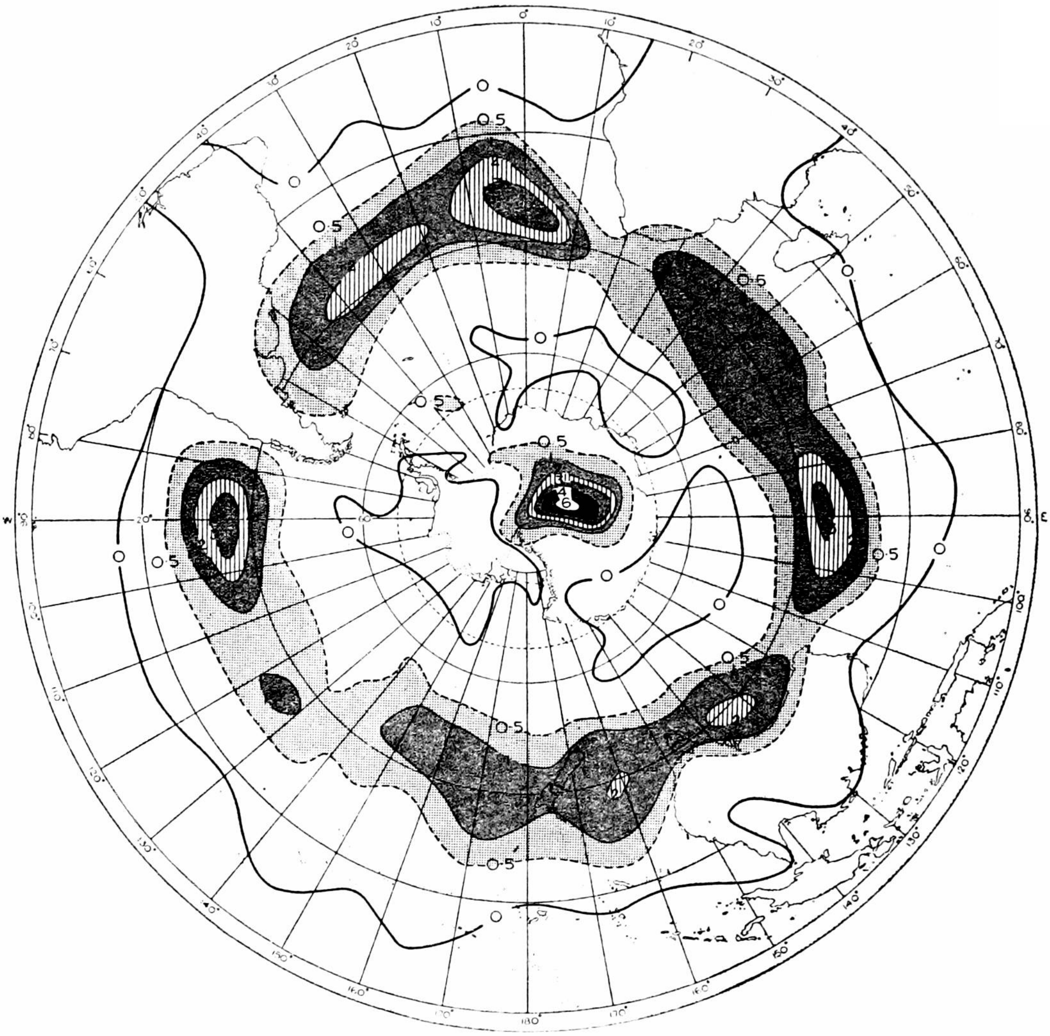
(ii) just east of South America, west of the trough in the South Atlantic,

(iii) between South Africa and about 60°E., west of the Indian Ocean trough.

These positions happen to be just east of each of the southern continents, not west as are the Alaskan and Scandinavian blocking anticyclones, but the relation to the thermal pattern is straightforward (that is, in keeping with Sutcliffe and Forsdyke[20]) in both hemispheres.

The large size* of the low pressure systems of the Antarctic fringe in the colder seasons produces outstandingly low mean pressures in late winter near the coast of Antarctica between about 50–90°E. and the Ross Ice Shelf

* More or less circular depressions attain a diameter of over 1,500 nautical miles several times a winter and depression complexes may be up to 3,000 miles or more across over the Southern Ocean.



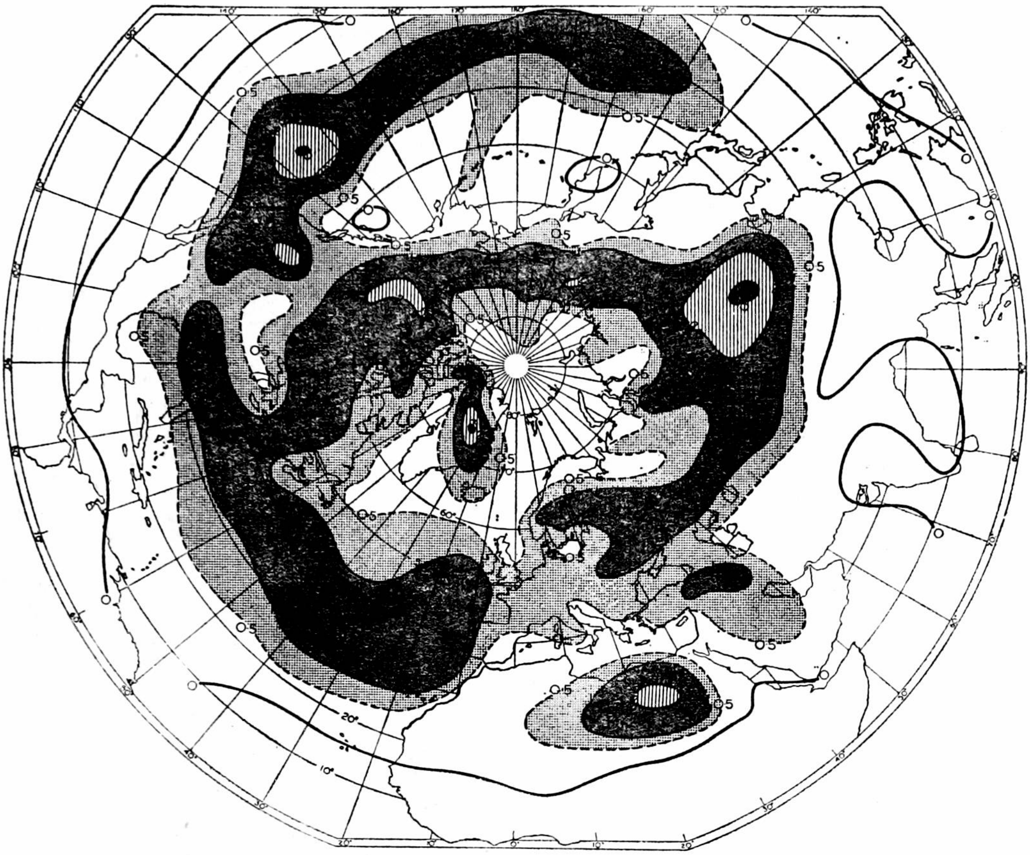
(*b*) Southern Hemisphere, summer, 1951–4

FIGURE 3.—DISTRIBUTION OF ANTICYCLONE CENTRES (*cont.*)

Unit: Percentage frequency of daily occurrencies per 100,000 square kilometres.

(160°E.–150°W.) and also incursions of some depression centres far over the Antarctic ice. The culminating phase is in August to October (October mean pressure, near 78°S., 166°W., from nine years' observations in the southern Ross Sea is 974 millibars, standard deviation 3 millibars; October mean pressure on the coast near 67°S., 90–95°E. is 980–982 millibars. Compare the lowest monthly mean pressures in the Icelandic depression—modal value 990 millibars, lowest known value in 85 years 977 millibars in 1890). The annual pressure trend in these eastern sectors of Antarctica appears "anti-monsoonal" (summer maximum and winter minimum); the only Arctic analogy is between South Greenland and Bear Island in the region most closely affected by the main Atlantic depressions.

Average mean-sea-level pressures south of about 45°S. are so much lower than in corresponding northern latitudes that there appears to be an over-all deficit of atmospheric mass in the Southern Hemisphere as compared with the Northern



(*c*) Northern Hemisphere, winter, 1952–55

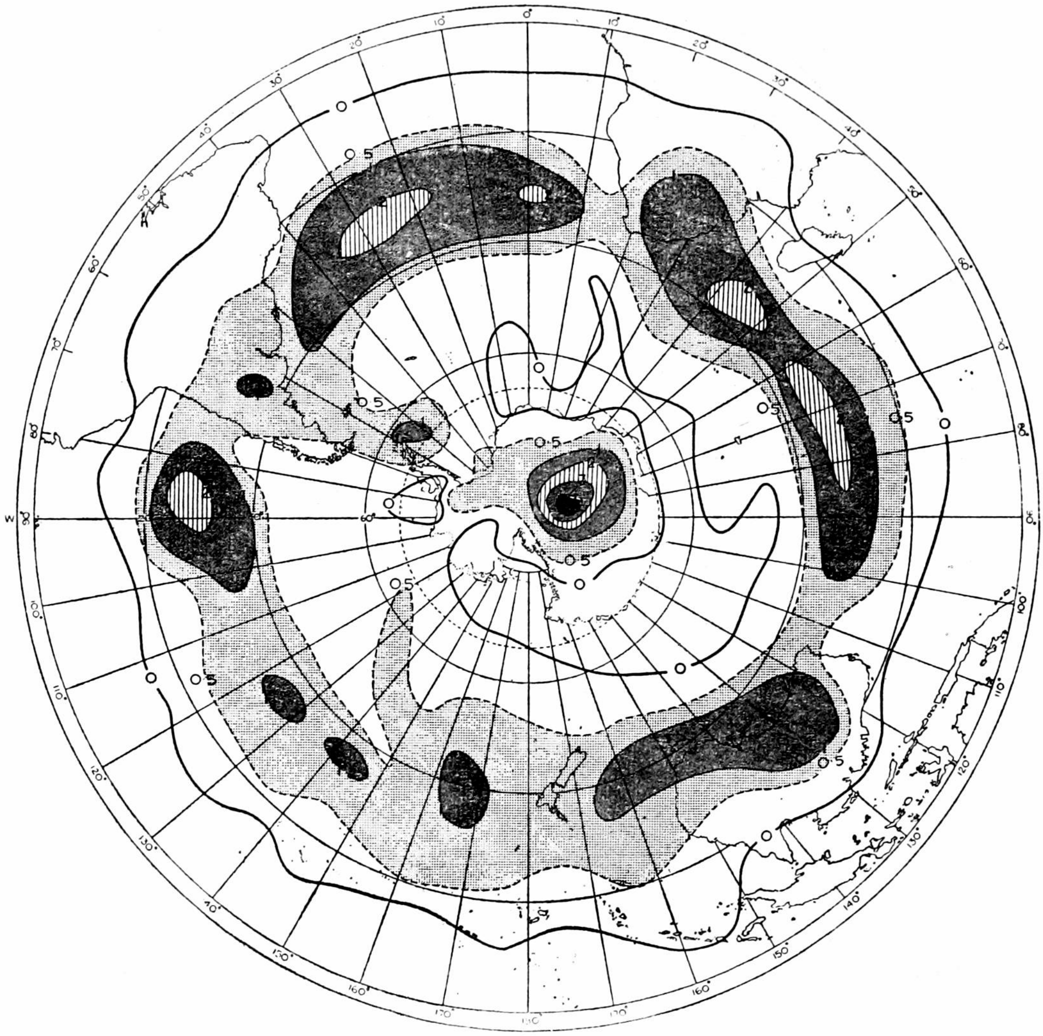
FIGURE 3.— DISTRIBUTION OF ANTICYCLONE CENTRES (*cont.*)

Unit: Percentage frequency of daily occurrencies per 100,000 square kilometres.

Hemisphere (Figure 4). In latitudes 60–70° the disparity amounts to 22–23 millibars.* The southern subtropical pressure maximum is about 5° latitude nearer the equator, summer for summer and winter for winter, than its northern counterpart.† These phenomena may be linked with the outstanding momentum of the southern westerlies, possibly through the Nullschicht effect,[19,23] which indicates on balance a more or less steady transference of mass towards the warm side of the strongest windstreams at altitudes near the maximum-wind level. (Meteorologists were first exercised by the problem of the very low atmospheric pressures in the Antarctic seen in the observations of Sir James Clark Ross in 1839 to 1842. As explanation, the centrifugal effect of the southern westerlies was put forward independently by Ferrel and by J. J. Murphy about 1856.)

* This disparity was to be seen in the figures for mean barometric pressure in latitude zones given by Teisserenc de Bort[21] in 1893 and was several times alluded to by Meinardus, but has so far hardly received notice in the text books, except in Hann's *Lehrbuch der Meteorologie.*[22]

† Another symptom of the displacement of the southern climatic zones into lower latitudes than their northern counterparts is to be observed in the latitude of glaciated features. The small mountainous island of Kerguelen (49°S., 70°E.) has many great glaciers some of which reach the sea. The northernmost glacier from the Patagonian ice-cap reaches the sea at 46° 40′S., 74°W. on the Chilean coast, ten degrees nearer the equator than any Alaskan glacier. Moreover the ice in 40–60°S. shows signs of advance rather than recession over the past century or so.



(*d*) Southern Hemisphere, winter, 1952–54

FIGURE 3.—DISTRIBUTION OF ANTICYCLONE CENTRES (*cont.*)
Unit: Percentage frequency of daily occurrencies per 100,000 square kilometres.

Table III gives comparative values of mean-sea-level pressure at the centres of the main subpolar and polar pressure systems on daily synoptic charts. In considering the lower pressures in the Antarctic and sub-Antarctic it must be remembered that the intensity of a particular system is related to the pressure departure from normal for the region. In the Antarctic winter there appear to be occasions, probably ranging from 10–50 per cent in different years (and over 50 per cent in occasional months) when there is no room for any anticyclone south of the depressions and jetstreams of the polar front. In the northern winter there is probably never a day when no polar anticyclone is present over some part of the extensive snow-cover, though there are days when relatively low pressure dominates most of the polar basin and the anticyclones are centred over the surrounding continents.

In summer, both in the Arctic and Antarctic, there is no polar anticyclone on a few days, probably varying from 0–10 per cent in different years.

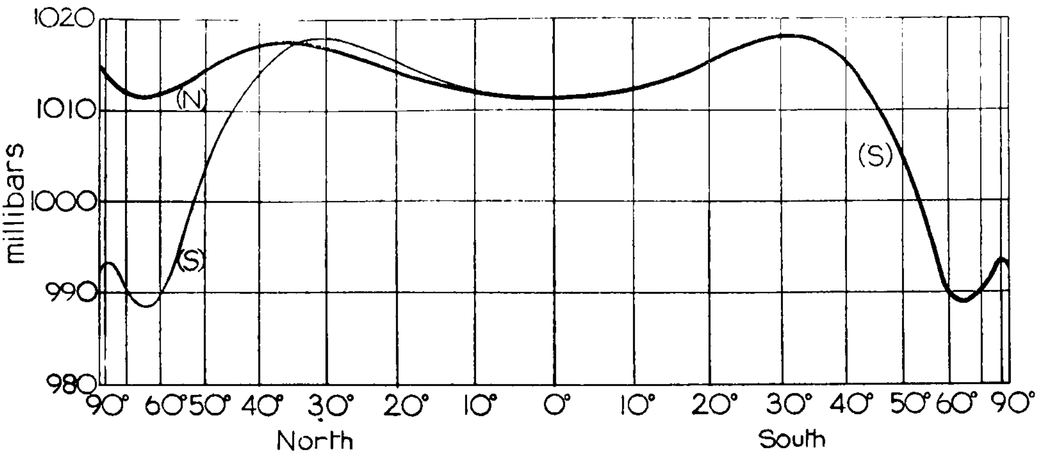


FIGURE 4.—MEAN PRESSURE OF THE ATMOSPHERE AT M.S.L. IN DIFFERENT LATITUDES—AVERAGE OF JANUARY AND JULY

The Southern Hemisphere curve is repeated as a thin line on the Northern Hemisphere side for comparison.

TABLE III—CENTRAL PRESSURE (IN MILLIBARS) OF MAIN SYSTEMS ON DAILY SYNOPTIC CHARTS

Period	Commonest range (mb.)	Approx. frequency (per cent)	Extremes likely about once a year (mb.)
	Sub-Antartic depressions		
Summer (Dec.–Feb.) ...	960–979	70–80	945
Winter (June–Sept.) ...	950–969	60–70	928
	Anticyclones over Antarctica		
Summer (Dec.–Feb.) ...	1000–1009	65	1018
Winter (June–Sept.) ...	1000–1009	60	1030
	North Atlantic depressions		
Summer (June–Aug.) ...	990–999	50–55	974
Winter (Dec.–Feb.) ...	970–979	30	947
	Northern polar anticyclones		
Summer (June–Aug.) ...	1020–1029	65	1038
Winter (Dec.–Feb.) ...	1030–1049	60–65	1065

Variations of the general circulation and climatic changes.—It appears that, owing to unlike geography, the responses of Northern and Southern Hemispheres (in temperate and polar latitudes) to any small changes in insolation should be fundamentally different.

Let us consider the likely effects of a reduction of a few per cent in the incoming radiation, such as may have been characteristic of the latter part of the nineteenth century, at least. There would be little, or only a very slow, effect upon the surface temperature of most oceans. Over the interiors of the temperate northern continents and Antarctica, however, summer and winter temperatures should fall by some degrees: this assumes insignificant changes of cloud amount over these regions, especially in Antarctica (where mean cloudiness is always low) and in the winter night. These changes might well suffice to stop all effective summer melting of the Antarctic ice-cap, reduce its plasticity and therefore reduce its rate of outflow. In consequence the sub-Antarctic belt of sea ice should contract, and places between 40°S. and the coast of Antarctica should become rather warmer. The southern westerlies should be displaced south by a degree or more. By contrast, over the Arctic Ocean the direct effects of insolation changes should be small on account of summer cloudiness, though the greater cooling of the temperate northern continents would contribute to greater production of sea ice and some equatorward expansion of the zone of maximum thermal gradient in the Northern Hemisphere.

These effects appear to act in the same sense as any world-wide adjustment to the strength and position of the southern westerlies.

If it is at bottom the overwhelming strength of the southern westerlies which maintains a generally low level of pressure over the Antarctic and climatic zones shifted towards the north, then either weakening or southward displacement of the southern westerlies might entail some southward adjustment of all the world's climatic zones. (On average over all longitudes secular fluctuations in recent centuries could only amount to 1 to 2° latitude, but for geographical reasons they might well be exaggerated in the North Atlantic sector.)

These propositions are in keeping with the occurrence of opposite climatic trends south of 40°S. and over most of the rest of the world, which appear to have been observed since the late nineteenth century, and imply that the trends observed up to about 1940–50 were such as might be expected with increasing radiation receipt.

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NOTES AND NEWS

Loan of American meteorological aircraft and instrumentation

Arrangements have been made by the Director-General of the Meteorological Office with United States authorities for the loan of the U.2 Meteorological Research Aircraft to be flown from this country by Royal Air Force pilots under the technical control of the Meteorological Office.

Flights in the United States with this aircraft have produced very valuable meteorological data and it is hoped that equally valuable results will come from flights from the United Kingdom.

The meteorological instrumentation specially designed for this aircraft has also been obtained on loan from the United States Air Weather Service and the National Aeronautics and Space Administration but it is the intention also to adapt British equipment as far as possible.

Lightning with upward branching

We are indebted to Mr. Terry Summers, 12 Holmwood Grove, Mill Hill, N.W.7 for the two photographs of lightning in the centre of this magazine. They were taken during the thunderstorm of Friday, 5 September 1958 at about 2015 G.M.T. looking north-east. They are of special interest as showing flashes with the unusual upward branching which is believed to be associated with the unusual "upward leader" type of lightning stroke first observed in flashes striking the Empire State Building, New York. Mr. Summers reports that there are two tall spiky buildings in the direction of the flashes on the photograph.

Lightning flashes

We are indebted to Mr. D. W. Leddra, 3 Beaconsfield Road, Mottingham, London, S.E.9 for the photograph, facing page 369, showing three very close bright flashes apparently going to earth taken from his home with a 5-second exposure at 2000 G.M.T. on the evening of 5 September 1958. The branching of these flashes is the more usual downward one.

Extreme wind speeds over Great Britain and Northern Ireland

The following corrections should be made to this article in the September 1958 Meteorological Magazine:

P. 258, line 16; *for* "plotted again" *read* "plotted against".

P. 262, line 1; *for* "49 anemograph stations" *read* "48 anemograph stations".

P. 265, line 22; *for* "order of 10 seconds" *read* "order of a second".

METEOROLOGICAL OFFICE NEWS

Academic successes.—The following members of the staff have been successful in recent examinations. We offer them our congratulations.

B.Sc. (General): P. D. J. Rae.

General Certificate of Education (Advanced Level): R. J. Adams, J. Barker, G. P. Carruthers, B. Castle, F. Dalton, C. M. Draper, L. Gurney, Miss V. L. Gurr, R. N. Hardy, Miss M. Hoare, W. J. Hunter, C. Johnson, R. F. Johnson, J. Lack, J. G. Leslie, Miss M. J. Llewellyn, Miss B. A. Marsh, J. D. Randall, W. R. Sparks, J. A. Walke, E. J. Whitelam.

Higher National Certificate: G. A. Samuel.

Sports activities.—*Swimming.*—At the Air Ministry Swimming Gala held at Marshall Street Baths on 3 November, Miss R. M. Overton won the Ladies' Championship. The Office Ladies' Relay Team (Misses Overton, Lonnen and Leyland) won the Relay Championship.

Shooting.—Mr. P. S. Griffiths and Mr. K. Bruley have had a very successful year in the Civil Service Rifle Association Competition, obtaining three first prizes and one second. Mr. Griffiths also won a Bronze Medal at the National Rifle Association Imperial Meeting at Bisley. In addition they were two of the Bishops Stortford Rifle Club team of four that won the Youngsbury Cup.

Courses of training for climatological observers

Two Courses, each lasting four and a half days, were held in October 1958, at the Meteorological Office Training School, Stanmore. Fifty-two observers came, the largest number ever to attend. Instruction and discussion covered all aspects of weather observing and recording. Special attention was given to the new monthly return form (Form 3208) which is to be used at all co-operating climatological stations from November 1958 so that their data may be punched on Hollerith cards. Talks were given on the application of the data to climatological, agricultural and hydrological problems. Films and slides were shown. During visits to Harrow the general work of the Climatological Branch, the punching of data on to cards (which attracted special interest this year) and the testing of instruments were seen and discussed. The London Forecast Office was also visited. The courses are designed to help the observers with their specific work, to broaden their interest in meteorology, and to give them an insight into the ultimate value of the observations. It is hoped to arrange similar courses in October 1959.

OFFICIAL PUBLICATION

The following publication has recently been issued:—

GEOPHYSICAL MEMOIRS

No. 101—*Upper air temperature over the world.* By N. Goldie, B.SC., J. G. Moore, B.SC., and E. E. Austin, M.A.

From upper air soundings made chiefly between 1941 and 1952, maps and diagrams have been reproduced which show the distribution of average temperature in both space and time, as well as the variability of the daily values from which the averages have been computed. Isopleths of average temperature and standard deviation of temperature are shown on maps of the world (excluding the Antarctic) for the 700-, 500-, 300-, 200-, 150- and 100-millibar pressure levels in the four mid-season months.

Additional charts and diagrams have been included to enable interpolation between different pressure levels and also between the four different months. For the interpolation of temperature values between different pressure levels, curves showing the variation of average temperature with height in different latitudes, and charts showing the average pressure and temperature at the tropopause, for the four main months, have been included. For interpolation between the months, curves showing the variation of the average monthly values throughout the year over different parts of the world, for the six standard levels, and the tropopause, have been reproduced.

Comparison of conditions in different longitudes is made by temperature cross-sections extending from the North Pole to 50°S.

The estimation of extreme values of temperature at any given level from the average temperature and standard deviation of temperature is also discussed. Diagrams are included showing the extremes of temperature in January and July at the six standard pressure levels, for all longitudes of the Northern Hemisphere. Also reproduced is a chart showing the minimum temperature in the troposphere and lower stratosphere over the world.

A complete list of sources of data is given in the Appendices.

WEATHER OF AUGUST 1958

Northern Hemisphere

The southward displacement of the depression track and polar front over the North Atlantic which had persisted since May continued throughout August. On the mean pressure chart the subpolar trough over the North Atlantic was of normal depth but its southward displacement gave pressures as much as 7 millibars below normal between Ireland and Newfoundland. Associated negative pressure anomalies occurred over Europe west of approximately 10°E. and over eastern areas of the North American continent.

The polar anticyclone was more intense than usual and was situated over North Greenland, while a low pressure area was centred to the north of Siberia over Severnaya Zemlya. Maximum pressure anomalies in these two areas were + 8 millibars and — 9 millibars respectively. The pressure distribution over other parts of the hemisphere resembled normal in all respects, and anomalies did not exceed 3 millibars.

Much of Europe had mean temperatures slightly above average during the month. The two main exceptions were southern Scandinavia and the Iberian peninsula where negative anomalies of approximately 1°C. occurred, although some exceptionally high temperatures were recorded during a heat wave in both Spain and Portugal at the beginning of the month.

Over the U.S.A. and Mexico temperatures were higher than the average almost everywhere, the largest anomalies being + 4°C. along the west coast of the U.S.A. Similar anomalies occurred in the Canadian Arctic as a result of increased southerly flow into that region. In Labrador, Quebec, and districts near the south of Hudson Bay, where an easterly surface flow predominated, the month was 2°C. or 3°C. cooler than usual. The largest reported anomalies in Asia were — 3°C. in northern Siberia and + 3°C. further south near the Urals.

Rainfall totals for the month were above average in most parts of western Europe, reaching nearly three times the normal at some stations in France. Many violent storms occurred in France, Germany, Austria, and Switzerland during the month, giving floods in many areas. Over the North American continent rainfall amounts were variable, some places near the east coast having nearly twice the average while in central states of the U.S.A. totals were below average. The Asian monsoon gave more rain than usual in many parts of India but Pakistan had a drier August than usual.

WEATHER OF SEPTEMBER 1958

Great Britain and Northern Ireland

September was mild, and in England and Wales very wet with widespread thunderstorms, although in Scotland rainfall was below average. During the first half of the month pressure was persistently low to the south-west of the British Isles and for much of the third week the country was on the fringe of an extensive Atlantic depression. For the remainder of the month weather was alternately cyclonic and anticyclonic.

South-easterly winds maintained warm weather over the country during the first few days of the month and weak fronts moving slowly north-east brought occasional slight rain to most districts on the 2nd, 3rd and 4th, while associated cloud helped to keep night temperatures around 60°F. in many places. Afternoon temperatures became progressively higher during this period and reached 81°F. at Mildenhall, Herne Bay and Whitstable on the 5th. On the same day thunderstorms, probably associated with a shallow trough of low pressure moving north-eastwards from France, reached the Hampshire coast early in the afternoon and moved north-east over much of south-east England. Some of the heaviest rain fell in Kent and Essex where many stations had more than 2 inches in 24 hours, while at some the fall exceeded 3 inches in that time. Very rare falls included 2·73 inches at Chelmsford in 58 minutes, 2·18 inches at Wickford in 90 minutes and 1·59 inches at Tilbury in 120 minutes. A minor tornado was reported to have travelled from Sussex to Kent on the 5th giving a gust of 69 knots at Gatwick and, during a severe thunderstorm, hailstones 2½ inches in diameter fell at Horsham not far away. The following day thunderstorms developed over northern England and moved to Scotland, where some places reported torrential rain with almost continuous lightning lasting several hours.

Temperatures fell to near normal on the 7th as the depression, which had been in our south-west approaches since the beginning of the month, moved to Scotland, and the wind veered towards the west. Weather was showery on the 7th and 8th with a few scattered thunderstorms but there were good sunny periods. Apart from an outbreak of thunder in the south-west on the 12th, the weather from the 9th to the 13th was mostly sunny and dry after patchy early morning fog. On the night of the 14th–15th a small depression moved eastward along the English Channel accompanied by heavy thunderstorms: several places recorded over 2 inches of rain in 24 hours and 2·16 inches fell that night at Nantcwnlle, Cardiganshire in 1 hour 20 minutes. Fronts, associated with a deep depression off south-east Greenland, moved slowly across the British Isles on the 18th and 19th, giving generally cloudy weather with rain in all districts. Thundery showers were widespread over the country during the next three days as the depression moved slowly south-east towards Scotland, and filled. A deepening depression from mid-Atlantic moving north-east toward Scotland brought prolonged rain to the whole country on the 23rd; the rain was heavy in many places and in parts of Wales more than 3 inches fell in 24 hours, causing extensive flooding. As this depression skirted the north of Scotland the following day, it became very intense before turning south-eastwards into the North Sea. There were severe gales in coastal districts of Scotland and eastern England; gusts of more than 50 knots were recorded at a number of places and one of 73 knots was recorded at St. Abbs Head.

The stormy weather was followed by two or three mainly dry days with sunny periods in most places as a ridge of high pressure moved slowly eastwards across the British Isles. Pressure, however, began to fall again on the 27th, as a deep depression on the Atlantic moved steadily eastwards, and on the night of the 28th–29th a major rainbelt crossed the country which led to a renewal of flooding in many areas. There were good sunny periods on the last day of the month but also frequent showers with occasional thunder.

Temperatures were above normal for September over the whole country. In Scotland mean temperatures were generally 3°F. to 4°F. above the average, while in the southern half of England and Wales the average was exceeded by about 2°F. Sunshine was below average over much of Great Britain. In many parts of the Midlands and south-east England there was a deficit of as much as 20 hours during the month, but in Lancashire sunshine was above average in most places. Rainfall was 160 per cent of the average in England and Wales, whereas in Scotland and in Northern Ireland it did not differ greatly from the average. Less than half the average was recorded over much of northern Scotland while twice the average was exceeded in west Cornwall, in Kent and Essex and over much of mid and south Wales and the Severn Valley. More than three time the average occurred in Shropshire.

Thunderstorms, hail and local tornadoes caused serious, though localized, damage to crops and glasshouses, and there were reports of cattle being killed by lightning. Harvesting, though very difficult, was more or less completed, with yields and quality ranging from good to very poor. Autumn cultivations were badly delayed, and weeds became a serious problem in some areas. Winter vegetable crops, however, were generally above average, as were the yields of apples and pears.

WEATHER OF OCTOBER 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 ...	69	28	+1·3	88	+1	95
Scotland	68	25	+2·1	81	−2	104
Northern Ireland ...	64	33	+1·8	73	−5	93

*1916-1950 †1921-1950

RAINFALL OF OCTOBER 1958

Great Britain and Northern Ireland

County	Station	In.	*Per cent of Av.	County	Station	In.	*Per cent of Av.
London	Camden Square ...	2·87	121	*Carm.*	Pontcrynfe	5·31	84
Kent	Dover	4·70	141	*Pemb.*	Maenclochog, Dolwen Br.	4·73	67
,,	Edenbridge, Falconhurst	3·36	101	*Radnor*	Llandrindod Wells ...	4·14	97
Sussex	Compton, Compton Ho.	2·96	76	*Mont.*	Lake Vyrnwy	4·22	59
,,	Worthing, Beach Ho. Pk.	2·62	89	*Mer.*	Blaenau Festiniog ...	10·57	84
Hants	St. Catherine's L'thouse	2·68	79	,,	Aberdovey	4·64	92
,,	Southampton, East Pk.	3·20	97	*Carn.*	Llandudno	2·48	77
,,	South Farnborough ...	2·41	93	*Angl.*	Llanerchymedd ...	3·44	75
Herts.	Harpenden, Rothamsted	2·44	93	*I. Man*	Douglas, Borough Cem.	3·70	73
Bucks.	Slough, Upton ...	2·36	94	*Wigtown*	Newtown Stewart ...	4·05	74
Oxford	Oxford, Radcliffe ...	2·85	114	*Dumf.*	Dumfries, Crichton R.I.	4·19	91
N'hants.	Wellingboro' Swanspool	2·21	96	,,	Eskdalemuir Obsy. ...	4·69	72
Essex	Southend W.W. ...	2·60	117	*Roxb.*	Crailing...	1·30	47
Suffolk	Ipswich, Belstead Hall	2·54	107	*Peebles*	Stobo Castle	2·14	53
,,	Lowestoft Sec. School	1·97	85	*Berwick*	Marchmont House ...	1·48	46
,,	Bury St. Ed., Westley H.	2·13	88	*E. Loth.*	N. Berwick	·86	32
Norfolk	Sandringham Ho. Gdns.	2·08	81	*Midl'n.*	Edinburgh, Blackf'd H.	·93	33
Dorset	Creech Grange... ...	3·41	84	*Lanark*	Hamilton W.W., T'nhill	3·20	73
,,	Beaminster, East St. ...	3·55	86	*Ayr*	Prestwick	...	...
Devon	Teignmouth, Den Gdns.	2·71	83	,,	Glen Afton, Ayr. San ...	4·80	74
,,	Ilfracombe	4·53	104	*Renfrew*	Greenock, Prospect Hill	6·37	86
,,	Princetown	8·11	90	*Bute*	Rothesay, Ardencraig...	7·41	88
Cornwall	Bude	3·56	94	*Argyll*	Morven, Drimnin ...	9·30	125
,,	Penzance	3·50	80	,,	Ardrishaig, Canal Office	7·41	88
,,	St. Austell	3·83	76	,,	Inveraray Castle ...	8·50	80
,,	Scilly, St. Mary ...	2·84	80	,,	Islay, Eallabus ...	4·94	77
Somerset	Bath	2·22	68	,,	Tiree	4·05	79
,,	Taunton	1·66	54	*Kinross*	Loch Leven Sluice ...	2·36	74
Glos.	Cirencester	2·36	73	*Fife*	Leuchars Airfield ...	1·52	54
Salop	Church Stretton ...	3·71	107	*Perth*	Loch Dhu	8·18	87
,,	Shrewsbury, Monkmore	2·07	78	,,	Crieff, Strathearn Hyd.	3·61	82
Worcs.	Worcester, Red Hill ...	2·00	87	,,	Pitlochry, Fincastle	2·92	72
Warwick	Birmingham, Edgbaston	2·49	86	*Angus*	Montrose Hospital ...	1·52	49
Leics.	Thornton Reservoir ...	2·40	90	*Aberd.*	Braemar	2·10	51
Lincs.	Cranwell Airfield ...	1·39	64	,,	Dyce, Craibstone ...	1·61	45
,,	Skegness, Marine Gdns.	1·41	71	,,	New Deer School House	3·18	86
Notts.	Mansfield, Carr Bank...	2·31	87	*Moray*	Gordon Castle	1·51	48
Derby	Buxton, Terrace Slopes	5·04	101	*Inverness*	Loch Ness, Garthbeg ...	4·74	105
Ches.	Bidston Observatory ...	2·93	97	,,	Fort William	10·39	113
,,	Manchester, Airport ...	2·50	78	,,	Skye, Duntulm... ...	6·35	106
Lancs.	Stonyhurst College ...	4·29	81	,,	Benbecula	5·19	101
,,	Squires Gate	3·12	85	R. & C.	Fearn, Geanies ...	2·78	107
Yorks.	Wakefield, Clarence Pk.	1·55	64	,,	Inverbroom, Glackour...	7·76	124
,,	Hull, Pearson Park ...	1·54	65	,,	Loch Duich, Ratagan...	12·89	141
,,	Felixkirk, Mt. St. John...	1·81	69	,,	Achnashellach	12·72	139
,,	York Museum	1·37	62	,,	Stornoway	3·68	84
,,	Scarborough	1·37	61	*Caith.*	Wick Airfield	3·48	112
,,	Middlesbrough... ...	1·24	52	*Shetland*	Lerwick Observatory ...	...	...
,,	Baldersdale, Hury Res.	2·54	66	*Ferm.*	Belleek	3·40	67
Nor'l'd	Newcastle, Leazes Pk....	1·25	48	*Armagh*	Armagh Observatory ...	3·91	117
,,	Bellingham, High Green	2·21	64	*Down*	Seaforde	2·50	62
,,	Lilburn Tower Gdns ...	1·72	54	*Antrim*	Aldergrove Airfield ...	2·05	57
Cumb.	Geltsdale	3·70	95	,,	Ballymena, Harryville...	2·24	49
,,	Keswick, High Hill ...	5·41	80	*L'derry*	Garvagh, Moneydig ...	2·95	66
,,	Ravenglass, The Grove	4·54	95	,,	Londonderry, Creggan	3·97	83
Mon.	A'gavenney, Plâs Derwen	5·05	113	*Tyrone*	Omagh, Edenfel ...	3·47	80
Glam.	Cardiff, Penylan ...	4·69	104				

* 1916–1950

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