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NORTHERN HEMISPHERE MONTHLY AND ANNUAL MEAN-SEA-LEVEL PRESSURE DISTRIBUTION FOR 1951-66, AND CHANGES OF PRESSURE AND TEMPERATURE COMPARED WITH THOSE OF 1900-39

BY

H. H. LAMB, M.A., P. COLLISON, B.Sc., and R. A. S. RATCLIFFE, M.A.

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NORTHERN HEMISPHERE MONTHLY AND ANNUAL MEAN-SEA-LEVEL PRESSURE DISTRIBUTION FOR 1951–66, AND CHANGES OF PRESSURE AND TEMPERATURE COMPARED WITH THOSE OF 1900–39

SUMMARY

Monthly average mean-sea-level pressure charts are produced for the period 1951–66 together with an annual average, and each of these average charts is compared with the corresponding chart for the period 1900–39. Charts showing how the monthly average temperature over Europe has changed between the two epochs are also included.

The principal change apparent in sea-level pressure since 1939 is the expansion and intensification of the polar high-pressure régime (especially in winter) and a corresponding weakening and southward displacement of the pressure gradient which produces the common westerly winds in middle latitudes. Comparison with data for 1968 and 1969 shows that these changes were still continuing at that time.

Changes in the level of monthly average temperature over much of Europe reflect the pressure changes; there is clear evidence that winters (particularly January and February) have been colder in the more recent period and there are smaller but interesting changes in other months.

1 – INTRODUCTION

For many years the most reliable set of average pressure charts with which to compare the situation observed in any individual month or year were 40-year average monthly mean-sea-level pressure charts derived from the U.S. *Historical Daily Weather Maps* series covering the years 1900–39,[1*] particularly the version produced in the Meteorological Institute of the Free University of Berlin[2] which incorporated a judicious adjustment of the values over the regions near the North Pole in the light of experience that the original daily charts were biased by a faulty presupposition of a more or less permanent polar anticyclone. The Berlin charts, slightly modified in a few areas to include some extra station reports, were used for many years in climatological and long-range forecasting research in the Meteorological Office as a datum from which to measure the departures or anomalies observed in any given year. It is this Berlin series which has been used here for comparison with the 1951–66 period.

The period 1900–39, though chosen by an accident of history (that it was the first period of any such length for which daily charts covering the northern hemisphere had been fully and carefully analysed), had special characteristics which made it an unusually convenient datum from which to measure deviations. For some purposes it may always remain the most convenient datum. This is because it was marked by the most sustained vigour of the general atmospheric circulation, and generally highest values of the zonal indices and mean pressure differences (P_m) measured across most of the world's prevailing windstreams, of any period for which observations are available: see, for example, the trend curves illustrated in Lamb[3] reproduced here as Figure 1 and the graphs, maps and tabulated values in Lamb and Johnson.[4,5,6] It was also an unusually homogeneous period, as shown for instance by a frequency, indeed a preponderance, of general Westerly-type situations over the British Isles (and, according to some investigators, over the whole northern hemisphere) unparalleled within the last 100 years (and probably for very much longer than that). Deviations from this 1900–39 standard are therefore simple to interpret as (a) exceptionally strong development of the zonal circulation, (b) displacements of the zonal circulation to higher or lower latitudes, (c) weaker circulations, or (d) more meridional circulations of various types.

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* The superscript figures refer to the Bibliography on page 36.

By the same tokens, however, the 1900–39 pressure distribution was quite wrongly called 'normal' and is very inconvenient for purposes of describing (especially to the layman or the general public) departures from what appears normal and familiar in other climatic periods.

Since about 1950 there has been a marked (and, up to the late 1960s at least, increasing) reversion to weaker, more meridional and more diverse, circulation patterns. Blocking anticyclones in the higher latitudes have been more frequent and have occurred in a great variety of positions, as is characteristic of the weaker, less zonal circulations. There have been far more anticyclones over Greenland, north-eastern Canada and the sea areas near Iceland in the recent period. Correspondingly conditions south of 50°N have been less anticyclonic than in 1900–39, and rainfall in the Azores has increased (at Ponta Delgada by 36 per cent when 1941–60 annual totals are compared with 1894–1940). Available evidence suggests that these patterns resemble the behaviour of the circulation at various times in the nineteenth century more than that at any time between 1900 and 1940. The frequency of Westerly-type situations over the British Isles, which averaged 101 days/year for 1900–39 (and 100 days/year for 1900–49), fell by the 1960s to lower values than at any time since 1860 (see Figure 2). Table I shows the frequencies decade by decade of the seven types recognized in Lamb's classification[7] of the daily isobaric patterns over the British Isles since 1861; it is seen that the fall off in frequency of Westerly situations from 1950 onwards has been compensated by higher frequencies than before of Northerly, Easterly and Cyclonic types. After

TABLE I – AVERAGE YEARLY FREQUENCIES, BY DECADES, OF LAMB'S SEVEN WEATHER TYPES*

	W	NW	N	E	S	Anti-cyclonic	Cyclonic
			number of days per year				
1861–69	98	21	25	27	27	95	62
1870–79	87	18	27	30	31	86	73
1880–89	85	19	27	30	36	93	62
1890–99	88	20	28	26	31	101	59
1900–09	97	15	28	26	33	93	62
1910–19	99	13	29	28	28	89	68
1920–29	109	16	25	26	34	79	65
1930–39	98	24	27	27	30	90	65
1940–49	95	19	24	30	31	97	57
1950–59	90	19	31	26	31	93	62
1960–69	80	19	30	34	31	84	70

* Defined by Lamb.[7]

allowing for the fact that the weather of successive days is usually correlated, a chi-square test applied to Table I shows that there was a significant excess of Westerly types in the 1920s. The only assumption made in this test is that the last 11 decades are a representative sample of British climate; the significant level of the abnormalities in the 1920s and 1960s reaches the 1 per cent level. With a 15 per cent decline (20 per cent in the 1960s) in the frequency of Westerly situations it has clearly become desirable to use charts of the period since 1950 to describe the range of situations that has become normal in recent years.

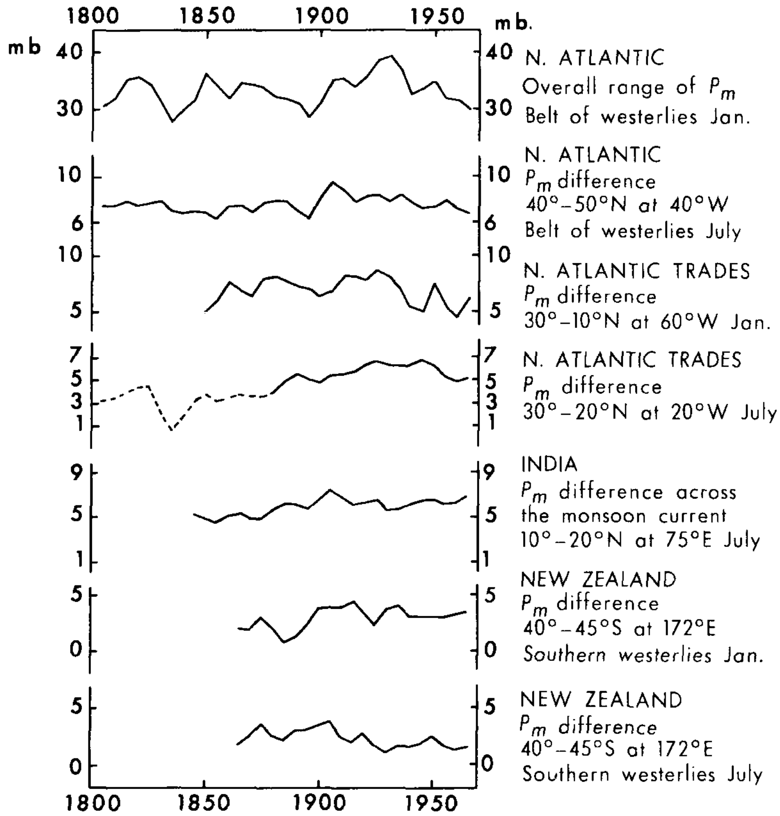


FIGURE 1. SELECTED INDICATORS OF THE STRENGTH OF THE MAIN CURRENTS OF THE ZONAL WIND CIRCULATION

——— 10-year means plotted against the middle of the period covered at 5-year intervals. Broken lines indicate unreliable information.

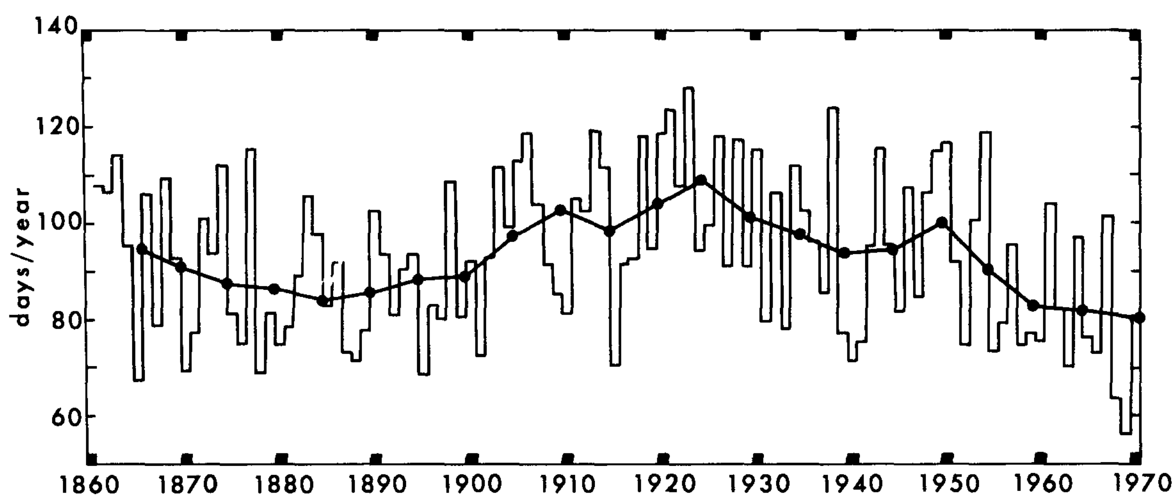


FIGURE 2. NUMBER OF DAYS OF GENERALLY WESTERLY TYPE IN THE BRITISH ISLES EACH YEAR

——— 10-year means, plotted at 5-year intervals. ⌐⌐∟∟ yearly frequency.

2 – CHARTS SHOWING AVERAGE PRESSURE, 1951–66

The charts here presented (Figures 3–15) show the average mean-sea-level pressure distribution over most of the northern hemisphere, computed for each month of the year and for the whole year for the period 1951–66. These are the charts used as datum in the long-range forecasting routine of the Meteorological Office since 1968. Seasonal mean charts for the same period are also available.

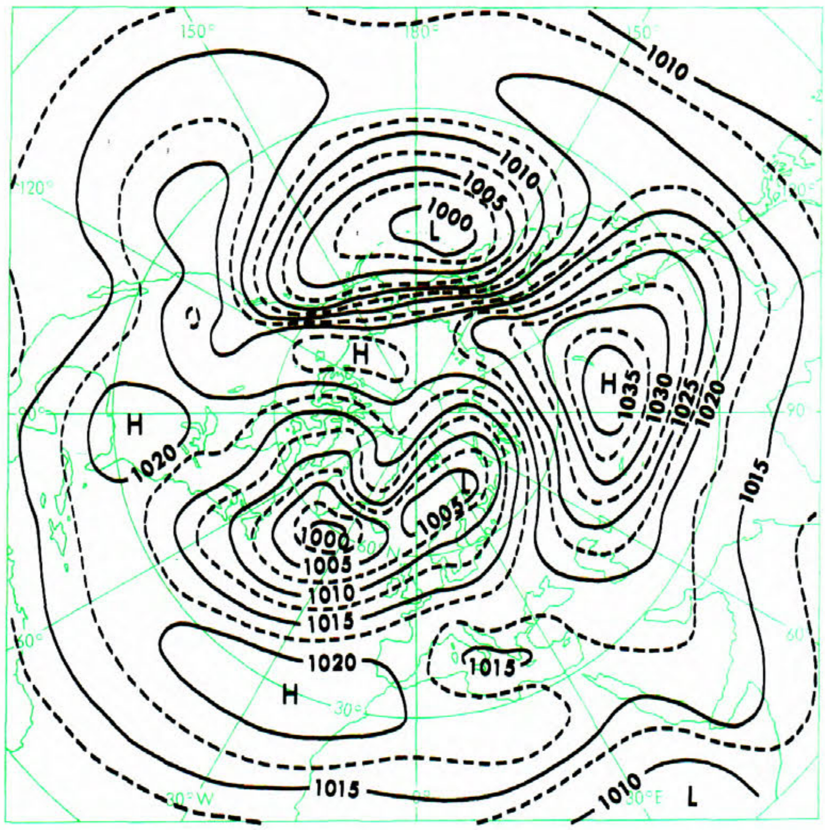


FIGURE 3. AVERAGE PRESSURE FOR JANUARY 1951–66

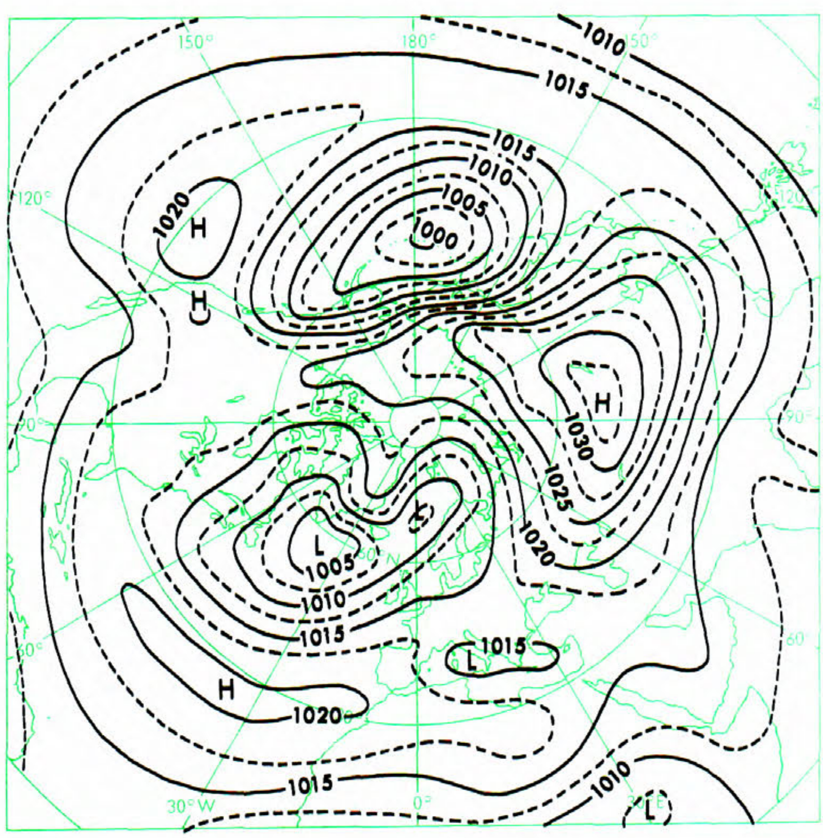


FIGURE 4. AVERAGE PRESSURE FOR FEBRUARY 1951–66

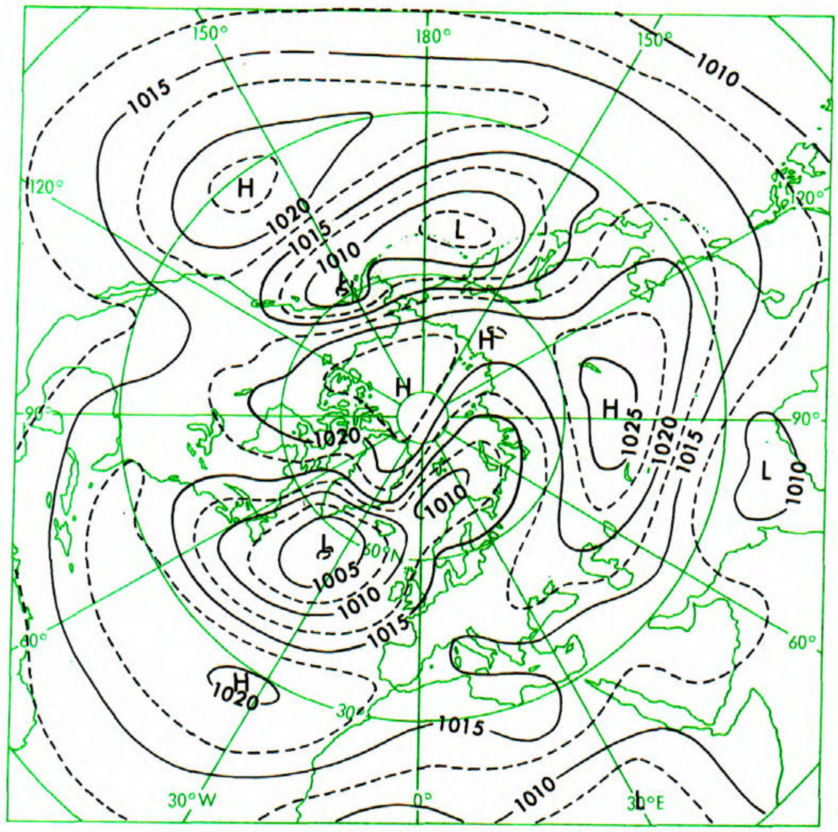


FIGURE 5. AVERAGE PRESSURE FOR MARCH 1951–66

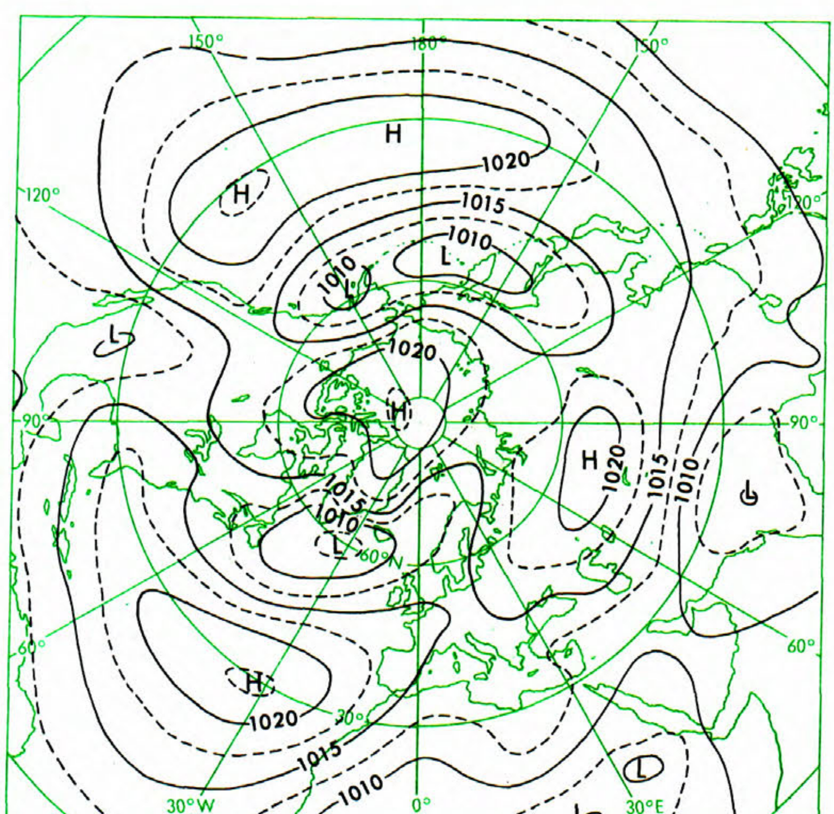


FIGURE 6. AVERAGE PRESSURE FOR APRIL 1951–66

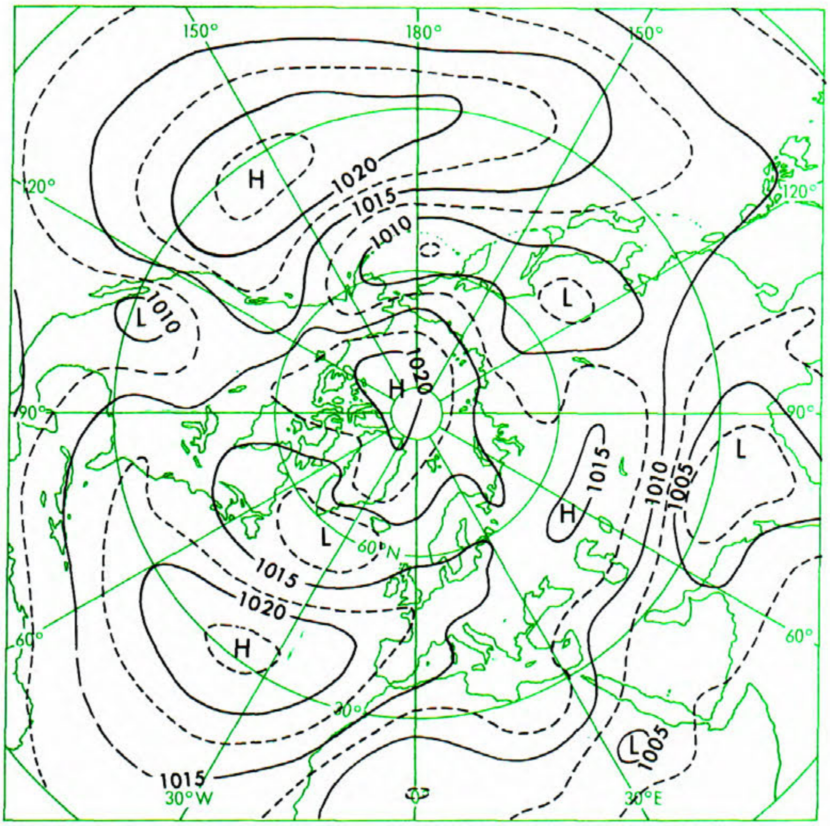


FIGURE 7. AVERAGE PRESSURE FOR MAY 1951–66

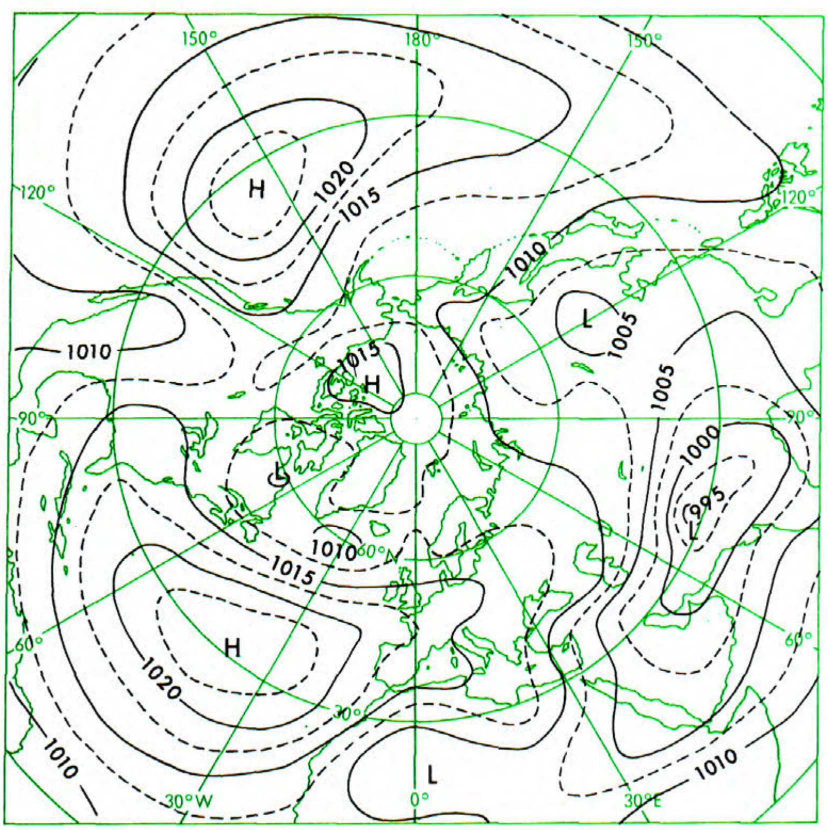


FIGURE 8. AVERAGE PRESSURE FOR JUNE 1951–66

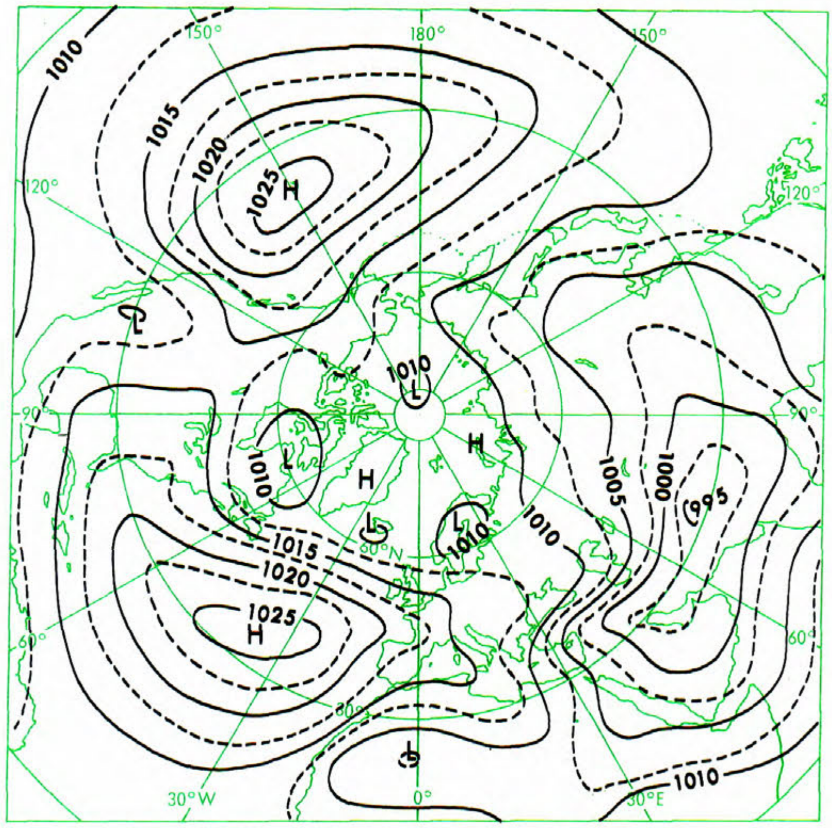


FIGURE 9. AVERAGE PRESSURE FOR JULY 1951–66

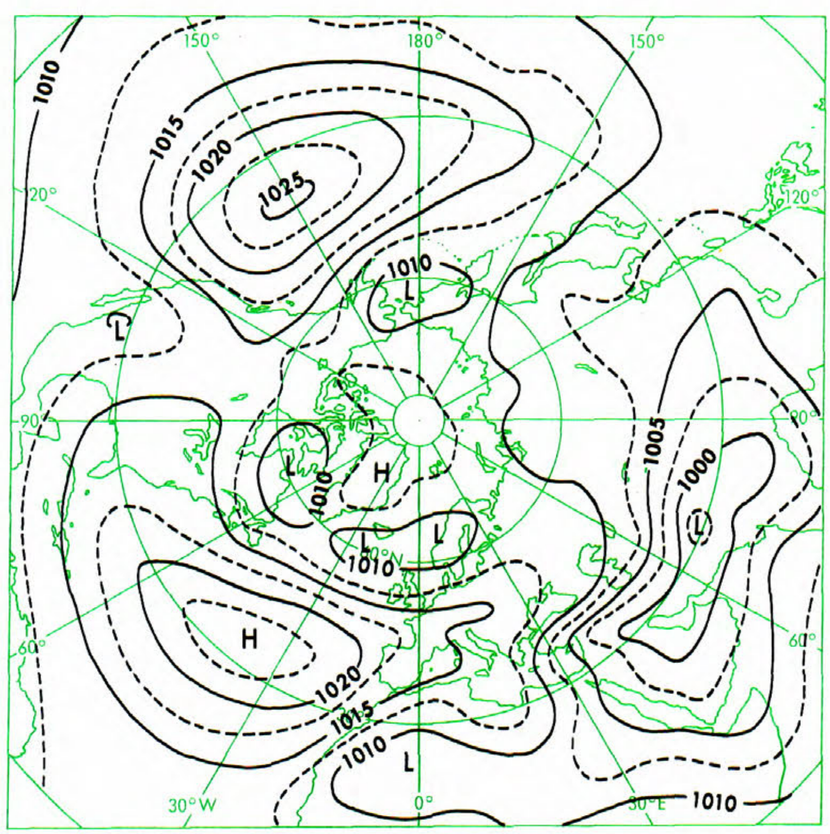


FIGURE 10. AVERAGE PRESSURE FOR AUGUST 1951–66

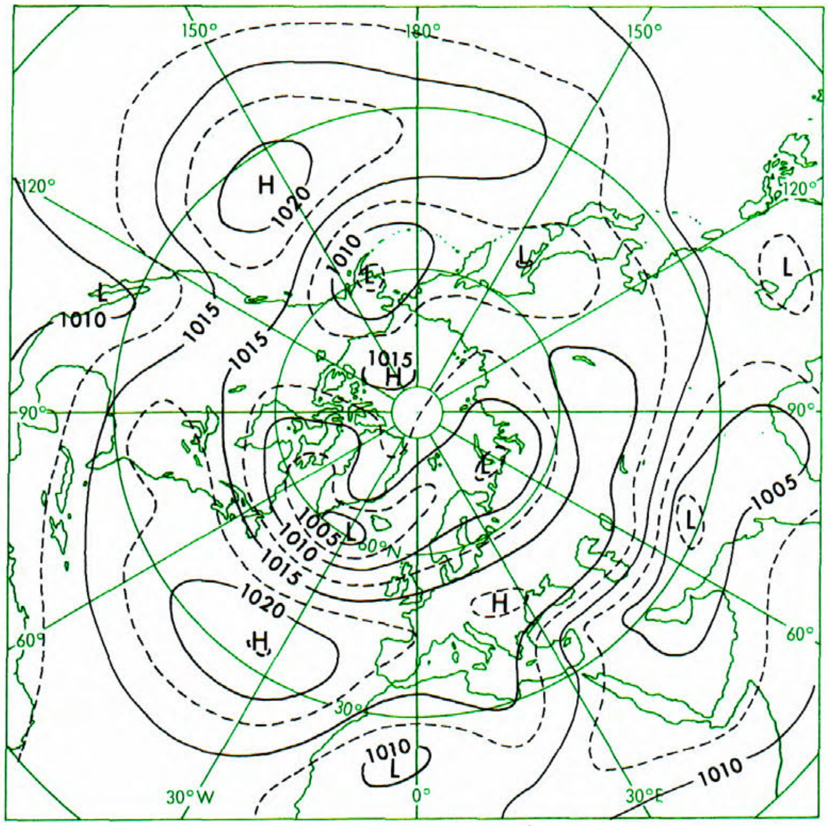


FIGURE 11. AVERAGE PRESSURE FOR SEPTEMBER 1951–66

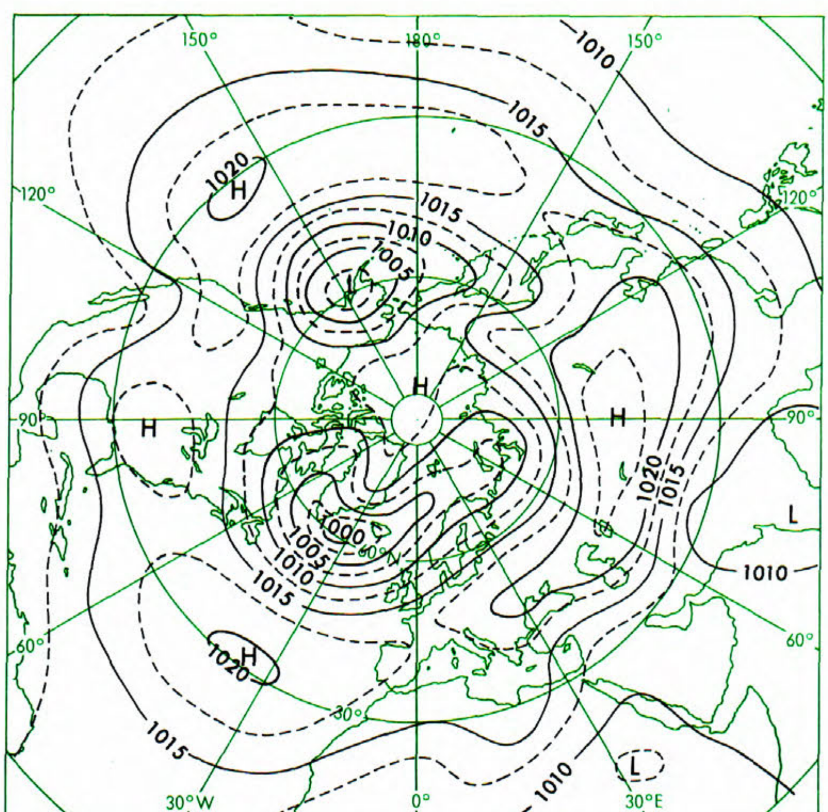


FIGURE 12. AVERAGE PRESSURE FOR OCTOBER 1951–66

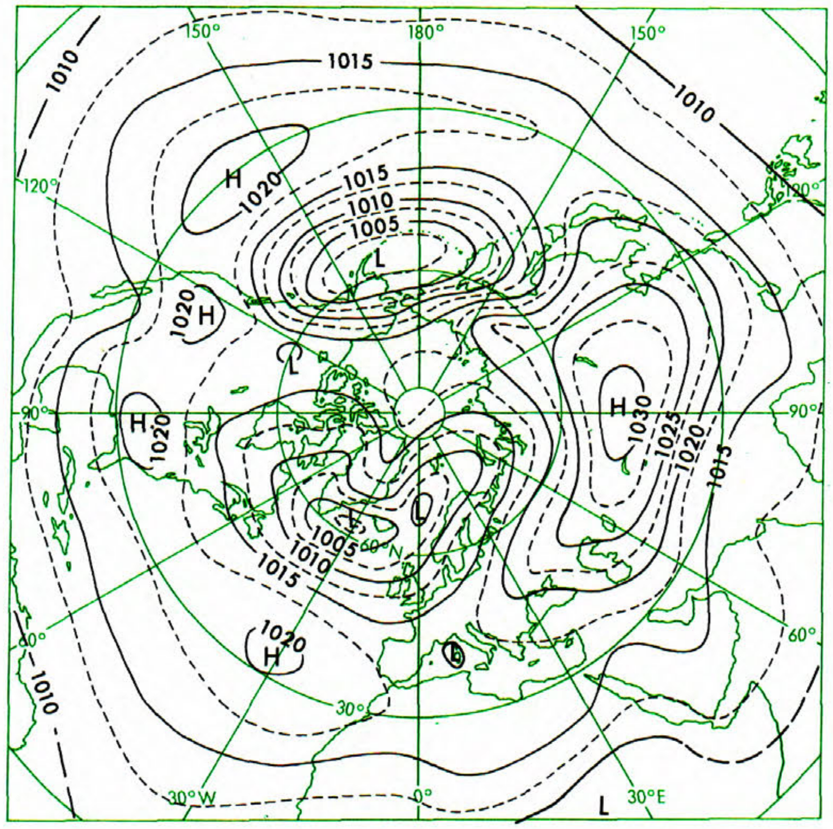


FIGURE 13. AVERAGE PRESSURE FOR NOVEMBER 1951–66

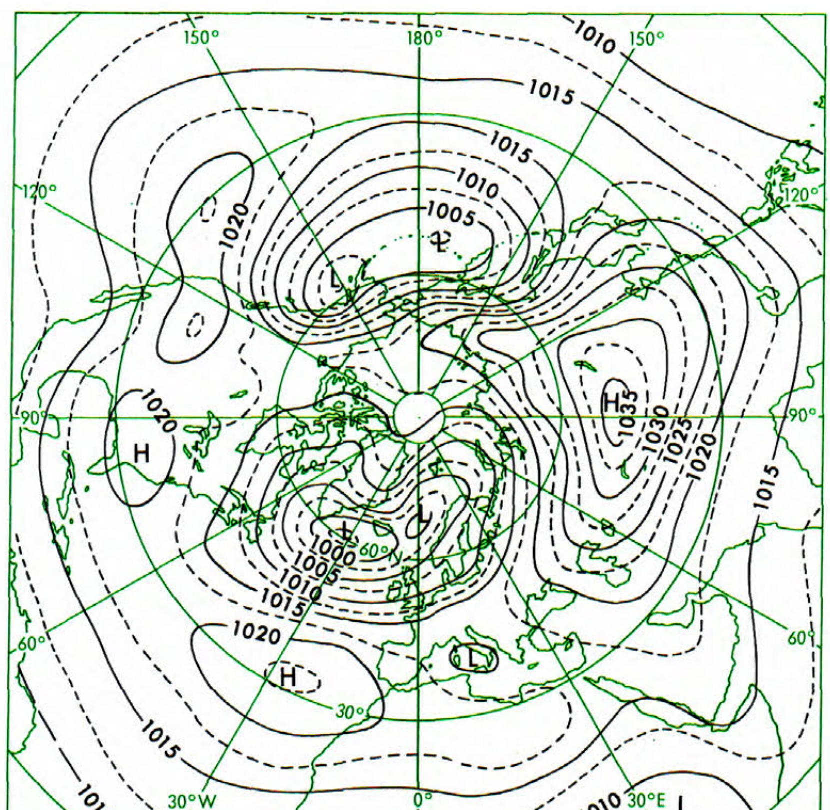


FIGURE 14. AVERAGE PRESSURE FOR DECEMBER 1951–66

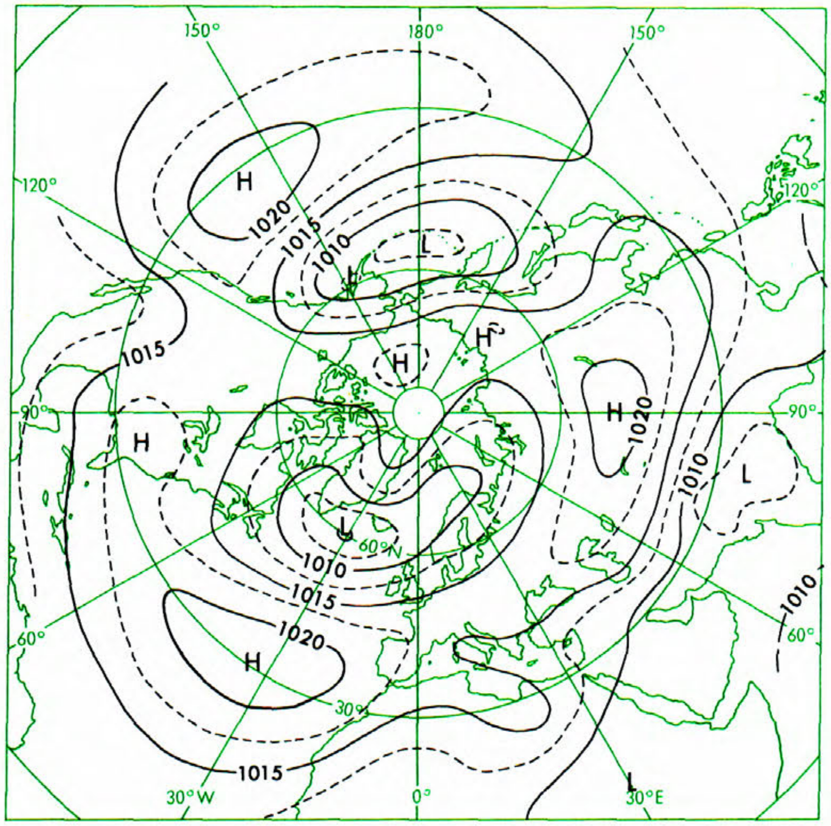


FIGURE 15. AVERAGE PRESSURE FOR THE YEAR, 1951–66

3 – CHARTS SHOWING CHANGES IN PRESSURE AND TEMPERATURE SINCE 1900–39

Figure 16 shows how the annual mean-sea-level pressure distribution for 1951–66 differs from the so-called 'normal' chart, previously used, i.e. the average of the period 1900–39. The principal change apparent since that time is expansion and intensification of the polar high-pressure régime and a corresponding weakening, and southward displacement, of the pressure gradient which produces the common westerly winds in middle latitudes. Average pressures have become somewhat lower than for 1900–39 in most parts of the subtropical anticyclone zone.

Pressure has risen most over Greenland, and the increased pressure gradient east of that country must have increased the movement of air from the north in the Norwegian Sea. The increased frequencies of Northerly, Easterly and Cyclonic weather types in Britain are seen as associated respectively with more northerly winds in the Norwegian Sea which are liable to spread south over Britain, expansion and increased frequency of the northern anticyclones and southward displacement of the North Atlantic cyclonic activity so that the centres of disturbances more commonly than before pass across these islands between 50° and 60°N.

Average pressure has probably changed relatively little near the North Pole, compared with that of 1900–39. This is known to be so at Spitsbergen, but the pressure change derived for the area shaded on Figure 16 must be regarded as more doubtful than elsewhere in high latitudes because of the lack of observations for 1900–39 and the originally misconceived analysis of that area already referred to.

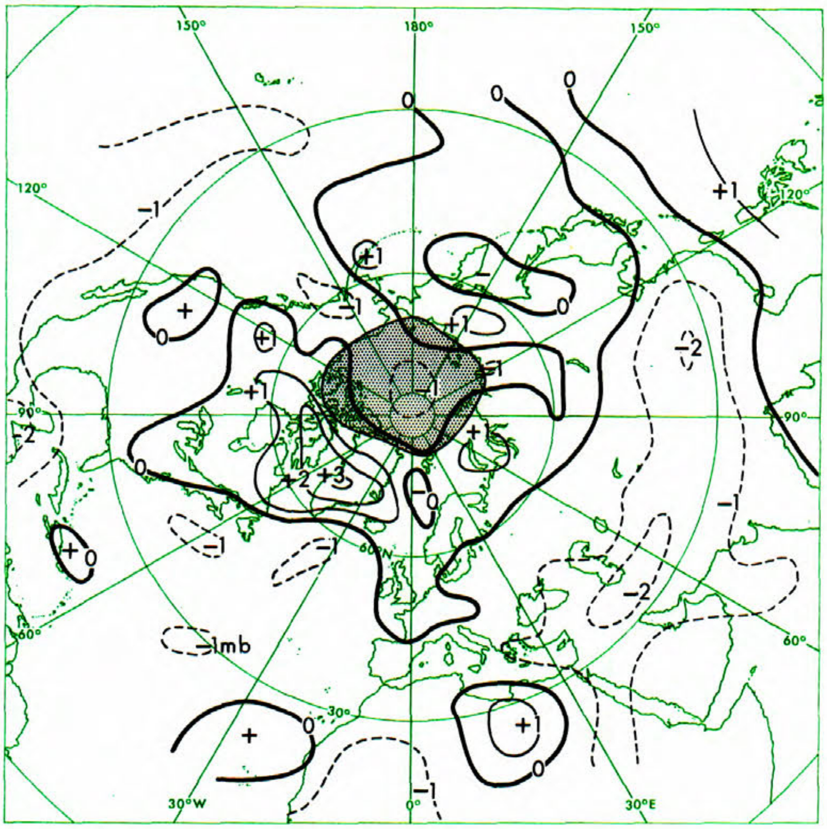


FIGURE 16. DIFFERENCE OF YEARLY AVERAGE PRESSURE 1951–66 MINUS 1900–39

Figure 17 shows how the average pressure distribution for 1968 and 1969 departed from the 1951–66 distribution here presented. The broad similarity between Figure 17 and Figure 16 indicates that the circulation behaviour in these two later years may be regarded in simple terms as a further development of the tendency represented by the 1951–66 averages. (In these two years the number of days of Westerly-type situation over the British Isles, 63 and 56 respectively, was lower than in any other year since 1860.)

Notes on the individual months

Figures 18–29(a) show the changes in average pressure from 1900–39 to 1951–66 for each month from January to December while Figures 18–29(b) show the corresponding mean monthly temperature changes over Europe.

January (Figures 18(a) and (b)). The main area of pressure rise (i.e. higher pressure in the recent, 1951–66, period) is over Greenland, where the greatest values, around +8 mb near 70°N 25°–40°W, are apparently an increase of 4σ (σ = standard deviation) for a 16-year average. The area of substantial pressure rise also covers most of North America north of 50°N, especially the Canadian Arctic archipelago (where the increase of about 4 mb represents a 3 to 4 σ change for the 16-year average). There is a further extension of the area of increased pressure across northern Alaska into north-east Asia and central Siberia, but mean pressure has become lower over northern Scandinavia, Novaya Zemlya and the nearer parts of the Siberian Arctic coast.

There is almost a complete zone of pressure lower than in 1900–39 between about 20° and 50°N, including a 3 to 4 σ change in this sense over much of the Atlantic (> 4 σ between Bermuda

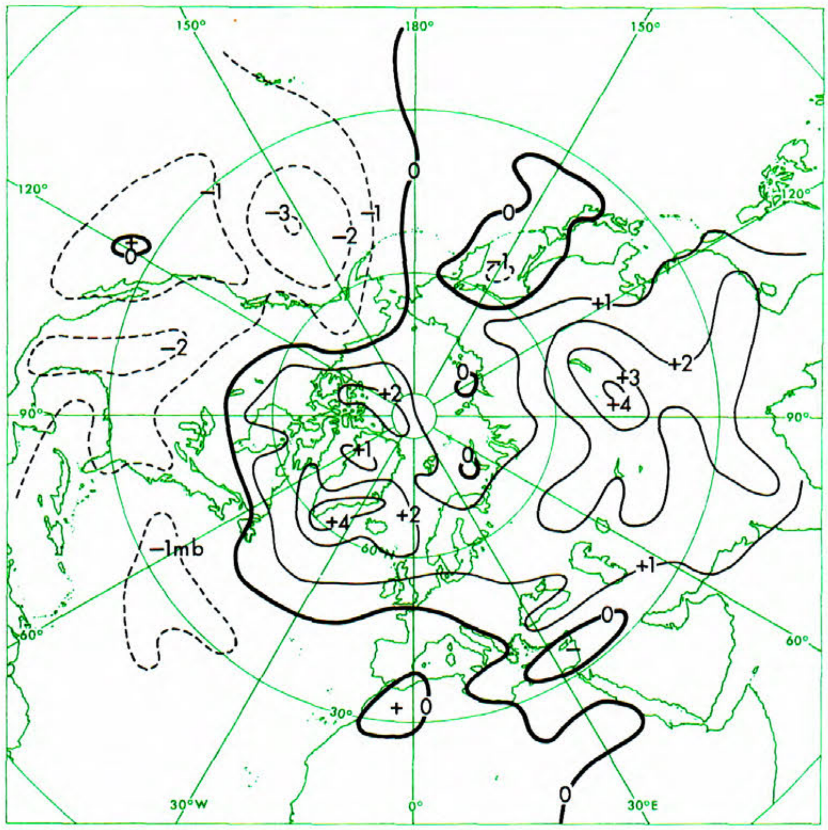


FIGURE 17. DIFFERENCE OF YEARLY AVERAGE PRESSURE 1968–69 MINUS 1951–66

and Newfoundland) and in the Pacific sector between Hawaii and about 30°N (though in millibars the greatest fall is at about 40°N).

Over Europe, associated mean temperature changes follow the pattern which would be expected from the pressure changes. All the area north of 42°N and west of 30°E appears colder in the later epoch with the axis of greatest change (greater than 1 degC) lying from Scandinavia to the British Isles. Over the Mediterranean and western Russia north of the Black Sea, the later period appears warmer than the earlier one, presumably because of extra cyclonicity and some anomalous flow from the south-east over the Ukraine. Greenland, especially west Greenland, is also warmer in the later epoch perhaps because of more southerly airflow up the Davis Strait than in 1900–39.

February (Figures 19(a) and (b)). The greatest rise of pressure is again over Greenland (about +8 mb near 70°N 25°–40°W and amounts to a 4σ change of the 16-year average at this point), but in this month the area of increased pressure extends eastwards from the Canadian archipelago across Greenland and northern Scandinavia to Novaya Zemlya, thence over all northern Siberia and most of the Pacific Ocean north of 30°N. Pressure has become lower than before over Alaska.

The subtropical zone of lowered pressure is strongest near the Azores (–4 mb) and near the Caspian (–4 mb) (a 3 to 4σ change of the 16-year average in both areas). Off east Asia this zone turns north over Japan to the Okhotsk Sea and does not continue east over the Pacific, though lowered pressure is again found at Hawaii and from there eastwards.

European temperature differences are very similar to those noted for January except that the axis of the greatest change lies from Scandinavia southwards into eastern Europe. The British Isles are again colder in the later period with the mean change about 0.5 degC. The recent (1951–66) warmth over Greenland noted in January is even more general in February.

March (Figures 20(a) and (b)). Pressure has risen over most of the Arctic, but the strong pressure increase is concentrated in two large areas (a) centred (+7 mb) over north-east Canada and Greenland with an extension south-east to the North Sea (+4 to +5 mb) and from there to Novaya Zemlya, and (b) over all the northern central Pacific (peak values +2 to +3 mb).

Pressure has become lower than in 1900–39 over much of North America, but especially in the central Atlantic 40°–50°N (–6 mb) and from Turkey across central Siberia and into northern China.

With higher pressure in the later period extending southwards from Scandinavia into Europe and with pressure in the Atlantic lower than before, winds will clearly be more north-easterly than before in eastern Scandinavia and eastern Europe and more south-easterly over western Europe and Britain. Temperature changes in 1951–66 follow the trend expected from the wind field, being slightly warmer in western Europe, particularly near the western fringes of the continent, but more than 1 degC colder in places from Finland southwards towards the Balkans.

April (Figures 21(a) and (b)). The pressure changes in this month are mostly similar to February and March, though weaker. The pressure rise is, however, more marked over south-east England, where there is a maximum (+3 mb) as great as any on the chart; and pressure has become higher over almost all Europe, especially from England to southern Scandinavia.

The generally higher pressure in the later period over practically the whole of Europe results in mean temperatures almost everywhere being a little higher in 1951–66 than in 1900–39. This increase is probably due mainly to increased sunshine in the rather more continental airflow. North-western Scandinavia, however, did not experience the slightly higher temperatures noted elsewhere in Europe.

May (Figures 22(a) and (b)). The greatest pressure increases (mostly about 2 mb) are in a belt from Libya (a 3 to 4σ change) across France, Ireland and Scotland and from there north-eastwards covering northern Scandinavia and latitudes 70°–80°N around the entire Eurasian sector (a 2 to 3σ change of the 16-year average in many parts of the belt). Pressures were also higher than in 1900–39 over most of North America.

The most extensive area of lowered pressure covers most of Asia and extends north-east to Kamchatka and Alaska, apparently indicating a path of increased cyclonic activity. Other areas of lowered pressure are (a) over the Pacific between Hawaii and Mexico, (b) over the central Atlantic, and (c) over north-west Africa.

Temperature differences observed over Europe are again much as would be expected from the pressure changes. The increased anticyclonicity over France, Britain and most of Scandinavia is reflected in a slight rise of mean temperature in the later epoch. Conversely, lower pressures in eastern Europe and the Ukraine result in a drop in mean temperature (in some places exceeding 1 degC) in those areas in the later epoch, probably because of increased cloudiness.

June (Figures 23(a) and (b)). Pressure in this month has fallen over most of the Arctic and over the Atlantic north-west of the British Isles, also over Alaska and north-east Asia (greatest values –3 mb in the areas named, about a 3σ change of the 16-year average in each case). Pressures are higher than before, again over Greenland and most of northern North America and in this month in a belt from the Azores across Biscay, central Europe and Siberia in latitudes 50°–60°N.

Lower pressures than in 1900–39 appear again over the Pacific between Hawaii, Mexico and California, as well as over Spain, north-west Africa and a wide area of Asia.

The ridge of relatively higher mean pressure in 1951–66 covers much of Europe and is accompanied by a small rise of mean temperature at most stations. Rather surprisingly most of Britain appears to share this warming trend although pressure is marginally lower than in 1900–39, especially in the north-west. Iceland, however, is colder in the recent period, probably as a result of increased cyclonicity and more north-easterly winds than in 1900–39.

July (Figures 24(a) and (b)). Pressure has fallen most over the Arctic Ocean with an extension of the area over the Norwegian Sea and Scandinavia. Pressures were also lower than before over most sectors south of about 30°N and over most of Asia.

Pressures higher than in 1900–39 cover most of North America, especially Canada, also Greenland and the Atlantic just south-west of Britain.

The higher pressure recorded recently over the Atlantic and southern Greenland coupled with lower pressures over Scandinavia appear to have resulted in a greater frequency of cooler north or north-westerly winds which penetrated to Iceland, Scandinavia and most of Europe north of about 50°N. The drop in mean temperature in the later epoch exceeds 1 degC over Iceland and Scandinavia, while elsewhere it is mainly about 0.5 degC.

August (Figures 25(a) and (b)). Much of the July pattern of change is repeated, especially the increased pressure over North America (most of all in northern and central Canada) and the lowered pressure over Asia.

The lowered pressure over the Arctic is in August confined to a narrow belt, probably a path of increased cyclonic activity, from the North Sea and Scandinavia along the 70°–80°N zone off Arctic Siberia to the Bering Strait. Two other belts of lowered pressure look important: (a) across the entire Atlantic and British Isles, centred about 55°N, and (b) north-east from the western Pacific to Alaska.

Britain and most of western Europe, with lower pressure and thus probably more cloud in the later period, are mainly a little cooler in 1951–66, although mean temperature differences are less than 0.5 degC in most places.

September (Figures 26(a) and (b)). As in August, there is a belt of lowered pressure across the Atlantic and British Isles (greatest fall –5 mb, a greater than 4σ change of the 16-year average, now concentrated south of Iceland near 58°N). This belt now continues east over much of northern Eurasia; but, though the greatest fall of pressure is along the zone indicated near 60°N, pressure is lower than in 1900–39 over almost all Europe and Asia.

Pressure is higher than in 1900–39 over most of North America, the Arctic and Greenland.

Lowered pressure occurs over much of the Pacific, especially the eastern Pacific between Hawaii and California.

Despite mean pressures over 1951–66 being generally lower over Britain and much of Europe than in 1900–39, the mean temperature changes are mainly positive. However the amount of this warming trend is generally small.

October (Figures 27(a) and (b)). The greatest fall of prevailing pressure level (–7 mb, apparently a change of 16-year average exceeding 6σ) is now strongly concentrated off south-east Greenland. This seems to indicate a strengthening of the increased cyclonic activity over the Atlantic south of 60°N, of which signs are noted also in August and September, but in October the zone affected is turned more south-west to north-east and runs from near Bermuda to the Norwegian Sea between Jan Mayen and north Norway. There is also a suggestion that much of the increased activity halts, or lingers, south-west of Iceland.

Pressure has risen over the British Isles and an area from Biscay to the Baltic and Barents Seas.

Increased anticyclonicity over Europe and increased south-westerly flow over Britain and northern Scandinavia have led to temperature changes which are almost the reverse of those noted for January and February: practically the whole of northern Europe including Britain is warmer in the later period with the main area of warmth over Scandinavia. In most parts of Europe north of about 45°N October has shown the greatest positive temperature changes for any month.

Pressure continues lower than before over most of Asia, especially north-west Siberia, but has risen over north-east Asia and neighbouring parts of the Pacific, including a broad area from the Bering Sea over the Aleutians towards the central Pacific. The main falls of pressure on that side of the hemisphere have been in a belt covering the eastern Pacific, the Gulf of Alaska and across Alaska to near the North Pole.

November (Figures 28(a) and (b)). There is no apparent continuity of the October pattern of change.

Pressure has increased most in a broad belt from Hudson Bay across Greenland, Scandinavia, the Barents Sea and all northern Asia, and extending from there across the Pacific between 40° and 50°N. The greatest increases (up to +6 mb) are over Baffin Land, Greenland, Lapland, Novaya Zemlya and north-east Asia (a greater than 3 to 4σ change of the 16-year average).

Pressure has become lower than in 1900–39 principally over Alaska and the northernmost Pacific, also apparently near the Pole. Lowered pressure also appears generally over the Atlantic south of 40°N, over Eurasia south of 45°N and over the eastern Pacific between Hawaii, Mexico and California.

Some of the mean temperature increase noted in October in 1951–66 continues into November. The area which continues warmer is mainly confined to Iberia, France and southern Britain where there is a slight anomalous southerly wind compared to the earlier epoch. Over most of the rest of Europe the sharp change in pressure pattern from October has resulted in rather random small mean temperature changes. The anomalous easterly wind apparent over northern Scandinavia results in mean temperatures there showing mainly a small decline.

December (Figures 29(a) and (b)). Again the pattern of change appears notably different from the preceding month.

Greatest pressure lowering is noted in three areas: (a) near the North Pole, (b) over Scandinavia and the Baltic, and (c) over the Gulf of Alaska. (The greatest changes in these areas, exceeding –4 mb, represent a 2 to 3σ change of the 16-year average.) Pressure has also fallen notably over the Atlantic and Asia south of 35°–40°N, over Spain, over central U.S.A. and over the Pacific east of Hawaii, the changes in these areas being a continuation of the development noted in November.

Pressure has risen strongly (up to +4 and 5 mb) in two large areas: (a) centred over Kamchatka and covering all northern Asia and the north-west Pacific, and (b) centred over Baffin Land and covering Greenland, Newfoundland and all the north-west Atlantic as well as eastern Canada.

Western Europe is affected by an anomalous northerly flow compared to 1900–39 and pressure is generally lower than it was in that epoch. These two trends in December lead to opposite temperature effects, the extra cyclonicity which tends to raise mean temperatures as a result of extra cloudiness, especially at night, while the northerly anomaly would lead to the invasion by colder air masses. In the event the combination produces lower mean temperatures in 1951–66 over the whole area from Finland to Iceland and southwards to about southern England. The area of Russia north of the Black Sea is notably warmer in the later epoch probably because of increased advection from the south.

Latitude means of pressure change

Figure 30 showing month by month the latitude means of pressure change, averaged (a) over all longitudes and (b) over the Atlantic sector, indicates that the change has been an increase of pressure over all latitudes north of 50°N in the late winter months, and some approximation to this in all months from November to April, the greatest rise being at about 70°N, while pressures in all latitudes between 30° and 50°N are lower than in 1900–39, especially about 40°N. (There has been a very great increase of rainfall in the Azores.) In the summer months the pattern is of increased pressures over the zone 65°–75°N and to a less extent over the zone 40°–50°N, while pressures are lower than in 1900–39 in the highest latitudes as well as about 55°–60°N and south of 35°N; this pattern is most strongly developed in June but can be traced from May to September with some modifications. October is peculiar in having lowered pressure over all latitudes north of 50°N, especially near 60°–65°N, but the beginnings of this development (which must be associated with October's continued warming in Britain) appear related to the increased cyclonic activity in the zone 50°–60°N in August and September.

Changes of mean pressure from month to month

Maps of the changes of mean pressure from one month to the next around the year in the two epochs were also prepared and show at least the following noteworthy features:

(a) Over the British Isles, north-east Atlantic and north Europe the pressure gradient indicates that the westerly winds have risen to their seasonal maximum in December (it is thought, in *early* December or around the turn of the month November–December) in the recent years, whereas in 1900–39 the increase continued to January. The December–January change in 1951–66 already shows a sharp decline of the westerlies; this decline did not begin until late January–February in 1900–39.

(b) The more intense development of the North Pacific cyclonic activity in the winters of the recent period proceeded to a seasonal maximum in January, followed by a rise of pressure over the whole northern part of the ocean from January to February. By contrast, in 1900–39 the strongest development of the North Pacific cyclonic activity was in December and February; in January the activity was weaker, pushed farther south and had more tendency to split into two main centres (over the north-west Pacific and the Gulf of Alaska).

(c) The May–June change over Britain in 1951–66 has been a matter of southward withdrawal of the anticyclonic régime and establishment of a much more westerly and somewhat more cyclonic tendency, whereas in 1900–39 the tendencies at this stage of the season were the other way. The general seasonal development from May to June of lower pressure over the Arctic and over Asia has, however, proceeded alike in both epochs. The next stage, from June to July, was when the increase of cyclonicity became noteworthy in Britain in 1900–39, whereas in 1951–66 the change at this stage has been mainly towards more northwesterly or northerly wind components with little change of pressure level apart from the opening up of more of a trough of low pressure (indicating the general drift of travelling depressions) east-south-eastwards across northern Europe and the Baltic towards Russia.

(d) The September–October pressure change, whilst similar in its broad aspects in both epochs with seasonally rising pressure over the continents and pressure falling over the oceans, giving an increased tendency to southerly winds over western Europe and western Canada alike, was, at this stage in 1900–39, towards a sharp drop in pressure over the British Isles and the eastern Atlantic at 50°–60°N; in 1951–66 the fall in pressure from September to October has been concentrated much more between Iceland and southern Greenland, whilst Britain has been involved in the fringe of the general rise of pressure over the Eurasian continent. This may be regarded as a winter monsoonal effect showing earlier and with wider scope in the recent years, brought about by weaker development of the zonal circulation. The Septembers of this period have been more westerly and less anticyclonic over Britain than in 1900–39; and it could be said that the seasonal expansion of the circumpolar vortex with increased eastward-moving cyclonic activity over the Atlantic which was normally a marked feature of October in 1900–39 has in recent years shown up in September. Thus the climatic cooling and weakening general circulation of the last two decades has had consequences of the sort that were to be expected in September, but the check to the progressive seasonal expansion of the zone of westerlies which is sooner or later forced by the winter-monsoon high-pressure tendency over the continent has lately come so much earlier and more strongly than before in October as to produce southerly surface winds and anticyclonic weather in western and central Europe at a time when these give warmth rather than chilly, foggy weather. This may, in part at least, be the paradox that has produced warmer Octobers in Britain and central Europe at a time when most other months of the year have become colder.

General temperature changes

The general trends of temperature change throughout the year can be seen in Figure 31. In fact for most observing stations north of 45°N in Europe the trends are very similar showing two peaks, one in spring and one in autumn (the autumn one being much more noticeable) and two troughs, one in summer and one in winter, the latter being generally much the greater. Stykkishólmur (Iceland) and Angmagssalik (Greenland) are rather different in that although the autumn maximum is still apparent, that observed in other places in spring appears here in late winter, with more apparent cooling in summer, especially in Iceland. This may be due to the excessive Arctic ice which has been observed recently. The ice reaches its largest extent in April, and is likely to depress mean temperatures in adjacent areas both in spring and summer.

Although most of the stations on which the various temperature trends noted in this paper have been based are regarded as being good observing sites, it is possible that many have been affected by urbanization so that observed trends may somewhat underestimate the cooling which has actually taken place. Stations particularly suspect in this respect are Paris, Copenhagen, De Bilt and Bergen. Urbanization affects the mean temperature in several ways. In the first place, the presence of vertical as well as horizontal surfaces in a built-up area results in a larger proportion of the solar energy being absorbed either directly or after multiple reflections; secondly, in the open country much of the incoming solar energy is used to evaporate moisture in the transpiration processes while in towns all the heat is absorbed by inert surfaces and later released to the surrounding air. These processes are more effective in summer but in winter the widespread use of central heating in buildings also has a marked warming effect on the ambient air. The general slight lowering of wind speeds in built up areas is also likely to raise temperatures, especially in summer. All these effects combine to produce a trend to higher mean temperatures in most months of the year as urbanization develops. The matter is more fully discussed by Craddock.[8,9]

Within the period 1951–66 the over-all trend of mean temperature has been downward for much of Scandinavia and northern Europe. Figure 32 shows 5-year running means of temperature for each season at Helsinki (Finland), where the downward trend in winter mean temperature noted since 1900–39 has increased in the 1960s and spread to autumn as well.

Similar graphs for central England, for which composite values are available for over 100 years, are shown in Figure 33. Clearly changes since 1950 are small but there has been a noticeable downward trend in spring temperatures (0.5 degC) and a slight fall in summer temperatures can be detected. Five-year running mean winter temperatures in central England, though fluctuating considerably, have been almost entirely below the 1900–39 average.

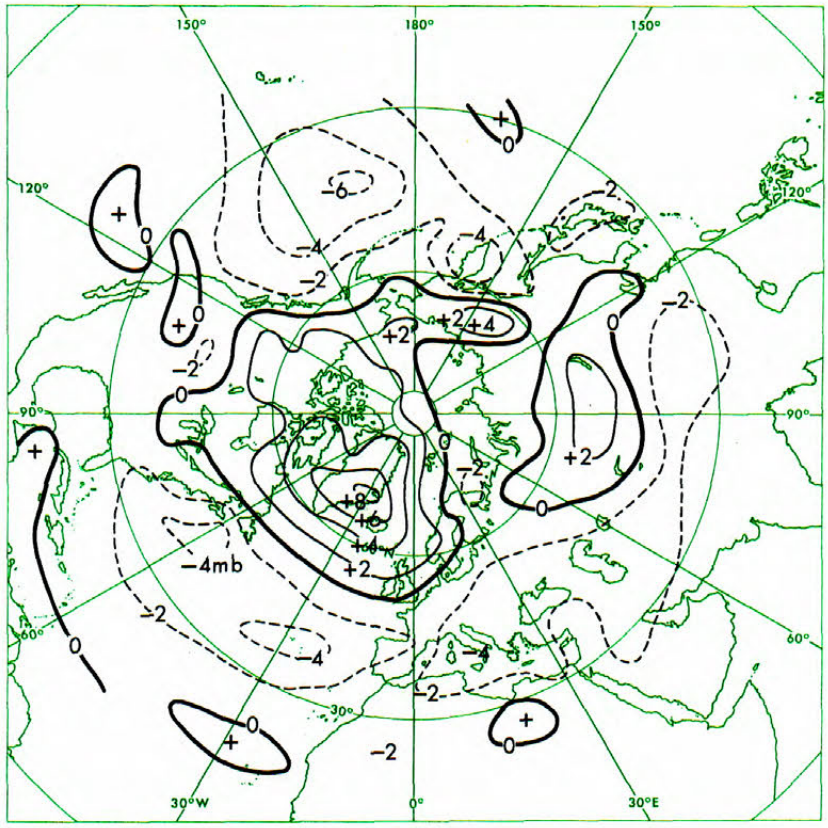


FIGURE 18(a). DIFFERENCE OF AVERAGE MONTHLY PRESSURE 1951–66 MINUS 1900–39, JANUARY

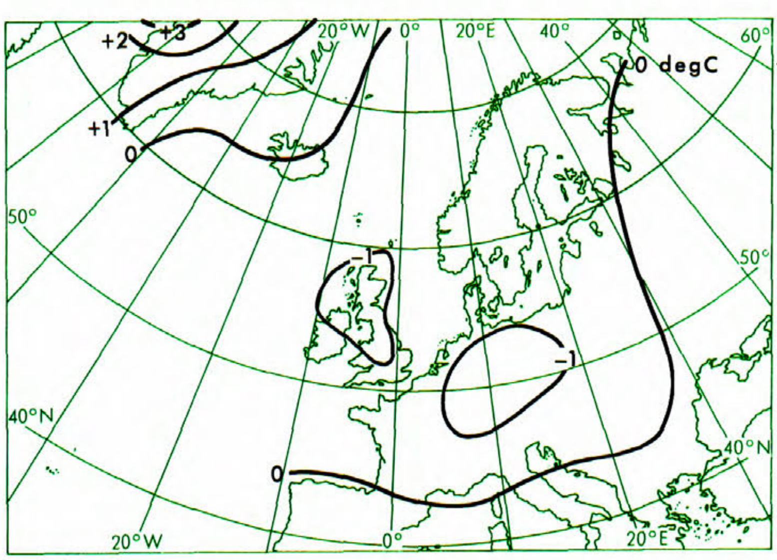


FIGURE 18(b). DIFFERENCE OF AVERAGE MONTHLY TEMPERATURE 1951–66 MINUS 1900–39, JANUARY

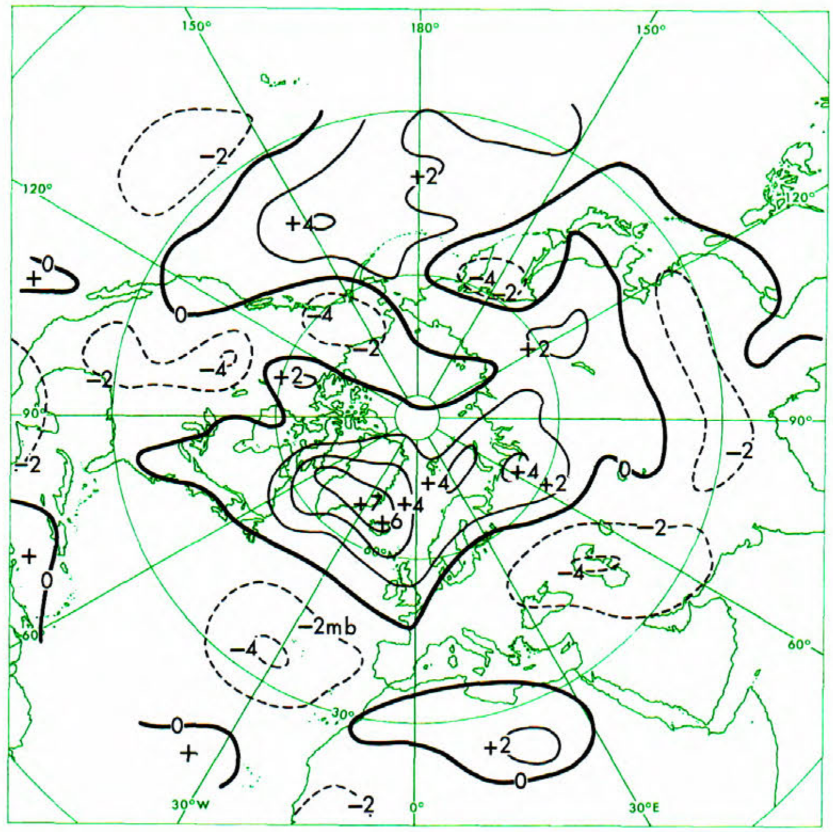


FIGURE 19(a). DIFFERENCE OF AVERAGE MONTHLY PRESSURE 1951–66 MINUS 1900–39, FEBRUARY

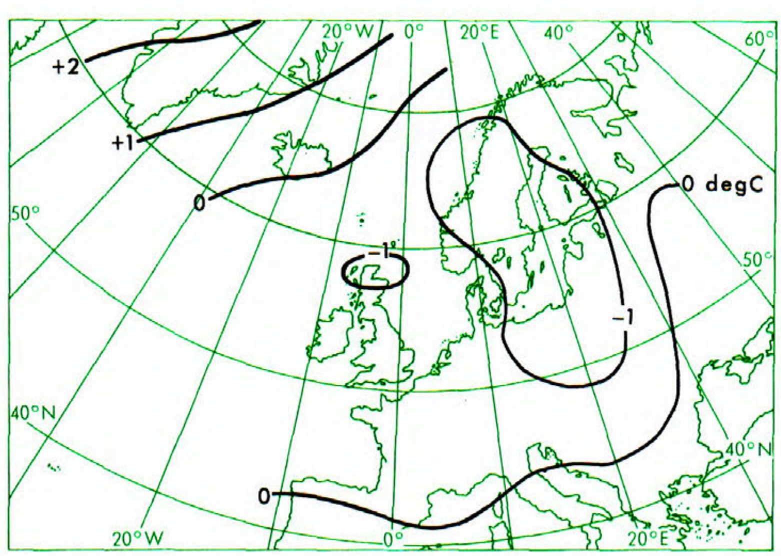


FIGURE 19(b). DIFFERENCE OF AVERAGE MONTHLY TEMPERATURE 1951–66 MINUS 1900–39, FEBRUARY

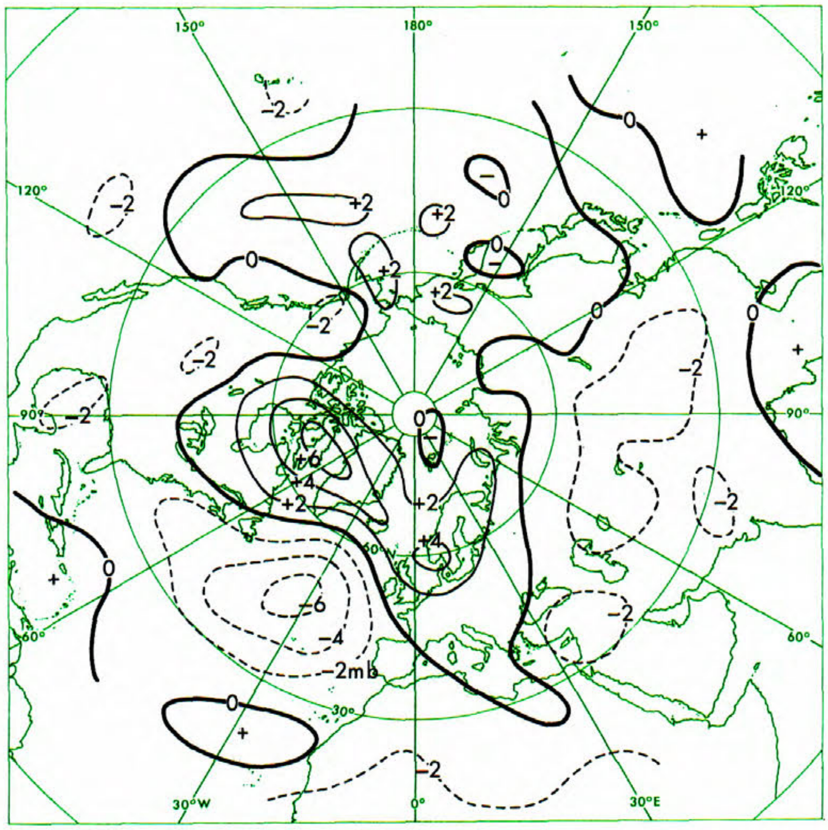


FIGURE 20(a). DIFFERENCE OF AVERAGE MONTHLY PRESSURE 1951–66 MINUS 1900–39, MARCH

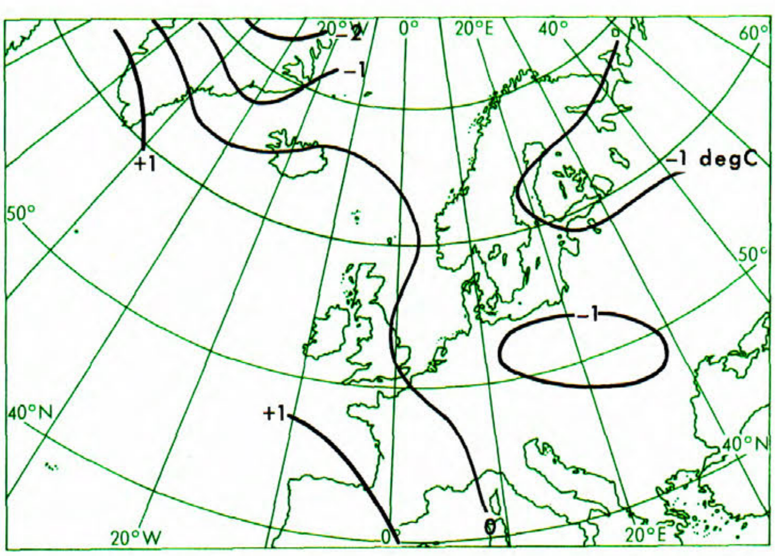


FIGURE 20(b). DIFFERENCE OF AVERAGE MONTHLY TEMPERATURE 1951–66 MINUS 1900–39, MARCH

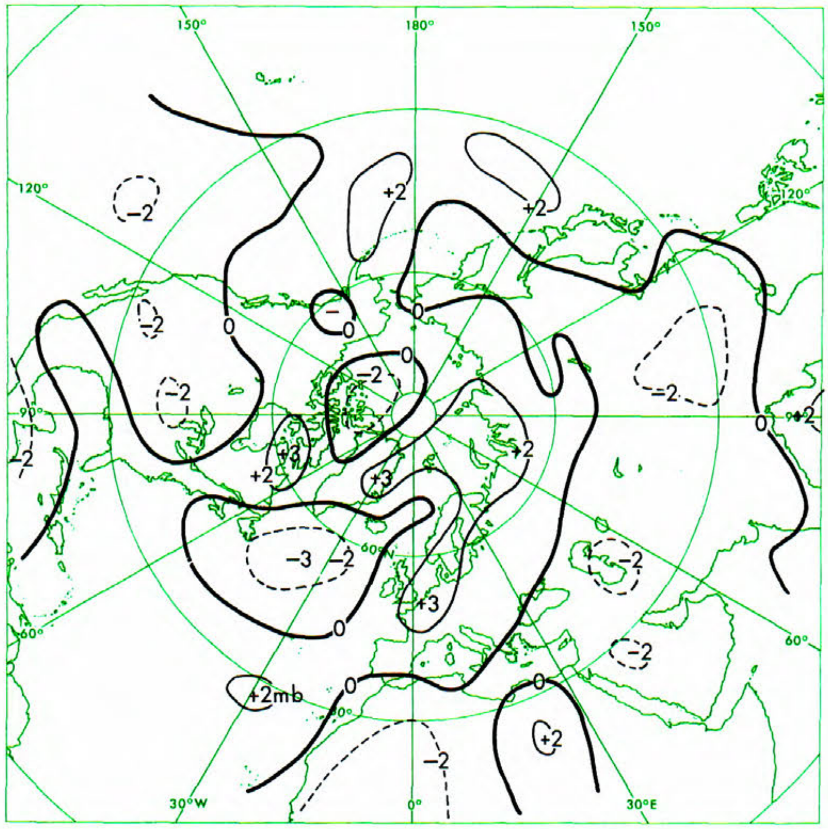


FIGURE 21(a). DIFFERENCE OF AVERAGE MONTHLY PRESSURE 1951–66 MINUS 1900–39, APRIL

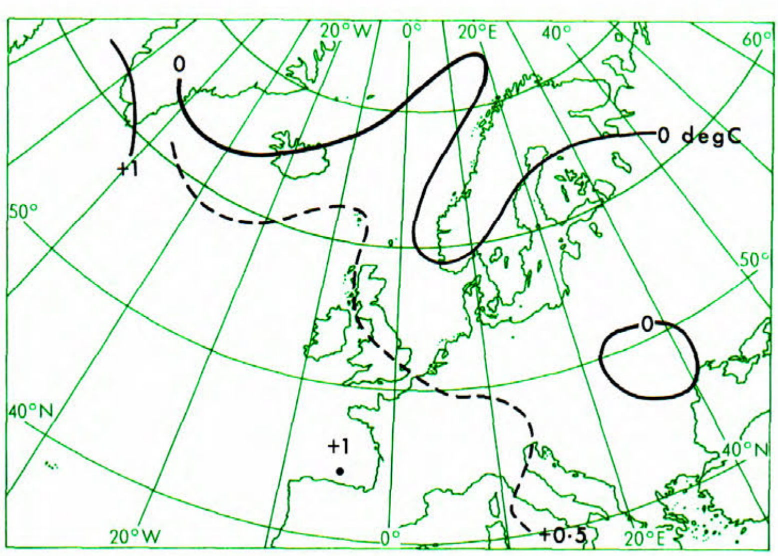


FIGURE 21(b). DIFFERENCE OF AVERAGE MONTHLY TEMPERATURE 1951–66 MINUS 1900–39, APRIL

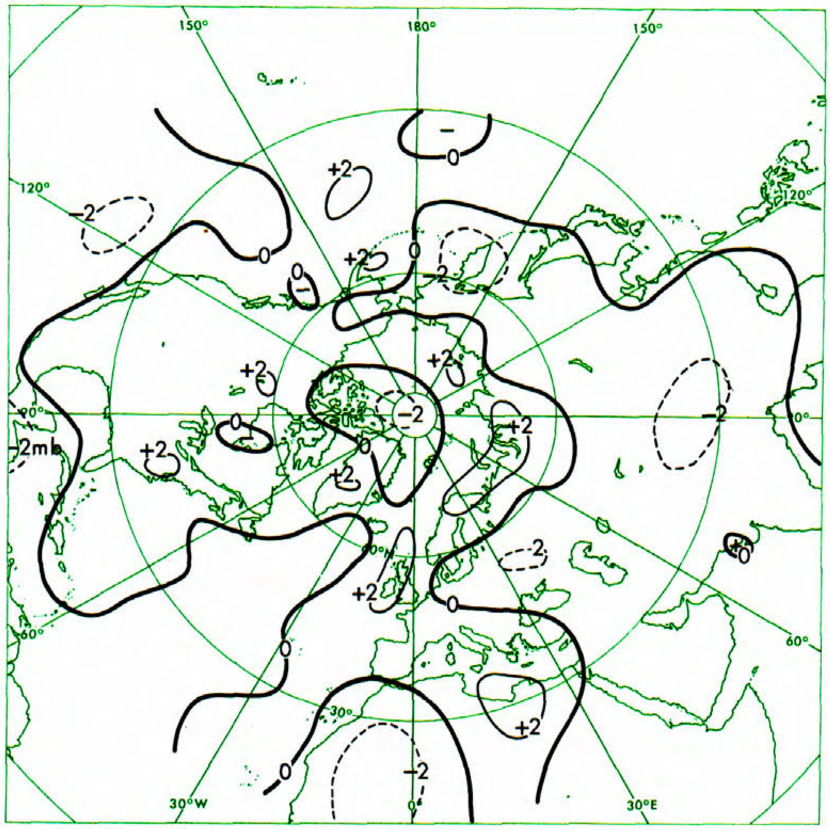


FIGURE 22(a). DIFFERENCE OF AVERAGE MONTHLY PRESSURE 1951–66 MINUS 1900–39, MAY

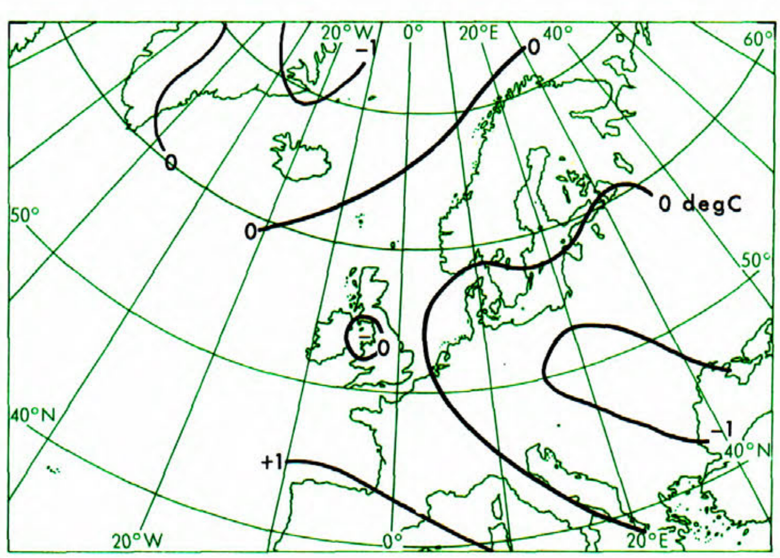


FIGURE 22(b). DIFFERENCE OF AVERAGE MONTHLY TEMPERATURE 1951–66 MINUS 1900–39, MAY

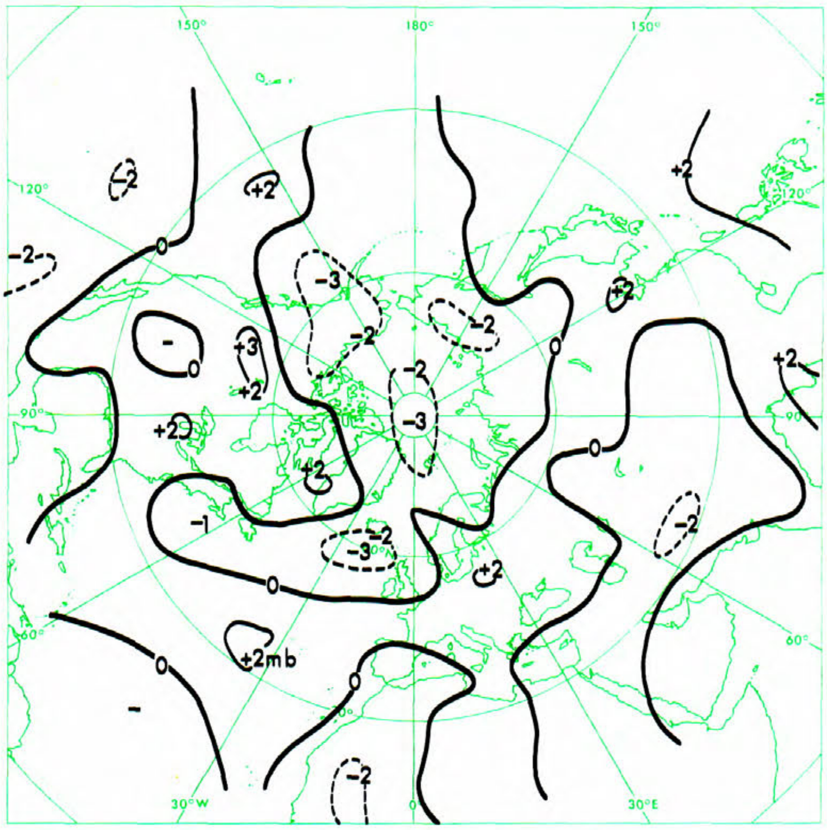


FIGURE 23(a). DIFFERENCE OF AVERAGE MONTHLY PRESSURE 1951–66 MINUS 1900–39, JUNE

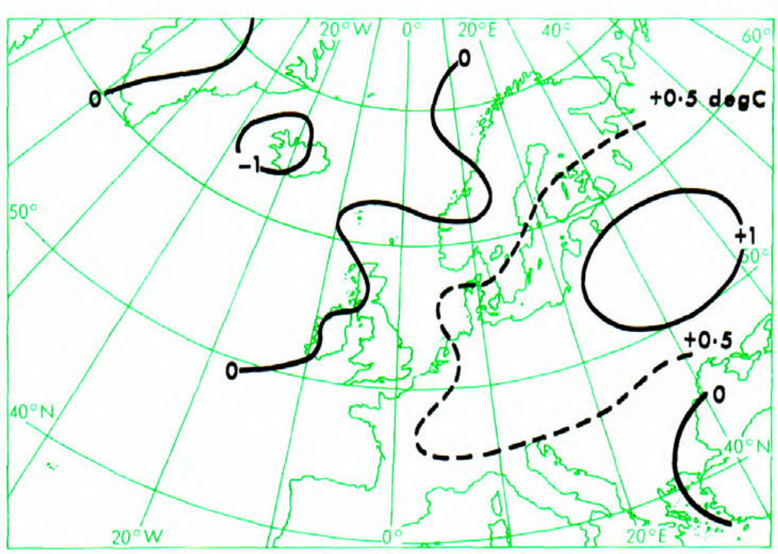


FIGURE 23(b). DIFFERENCE OF AVERAGE MONTHLY TEMPERATURE 1951–66 MINUS 1900–39, JUNE

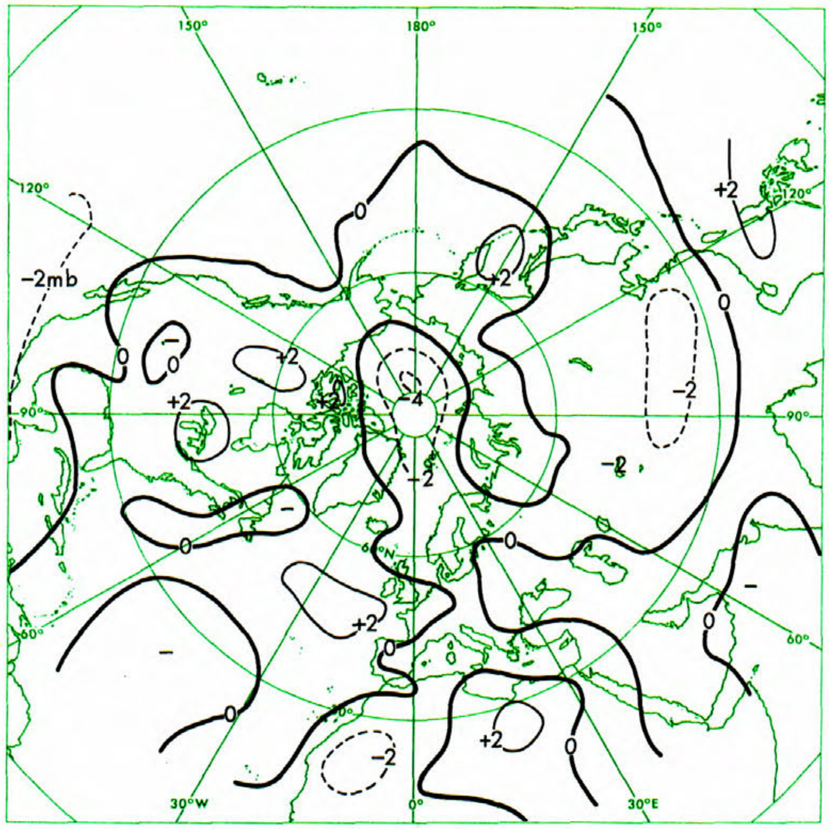


FIGURE 24(a). DIFFERENCE OF AVERAGE MONTHLY PRESSURE 1951–66 MINUS 1900–39, JULY

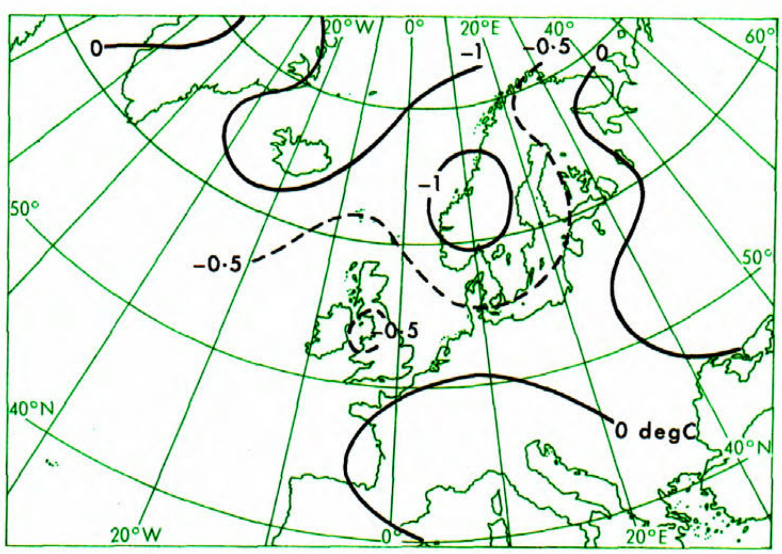


FIGURE 24(b). DIFFERENCE OF AVERAGE MONTHLY TEMPERATURE 1951–66 MINUS 1900–39, JULY

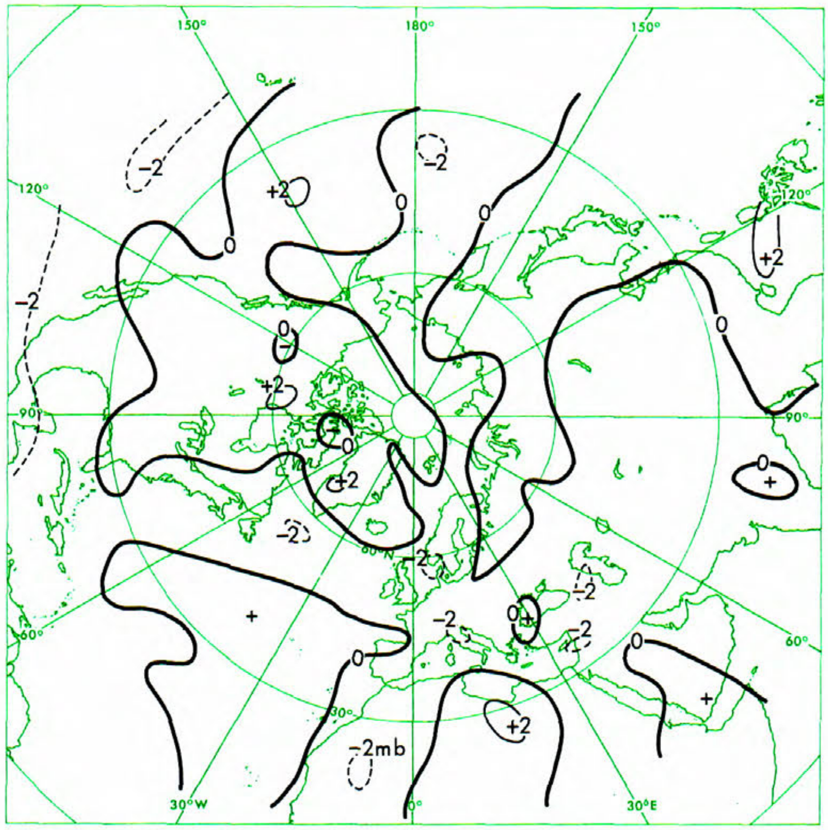


FIGURE 25(a). DIFFERENCE OF AVERAGE MONTHLY PRESSURE 1951–66 MINUS 1900–39, AUGUST

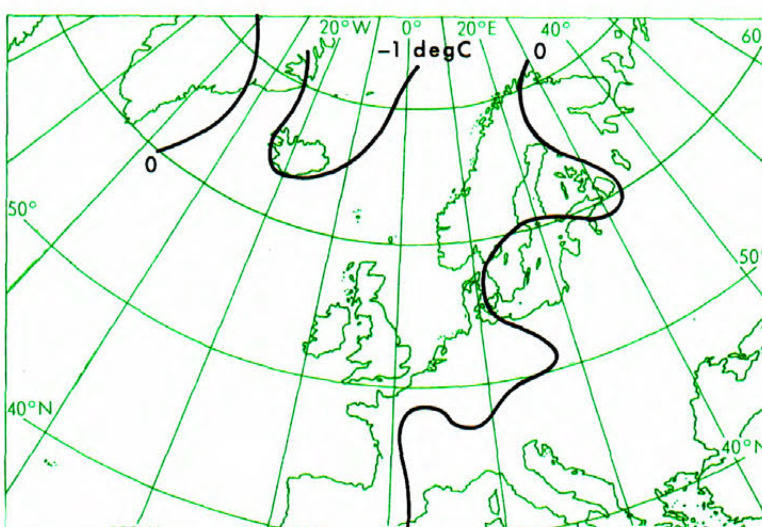


FIGURE 25(b). DIFFERENCE OF AVERAGE MONTHLY TEMPERATURE 1951–66 MINUS 1900–39, AUGUST

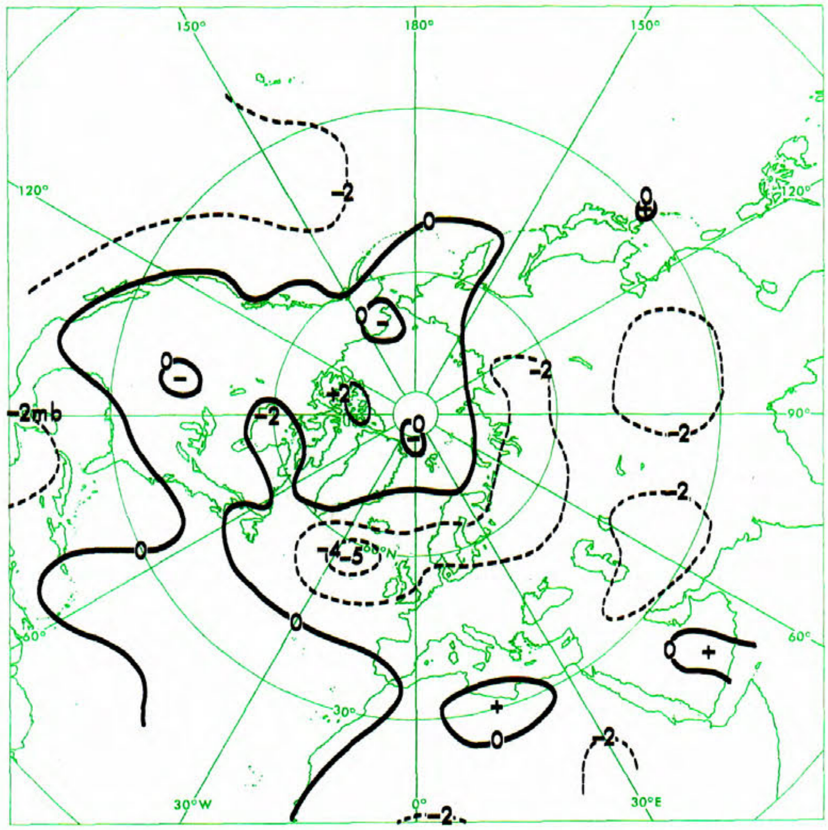


FIGURE 26(a). DIFFERENCE OF AVERAGE MONTHLY PRESSURE 1951–66 MINUS 1900–39, SEPTEMBER

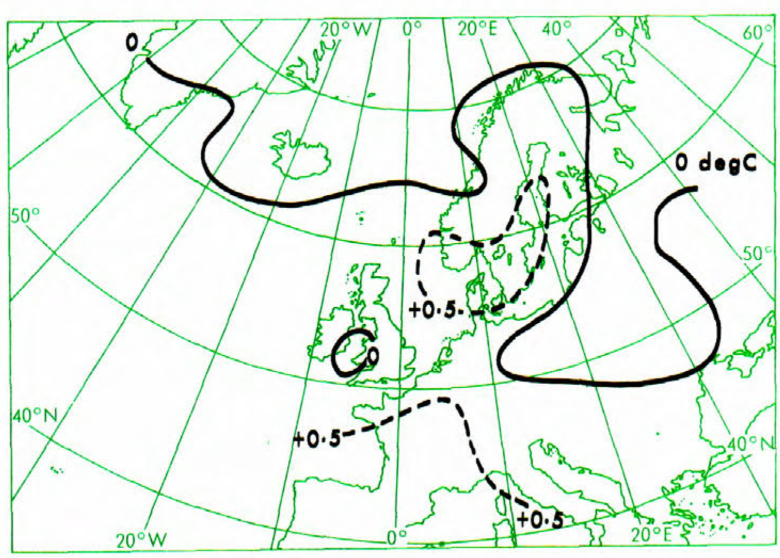


FIGURE 26(b). DIFFERENCE OF AVERAGE MONTHLY TEMPERATURE 1951–66 MINUS 1900–39, SEPTEMBER

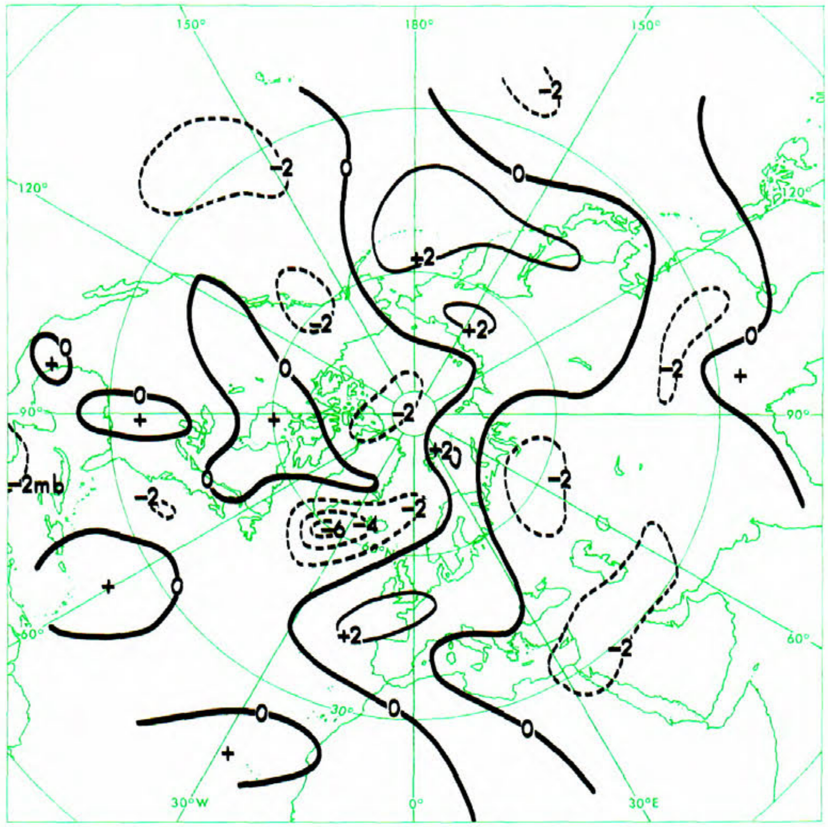


FIGURE 27(a). DIFFERENCE OF AVERAGE MONTHLY PRESSURE 1951–66 MINUS 1900–39, OCTOBER

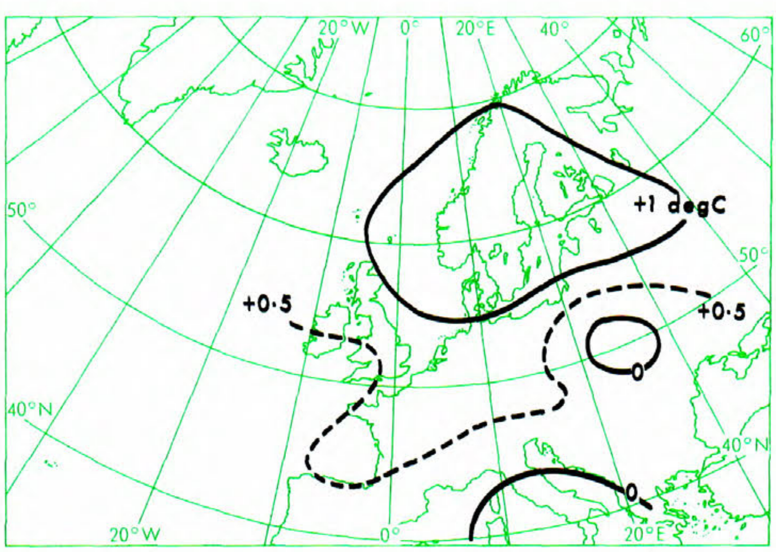


FIGURE 27(b). DIFFERENCE OF AVERAGE MONTHLY TEMPERATURE 1951–66 MINUS 1900–39, OCTOBER

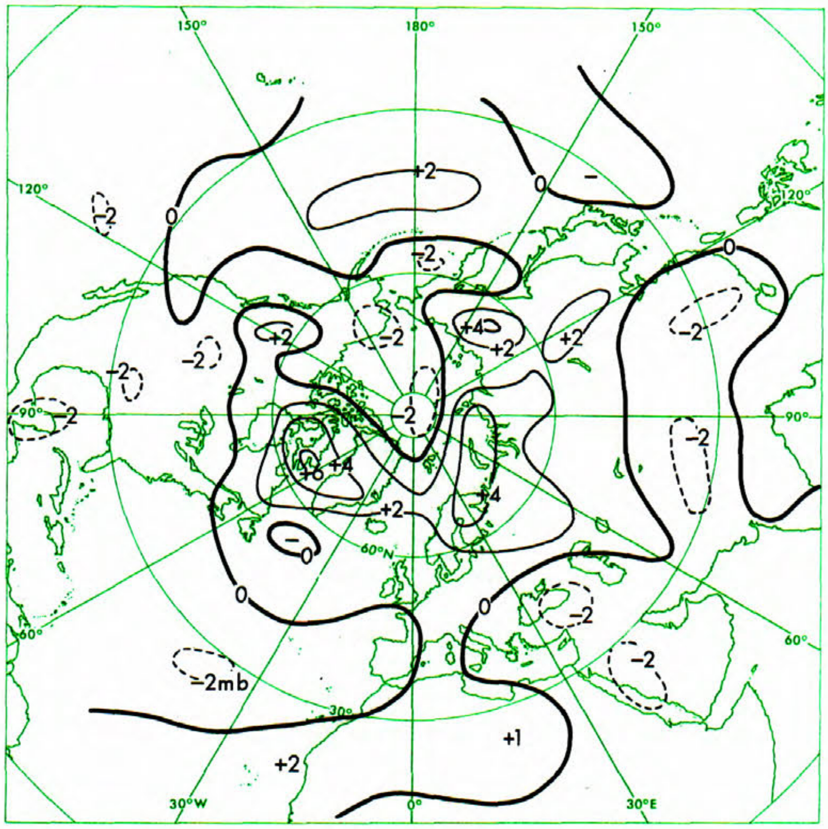


FIGURE 28(a). DIFFERENCE OF AVERAGE MONTHLY PRESSURE 1951–66 MINUS 1900–39, NOVEMBER

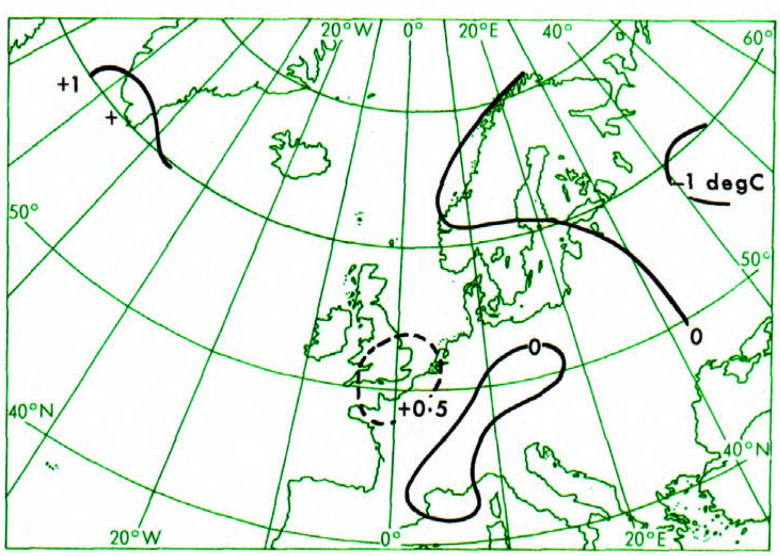


FIGURE 28(b). DIFFERENCE OF AVERAGE MONTHLY TEMPERATURE 1951–66 MINUS 1900–39, NOVEMBER

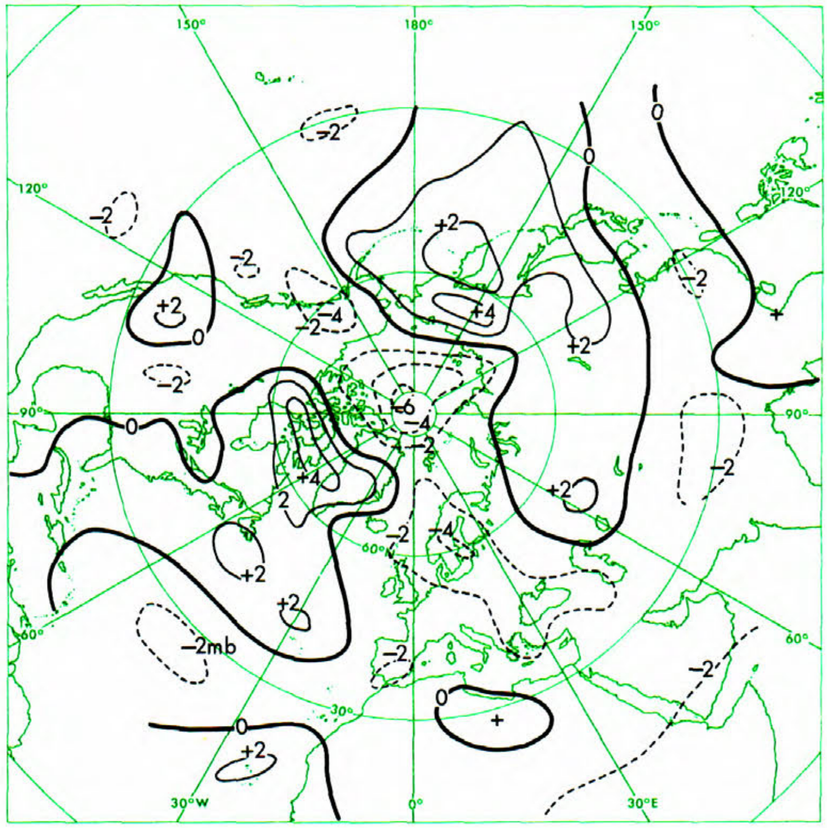


FIGURE 29(a). DIFFERENCE OF AVERAGE MONTHLY PRESSURE 1951–66 MINUS 1900–39, DECEMBER

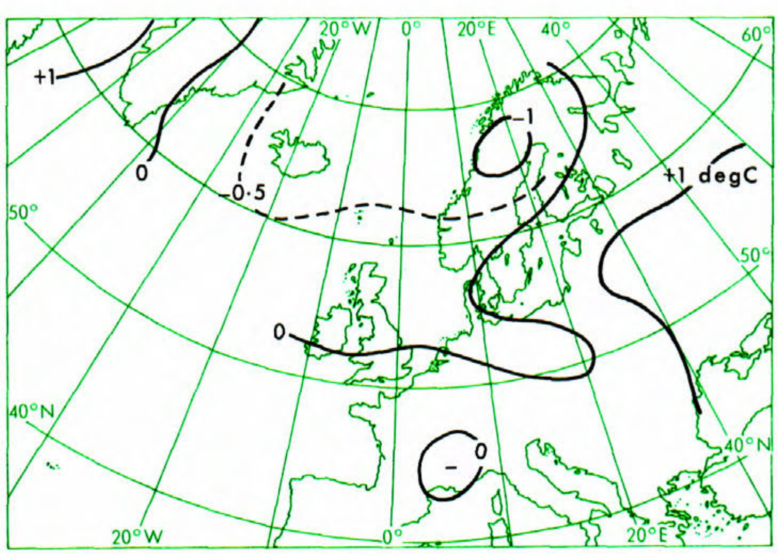
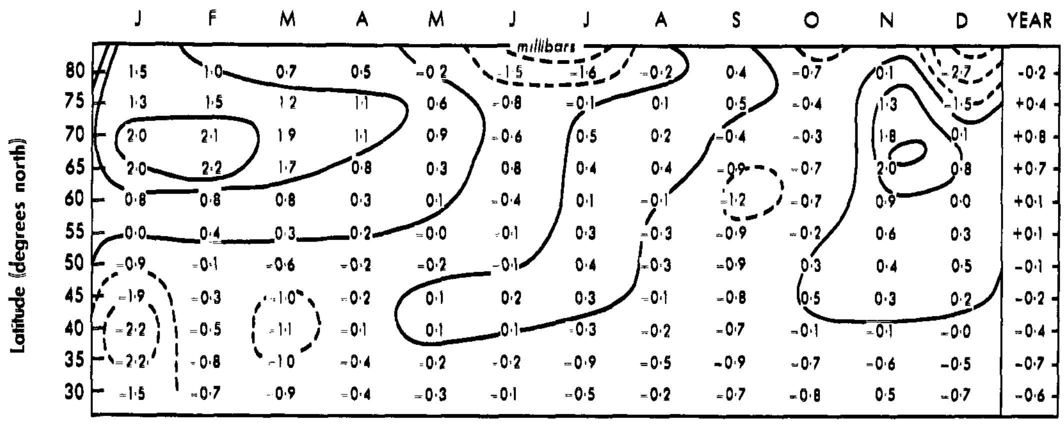
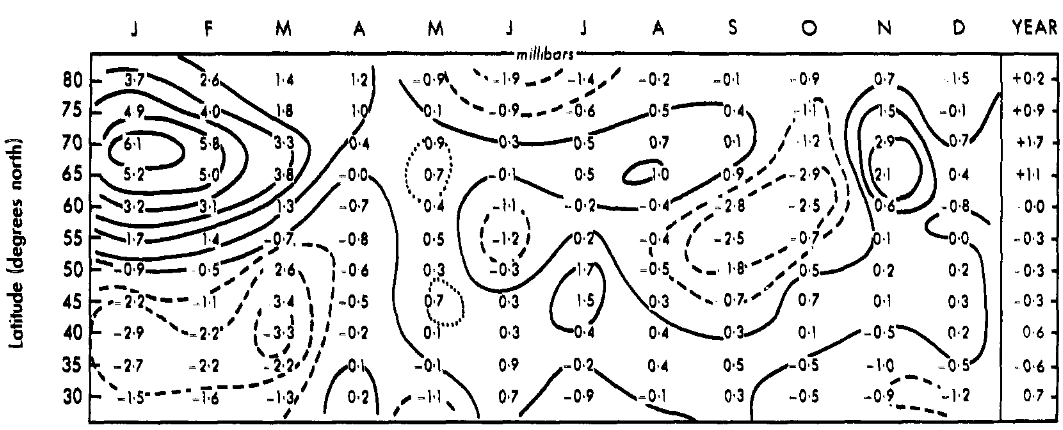


FIGURE 29(b). DIFFERENCE OF AVERAGE MONTHLY TEMPERATURE 1951–66 MINUS 1900–39, DECEMBER



(a) Averaged over all longitudes



(b) Averaged over the Atlantic sector 0° to 50°W

FIGURE 30. LATITUDE MEANS OF SEA-LEVEL PRESSURE CHANGE 1951-66 MINUS 1900–39

AVERAGED MONTH BY MONTH WITH YEARLY AVERAGE

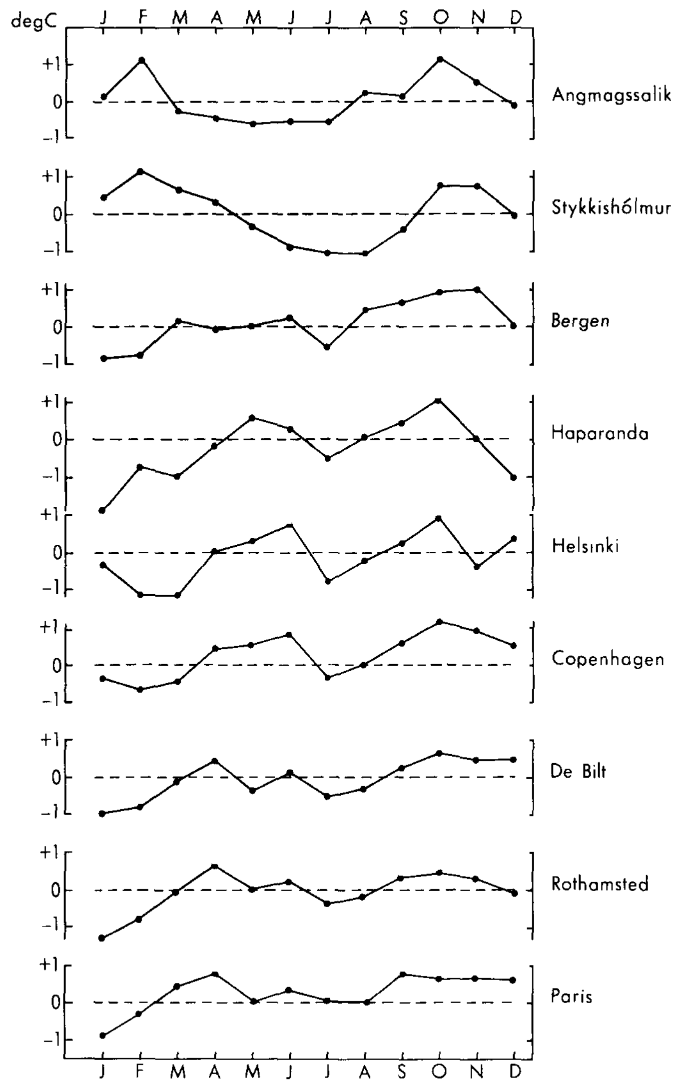


FIGURE 31. GENERAL TRENDS OF MONTHLY AVERAGE TEMPERATURE MONTH BY MONTH AT SELECTED STATIONS 1951–66 MINUS 1900–39

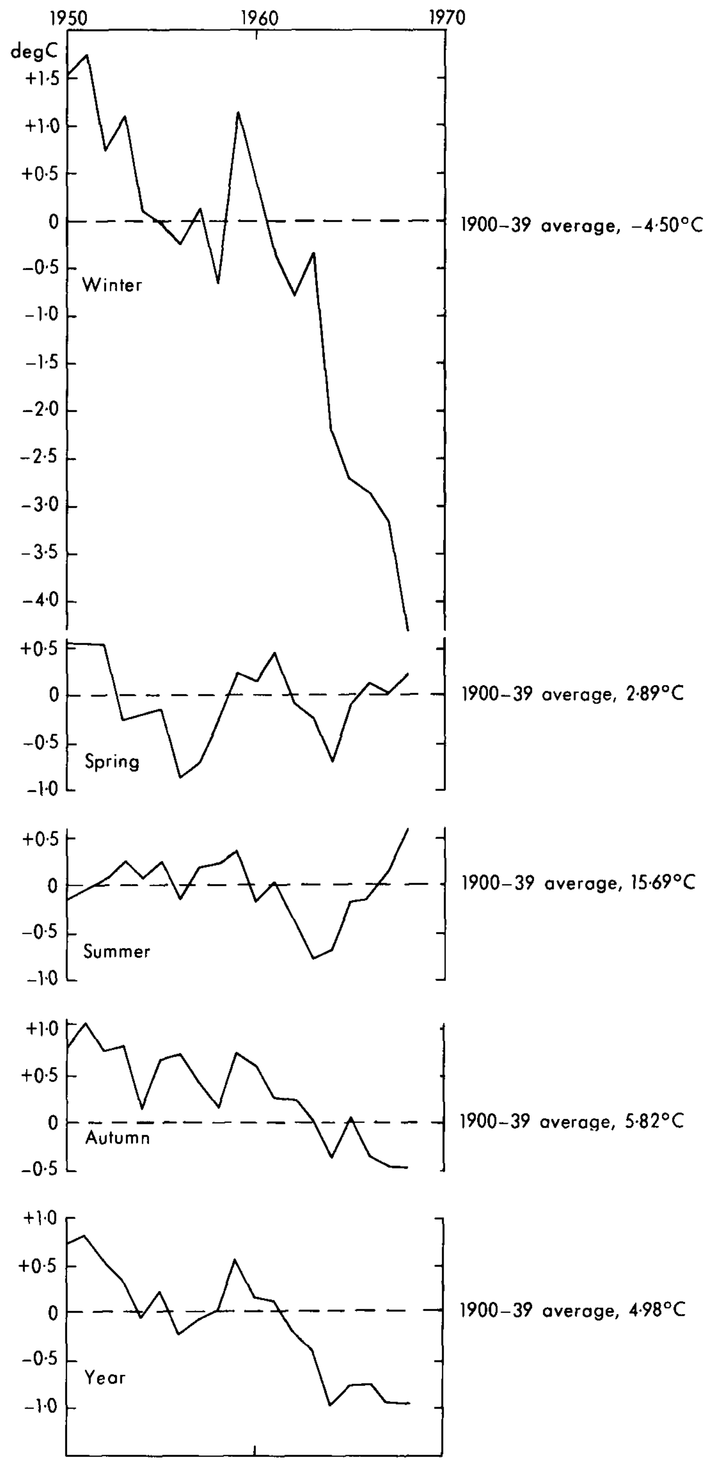


FIGURE 32. ANOMALIES OF 5-YEAR RUNNING MEANS OF TEMPERATURE FROM 1900–39 AVERAGES AT HELSINKI FOR EACH SEASON PLOTTED AT MIDDLE YEAR OF PERIOD COVERED

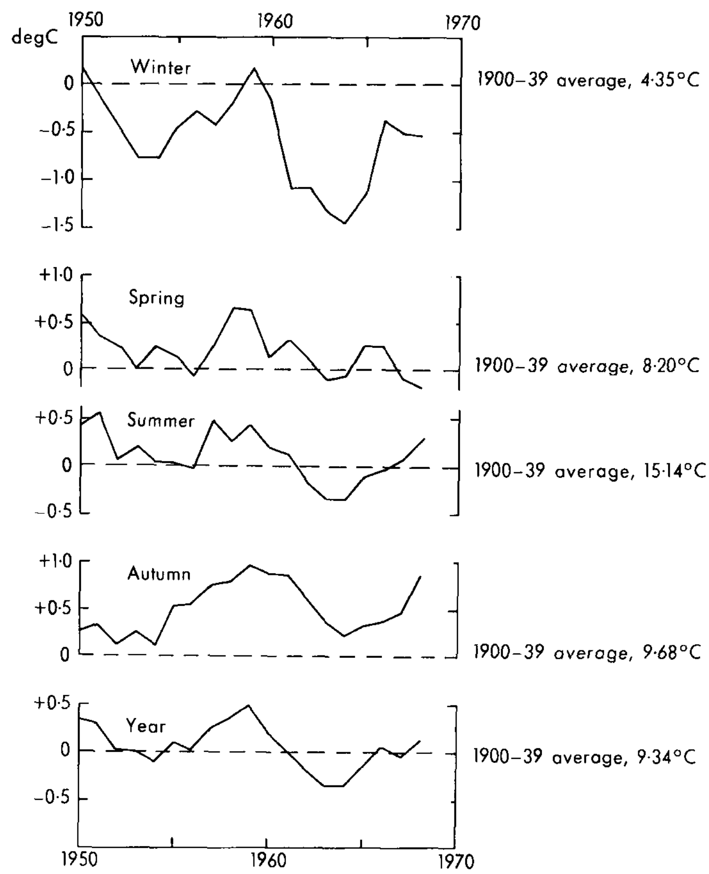


FIGURE 33. ANOMALIES OF 5-YEAR RUNNING MEANS OF TEMPERATURE FROM 1900–39 AVERAGES OVER CENTRAL ENGLAND FOR EACH SEASON PLOTTED AT MIDDLE YEAR OF PERIOD COVERED

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