CHAPTER 7

ANTICYCLONES AND RELATED FEATURES

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CHAPTER 7

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7.1 INTRODUCTION

Current techniques in the use of surface and upper-air charts, and in the application of numerical models of atmospheric behaviour, are reasonably satisfactory in the general prediction of the formation, development and movement of anticyclones and ridges. However, the detailed weather accompanying these systems is often difficult to forecast. As a consequence of the subsidence which occurs through much of the troposphere in anticyclones, the weather expected to accompany an anticyclone is very largely determined by conditions in the lowest thousand metres or so of the atmosphere. It is only when these conditions can be estimated in some detail that the weather conditions can be forecast accurately. To a large extent the weather of the anticyclone is essentially confined to lower levels. This is in direct contrast to the weather associated with depressions where the associated general ascent through the lower and middle troposphere leads to the formation and maintenance of weather (that is clouds and/or precipitation) through extensive depths of the troposphere.

Anticyclones are conveniently classed as warm or cold according to the general temperature in the troposphere over them when compared with surrounding areas. This classification will be followed below. (See also Section 2.3.2 of Chapter 2 - Dynamical ideas in weather forecasting.)

7.2 COLD ANTICYCLONES

7.2.1 Mobile type

A cold mobile anticyclone is normally embedded in a strongly baroclinic flow which exhibits only relatively flat wave patterns in the middle troposphere. The surface anticyclone is often sandwiched between two depressions existing in the same general baroclinic current. It often moves at a similar speed and in a broadly similar direction to those of the depressions. A typical thickness pattern associated with a cold mobile anticyclone is shown in Figure 1.

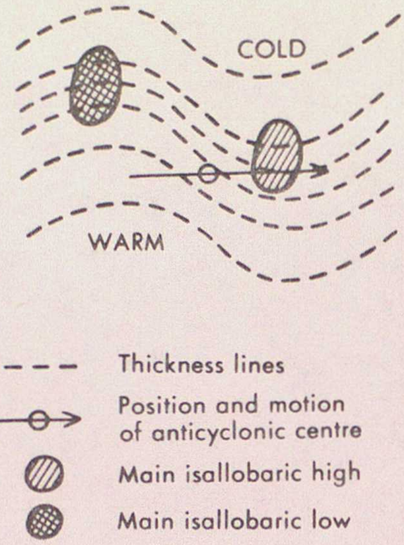

FIGURE 1. Thickness pattern associated with a cold anticyclone – mobile type

The circulation of such cold mobile anticyclones has a barely perceptible effect on the 500-millibar flow and often but little effect as low as 700 millibars. At a place traversed both by an anticyclone and a preceding and a following front, a typical sequence of weather would be as follows. A clearance would follow the cold-front passage as cold air spread in behind the depression. For a time the cold air would deepen and might attain a sufficient depth for the development of instability cloud and precipitation. As the anticyclone moved in, there would be substantial rises of pressure and also marked stabilization of the air in the lower middle troposphere so that, within the central and forward parts of the anticyclone, there would be little low cloud - probably just a little shallow cumulus. Visibilities would be generally excellent. As the anticyclone continued to move across, tendencies would probably quickly become negative and there would often be quite a rapid spread of high cloud soon after the surface centre of high pressure had moved away. Only occasionally might the upper cloud appear before the axis of highest pressure had reached the area. The essence of successful forecasting of weather of mobile anticyclones is usually in the timing of movement. A mobile cold anticyclone provides a short fine interlude between successive depressions. Foreknowledge of this type of weather is often of much importance particularly for operations whose success depends on the completion of some outdoor tasks. As the cold anticyclone produces a relatively short dry episode between what may be relatively prolonged wet spells, its accurate forecasting is not just an academic matter. Much outdoor activity may be accomplished in the brief intervening dry, often sunny, spell. Even near the centre of cold anticyclones, visibilities at night are seldom poor, partly owing to the fact that the recent fresh cold air is often unstable in the lower thousand metres or so and also owing to movement of the system. This movement usually results in but a brief period of slack winds and clear skies. Consequently fog formation is relatively rare and there is scarcely time for an accumulation of much atmospheric pollution.

The cold high remains on the cold side of the cold front so that areas lying in the warm air on the other side of the cold front are not directly affected by the cold anticyclone. There may well of course be secondary effects, for example, those due to the anticyclone causing the cold front to progress more rapidly or more slowly, but these are problems for the general prognostic charts (see Chapter 14 - Surface prognoses).

7.2.2 Slow-moving type

Whereas with the mobile type of cold anticyclone the thickness pattern is only slightly distorted, the slow-moving type has either a very distorted ridge-trough pattern or a confluent trough pattern of thickness lines. A typical thickness pattern is shown in Figure 2.

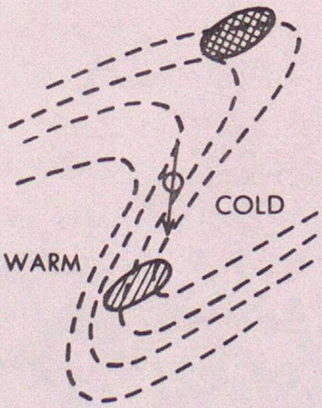

FIGURE 2. Thickness pattern associated with a cold anticyclone — slow-moving type

When the thickness patterns display the distorted ridge-trough or confluent trough pattern there is generally an associated outbreak of polar air. Such outbreaks may occur in the rear of fairly deep depressions and they then often arrive as a broad deep stream, sometimes several hundred kilometres in width, and often extend in depth throughout the whole of the troposphere. With such major changes in tropospheric flow there is naturally an associated change of synoptic type. With the cold polar outbreak a surface anticyclone often appears or intensifies. Initially the anticyclone is closely associated with the baroclinic zone but, if the anticyclone continues to exist for several days, the degree of baroclinicity over its central areas tends to become weaker. At this stage the upper-air temperatures will probably have become higher than in the surrounding areas and the anticyclone is no longer readily distinguishable from the 'warm' type.

These cold anticyclones tend to move fairly quickly in the early stages of the polar outbreak and, in this period, their movement near the British Isles is often along a heading between about east-south-east and south but occasionally the movement may be somewhat to west of south. When the polar outbreak is well established and is losing its initial impetus after penetrating well to the south, any associated cold anticyclone usually becomes much more slow moving.

During the early periods of their existence the central regions of these cold anticyclonces are often almost cloudless with a brilliantly clear atmosphere. The forward eastern regions are much closer to the preceding thermal trough and in these areas there is sometimes a fairly sharp transition between the showery weather associated with the deepening cold air in the rear of the trough and the dry stable conditions associated with the anticyclone proper. Topography sometimes has an important bearing on this demarcation between showery and dry conditions. For example a deep northerly airstream flowing across the North Sea, which is relatively warm and so able to maintain deep convection, leads to very frequent showers near the east coast of the British Isles. Further inland the showers tend to be much less frequent and sometimes the weather is quite dry. When rain has fallen and the ground and lower atmosphere have been thoroughly wetted, fog may form after one night's radiational cooling.

Towards the southern and western flanks of the anticyclone the weather is usually very quiet. There may, however, be extensive sheets of upper cloud near the western periphery of the anticyclone, particularly if a disturbance is embedded in the strong baroclinic zone which usually exists to westward of the cold anticyclone.

In the central regions of mature cold slow-moving anticyclones the amounts of low cloud may lie anywhere between nil and a complete cover. Low-cloud bases are not usually particularly low and bases of about 800 to 1200 metres are probably typical of stratocumulus cloud sheets. Low-cloud conditions depend critically on the distribution of temperature and humidity in the lowest 1200-1500 metres and sometimes the recent fetch of the low-level winds is important. Low-cloud conditions in these anticyclones do not always show a substantial diurnal variation but in some marginal cases cooling at night or heating and convection from the ground during the day may have an important effect. Findlater[1] has investigated the variations in the thermal structure of this lower layer and the associated changes in cloud amount (some further remarks on this topic will be found in 7.5. In the central regions of anticyclones, drizzle, sometimes heavy, may occur if the inversion is not too low (say at 900-1200 metres). The problem of forecasting the formation or dissipation of non-frontal layer clouds is more fully discussed in Chapter 19 - Clouds and precipitation. There are also some seasonal variations in low-cloud conditions. Although there is some tendency for the central regions to be either almost clear of low cloud or almost completely overcast, a half cover of cloud is quite common in spring and summer in the late morning and afternoon. In late summer and early autumn an overcast is rare.

In the mature cold slow-moving anticyclone the air has not recently arrived from the polar regions and visibilities near land masses will often have decreased to a few kilometres because of the accumulation of atmospheric pollution in the lower stable layer. In very stagnant conditions with an inversion reaching down to ground level in winter there may be very heavy concentrations of atmospheric pollution near built-up areas reducing visibilities to below fog limits. True water fogs can also be expected at times, more particularly in autumn and winter, in cold slow-moving anticyclones, although not as extensively as in the warm type.

When the central regions of cold anticyclones are cloudless, strong outgoing nocturnal radiation will usually lead to low night minimum temperatures, both in the screen and on the grass, particularly when fog does not form. These are the weather situations for late spring frosts and early autumn frosts. In the depths of winter night minima may be exceptionally low.

7.3 WARM ANTICYCLONES

The major features of the long-wave pattern associated with well-marked and extensive warm anticyclones are such that the warm anticyclone is usually a slow-moving and often long-lived feature of the synoptic chart - at least for several days, sometimes even weeks. In many cases a warm anticyclone constitutes a part of a blocking pattern (see 7.6). The adjective 'warm' applies to the middle tropospheric air masses which are warm and indicated on upper-air charts by a well-marked ridge or set of closed 1000-500-millibar thickness lines and contours (see Figure 3).

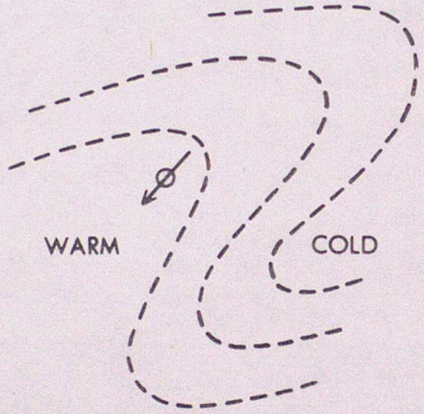

FIGURE 3. Thickness pattern associated with a warm anticyclone

The air in the lowest thousand metres or so may be either warm or cold. In summer, warm anticyclones often cause warm, dry, sunny weather in the British Isles. Visibilities are then generally moderate to good but, around dawn, there may be a few fog or mist patches which are usually soon dispersed by insolation. By contrast a warm anticyclone in winter may be associated with some of the coldest surface weather in the British Isles. If the cell is centred over the British Isles and the ground is cold there may be clear but very cold frosty nights and sunny days. With higher dew-points there may be persistently foggy periods which in some areas may not clear by day - even for several days. With persistently very slack surface winds and intense stability in the lower layers there may be great accumulations of atmospheric pollution. In midwinter when there is a belt of high pressure extending from northern Europe westwards to the British Isles with the axis of the ridge or anticyclone situated towards the north of the British Isles and when the Mediterranean and southern Europe are covered by an extensive low-pressure area, persistent easterly winds may affect the

British Isles. When much of the ground in north-western Europe is frozen, as in the latter part of a severe winter, these easterlies bring some of our coldest weather. This cold weather may be mainly dry with only small amounts of low cloud or, on the other hand, the weather may be mainly overcast with periods of precipitation, depending on the length of the sea track. In late winter or early spring this precipitation may fall as continuous snow or as very frequent snow showers, particularly in eastern districts. Some further remarks on these easterly situations are contained in Chapter 19 - Clouds and precipitation.

Sometimes, the north-westerly quadrant of a warm anticyclone may be invaded by a thermal trough. The warm high retreats, often south-westwards and with marked diminution of central pressure, as the trough advances and moves through the area formerly occupied by the warm anticyclone, bringing a period of unsettled weather. In some cases there is renewed rise of pressure in the rear of the thermal trough, a new anticyclone is built up and high pressure is re-established in a location close to that previously occupied by the old warm high which, although initially it moves away as the trough advances, later often turns, migrates towards and is finally absorbed by the newly developing anticyclone. The net result is the re-establishment of a warm high. This sequence of events results in the transport of a fresh air supply at lower levels in the warm high and, where there had previously been poor visibility due to the accumulation of pollution, this results in an improvement of general visibilities which, in time, may again deteriorate as pollution once more accumulates.

The problem of forecasting cloud cover in the central region of warm anticyclones is sometimes difficult. There seems to be a delicate state of balance between the various processes leading to the formation or dissipation of extensive layer cloud at low levels in anticyclones. The subject is rather more fully discussed in Chapter 19 - Clouds and precipitation. There are usually either very small amounts of low cloud or almost a complete cover. Thus when the forecaster has doubts as to whether there will or will not be low cloud a compromise forecast of about half cover will be seldom correct - a decision should be taken to forecast small or large amounts.

7.4 RIDGES

In many cases regions of rising pressures produce only ridges of high pressure and separate closed anticyclonic cells do not occur. Ridges are more frequent than anticyclones. The weather associated with ridges shows a marked similarity to that in the type of anticyclone which would form if the development of high pressure continued sufficiently. Accordingly some of the comments in the preceding sections may be regarded as applicable also to ridges. The orientation of the major axis of a ridge often has an important effect on associated weather and some comments on this aspect are given below.

In the forward regions of cold-air ridges which have an approximately north/south axis there is often considerable southward penetration of cold unstable air with associated showers. Nearer the axis of the ridge the air usually shows marked stabilization and the depth of convection decreases. If there has previously been considerable convection, this stabilization may lead to the spreading-out of the convection cloud under an inversion (perhaps still as high as 700 millibars). If the ridge is mobile and there is a developing disturbance moving in behind the ridge, there is often an appreciable invasion of the ridge by the associated upper clouds. In some cases this penetration will reach as far as the surface ridge line and occasionally beyond. If, with the development of the ridge with a north/south axis, there is also a marked wave pattern in the thickness lines in phase with the ridge, then such ridges are generally slow-moving and the penetration of the weather associated with any developing disturbance is generally in a more north-easterly direction towards the rear quadrant of the apex of the ridge. In the front south-easterly quadrant there is very marked penetration of cold unstable air to southerly latitudes and at times the penetration of cold air may be to some point west of south. If the location of the axis of the ridge is such that the northerly or north-easterly flow has a marked sea track (for example, down the Norwegian coast or North Sea) before it reaches the British Isles, the shower activity may be frequent and prolonged and the accumulated amounts of precipitation may be considerable in eastern districts.

Anticyclones and related features

A common occurrence over the British Isles is the north-eastward extension of a ridge from the Azores anticyclone. This usually occurs in association with an extensive flow of warm air north-eastwards, and the accompanying warm front gives little precipitation. Such a ridge usually brings a few days of mainly dry weather to the British Isles. In western and south-western districts and areas near the south coast there may be extensive low cloud which sometimes persists by day and by night and, at times, light drizzle or rain may fall near windward coasts and on hills not far inland. When dew-points are appreciably in excess of the adjacent sea temperatures, as in early summer, the cloud base may be very low (say 50-150 metres) covering even quite low hills near coasts, and rather extensive fog patches will occur in many coastal districts and there will be hill fog (see Chapter 20 - Visibility). Well inland and to the lee of the larger masses of high ground (for example, Welsh mountains, Pennines) cloud bases are noticeably higher; insolation will sometimes cause breaks in the low cloud, giving days which are very warm for the time of the year. The low cloud often reforms at night. In suitable conditions the cloud may burn off almost back to windward coasts by day but the cloud must be thin and the advective component light (say $<$ 15 knots at 600 metres) before this could be expected with any certainty in early summer.

On some occasions when the axis of the ridge extending north-eastwards from the Azores anticyclone lies somewhat to the south of the British Isles (for example, over north-west France), minor troughs or disturbances on fronts located along the north-western flank of the ridge may move generally east-north-east or north-eastwards, causing a thickening of the cloud systems and an increase in the amount of precipitation over areas near the track of the disturbances.

On some occasions a ridge extends southwards across the British Isles from an extensive anticyclone located in northern latitudes. The anticyclone is sometimes centred to north of the Arctic circle and it often maintains a general easterly low-level flow from Scandinavia, across the Iceland region and even to Greenland at times. A ridge extending southwards from this anticyclone towards Scotland and the border country will maintain cold (or cool) and often predominantly cloudy weather in eastern districts of Scotland and northern England. In contrast, western districts of those areas and northern Ireland can have some brilliantly sunny and exhilarating weather but, in winter, the nights may be very cold if the wind falls light and the skies remain clear. In such a situation, disturbances moving across the Atlantic from the west towards the British Isles tend to follow tracks rather farther south than usual and southern parts of England may experience unsettled weather from the northern parts of such disturbances.

A variant of this type of ridge is one extending to the British Isles approximately south-westwards from an anticyclone centred near the region of Scandinavia, Finland or north-western Russia. Such ridges tend to dominate the weather over much of the country and any unsettled weather is then usually confined to the extreme south-western districts of England or north-west Ireland and the western fringes of Scotland.

Of the many other types of ridge situations which affect the weather over the British Isles the only one selected for comment in this chapter is the 'col'-like area between pairs of anticyclones and cyclones. These cols tend to be predominantly either cyclonic or anticyclonic according to the shear between the low-level flow on opposite sides of the col. For example, over the British Isles in an anticyclonic type of col between anticyclones centred near the Azores and the Gulf of Bothnia, the air to the north-west arrives predominantly from a south-west direction from the Atlantic whilst that to the south-east is predominantly from a north-east direction from north-western Europe. This situation may cause quite dissimilar weather in, say, southern England and southern Scotland. When a slow-moving upper thermal ridge exists over such a col, that col, although possibly appearing as quite a weak feature on surface charts, may be quite persistent and successfully resist invasion and displacement by air masses involved in the circulation of quite vigorous disturbances associated with the stronger middle tropospheric flow patterns which sometimes exist well to north-west and south-east of the axis of the high-pressure belt. The weather associated with such a col is typically anticyclonic. Thick fogs may form, particularly in the damp air mass, and sometimes they are persistent.

7.5 MESOSCALE FEATURES OF ANTICYCLONES

Problems of forecasting local weather changes in anticyclonic conditions are often tackled by analyses of the limits of cloud and fog systems, haze streams or local wind regimes, and mesoscale discontinuity lines located in this way can be followed from chart to chart on many occasions. Few anticyclones are homogeneous, in particular Findlater[1] showed that marked horizontal temperature gradients exist near the level of the subsidence inversion. Although many such small-scale features can be neglected when problems of large-scale motion are being considered, this is not necessarily so for detailed local forecasting, and analysis of small-scale features, delineated by discontinuity lines, have long since proved their usefulness.

Findlater[2] has shown that some insight into the structure and shape of anticyclones can be gained from a detailed analysis of surface pressures. For example, Figure 4 shows an anticyclone over the British Isles at 0000 GMT on 28 April 1960. Isobars were drawn carefully at intervals of one millibar (using half-millibar isobars as guidance lines in difficult areas). This analysis shows the central area of the anticyclone to be composed of a central cluster of individual cells separated by minor troughs which spiral outwards from the central area. Some of the troughs link up with frontal troughs and others appear to be the remnants of old frontal troughs which were engulfed during the growth of the anticyclone.

Figure 5 shows the same anticyclone 12 hours later, at which time it is apparent that the individual cells of the central cluster have tended to circulate around each other, and the troughs separating them can still be located. Geostrophic trajectories of the air at 600 metres showed that at least two air masses were detectable on this occasion, although the air had to be tracked for two to four days for positive identification. Some of the trajectories are shown in Figures 4 and 5. The meshing together of cold air from Scandinavia and the area north of Iceland with warmer air from mid Atlantic resulted in alternate masses of the two types reaching eastern England. This type of pattern was most distinct during the growth period of the anticyclone. During periods of decay detailed analysis was much more difficult and patterns in the central area were diffuse.

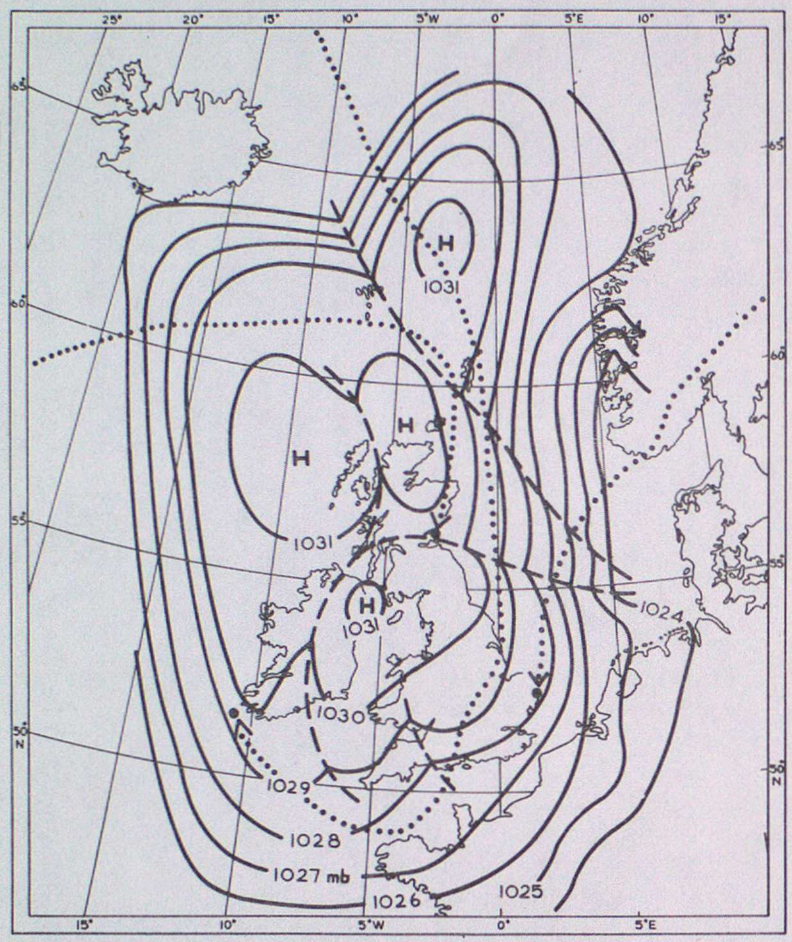

FIGURE 4. Detailed analysis of an anticyclone at 0000 GMT on 28 April 1960, showing a cluster of cells in the central area

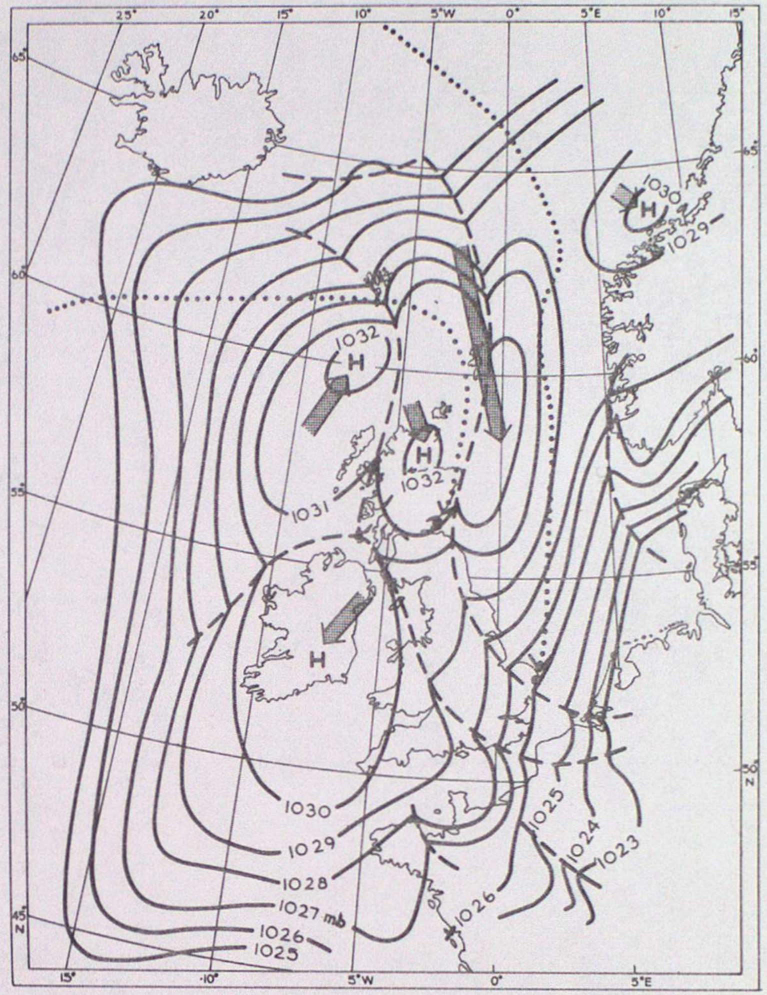

FIGURE 5. Detailed analysis of an anticyclone at 1200 GMT on 28 April 1960, showing the 12-hour displacement of cells in the central cluster

Broad arrows show the 12-hour displacement of centres

——— Isobars at 1-mb intervals — — — — Trough lines •••••••••• Trajectories of air at 600 metres

It is not at present known if the cluster formation is directly linked to variations in cloud, temperature or wind, but increased familiarity with the types of analysis shown in Figures 4 and 5 may lead eventually to the recognition of some associations between them and other weather elements. At the least, a detailed analysis of the topography of surface pressure in anticyclones is a good starting point for detailed local forecasting.

7.6 BLOCKING ACTION

Some remarks on the synoptic evolution of blocking systems have been made in Section 2.15.3 of Chapter 2 - Dynamical ideas in weather forecasting. Sumner[3] has made a statistical study of blocks near the British Isles, and some of the results are mentioned below; the study covered the four years 1949 to 1952 inclusive.

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, for 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 (progressive) and at other times it may be towards the west (retrogressive). Some blocks exhibit various combinations of progression, retrogression or little movement at all during the course of their existence.

Sumner further examined the longitudinal movement of the systems and attempted to classify the movement 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^{o} longitude per day or more).
>
> Movements lasting two days or less had to be more than 5^{o} longitude in all, to be placed in one of these classes.
>
> The remaining periods were all placed in the Q class.

The monthly distribution and the movements of the blocking systems are summarized in Figure 6.

The distribution of blocking systems with latitude and with longitude is shown in Figures 7 and 8. Progression is proportionately rather more frequent in lower than in higher latitudes, while the opposite is true for retrogression.

The duration of blocked spells ranged from 5 to 54 days: the distribution is shown in Figure 9.

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3. SUMNER, E.J.; A study of blocking in the Atlantic - European sector of the northern hemisphere. Q J R Met Soc, 80, 1954, pp. 402-416.

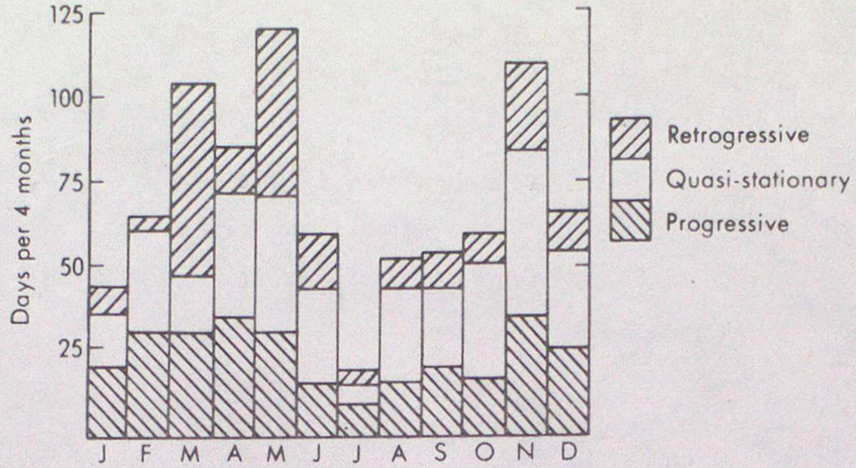

FIGURE 6. Monthly distribution of blocking

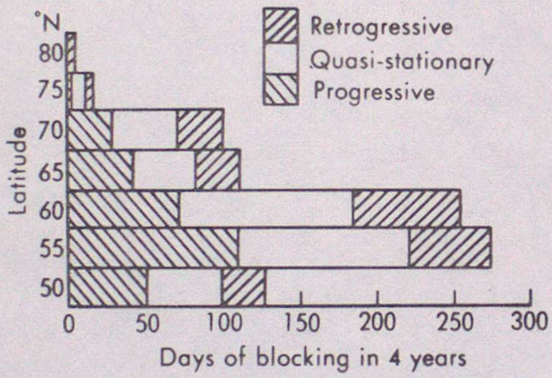

FIGURE 7. Distribution of blocking with latitude

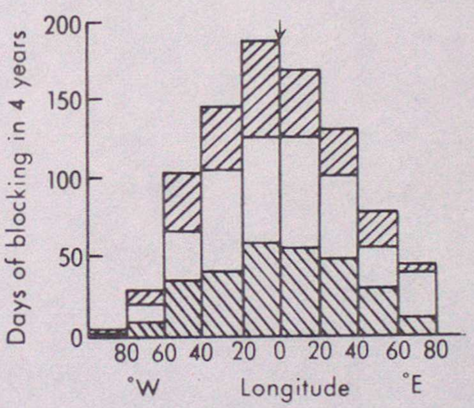

FIGURE 8. Distribution of blocking with longitude

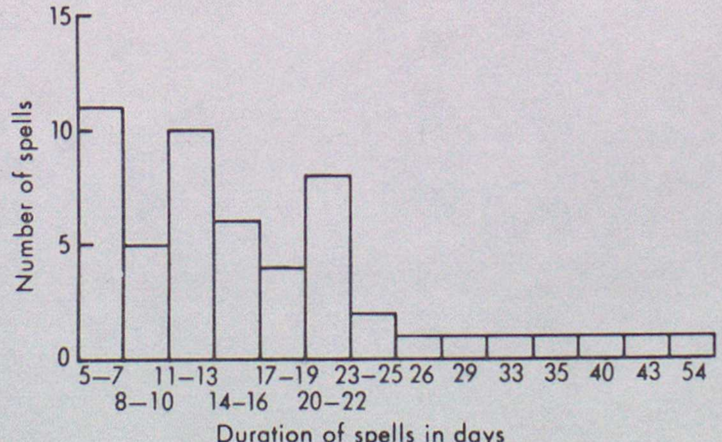

FIGURE 9. Frequency distributions of durations of spells of blocking

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