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A SYNOPTIC STUDY OF ANOMALIES OF SURFACE AIR TEMPERATURE OVER THE ATLANTIC HALF OF THE NORTHERN HEMISPHERE

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A SYNOPTIC STUDY OF ANOMALIES OF SURFACE AIR TEMPERATURE OVER THE ATLANTIC HALF OF THE NORTHERN HEMISPHERE

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

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

Introduction.—A good deal is known about the yearly variation of air temperature at the ground surface over the world, while the diurnal temperature variation has also been studied extensively. The present work deals with temperature variations on an intermediate time scale. The effect of the diurnal variation and any other short-period fluctuation has been eliminated by averaging the observations over periods of five days, while annual variations have been removed by subtracting from the observed five-day mean values the appropriate normal value. Thus the charts discussed here distinguish the geographical areas which are unseasonably warm from those which are unseasonably cold.

Before the temperature anomaly charts could be produced, the normal air temperature had to be estimated for each of a network of stations covering the Northern Hemisphere for each of the 73 non-overlapping five-day periods which cover the year. This ground-work has been described by Craddock,[1,2*] the essential feature being that for every station the annual temperature variation is represented by the best fitting two-term harmonic form.

The actual five-day mean temperatures were found for a network of about 240 stations covering the Atlantic sector of the Northern Hemisphere. Values observed twice daily were copied from the reports of synoptic broadcasts received at the Central Forecasting Office and were averaged. From each five-day mean value the corresponding normal was subtracted to give the anomaly.

The work of finding a suitable method for estimating the five-day temperature normals and carrying out the actual estimations on a hemisphere-wide scale was carried out during 1954. The normals were mostly derived from data for the period 1921-40, that being the latest for which adequate data were available (mostly in the Smithsonian World Weather Records), but it is intended that as the network of normals is amplified, as will certainly be necessary, data for the full international period 1921-50 should be used wherever possible. A programme of synoptic study, involving charting (*a*) the normal temperature for each five-day period, (*b*) the actual mean temperature for the same period, (*c*) the temperature anomaly and (*d*) the total rainfall in that period, was started from 1 May 1955, the first five-day period being 1–5 May, and since then

* The index numbers refer to the bibliography on p. 6.

has been carried on currently, so that the series up to date covers more than a year. These charts are discussed weekly at the Central Forecasting Office, Dunstable, together with charts showing once daily the distribution over the Northern Hemisphere of the surface pressure, the height of the 500-millibar surface and the 1000–500-millibar thickness.

The next section describes the main changes in the surface temperature anomaly patterns during the year May 1955 to April 1956. The area studied always included Europe and the eastern Atlantic, and by July 1955 was extended to cover the whole North Atlantic, North America east of the Rocky mountains, and western Siberia. The description deals mainly with about ten major anomalous areas, each of which dominated the pattern over much of the region. These areas can be followed without much difficulty from chart to chart, and most of them lasted more than a month.

Charts of the five-day mean air pressure are published monthly by the German Weather Service.[3] These charts cover an area extending from Labrador to European Russia and unlike our temperature anomaly charts cover overlapping five-day periods centred on each calendar day. They are not received at Dunstable early enough to be used at the weekly discussions, but it is interesting to see how far the significant features of the temperature anomaly pattern can be explained in arrear in terms of the five-day mean pressure field.

The sequence of anomaly patterns during the year May 1955 to April 1956.—The first temperature anomaly charts to be drawn showed several striking and rather surprising features. The patterns were not only unexpectedly simple and well defined but were on a very large scale. The charts were clearly divided into regions of positive and negative anomaly which individually covered large areas. The size of these areas in general ranged from that of the British Isles to that of the continent of Europe. The chart for 21–25 May (Figure 1) illustrates in a striking manner the large scale of the patterns.

The very large anomalies recorded at the centres of many of the warm and cold areas were a further unexpected feature. The cold area over Europe in Figure 1 had a maximum value of −9°C.

On the temperature anomaly charts, odd value isopleths are drawn at intervals of 2°C. and zero isopleths are shown as pecked lines. The maximum value at the centre of each area is shown to the nearest whole degree.

European cold area† (6 *May*–4 *July*, 1955).—The charts for May were dominated by a cold area which first appeared near Iceland. It extended southwards across the British Isles and then moved east, expanding and intensifying, until by the end of May its eastern boundary had reached the Urals.

This anomaly appears from the pressure charts to have been associated with persistent northerly advection behind a centre of low pressure which appeared off the Norwegian coast by 9 May and later drifted eastward to north Russia

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† A large-scale pattern such as this which persisted for several weeks and which moved with some degree of continuity seemed worthy of further study. An investigation was made to determine whether any such cold areas had affected Europe in previous years. Data for Kew and Potsdam suggested that between 1901 and 1940 there were two years, 1923 and 1928, in which a similar cold area affected Europe in May. In both these years the cold May at Kew was followed by a cool June and a warm July. It was later found that the same sequence occurred in 1955.

FIGURE 1—TEMPERATURE ANOMALY IN °C., 21–25 MAY 1955

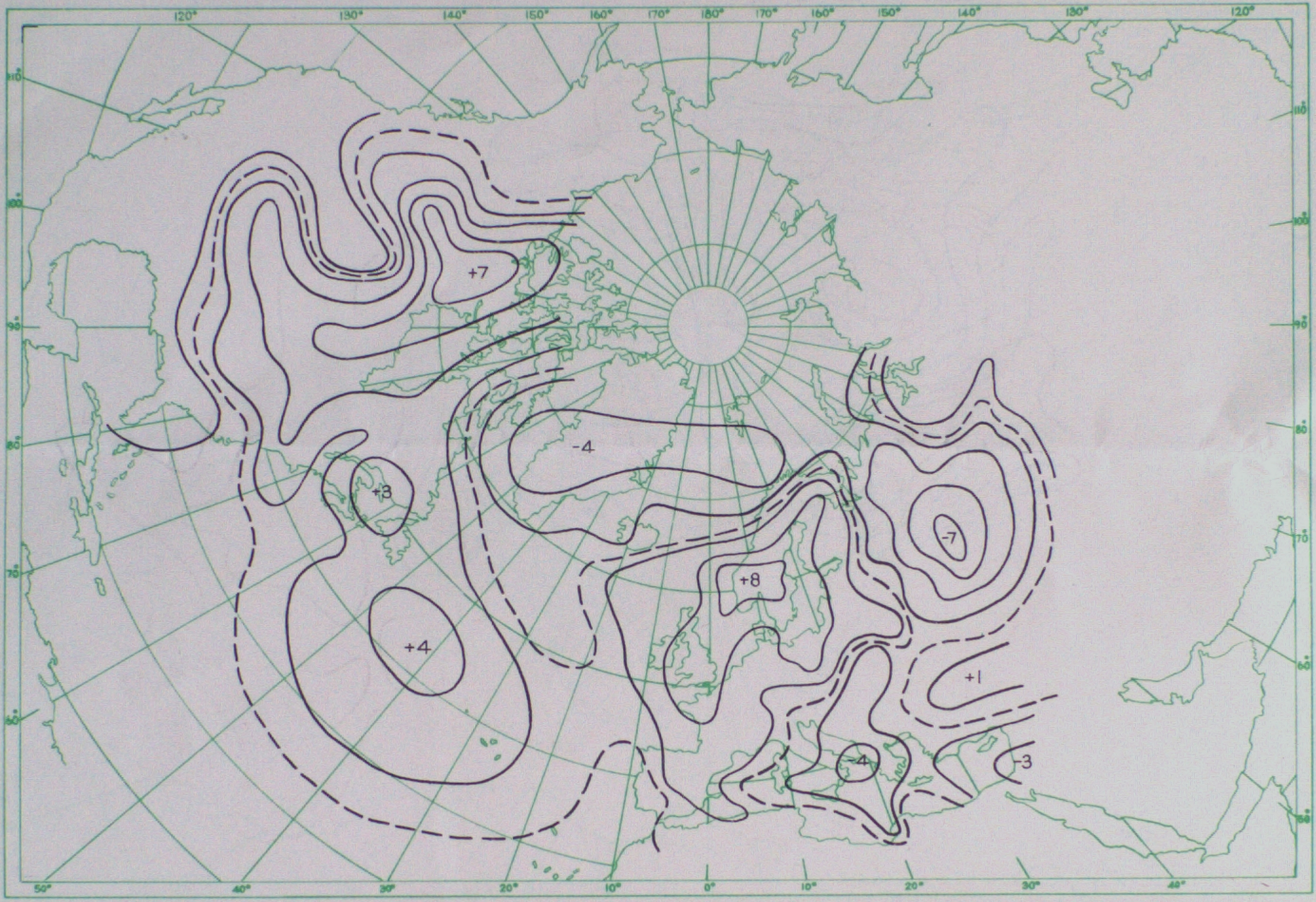

FIGURE 2—TEMPERATURE ANOMALY IN °C., 10–14 JULY 1955

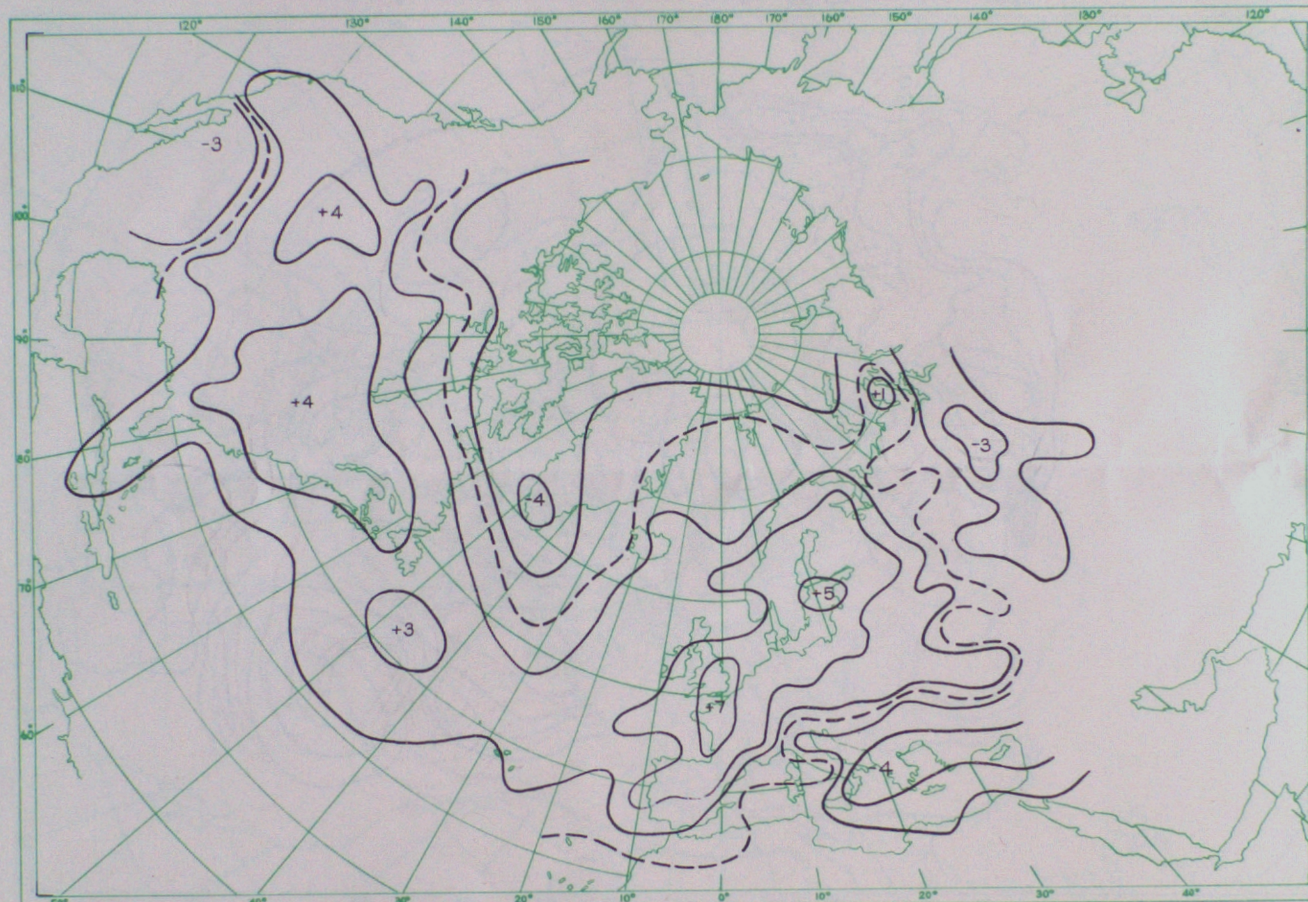

FIGURE 3—TEMPERATURE ANOMALY IN °C., 19–23 AUGUST 1955

FIGURE 4—TEMPERATURE ANOMALY IN °C., 23–27 SEPTEMBER 1955

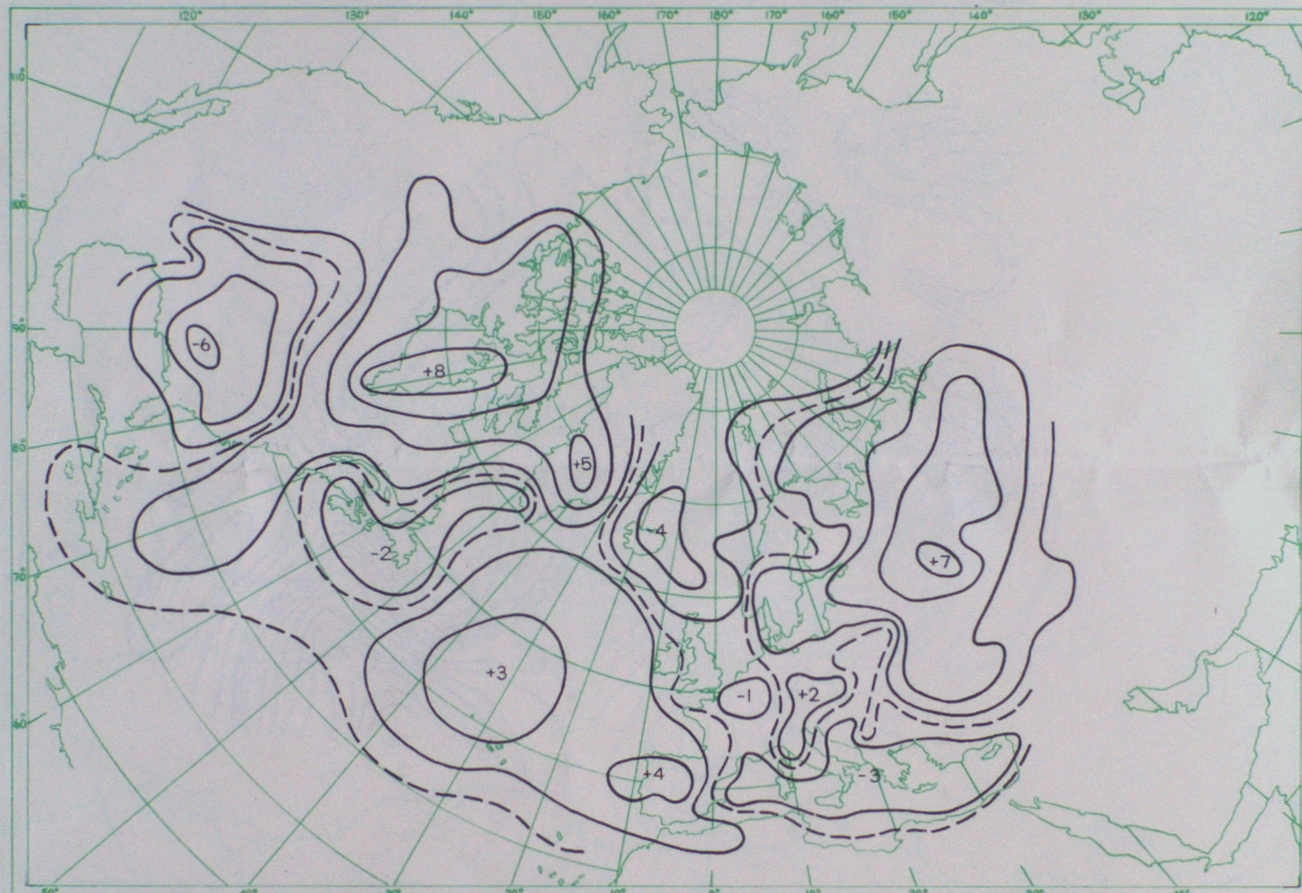

FIGURE 5—TEMPERATURE ANOMALY IN °C., 13–17 OCTOBER 1955

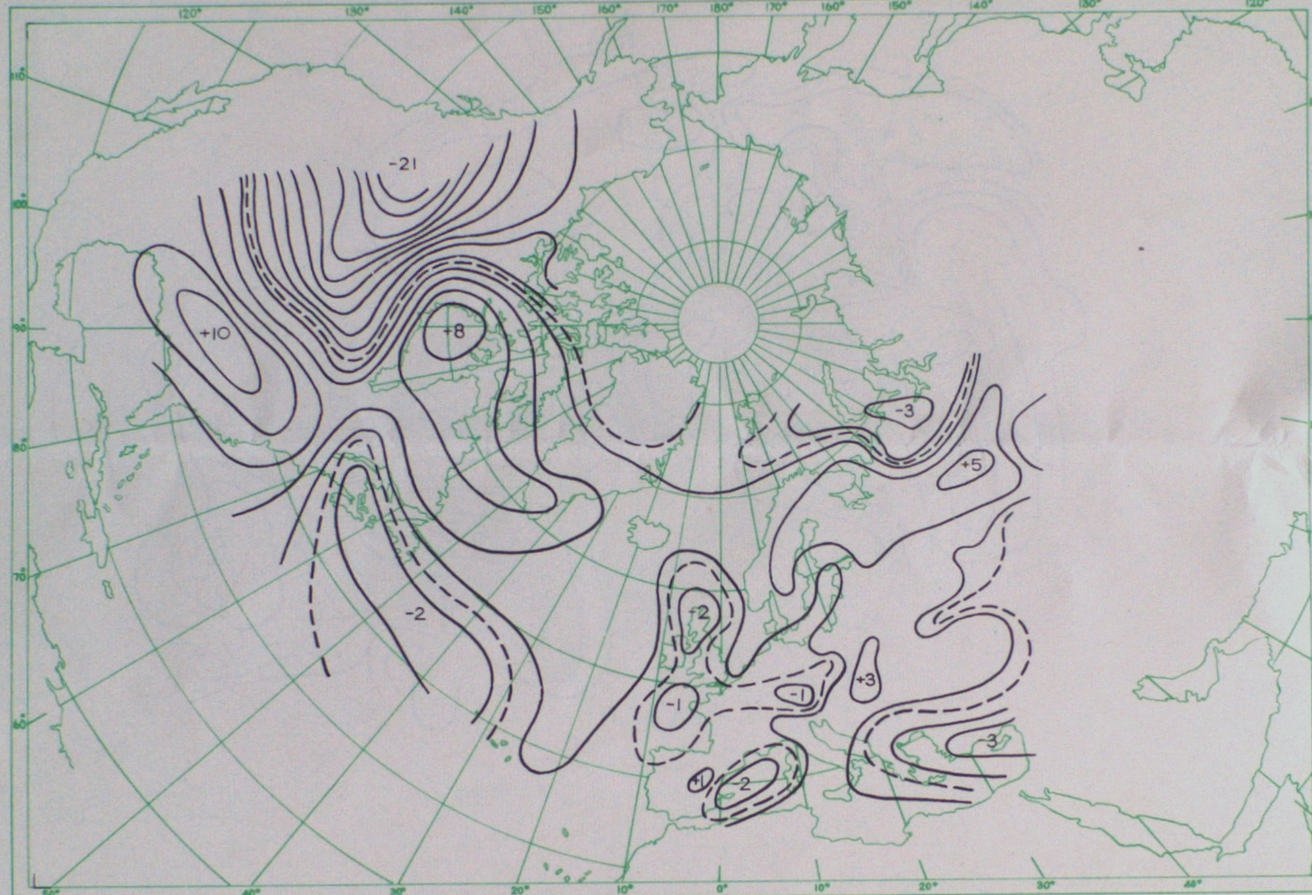

FIGURE 6—TEMPERATURE ANOMALY IN °C., 12–16 NOVEMBER 1955

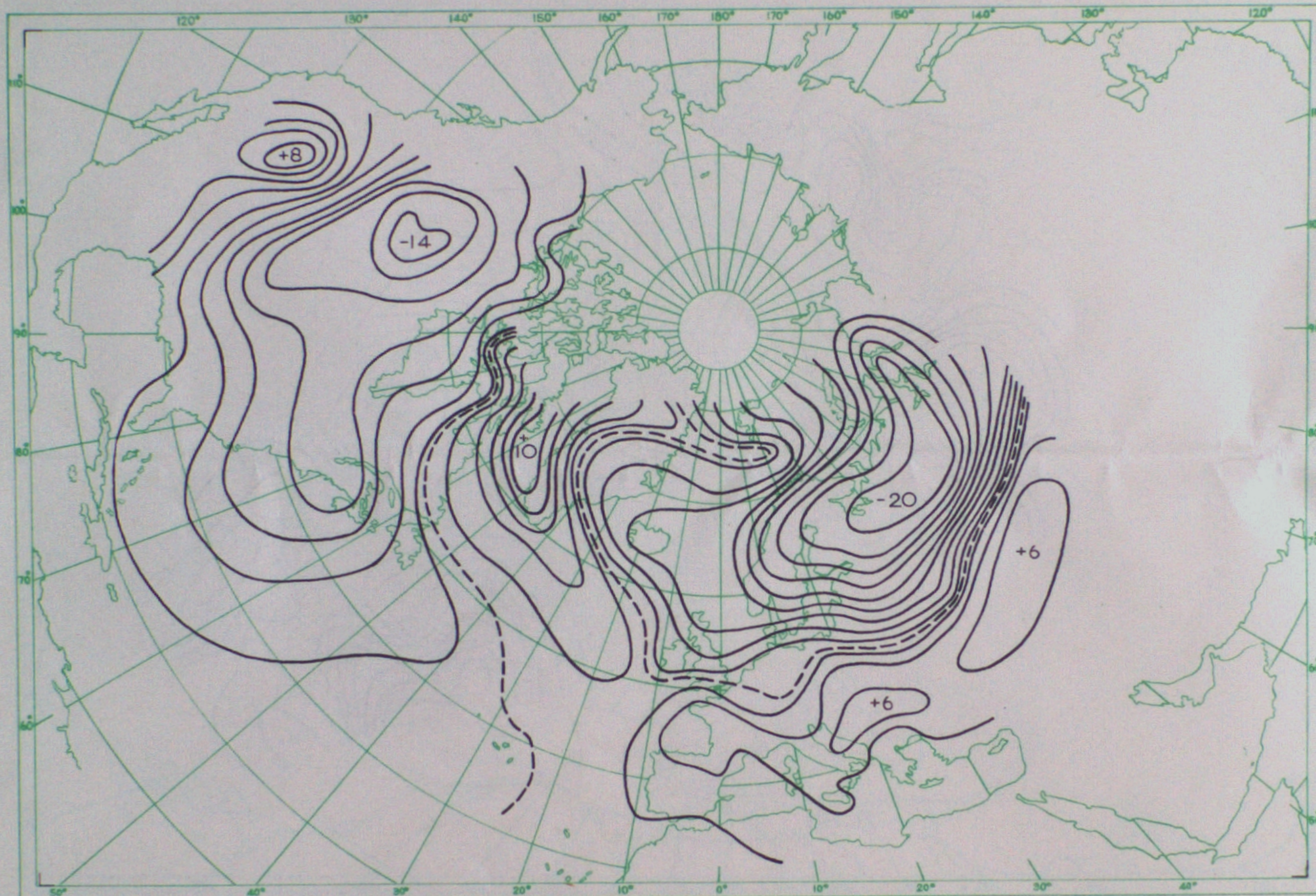

FIGURE 7—TEMPERATURE ANOMALY IN °C., 17–21 DECEMBER 1955

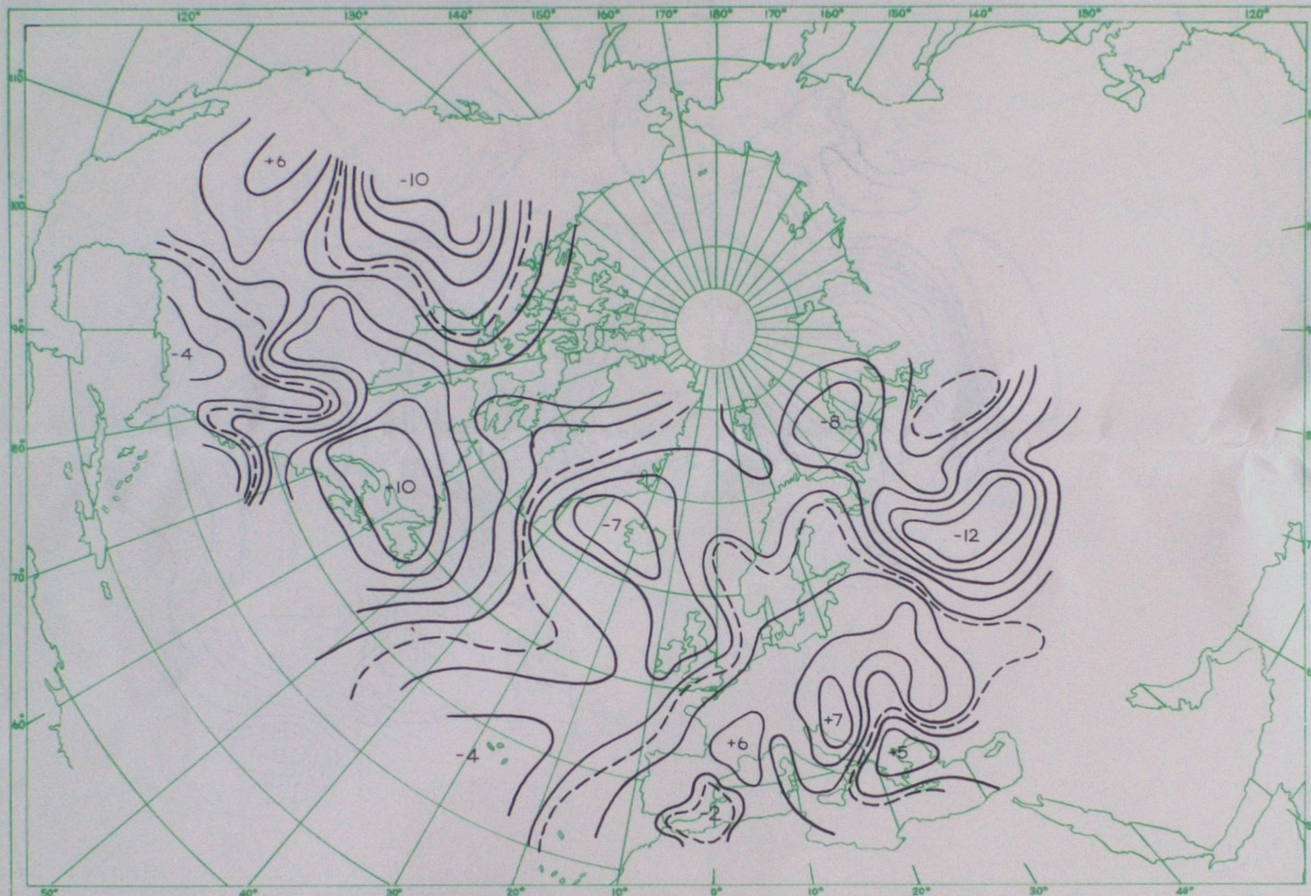

FIGURE 8—TEMPERATURE ANOMALY IN °C., 11–15 JANUARY 1956

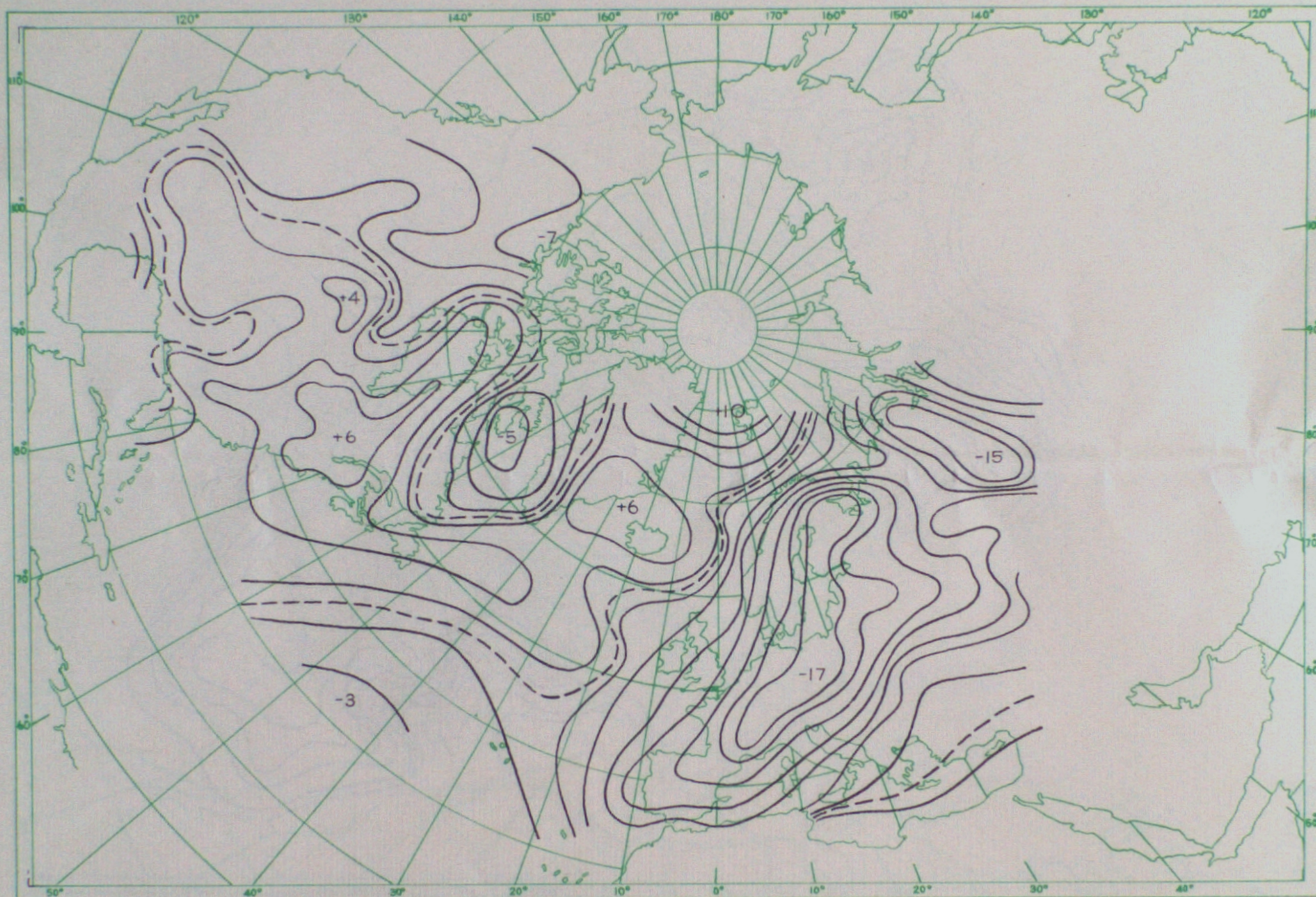

FIGURE 9—TEMPERATURE ANOMALY IN °C., 10–14 FEBRUARY 1956

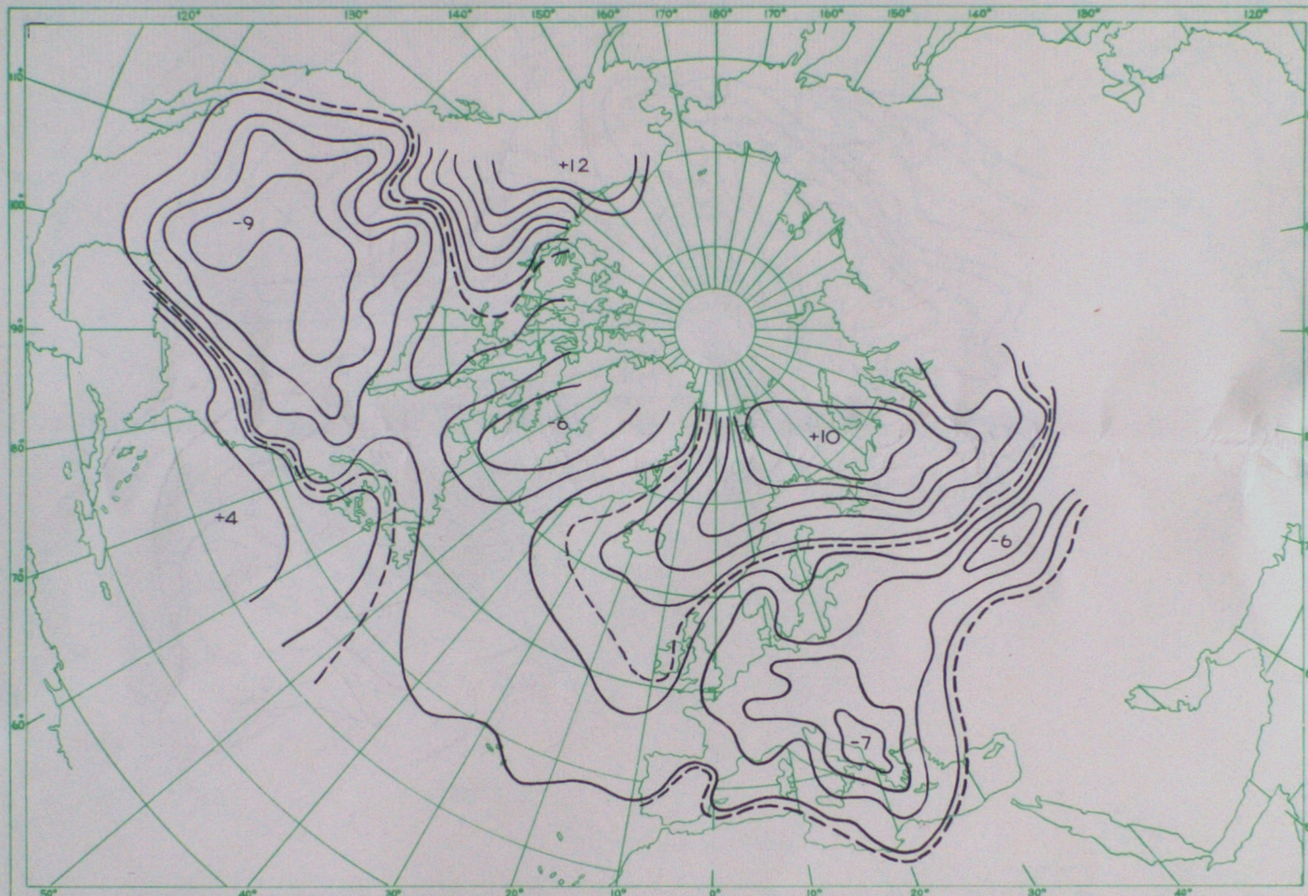

FIGURE 10—TEMPERATURE ANOMALY IN °C., 12–16 MARCH 1956

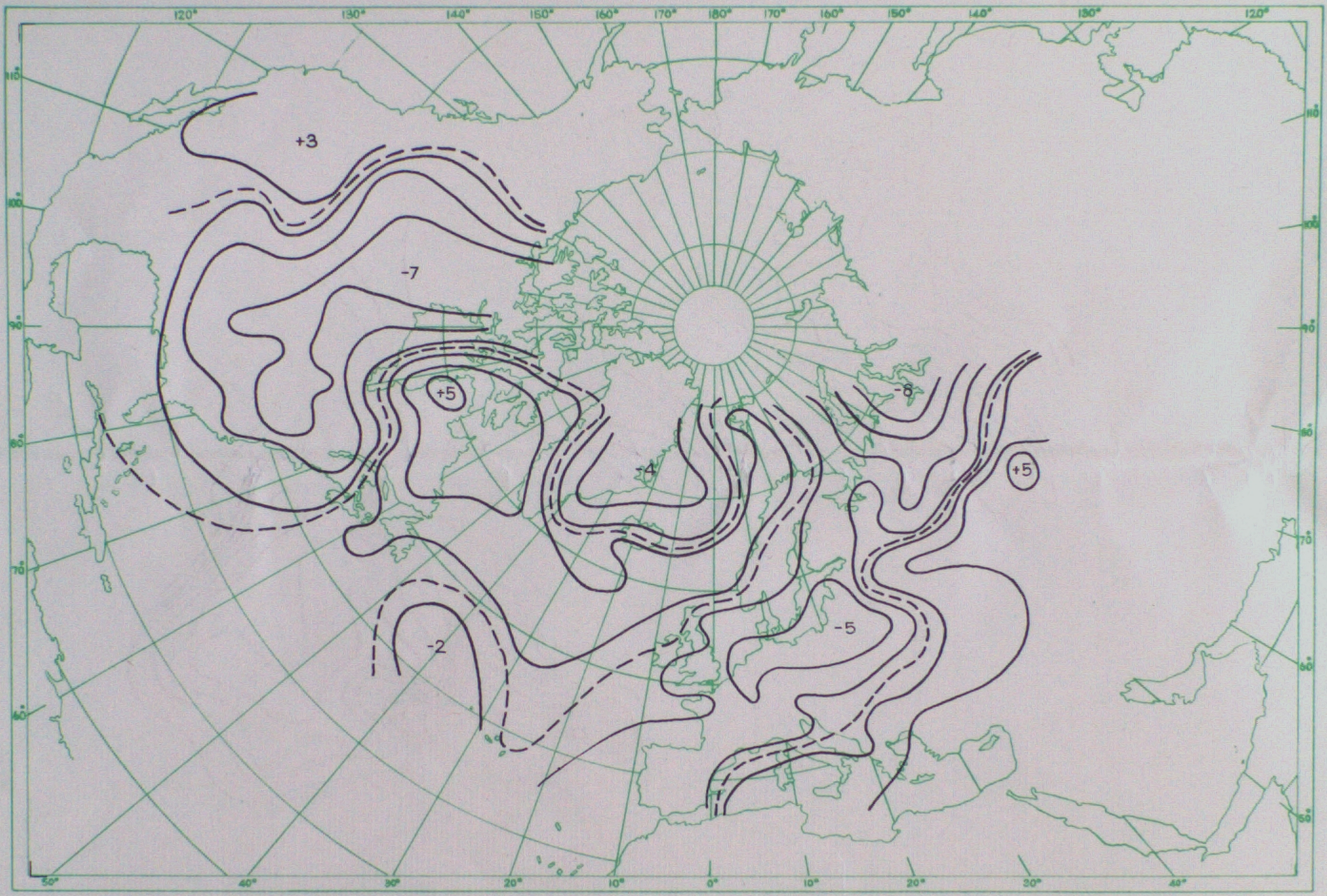

FIGURE 11—TEMPERATURE ANOMALY IN °C., 21–25 APRIL 1956

and there intensified. This low decayed on 28 May, but another lasted over north Russia from 7 to 22 June. The cold anomaly, however, extended over a much larger area than that affected by northerly advection and lasted for about a fortnight after the advection had ceased.

In early June, this cold area covered most of Europe, though a warm area persisted over southwest Europe with little interruption from 1 May to 9 July. Towards the end of June an extension of the European cold area from Scandinavia to Greenland became a persistent feature whilst the original cold area weakened and dispersed in early July.

Greenland cold area (25 *June*–23 *August*).—The cold area over Greenland continued throughout July and the first half of August. The chart for 10–14 July (Figure 2) gives a good indication of its size and shape.

This Greenland cold area shows no obvious connection with the five-day mean pressure gradient which during late June and early July was mostly weak easterly or southerly, or else indefinite.

Trans-Atlantic warm area (10 *July*–7 *September*).—By 10–14 July (see Figure 2) a large warm area had formed extending from east America across the Atlantic to Scandinavia. This area persisted as a major feature for nearly two months. It was disrupted by cold areas in only three periods, twice south of Greenland and once in the longitude of the British Isles. The chart for 19–23 August (Figure 3) shows the warm area stretching from the west coast of America to the Urals.

This warm anomaly was associated with a well-developed Azores high. Moving anticyclones crossed the British Isles into Scandinavia, and by late July the five-day mean high, still with its main centre northwest of the Azores, had an extension northeastwards across the British Isles to Finland. This extension was broken on 6 and 7 August, and the warm anomaly also broke down over Europe in the period from 4–8 August. The high over Scandinavia and the warm anomaly over Europe then became established again ; the warm anomaly disappeared over America early in September and the Scandinavian high declined about the same time but the warm anomaly over Europe persisted subject to gradual encroachments until late October.

Mediterranean cold area (30 *July*–17 *October*).—At the beginning of August a cold area formed over southern Europe and moved slowly southwards to the Mediterranean by the middle of the month. Although not very intense, it appeared on every chart for the next two and a half months with some variation in size and position. The chart for 19–23 August (Figure 3) shows the cold area centred over Greece. This cold anomaly is not readily explicable in terms of the five-day mean pressure charts, which during most of the period showed only indefinite gradients over the area.

During September, a cold area formed over America disrupting the western end of the trans-Atlantic warm area. Over America and Russia there were rapid changes in pattern from one period to the next, intense warm areas being replaced by cold and vice versa. At the same time a warm area persisted over the Atlantic. The chart for 23–27 September (Figure 4) illustrates this phase. The cold area over Russia had replaced a warm area of comparable size on the preceding chart.

Canadian warm area (3–27 *October*).—The patterns over America became more stable during October, a warm area covering most of Canada and the northern part of the United States.

The central Atlantic continued warm whilst a cold area persisted near Iceland. The chart for 13–17 October (Figure 5) shows these features and also the Mediterranean cold area just before dispersal.

During early November the patterns became unstable over the Atlantic, Europe and Russia. In the American sector the warm area persisted over eastern Canada whilst cold areas appeared over the Rockies.

Rockies cold area (12 *November*–21 *December*).—About mid-November an intense cold area suddenly formed over the Rockies with a maximum anomaly of −21°C. (see Figure 6). This feature dominated the American sector for over a month extending southeast at times to the east coast and beyond.

Russian cold area‡ (17 *November*–31 *December*).—At about the same time a cold area formed over Russia and became a persistent feature until the end of December. During this period the maximum anomaly increased from −8°C. to −20°C. and the area extended westward at times to Greenland and the British Isles. At the same time there was a marked tendency for a warm area to persist in the region of Hudson Bay and over the Atlantic. The chart for 17–21 December (Figure 7) shows the Rockies and Russian cold areas at their maximum eastward and westward extension respectively.

The Russian cold area is only rudimentary on the chart for 12–16 November whereas on that for 17–21 November negative anomalies cover nearly all Europe. During the period of change a high was centred over the British Isles and the extension of the cold anomaly over western Europe may have been partly due to advection on the periphery.

The cold area broke down over western Europe towards the end of December as a result of westerly advection associated with intense cyclonic activity near Iceland.

Nova Scotia warm area (6–30 *January* 1956).—Early in January a warm area formed over Nova Scotia and persisted to the end of the month. The chart for 11–15 January (Figure 8) shows this feature and also a cold area near Iceland which was associated with it for most of the period. This anomaly seems to have been due to persistent advection across Labrador of relatively warm air from the open sea. The patterns over Europe were rather unstable at this time.

European cold area (21 *January*–1 *March*).—During the last week in January an intense cold area with a maximum anomaly of −18°C. developed over northeast Europe and spread rapidly westwards to cover the continent. The chart for 10–14 February (Figure 9) shows this feature and also a warm area over Spitzbergen which persisted over much the same period. Violent fluctuations were taking place over America. The development of the European cold area seems to have started with a northerly outburst behind a low centred over Scandinavia about 20 January, but by the 24th this had declined and had been replaced by a high which persisted with variations until mid-February. The cold anomaly lasted until the end of February, but early in March was broken down for five days only by advection of warm air from the west.

‡ The Russian cold area was not, as might be supposed, mainly associated with anticyclonic conditions. It developed as a result of intense cyclonic activity near the Russian Arctic coast which brought down cold air from the polar regions. Except for the period 17–21 December the area continued mainly cyclonic.

The Rockies cold area was, on the other hand, associated with anticyclones during most of its lifetime.

European cold area (7 *March*–30 *April*).—By 7 March a less intense cold area had established itself over most of Europe. The new cold area intensified and retreated to eastern Europe by the end of the month. The chart for 12–16 March (Figure 10) shows this feature and also a warm area over the Barents Sea which persisted over much the same period. The resurgence of the European cold area and the warm area further north seems to have been due to advection round an anticyclone over south Scandinavia. The patterns over America continued to fluctuate widely.

Early in April the cold area returned to western Europe. The chart for 21–25 April (Figure 11) shows the elongated shape of the area during the latter half of the month. Over America, a warm area persisted in the region of Hudson Bay for the first three weeks of the month.

Summary.—This completes an outline of most of the salient features of the temperature anomaly charts covering the year.

There is evidently a relation between the patterns on these charts and the character of the general circulation, though the nature of the association varies with place and time of year. For example, a large negative surface temperature anomaly is generally associated with a persistent trough or cold pool in the 1000–500-millibar thickness pattern, while in winter over the continents a positive temperature anomaly is usually associated with the persistent advection of air from the direction of the open sea and a negative temperature anomaly with stagnant air, or air which has had a long land track. With more experience we should be able to describe these relations more fully.

It is, however, obvious that the relationship between the temperature anomaly patterns and the daily surface pressure patterns is quite loose and changeable.

The bigger anomalies usually occur over the continents rather than over coastal or sea areas.

Comparison between temperature anomaly and mean pressure charts.—Finally, a general comparison was made between the series of temperature anomaly charts and a series of five-day mean pressure charts for the same non-overlapping periods. The latter series was obtained from the German series covering overlapping periods by masking the charts centred on intermediate days. When this was done it appeared that the patterns on the temperature charts show a good deal more persistence than those on the pressure charts. Often a new temperature pattern would be accompanied by advection in the right direction on the pressure chart, but the temperature pattern would persist after the pattern on the pressure chart had become something quite different. Occasionally, too, a temperature pattern would occur first, and advective flow to maintain it would develop later.

Discussion.—The outstanding impression of the year's charts, which the preceding section tries to convey, is that the patterns of temperature anomaly are large, slow-moving and long-lived, with a good deal more stability than might have been expected. There are two possibilities for using them as a tool in long-range forecasting.

For the inside of a large area of positive or negative anomaly, a "persistence" forecast that the present anomaly will continue for several days to come must have quite a high expectation of success. Such forecasts may be useful for continental areas especially when the anomaly is big enough to make it the most important feature of the local weather, but are likely to be less useful over the British Isles, since the country is often near the boundary of two large areas of opposite temperature anomaly, so that a small change in the boundary may alter the British weather from warm to cold, or vice versa.

A more attractive possibility is to use the temperature anomaly pattern as an indicator of the state of the general atmospheric circulation. If we are justified in doing this, then we may be able to apply arguments concerning the general circulation to data for years before the era of upper air analysis.

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