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HANDBOOK

OF

WEATHER FORECASTING

METEOROLOGICAL OFFICE

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PREFACE

The Handbook of Weather Forecasting was written mainly for distribution within the Meteorological Office to provide forecasters with a comprehensive and up-to-date reference book on techniques of forecasting and closely related aspects of meteorology. The work, which appeared originally as twenty separate chapters, is now re-issued in three volumes in loose-leaf form to facilitate revision.

Certain amendments of an essential nature have been incorporated in this edition but, in some chapters, temperature values still appear in degrees Fahrenheit. These will be changed to degrees Celsius when the chapters concerned are completely revised.

CHAPTER 12

STATISTICAL AND CLIMATOLOGICAL DATA OF VALUE TO FORECASTERS

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SOME STATISTICAL AND CLIMATOLOGICAL DATA OF VALUE TO FORECASTERS

12.1. GENERAL

There are very few occasions when experience does not affect to some extent the final views which a forecaster takes of the way in which the current synoptic situation is expected to develop and of the weather which will be associated with that synoptic pattern. It may be that physical and dynamical concepts currently provide the main bases on which day-to-day forecasting is generally accomplished but the part played by experience is never negligible and in some cases is dominant. In this context experience may be regarded as the accumulated memory acquired by day-to-day work on the forecast bench, the somewhat bitter-sweet residue left from the recollection of some excellent and also some not so excellent forecasts in the past, the reading of meteorological literature and also discussions with fellow forecasters. For many, memory is inclined to be fickle and misleading. It is therefore important that forecasters should have a sound working knowledge of the climatology of the regions with which they are concerned. It is hoped that the data in this chapter will prove valuable in providing a basis against which the experienced forecaster can check and refresh his memory from time to time. It should also give the inexperienced forecaster a useful start in the struggle to acquire that harmonious blend of physical reasoning, insight and experience which enables the practising forecaster to take a balanced view – an essential attribute of the forecaster who consistently achieves high accuracy in his day-to-day work.

Much of this chapter consists of information obtained from investigations largely free from personal bias. There is a large amount of literature on general climatology but relatively little dealing with the more specialized synoptic climatology. The following selection from the available literature should form a useful first version of this chapter of the handbook. In the final section of this chapter an attempt is made to describe some features associated with a few synoptic types near the British Isles and the contents of this section must reflect to some extent the personal experiences of the writer and those who have offered advice on that section.

In order to reveal some sort of order in the infinite variety of synoptic situations it is necessary to subject the mass of data to a series of smoothing operations so that the principal or chief modes of behaviour can be estimated. These modes are thus devoid of the embroidery of detail which is always present on the chart with which any practising forecaster has to deal. It follows that the mean values given here will indicate only the general lines on which the majority of subsequent events may be expected to develop. Even on those occasions when the situation evolves in general agreement with the means for a particular month or season there will be minor deviations which are always vital for accurate short-period forecasting and often also for periods up to 24 hours ahead. Furthermore some months or even seasons are sometimes persistently abnormal. At the present time these abnormalities cannot be accurately foretold in advance. However, when they are well established, experience indicates that, for some period often measured in days and perhaps weeks, it is sometimes sound policy to anticipate that there will be a persistence of type or continued abnormality and that a forecast based on normality or reversion to normality is likely to be seriously in error. It has so far proved quite impossible to give sound advice as to the circumstances in which continued abnormality should be forecast or even to catologue these cases in a manner which is concise and at the same time useful and practical on the forecast bench. Climatological data such as those given in the following pages cannot alone form a satisfactory basis for a forecast. However, they can be very valuable in assessing the probability of events forecast on the basis of physical theory or extrapolation and can ensure that very unusual events are not forecast without careful scrutiny of the basis of the forecast.

An important part of the mental equipment of the skilled and efficient forecaster is a good working knowledge of climatology over an area which is substantially greater than the area for which forecasts have to be prepared. In compiling a suitable account for the handbook some compromise decision on the area to be covered was necessary. Taking account of the desirability of limiting the treatment to a reasonable length, the general eastward motion of many migratory weather systems of middle latitudes and the long inter-continental aircraft routes likely to be flown, it appeared that the needs of forecasters would probably be best met by giving some fairly general data for an area of a quadrant of the earth's surface extending from 120°W. eastwards to 60°E. and from the North Pole well into the subtropics. Some rather more detailed data for much more restricted areas near the British Isles to supplement the more general data over the wider area are also included. It is hoped that this selection will prove to be a useful compromise solution to the needs of the various categories of forecasters.

12.2. PRINCIPAL TRACKS AND MEAN FREQUENCIES OF CYCLONES AND ANTICYCLONES OVER MUCH OF THE NORTHERN HEMISPHERE LYING BETWEEN 120°W. AND 60°E.

This subsection is based entirely on an extensive paper by Klein[1*] who consulted a great number of papers concerned with synoptic systems in various areas of the northern hemisphere. He also used extensive data prepared by United States authorities including the 40-year Historical Map Series[2] (1899–1939), 20-year Historical Map Frequencies[3] (1909–1914 and 1924–1937) and punched cards prepared therefrom.[4] By processing the large amount of available data in various ways (for details the reader should consult the original paper) Klein obtained, *inter alia*, three series of monthly charts at sea level. One series showed the frequencies of cyclones and anticyclones per unit area. Another series showed the frequencies of cyclogenesis and anticyclogenesis per unit area and the third showed the principal tracks of cyclones and anticyclones. Sections of these charts are reproduced in Figures 12.1 to 12.24 and the supporting text is taken almost verbatim from Klein's paper. Figures 12.1, 3, 5 etc. to 23 contain sections showing the data for sea level for cyclones, cyclogenesis and the principal tracks of cyclones for each month of the year. Figures 12.2, 4, 6 etc. to 24 contain similar data for anticyclones. Explanatory text relating to the method of preparation and the meaning of data or symbols on the charts is contained in Section 12.2.1. The regional climatological aspects of the tracks and frequencies for both cyclones and anticyclones are discussed, month by month, in Section 12.2.2. The data has been arranged in this manner so that a practising forecaster can readily refer to the available material for both cyclones and anticyclones for the times of the year with which he is at that time operationally concerned.

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*The superscript figures refer to the bibliography at the end of this chapter.

Statistical and Climatological Data

12.2.1. *Explanation of the charts*

12.2.1.1. *Frequencies of cyclones per unit area at sea level* (Figures 12.1*(a)*, 3*(a)* etc. to 23*(a)*). The values plotted in green indicate, for each calendar month, the number of days when a low pressure centre of any type was located within unit boxes at 1230 G.M.T. during the 40-year period of the original Historical Map Series,[2] from 1 January 1899 to 31 December 1938. The frequencies were initially counted in boxes 5° latitude in length and of the varying widths listed in Table 12.1. They were then adjusted to unit box size (5° latitude by 5° longitude at 45°N.), rounded to the nearest whole number, and plotted in approximately the centre of the appropriate box. Blank boxes indicate zero frequency or missing data. No analysis of these numbers is reproduced.

The isopleths indicate, for each calendar month, the number of different low-pressure centres (excluding thermal lows and hurricanes) located within unit boxes at 1230 G.M.T. during the 20 years of the original Historical Map Series with best coverage of hemispheric data: 1909–14 and 1924–37. For this tabulation no one low was counted more than once in the same box, regardless of how many days it stayed there. The frequencies were compiled using boxes 5° latitude in length and of the varying widths listed in Table 12.2. Since all boxes were roughly equal in area to a unit box 5° latitude by 5° longitude at 47°N., no further adjustment was made. The isopleths are analysed at intervals of 10, with selected intermediate lines (at intervals of 5) dashed and the zero line heavier. Centres of maximum frequency are labelled in large vertical numerals; centres of minimum frequency in small underlined numerals. These labels are sometimes offset from the centres to avoid obscuring the numbers in green. Individual frequencies in each box upon which the analysis is based are not reproduced.

TABLE 12.1 *Size of unit boxes in which frequencies of lows and highs were compiled for 40 years of historical maps, and coefficients used for adjusting these frequencies to equal-area basis*

Latitude (°N.)	*Number of 5° boxes used*	*Width (° long.)*	*Adjusting coefficient*
05–09	1	5	0.7174
10–14	1	5	.7283
15–19	1	5	.7451
20–24	1	5	.7685
25–29	1	5	.7998
30–34	1	5	.8403
35–39	1	5	.8923
40–44	1	5	.9590
45–49	1	5	1.0454
50–54	1	5	1.1588
55–59	1	5	1.3114
60–64	1	5	1.5244
65–69	2	10	.9188
70–74	2	10	1.1685
75–79	3	15	1.0816
80–84	6	30	.8964
85–89	18	90	.8940

TABLE 12.2 *Size of unit boxes in which frequency of occurrence, genesis, and motion were compiled for 20 years of historical maps*

Latitude (° N.)	*Width (° long.)*	*Width (miles)*
05–09	3	206
10–14	3	203
15–19	4	265
20–24	4	257
25–29	4	247
30–34	4	235
35–39	4	221
40–44	5	257
45–49	5	236
50–54	5	213
55–59	6	227
60–64	8	260
65–69	9	244
70–74	12	257
75–79	15	234
80–84	24	232
Mean		237

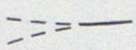
12.2.1.2. *Frequencies of anticyclones per unit area at sea level* (Figures 12.2*(a)*, 4*(a)* etc. to 24*(a)*). Preparation and analysis of these charts are the same as for cyclones (see Section 12.2.1.1).

12.2.1.3. *Frequency of cyclogenesis per unit area at sea level* (Figures 12.1*(b)*, 3*(b)* etc. to 23*(b)*). The isopleths indicate, for each calendar month, the number of cyclones that originated within unit boxes during the 20 years of the original Historical Map Series with the best coverage of hemispheric data: 1909–14 and 1924–37. Only the location of the low at 1230 G.M.T. on the first day of its existence was considered. The frequencies were counted in boxes 5° latitude in length and of the varying widths listed in Table 12.2. Since all boxes were roughly equal in area to a unit box 5° latitude by 5° longitude at 47°N., no further adjustment was made. The isopleths are drawn at intervals of 4, with selected intermediate lines (at intervals of 2) dashed and the zero line heavier. Centres of maximum frequency are labelled in large vertical numerals; centres of minimum frequency in small underlined numerals except for zero centres which are left blank. Individual frequencies in each quadrangle upon which the analysis is based are not reproduced.

12.2.1.4. *Frequency of anticyclogenesis per unit area at sea level* (Figures 12.2*(b)*, 4*(b)* etc. to 24*(b)*). Preparation and analysis of these charts are the same as for cyclogenesis (see Section 12.2.1.3).

12.2.1.5. *Principal tracks of cyclones at sea level* (Figures 12.1*(c)*, 3*(c)* etc. to 23*(c)*). The prevailing direction of motion of systems is indicated by the arrows. Heavy solid lines denote primary tracks – those which are most frequent and generally indicated by various data sources; thin dashed lines denote secondary, less frequent, and less well defined tracks. All arrow-heads end in areas where cyclone frequency is a local maximum. Here the tracks may cross, branch and merge, although they are not specifically so drawn. Locally preferred regions of genesis are indicated where secondary or primary tracks begin, whether in centres of maximum cyclone frequency or elsewhere. An area of frequent genesis is also indicated by either of the following two track symbols (all motion from left to right):

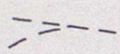
 A single secondary track changes to a single primary track.

 Two secondary tracks merge to form a primary track, with a break between dashed and solid line.

Other track representations occasionally used, none of which represent genesis, are illustrated below (again all motion from left to right):

 Two secondary tracks merge to form a primary track, without a break between dashed and solid line.

 A secondary track merges with a primary track, without a break between dashed and solid line.

 Two secondary tracks merge to form another secondary track.

 Two primary tracks merge.

 A primary track decreases in frequency to a secondary track.

 A secondary track branches off from a primary track.

 A primary track splits into two primary branches.

 A secondary track splits into two secondary branches.

12.2.1.6. *Principal tracks of anticyclones at sea level* (Figures 12.2(*c*), 4(*c*) etc. to 24(*c*)). Preparation and analysis of these charts and the symbols are the same as for cyclones (see Section 12.2.1.5).

12.2.2. *Regional climatological aspects of tracks and frequencies (by months)*

12.2.2.1. *January*

12.2.2.1.1. Cyclones (Figure 12.1). Most North American cyclones originate (or redevelop) in Alberta where fronts and troughs from the Pacific produce closed sea-level lows on the lee (eastern) slopes of the Rocky Mountains along the quasi-stationary Arctic front. The primary storm track from southern Alberta east-south-eastward to a centre of maximum frequency in the upper Great Lakes region is one of the most frequent and best defined in the northern hemisphere. Here the track of these well known Alberta lows is joined by paths of cyclones from several parts of the United States. Most prominent are the so-called Colorado lows which may form in the Great Basin, northern Rockies, or Central Plain, as well as Colorado proper, before moving north-eastward across the central United States. Cyclones which develop in Texas or the Ohio valley also find their way into the centre of maximum frequency in the upper Lakes. From here most of the storms go east-north-eastward along a well defined primary track through the St. Lawrence valley into a centre of maximum frequency near Newfoundland. Many of the lows contributing to this centre travel up the east coast of the United States, where the thermal contrast between land and water favours cyclogenesis along the Atlantic polar front. Some of these cyclones originate over the warm waters of the western Gulf of Mexico and pass north-eastward across the Gulf States before intensifying near Hatteras.

In the Atlantic a characteristic Y-shaped track appears, as most of the Newfoundland lows migrate north-north-eastward toward southern Greenland. Here the high ice-covered plateau shunts storms north-westward up the west coast or north-eastward along the east coast. A few cyclones enter the Davis Strait by way of Hudson Bay, and a few leave by moving north-westward across Baffin Bay, but those routes are seldom travelled. On the other hand, the Icelandic area is approached by another primary track, composed of some Newfoundland lows but mostly of cyclones developing near the Gulf Stream south or east of Newfoundland. Break-offs from the semi-permanent Icelandic low usually move north-eastward along several different routes, to a pronounced centre of maximum cyclone frequency at the western edge of the Barents Sea.

Most European cyclones move in a generally zonal direction along one of three preferred paths. There are primary tracks along the northern and southern borders of the continent and a third track, of lesser frequency, across the North and Baltic Seas. The northern track extends eastward through the Barents and Kara Seas. Although a few storms enter the southern track from the English Channel, the overwhelming majority form south of the Alps near the relatively warm waters of the Gulf of Genoa or Adriatic Sea. In fact there were more cases of cyclogenesis around northern Italy during the 20 Januarys of record than in any other equal area of the northern hemisphere (note maximum frequency of 19 lows per 5° box in Figure 12.1*(b)*). Most of the Mediterranean cyclones travel along a well defined path east-south-eastward into a centre of maximum frequency near Cyprus, where a mean low appears on the normal map. From here a weak secondary track extends across Iraq and Iran into northern India, where centres of maximum cyclogenesis and cyclone frequency occur. A few depressions may even pass south of the Himalayas into China. Some of the Mediterranean lows migrate north-eastward across the Aegean and Black Seas, and a few go farther east (north of the Caucasus Mountains) into the Caspian Sea or Sea of Aral. Occasionally storms pass north-eastward across Russia to merge with the primary track in northern Siberia.

12.2.2.1.2. Anticyclones (Figure 12.2). Migratory anticyclones are primarily of two types: those which originate in middle latitudes and move mainly eastward, and those which originate at high latitudes and usually move southward. Some of the latter form in Scandinavia, eastern Siberia, Greenland, British Columbia, or the Arctic Ocean; but the great majority form in Alaska or north-western Canada, where anticyclone frequency is higher in January than in any other month (Figure 12.2*(a)*). From here most of these polar highs travel south-eastward along a well defined primary track into a centre of maximum anticyclone frequency in the Dakotas. They then usually take a cyclonically curved trajectory through the Missouri and Ohio valleys and contribute to a centre of maximum frequency in the middle Atlantic States. However, a few polar anticyclones penetrate farther southward into Texas, where their arrival is often preceded by the notorious "northers". Here their path merges with that of highs originating in the Great Basin, where the frequency of both anticyclones and anticyclogenesis is higher than anywhere else in the northern hemisphere (Figures 12.2*(a)* and *(b)*).* These Basin highs frequently lose their identity upon crossing the Rocky Mountains, where the solid primary track of Figure 12.2*(c)* changes to a dashed secondary track, only to redevelop farther east in one of the Southern States.

After leaving Texas, most highs recurve sharply north-eastward, tending to avoid the warm waters of the Gulf of Mexico, as noted by Wasko.[5] A similar effect is even more striking in the Great Lakes region, where heating over the water provides a local source of cyclonic vorticity. As a result, a distinct minimum of anticyclone frequency is present over the Great Lakes during all of the cold-season months from November through March. Those polar anticyclones which do not go south of the Lakes usually pass north of the area, over the cold land between the Lakes and James Bay. These are often referred to as "glancing highs" which slip across southern Canada and northern New England when strong westerlies prevent them from plunging southward.

A double track is also found in the Atlantic, where a centre of minimum anticyclone frequency occurs every month from December through April off the coast between Hatteras and Nantucket, where the land is concavely shaped with respect to the water. Most American anticyclones pass south of this minimum, through Bermuda and then across the Atlantic between 30° and 35°N.; but the glancing highs usually keep to its north, traversing the Atlantic between 40° and 45°N. The two tracks merge near the area where the quasi-permanent Azores high cell is found on normal maps. Most break-offs from the Azores high enter western Europe and contribute to a primary track around 50°N., which is re-enforced by anticyclogenesis in France, the Balkans, Russia and Scandinavia. However, a few Azores offshoots find their way into Spain and Algeria, where frequent anticyclogenesis is responsible for a primary track in North Africa around 30°N. A double anticyclone route of this sort, corresponding to a normally split jet stream aloft, is characteristic of this area nearly every month of the year, and is particularly well marked during the cold season. In fact, during every month from October through April, a distinct centre of minimum anticyclone frequency over the Mediterranean contrasts with centres of maximum frequency over North Africa to the south and western Europe to the north.

In Asia the primary anticyclone track is an extension of the main European one around 50°N., although to the south a few highs from Egypt may reach Iran and northern India.

12.2.2.2. *February*

12.2.2.2.1. Cyclones (Figure 12.3). In February the westerlies of low latitudes are normally stronger than during any other month of the year at both

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*The concentration of highs in the Great Basin may be partly fictitious due to the process of reducing to sea-level pressure. On the other hand, topographic factors favour dynamic anticyclogenesis in this area.

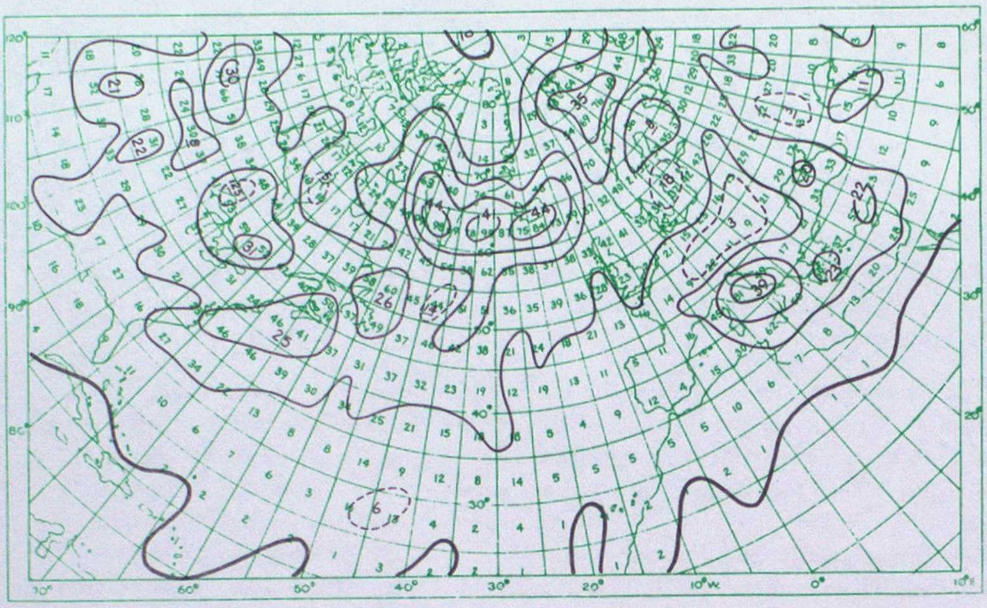

FIGURE 12.1(*a*) *Cyclones at mean sea level – January*

Black isopleths: number of cyclones (20 years)
Green figures: days with cyclones (40 years)

FIGURE 12.1(*b*) *Frequency of cyclogenesis at mean sea level – January*

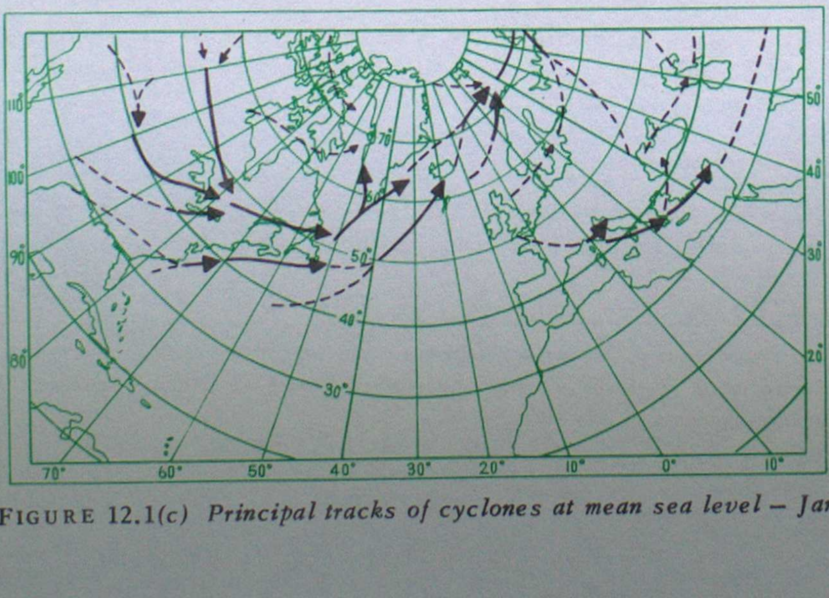

FIGURE 12.1(*c*) *Principal tracks of cyclones at mean sea level – January*

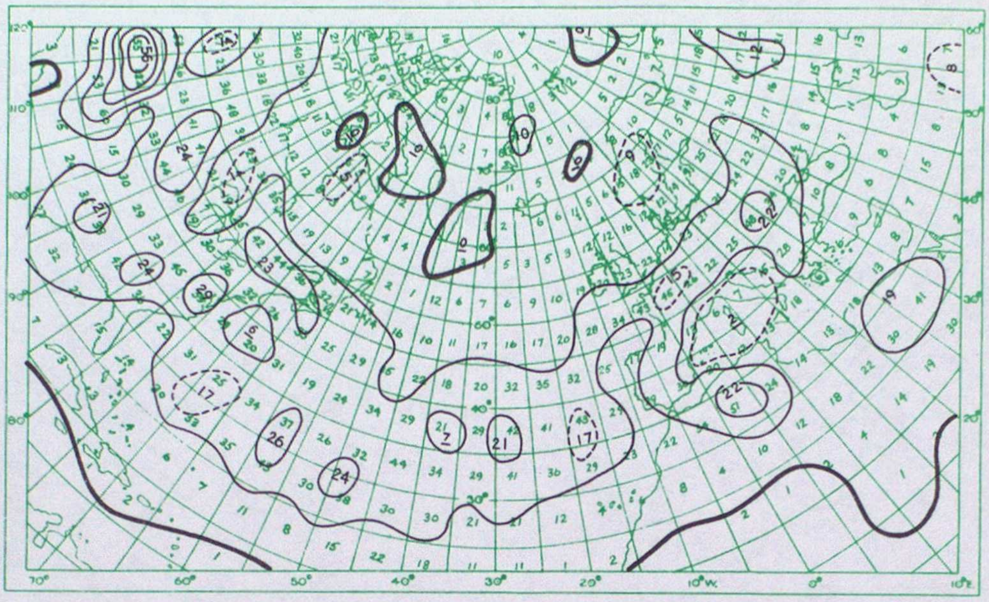

FIGURE 12.2(*a*) *Anticyclones at mean sea level – January*

Black isopleths: number of anticyclones (20 years)
Green figures: days with anticyclones (40 years)

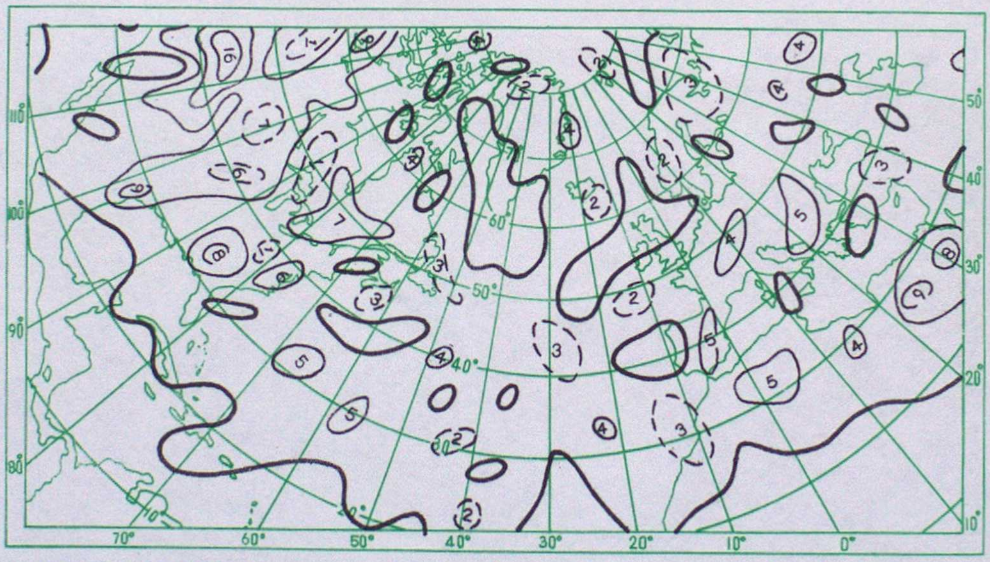

FIGURE 12.2(*b*) *Frequency of anticyclogenesis at mean sea level – January*

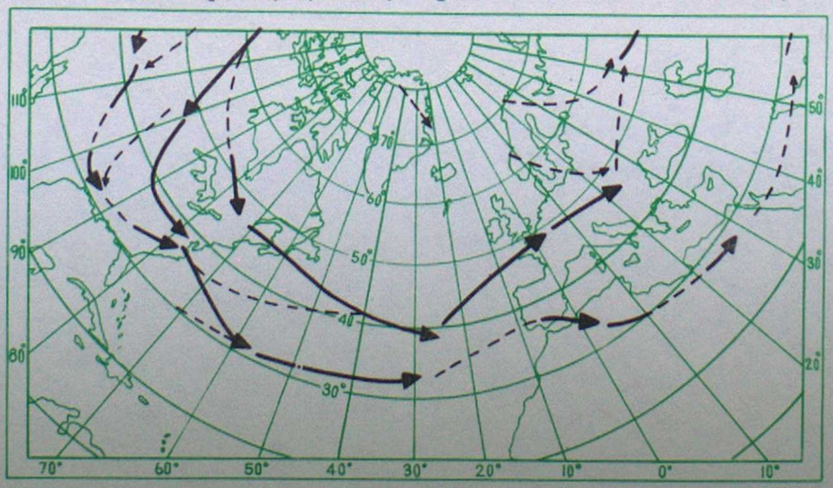

FIGURE 12.2(*c*) *Principal tracks of anticyclones at mean sea level – January*

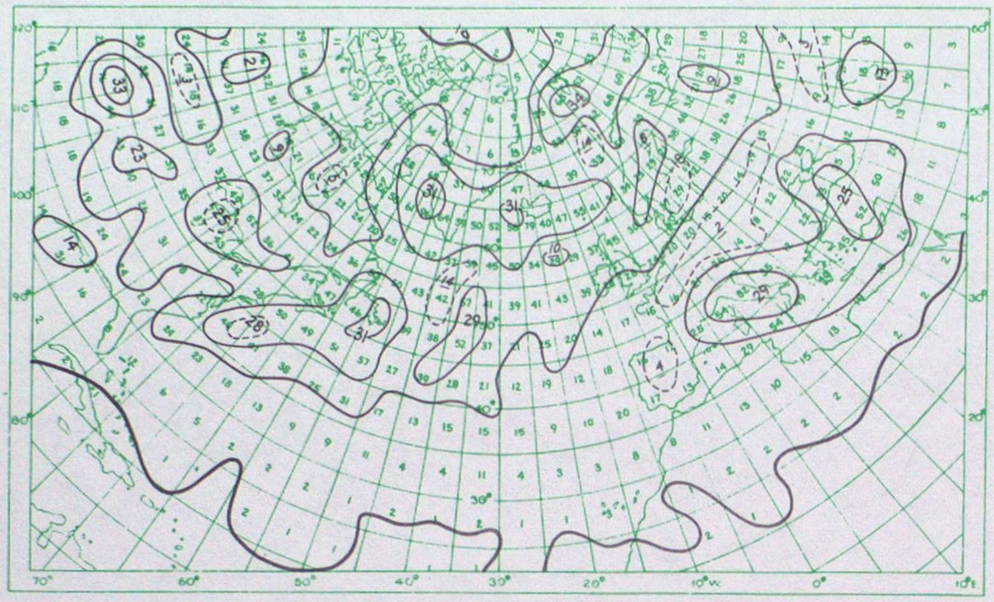

FIGURE 12.3(*a*) *Cyclones at mean sea level – February*

Black isopleths: number of cyclones (20 years)
Green figures: days with cyclones (40 years)

FIGURE 12.3(*b*) *Frequency of cyclogenesis at mean sea level – February*

FIGURE 12.3(*c*) *Principal tracks of cyclones at mean sea level – February*

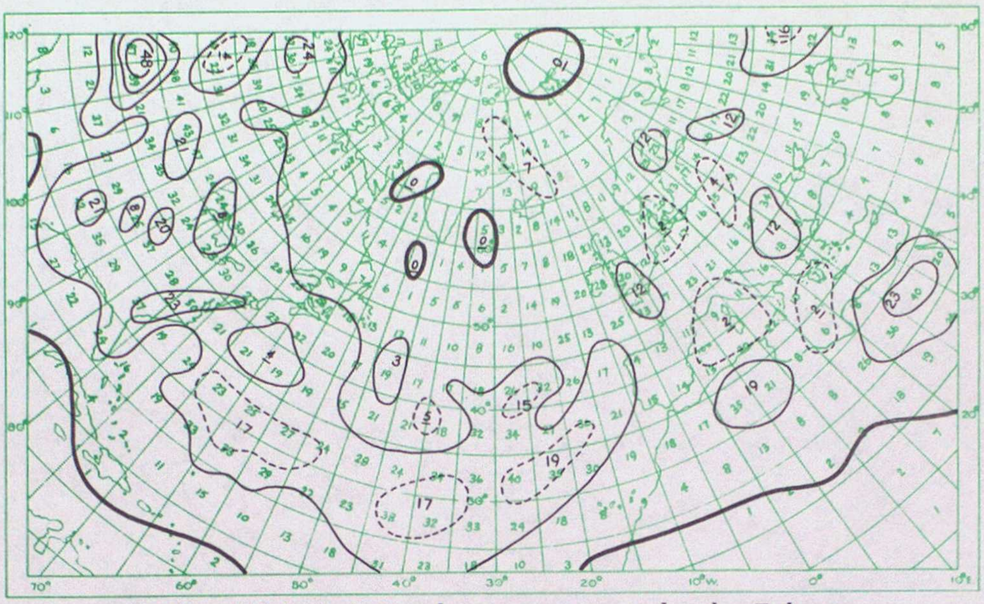

FIGURE 12.4(*a*) *Anticyclones at mean sea level – February*

Black isopleths: number of anticyclones (20 years)
Green figures: days with anticyclones (40 years)

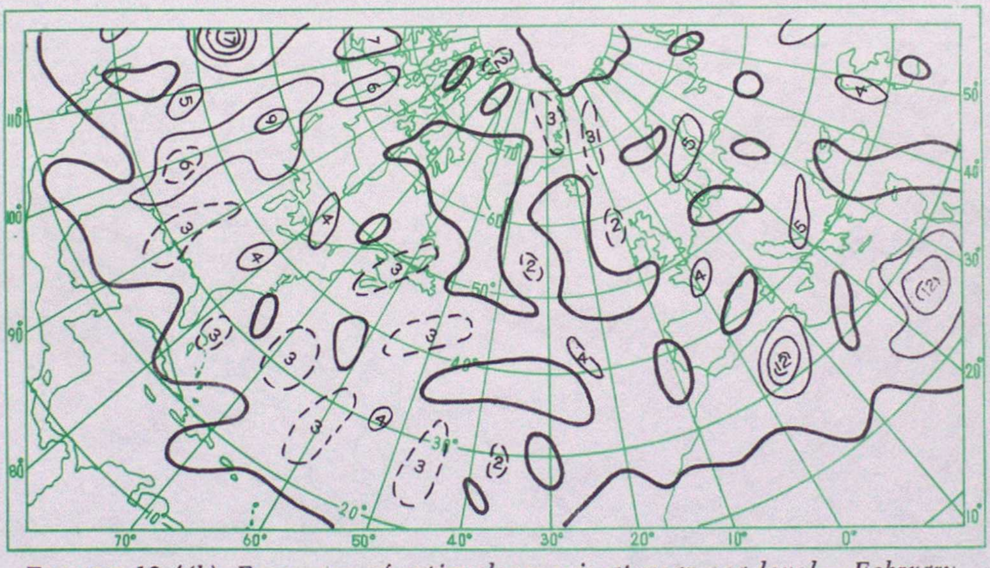

FIGURE 12.4(*b*) *Frequency of anticyclogenesis at mean sea level – February*

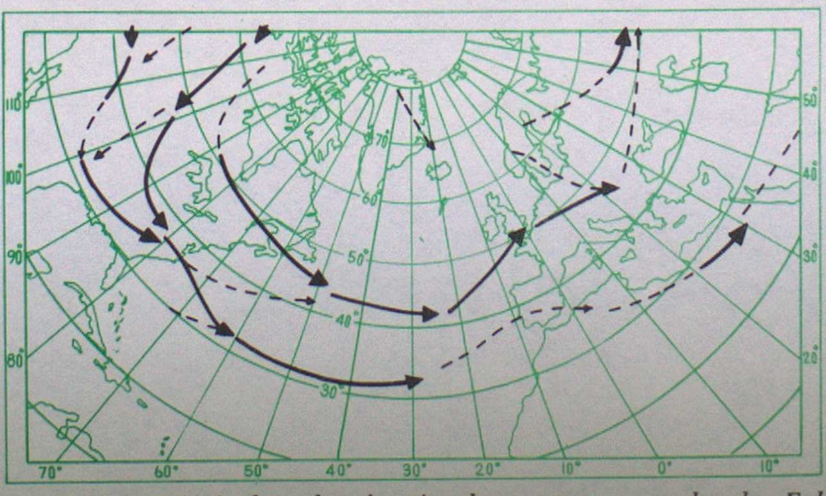

FIGURE 12.4(*c*) *Principal tracks of anticyclones at mean sea level – February*

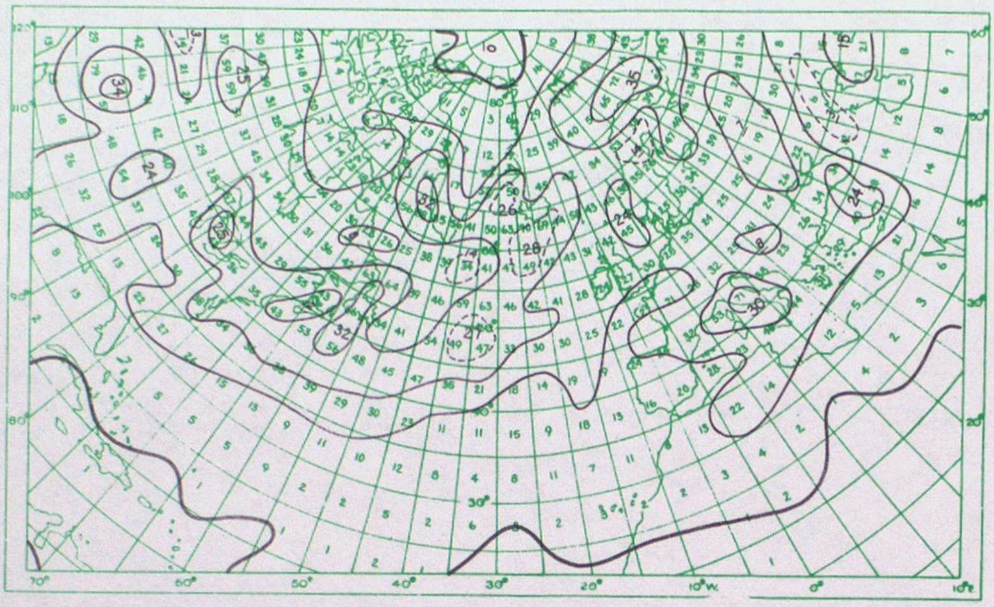

FIGURE 12.5(*a*) *Cyclones at mean sea level – March*

Black isopleths: number of cyclones (20 years)
Green figures: days with cyclones (40 years)

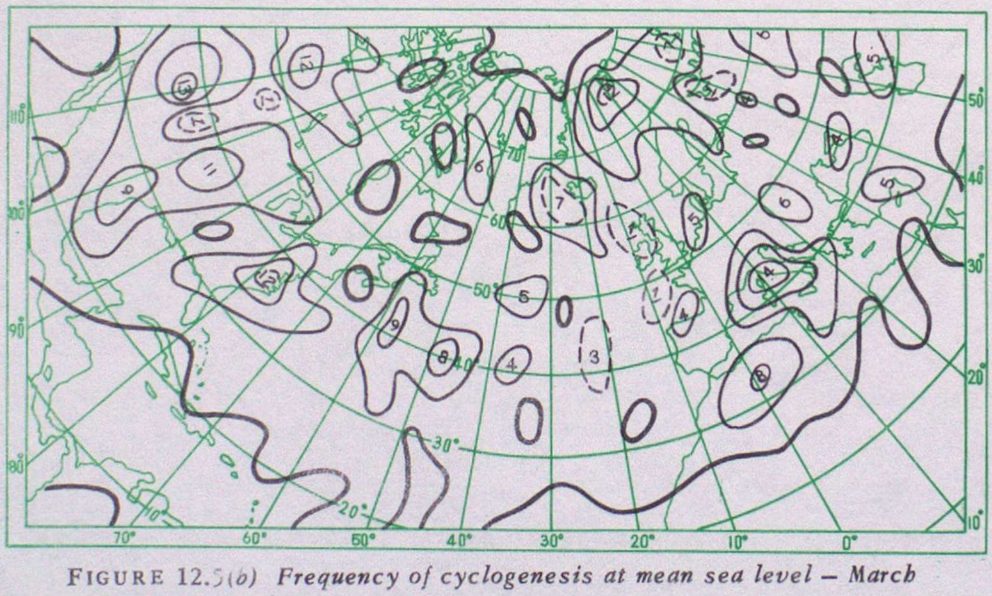

FIGURE 12.5(*b*) *Frequency of cyclogenesis at mean sea level – March*

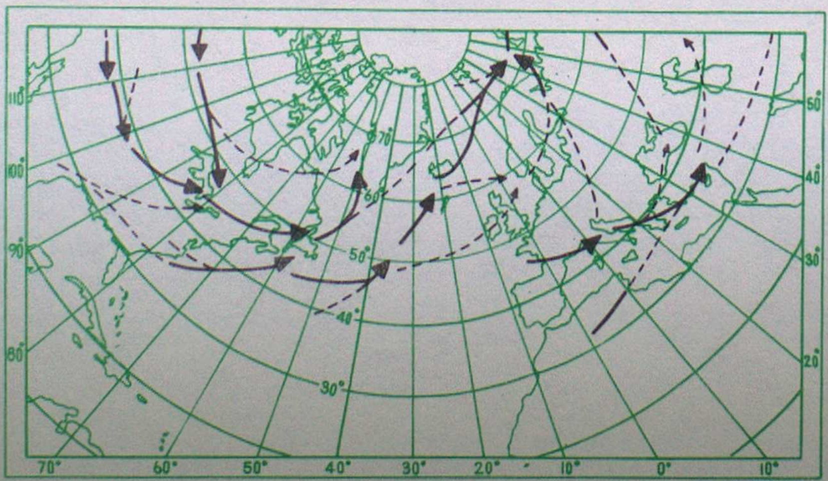

FIGURE 12.5(*c*) *Principal tracks of cyclones at mean sea level – March*

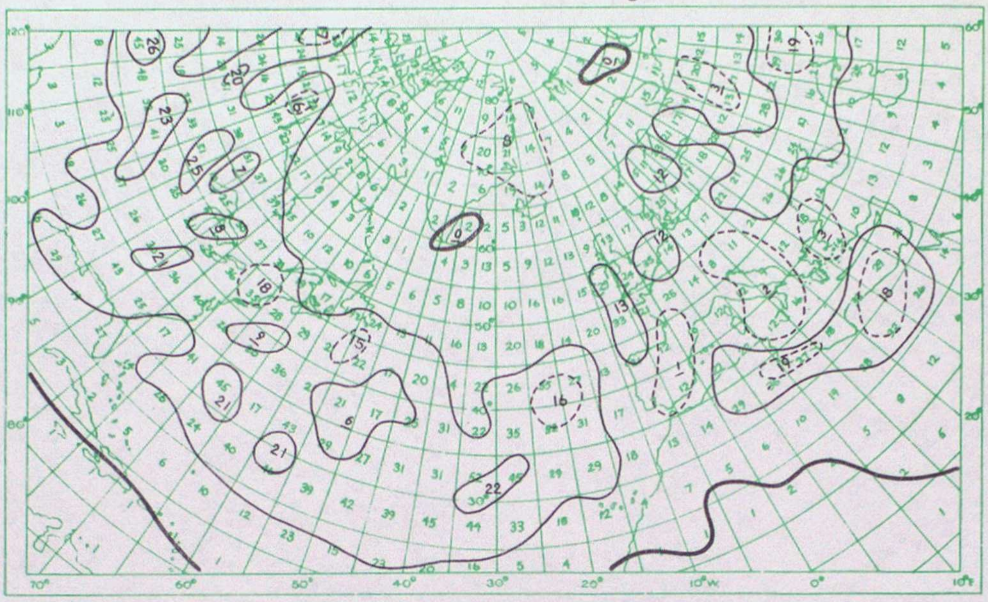

FIGURE 12.6(*a*) *Anticyclones at mean sea level – March*

Black isopleths: number of anticyclones (20 years)
Green figures: days with anticyclones (40 years)

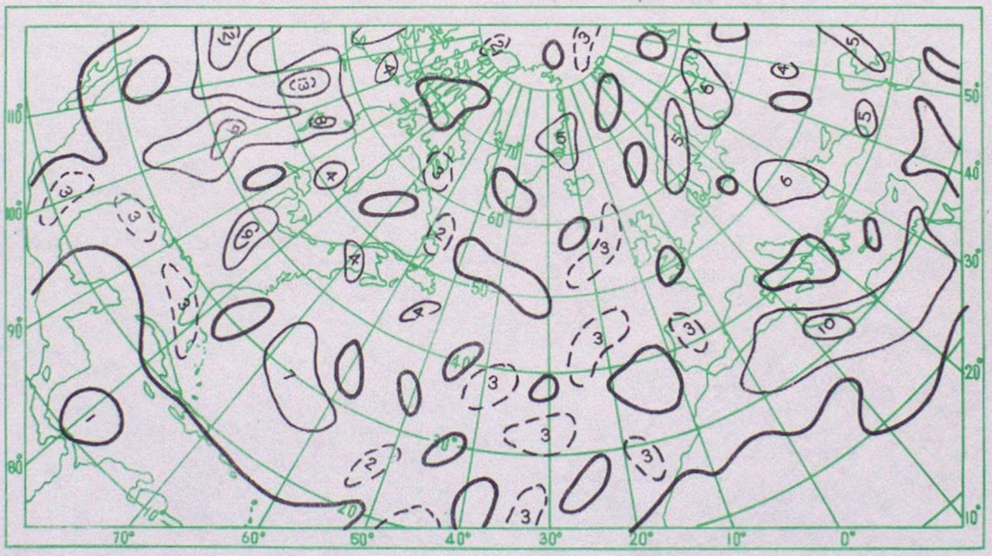

FIGURE 12.6(*b*) *Frequency of anticyclogenesis at mean sea level – March*

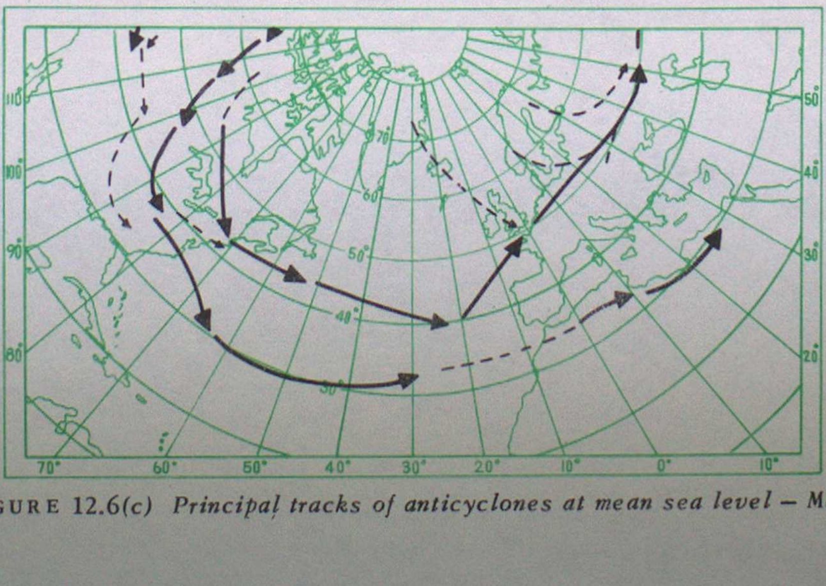

FIGURE 12.6(*c*) *Principal tracks of anticyclones at mean sea level – March*

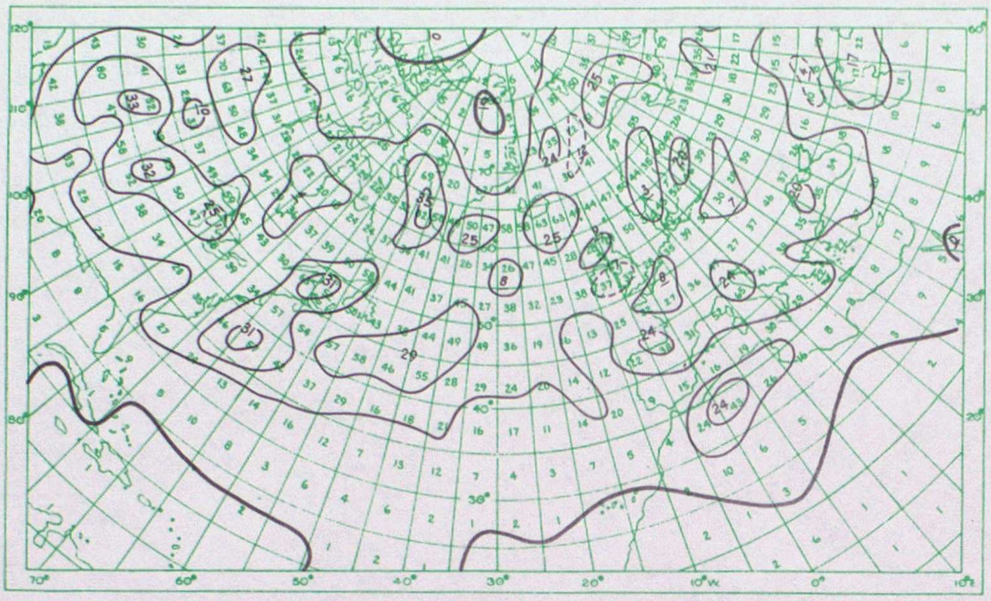

FIGURE 12.7*(a)* *Cyclones at mean sea level – April*

Black isopleths: number of cyclones (20 years)
Green figures: days with cyclones (40 years)

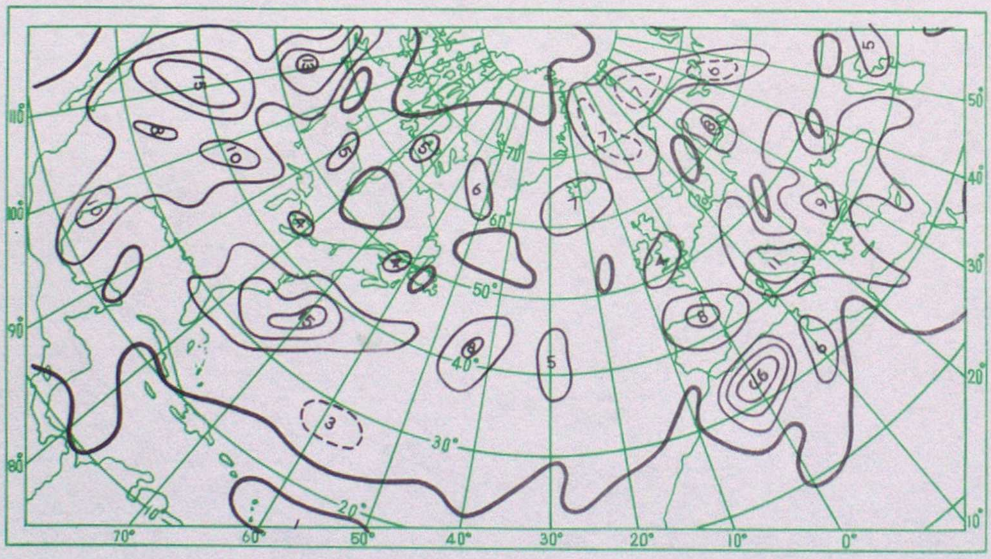

FIGURE 12.7*(b)* *Frequency of cyclogenesis at mean sea level – April*

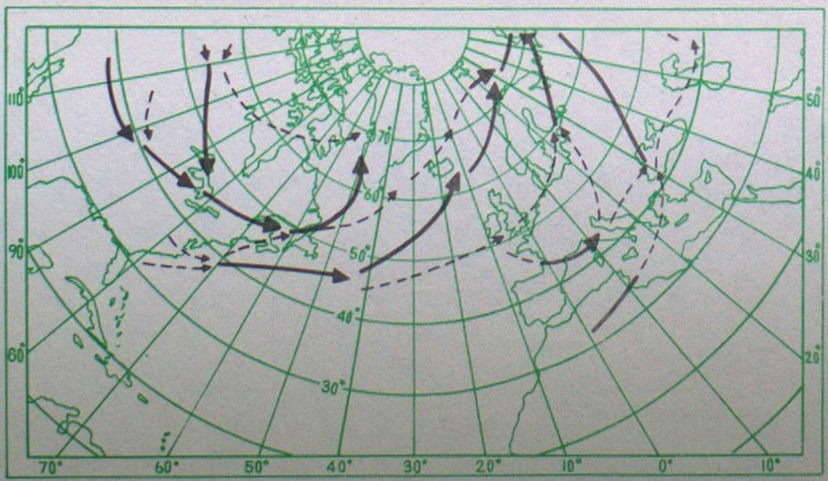

FIGURE 12.7*(c)* *Principal tracks of cyclones at mean sea level – April*

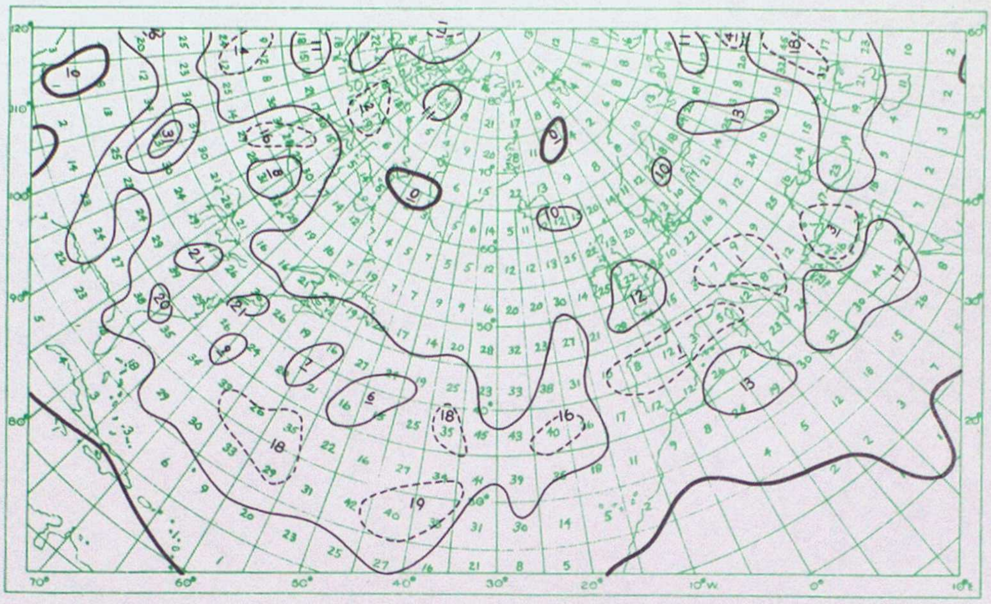

FIGURE 12.8(*a*) *Anticyclones at mean sea level – April*

Black isopleths: number of anticyclones (20 years)
Green figures: days with anticyclones (40 years)

FIGURE 12.8(*b*) *Frequency of anticyclogenesis at mean sea level – April*

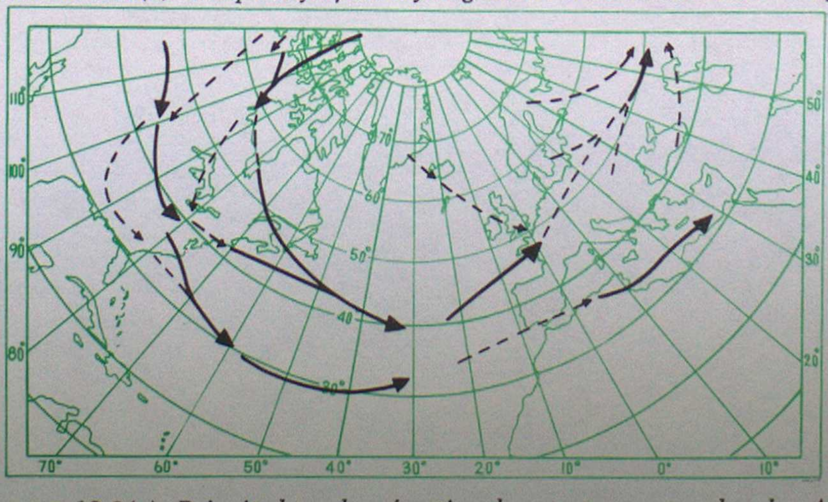

FIGURE 12.8(*c*) *Principal tracks of anticyclones at mean sea level – April*

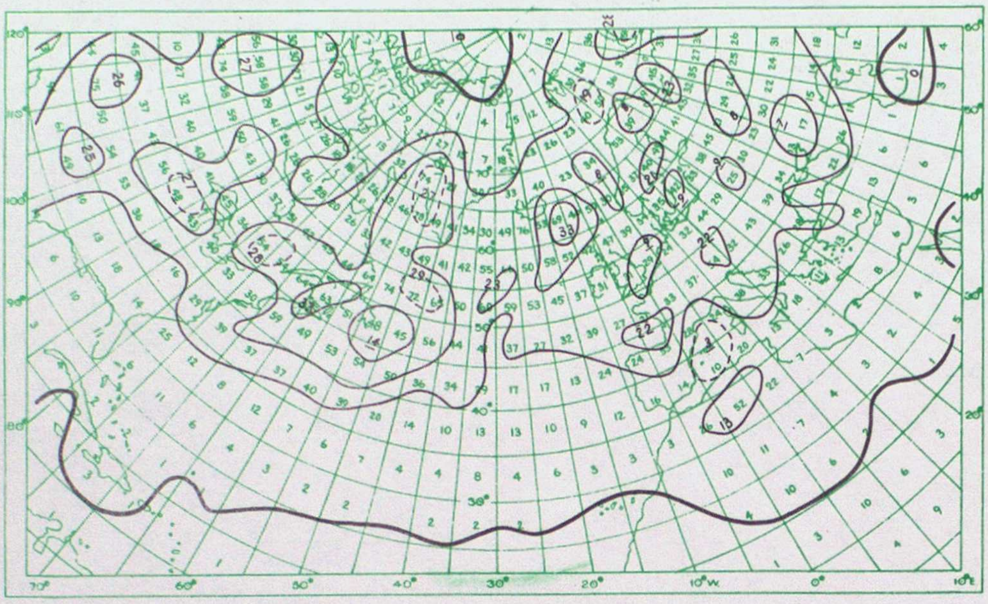

FIGURE 12.9(*a*) *Cyclones at mean sea level – May*

Black isopleths: number of cyclones (20 years)
Green figures: days with cyclones (40 years)

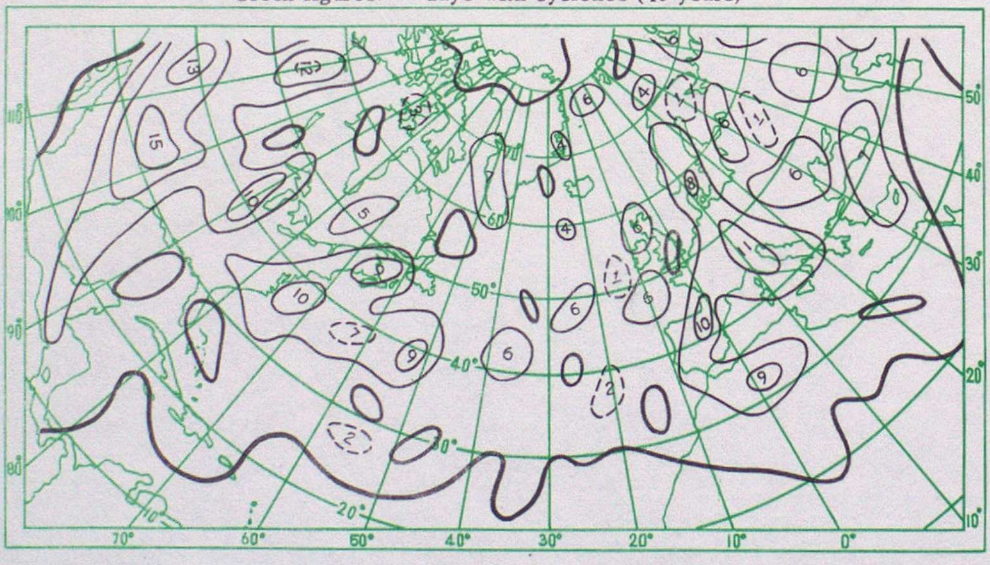

FIGURE 12.9(*b*) *Frequency of cyclogenesis at mean sea level – May*

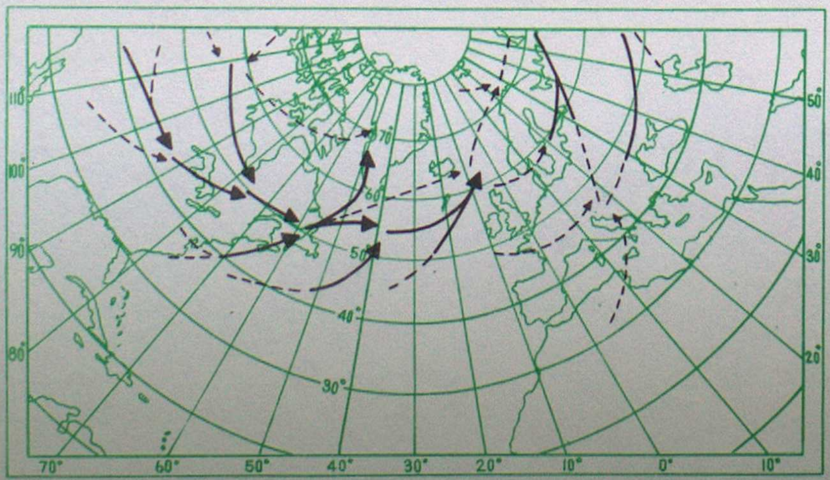

FIGURE 12.9(*c*) *Principal tracks of cyclones at mean sea level – May*

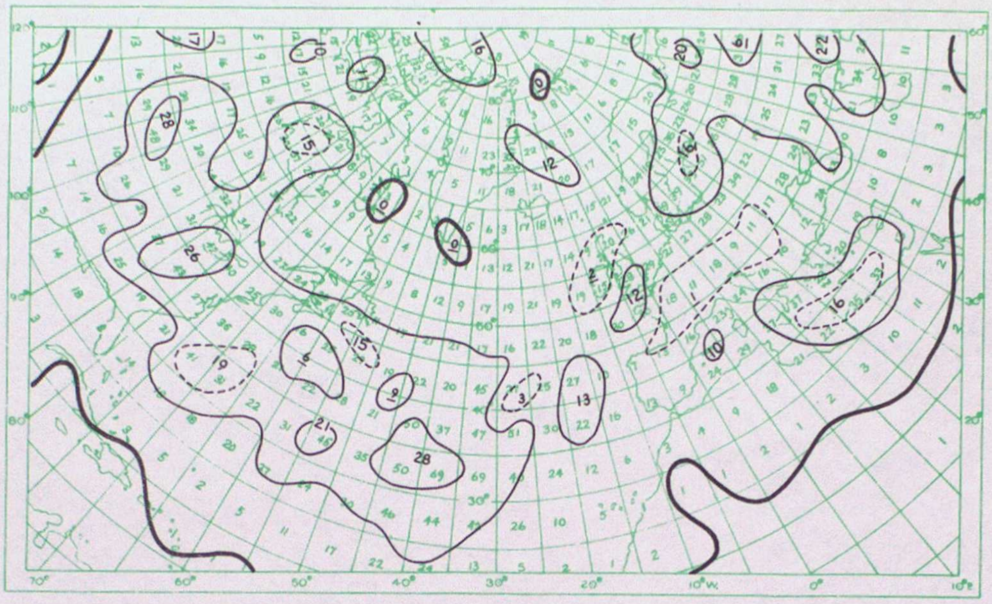

FIGURE 12.10(a) *Anticyclones at mean sea level – May*

Black isopleths: number of anticyclones (20 years)
Green figures: days with anticyclones (40 years)

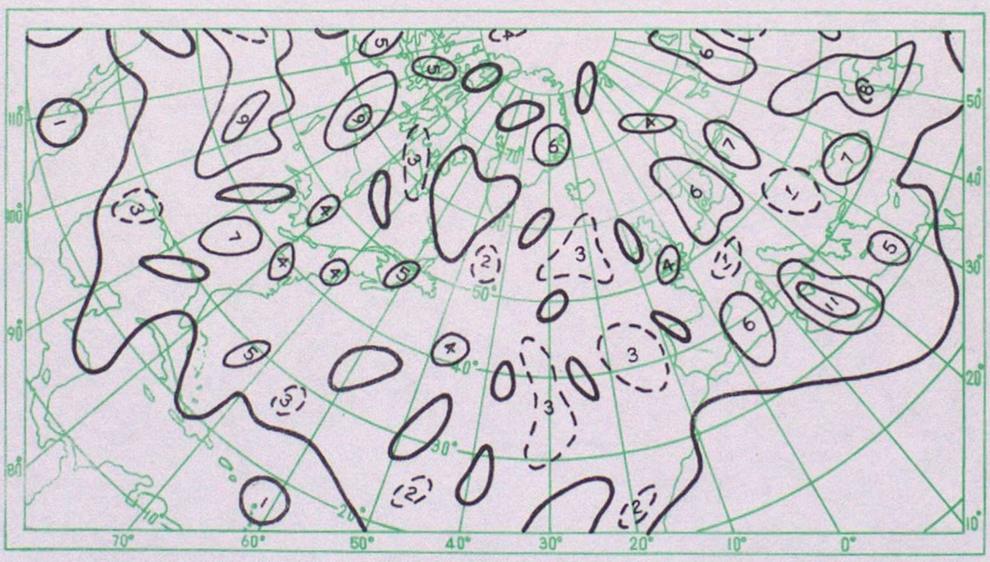

FIGURE 12.10(b) *Frequency of anticyclogenesis at mean sea level – May*

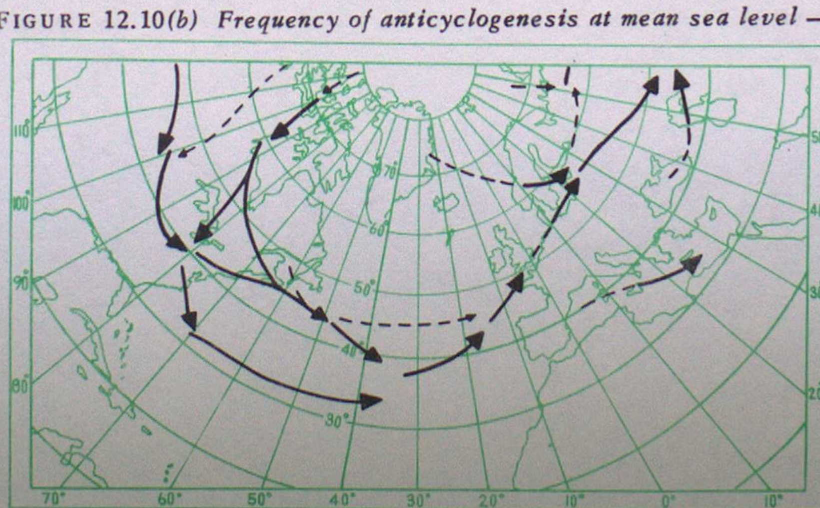

FIGURE 12.10(c) *Principal tracks of anticyclones at mean sea level – May*

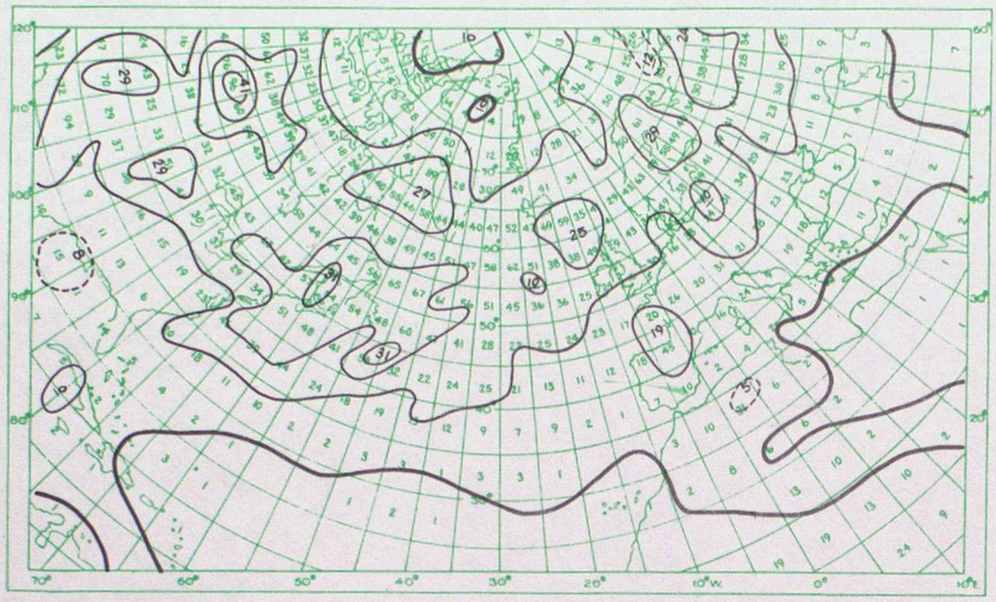

FIGURE 12.11(a) *Cyclones at mean sea level – June*

Black isopleths: number of cyclones (20 years)
Green figures: days with cyclones (40 years)

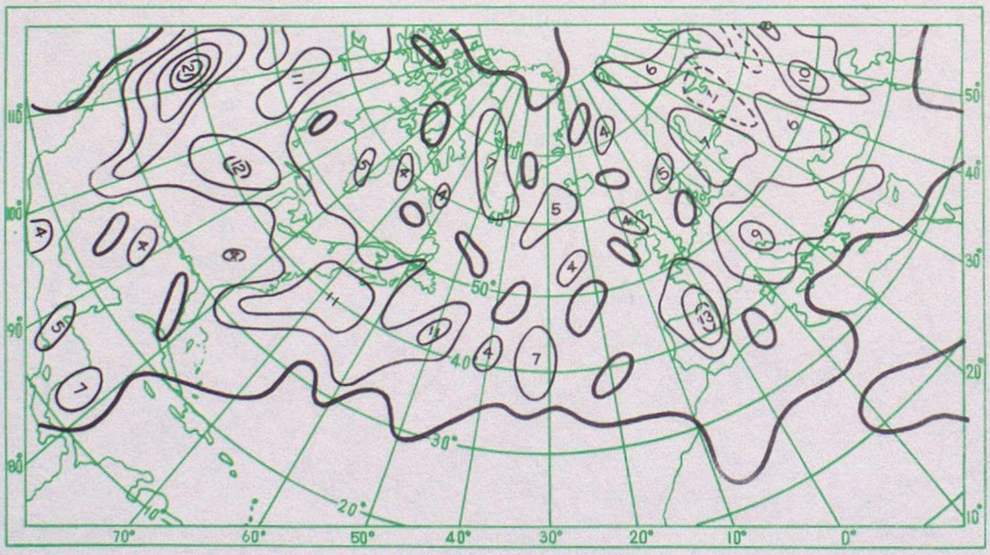

FIGURE 12.11(b) *Frequency of cyclogenesis at mean sea level – June*

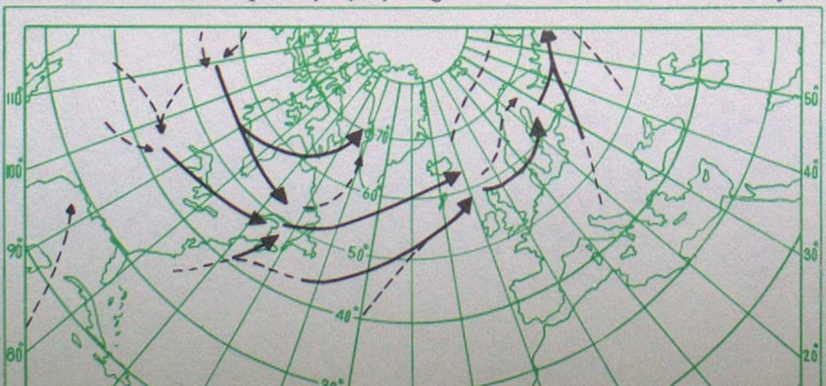

FIGURE 12.11(c) *Principal tracks of cyclones at mean sea level – June*

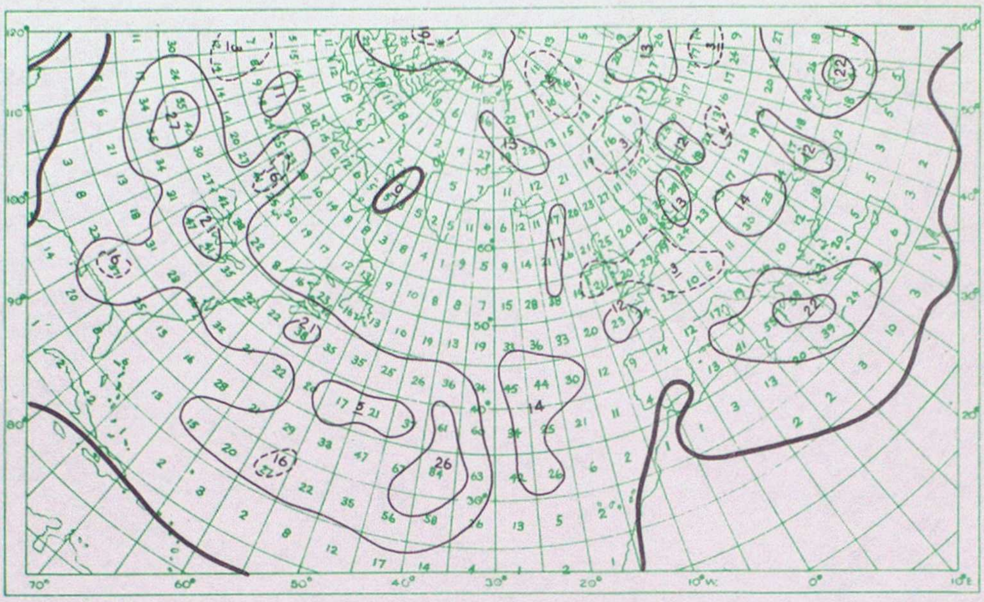

Figure 12.12(a) *Anticyclones at mean sea level – June*

Black isopleths: number of anticyclones (20 years)
Green figures: days with anticyclones (40 years)

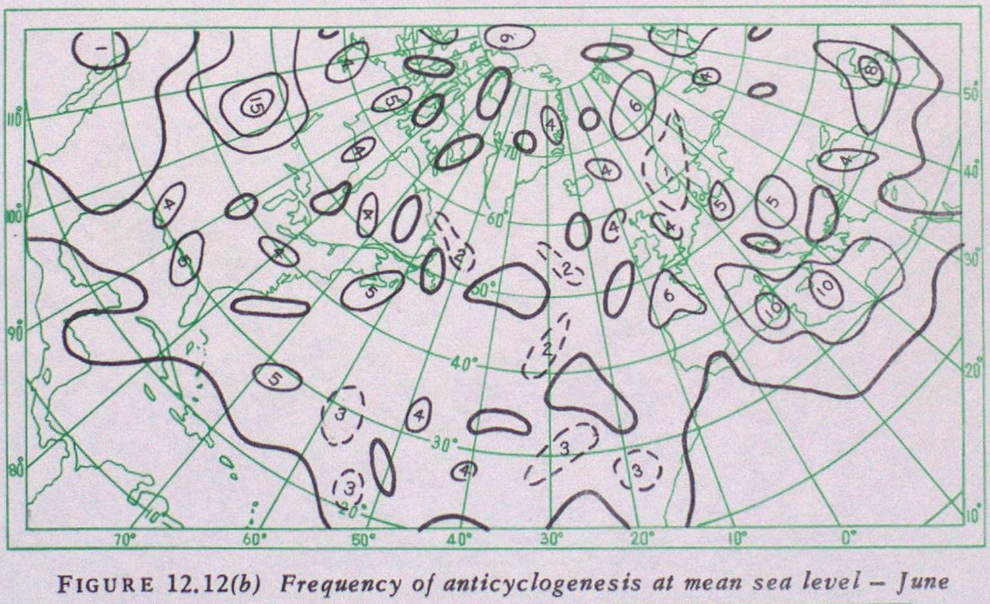

Figure 12.12(b) *Frequency of anticyclogenesis at mean sea level – June*

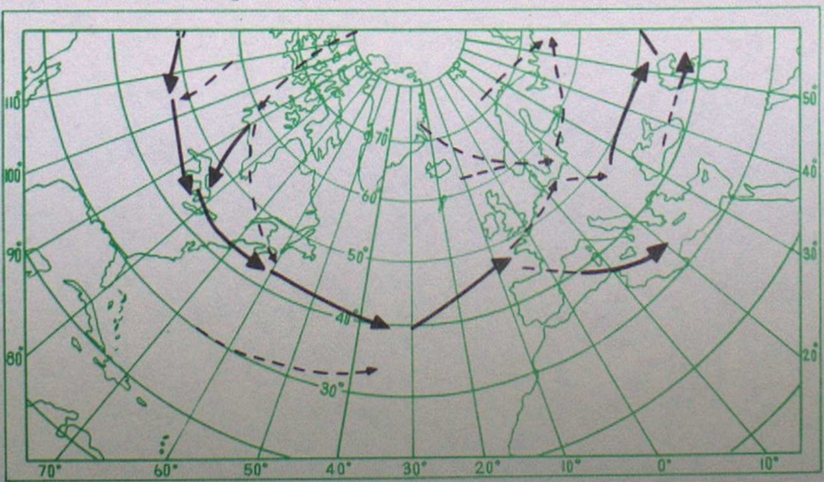

Figure 12.12(c) *Principal tracks of anticyclones at mean sea level – June*

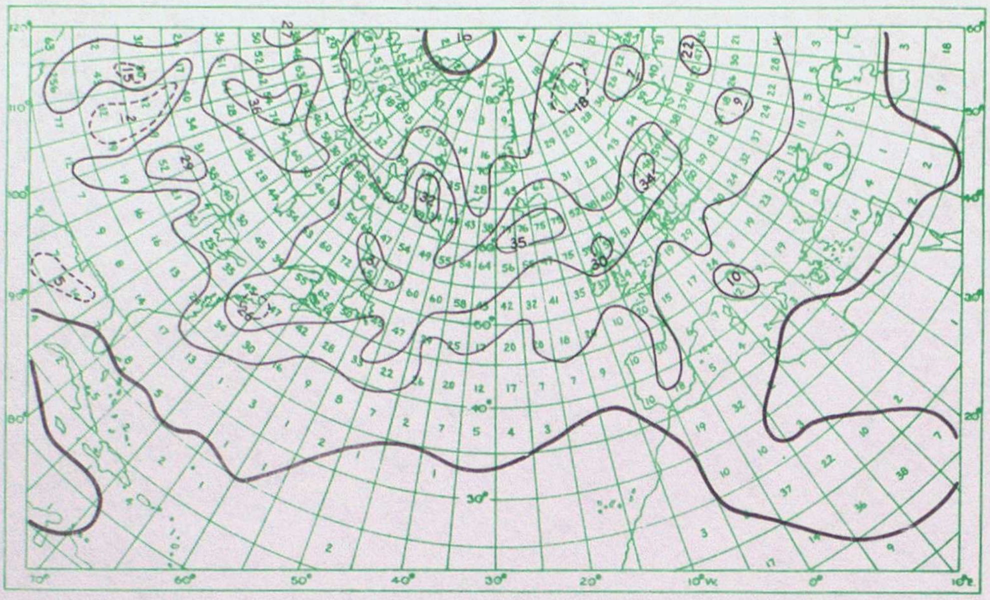

FIGURE 12.13*(a)* *Cyclones at mean sea level – July*

Black isopleths: number of cyclones (20 years)
Green figures: days with cyclones (40 years)

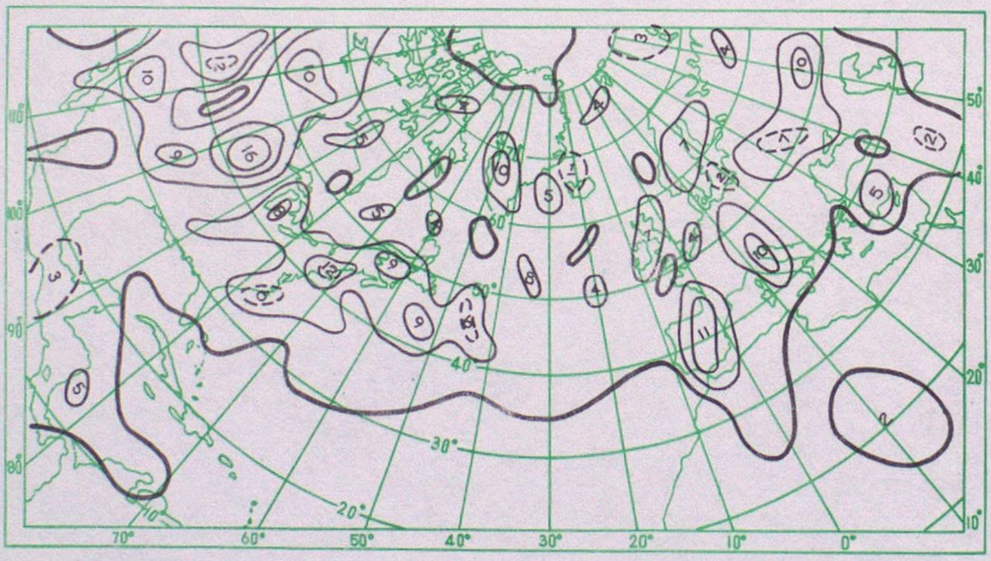

FIGURE 12.13*(b)* *Frequency of cyclogenesis at mean sea level – July*

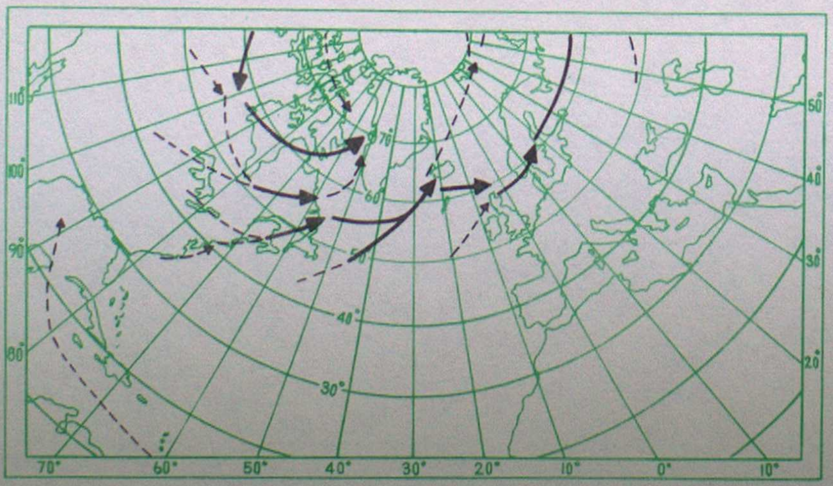

FIGURE 12.13*(c)* *Principal tracks of cyclones at mean sea level – July*

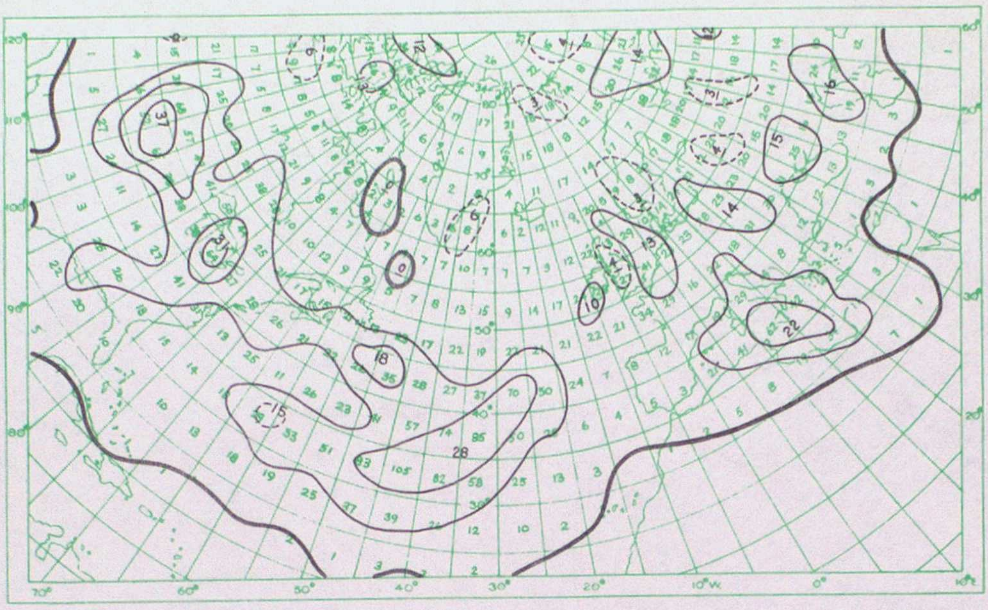

FIGURE 12.14(a) Anticyclones at mean sea level – July

Black isopleths: number of anticyclones (20 years)
Green figures: days with anticyclones (40 years)

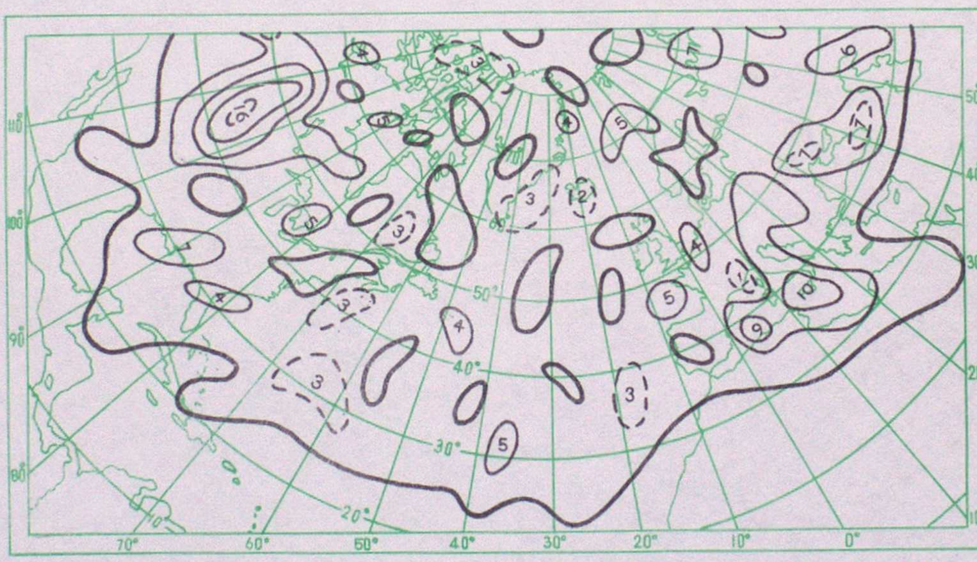

FIGURE 12.14(b) Frequency of anticyclogenesis at mean sea level – July

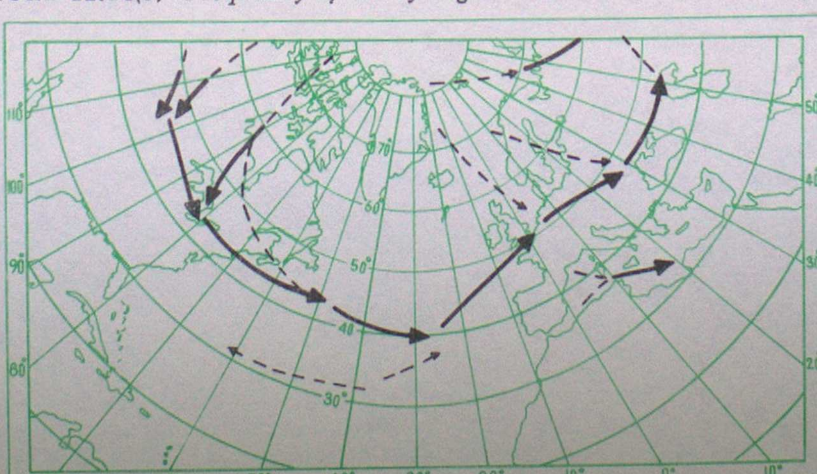

FIGURE 12.14(c) Principal tracks of anticyclones at mean sea level – July

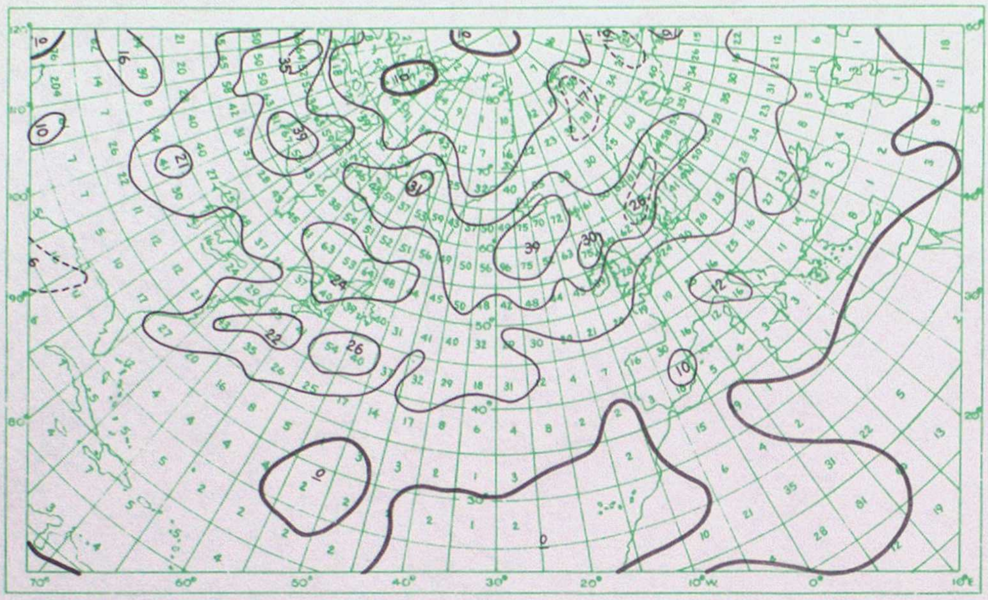

FIGURE 12.15(*a*) *Cyclones at mean sea level – August*

Black isopleths: number of cyclones (20 years)
Green figures: days with cyclones (40 years)

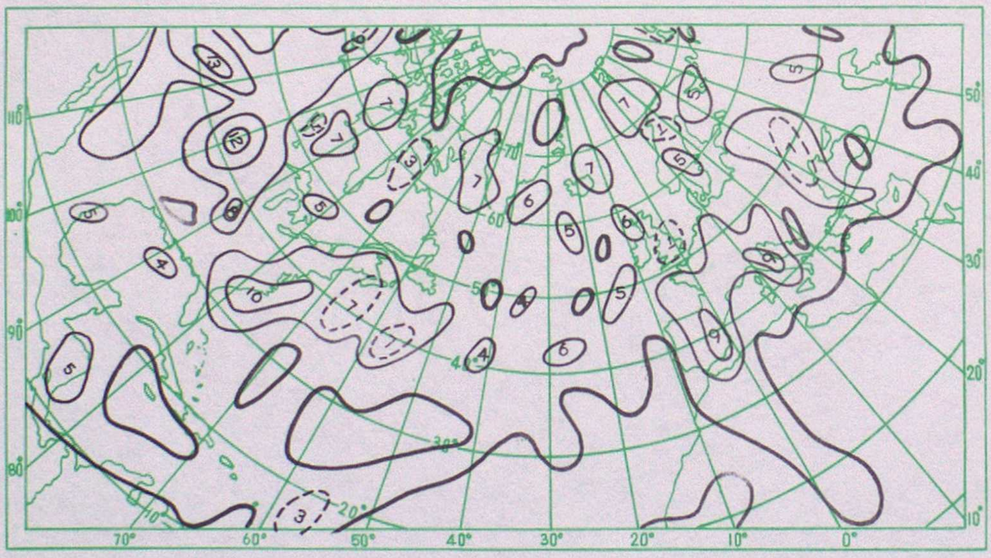

FIGURE 12.15(*b*) *Frequency of cyclogenesis at mean sea level – August*

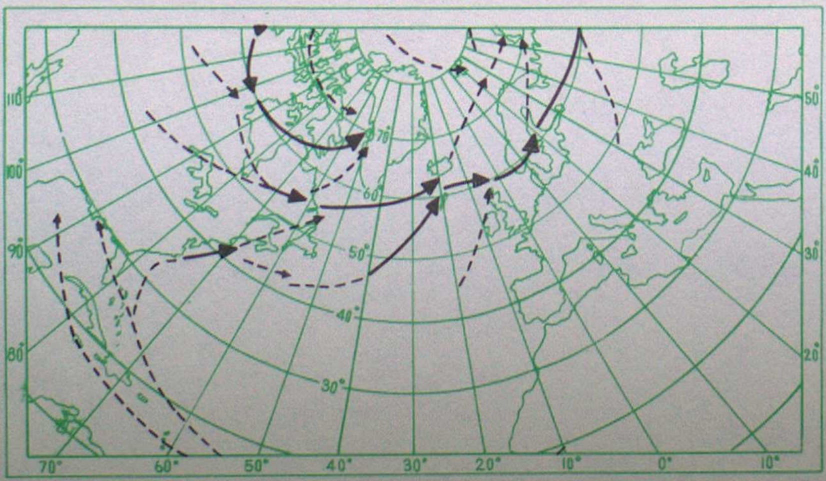

FIGURE 12.15(*c*) *Principal tracks of cyclones at mean sea level – August*

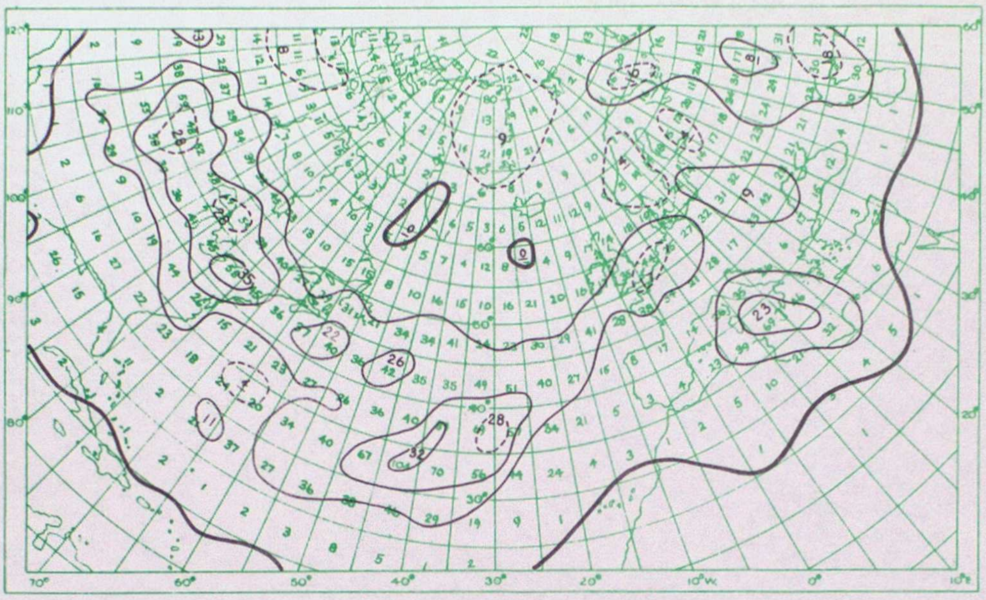

FIGURE 12.16(a) *Anticyclones at mean sea level – August*

Black isopleths: number of anticyclones (20 years)
Green figures: days with anticyclones (40 years)

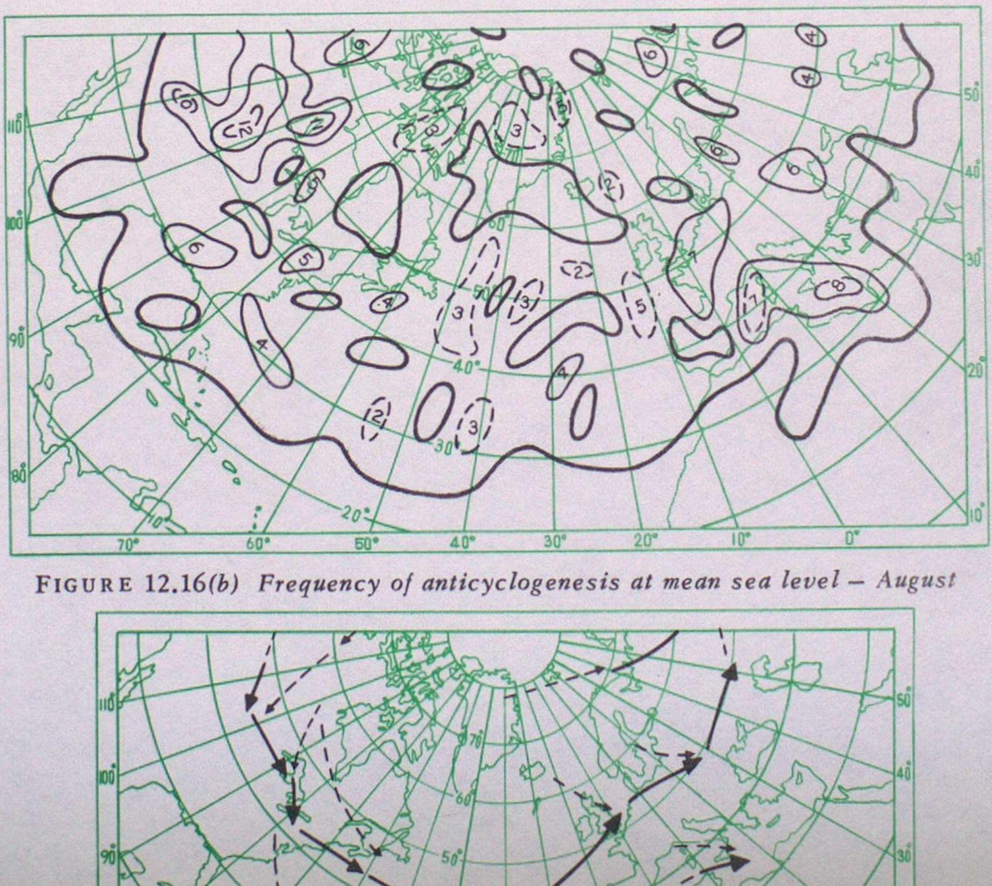

FIGURE 12.16(b) *Frequency of anticyclogenesis at mean sea level – August*

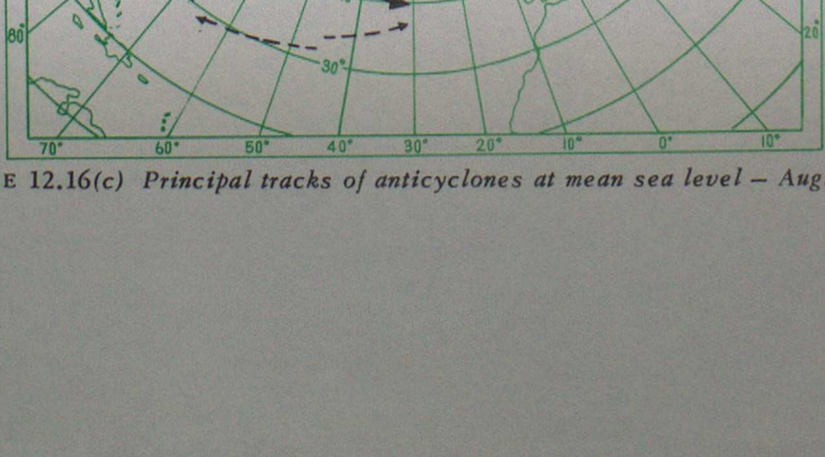

FIGURE 12.16(c) *Principal tracks of anticyclones at mean sea level – August*

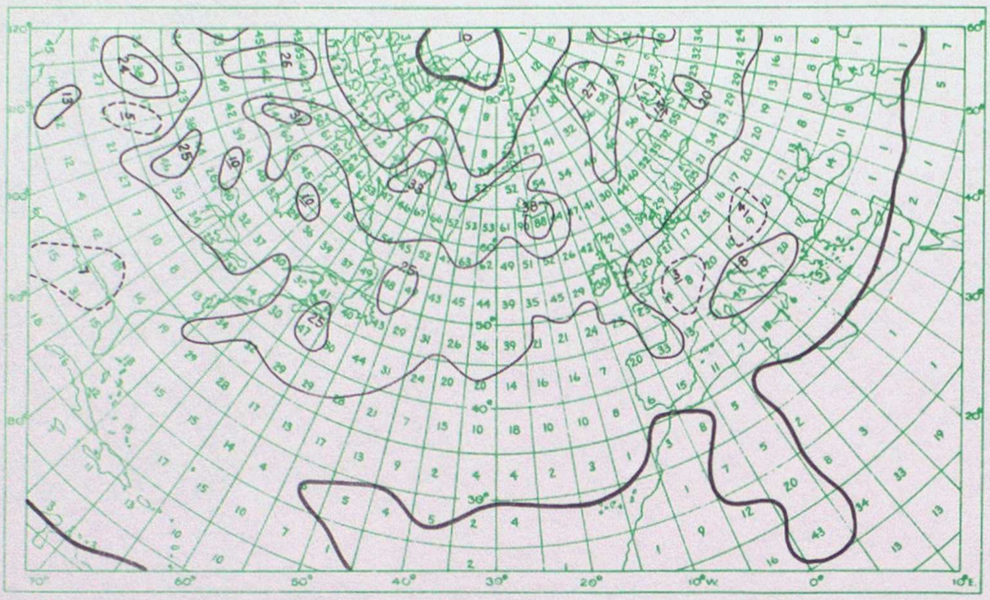

FIGURE 12.17(a) *Cyclones at mean sea level – September*

Black isopleths: number of cyclones (20 years)
Green figures: days with cyclones (40 years)

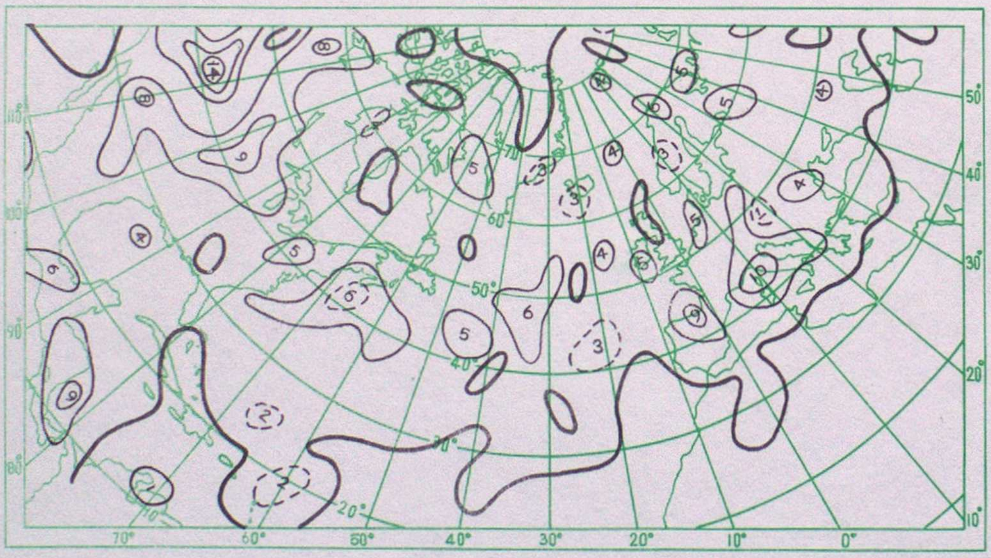

FIGURE 12.17(b) *Frequency of cyclogenesis at mean sea level – September*

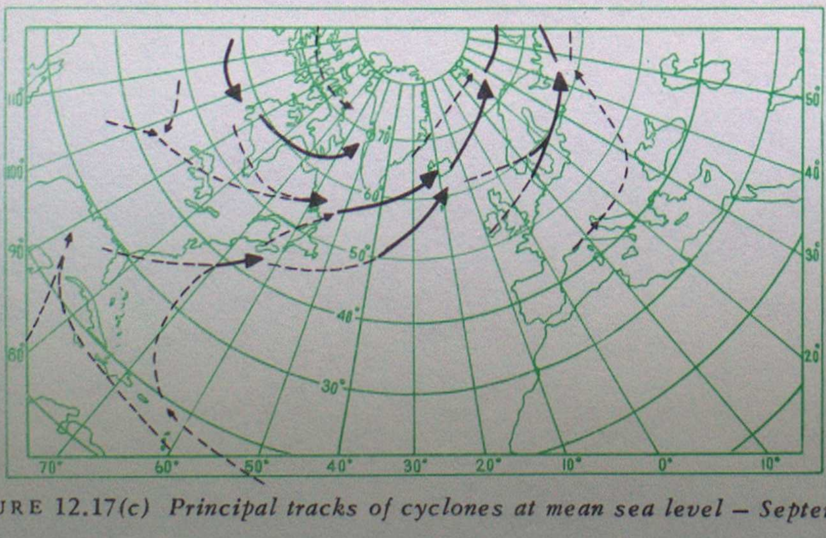

FIGURE 12.17(c) *Principal tracks of cyclones at mean sea level – September*

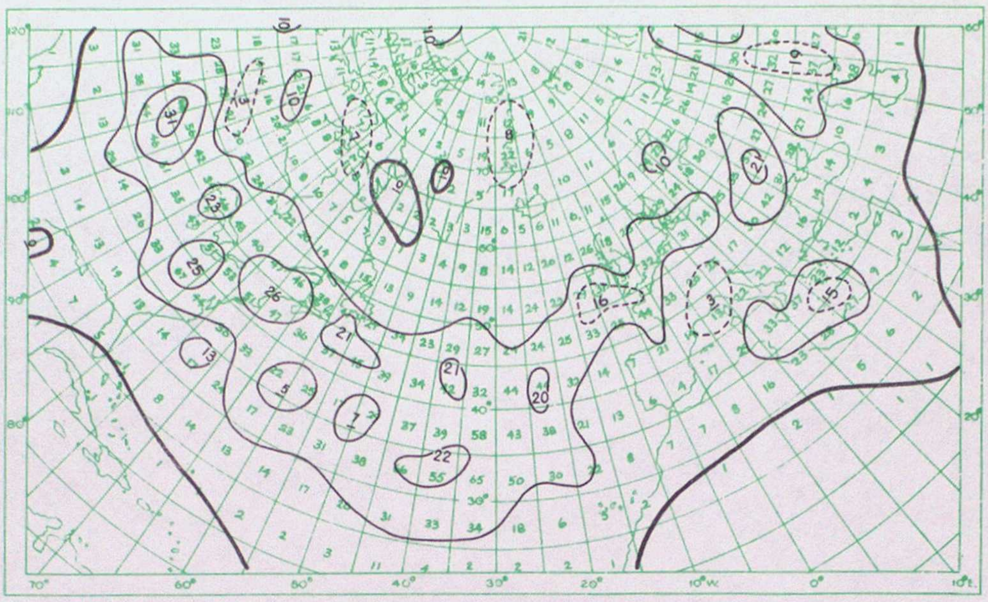

FIGURE 12.18*(a)* *Anticyclones at mean sea level – September*

Black isopleths: number of anticyclones (20 years)
Green figures: days with anticyclones (40 years)

FIGURE 12.18*(b)* *Frequency of anticyclogenesis at mean sea level – September*

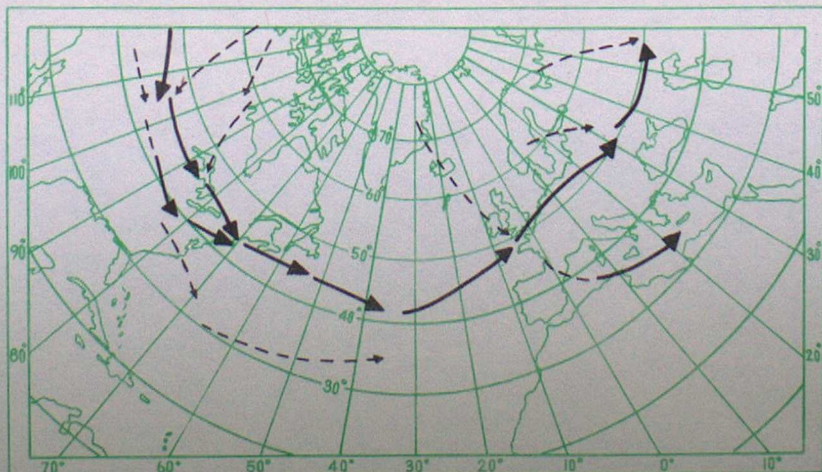

FIGURE 12.18*(c)* *Principal tracks of anticyclones at mean sea level – September*

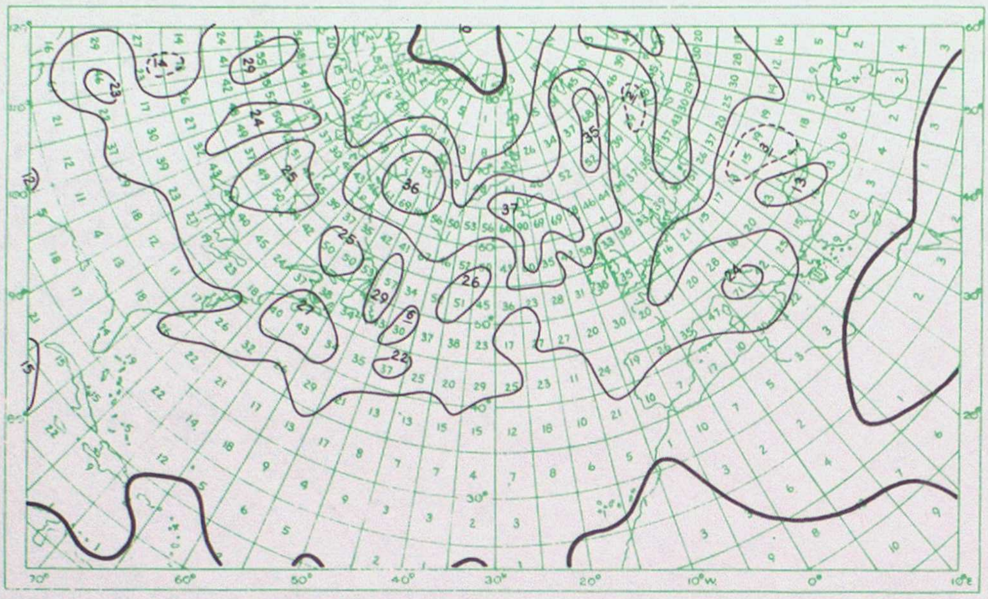

FIGURE 12.19(a) *Cyclones at mean sea level – October*

Black isopleths: number of cyclones (20 years)
Green figures: days with cyclones (40 years)

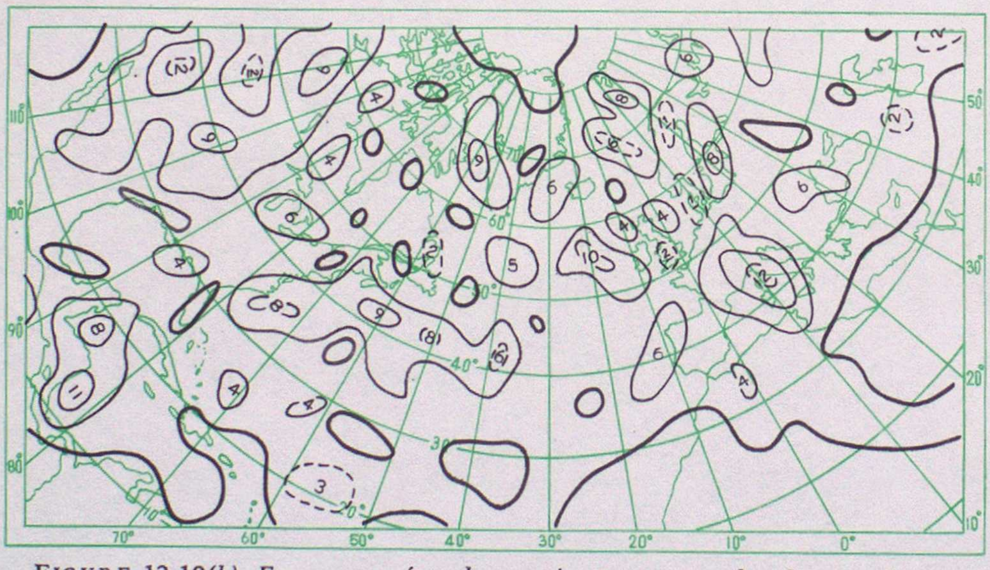

FIGURE 12.19(b) *Frequency of cyclogenesis at mean sea level – October*

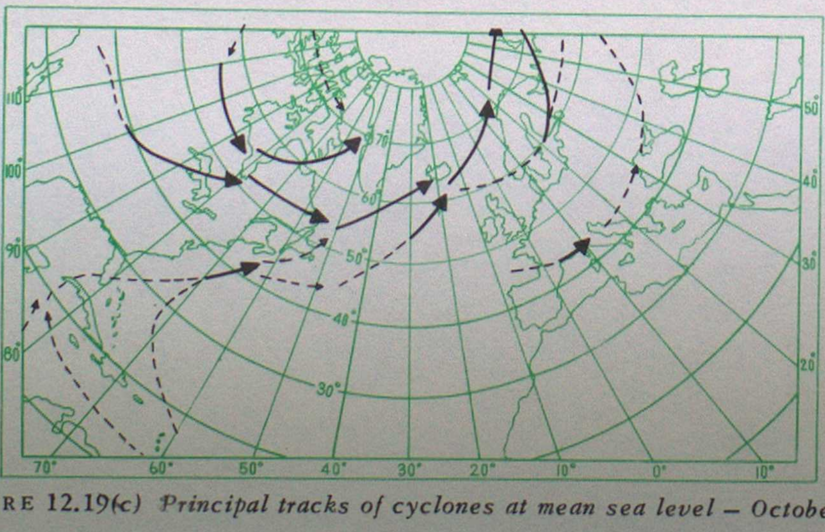

FIGURE 12.19(c) *Principal tracks of cyclones at mean sea level – October*

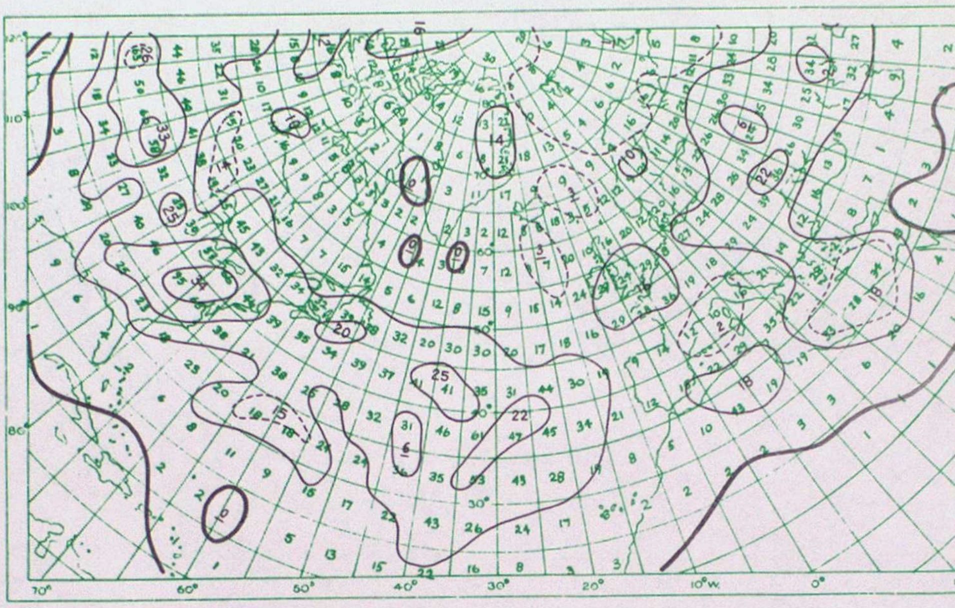

FIGURE 12.20*(a)* *Anticyclones at mean sea level – October*

Black isopleths: number of anticyclones (20 years)
Green figures: days with anticyclones (40 years)

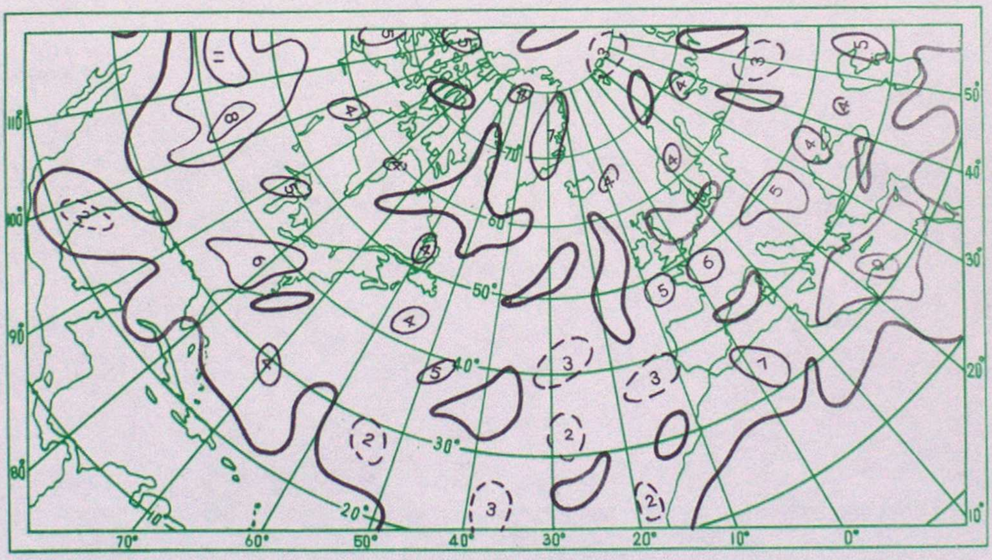

FIGURE 12.20*(b)* *Frequency of anticyclogenesis at mean sea level – October*

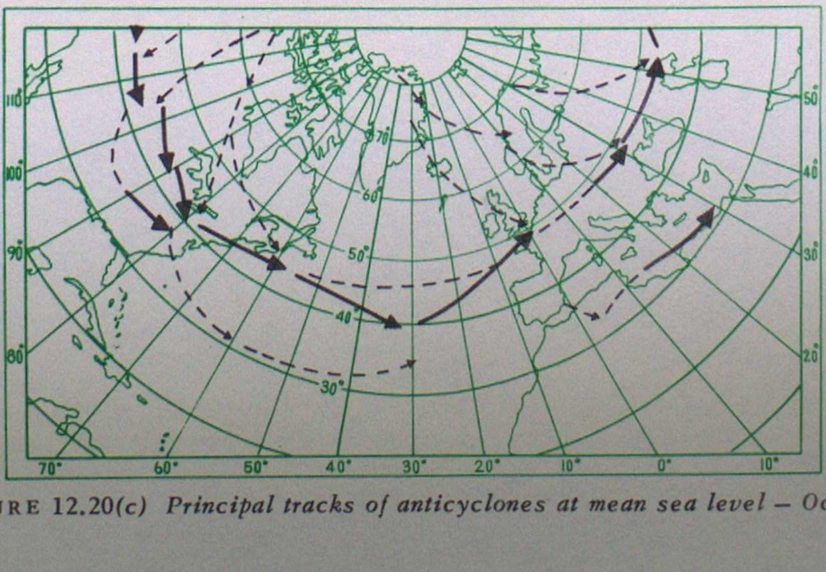

FIGURE 12.20*(c)* *Principal tracks of anticyclones at mean sea level – October*

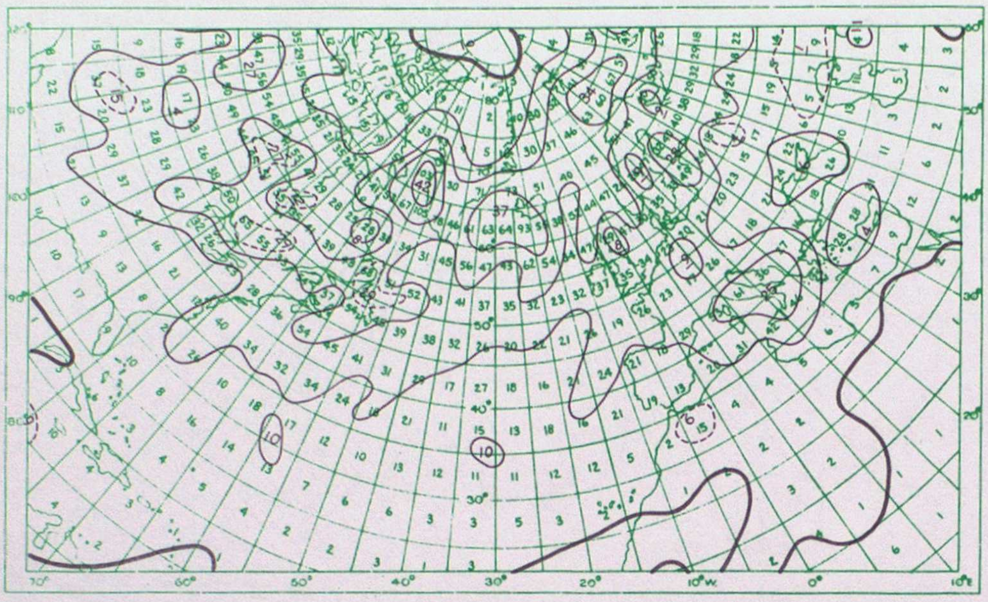

FIGURE 12.21*(a)* *Cyclones at mean sea level – November*

Black isopleths: number of cyclones (20 years)
Green figures: days with cyclones (40 years)

FIGURE 12.21*(b)* *Frequency of cyclogenesis at mean sea level – November*

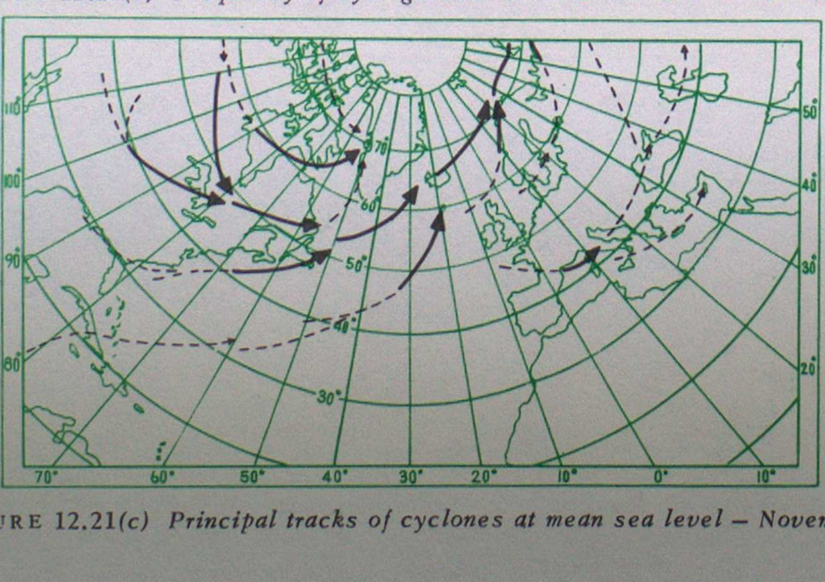

FIGURE 12.21*(c)* *Principal tracks of cyclones at mean sea level – November*

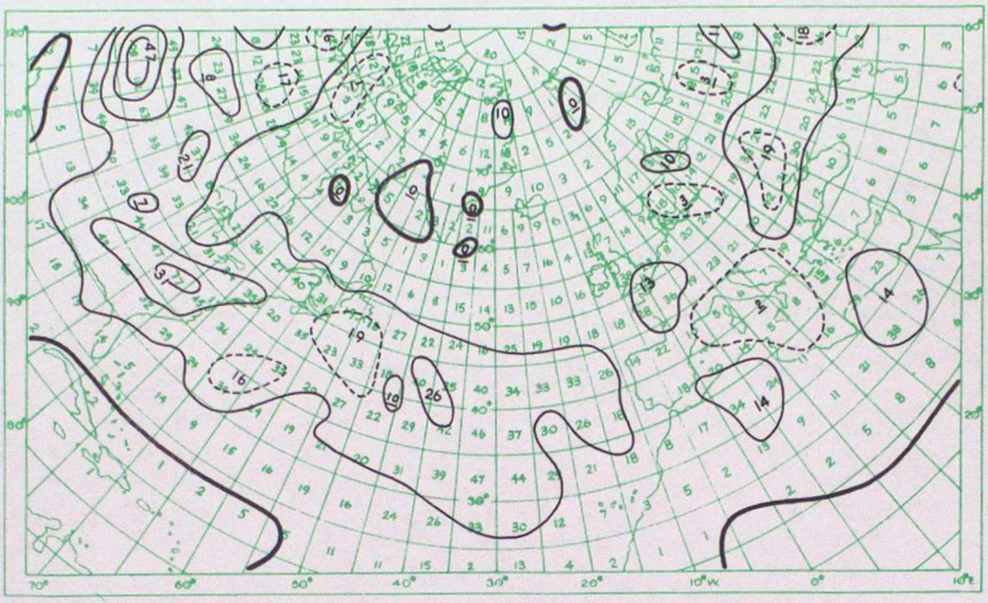

FIGURE 12.22(*a*) *Anticyclones at mean sea level – November*

Black isopleths: number of anticyclones (20 years)
Green figures: days with anticyclones (40 years)

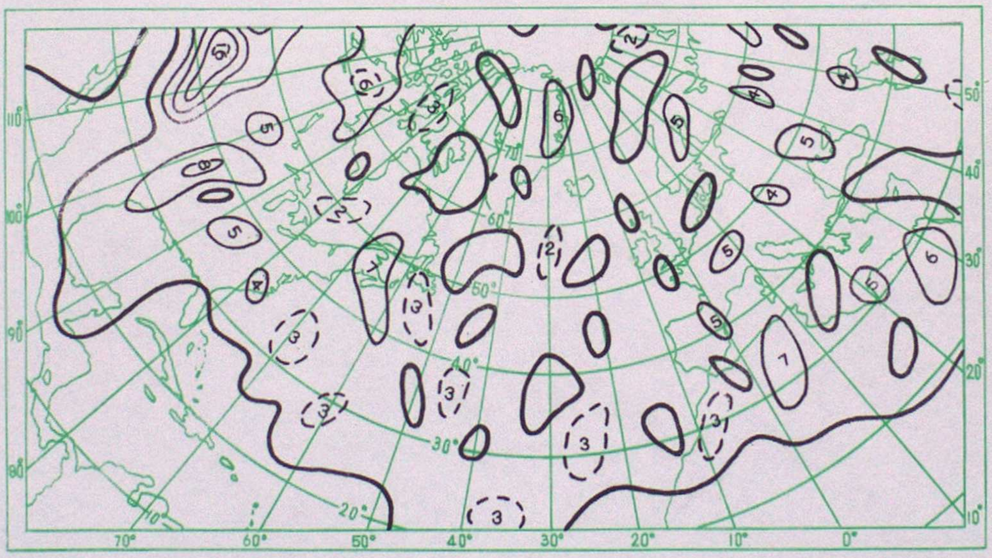

FIGURE 12.22(*b*) *Frequency of anticyclogenesis at mean sea level – November*

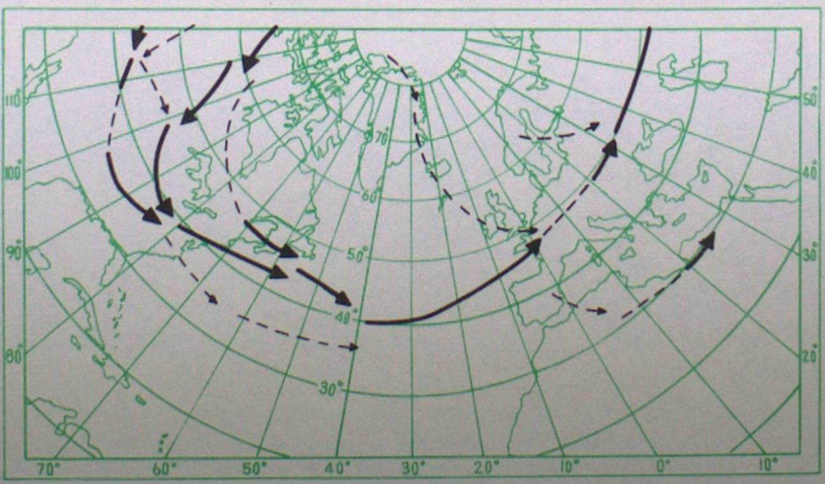

FIGURE 12.22(*c*) *Principal tracks of anticyclones at mean sea level – November*

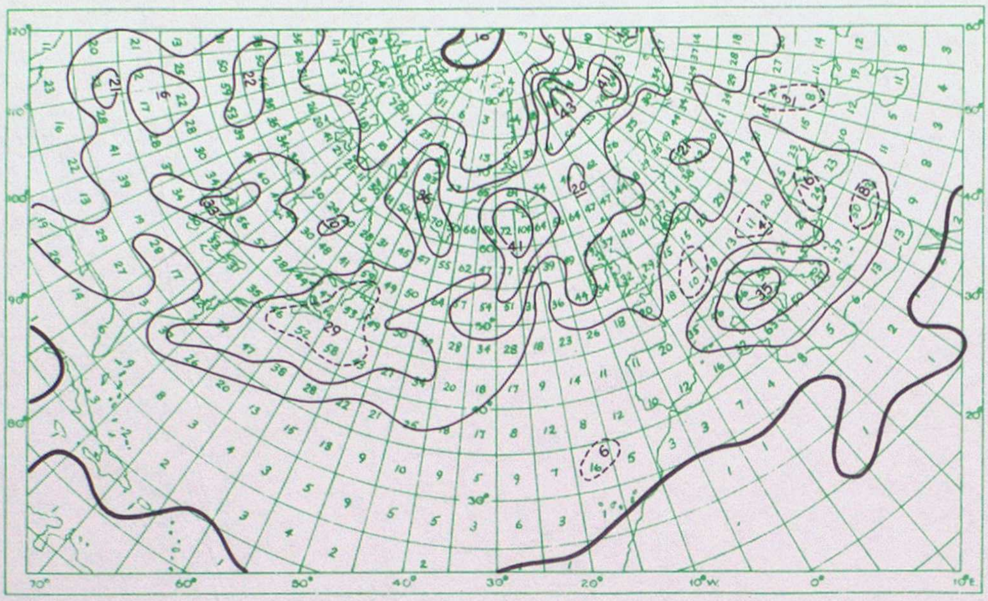

FIGURE 12.23(*a*) *Cyclones at mean sea level – December*

Black isopleths: number of cyclones (20 years)
Green figures: days with cyclones (40 years)

FIGURE 12.23(*b*) *Frequency of cyclogenesis at mean sea level – December*

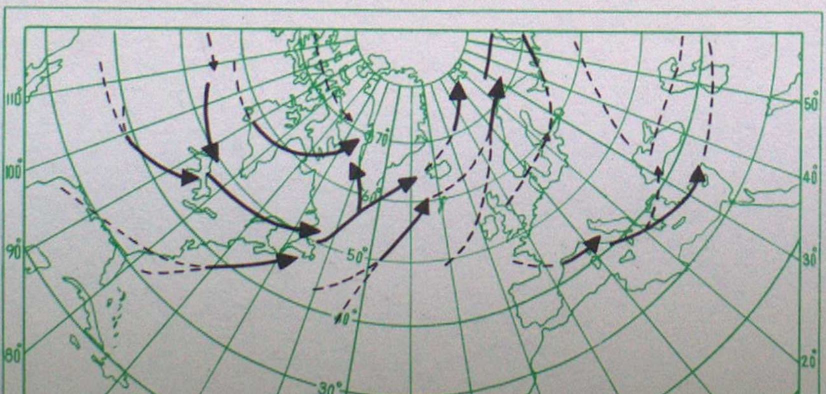

FIGURE 12.23(*c*) *Principal tracks of cyclones at mean sea level – December*

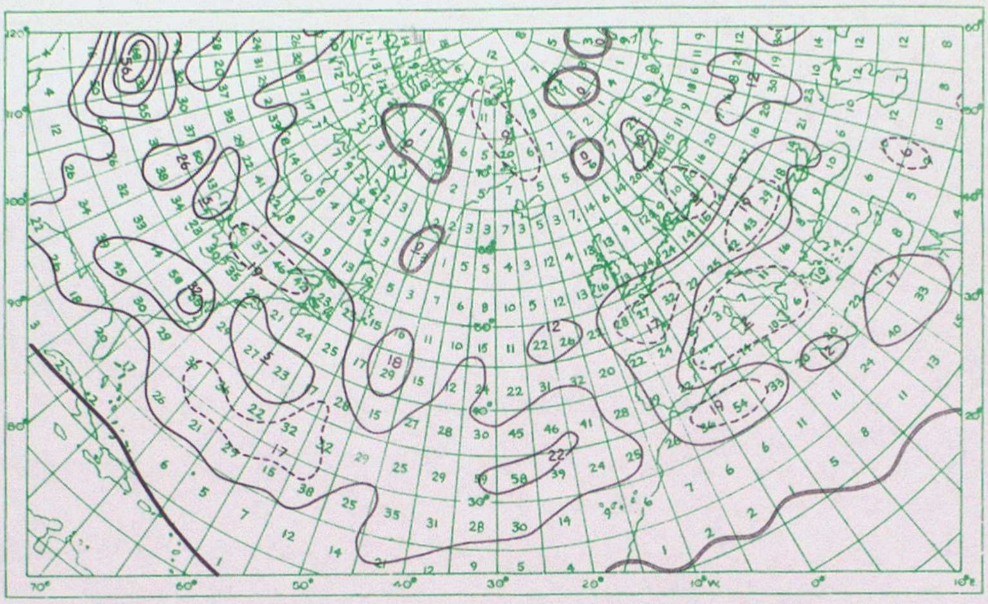

FIGURE 12.24(a) *Anticyclones at mean sea level – December*

Black isopleths: number of anticyclones (20 years)
Green figures: days with anticyclones (40 years)

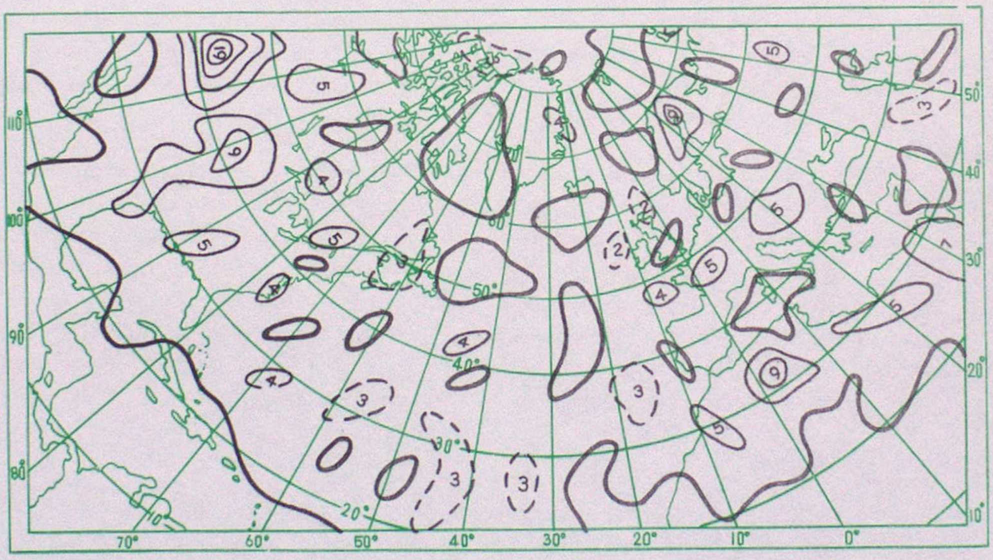

FIGURE 12.24(b) *Frequency of anticyclogenesis at mean sea level – December*

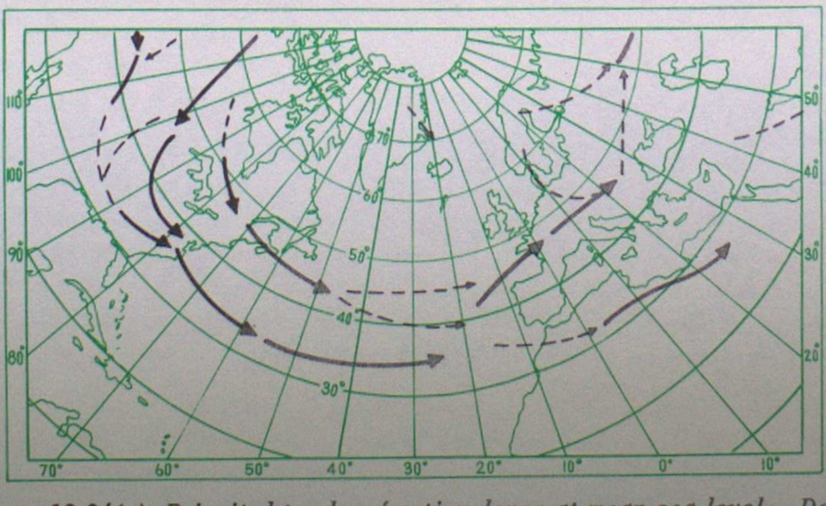

FIGURE 12.24(c) *Principal tracks of anticyclones at mean sea level – December*

700-millibar and 500-millibar levels. This may be related to the following singular features of the storm tracks:

(a) A centre of maximum cyclone frequency appears in the Gulf of Mexico, where there are more storms in February than in any other month.

(b) Cyclogenesis off the east coast of Florida is more frequent and farther south than in any other month.

(c) A secondary storm track originates west of Portugal and enters the southern Mediterranean through Gibraltar.

(d) The primary track of Mediterranean cyclones is farther south in February than in any other month.

(e) A few depressions from the eastern Mediterranean are displaced so far south that they may cross the Persian Gulf and northern Arabian Sea before entering India.

(f) The frequency of tropical cyclones is at a minimum in most sectors of the northern hemisphere.

The strength of the westerlies at low latitudes in February may be associated with several additional features of the February storm tracks which differentiate them from the January tracks, even though they are also exhibited by one or two later months. These include: higher cyclone frequency in the Great Basin and Great Plains of the United States than in the Alberta region of Canada, the appearance of a secondary storm track from Cyprus across Turkey into the southern Caspian Sea, and higher frequency of cyclogenesis in portions of the United States than in any other equal area of the hemisphere (note maxima of 13 both over the Great Basin and off the east coast in Figure 12.3*(b)*).

12.2.2.2.2. Anticyclones (Figure 12.4). The principal anticyclone tracks for February closely resemble those for January in all parts of the northern hemisphere. However, some southward displacement is evident at low latitudes in the Atlantic, where the primary anticyclone tracks are farther south (as far as 30°N.) in February than in any other month. Anticyclone frequency decreases somewhat in Spain, the Yukon, northern New England, the Great Basin, and central Europe. On the other hand, increased frequency is evident in Egypt, Finland, Ontario, and the District of Mackenzie (Figure 12.4*(a)*).

12.2.2.3. *March*

12.2.2.3.1. Cyclones (Figure 12.5). March is a transition month in which the storm tracks retain many of the wintry aspects of January and February at the same time that they begin to exhibit some features which are typical of spring. Characteristic of spring is the increased frequency of cyclogenesis inland during March. This occurs over such widely scattered areas as the Rio Grande valley, and to the lee of the Appalachian Mountains of eastern United States and the Atlas Mountains of North Africa.

Additional portents of spring are: the appearance of a secondary storm track from the northern Adriatic through central Europe, the classical Type Vb of van Bebber[6]; diminution in cyclone frequency in the American Arctic and southeastern Pacific; reduction to secondary importance of the path through the Denmark Strait; and the appearance of a secondary track from the mid-Atlantic through the British Isles. The latter two features may be associated with the fact that blocking activity over the Atlantic is most frequent during spring.

A few features of March are not shared by either the winter or the spring months. These include the centre of maximum cyclone frequency over the North

Sea and the single primary storm track from the Gulf of Alaska into Alberta.

12.2.2.3.2. Anticyclones (Figure 12.6). Although the principal anticyclone tracks during March retain most of the characteristics of the winter months, several typically spring features are introduced. For example, in the Great Basin the number of different highs (Figure 12.6*(a)*, black), the number of days with high centres (Figure 12.6*(a)*, green) and the frequency of anticyclogenesis (Figure 12.6*(b)*) all continue to exhibit local maxima, but they are no longer the highest in the entire hemisphere as they were during the five previous months. For example, anticyclogenesis is most frequent in Saskatchewan. These changes are associated with a reduction to secondary importance of the paths through the Great Basin and southern United States. The latter are characteristically farther north in March than in February, as are also the primary anticyclone tracks in Europe and the Pacific. Another typical spring characteristic is the increased importance of the Arctic Ocean as a source of polar highs in North America, at the expense of Alaska and north-eastern Siberia, where anticyclone frequency diminishes. Finally, the appearance of two new secondary tracks, one from Ohio to Massachusetts and the other from Greenland to England, should be noted.

12.2.2.4. *April*

12.2.2.4.1. Cyclones (Figure 12.7). During April the axis of the main westerly belt at 700 millibars in the western hemisphere is still quite far to the south (around 38°N.). This is related to the fact that normally April is one of the months with the greatest number of storms in the United States. Note the large area covered by the 20 line (black) in Figure 12.7*(a)* and the centres of maximum cyclone frequency (exceeding 30) in the Great Basin, Central Plains, and off the middle Atlantic coast. These are the highest frequencies of the year in the latter two areas. Furthermore, cyclogenesis is more frequent in the Great Basin and east coastal regions of the United States than in any other part of the hemisphere (Figure 12.7*(b)*). Other mid-latitude areas of the hemisphere also reach their annual maximum in cyclone frequency during April; for example, North Africa, Spain, China and the Black and Aral Seas.

The relatively low latitude of the main belt of westerlies during April is accompanied by intensification of the polar anticyclones and the polar easterly index (55° – 70°N.) to their maximum strength of the year on a mean basis. As a result, cyclonic activity in the arctic portions of North America and Siberia reach their annual minima. Continued high frequency of blocking action may be responsible for the appearance of a centre of maximum cyclone frequency over the southern British Isles (Figure 12.7*(a)*). Otherwise the storm tracks for April closely resemble those for March, except for some northward displacement near Canada and the eastern Mediterranean and also the disappearance of secondary tracks through the south-eastern United States and California.

12.2.2.4.2. Anticyclones (Figure 12.8). During April the effect of locally cold bodies of water as sources of anticyclonic vorticity becomes marked. As a result, secondary anticyclone tracks now appear in the vicinity of the Great Lakes, Hudson Bay, James Bay, the Black Sea and the Caspian Sea. Moreover, the primary track in North Africa is displaced northward over the Mediterranean. Also noteworthy is the presence of a centre of maximum anticyclone frequency over Lake Erie in April, close to where a centre of minimum frequency was located the previous month (Figure 12.8*(a)*, black).

Rapid warming of the land leads to a decrease in frequency of anticyclones in Europe, where no primary track is indicated, and to a reduction from primary to secondary status of routes in western Canada. The primary path of polar anticyclones in North America is now shifted eastward to central Canada as the famous Hudson Bay highs become prominent in spring. In the Great Basin frequent cyclonic activity during April and northward displacement of the principal anticyclone track are accompanied by complete elimination of the centre of maximum anticyclone frequency present in that area every month from October through March.

The principal trajectories of highs of Pacific and western Canadian origin, which are entirely separate during the winter months, now merge in a pronounced centre of maximum anticyclone frequency in South Dakota, an area with more anticyclogenesis than any other part of the northern hemisphere in April. From here most anticyclones travel eastward through the central part of the United States, but a few take a more southerly route. In other respects the April anticyclone tracks resemble those for March.

12.2.2.5. *May*

12.2.2.5.1. Cyclones (Figure 12.9). During the first four months of the year, the greater warmth of water surface relative to adjacent land is partly responsible for the existence of maximum cyclone frequency over many inland bodies of water, where cyclonic vorticity is locally produced. During May, however, rapidly increasing insolation results in more rapid heating of land than of surrounding water surfaces and even reverses the local temperature gradient in some regions. As a consequence, previously existing centres of maximum cyclone frequency over the Great Lakes, Denmark Strait, Adriatic Sea, Black Sea, and Aral Sea either disappear or are displaced landward, while new centres of minimum cyclone frequency appear in the western Mediterranean, Baltic Sea, English Channel, west coast of Norway, and south-eastern coast of Newfoundland (Figure 12.9*(a)*). At the same time, new centres of maximum cyclone frequency occur inland over such areas as Alaska, New Mexico, central Europe, and southern Scandinavia. Changes appear in the occurrence of cyclogenesis (Figure 12.9*(b)*), which is now most frequent over inland areas such as the Southern and Central Plains, the Great Basin, Alberta, and the Alpine region.

These changes in the distribution of cyclone frequency and cyclogenesis are reflected in the principal storm tracks. In Europe, cyclone paths which had been over water (that is, in the Mediterranean, Black, Caspian, and Baltic Seas) during the first four months of the year, are displaced northward to land areas during May. The track over the Arctic Ocean north of the continent is reduced to secondary importance, while the one over southern Scandinavia becomes primary. New secondary tracks emerge in Alaska and north-western Texas, while the course of Alberta lows shifts northward from the Great Lakes to Ontario.

12.2.5.2. Anticyclones (Figure 12.10). The poleward shift of the principal anticyclone tracks which commences in March and April becomes more extensive during May. Not only does this northward displacement continue in the western United States, Europe, and the Mediterranean, but it also occurs in Russia and along the southern Atlantic track. Weakening of the westerlies at low latitudes accompanies the disappearance of secondary anticyclone tracks in the southern United States and in the Gibraltar area. Farther north, however, tracks through Pennsylvania, the Baltic and the northern Urals, which were of only secondary importance during April, become of primary rank in May.

The effect of the land-water temperature contrast is further heightened during May. It is responsible for continued increase in anticyclone frequency over the Great Lakes, Hudson Bay, and James Bay, which are now traversed by primary tracks for the first time. These changes, coupled with eastward shift of the course of arctic and polar highs, result in a higher frequency of anticyclones in central Canada than in western Canada, a phenomenon which is pronounced only during spring (Figure 12.10*(a)*). Anticyclone frequency also increases over the locally cold waters of the Baltic Sea. Anticyclogenesis becomes frequent over cold bodies of water such as the Baltic Sea, the Black Sea, Caspian Sea and English Channel. In the Mediterranean the frequency of anticyclogenesis now exceeds that in any other area of the northern hemisphere (note maximum of 11 in Figure 12.10*(b)*).

12.2.2.6. *June*

12.2.2.6.1. Cyclones (Figure 12.11). Although June is usually considered as the first month of summer, it retains many of the characteristics of spring and even of winter in its cyclone distribution. For example, in June a primary storm track extends north-eastward across the Great Lakes, St. Lawrence valley, and just north of Newfoundland, along a route virtually unchanged during the first six months of the year. As before, most of these storms originate in either the Great Basin or the Great Plains. In fact, Figure 12.11*(b)* shows that 21 lows were formed in a 5° quadrangle in the Great Basin during the 20 Junes of record, the highest frequency of cyclogenesis per unit box recorded in any part of the northern hemisphere at any time of year.*

Typical cyclone characteristics of spring which persist into June include the absence of a storm track in the Canadian Arctic, meridional track in central Europe, double secondary track in western Canada and diminished cyclone frequency over cold coastal waters just east of Greenland and Newfoundland.

On the other hand, many new and typically summer features appear during June including a more zonal trajectory of cyclones in the eastern Atlantic, northward displacement of the track of Alberta lows (with primary importance attached to the branch through southern Hudson Bay), disappearance of the zonal track in southern Europe and marked increase in cyclone frequency in the Canadian prairie provinces. In Alberta, the number of different lows exceeds that found anywhere else in the hemisphere (note maximum of 41 on Figure 12.11*(a)*, black), and June is the only month with a low-pressure centre there on the normal map. As a result, the centre of action in the Davis Strait in June is fed primarily by storms originating in western Canada, while the track from Labrador and Newfoundland is reduced to secondary status.

A few aspects of summer which made their initial appearance in May become more marked during June. These include the presence of storm tracks and centres of maximum cyclone frequency in Alaska, and primary importance of the tracks over land across the northern part of Eurasia, in contrast with secondary rank of those over the Arctic Ocean to the north. Some tropical depressions also appear in the Gulf of Mexico and Caribbean Sea.

12.2.2.6.2. Anticyclones (Figure 12.12). During June the primary anticyclone tracks have a fairly simple appearance. They extend for the most part in a zonal fashion, across North America and the Atlantic between 40° and 50°N., and across the Soviet Union between 50° and 55°N. The primary track across the

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Some of this cyclogenesis may be spurious due to the process of reducing pressure to sea level or because of thermal lows not properly classified. These factors may also explain, in part, the fact that Figures 12.1(a)*, 3*(a)* etc. to 23*(a)* show centres of maximum cyclone frequency in the Great Basin during each month of the year, whereas summaries of cyclone frequency based upon the storm tracks published in the *Monthly Weather Review*[7,8] generally do not show this feature. On the other hand, the latter may be deficient because quasi-stationary lows in the Great Basin are difficult to track.

northern tier of States in the United States is particularly significant because it exists virtually unchanged during the four summer months June through September. It passes directly across the Great Lakes, where an area of maximum anticyclone frequency is centred and where it is joined by another primary path composed of polar highs from western Hudson Bay. The only other part of the northern hemisphere with a primary track of polar anticyclones during June is the area just east of the Ural Mountains. Secondary tracks of polar highs originate over the cold waters south of Iceland and Spitsbergen, north of Canada, as well as in Greenland and Alberta. The cold-water effect is also indicated by increase of anticyclone frequency over the Mediterranean and the appearance of additional centres of maximum anticyclone frequency over Sable Island, the Black Sea, Caspian Sea, Barents Sea, Bay of Biscay and Gulf of Finland (Figure 12.12*(b)*, black).

General northward shift of the westerlies during June is accompanied by northward displacement of the anticyclone tracks in the United States and by reduction from primary to secondary importance of the route in the Atlantic between 30° and 35°N. Primary tracks are likewise diminished to secondary ones in Europe.

12.2.2.7. *July*

12.2.2.7.1. Cyclones (Figure 12.13). From June to July a marked northward shift of most features of the general circulation normally occurs. A corresponding northward displacement of the principal storm tracks is evident in Canada, the Atlantic and north-eastern Siberia. Manifestations of this change are the disappearance of cyclone tracks at low and middle latitudes in such places as the Great Basin, the Southern Plains, British Columbia and central Europe, at the same time that new paths appear at high latitudes in the American Arctic, and Russian Arctic. In the western hemisphere little change in hurricane frequency or tracks occurs from June to July.

The only sector of the northern hemisphere which fails to experience a northward shift of the principal storm tracks from June to July is the European area, where a well defined zonal track around 60°N. extends from the eastern Atlantic into western Siberia. It is well known that the Atlantic Arctic front actually drifts southward in this region in summer. In Sweden the maximum cyclone frequency of 34 (Figure 12.12*(a)*, black) is one of the highest in the hemisphere and the greatest of any month in this area.

12.2.2.7.2. Anticyclones (Figure 12.14). Except for continued southward displacement in Russia, the primary anticyclone tracks show little change from June to July.. The zonal track across the northern United States is even more definitive, with pronounced centres of maximum anticyclone frequency located over the Northern Plains and the Great Lakes. These two areas are the only parts of the hemisphere with more than 30 different highs per 5° unit box during the 20 Julys of record (note maximum frequencies of 37 and 31 in Figure 12.14*(a)*, black). In the former region, anticyclone frequency is greater during July than in any other month of the year, and a separate centre of high pressure appears over eastern Wyoming on the normal sea-level chart. Most American highs are formed in this sector, which leads the northern hemisphere in rate of anticyclogenesis during July (note maximum of 15 in Figure 12.14*(b)*).

An interesting reversal from June occurs in the southern North Atlantic, where the secondary anticyclone track between 30° and 35°N. is now directed westward instead of eastward, toward a centre of maximum anticyclone frequency near Bermuda. This shift reflects the poleward extension of the subtropical easterlies at 700 millibars in the western hemisphere to 30°N. during July. In Europe the anticyclone paths are more coherent during July than June, and a single primary track now reappears around 50°N. This zonal track is reinforced by secondary intrusions of polar highs which originate in the vicinity of the Norwegian or Greenland Seas. As before, the primary trajectory of polar highs extends from the Barents Sea south-eastward through the central Urals into central Siberia.

12.2.2.8. *August*

12.2.2.8.1. Cyclones (Figure 12.15). In August the axis of the hemispheric west-wind belt at the 500-millibar level is normally at 50°N. farther north than in any other month. The principal storm tracks are likewise farthest north, with the primary path around 60°N. across North America, the Atlantic and Eurasia. Secondary tracks are found even farther north, at both 70° and 80°N. Storms are infrequent in the United States, but very frequent in central Canada. In fact, the number of different lows per 5° box in the Canadian prairie provinces is equalled only by that in the vicinity of Iceland (Figure 12.15*(a)* , black). In the latter area blocking activity diminishes and the frequency of cyclones during August is surpassed only by that during the winter months of December and January.

Not only the zonal westerlies but also the subtropical easterlies are normally farther north in August than in any other month. Some disturbances originate in the vicinity of the Cape Verde Islands, develop as they are carried across the southern North Atlantic by the prevailing easterlies, and then enter the Caribbean, Gulf of Mexico, United States or western Atlantic as fully fledged hurricanes. Characteristic of this activity is the split track around the West Indies, with one branch passing to the north and one to the south of the islands.

12.2.2.8.2. Anticyclones (Figure 12.16). On an overall basis, the principal tracks of anticyclones like those of cyclones are farthest north during August. However, the northward shift from July is only slight, being perceptible only in Europe, the Pacific and the Great Lakes region. In the United States the primary track across the northern border States is more frequent than ever, as anticyclone frequency increases throughout the northern part of the country except for the Northern Plains. Nevertheless, the latter region is still one of the most anticyclogenetic in the hemisphere (note maximum of 12 in the Black Hills area in Figure 12.16*(b)*). The sharpest increase in anticyclone frequency occurs in New York and Pennsylvania. Along the border between these two States there were 35 different highs per 5° box during the 20 Augusts of record (Figure 12.16*(a)*, black) – the highest frequency in the entire hemisphere during August and the highest of any month anywhere except for the western United States and the eastern Pacific. Since most of these highs move on eastward across the Atlantic, anticyclone frequency also increases from July to August in this sector, reaching its high point of the year in mid-ocean (note maximum frequency of 32 around 35°N., 40°W. in Figure 12.16*(a)*, black). A similar increase occurs in the middle Atlantic States as some of the highs from the Pennsylvania area travel south-eastward toward Bermuda.

The predominant track of polar and arctic highs in North America undergoes an interesting westward shift from July to August. Instead of passing through the Canadian Archipelago and western Hudson Bay regions, as in the four months from April to July, it now crosses the Beaufort Sea, Mackenzie valley and Canadian prairie provinces in a fashion reminiscent of winter. However, the frequency of these polar outbreaks is quite low. Warming of Hudson Bay puts an end to appreciable anticyclogenesis in this region, although some polar highs still form in nearby Manitoba. Some polar anticyclones continue to enter eastern Europe and the North Sea, but their point of origin is considerably farther south than in July. In the Soviet Union the primary track of polar anticyclones is very pronounced, and anticyclone frequency in the Barents Sea reaches its high point of the year.

12.2.2.9. *September*

12.2.2.9.1. Cyclones (Figure 12.17). Although September is the first month of autumn, it greatly resembles August in many aspects of its cyclonic activity. The prevailing westerlies and associated storm tracks are still far to the north. In North America cyclones continue to be much more frequent in Canada than in the United States and the primary track remains around 60°N. The Icelandic area again leads the hemisphere in number of lows per 5° quadrangle (note maximum cyclone frequency of 38 in Figure 12.17*(a)*, black). Primary storm tracks are still located in southern Scandinavia, with secondary paths between 70° and 75°N. in the American and Siberian Arctic. The prevailing tracks of tropical storms are generally similar to those of the preceding month, except for some eastward shift in the Atlantic and resumption of cyclogenesis in the western Caribbean (during the second half of September). In most of the hemisphere the monthly frequency of tropical cyclones reaches its annual maximum in September.

There are several characteristics of September which differ from those of August but are typical of the cooler portion of the year. Most prominent of these is the marked increase in cyclone frequency over open water west of Norway and north of Europe, where primary storm tracks are located every month from September through April. At the same time cyclonic activity is resumed, but weakly, over the Mediterranean region, where storms are absent only during the summer period from June to August.

12.2.2.9.2. Anticyclones (Figure 12.18). The principal anticyclone tracks during September resemble those of the summer months for the most part. A well defined primary track still extends in a zonal direction across the United States and the Atlantic around 45°N. and across Europe at about 50°N. The Northern Plains region of the United States again leads the hemisphere in number of highs (Figure 12.18*(a)*, black) and frequency of anticyclogenesis (Figure 12.18*(b)*). The trajectories of polar highs are only of secondary importance, not only in North America as in August, but also in all other parts of the northern hemisphere.

Some portents of autumn appear during September. Most significant, perhaps, is the renewal of anticyclogenesis in the Great Basin (Figure 12.18*(b)*). From here a secondary track extends across the central United States into a pronounced centre of maximum anticyclone frequency located over West Virginia. In the Atlantic the secondary anticyclone path between 30° and 35°N. is once again directed from west to east, as the zone of subtropical easterlies normally shifts southward. A sharp fall in anticyclone frequency occurs over previously cold water surfaces, such as the Barents Sea, where primary anticyclone tracks of August vanish in September. The marked resurgence of cyclonic activity in the Barents Sea during September has previously been noted.

12.2.2.10. *October*

12.2.2.10.1. Cyclones (Figure 12.19). October is a typical autumn month in which cooling due to decreasing insolation occurs more rapidly over land than over many adjacent water surfaces. It is not surprising, then, that new centres of maximum cyclone frequency now appear over James Bay, the Black Sea, and the Sea of Okhotsk. At the same time storminess increases in previously existing centres over the Davis Strait, Adriatic Sea and Kara Sea. In the last-named sea, cyclone frequency reaches its annual maximum during October. Also noteworthy is the increased frequency of cyclogenesis over the Gulf of Genoa and vicinity, which is one of the most cyclogenetic areas in the hemisphere every month from October through March.

During October the main belt of westerlies normally begins to move south. A corresponding southward displacement of the principal storm tracks is evident in Canada. Increased speed of the westerlies and strengthened meridional temperature gradient at middle latitudes are accompanied by greater frequency of cyclonic activity in the United States, southern Canada and the western Mediterranean. In all of these areas, secondary storm tracks of September are converted to primary ones during October. The tracks of tropical cyclones are also farther south in October, particularly in the Caribbean. Southward shift of the westerlies results in earlier and more frequent recurvature, so that the main tracks of hurricanes are now definitely east and south of Florida. The frequency of tropical depressions increases somewhat in the western Caribbean and decreases markedly in the Atlantic and Gulf of Mexico.

12.2.2.10.2. Anticyclones (Figure 12.20). One of the outstanding features of October is the prevalence of anticyclonic activity in the central Appalachian Mountain region of the United States, where a prominent centre of high pressure is located on the normal sea-level map. Near West Virginia there are more days with high centres (maximum of 95 plotted in green in Figure 12.20(*a*)) and more different highs (maximum of 34, in black, Figure 12.20(*a*)) than in any other 5° quadrangle in the northern hemisphere. In this area anticyclone frequency is greater during October than in any other month of the year, with a resulting high incidence of smog and "Indian summer" weather.

Highs enter the Appalachian region along two principal paths. The most frequent, from the north-west, is essentially a continuation of the zonal track of summer across the northern United States, but displaced slightly to the south. The second path, from the south-west, may be considered as a precursor of the winter route through the southern United States, but shifted a few degrees to the north. Both of these tracks are composed primarily of anticyclones originating at middle latitudes, either in the eastern Pacific, which contributes more highs to the United States in October than in any other month; the Great Basin, which leads the hemisphere in anticyclogenesis during October (maximum frequency of 11 in Figure 12.20(*b*)); or the Northern Plains, which has the second largest number of highs per 5° box in the hemisphere (maximum frequency of 33 in Figure 12.20(*a*), black). Some highs of polar origin also find their way into the Appalachian region, either directly from central Canada through the Great Lakes, or indirectly from western Canada via the Northern Plains.

The principal anticyclone tracks for October differ from those of September primarily in lying farther south. This southward displacement is evident in all sectors of the northern hemisphere except the Atlantic and eastern Asia and is most pronounced in the Pacific, western and southern United States and Europe. October also differs from September by decrease in anticyclone frequency and disappearance of secondary tracks over bodies of water such as south-eastern Gulf of Alaska and Lake Superior. At the same time new centres of maximum anticyclone frequency appear over rapidly cooling land areas like Algeria and the Great Basin, and the frequency of highs increases in much of the United States, western Canada and Greenland.

12.2.2.11. *November*

12.2.2.11.1. Cyclones (Figure 12.21). In November several features of the storm tracks which are characteristic of the winter months make their appearance. A feature of November is the convergence of two primary storm tracks, composed of Alberta and Colorado lows, into a centre of maximum cyclone frequency around the Great Lakes. This occurs every month from November through April. In the Atlantic the primary track shifts from the east to the west side of Iceland; and a centre of maximum cyclone frequency is now found in the Denmark Strait, where it remains during the next five months. Additional cyclone paths which appear in November and intensify during the winter months are those through the northern Gulf of Mexico, eastern Mediterranean, Caspian Sea and southern Davis Strait. Otherwise, the principal tracks are quite similar during November and October. However, some southward displacement is evident in the primary track in southern Canada and also in the latitude of recurvature of tropical storms which diminish in frequency.

12.2.2.11.2. Anticyclones (Figure 12.22). During November the majority of anticyclone tracks take on typical wintertime characteristics. In North America the meridional trajectory of polar highs in western Canada becomes of primary importance for the first time since March. Most of these highs move southeastward through the central United States along a well defined path which is now definitely south of the Great Lakes, where anticyclone frequency is once again at a minimum (Figure 12.22*(a)*). As in winter, some of these Canadian highs travel north of the Lakes, through Ontario and southern Quebec, before passing out to sea through Maine and the Maritime Provinces. Wintertime properties also reappear in the Great Basin, where frequency of both anticyclones and anticyclogenesis is highest in the hemisphere for November, and a pronounced centre of high pressure appears on the normal sea-level map. Most of the Basin highs move through the southern United States on a course which does not merge with the primary track of polar anticyclones until the Appalachian area is reached.

Continued southward displacement of the principal anticyclone tracks during November is responsible for their more wintry appearance in the eastern hemisphere. The North African track is now completely south of the Mediterranean Sea, over which a pronounced minimum in anticyclone frequency is located.

On the other hand, some of the anticyclone tracks during November retain the aspects of autumn and even summer. This is particularly true in the Atlantic where the primary path is located between 40° and 45°N., every month from June through November. Characteristic of the autumn months only is the presence of a primary anticyclone track from West Virginia north-eastward along the southern New England coast, as well as merging of the paths of some Great Basin and polar highs in the Northern Plains. Another of the tracks of November which are prevalent during autumn but disappear in winter is that of a secondary nature from Greenland into Great Britain.

12.2.2.12. *December*

12.2.2.12.1. Cyclones (Figure 12.23). December is a month of great cyclonic activity in many parts of the world. Stormy areas which have their highest cyclone frequency of the year during December include the Great Lakes, Barents Sea, and Spitsbergen. In addition the Davis Strait and Italy experience their second highest frequencies. Furthermore, Iceland has more days with low centres in December than in any other month (Figure 12.23*(a)*, green). Finally, the frequency of cyclogenesis in the Gulf of Mexico reaches its annual maximum in December, while in the Italian region it is exceeded only by January (Figure 12.23*(b)*).

Many of the principal storm tracks and associated centres of maximum cyclone frequency are farther south in December than in November. This southward displacement is quite evident around British Columbia, Newfoundland and the Balkans. Increased cyclonic activity at lower latitudes results in the appearance of new tracks through the southern Caspian Sea and the conversion of a secondary to a primary route in the eastern Mediterranean.

12.2.2.12.2. Anticyclones (Figure 12.24). By December the last vestiges of the autumn anticyclone pattern, including tracks from the Great Basin into the Northern Plains, from West Virginia to southern New England and from Greenland to England have disappeared. On the other hand, certain features appear which are unique to the winter months. These include centres of maximum anticyclone frequency in southern Quebec and the Balkans, and secondary tracks of polar highs from the Dakotas into Texas and from Alaska into the Yukon. Other new aspects of December are typical of spring as well as winter, including a centre of minimum anticyclone frequency south-east of Nantucket, a secondary track from the eastern Atlantic into North Africa, and a primary route through the middle Atlantic States toward Bermuda and then eastward across the Atlantic between 30° and 35°N.

Perhaps the outstanding feature of December is continued intensification of anticyclonic activity in the Great Basin. In 5° quadrangles within this area both the number of days with high centres (168 in Figure 12.24*(a)*, green) and the frequency of anticyclogenesis (19 in Figure 12.24*(b)*) are absolute maxima for any month and any place. The number of different highs in the Basin in December (56 in Figure 12.24*(a)*, black) exceeds that observed at any time anywhere else; but it is equalled by January in the same region.

12.2.3. *Summary*

The principal conclusions of Klein's work[1] are (for the area 120°W. to 60°E.) contained in Figures 12.1 to 12.24. The following remarks summarize some of the general characteristics of which many are well known.

(1) Most cyclones, whether tropical or extratropical in origin, tend to have a northward component of motion. Anticyclones originating at high latitudes usually move southward, but in middle latitudes the predominant motion of anticyclones is from west to east.

(2) For both cyclones and anticyclones the prevailing tracks, as well as areas of maximum occurrence and genesis, are generally farthest south in February, farthest north in August and farther south in spring than in autumn. Northward displacement is most rapid in late spring; southward displacement in late autumn. A similar annual march is exhibited by the hemispheric axis of maximum west wind speed on normal 700-millibar maps.

(3) The principal cyclone tracks and the areas of greatest cyclone frequency generally lie to the left of the axis of maximum wind speed at 700 millibars, in regions of maximum cyclonic relative vorticity. Anticyclone tracks and regions of maximum anticyclone occurrence are frequently located just south of this axis, in areas of strong anticyclonic shear and vorticity. Both cyclogenesis and anticyclogenesis are frequent at the latitude of peak 700-millibar westerlies.

(4) Cyclones tend to travel over locally warm surfaces, anticyclones over locally cold surfaces. This effect is particularly striking over inland bodies of water, where there occur centres of maximum cyclone frequency in autumn and winter and centres of maximum anticyclone frequency in spring and summer.

(5) Mountainous areas are favoured sites for anticyclones and anticyclogeneis, while cyclonic activity is frequent on the lee side of mountain ranges. Cyclones usually stay over flat surfaces and avoid mountainous terrain, while anticyclone tracks tend to curve anticyclonically on crossing mountains.

(6) Cyclogenesis is most frequent to the lee of mountain ranges, over locally warm bodies of water, and on quasi-permanent frontal zones along the south-eastern coasts of continents.

(7) The spring season is characterized by frequent cyclonic activity at middle latitudes and minimum storminess at high latitudes, where blocking and anticyclonic circulations are frequent. For the hemisphere as a whole, March leads all other months in total number of lows, highs and anticyclogenesis.

(8) One of the most active meteorological areas of the world is the Great Basin of the United States, which has the greatest mean annual frequency of any part of the northern hemisphere for both cyclogenesis and anticyclogenesis.*

(9) Maximum frequency of daily cyclones is found not only in the vicinity of the Icelandic and Aleutian lows, but also in other areas not customarily considered as centres of action, especially the Barents Sea, Newfoundland, the Great Basin, Mediterranean Sea and Canadian prairies.

(10) The average life span of pressure centres is about five days, with anticyclones tending to persist for approximately one day longer than cyclones. Furthermore, most lows and highs tend to move at least 5° per day. Hence, activity in the great centres of action is usually replenished by an influx of migratory systems.

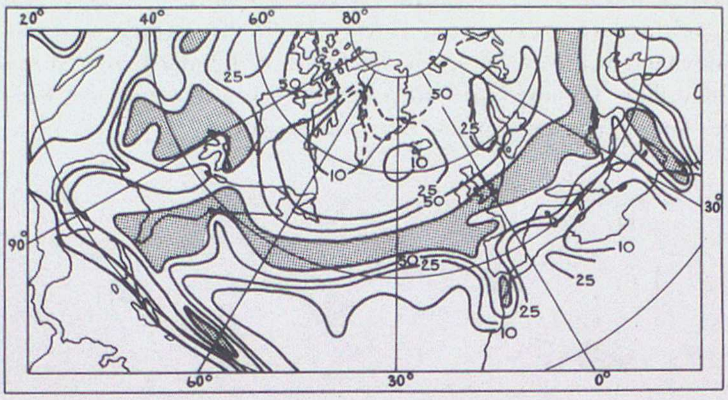
12.3. RATES OF ALTERNATION BETWEEN CYCLONES AND ANTICYCLONES

The charts showing frequencies of cyclones and anticyclones (Figures 12.1*(a)*, 2*(a)* etc. to 24*(a)*) include both the migratory systems and the stationary and quasi-permanent systems. Certain features of these charts are due largely to some of these latter systems, for example the Iceland low and the Azores high. Petterssen[9] has devised a method which indicates the regions within which there is a high rate of alternation between cyclones and anticyclones. Petterssen took the ratios of the frequencies of cyclones and anticyclones over given equal areas of the northern hemisphere and evaluated the ratio of these frequencies as a proper fraction. He regarded this fraction as an expression of the rate of alternation between cyclones and anticyclones. Isopleths were drawn for summer and winter over the northern hemisphere. Figures 12.25*(a)* and *(b)* reproduce these isopleths over the area covered by the charts in Section 12.2.

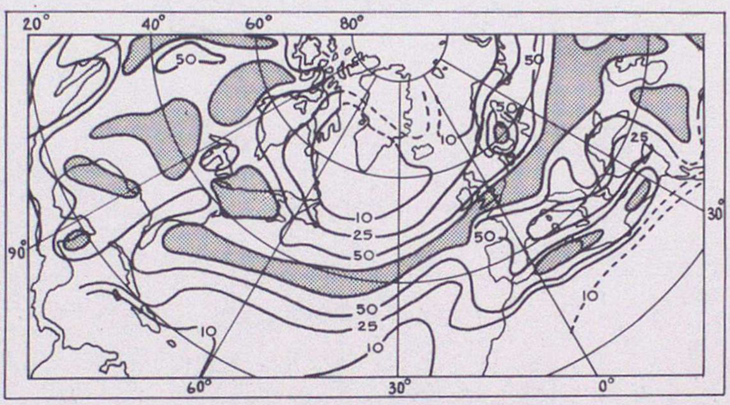
A striking feature of the summer distribution (Figure 12.25*(a)*) is a well defined narrow lane of maximum rate of alternation extending west-north-westward from near the West Indies towards Florida, then north-eastwards along the Atlantic coast of the United States to New England and then in a general east-north-easterly direction across the North Atlantic to Europe. Near western Europe the belt divides. One tongue extends from the south-west approaches towards Spain and northern Morocco but the main belt extends across continental Europe in an easterly direction to the Ukraine and continues in a somewhat more east-north-easterly direction right into the heart of Russia in Asia. A rather shorter belt of maximum rate of alternation extends from the Suez Canal area, across the Levant to the eastern end of the Black Sea.

In winter (Figure 12.25*(b)*) the pattern across the North Atlantic is rather similar to summer but is located farther south. However, the tropical branch from

*However, see footnotes on pages 7 and 35.



(a) Summer



(b) Winter

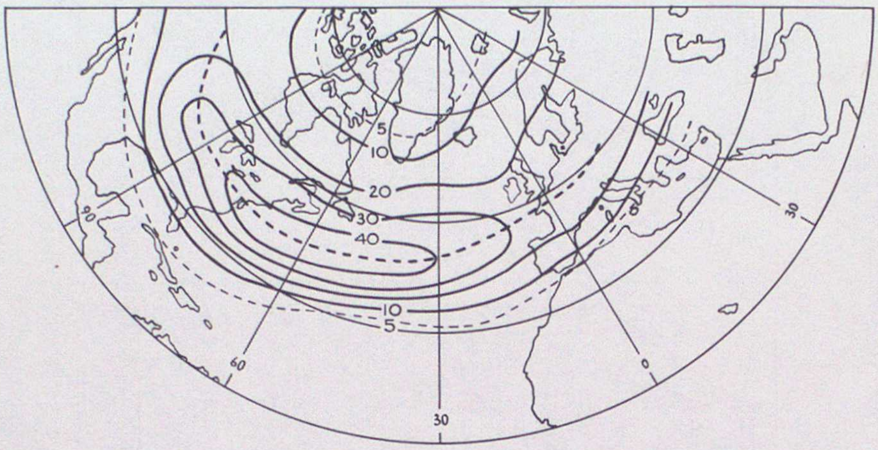
FIGURE 12.25 *Rates of alternation (per cent) between cyclones and anticyclones, indicating the distribution of travelling disturbances*
Areas greater than 75 per cent are shaded

the West Indies to Florida is much more feeble and there is a pronounced belt extending through the Mediterranean with separate maxima in both its western and eastern parts. The pattern in North America has a number of separate cells of maxima and generally displays a more ragged appearance in winter than in summer. Figure 12.25*(b)* shows also the winter extension of travelling pressure systems across the Middle East to Iran and eastwards of the Caspian Sea to Turkestan.

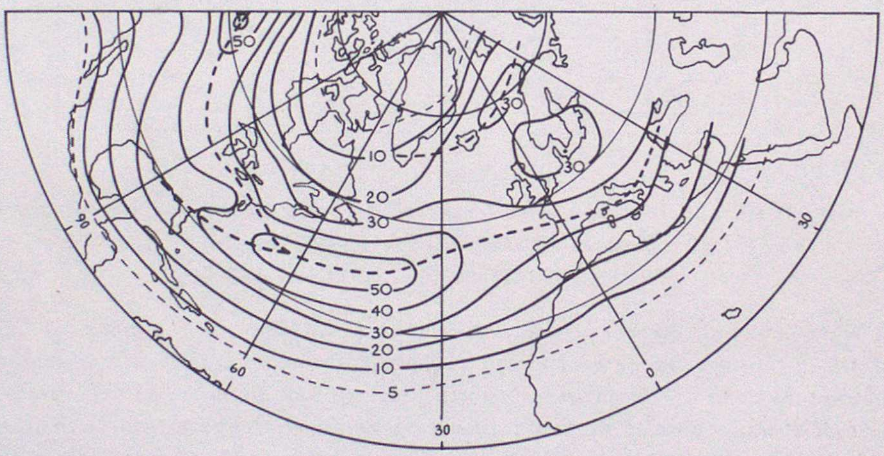
12.4. FREQUENCY OF FRONTS

Figures 12.26*(a)* and *(b)* show, over a substantial part of the northern hemisphere, the percentage frequency of fronts during winter and summer. The diagrams are taken from a paper by Schumann and van Rooy.[10] The frequency of fronts was defined as the number of times per hundred days when part of a surface front lay within a given unit area. The unit of area was taken as the curvilinear quadrangle with sides 5° of latitude and longitude, and the number of fronts in each 5° area was weighted to take account of the diminishing area with increasing latitude. The value of the weighting factor used depended on the assumption that the orientation of fronts was randomly and evenly distributed. The authors remarked that this was not strictly true since the fronts showed a tendency towards a west-east orientation but they did not further investigate this point.

The basic material used in the investigation was the series of daily *Historical Weather Maps*[2] for a ten-year period 1928 to 1938. No attempt was made to distinguish between cold, warm or occluded fronts and upper fronts were not included. Data for December, January and February were used to obtain the winter values and data for June, July and August the summer values.



(a) Summer (June, July, August)



(b) Winter (December, January, February)

FIGURE 12.26 *Percentage frequency of fronts*
Heavy broken lines indicate ridges of maximum frequency

The summer pattern in Figure 12.26*(a)* shows a single axis of maximum frequency associated with the polar front. The area of maximum activity is located over the western North Atlantic, but the activity is less intense than in winter. Figure 12.26*(b)* shows the winter pattern. An axis of secondary maximum frequency extends from northern Scandinavia through Iceland to south Greenland and this is associated with the arctic front. The axis of primary maximum extends from southern Europe across the North Atlantic and North America and is associated with the polar front. Figure 12.26*(b)* shows that separate branches merge into a single axis near the Canadian Rockies and in the western Atlantic, in both of which areas there is a maximum of activity along the axis.

Statistical and Climatological Data

12.5. SOME STATISTICAL DATA FOR AREAS NEAR THE BRITISH ISLES

The information in Sections 12.2, 12.3 and 12.4 should give forecasters sufficient background knowledge for general purposes, but for detailed forecasting near the British Isles it seems desirable to present in rather more detail some of the data which is available.

12.5.1. *Blocking action*

Studies of blocking action generally, and near north-west Europe in particular, have been made by several workers. It is unfortunate that there is no commonly accepted definition of what constitutes a block. Many of the individual investigators have each adopted their own criterion of a block and these all differ in some degree or other. Accordingly a direct comparison of the various results cannot be carried out with much exactitude.

From the point of view of the synoptic forecaster in north-west Europe the essential characteristics of blocking action are probably:

(a) A distortion of the main tropospheric westerly flow, such distortion being a durable feature of the charts for several days.
(b) An anticyclone or ridge of high pressure in relatively high latitudes (say north of 50°N.) associated with the thermal ridge of the distortion.
(c) The diversion of migratory cyclones generally to paths which lie to north or south of the blocking high.

In the northern hemisphere in temperate latitudes there are two well marked areas of maximum frequency of blocking action. Both lie near the eastern edges of oceans and the western edges of continents, example, near the eastern Pacific and eastern Atlantic Oceans. The maximum in the eastern Atlantic is the more pronounced. These blocks near Europe will now be considered in greater detail. The majority of these blocks are located between about 50° and 60°N. latitude and over a band of longitudes which extends to west and east of the Greenwich Meridian. Blocking in the eastern Atlantic usually shows a maximum in May and falls away quickly to a minimum in July. Although blocks may exist for several days (or even a few weeks) they are not necessarily stationary and indeed many of them move relatively steadily often for one or two days or so. Sometimes the movement is towards the east (sometimes called progressive) and at other times it may be towards the west (sometimes called retrogressive or regressive). Some blocks exhibit various combinations of progression, retrogression or little movement at all during the course of their existence. Some statistical data are now given.

12.5.2. *Blocking northwards of 50°N. in the sector from 100°W. eastwards to 60°E. (after Sumner[11])*

Sumner[11] regarded the essential characteristic of blocking action as the local and, in well developed cases, rather sharp diminution of zonal flow within the band occupied elsewhere and previously by the main concentration of westerlies. He examined data for the four-year period from January 1949 to December 1952 for the area northwards of 50°N. extending from 100°W. to 60°E. He considered that the most reliable and definitive feature of blocking patterns was the upper ridge or high and, in positioning blocks, the following convection was adopted. If the upper anticyclonic vortex (or, if absent, the surface high) was well formed and fairly symmetrically placed with respect to the upper ridge, then its latitude and longitude were taken. If the surface or upper cells were not very well associated with the ridge (sometimes the surface high was displaced into the baroclinic zone around the upper ridge) then an attempt was made to fix a position in the weakest westerlies in the ridge, bearing in mind the day-to-day continuity. All these measurements were made to the nearest 5°.

Sumner attempted to classify the longitudinal movement of blocking patterns into three classes:

(i) eastward-moving or progressive *(P)*
(ii) quasi-stationary *(Q)*
(iii) westward-moving or retrogressive *(R)*.

In view of the complex and discontinuous nature of some of the displacements (in the cases of retrogression especially) and the crudity of some of the measurements, Sumner adopted the following rough criteria:

> Movements sustained for at least three days, of any magnitude but consistently east or west, were classified in the *P* or *R* classes respectively (by far the greater proportion of these averaged 5° longitude per day or more).
>
> Movements lasting two days or less had to be more than 5° longitude in all, to be placed in one of these classes.
>
> The remaining periods were all placed in the *Q* class.

12.5.2.1. *General characteristics.* The total number of days of blocking (in four years) was 878; 296 with progressive patterns, 364 quasi-stationary and 218 retrogressive; however, only 835 of these were for blocks actually situated within the area considered, of which 45 days were overlapping. They were arranged in 53 distinct spells of average duration 16·5 days.

12.5.2.2. *Monthly and seasonal distribution.* Figure 12.27 shows the monthly distribution, together with the relative occurrence of days of progression, stagnation and retrogression.

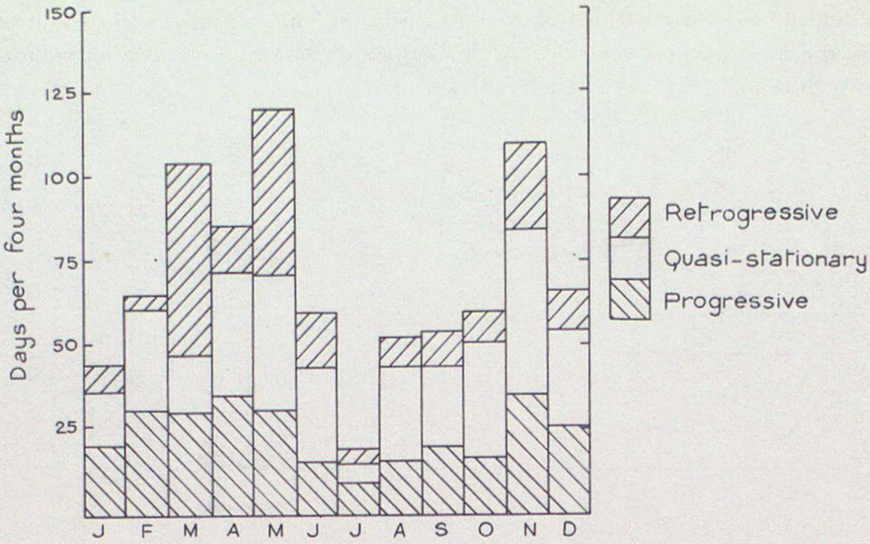
Sumner remarked that the general profile of Figure 12.27 with its May maximum and July minimum was in close agreement with that obtained for a similar sector by Rex[12] from an examination of 14 years' data from the end of 1932 to 1940 and from 1945 to the beginning of 1950. These features were also in close agreement with the results for the sector 20°W. to 50°E. obtained by Brezowsky, Flohn and Hess[13] from an examination of 70 years' data 1881–1950. However, the secondary maximum in autumn on Figure 12.27 showed up only weakly in the data of Brezowsky *et alii* and was not supported by Rex's data.

Figure 12.27 shows little significant change from month to month in the proportion of days of progression, but retrogression was relatively most frequent in March, with May a close second and June and November next in order.

During the year the preferred location of the blocks shows a noteworthy variation. Brezowsky *et alii* classified their blocks into two broad groups: one consisting of blocks located over the north-eastern Atlantic with their centres at sea (*A*-group) and the other consisting of blocks located over northern Europe (*E*-group). Blocks in the *A*-group were normally concentrated in the period middle of April to middle of June and rarely occurred in summer and winter. Blocks in the *E*-group were most frequent in the period October to May with weak maxima in the first half of March and the second half of October, but were rather rare in summer.

The statistics of the monthly distribution of days with a block situated within narrow sectors of longitude as given by Sumner[11] were generally in agreement with the findings of Brezowsky *et alii.*

Statistical and Climatological Data



	Spells centred within												
	Jan.	*Feb.*	*Mar.*	*Apr.*	*May*	*June*	*July*	*Aug.*	*Sept.*	*Oct.*	*Nov.*	*Dec.*	*All*
Number	3	3	7	6	7	3	1	2	3	5	8	5	53
Average duration (days)	14.0	36.0	15.0	10.0	22.5	12.5	13.0	22.0	21.0	14.0	15.0	11.5	16.5
Average speed within periods of progression (°long. per day)	6.5 (7)	5.0 (5)	7.0 (8)	5.5 (8)	5.0 (7)	3.0 (3)	6.0 (3)	5.0 (3)	7.0 (5)	6.5 (4)	7.5 (10)	6.5 (8)	6.0
Average speed within periods of retrogression (°long. per day)	12.0 (3)	11.5 (1)	7.5 (12)	9.0 (3)	6.5 (8)	5.5 (3)	10.0 (1)	8.0 (2)	9.0 (3)	6.5 (2)	6.5 (7)	7.5 (1)	7.0

Number of periods in brackets

FIGURE 12.27 *Monthly distribution of blocking*

Blocking highs over the eastern North Atlantic Ocean and western Europe have also been examined by Sanders[14] who adopted the following criterion of a block:

"If within the area bounded by latitudes 40° and 65°N. and between longitudes zero and 30°W. any isobar on the western lobe of a High moved west or remained in the same position on the following day, then by definition an instance of blocking was said to exist, the associated High was identified as a blocking High, and its position and central pressure were recorded."

Using this criterion, the daily synoptic series of Historical Weather Maps[1] was examined, chart by chart, for the period 1899–1938. From this examination monthly maps showing the positions of all blocking highs during the 40-year period were prepared. These are not reproduced here.

Although Sanders' criterion would seem likely to include highs which many synopticians would not regard as blocks it seems legitimate to interpret his results as indicating a more or less orderly oscillation, in the mean, of the distribution of blocking highs over the north-eastern Atlantic Ocean and western Europe. In January the blocking highs (as defined by Sanders) lie on a band from the Azores north-eastwards towards Finland. By May the band has moved north-westwards, has mainly left the European continent and extends northward from the Azores through the Norwegian Sea. In July, August and September the concentration of blocking highs (a minimum in this period) was north of the Azores. In October the blocking highs became more frequent over land and by December the south-west to north-east pattern was re-established.

12.5.2.3. *Latitudinal and longitudinal distribution.* The general latitudinal and longitudinal distributions obtained by Sumner[11] are reproduced in Figures 12.28 and 12.29, together with the relative proportions of days of progression (*P*), stagnation (*Q*) and retrogression (*R*).

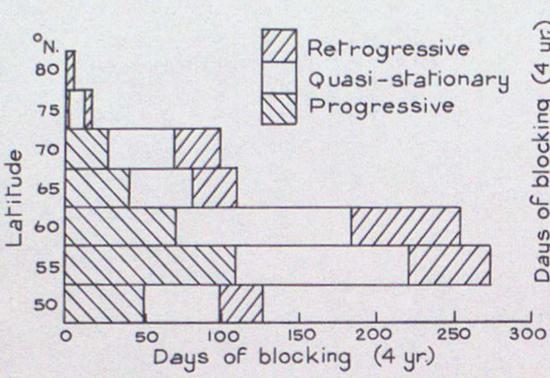


FIGURE 12.28 *Distribution of blocking with latitude*

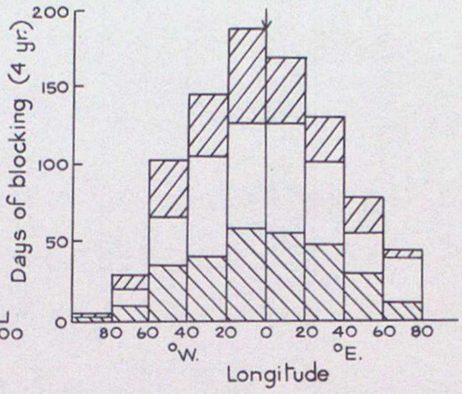


FIGURE 12.29 *Distribution of blocking with longitude*

Sumner found that, for all the data, progression was proportionately rather more frequent in lower than in higher latitudes. Conversely retrogression was proportionately rather more frequent in higher than in lower latitudes. The quasi-stationary class had about the same relative frequency at all latitudes. The latitudinal data were originally segregated east and west of Greenwich but little significant difference in the profiles or in the relative proportions of *P*, *Q* and *R* with latitude was apparent.

Variations in latitude from month to month were irregular and often small but some general "lifting" to higher latitudes from winter to summer was apparent with superposed peaks when blocking was most frequent and furthest west. Within the individual spells, short-period variations – gradual trends and irregular fluctuations – in latitudinal position were continually occurring but by far the greater number of these were only of the order of 5°–10°. In fact 32 of the 53 spells varied in latitude throughout their life only by 10° or less (these included most of the shorter spells, but also three spells of 22 days and one each of 26 and 42 days (see Figure 12.30)); 14 spells fluctuated by as much as 15° of latitude and the remaining 7 by about 20°. There was a tendency for blocking patterns to move to higher latitudes within a few days of initiation and to lower latitudes as the spell was ending; 18 spells showed an initial rise of 10°–15° of latitude, while 20 ended with a similar fall.

Figure 12.29 shows a peak of blocking just west of Greenwich falling more sharply to the west than to the east. Retrogression was the more frequent over the Atlantic and progression the more frequent over Europe, but only slightly so. The almost complete absence of clear-cut blocking over the United States is noteworthy; large surface anticyclones with depressions trapped in lower latitudes do occur in that sector but the upper flow remains relatively undistorted and fails to show the characteristic blocking pattern in any degree.

12.5.2.4. *Duration and constitution of spells of blocking.* Figure 12.30 shows the distribution of durations of spells. The durations ranged from 5 to 54 days with a mode near the lower extremity but there was no really decisive decrease in frequency until after 22 days.

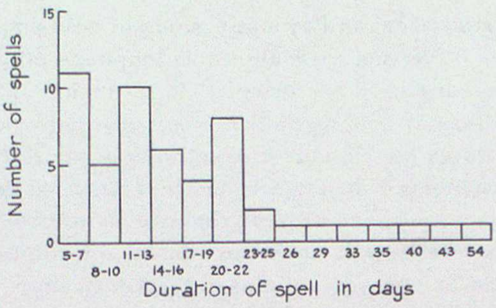


FIGURE 12.30 *Frequency distribution of durations of spells of blocking*

53 spells: 878 days of blocking
Average duration 16.5 days (4 years' data)

The individual data indicated that periods of progression, stagnation or retrogression were rather haphazardly distributed throughout the spells; 25 spells had all three ingredients, *P*, *Q* and *R*, and 21 had two ingredients, some of them more than once; the remaining seven were "pure" spells. The frequency distribution found by Sumner is given in Table 12.3. Periods of progression and stagnation

TABLE 12.3 *Frequency distribution of periods of progression (P), stagnation (Q) and retrogression (R), of various durations*

Type of movement	*Duration of period (days)* 1	2	3	4	5	6	7	8	9	10	*More than 10 days: length given*	*Total* *No. of periods*	*days*	*Average (days)*
P	4	13	17	10	5	12	6	2	1	1		71	296	4.2
Q	1	10	11	15	12	7	2	1	2	-	11,12,13,14,17,18,23	68	364	5.4
R	-	7	8	13	4	7	2	1	-	1	11,12,12	46	218	4.8
Totals	5	30	36	38	21	26	10	4	3	2	10	185	878	4.8

were about equally frequent and much more frequent than those of retrogression. However, on average, stagnation was more lasting than progression (5·4 days compared with 4·2 days) and, on the whole, blocking patterns were more frequently quasi-stationary than progressive. Retrogression, although its average duration (4·8 days) was greater than that for progression, was least frequent on the whole. There was a slight suggestion that retrogression and stagnation were more consistent with longevity than was progression during the four years examined.

The number of sub-periods of progression and retrogression which commenced each month and the corresponding monthly mean speeds are given in the table at the foot of Figure 12.27. The mean speeds showed little significant variation throughout the year from their annual mean of 6·0° and 7·0° longitude per day respectively. Individual values in both classes were fairly closely grouped within 2° to 3° of their appropriate means; the rare extremes were 2° and 20° longitude per day.

12.5.2.5. *Formation and dissipation of blocks.* Sumner included an interesting, informative but mainly narrative account of the formation and dissipation of blocks. No single synoptic evolution was always present and dominant in either the formative or dissipating stage of a block. Furthermore the statistical data seemed unlikely to be very useful to practising forecasters. For these reasons details are not included in this handbook.

12.5.3. *Cold pools*

Sumner[15] made a statistical and synoptic study of cold pools for the area southwards of latitude 80°N. and extending from longitude 60°W. eastwards to 30°E. during the five-year period September 1946 to August 1951. A cold pool may be defined as a mass of cold air in depth entirely surrounded by relatively warm air and it appears as one or more closed lines in the thickness isopleths for any fairly deep atmospheric layer. For his investigation Sumner regarded the area within the outermost of these closed isopleths as the cold pool. Only well defined and fairly persistent pools were considered, the minimum requirements being that there should be two or more closed thickness lines (drawn at intervals of 200 feet) surrounding the pool which should appear on at least two successive 0300 G.M.T. circumpolar upper air charts, the closed lines lying entirely within the area of the investigation. Exceptions were made in five cases in all when during a particular spell there was an interruption of one day during which the pool was represented by a single closed thickness line, thus allowing for a period of temporary waning. The centre of the pool was taken as the approximate centre of gravity of the area of the pool, its position estimated to the nearest degree of latitude and longitude and the 1,000–500-millibar thickness at the centre was estimated to the nearest 50 feet. The number of closed thickness lines associated with the pool were used to classify the intensities on the following arbitrary scale:

Intensity one – one closed thickness line
Intensity two – two closed thickness lines
Intensity three – three closed thickness lines
. . . and so on.

12.5.3.1. *General statistics.* Sumner[15] commented as follows:

"Within the 5-yr. period under consideration the total number of spells [with cold pools] was 75, ranging from 2 to 10 days' duration, the average being almost exactly 3 days. (A spell is said to be of *n* days' duration if the same cold pool, beginning and ending with intensity two or more but possibly with one-day interruptions of intensity one, appeared on *n* successive 0300 charts.) The total number of individual pools involved (i.e. occurrences on 0300 charts) was 224. There were 171 pools of intensity two, 41 of intensity three, 5 of intensity four and 2 of intensity five; all those of intensity greater than three were north of 65°N. There was no relationship between the initial intensity and the subsequent duration of a spell, although there was a small positive correlation between the duration and the average intensity within a spell.

"With respect to the geographical and seasonal distribution of cold pools the greatest concentration was over Europe in all seasons, but in spring and summer there were several other clusters, more notably over the Atlantic and in the area between north-east Greenland and north Scandinavia. There was an almost complete absence of pools of intensity two or more just west of the British Isles, around and to the east of Iceland, and over the western Atlantic south of 50°N. (summer and autumn only); though actually a very small number of pools of intensity two did occur in these areas but did not last beyond a day. . . .

"Most of the pools were fairly slow moving (usually less than 500 miles a day), and any rapid displacements were seldom continued beyond a day. In particular the pools in high latitudes showed no tendency to come southwards beyond 65°N.; these latter are presumably the cold "poles" of the northern hemisphere, and in what follows they were conveniently separated from the others and later left out of account.

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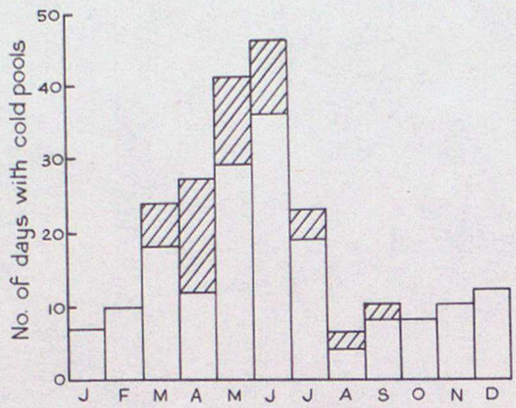
"Figure 12.31 shows the frequency distribution of pools by months (5 Januaries, 5 Februaries, etc.), pools north and south of 65°N. being distinguished. Table 12.4 gives the number of spells by months. It is evident that, within the area considered, these intense cold pools are largely spring and early summer phenomena, an outstanding maximum occurring in May and June.



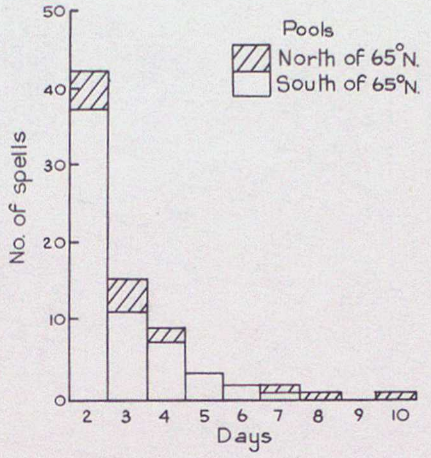


FIGURE 12.31 *Frequency distribution of intense cold pools* FIGURE 12.32 *Frequency distribution of spells with cold pools*

Five-year period September 1946 to August 1951

TABLE 12.4 *Number of spells*

	Jan.	*Feb.*	*Mar.*	*Apr.*	*May*	*June*	*July*	*Aug.*	*Sept.*	*Oct.*	*Nov.*	*Dec.*	*Total*
South of 65°N.	3	2	7	5	12	14	6	2	3	3	2	3	62
North of 65°N.	0	0	2	2	4	1	2	1	1	0	0	0	13

"The frequency of spells in days is given in Figure 12.32. A persistence of two days, the minimum required by our definition, is very much more likely than any longer spell. This applies to all seasons. The average spells north and south of 65°N. were 3·9 days and 2·8 days respectively. North of 65°N. there were 51 pools (13 spells) in all, the corresponding figures south of this parallel being 173 pools (62 spells)."

12.5.3.2. *Statistics for pools south of 65°N.* Partly because pools in high latitudes showed no tendency to move southwards beyond 65°N. and partly because pools north of 65°N. could not be studied in detail owing to insufficiency of observations, Sumner confined his more detailed statistics to pools south of 65°N. The following text in this subsection is based on Sumner's account:

(a) Mode of formation and disappearance

The greatest number of pools starting a spell – 49 out of 62 – were formed as a result of a partial or complete cutting-off of the cold air near the southernmost extremity of a cold trough. The cold trough was usually fairly slow-moving and of large amplitude at the time of cutting-off or was increasing in amplitude, the low-latitude part slowing down still further or stagnating while the high-latitude part moved on. A good example of this cut-off process is given in Figures 12.33, 12.34 and 12.35. In this example there was marked anticyclonic building across the middle of the trough (blocking) with a cyclone maintained to

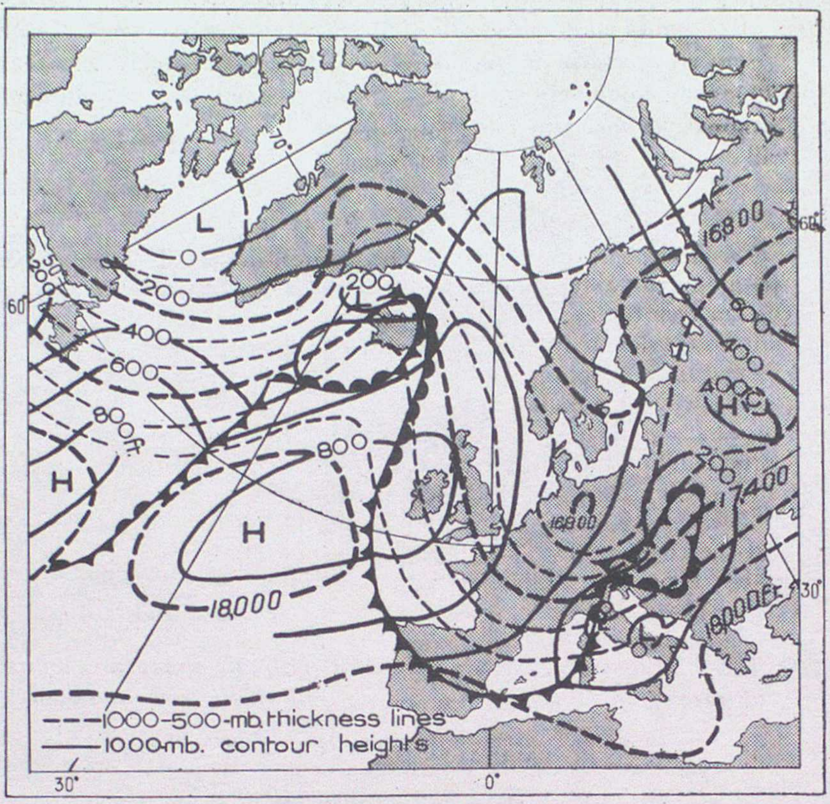


FIGURE 12.33 *1000-millibar contour pattern and 1000–500-millibar thickness lines, 0300 G.M.T., 19 March 1949*

the south in association with the developing pool. A certain amount of warm advection from the west round the top of the anticyclone completed the cutting-off. There are, however, many variants of this basic model mainly depending on the degree of development of these surface features.

The greatest number of pools (33 out of the 62) disappeared, or were reduced in intensity and therefore no longer considered, by warming more or less *in situ*. In nine further cases the pool moved so as to be absorbed into the colder air of higher latitudes, two were re-absorbed into the original cold trough by renewed advection from the north, and another two seemed to be re-absorbed in this way by local cooling to the north of the pool. The remaining 16 disappeared as a result of a combination of these factors, warming of the central core being one important agency in most of them. In all these classes about half the pools remained at intensity one for a further day or more before finally disappearing from the charts.

(b) Surface-pressure systems associated with cold pools

It is evident from experience that cold pools may be associated with practically any synoptically possible surface-pressure field. Sumner found it convenient to classify associated surface patterns in terms of a few well known types as follows: a low (L), a trough (T), a high (H), a ridge (R), a slack area or col (C),* and a fairly straight run of isobars more or less midway between a large high and a large low (S). Three of these types are usually called the cold

* In Sumner's investigation only one instance of a col was recorded, the rest were cases of a very weak and irregular pressure field.

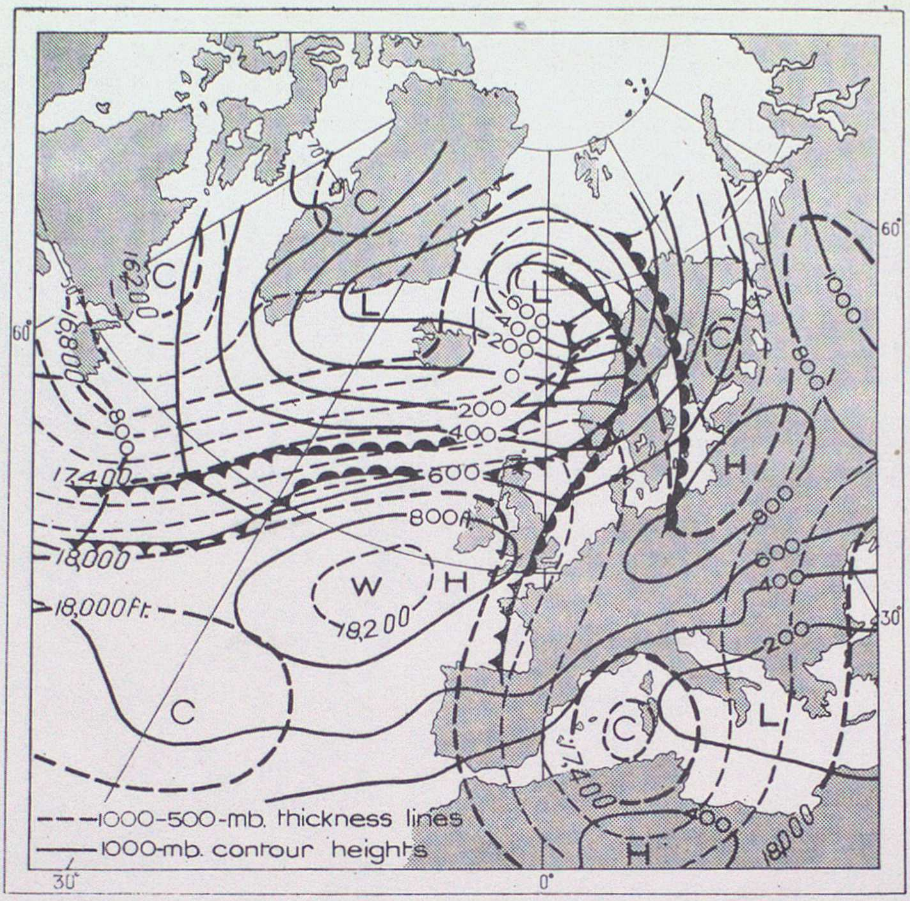


FIGURE 12.34 *1000-millibar contour pattern and 1000–500-millibar thickness lines, 1500 G.M.T., 20 March 1949*

low (L type), the cold high (H type) and the cold drop (S type) respectively, but the terms cold trough or cold ridge are not used in this context. The results of Sumner's classification on a seasonal and "land-sea" basis are shown in Table 12.5.

TABLE 12.5 *Classification of surface-pressure patterns associated with cold pools*

Associated surface-pressure system	*Winter Dec.-Feb.*		*Spring Mar.-May*		*Summer June-Aug.*		*Winter Sept.-Nov.*		*Year*		*Both*
	Land	*Sea*	*Land*	*Sea*	*Land*	*Sea*	*Land*	*Sea*	*Land*	*Sea*	
L	9	2	7	23	4	18	7	1	27	44	71
T	0	2	3	4	7	6	1	1	11	13	24
H	1	1	0	0	1	0	3	2	5	3	8
R	3	0	1	0	5	0	3	1	12	1	13
C	4	2	3	2	5	4	2	1	14	10	24
S	5	2	11	4	3	6	2	0	21	12	33
Total	22	9	25	33	25	34	18	6	90	83	173

By far the greatest number of cold pools were associated with surface lows at all seasons, the second greatest being cold drops. Associated troughs and slack areas were next in almost equal proportions, ridges and anticyclones being in a minority. Lows and troughs were relatively more frequent over the sea, and all other types (highs and ridges especially) over land. Except in the case of

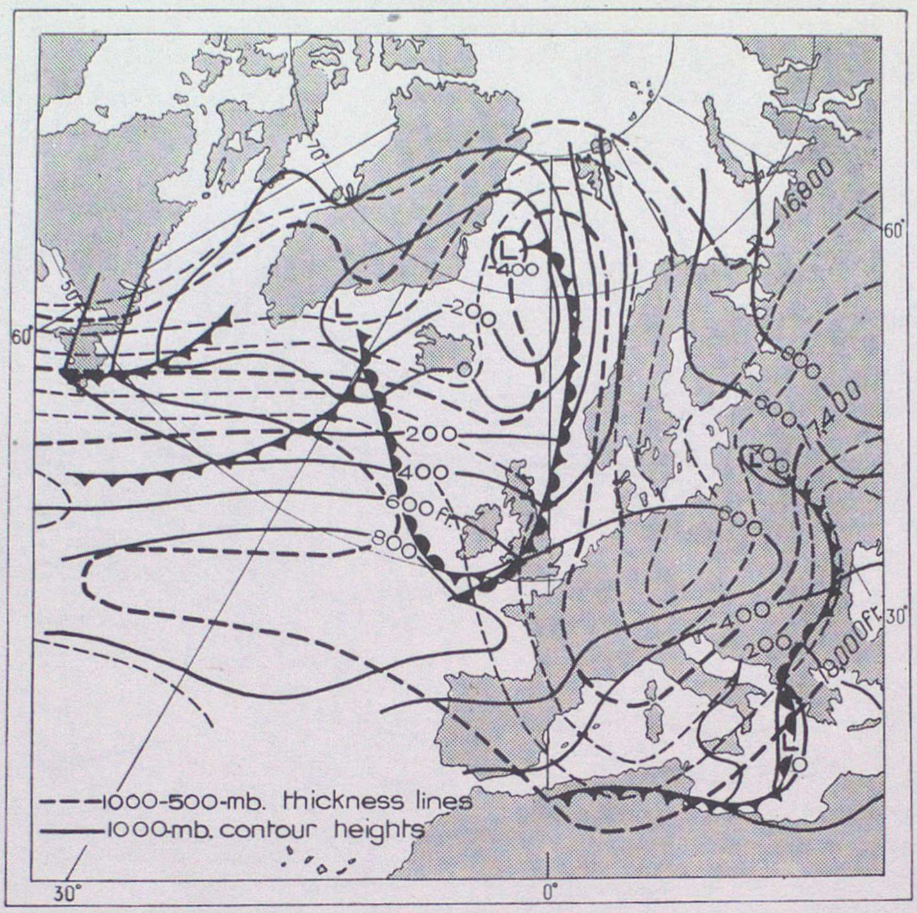


FIGURE 12.35 *1000-millibar contour pattern and 1000–500-millibar thickness lines, 0300 G.M.T., 22 March 1949*

highs and ridges, the seasonal distribution for each class was in keeping with Figure 12.31, that is with a maximum in spring and summer. In winter and autumn cold pools are more frequent over the land than over the sea, and vice versa in spring and summer.

Within about half the spells, there was no great change of surface type from beginning to end. The remaining half showed day-to-day type changes, usually within the combinations L-T-S and R-H-C, respectively. There was a definite tendency for the straight isobars of the S type to become more cyclonically curved with time, with a change to a T or even an L type; in fact, over the sea, there were no pure S types: all changed, mostly to L or T types.

Most of the associated lows were 300 miles or less from the cold pools, although few of them (especially over the land) were quite concentric with the pool. The average distance between the centre of the pool and that of the surface low was about 300 miles over the land and 220 miles over the sea. All lows more than 300 miles away were situated in the sector between south-east and north-east from the associated pools; the remainder were randomly distributed in direction with respect to the centre of the pool. The corresponding averages for the few cold anticyclones were 340 miles over the land and 700 miles over the sea.

Cyclonic circulations tended to be more intense and relatively more frequent over the sea. A few cases were recorded where a cold pool, associated with more or less straight surface isobars or with a weak surface low, moved from the land to the relatively warm sea in winter. In each case there was a noticeable increase in the associated cyclonic circulation at the surface (with the formation of a low if one were not present originally), although with a pressure drop of only a few millibars in the general level of pressure.

Surface-pressure changes at the centres of the pools were usually small; the overwhelming majority were less than 10 millibars (rise or fall) a day, the average, irrespective of sign, being 4·5 millibars per day (5·5 millibars per day over the sea and 3·5 millibars per day over the land). The greatest pressure rise found was 16 millibars in 24 hours (with an associated surface low) and the greatest fall was 23 millibars (cold-drop type); both were over the sea.

The pressure changes at the centre of an associated low or high were even smaller, most of them being less than or equal to 5 millibars per day. The greatest 24-hour rise was 11 millibars (over the land) and the greatest fall 9 millibars (over the sea); both were in a low. The average changes irrespective of sign were 4·5 millibars per day, whether over land or sea.

12.5.4. *Some publications on climatology and weather near the British Isles*

It is appropriate that mention should be made of some of the literature on the climate and weather near the British Isles. References to the climatological publications which are openly available will be found in the current number of *Government Publications.*[16] There is a large amount of climatological literature which is on a more restricted distribution and/or availability. Forecasters engaged on day-to-day duties will find that a general knowledge of the contents of some of the following publications is of considerable value in their routine work:

Climatological atlas of the British Isles[17]
The series of *Avaiation meteorological reports*[18]
Weather in home waters and the North Eastern Atlantic.[19]

Forecasters who have need or wish to obtain more detailed climatological information should consult the list of publications available in the outstation library. If the required information is not available, reference should be made through the proper channels to higher authority.

12.5.5. *Extreme mean-sea-level pressures in the British Isles*

Ready reference to extreme mean-sea-level pressures is sometimes useful in day-to-day work and Tables 12.6 and 12.7 contain some data, by months, for the British Isles and for Kew Observatory respectively.

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TABLE 12.6 *Highest and lowest recorded mean-sea-level pressure in the British Isles (to end of 1959)*

	Highest recorded			*Lowest recorded*		
	Pressure	*Date*	*Place*	*Pressure*	*Date*	*Place*
	mb.			*mb.*		
January	1054.7	31st, 1902	Aberdeen	925.5	26th, 1884	Ochtertyre
February	1051.1	1st, 1902	Nairn Aberdeen Sumburgh Head	942.3	4th, 1951	Cork
March	1045.7	6th, 1874	Glasgow, Leith Ardrossan Greencastle	948.4	15th, 1818	Gordon Castle
April	1044.5	4th, 1938	Eskdalemuir	953.1	1st, 1948	Benbecula
May	1042.0	15th, 1943	Dublin	968.0	8th, 1943	Sealand
June	1042.9	13th, 1959	Clones	976.8	5th, 1944	Wick
July	1037.9	1st, 1933	Malin Head	976.0	6th, 1922	Tynemouth
August	1035.2	21st, 1874	York	967.0	23rd, 1957	Cape Wrath
September	1038.6	27th, 1906	Oxford, Kew	957.0	21st, 1953	Claremorris
October	1045.6	31st, 1956	Dyce	946.8	14th, 1891	Cawdor Castle
November	1044.0	1st, 1956	Benbecula	939.7	11th, 1877	Monarch Lt. Ho.
December	1050.3	24th, 1926	Aberdeen	927.2	8th, 1886	Belfast

TABLE 12.7 *Mean pressure at mean sea level, 0-24h., 1871–1915 and extremes recorded during 1869–1959 at Kew Observatory*

Month	*Maximum*	*Date*	*Minimum*	*Date*	*Mean*
	mb.		*mb.*		*mb.*
January	1049.2	1882	960.5	1872	1016.04
February	1048.7	15th, 1934	961.2	4th, 1951	1014.40
March	1044.6	10th, 1953	964.5	1876	1012.49
April	1042.6	11th, 1938	976.1	1919	1012.67
May	1041.6	16th, 1943	984.0	16th, 1958	1014.68
June	1038.4	14th, 1959	988.0	2nd, 1946	1015.03
July	1035.4	1911	981.7	29th, 1956	1014.33
August	1033.6	1874	972.1	1917	1013.84
September	1038.6	27th, 1906 1958	973.8	1896	1015.56
October	1040.6	6th, 1877 1891	967.9	27th, 1959	1012.53
November	1043.7	16th, 1922	964.4	20th, 1926	1012.92
December	1046.9	1905	959.4	1886	1012.62
Year	1049.2	10h. 18 Jan. 1882	959.4	05h. 9 Dec. 1886	1013.93

12.6. WEATHER TYPES AFFECTING AREAS NEAR THE BRITISH ISLES

12.6.1. *Classification and statistics*

Several attempts have been made to classify British weather according to types; the classifications varying in character from the simple, with but a few types, to the complex, with a multiplicity of sub-types. The published work relates mainly to surface weather maps and so far no systematic attempt to incorporate upper air conditions into all classifications has appeared. Since upper air data from a useful number of stations around north-west Europe have been available for a number of years it may be that a further investigation of the classification of weather which incorporates some upper air configurations might prove very useful to practical forecasters.

For the compilation of the first version of this chapter it has been necessary to use results which are currently available and some choice had to be made from the various classifications which have been published. It was felt that the balance of advantage lay with the simple classification of only six types over a long period by Levick[20] rather than with a more sophisticated classification over shorter periods (for example, Gold,[21] Newnham[22] or Jones[23]) or with the more complex classification of Atlantic-European weather types for the period 1899–1945 contained in *Air Weather Service Technical Report* 105–37.[24] In addition to the description of the classifications this latter report contains some statistics on frequency and duration of types and also a catalogue of the weather types for each day of each year from 1899 to 1939. It is rather too complex for general day-to-day use and is not included in the handbook but it contains much information which could be of value for investigations of weather types and their subsequent development into other types in the eastern Atlantic and Europe.

Levick[20] describes the six main types in his classification as follows:

1. Westerly type. Associated with the absence of anticyclones of any permanence near Britain, when a sequence of troughs, depressions and ridges moves from west to east across the country. Unsettled, with winds shifting rapidly between south and north-west, and occasionally east for a short time. Cool in summer; mild in winter, with frequent gales.
2. Anticyclonic type. Associated with an anticyclone centred over or near Britain, or with a col between two anticyclones. Mainly dry with light winds. Warm in summer; misty in autumn; very cold in winter.
3. Easterly type. Associated with an anticyclone over Scandinavia or high pressure from Scandinavia to Iceland, and with a persistent low-pressure area to the south-west or south of Britain. Depressions, often intense in winter, frequently move south-eastward from mid-Atlantic to the Bay of Biscay. Intensely cold from December to March with frequent snow. Warm and thundery from June to August.
4. Northerly cyclonic type. Associated with an anticyclone to the west and north-west, producing a flow of polar air over the country. Depressions, often intense, move slowly southwards over Scotland and England or the western European seaboard, or alternatively take the form of large stationary complex areas of low pressure while a belt of high pressure extends from the Greenland-Iceland area to the Azores. Cold and unsettled at all times of the year, with snow or sleet in winter.
5. North-westerly type. Occurs when the Azores anticyclone moves somewhat north and east, with its centre between the Azores and Britain. Similar to the westerly type with its unsettled weather and changeable temperature, but colder on the whole, since the air of the warm sectors comes from higher latitudes.
6. Southerly type. Associated with an anticyclone over central Europe which prevents Atlantic depressions from moving eastward and tends to make them circulate in mid-Atlantic. Warm and thundery in summer; very mild in winter with light to moderate rainfall and often strong winds from between south and south-west.

The average frequency and monthly variation of frequency of the six types of weather over England, as determined by Levick for the years 1898–1947, are shown in Figure 12.36.

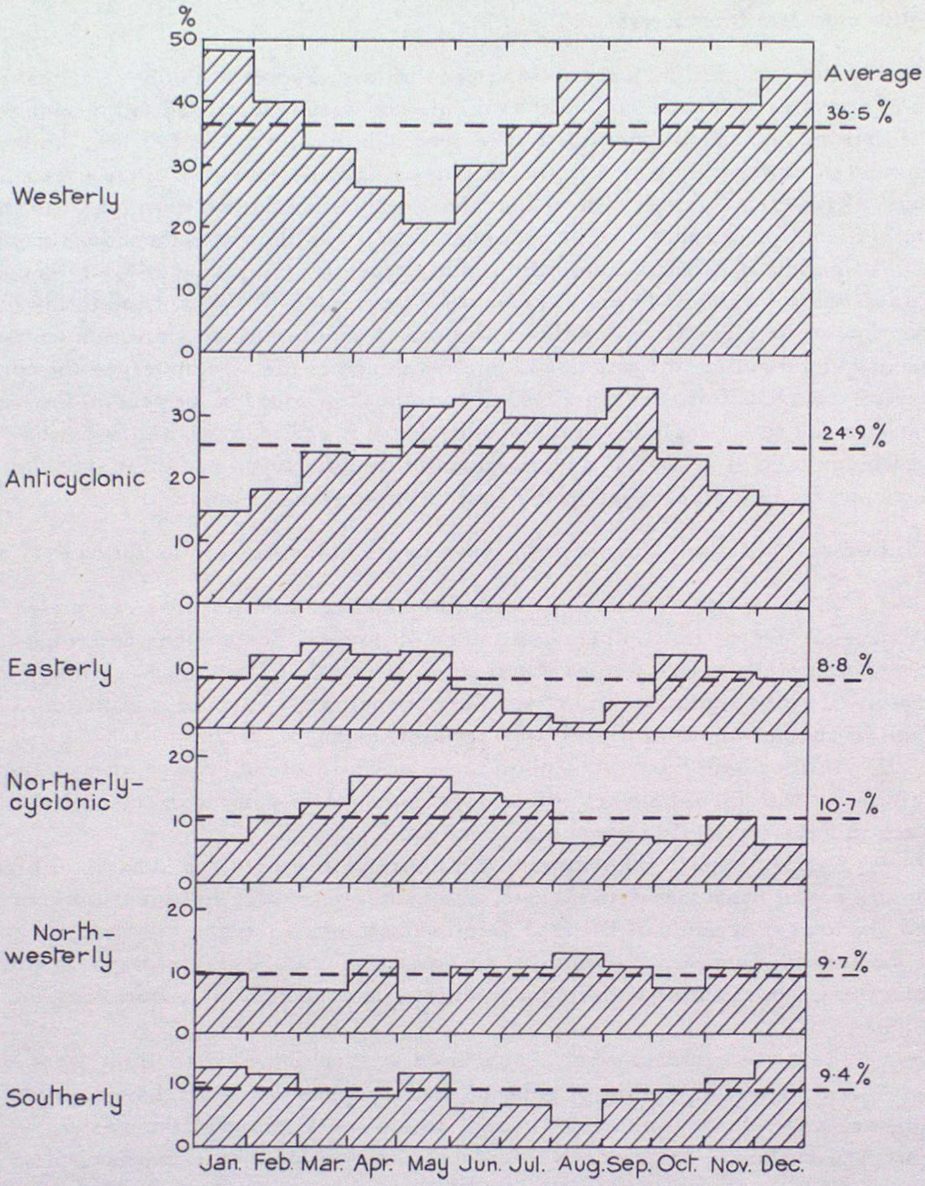

FIGURE 12.36 *Monthly frequency of weather types over England (1898–1947)*

The main features illustrated by Figure 12.36 are as follows:

(i) The westerly type has a pronounced maximum in January and a minimum in May; it is relatively frequent in July and August.

(ii) The anticyclonic type has a summer maximum and a winter minimum.

(iii) The easterly type is infrequent from June to September.

(iv) The northerly type has a well defined spring maximum.

It should be stressed that Levick's[20] account was restricted to the weather over England. At times the type of weather over Scotland and Ireland may be of similar type but at others it may be of different type, particularly when England is under the influence of almost the fringe of a weather type whose main centre of action lies some distance away from England and is still more remote from Scotland and Ireland. This sort of difficulty is, of course, a great handicap in any attempt to describe typical weather associated with the various types. Apart from the purely orographic effects the spatial location of the area with respect to the type is very important. An example will readily illustrate the point. Consider the northerly cyclonic type with an anticyclone to west or north-west and cyclonic disturbances moving generally south near the country. Rather nearer the track of the disturbances (often eastern districts) weather will be typically cold and unsettled with frequent precipitation, either continuous or showery, much cloud and perhaps cold and strong onshore winds. Rather nearer the anticyclone (western districts) the direct effects of cyclonic disturbances are often very feeble, associated fronts may not reach those areas and a combination of subsidence and favourable land track may reduce showers to almost negligible amounts. There may also be only very small amounts of cloud. The weather experienced in the west is then very different from that in the east although both occur in the same synoptic type. There are often also marked differences in weather associated with synoptic types in different seasons.

The following subsections contain descriptive accounts of some of the characteristics of the main weather types. These follow very closely the classification of Levick but some subdivision of the westerly and anticyclonic types seemed desirable and one additional type (the cyclonic type) has been introduced.

12.6.2. *Westerly and south-westerly types*

12.6.2.1. *Westerly type.* With this type, pressure is usually high to the south and low to the north of the latitude of the British Isles. In the pure westerly type there is often a vigorous flow across the North Atlantic Ocean, particularly at mid and upper tropospheric levels, with a marked broad baroclinic zone extending from near the Canadian Maritime Provinces towards the British Isles. Disturbances forming in this flow travel quickly eastward. In many cases the probable track of the disturbance is relatively easy to estimate, particularly if the disturbance is not expected to develop and become a major synoptic feature. Nevertheless the speed of movement may be difficult to estimate accurately particularly when the disturbance is over the ocean where the observational network may be sparse so that there is some uncertainty of the positions on the analysed charts. Fast-moving depressions are usually over the ocean when forecasts for 12 or 24 hours have to be made and the problem is therefore a very practical one.

Pure westerly flow does not generally persist for many days before some major synoptic system emerges. It seems as if the flow is particularly liable to instability. Accordingly it usually happens that one out of the number of minor disturbances which usually appear in westerly types develops and grows into a major feature of the charts. With this development there is an associated distortion of the westerly or zonal flow throughout much of the troposphere into a marked meridional pattern. The depression frequently slows down and changes its direction of movement when these changes take place and there is then generally a change of type over the British Isles.

In westerly types weather is typically unsettled and changeable. On the whole more precipitation falls in the north and west than in the south and east. In winter the weather is usually mild. In summer, however, westerly types usually bring cool weather. Winds usually change direction fairly frequently as the synoptic patterns move across the area. In winter when deep depressions form there are frequent gales. Sometimes a depression which appears relatively shallow when well out in the Atlantic may suddenly deepen at a rapid rate and continue to do so – perhaps for 12 to 24 hours leading to an intense and extensive depression with very strong pressure gradients. Gales are then usually widespread and often severe. Sometimes the deepening occurs when the depression moves through a thickness pattern favourable for development so that the deepening may be foreseen and allowed for at least qualitatively. On some occasions, however, the deepening seems to take place almost with explosive violence and does not seem to have been associated with any well marked configuration of the thickness pattern or a thickness pattern of sufficient magnitude to indicate that marked deepening ought to be expected by the forecaster.

Visibilities are usually good or very good except in precipitation. The vigour and mobility of the synoptic systems generally disperse effectively any atmospheric pollution. Any radiation fog, which may occur occasionally in areas largely free from cloud and with light winds, is usually short-lived as a further disturbance moves towards the area bringing increased cloud cover and increased surface winds.

12.6.2.2. *South-westerly type.* When the large, semi-permanent Azores anticyclone extends as a ridge to north-western Europe and pressure is low to northwest and north of the British Isles then a south-westerly type exists. The associated baroclinic belt extends approximately from south-west to north-east and depressions move north-east. In such situations precipitation is often confined to north-western districts. The south-eastern edge of the precipitation belt depends in a general way on the location of the main baroclinic and frontal belt, but that edge of the precipitation area is often difficult to forecast accurately. If south-western districts are fairly near the ridge-line the weather there is often predominantly dry (except, perhaps, for extreme windward coastal districts) and inland areas may have only small amounts of low cloud, particularly by day. In such a situation south-eastern districts would be even drier and more cloud-free. This is particularly noticeable when there is an anticyclonic cell centred in north-eastern France, the Low Countries or western Germany. Although the European anticyclone is generally small compared with the usually more extensive Azores anticyclone, it nevertheless often feeds relatively dry continental subsided air to south-eastern districts so that the weather is dry and sunny. In late spring and summer such situations can usually be relied on to produce temperatures which are relatively high for the time of the year.

If, however, the main axis of the Azores high and the north-eastward extending ridge is located well to the south-east of Britain – say from south of the Azores across Spain to southern France – then air reaches south-western districts after a long over-water fetch, sometimes as an almost straight current extending from the Azores or beyond. There are then large amounts of extensive low cloud perhaps with some non-frontal, but sometimes rather persistent, coastal precipitation. When the south-westerly airstream is both warm and moist and the underlying water surface cold (for example, particularly late winter to spring or early summer) low cloud bases may be very low and cover even quite low hills both on coasts and for some tens of miles inland. Genuine sea and coastal fogs may also occur and be advected a little way inland particularly by night, but day-time insolation, especially in late spring and summer, will often clear the fog almost to windward coasts. South-eastern districts often have relatively large amounts of low cloud but the bases, particularly by day, are usually higher than in the south-west.

On some occasions with south-westerly types the baroclinic or frontal zones become stationary for periods of perhaps a few days with but minor lateral movements as shallow waves or disturbances move generally north-east with but little development. In such circumstances the weather may be of a quasi-steady but quite different nature over different parts of the British Isles. Near the frontal zones there is usually frequent and persistent precipitation with extensive clouds. The surface winds are then often steady in direction and moderate in speed, but at times they may be quite light.

In winter the weather is usually mild, sometimes even very mild. In summer the south-westerly type generally brings rather cool weather. However, in all seasons of the year, if there should be little cloud inland and a layer of strongly subsided air below about 4,000 feet, insolation will usually produce a warm or very warm day. Windward coastal districts would, however, be fairly cool in late spring and summer.

Visibilities in south-westerly types are not usually so good as in westerly types but they are seldom below about four miles. Exceptions to this are likely to occur when warm moist air moves fairly slowly across a much colder ground. In extreme cases, extensive fog will occur (for example, when a very mild south-westerly follows a cold spell and the ground is snow-covered). Occasionally in a ridge, a thick and vertically extensive radiation fog may occur in winter in the air of south-westerly origin. Day-time winter insolation may be too weak to clear the fog but at other seasons of the year day-time insolation is usually sufficient to clear similar fogs during the morning. Notably in late spring and early summer extensive and prolonged sea and coastal fogs sometimes occur.

12.6.3. *Anticyclonic type*

It is important to distinguish between the slow-moving (or stationary) anticyclone, often existing as a feature of the synoptic charts for several days, and the mobile baroclinic anticyclone (or wedge) often occurring as a distinct feature of the chart for a day or two and located between two, often moving, depressions.

12.6.3.1. *Mobile anticyclone.* The mobile baroclinic anticyclone (or wedge) usually brings a brief dry interval between two periods of cyclonic weather. The weather clears behind the cold front and advection of cold air often brings very good, sometimes exceptional, visibilities. There is normally a pronounced thickness pattern associated with the baroclinic high and the region in which cold air is sufficiently deep for the formation of showers is often very clearly defined by the thickness patterns. As the high recedes and a fresh disturbance approaches, warm air replaces cold air aloft and the rear part of the receding anticyclone is often invaded by extensive sheets of cirrus or medium clouds. The cirrus clouds may, on occasions, extend to and sometimes beyond the ridge-line of the surface anticyclone. Near the centres of baroclinic highs, winds are often light and over areas somewhat forward of the ridge-line skies at night may be cloudless and radiation fogs may form. Continued movement of the high will usually bring some increase of wind which itself might clear or lift the fog but there is often also the increase of cloud which at times may clear a pre-existing fog or come sufficiently quickly to prevent the formation of radiation fog. (Some rather more detailed comment on the effect of advection of cloud cover above a pre-existing fog is contained in Chapter 17, Section 17.7.8.) Periods of fog associated with baroclinic highs are usually fairly short-lived since the synoptic situation is usually mobile and a further disturbance often brings a return to cyclonic weather. At times, however, the synoptic pattern may develop in such a manner that the baroclinic high slows down as the thermal pattern becomes distorted and the high gradually transforms into a slow-moving high. If such a synoptic evolution seems at all possible, forecasters should watch the situation particularly closely so that the changes may be reliably inferred at the earliest possible time.

12.6.3.2. *Slow-moving anticyclone.* The slow-moving anticyclone usually produces quiet settled weather which may be either cloudless or completely overcast. When the latter occurs there is generally a sheet of high stratocumulus cloud. Precipitation amounts are usually negligible except near windward coasts when the lowest few thousand feet of the atmosphere is unstable to sea temperature. Convection from the sea will then usually maintain a fairly deep layer of cloud and periods of precipitation may occur near windward coasts. (On cloudless nights there may also be heavy deposits of dew when temperatures and humidities are suitable.) The problem of forecasting whether there will be low cloud or not is often a very difficult one as the cloud system seems to be in a very delicate balance (see Chapter 16, Section 16.6.3 for further consideration). Visibilities are seldom very good. In winter if the anticyclone persists and the air becomes stagnant with a very strong inversion in the lowest 1,000 feet or so, accumulation of atmospheric poolution may lead to visibilities being below 1,000 yards over quite extensive areas even though a water fog does not form. Pollution is generally greater nearer the sources so that a knowledge of the local sources and accurate forecasts of the low-level wind drift are often vital to detailed and precise short-range local forecasting. Typical radiation fogs also are likely to occur in these anticyclones.

Temperatures vary considerably with the season. When cloudless conditions in association with light surface winds prevail there is usually a very marked diurnal variation of temperature at all seasons.

In regard to synoptic developments there is seldom any danger of sudden unexpected synoptic changes well within the system – the extensive nature of the static anticyclone and its associated thickness pattern normally prevent this. Indeed it has been somewhat waggishly remarked that one need only make two mistakes when forecasting anticyclones, namely, when they form and when they disperse. This is far too cynical a view. Occasionally anticyclones do form with but little warning (for example, when a surge of pressure sets in and continues), but generally the building process takes a day or two to evolve. Likewise the decline of large anticyclones is heralded by falling pressures for a day or two, sometimes associated with advancing depressions. However, there are sometimes a number of false alarms when, after a period of decline (perhaps lasting one or two days) and the passage of a nearby depression, there sets in a further period of intensification leading to the re-establishment of the high. (This feature has been discussed in earlier chapters.) The achievement of satisfactory, accurate forecast charts in such situations demands very careful analysis and a very finely balanced judgement. When the breakdown of an anticyclone is likely to lead to a respite from a cold or foggy spell, a thaw after snow or the end of a fine hot spell, success or failure to achieve a correct forecast can have a great impact on the minds of persons using the forecasts and consequently on the general reputation of the Meteorological Office.

12.6.4. *Easterly type*

This type is associated with anticyclones over Scandinavia or extending over Scandinavia and towards Iceland. Depressions are usually persistent in an area to the south-west or south of the British Isles and there are often depressions in in the western North Atlantic Ocean also. Easterly spells may be very persistent.

From late autumn through winter to early spring the easterly type usually brings cold weather. It is sometimes intensely cold in southern districts and suitably exposed localities elsewhere in late winter or even early spring, especially when the easterly flow comes from the heart of eastern Europe across the north European plains, which, towards the end of a severe winter, are frozen hard almost up to the coastline of the North Sea. Whether the easterly airstream arrives as an almost cloudless or almost overcast airstream depends on its characteristics on leaving the European mainland and the modifications undergone on its passage across the North Sea (see Chapters 14, 15 and 16).

In the majority of easterly situations there is a subsidence inversion in the lower troposphere and the weather is predominantly dry. Occasionally, however, in the winter half of the year, the lowest few thousand feet of an easterly airstream are unstable to North Sea temperatures. Showers then occur and, when the 0°C. isotherm is very low, the showers may be in the form of snow or sleet. Showers are more frequent and numerous in coastal regions and on nearby hills. With an easterly flow, eastern and north-eastern districts suffer most while south-eastern counties (as far north as about Suffolk) may often escape instability precipitation because of the short sea track. (With a more north-easterly flow, however, instability precipitation may affect south-eastern districts more severely than those further north.) Areas well to the west and north-west usually escape any instability snow showers bred by convection over the North Sea and areas only 50 miles or so inland escape except perhaps for an occasional slight fall. (For a more complete discussion see Chapter 16.)

When the snowfall is due to a small secondary or trough which moves westwards across the country then areas well inland and in the west do not wholly escape although falls may be rather lighter than in the east. In easterly situations forecasters should look very carefully at the synoptic charts over the German plains and the Low Countries for signs of fronts, troughs or secondaries. The snowfall associated with westward-moving upper troughs or cold pools often seems to be heavier and more continuous and widespread in Britain than it was on the continent. It would be wise to allow for some intensification when a disturbance reaches Britain after leaving the German plains and crossing the North Sea in winter.

In summer, easterly situations generally bring very warm or very hot weather particularly when the flow is from south of east. Such air often shows marked subsidence and dryness in the lower layers and, in such cases, screen temperatures usually reach high levels. Thunderstorms sometimes break out in such a hot spell but they tend to be associated with a rather more southerly current, particularly at levels between about 750 and 500 millibars. In many cases in summer the easterlies produce very dry weather in western districts and dry weather in most others except for a few coastal areas. If a thundery outbreak occurs it tends to do so when the easterly spell is breaking down.

When the low-level flow is easterly or rather more north-easterly, extensive stratus cloud in the low-level inversion sometimes occurs in eastern districts, particularly during late spring or summer. The formation of the cloud is nearly always due mainly to the modification to the temperature and humidity structure of the lower layers of the atmosphere during its passage across the North Sea. Over eastern coastal districts and the neighbouring North Sea the cloud layer may persist by night and by day. Well inland the cloud is usually dispersed by insolation during the morning but it often reforms at night. Western districts of the British Isles often remain virtually clear of low cloud. In the North Sea and eastern districts of England and Scotland the base of the cloud extends on some occasions to the surface and fog then occurs. (These conditions are sometimes termed a haar.) At sea and sometimes also along a very narrow coastal strip the fog may persist by day as well as by night.

Visibilities are normally fairly good in easterlies except in precipitation or sea and coastal fog. At times with a low inversion and light winds, much atmospheric pollution may seriously restrict visibilities to the lee of towns and industrial areas. Sometimes air reaching the extreme south-east seems heavily laden with pollution acquired during passage across industrial areas of western Germany, the Low Countries, or north-east France.

12.6.5. *Northerly type*

In this type, pressure is high to the west and north-west of the British Isles, particularly over Greenland. Sometimes there is a continuous belt of high pressure extending southwards from a Greenland anticyclone towards the Azores. To the east of the British Isles pressure is usually low over the North Sea, Scandinavia and the Baltic. Depressions move generally south or south-eastwards from the Norwegian Sea, sometimes fairly slowly. These depressions reach the Norwegian Sea from several areas:

(i) Sometimes from areas to the farther north.

(ii) Sometimes from the Iceland – Jan Mayen region where they may have formed or into which depressions may have moved from farther west by way of a col near south Greenland.

Northerly outbreaks bring cold and disturbed weather at all seasons of the year – especially in eastern and northern districts. In winter precipitation is commonly in the form of snow or sleet particularly on the higher hills but also on quite low hills near windward coastal areas. For a few hours after the onset of a northerly outbreak winds are often strong. These strong winds will lead to considerable drifting of any snow which may fall shortly after the onset. Later on winds tend to moderate but they may well be 15 to 20 knots near the surface for one or two days after onset, so that drifting of any snow from showers which sometimes continue to be frequent may build up to serious proportions.

Northerly outbreaks show a maximum mean frequency in April and May when they may cause late snowfalls on higher ground – especially in the north. A clearing of skies inland at night usually leads to low night minimum temperatures and there tend to be late spring frosts which may cause much damage horticulturally. If the winds should also be very light or calm the late frosts can sometimes be very destructive. In some years an outbreak of northerly weather in autumn may bring early frosts and snow on higher ground.

With northerly outbreaks the Scottish mountains produce a "shadow" in the lee, a shadow often virtually free from showers. The northerly outbreaks often have a low total water content so that, once the air has reached land and produced precipitation, areas further inland may remain dry. With northerly winds this shadow can extend for quite long distances downwind. On a broad scale the eastern and western coastlines of the British Isles extend in a general north-south direction so that northerly winds are more or less parallel to long stretches of eastern and western coasts. Thus quite small changes in wind direction may be accompanied in some areas by quite large changes in the weather associated with northerly outbreaks. For example, if the winds sweep down across Scotland and northern England as a north-north-westerly current, quite substantial areas in eastern Scotland south of the Highlands and also eastern England will often have mainly dry weather. If, however, the winds are somewhat farther round to, say, north-north-easterly between Scotland to Norway, and northerly farther south in the North Sea then scarcely any area in eastern Scotland and England will escape extensive cloud amounts and frequent showers. In these situations it is thus important to pay especial attention to the accurate forecasting of wind direction.

The high relative humidity of the air reaching windward coasts after an extensive sea track coupled with large amounts of cloud gives the air a characteristic "raw" feeling. The weather well inland and in the south-west may, however, be sunny and invigorating but still rather cold.

In northerly types it is important that forecasters, as well as looking upwind for signs of new secondaries and westward for signs of a decay in the high-pressure system to the west, should also inspect the charts very carefully to the east, say over the North Sea, Scandinavia and north-western continental Europe. Sometimes quite complex depressions exist and are subject to complex changes from day to day. For example, a complex depression consisting of a primary and one or more secondary depressions may be slowly rotating in a cyclonic sense and one feature of the complex may move with a westward component from the European coast and approach the British Isles from the North Sea. Such features will usually bring a return of wet cloudy weather to eastern districts. The timing of this return is often difficult due in part to the paucity of observations from the North Sea.

12.6.6. *North-westerly type*

In this type the Azores anticyclone is displaced either north-eastward towards the British Isles or northward over the Atlantic to westward of the British Isles or there are extensions in those directions. Depressions travel south-eastward or south-south-eastward, often along a track through the North Sea towards Scandinavia and the Baltic over which areas they tend to reach their greatest intensity. Many of these depressions often form near Iceland. Since observations at sea in these areas are often sparse the presence of a small depression in its formative stage may remain unnoticed for some hours and, even when the presence of such a feature is suspected or even confirmed generally by perhaps one or two observations, it may well be difficult to reach any firm conclusions within fine limits about the depth, location and intensity of the system. If coarse deductions only can be drawn it then follows that forecasts must be necessarily rather loosely drawn.

The weather is typically unsettled and usually changeable particularly in the north and east. In southern and western districts well away from the track of the disturbances weather may be much more settled and also warmer. In the north and east the weather is rather cool – cooler than for westerly types but not so cold as with the northerly type when the air usually arrives quickly from Arctic regions directly to northward.

When the north-westerly consists of deep cold air unstable to great heights then vigorous convection maintained by the sea can produce massive showers causing substantial amounts of precipitation in coastal regions and on hills. Maritime thunderstorms are also fairly common in the winter half of the year. Lamb[25] has remarked that the warm sectors of disturbances in a north-westerly type may contain unstable air in late winter and spring. In winter, precipitation on hills may fall as snow.

Winds are generally between about west and north-west but may vary outside these limits, more particularly in association with the travelling disturbances. Speeds vary within wide limits but are sometimes fresh. Gales sometimes occur, generally from a direction between west and north.

Visibilities are generally good except in precipitation and in polluted areas downwind of industrial regions, particularly with light winds in the southern half of the country when an inversion at lower levels restricts convection and so prevents pollution from being dispersed vertically.

12.6.7. *Southerly type*

In this type, high pressure covers central and northern Europe. Atlantic depressions are blocked off western coasts of the British Isles and are usually either slow-moving or travelling north or north-east to pass well to westward of the British Isles and to northward of the block.

In winter, southerly streams are mild or cold according as the air mass reaching the British Isles is of maritime or continental origin prior to its immediately recent passage across western Europe. In spring and summer the weather is often warm or very warm and tends to be thundery. The thunder may occur when a southerly or south-south-westerly airstream is subject to strong heating over land for a long enough period (see Chapter 11, Section 11.1), that is as air-mass thunder. It may also break out in association with the eastward approach of a cold front, often orientated broadly north–south, that is with the approaching end of the southerly weather. The thunder often breaks out ahead of the cold front proper but on some occasions may not occur except at the cold front. These types of thunderstorms are more fully discussed in Chapters 11 and 16.

Visibilities are normally moderate. If the humidity of the southerly airstream is high, radiation fog may occur if skies are cloudless at night but the ensuing insolation on the following day normally disperses the fog. In summer any such fogs are confined to a few hours around dawn and usually soon disperse. However, sometimes they lift to form a low stratus which may cause bad flying weather to persist well into the forenoon.

12.6.8. *Cyclonic type*

This type was described by Lamb[25] as depressions stagnating over or frequently passing across the British Isles (see Section 12.7.2). To some extent therefore it may be associated with some of the types previously described. However, because of the proximity of the depressions the weather is usually mainly wet and disturbed. In the autumn and early winter the weather is usually mild but in spring and summer the cyclonic type often brings cool or cold weather. A cyclonic type with much cloud and frequent showers often produces a day which is least summery in character – particularly if the winds are strong. Even in late winter a cyclonic type may at times bring quite cold weather. Areas to the left of the track of the depression sometimes remain in cold air and, in winter, precipitation in those areas may fall almost wholly as snow. Such situations can lead to heavy snowfalls. (This topic is mentioned in Chapter 11, Section 11.3 and a synoptic example is included in Chapter 16, Section 16.9.4.3.) Precipitation is usually widespread and general, irrespective of orography but orographic effects do cause variations in the amounts of precipitation at times (see Chapter 16, Sections 16.8 and 16.9.6).

Wind directions and strengths are variable. There is usually much cloud and it is not profitable to attempt descriptions of any particular distribution, since distributions are greatly dependent on the location and intensity of the system. Apart from areas of precipitation, visibilities are seldom poor.

Statistical and Climatological Data

12.7. SINGULARITIES OF EUROPEAN WEATHER

A singularity may be regarded as a well marked episode of weather (sometimes involving a temporary reversal of the seasonal trend or an enhancement of that trend) having a relatively short duration and recurring more or less regularly from year to year. A deep study of singularities is not appropriate to this handbook. They do not recur with clockwork precision nor are they even sufficiently regular to be of direct use in forecasting. It is difficult to be certain that a singularity which appears in the meteorological records for a period of several decades is not a statistical accident and a good deal of controversy exists regarding the reality of the singularities which have been proposed and whether they can be expected to recur in future periods. Nevertheless a knowledge of the singularities which have been proposed by various investigators is often valuable background when assessing analysed charts and is certainly a useful pointer to bear in mind when considering the rather longer-term possible developments of the current synoptic situation. It is for these latter reasons that the following condensed account is included in the handbook. It cannot be over-emphasized that singularities should not be directly used in day-to-day forecasting unless the current charts and developments justify, on their own merits, a forecast of the occurrence of a type of weather coinciding with a particular singularity.

The following treatment is based on the published accounts of two workers in the British Isles. They are to some extent complementary but there are differences of treatment and emphasis here and there.

12.7.1. *Brooks' account*

Details of the methods by which Brooks[26] determined and identified the singularities are contained in the original paper and are not reproduced here. The singularities which Brooks finally accepted as probably real are set out in Table 12.8, which gives the average and extreme dates of beginning and ending of each singularity, the number of years in 52 (1889–1940) in which the singularity could be recognized, and the frequency of persistent anticyclonic or stormy conditions on the "peak" day. (For Brooks investigation a stormy day was one on which pressure over or very near the British Isles was below 992 millibars; an anticyclonic day was one on which the curvature of the isobars over the British Isles was anticyclonic and the pressure was 1,020 millibars or above; for the summer months an additional category "unsettled" was added on which pressure over or very near the British Isles was below 1,000 millibars.) It will be noted from the last column of Table 12.8 that a few of the singularities consist of two parts and have two "peak" dates.

Brooks considered that the singularities could be divided into four seasonal groups:

(1) October to early February, characterized by stormy periods with minor anticyclonic intervals;

(2) February to May, in which the main phenomena are cold waves associated with northern anticyclones;

(3) The European "summer monsoon", consisting of incursions into Europe of polar maritime and tropical maritime air, alternating with some regularity;

(4) September and early October, characterized by spells of anticyclonic conditions and late summers.

The general characteristics of a "stormy" singularity are either the displacement of the Icelandic low southwards or an increase in its intensity with a trough

TABLE 12.8 *List of "singularities" in Europe (as given by Brooks[26])*

Singularity	Beginning date			Ending date			Occurrences in 52 years	
	First	Mean	Last	First	Mean	Last	No. of years	Frequency at peak date
Early January, stormy	*	Jan. 5	Jan. 18	Jan. 6	Jan. 17	Jan. 22	45	31, Jan. 8
Mid-January, anticyclonic	Jan. 7	Jan. 18	Jan. 23	Jan. 17	Jan. 24	Jan. 30	45	18, Jan. 20-21
Late January, stormy	Jan. 18	Jan. 24	Jan. 31	Jan. 24	Feb. 1	Feb. 24	44	31, Jan. 31
Early February, anticyclonic	Feb. 1	Feb. 8	Feb. 15	Feb. 6	Feb. 16	Feb. 28	29	22, Feb. 13
Late February, cold spell	Feb. 16	Feb. 21	Feb. 23	Feb. 22	Feb. 25	Mar. 3	22	21, Feb. 22
Late February and early March, stormy	Feb. 11	Feb. 26	Mar. 9	Mar. 1	Mar. 9	Mar. 30	46	32, Mar. 1
Mid-March, anticyclonic	Feb. 27	Mar. 12	Mar. 19	Mar. 12	Mar. 19	Mar. 29	27	17, Mar. 13-14
Late March, stormy	*	Mar. 24	Mar. 29	Mar. 24	Mar. 31	Apr. 11	35	26, Mar. 28
Mid-April, stormy	Mar. 28	Apr. 10	Apr. 15	Apr. 10	Apr. 15	Apr. 26	37	25, Apr. 14
Late April, unsettled	Apr. 19	Apr. 23	Apr. 27	Apr. 23	Apr. 26	Apr. 30	27	19, Apr. 25
June, summer monsoon	May 24	June 1	-	June 6	June 21	June 28	(40)	-
July, warm period	-	July 10	-	-	July 24	-	-	-
Late August, stormy	Aug. 14	Aug. 20	Aug. 29	Aug. 20	Aug. 30	Sept. 3	35	16, Aug. 28
Early September, anticyclonic	Aug. 21	Sept. 1	Sept. 6	Sept. 7	Sept. 17	Sept. 30	43	25, Sept. 10
Mid-September, stormy	Sept. 7	Sept. 17	Sept. 20	Sept. 18	Sept. 24	Oct. 3	31	22, Sept. 20
Old wives' summer	Sept. 9	Sept. 24	Oct. 10	Sept. 14	Oct. 4	Oct. 16	33	-
Early October, stormy	Sept. 28	Oct. 5	Oct. 10	Oct. 5	Oct. 12	Oct. 30	35	26, Oct. 8-9
Mid-October, anticyclonic	Oct. 8	Oct. 16	Oct. 19	Oct. 15	Oct. 20	Oct. 28	35	19, Oct. 19
Late October and early November, stormy	Oct. 11	Oct. 24	Oct. 31	Oct. 30	Nov. 13	Nov. 27	52	{31, Oct. 29 28, Nov. 9, 12
Mid-November, anticyclonic	Nov. 7	Nov. 15	Nov. 22	Nov. 14	Nov. 21	Nov. 30	34	20, Nov. 18, 20
Late November and early December, stormy	Nov. 9	Nov. 24	Nov. 30	Dec. 4	Dec. 14	Dec. 26	51	{25, Nov. 25 34, Dec. 9
Pre-Christmas, anticyclonic	Dec. 9	Dec. 18	Dec. 24	Dec. 19	Dec. 24	Jan. 5	29	19, Dec. 19-21
Post-Christmas, stormy	Dec. 19	Dec. 25	Jan. 1	Dec. 25	Jan. 1	Jan. 21	43	35, Dec. 28

* Merged with preceding stormy period.

extending south-eastwards. These are associated with a tendency for primary or secondary depressions to traverse the coastal regions of north-west Europe, including the British Isles, and penetrate Scandinavia or the Baltic. The "fair" or anticyclonic periods are due either to an increased frequency of anticyclones forming in polar air moving southwards or to extensions of the Azores high north-eastwards. Periods of special interest are the cold spell of mid-February, associated with an outbreak of cold polar or continental air; the beginning of the European summer monsoon, when the quiet conditions of late May give place abruptly to north-west or west winds, bringing maritime air into Europe; and the old wives' summer, a more or less autogenous anticyclonic period in central Europe in late September.

12.7.2. *Lamb's account*

Lamb[25] has given a rather more detailed account of singularities. The weather over the British Isles and surrounding areas was classified according to seven types for each day of the 50 years 1898 to 1947. Out of the 18,261 days covered, only 120 (or about two-thirds of one per cent) were considered unclassifiable. The seven types were:

(i) Anticyclonic type (AC). Anticyclones centred over, near, or extending over the British Isles; therewith also cols situated over the country, between two anticyclones. Mainly dry with light winds (though thunder often occurring in cols in summer). Usually warm in summer, cold or very cold in winter; mist and fog frequent in autumn.

(ii) Cyclonic type (C). Depressions stagnating over, or frequently passing across, the British Isles. Mainly wet or disturbed weather, with very variable wind directions and strengths. Usually mild in autumn and early winter, cool or cold in spring, summer and (sometimes) in later winter. Both gales and thunderstorms occur.

(iii) Westerly type (W).* High pressure to the south (also sometimes south-west and south-east) and low pressure to the north of the British Isles. Sequences of depressions and ridges travelling east across the Atlantic. Generally unsettled or changeable weather, usually with most rain in the northern and western districts of the British Isles. Winds shifting rapidly between south and north-west, occasionally south-east or even east for a short time. Cool in summer, mild in winter with frequent gales.

(iv) North-westerly type (NW). Azores anticyclone displaced north-east towards the British Isles or north over the Atlantic west of our coasts, or with extensions in these directions. Depressions (often forming near Iceland) travel south-east or east-south-east into the North Sea and reach their greatest intensity over Scandinavia or the Baltic. Unsettled or changeable weather, particularly in northern and eastern districts of the British Isles, sometimes with fresh or gale-force winds between west and north. The warm sectors may contain unstable air in later winter and spring. Cooler than the westerly type and milder than the northerly type.

(v) Northerly type (N). High pressure to the west and north-west of the British Isles, particularly over Greenland, and sometimes extending as a continuous belt southward over the Atlantic Ocean towards the Azores. Low pressure over the Baltic, Scandinavia and the North Sea. Depressions move south or south-east from the Norwegian Sea (sometimes having formed in the Iceland – Jan Mayen region, sometimes having come through from farther

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* The type here defined as westerly has been variously described as westerly or south-westerly in meteorological literature and popular usage.

north, sometimes having entered the Iceland–Jan Mayen region by way of a col near south Greenland). Cold, disturbed weather at all seasons, especially in eastern and northern districts. Snow and sleet common in winter; also associated with late spring and early autumn snow on high ground in the north and with late spring frosts in all districts. The onset of northerly-type weather is often accompanied by high winds.

(vi) Easterly type (E). Anticyclones over, or extending over, Scandinavia and towards Iceland. Depressions circulating over the western North Atlantic and in the Azores–Spain–Biscay region. Cold in autumn, winter and spring; sometimes intensely cold in southern districts and suitably exposed localities elsewhere, with occasional snow in the south and snow or sleet showers in eastern and north-eastern districts; fine in the west and north-west. Warm in summer, sometimes thundery. Very dry weather in western districts, relatively dry in many or most other districts.

(vii) Southerly type (S). High pressure covering central and northern Europe. Atlantic depressions blocked west of British Isles or travelling north and north-eastward off our western coasts. (Seems less persistent than the other types, occurring mainly as occasional variations within spells that are predominantly either westerly or easterly; very rare in summer.) Warm and thundery in spring and summer, mild in autumn. In winter mild or cold according as the air mass carried over the British Isles is oceanic or continental in origin.

12.7.2.1. *Singularities affecting the British Isles as given by Lamb.*[25] (Slightly abbreviated version.)

(1) 5–11 January

Renewed storminess of early January. Year's maximum frequency of W type in Britain exceeding 50 per cent 1–11 January, 60 per cent 8 January. Types other than AC 90 per cent.

Maximum intensity of the zonal westerlies around the hemisphere shown by many indices.

The mild oceanic air masses do not penetrate into central Europe as often around these dates as with the earlier cyclonic singularities in fore-winter (peak of 46 per cent on 8 January against 51–54 per cent on 26 November, 8 December, 28 December and (later) 1 February).

(2) 20–23 January

Anticyclonic in Europe and southern and eastern Britain. Dry frosty weather over the continent with sunshine on the mountains above 1,400 metres, frequencies reaching 70 per cent. Types AC, S and E together about 50 per cent in Britain.

(3) 27 January – 3 February

Renewed storminess, gales and rain or snow. Depressions pass into north and central Europe from the Atlantic. The first depressions of the series commonly approach England from the south-west: situation bringing liability to freezing rain with advance of mild air after some days of frost (compare 1940, 1950). Types other than AC in Britain over 80 per cent.

(4) 8–13 February

February anticyclones. (A second peak follows in central and eastern Europe 19–24 February.) Year's highest frequency of winter sports conditions in Alps and southern Germany; snow over 10 centimetres deep in upper Bavaria 1–16 February over 80 per cent. Record frosts in cold winters. When the anticyclones form over the British Isles in air of maritime origin, fogs are common inland. In other cases drier continental air reaches England. Combined frequencies of types AC, S and E about 50 per cent. (Italy less affected than by December and January anticyclones.)

(5) 26 February – 9 March
Cold, stormy period. Northerly outbreak from Norwegian Sea and cyclonic weather over North Sea and surrounding lands; type C 30–38 per cent in Britain 26 February – 2 March, peak of type N 20–22 per cent 28 February – 3 March.

Depressions also form in the Mediterranean, causing warming in Rome and year's greatest frequency of rainfall in the Adriatic about 3–8 March.

(6) 12–22 March
Early spring anticyclones over Britain and Europe. Great diurnal range of temperature common in prevailing quiet weather in Britain and Europe. AC, N and E types in Britain together about 70 per cent.

Dry weather in south Germany and Austria 70 per cent. Cold northerly winds in Greece and south-east Europe.

(7) 28 March – 1 April
Cold, stormy period. Approximate date of the first of a series of northerly outbreaks from the Norwegian Sea and cyclonic periods in western and central Europe and the Mediterranean (repeated commonly about four times in April and early May), punctuated by warm, quiet anticyclonic intervals. Dates and degree of development variable (but see 12–19 April); cyclonic type in Britain, however, reaches 25–30 per cent 28 March – 1 April.

(8) 12–19 April and 25–28 April
Cold, stormy period. The most regular of the successive stormy, cold spells in April. Year's equal highest peak of northerly weather in the British Isles 28 per cent 17–19 April. Minor peak of cyclonic weather in Britain and (van Bebber's[27] Vb depressions) in Germany and the Mediterranean. Atlantic anticyclones liable to affect western and south-western districts of the British Isles.

(9) 29 April – 16 May
Northerly weather: some anticyclonic intervals. Equal highest frequency of northerly weather in the British Isles, often anticyclonic in the west; also leading up to year's greatest frequency of van Bebber's[27] Vb (inverted) depressions over central Europe 17–20 May and the last spring peak of raininess in Italy 20–27 May.

Year's highest frequency of easterly and lowest frequency of westerly weather in the British Isles; AC and E together exceed 50 per cent 29 April – 3 May, AC, N and E over 70 per cent. C prominent around 7 and 17 May. Types other than W 80–90 per cent.

Year's minimum of zonal westerlies in middle latitudes measured by various indices.

(10) 21–31 May
Fore-monsoon fine weather periods. Types AC and S, together about 70 per cent, give character of prevailing weather in British Isles. Year's highest peak of type AC 46 per cent 21 May; AC and E together over 50 per cent on 21–22, 24 and 30–31 May.

Dry days in Germany and Austria 70–80 per cent about 21–22 May and 28–31 May.

(11) 1–4 June and 12–14 June
First waves of European summer monsoon: stormy, cool episodes. Depressions tend to move across the British Isles from the Atlantic, in one of the year's

highest peaks of cyclonic weather (30–36 per cent) 1–4 June. Westerlies are still infrequent over the British Isles, but successive depressions travel rather farther north and the westerlies become more frequent; the second monsoonal wave ("Sheep-cold") reaches Germany around 12–14 June and the third wave 18–22 June brings the westerlies in across the British Isles as the commonest type once more. These events are punctuated by recoveries of the anticyclonic tendency associated with advances of the Azores anticyclone.

Peak frequencies of thunder accompany the invasions of the Continent by cool oceanic air, the year's highest frequency of thunder in south Germany 3–5 June.

(12) 5–11 June
June anticyclones over the British Isles and western Europe. These anticyclones move in as extensions or offshoots of the Azores high, causing also a peak of north-westerly weather in Britain associated with their advance. Type AC recovers to its second highest peak of the year (44 per cent) on 7 June; AC and E together exceed 50 per cent on 5–6 June.

(13) 18–22 June and following fortnight
Return of the westerlies. The most regular monsoonal invasion of the continent by cool oceanic air from west and north-west leading to thunderiness and cyclonic activity. The south and south-west of the British Isles often remain anticyclonic. Types W, NW and AC together exceed 70 per cent, W alone 52 per cent 20 June.

The third wave of the monsoon reaches Germany about 24–26 June; later waves are usually less pronounced and occur with varying regularity about 2–7 July, 18–22 July, 29 July – 1 August and 16–18 August.

Pressure at the Azores approaches the year's maximum.

(14) 23–30 July and following week
Thundery, cyclonic weather over Europe and the British Isles. Stagnant depressions common. Cyclonic type approaching its greatest frequency of the year in Britain 4–8 August accompanying peaks of the north-westerly and westerly types. Type C 30–38 per cent throughout from 22 July until 8 August.

Buchan's[28] cold spell of 6–11 August seems merely to mark the onset of seasonal cooling. The year's peak of the mean temperature curve is in the week 30 July – 6 August in most districts of the British Isles, almost equalled also 16–23 July; 23–30 July is a little cooler.

Peak dates for invasion of Germany by maritime air, marked by frequent thunderstorms around 18–22 July and 29 July – 1 August. Main maximum of thunderstorm-days both at Utrecht and Edinburgh (Mossman[29]) approximately 21 July – 13 August.

Note: Following this singularity late-summer anticyclones give a peak of AC type in Britain 42 per cent on 15 August. Buchan[28] quotes 12–15 August as a warm spell, before the first storms of autumn.

(15) 16–30 August
First storms of autumn. Depressions passing in high latitudes commonly produce northerly outbreaks in the Norwegian Sea about this time. Year's second highest frequency of westerly weather in the British Isles, commonly cyclonic, although an anticyclonic tendency may continue in the south. Types W and NW together about 70 per cent; W alone 58 per cent 18 August, also exceeds 50 per cent 17–22, 24 and 26–28 August.

Frequency of rain-days exceeds 70 per cent in north-west Germany on some dates, often regarded as last wave of the summer monsoon.

(16) 5–30 September
Old wives summer anticyclones. Anticyclones passing across the British Isles and Europe into Siberia. AC type about 40 per cent on peak dates 7–10 September,

16–21 September and 30 September in Britain. Cyclonic activity increases in the Mediterranean with increasing thunderiness. The dry period in the Adriatic and at Rome ends about 9 September. A peak of van Bebber's[27] Vb (inverted) depressions affecting central Europe also around 13–18 September. More cyclonic and southerly weather affects the British Isles after each anticyclonic system has passed away east into the Continent. The cyclonic type recovers to 30 per cent about 24 September. In cyclonic autumns the anticyclones keep farther south and the period around 24 September is particularly liable to gales with depressions passing close to the British Isles. There is an increasing cyclonic trend during October in most years, but the frequency of anticyclones remains high in the early part of the month 1–10 October.

In parts of central Europe dry days exceed 70 per cent around 5–8 September, 17–21 September and the last days of the month, with sunshine.

(17) 24 October – 13 November

Late autumn rains. Cyclonic, often stormy, period with depressions passing close to the British Isles and into the Baltic, especially about two peak periods 26–29 October and 9–12 November. In the interval between these peaks there is a tendency to fair, mild southerly weather with high pressure over the Continent. Year's minimum of anticyclonic weather in the British Isles 26–28 October, types other than AC 96 per cent. Commonly one or more cyclonic centres cross the British Isles, or may even skirt the south of the country, during the first peak of cyclonic activity. The later depressions tend to pass rather farther north; and westerly weather in Britain increases gradually to a peak of about 50 per cent on 8–12 November. One of the year's highest peaks of easterly weather (20 per cent) occurs on 1–2 November, having been equalled earlier on 22 October, and falls away later. The first and most prominent autumn peak of type N occurs (18 per cent) on 25–26 October, marking a phase when northerly outbreaks in the Norwegian Sea are common, followed in some years by rising pressure in Scandinavia leading to the continental anticyclones common around 30 October – 6 November.

Peaks of raininess occur in Europe, notably in Italy 23–26 October and 8–10 November, the latter dates giving the year's highest frequency of rainfall in Rome. At Konigsberg on the Baltic the frequency of rainfall also exceeds 70 per cent about 10 November.

(18) 15–24 November

Quiet, foggy, anticyclonic interlude. Sharp recovery of frequency of AC type in the British Isles from its late October minimum to a brief peak of 30 per cent about 17–19 November. This coincides with sharp minima in the frequency curves of westerly and cyclonic weather. The anticyclones generally form over the British Isles and western Europe in maritime air.

Subsidence conditions at the German mountain stations are more pronounced than at any other time of the year.

(19) 25 November – 10 December

Early-winter storms and rains. Cyclonic period mainly associated with progressive intensification of the Atlantic westerlies, more rarely with stagnant cyclonic situations over Europe. The Atlantic westerlies approach their strongest development about the end of the year, and waves of mild air spread east until blocked and lifted by the monsoonal development of stagnant cold air in the heart of the Eurasian continent. There are two main peaks of cyclonic activity in the British Isles 25–29 November and 6–12 December and signs of a further pulse from the Atlantic around 17–20 December. Types other than AC 90 per cent; combined frequencies of W and NW about 70 per cent, W alone reaching 50 per cent on 27 November and 50–56 per cent on 4–9 December.

(20) 19–23 December
Continental and north European anticyclones of the winter solstice. (A notable preliminary peak about 12 December commonly affects only eastern and northern Europe.)

Quite frosty weather common on the European lowlands. Year's highest peak of southerly weather in Britain; types AC, S and E together exceed 50 per cent. Gales still frequent in Scotland.

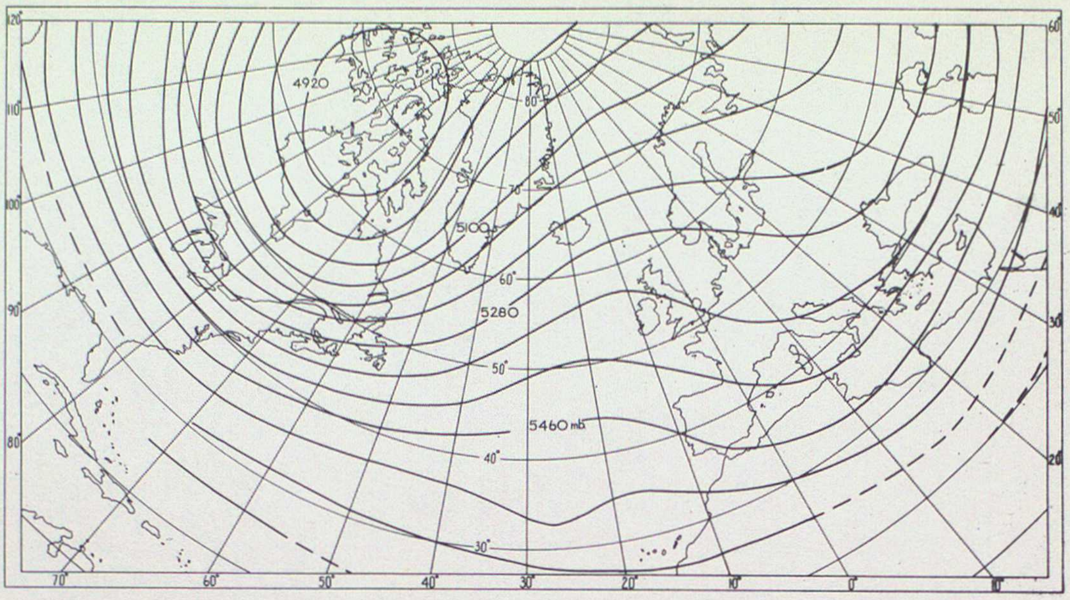
(21) 25–31 December
Christmastide thaw and storms of the end of the year. Cyclonic and westerly weather in the British Isles, carried by a second stage into central Europe. Type W reaches 50 per cent on 31 December, C 30–38 per cent on 27–29 December.

12.8 1000–500 MB. THICKNESSES

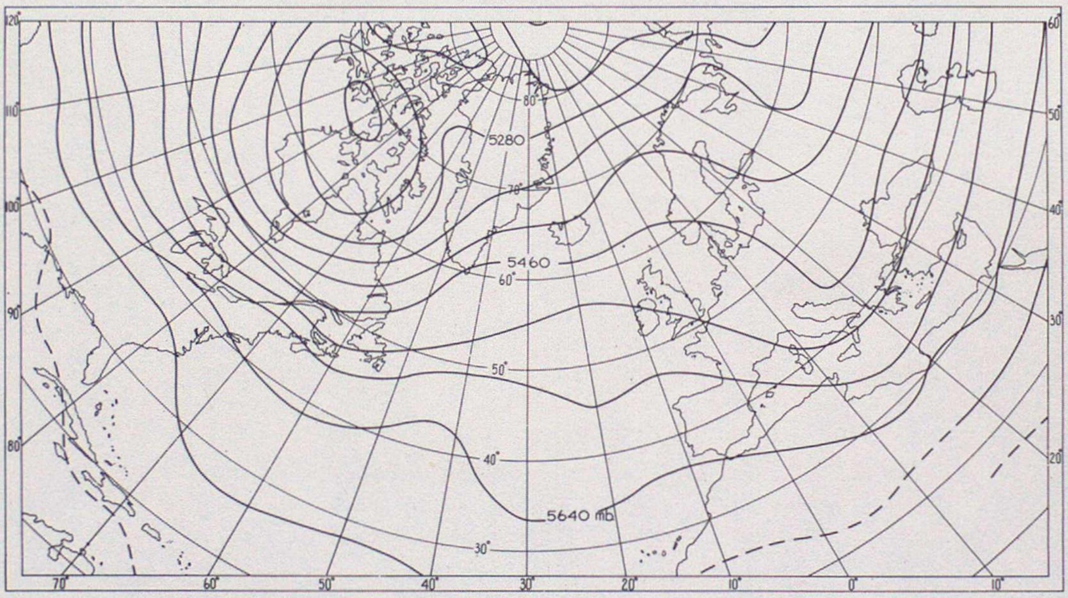
Monthly means and extremes of 1000–500-millibar thicknesses from western North America to eastern Europe over the period 1946–1951 have been published in *Meteorological Report No. 13*.[30] That report was distributed widely to outstations and should be readily available to forecasters when analysing and forecasting thickness patterns. The monthly mean provides a convenient reference level and the extremes provide limits which the prudent forecaster will exceed only when there is very strong (perhaps almost overwhelming) evidence that the 1000–500-millibar thickness is likely to be outstandingly high or low.

A further set of charts of mean and extreme thicknesses for a later period has also been prepared. This latter set covers much of the northern hemisphere but has been distributed less widely to outstations. Sections of the charts from 120°W. eastwards to 60°E. (that is, the area covered by Figures 12.1 to 12.24) are reproduced as Figures 12.37 to 12.48.

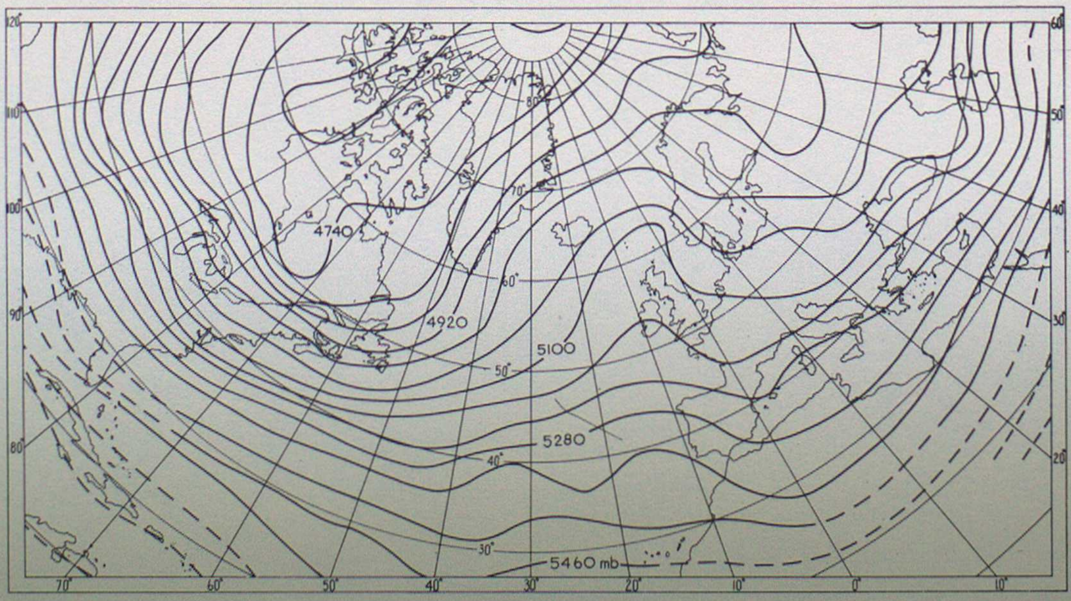
Little comment on Figures 12.37 to 12.48 or *Meteorological Report No. 13* is called for. It should be noted that both sets of means and extremes are based on a five-year period. This is a relatively short time from a climatological viewpoint and some values may be very slightly unrepresentative of the true long-period average or extreme. From the viewpoint of the practical forecaster the values are most probably sufficiently accurate for use in day-to-day forecasting.



(a) Mean

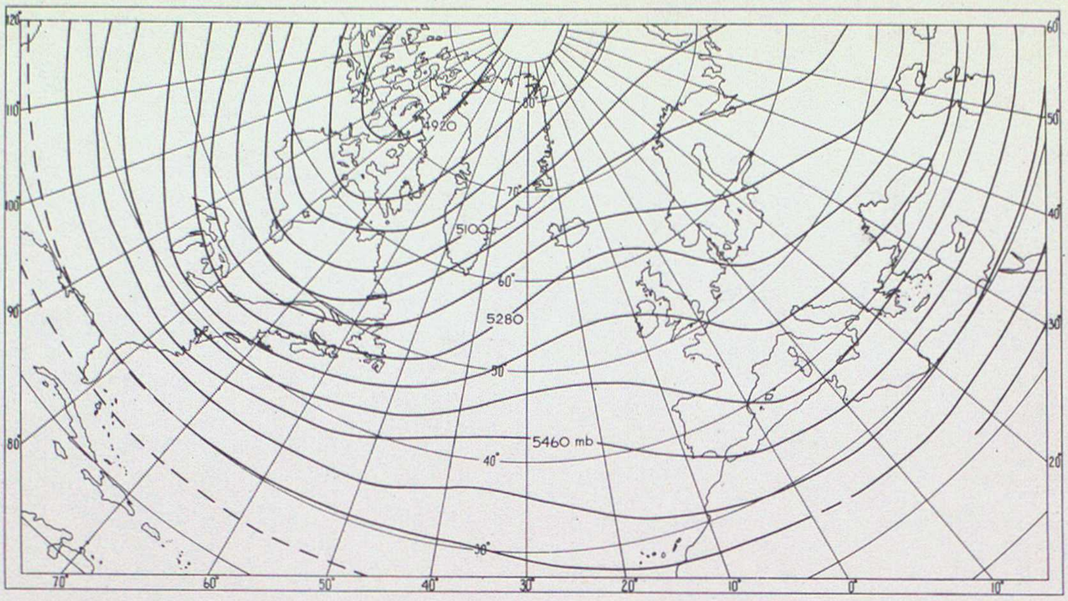


(b) Maximum

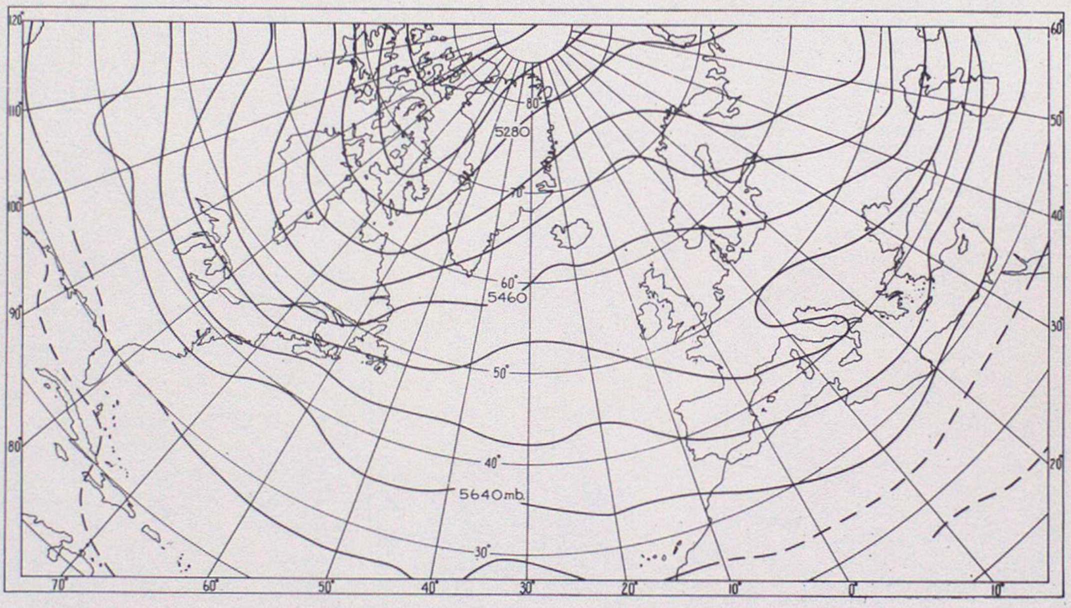


(c) Minimum

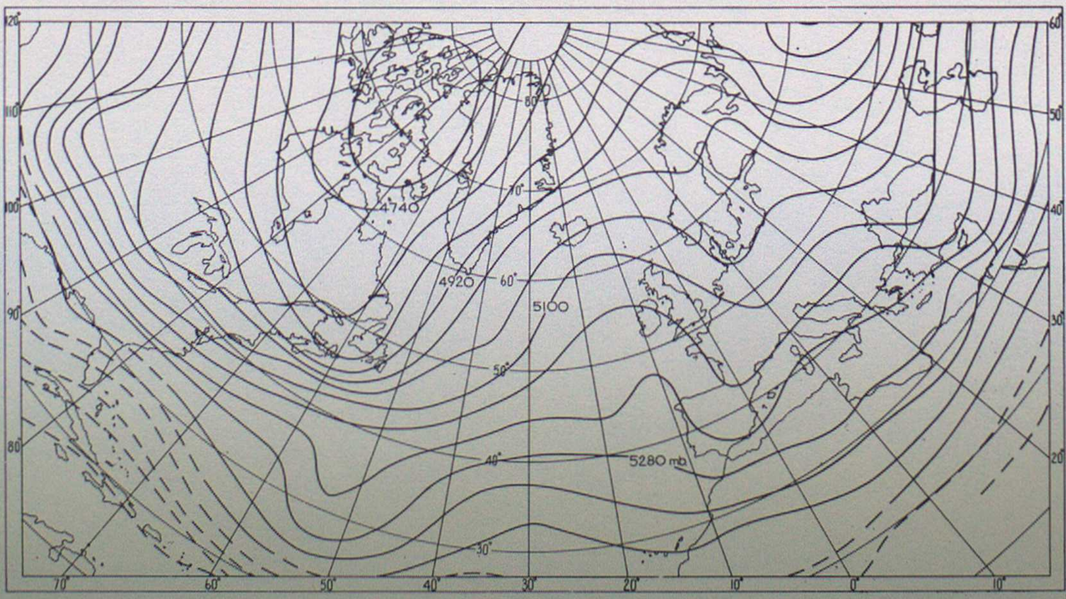
FIGURE 12.37 *Five-year 1000–500-millibar thickness, January 1950–54*



(a) **Mean**

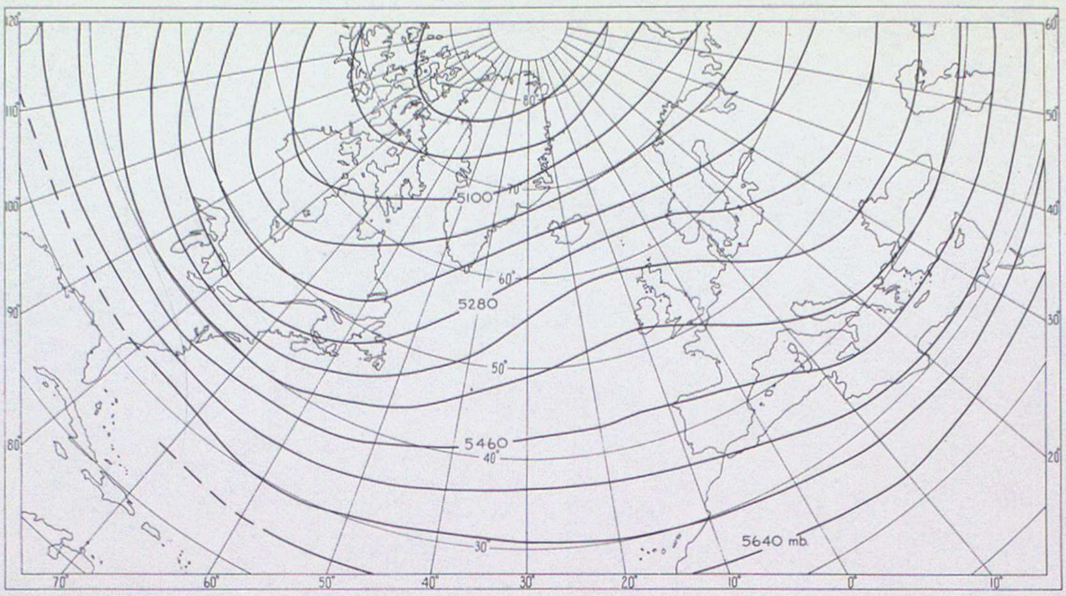


(b) **Maximum**

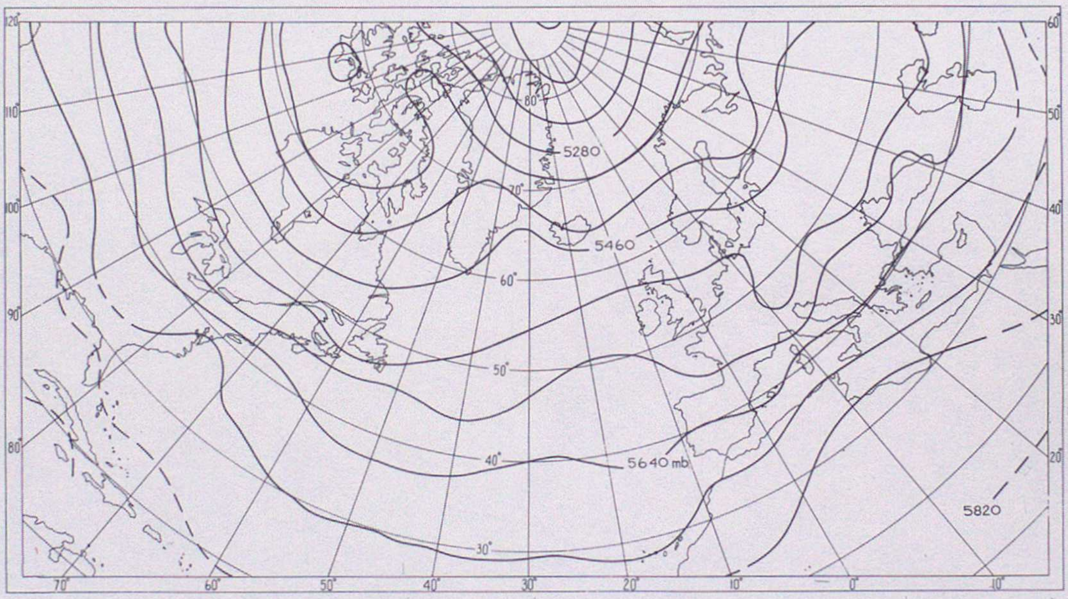


(c) **Minimum**

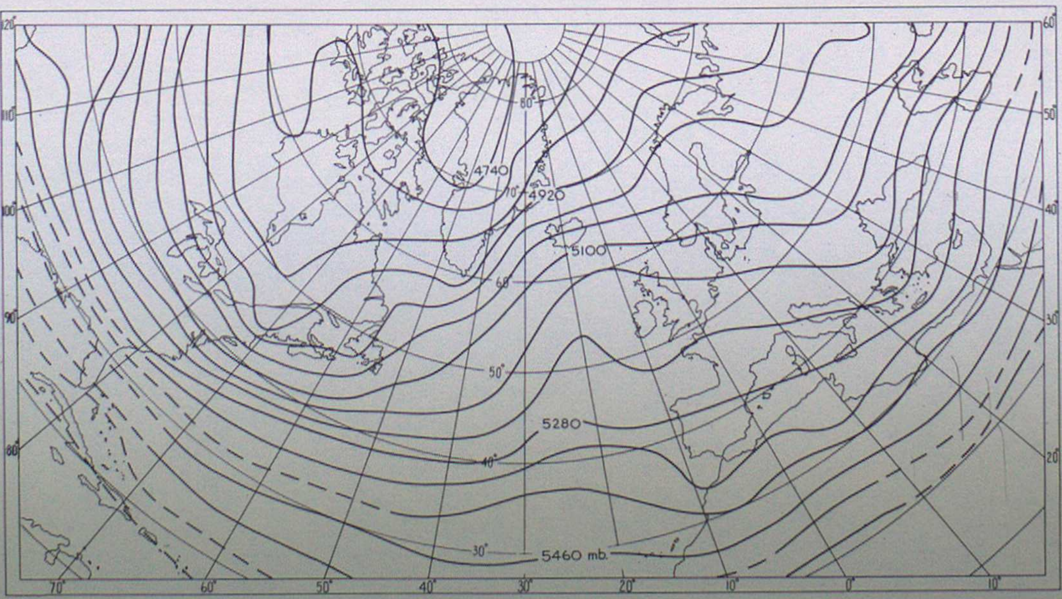
FIGURE 12.38 *Five-year 1000–500-millibar thickness, February 1950–54*



(a) Mean

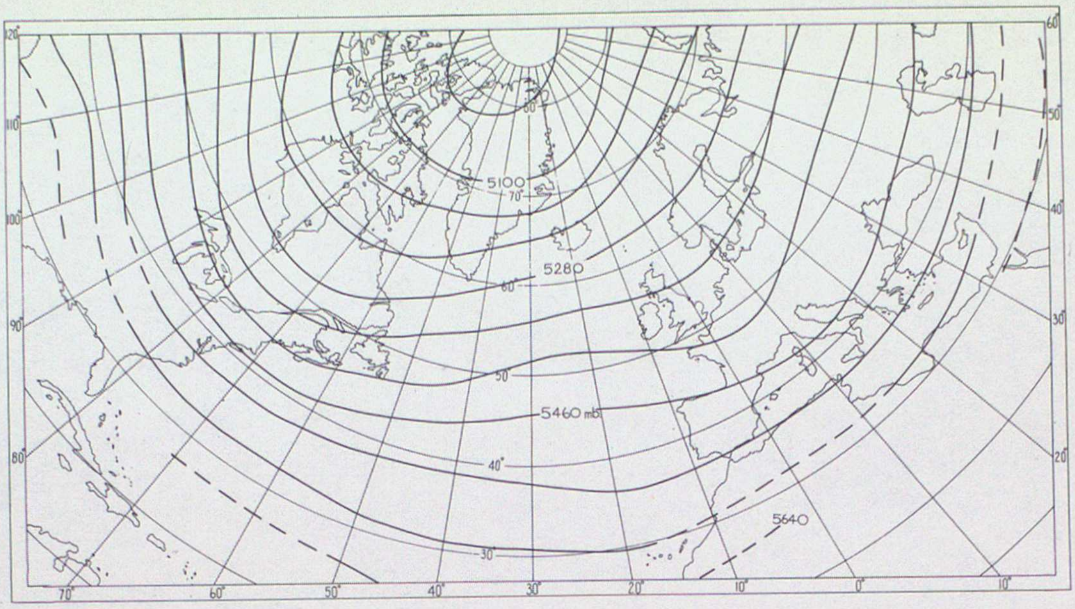


(b) Maximum

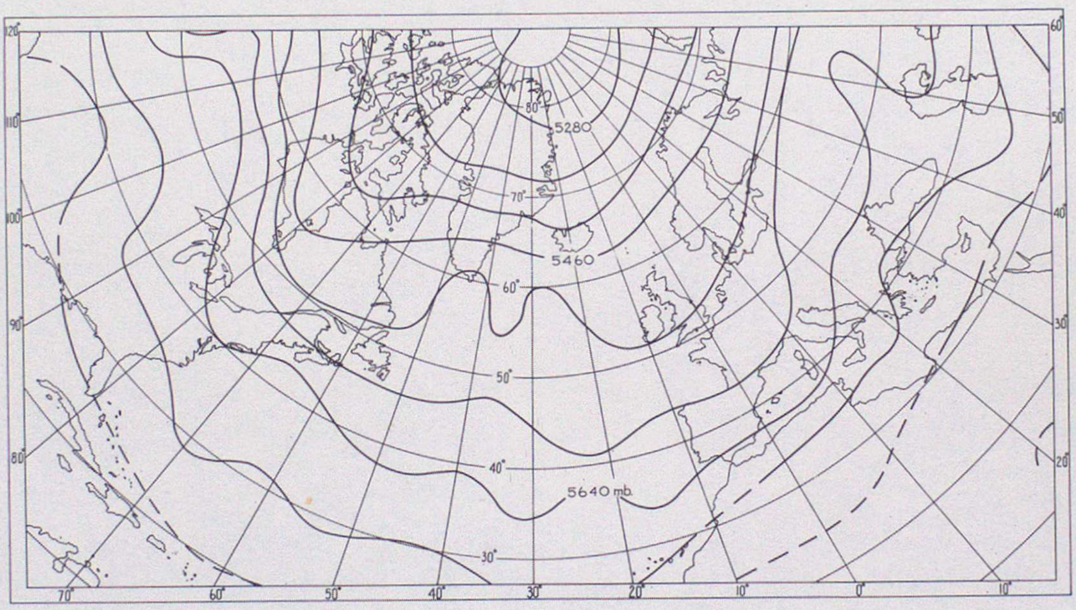


(c) Minimum

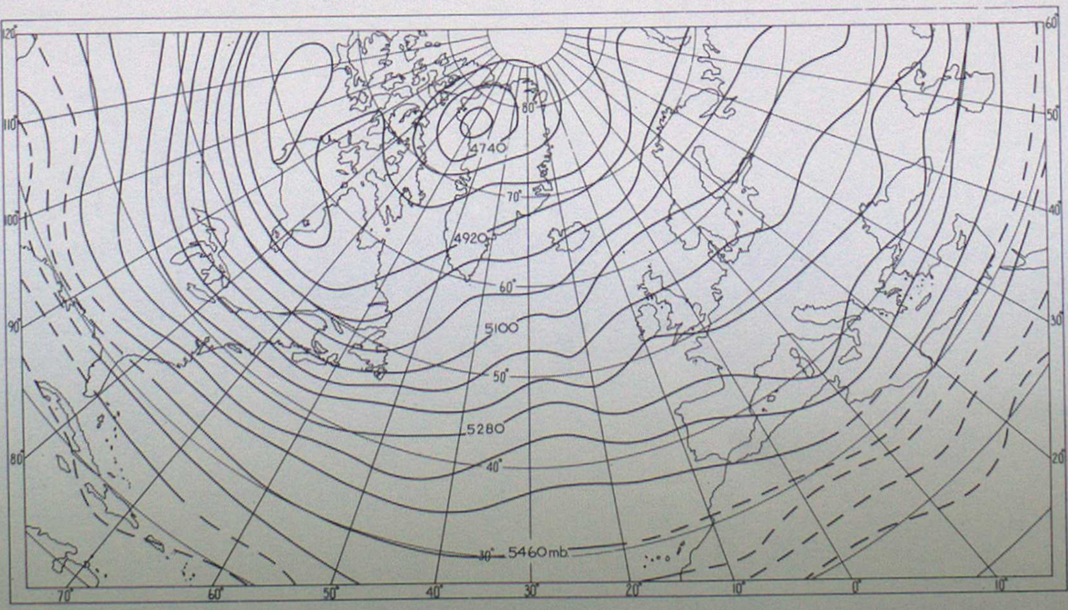
FIGURE 12.39 *Five-year 1000–500-millibar thickness, March 1950–54*



(a) Mean

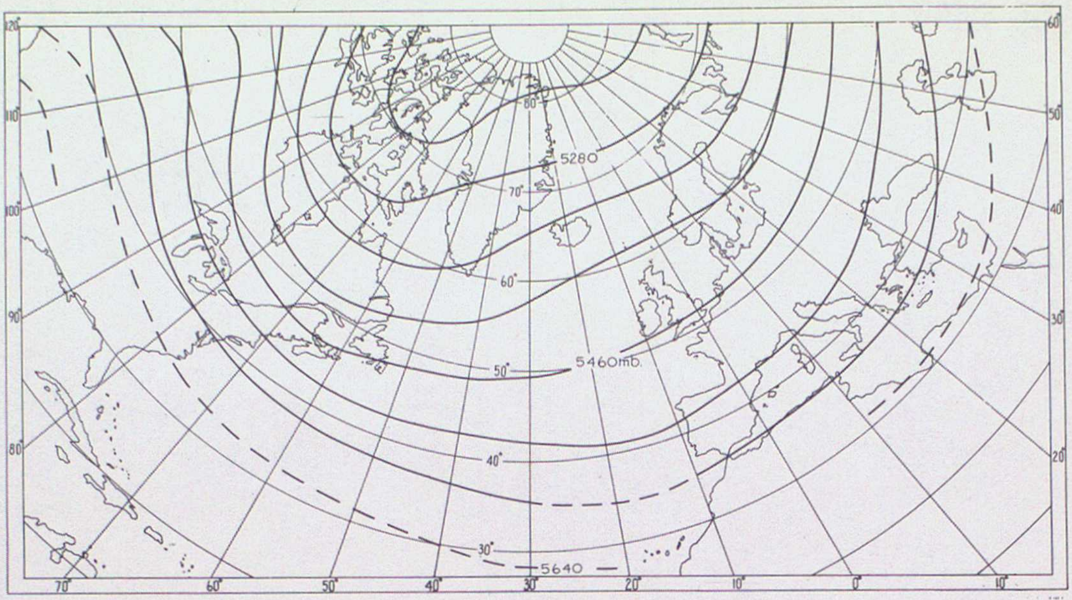


(b) Maximum

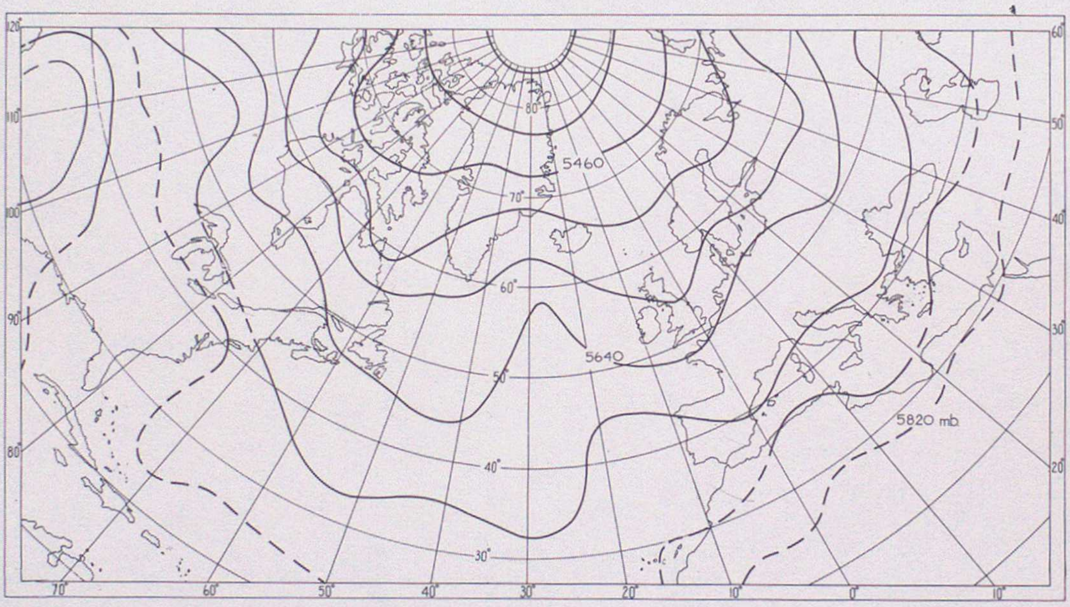


(c) Minimum

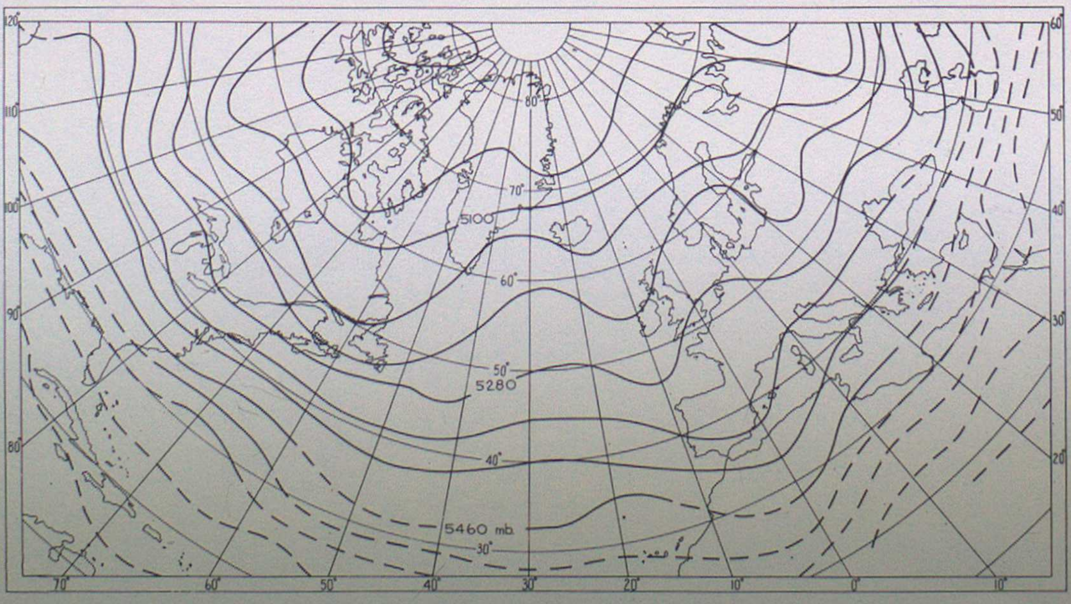
FIGURE 12.40 *Five-year 1000–500-millibar thickness, April 1950–54*



(a) **Mean**

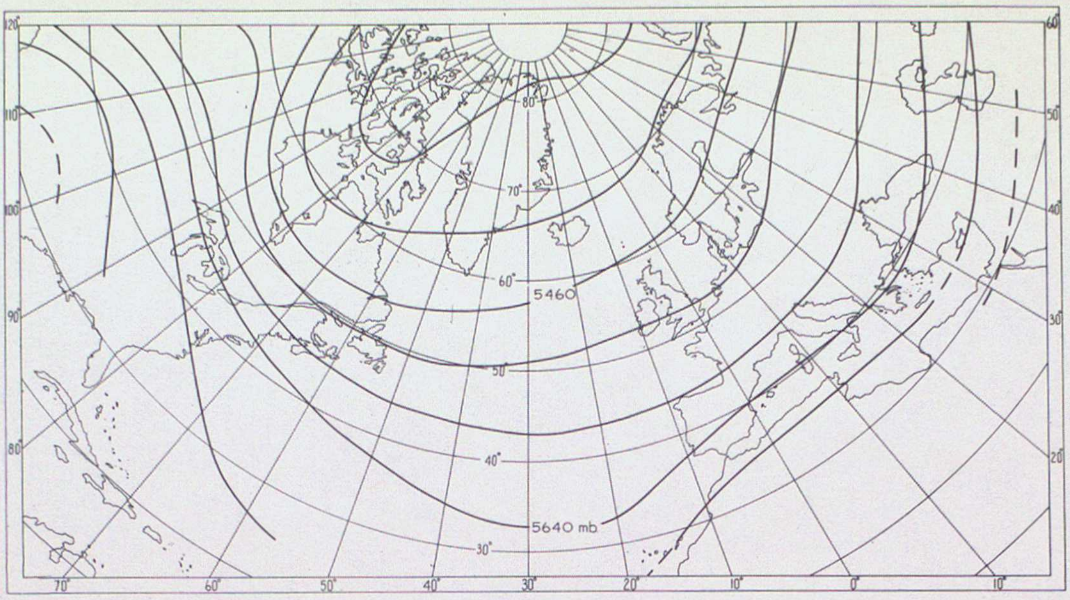


(b) **Maximum**

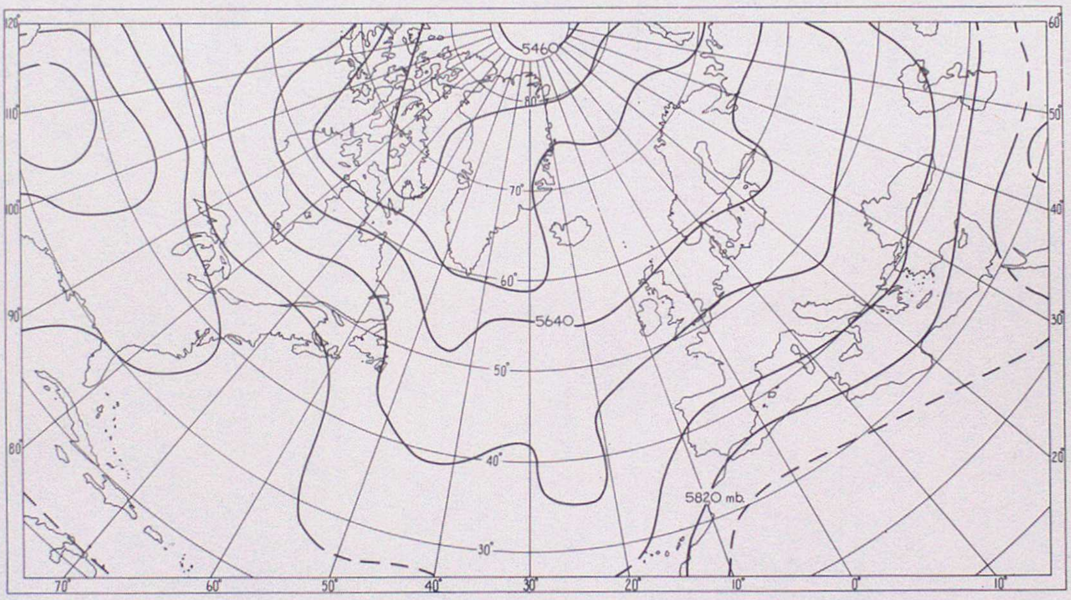


(c) **Minimum**

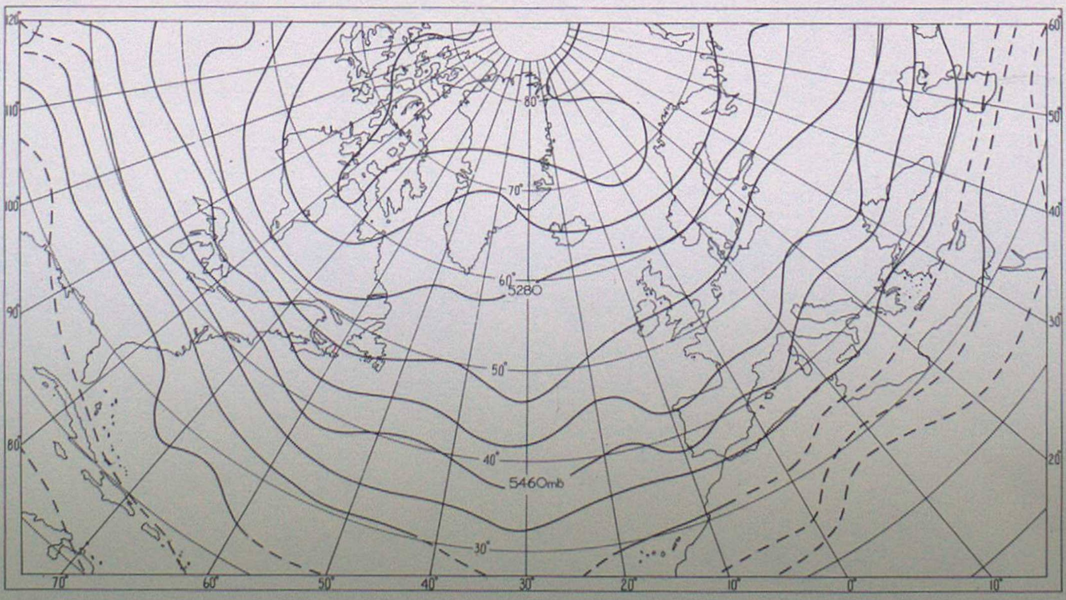
FIGURE 12.41 *Five-year 1000–500-millibar thickness, May 1950–54*



(a) Mean

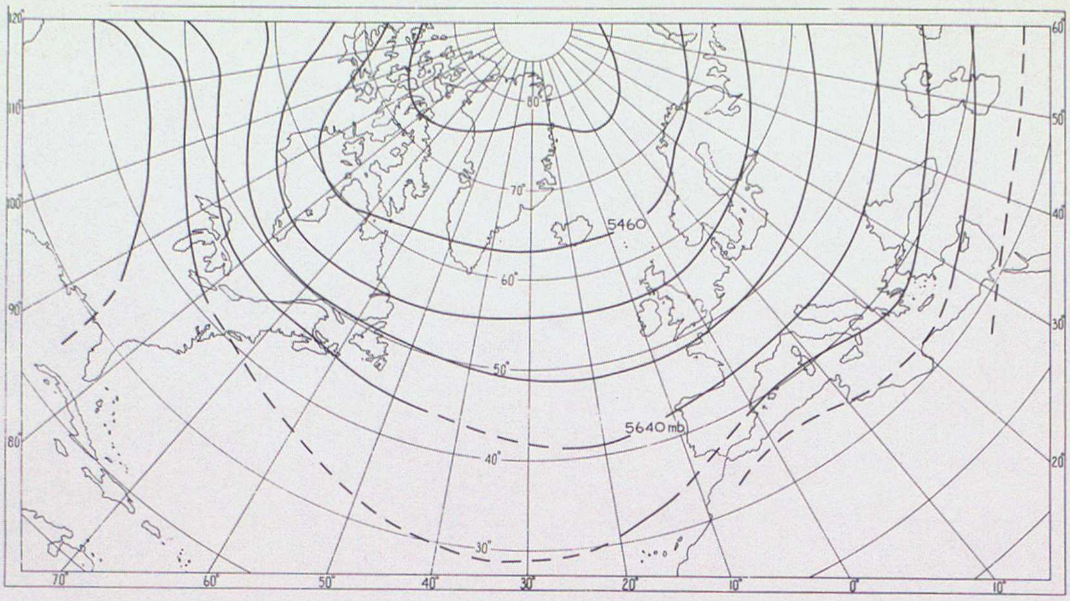


(b) Maximum

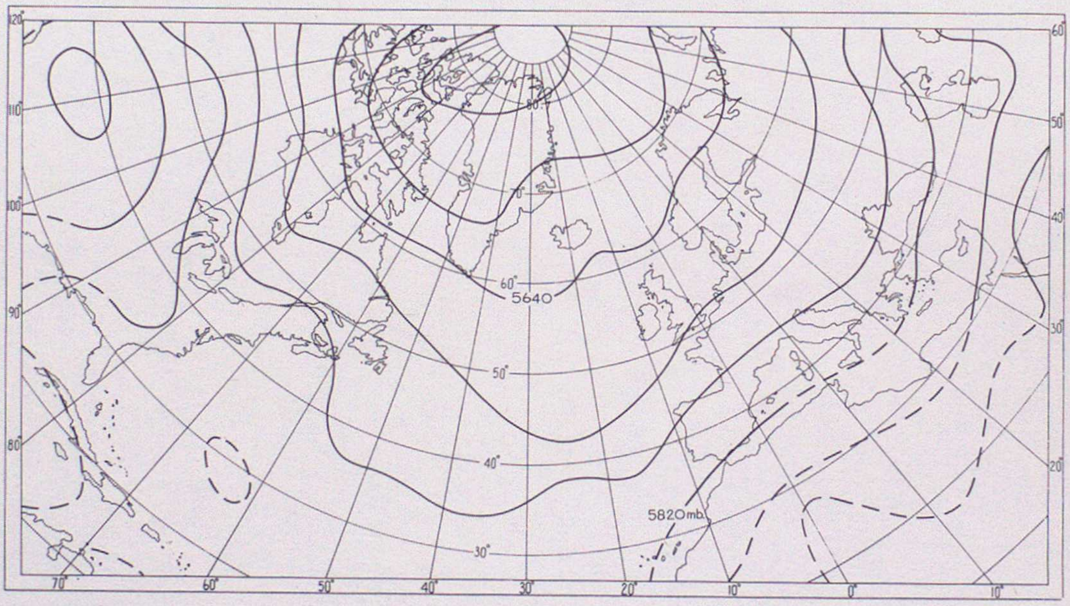


(c) Minimum

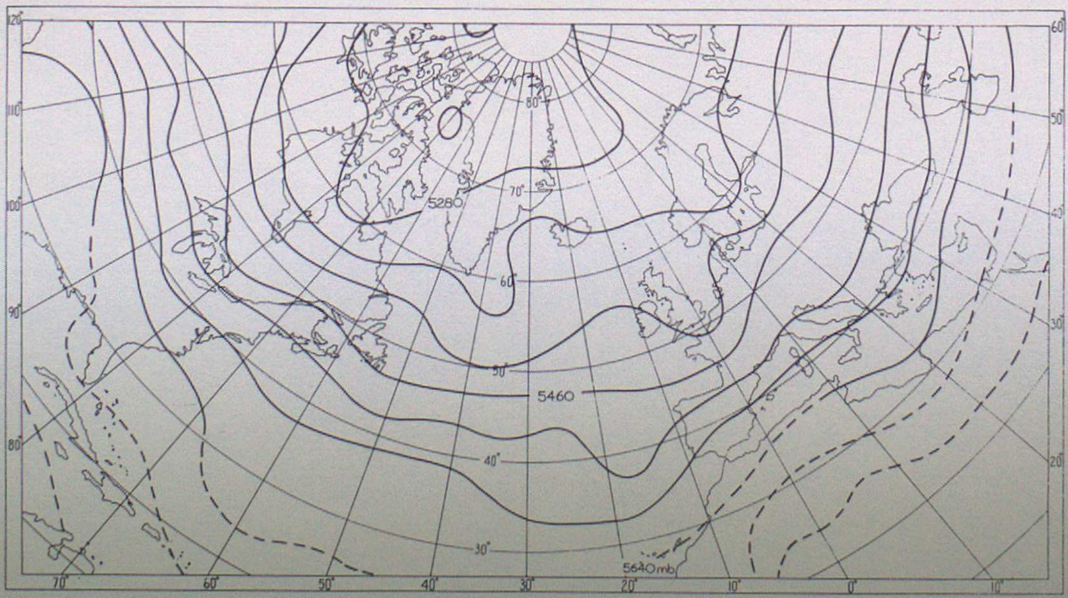
FIGURE 12.42 *Five-year 1000–500-millibar thickness, June 1950–54*



(a) **Mean**

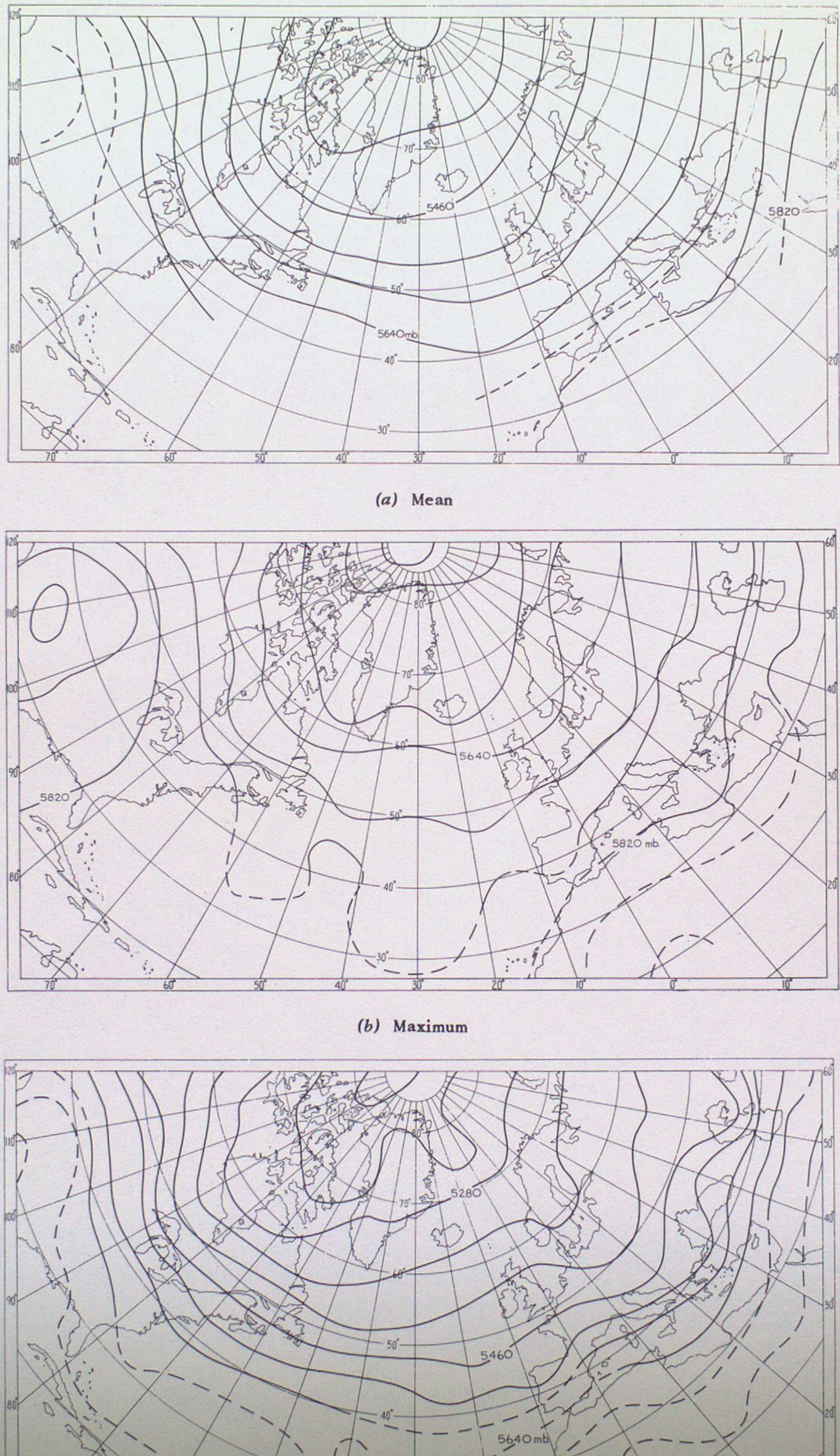


(b) **Maximum**



(c) **Minimum**

FIGURE 12.43 *Five-year 1000–500-millibar thickness, July 1950–54*

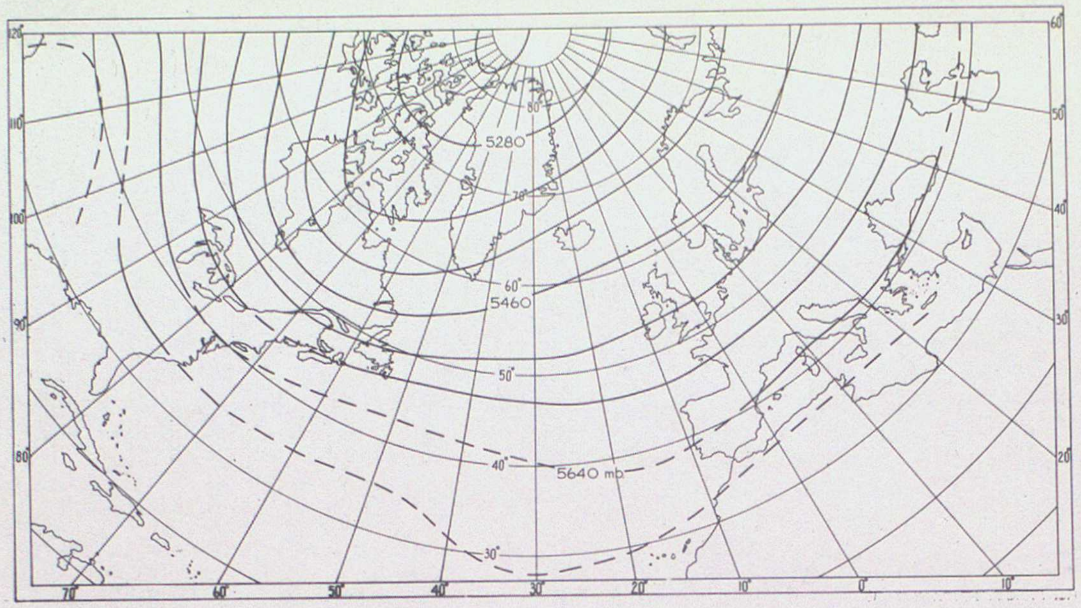


(a) **Mean**

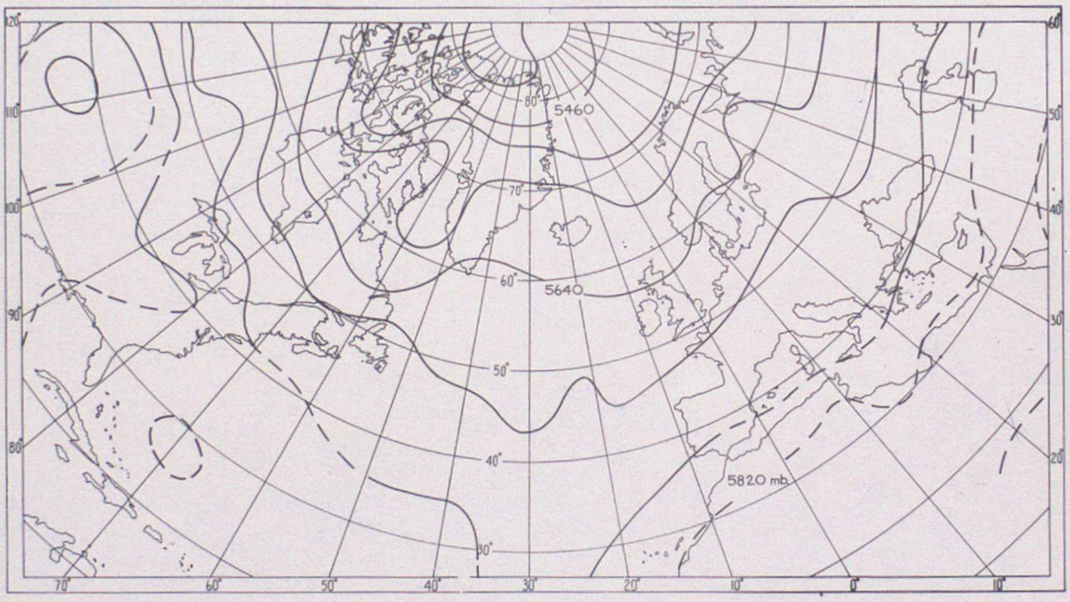
(b) **Maximum**

(c) **Minimum**

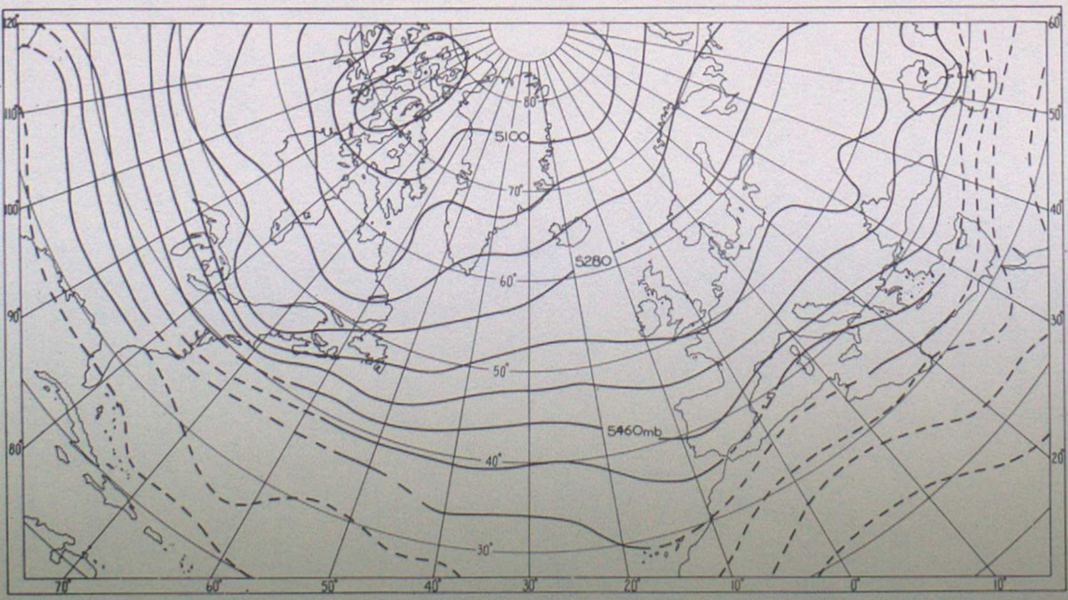
FIGURE 12.44 *Five-year 1000–500-millibar thickness, August 1950–54*



(a) **Mean**

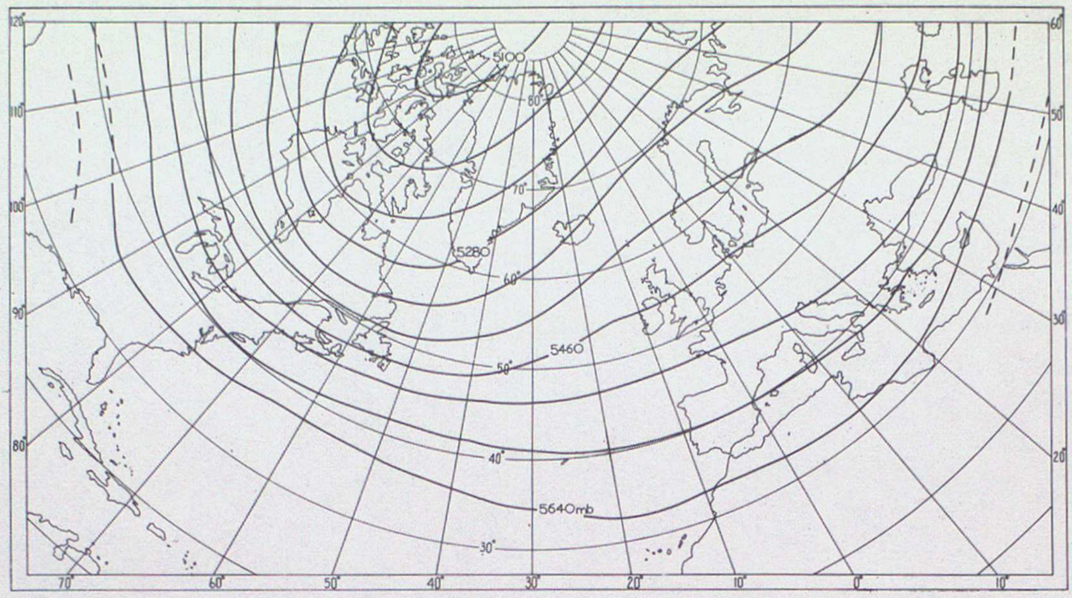


(b) **Maximum**

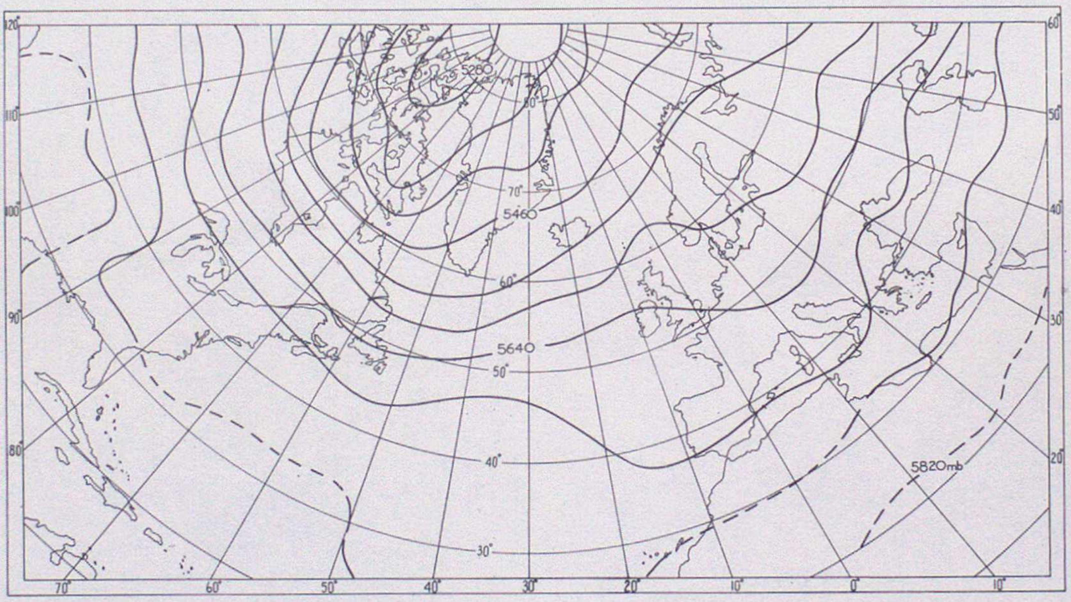


(c) **Minimum**

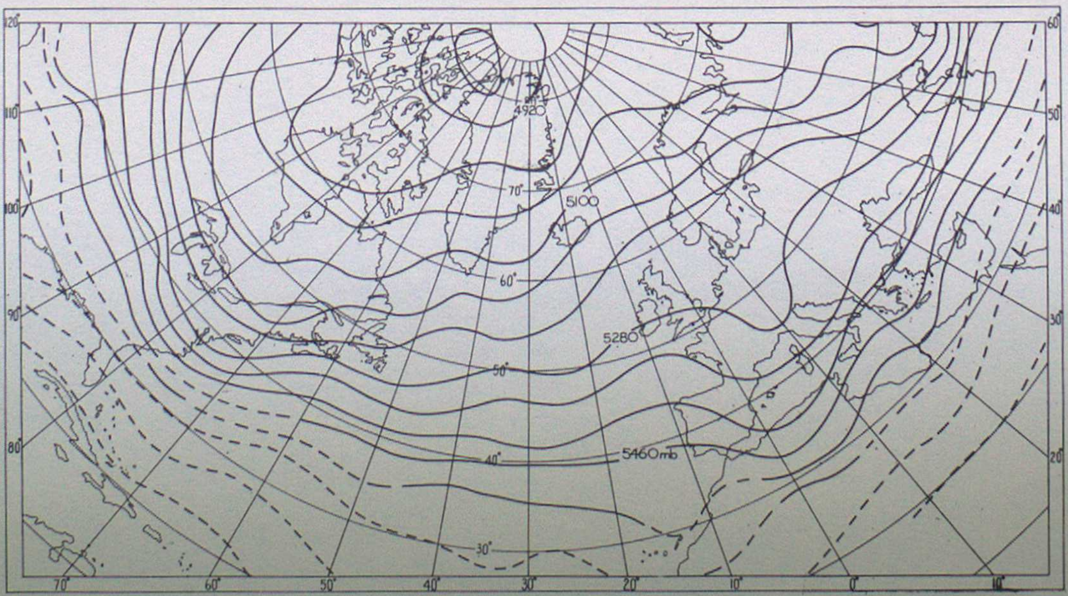
FIGURE 12.45 *Five-year 1000–500-millibar thickness, September 1950–54*



(a) **Mean**

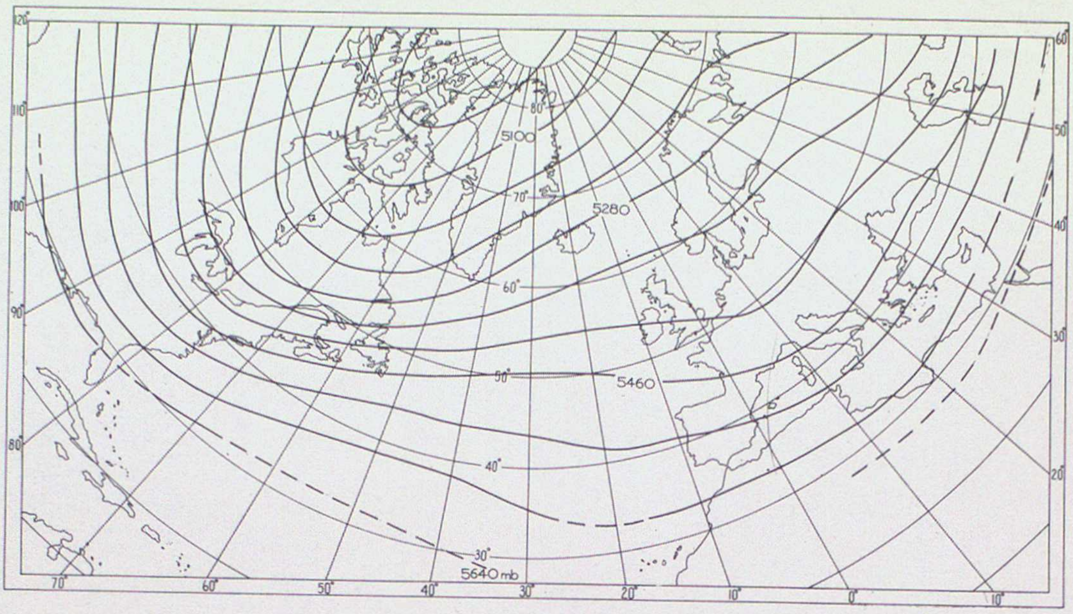


(b) **Maximum**

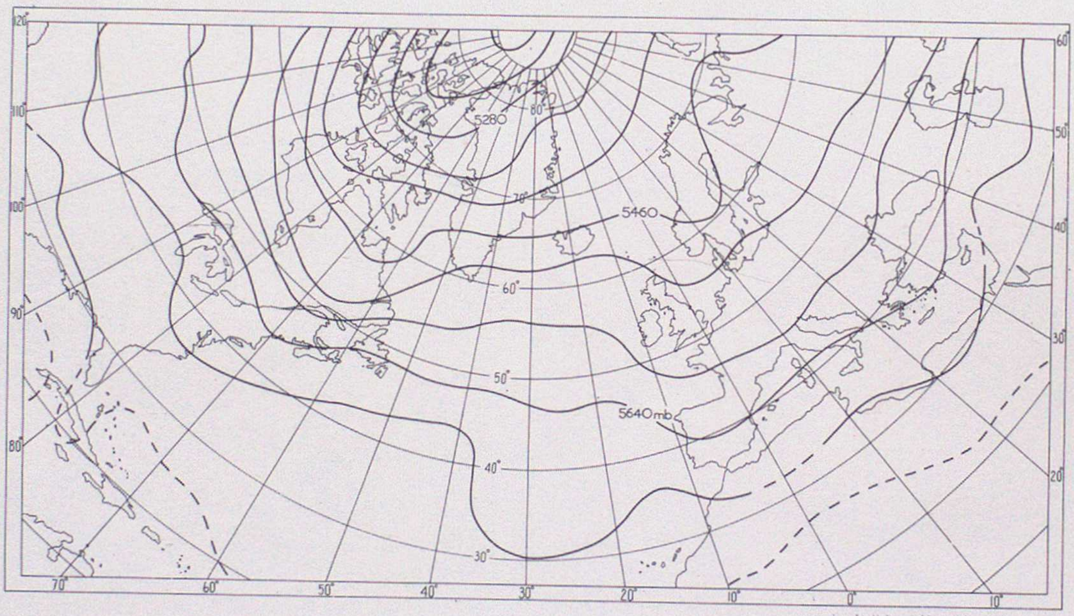


(c) **Minimum**

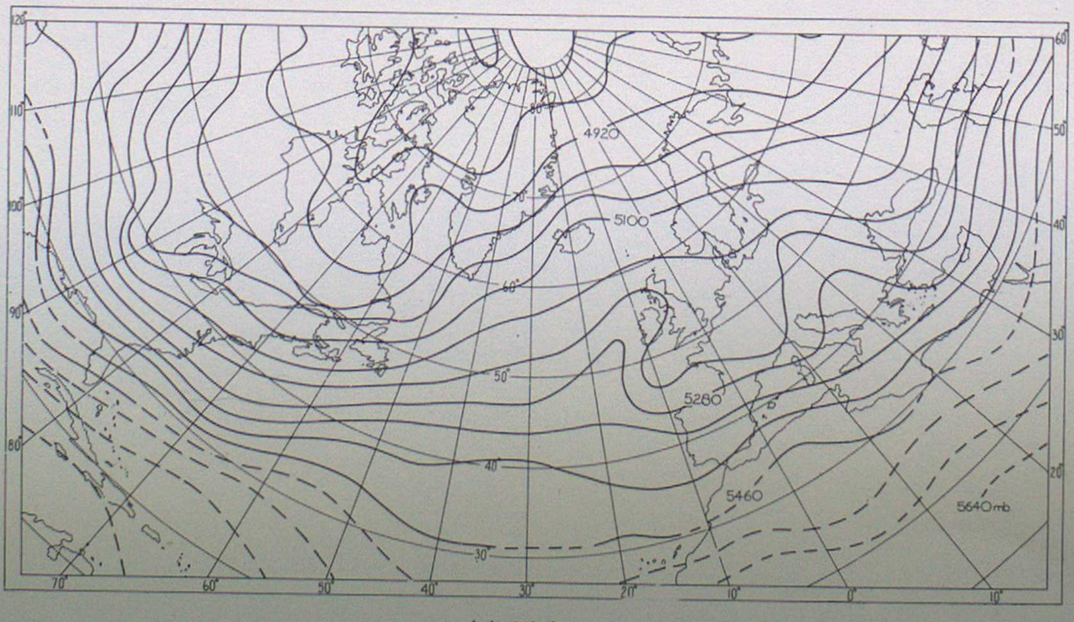
FIGURE 12.46 *Five-year 1000–500-millibar thickness, October, 1950–54*



(a) Mean

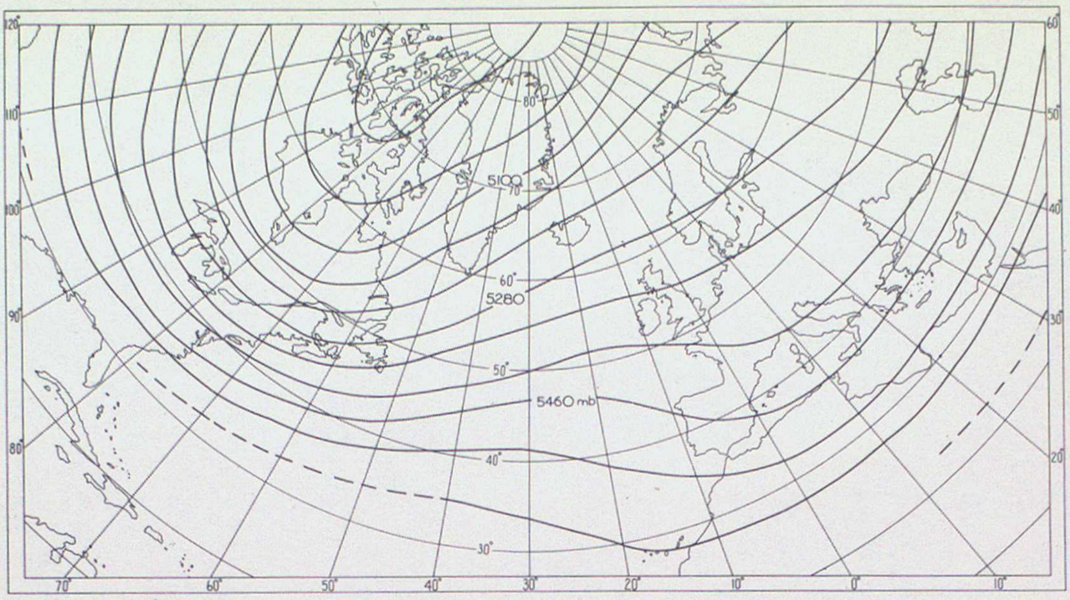


(b) Maximum

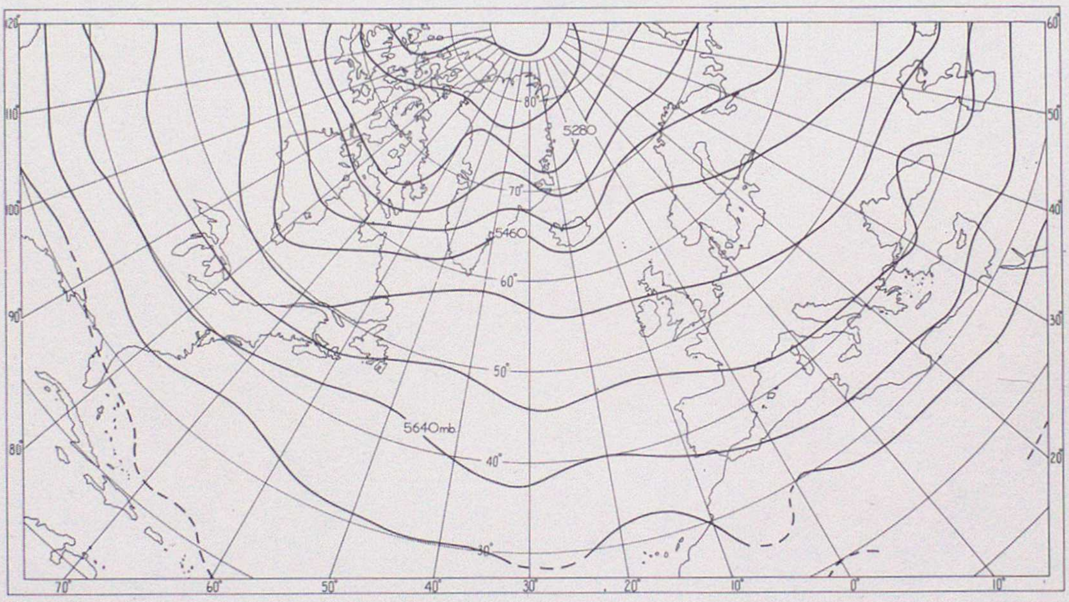


(c) Minimum

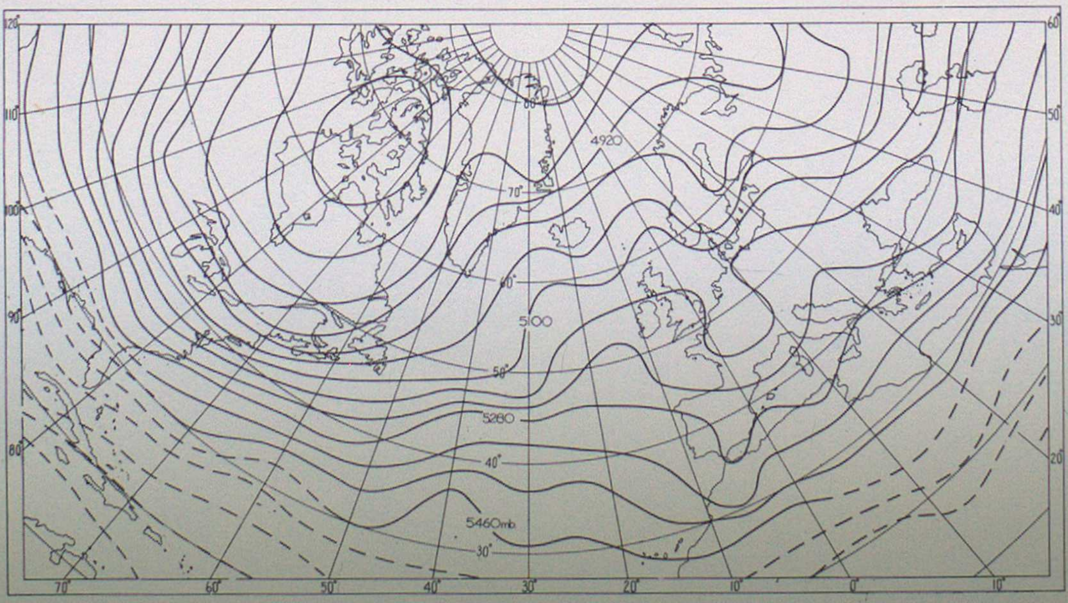
FIGURE 12.47 *Five-year 1000–500-millibar thickness, November 1950–54*



(a) **Mean**



(b) **Maximum**



(c) **Minimum**

FIGURE 12.48 *Five-year 1000–500-millibar thickness, December 1950–54*

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