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HANDBOOK

OF

WEATHER FORECASTING

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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 10

FRONTS AFFECTING THE BRITISH ISLES

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FRONTS AFFECTING THE BRITISH ISLES

10.1 INTRODUCTION

The theory of frontal surfaces is contained in many textbooks which are widely available and the material is not repeated in this handbook. Some features of fronts when in the neighbourhood of the British Isles have been described in Chapter 7, Section 7.2. The detail of such descriptions rested largely on special flights by research aircraft and will, in general, exceed that which the practising forecaster could hope to determine from routine analyses. In this chapter the general synoptic weather accompanying fronts in the neighbourhood of the British Isles is discussed from the point of view of the practical forecaster.

10.2 WARM FRONTS

It is very difficult to draw reliable inferences about the activity of a warm front from the temperature and humidity characteristics of the air masses involved. This renders the interpretation of warm fronts on 24-hour prebaratics, in terms of rainfall, subjective and rather vague. When the observational network is dense and the character and distribution of weather currently associated with the front can be reliably determined or inferred on a sequence of charts, extrapolation of observed trends is very valuable for short-period forecasts provided account is taken of the general and somewhat longer-term development portrayed on the 24-hour prebaratic chart. Even for 24-hour forecasts of weather, the current distribution of cloud and precipitation associated with a warm front provides a useful starting point. When this current information is not available and in the case of new synoptic systems, the interpretation of warm fronts on prebaratics must remain fairly general.

It is very difficult to give any general guidance regarding the rainfall to be expected at a warm front. Corby [1*] conducted a statistical investigation of the relation between rainfall at some 82 of the warm fronts which crossed England during the years 1946-51, and various synoptic factors. The synoptic factors included surface pressures, tendencies, the intensity of the surface pressure trough across the front, isobaric curvature, the Sutcliffe development factor and various parameters related to stability and humidity of the warm air at several levels from the surface to about 500 millibars. Correlation coefficients were evaluated between both the mean total and the mean hourly rate of rainfall and each of the synoptic parameters. Broadly speaking the simpler synoptic parameters, namely pressure, tendency and trough intensity, provided the best correlations (correlation coefficients of total rainfall with pressure, mean tendency and trough intensity being 0.65, 0.53 and 0.52 respectively) whilst the more complicated parameters gave poorer values (for example correlation coefficients with static instability, wet-bulb potential temperature and potential instability of the warm air were not significant at the one per cent level). Tests of some of these correlations against independent data from some 47 of the warm fronts from the years 1952 to 1954 showed substantial differences in correlations, indicating that the actual correlations for 1946 to 1952 might have been to some degree fortuitous. It was then clear that the investigation was not likely to provide any simple or multiple regression equation which

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

could be usefully employed with confidence in practical forecasting. This view was further strengthened when account was taken of the great variability of the rainfall over the area from a particular front.

This investigation emphasizes the degree of subjectivity when interpreting warm fronts on prebaratics in terms of rainfall. The negative correlation between rainfall and surface pressure indicates that the higher the pressure the smaller is likely to be the total amount and rate of rainfall associated with the warm front. Some practising forecasters regard a pressure of 1016 millibars as a very approximate value separating the areas where the front is likely to be rainy or free from rain at the ground. It is, of course, useful to have some figure in mind when engaged in practical forecasting but forecasters should consider 1016 as nothing more than the broadest indication. Some further general remarks on the weather associated with warm fronts are given below.

Appreciable rain is likely at a warm front if the water content of the warm air is high to the 800-millibar level or above and some ascent seems likely. If the warm air is dry above 950 millibars the front will generally give only drizzle which may be confined to the west. Douglas[2] remarks that "in many cases the very high humidity goes up to 900 millibars or only a little higher and the situation is of a marginal type in which definite deductions are impossible at present. Where information is scarce the older air mass conceptions are sometimes useful. A warm air mass from tropical regions is more rain-producing than one which has previously subsided in the subtropical high at 40° - 50°N. and has not been over a really warm sea long enough to have much moisture in it. If an approaching warm front has tropical air behind it the chances of escaping rain are not high even in the south-east in summer, except in an anticyclone."

If the synoptic situation shows that the lower tropospheric air in the warm sector is approaching this country more or less directly from tropical regions (say a general current of air below 700 millibars from a direction between about south and south-west) it would be prudent to include a forecast of warm-front rain. Rainfall amounts tend to be less when the general current of warm air arrives from a direction to the north of south-west.

If recent observations show that tendencies are consistently negative and becoming increasingly so, or if the prebaratic indicates that a substantial decrease of pressure is expected, it would be prudent to expect some increase in the extent, amount and intensity of warm-front rain. Experience indicates that a warm front often becomes more active when it approaches a pre-existing thermal band lying parallel to it.

On some occasions there appear to be two bands of precipitation occurring ahead of a surface warm front. Where the thermal wind is at a considerable angle to the front and the winds increase strongly with height (that is there is a marked vertical shear across the front) the bands of precipitation, notably the one farther forward, tend to move a long way ahead of the surface warm front. At times, the forward rain belt may, for all practical purposes, be considered as having become detached from the front. On some occasions the main rain belt also moves to a position ahead of the sea-level warm front and there is only slight drizzle near the surface front.

Warm fronts often show a variation in intensity along the front. For example, there may be a relatively steady decrease in activity and precipitation from an area near the centre of an active depression to an area where the front is under the influence of a neighbouring anticyclone. In such regions the front may be rainless and the cloud system fairly thin and scattered. There is another variation in activity along a front which should be noted. Sometimes an area of heavier rain, within the general rain area associated with the front, moves along the front. Such rains seem somewhat analagous to a warm-front wave although, even on very detailed charts, a definite wave can seldom be detected. Sometimes the wave appears to be of a meso-scale extending no more than a few tens of miles in a horizontal dimension. Such variations in rain intensity seem to persist on some occasions for a few hours and, if the presence and movement of such an area of more intense rain can be determined or deduced from synoptic data or radar reports, some reliance may be placed on extrapolation for short-period forecasting. When these wave-like variations occur, the thermal winds are often closely parallel to the front and the area of heavier precipitation moves generally down the thermal wind. In such situations it is therefore important to scrutinize very carefully observations from areas lying perhaps as far as a few hundred miles in a direction up the thermal wind from the forecast area. A number of reports from several stations showing consistently heavier rain than elsewhere may reveal such a wave or meso-scale ripple on the front. Sometimes somewhat larger negative tendencies over a limited area may be associated with and indicate these regions of more intense precipitation. In the rear of such minor disturbances the frontal rainfall may be only slight. Such minor ripples or waves occur more commonly when the thermal pattern is strong and is aligned with the front, both lying approximately in a north-west to south-east direction. In such cases heavier rains over, say, Wales and south-western districts tend to move away into north-west France, but minor ripples appearing over western Scotland may move quite rapidly south-east to affect eastern and south-eastern districts of England.

Aircraft observations of the structure of fronts near the British Isles, as analysed by Sawyer[3] and Freeman[4], have shown that the slope of the cloud system associated with warm fronts (and ana-cold fronts) is approximately twice the slope of the front. This means that most of the cloud mass lies in the warm air. It would appear that the cloud mass often intersects the warm boundary of the frontal zone around or somewhat below the 600-millibar level.

On some occasions slight rain falling from upper clouds may evaporate whilst falling through lower dry layers and the precipitation fails to reach the ground. When this happens and the front is already degenerate, the medium clouds are thinning and there may be little or no general ascent, so that such fronts may remain virtually devoid of precipitation at ground level. With active fronts associated with general ascent, continued precipitation will soon moisten the dry layer which, if it also becomes subject to general ascent, will soon have a high relative humidity as it undergoes cooling on ascent and clouds will soon form in the initially dry layers.

Orographic effects are important. Since much of the weather moves from the west towards the east and the higher ground lies more to the west than the east of the country, heavier falls of precipitation occur, on the average, in the west but there are individual exceptions. Douglas[2] has commented that experience indicates that warm-front rain weakens more readily as it spreads east when most of the rain is falling out of the lowest 10,000 feet or less. However, if there are dense masses of medium cloud extending to a high level, Douglas considers that a weakening of the rain as the front moves across the country from west to east should not generally be forecast. On some occasions orographic waves may occur in the atmosphere and, when associated with warm fronts, may cause some local intensification of rain. (Conditions suitable for the formation of orographic waves are discussed in Chapter 20.)

10.3 COLD FRONTS

On the forecast bench practising forecasters should be able to identify and recognize at sight two types of cold front, namely those that are active or inactive (in relation to the weather which accompanies them). These cold fronts are often called ana- and kata-cold fronts respectively. Some information regarding the synoptic features occurring in association with ana- and kata-cold fronts was given in Chapter 7, Section 7.2. In this chapter attention is concentrated on weather features and the following additional remarks are made.

There is usually an extensive area of upper and high cloud and a substantial band of precipitation to the rear of an ana-cold front. The belt of cloud and precipitation has its major horizontal dimension aligned along the front. In the horizontal direction at right-angles to the front the pall of cloud might well extend in a typical case for something like 100 miles to the rear. When the cold front is continuing to move away the width of the belt of precipitation often seems to be very close to that of the cloud sheet to the rear of the front. In some cases there is a short burst of heavy precipitation at the frontal passage, followed by a marked clearance of low cloud which reveals the extensive sheet of upper cloud from which precipitation often of a light (but sometimes moderate) intensity continues to fall. On some occasions a distinct clear cut edge of the upper cloud can be seen near the horizon but, in such cases, rain often seems to persist almost up to the time the very edge of the cloud sheet reaches the area.

The weather accompanying kata-cold fronts is different in detail from that associated with ana-cold fronts. Air near the kata-cold front surface is descending and this descent usually limits the vertical extent of the frontal-cloud system. In many kata-cold fronts affecting the British Isles the top of the main frontal cloud mass probably does not extend much above 10,000 feet, but isolated cumuliform tops may protrude to higher levels. Any higher medium-cloud systems are usually thin and rather patchy. Precipitation amounts are usually small and precipitation does not normally continue after the frontal passage. It either ceases abruptly at or even slightly before the time of passage of the surface front. The cloud systems usually break and clear almost simultaneously with the frontal passage at the surface and, in some cases, small breaks in the cloud system may be apparent a few miles ahead of the surface front. Where the rain ceases and the clouds tend to break somewhat ahead of the front it is usually found that the orientation of the edge of precipitation and the breaks in the cloud is closely parallel to that section of the front. The distance of this pre-frontal clearance from the actual front is variable from case to case but experience suggests that distances of 10 to 30 miles would probably be typical.

Some features of both ana- and kata-cold fronts have been listed by Sansom[5] and a selection of these was given in Chapter 7, Tables 2, 3 and 4. Of the other features described by Sansom the following may also be of value. Rather surprisingly Sansom found that, over the British Isles, the mean speed of ana-cold fronts was slightly higher than that of kata-cold fronts. The actual mean speeds for all the cold fronts examined were:

ana-cold fronts - 20.5 knots
kata-cold fronts - 17.5 knots
unclassified - 16 knots

Perhaps the type of ana-cold front most quickly and regularly recognized by forecasters is the slow-moving cold front which is about to return as a warm front. This slow movement in one direction and subsequent return towards another results in a prolonged period of cloud and precipitation in areas near the turning point. It is accordingly easy to form the impression that ana-cold fronts tend to be slow-moving. Sansom's figures show that this is erroneous. Although some are slow-moving the fact that the mean speed comes out higher than that for kata-cold fronts implies that a number of ana-cold fronts must have moved at quite substantial speeds. Sansom concluded that there is no direct relation between the speed of a cold front and its general behaviour.

In the region of the British Isles there is a seasonal variation in the distribution of ana- and kata-cold fronts. In summer most cold fronts crossing the British Isles are kata-fronts but there are occasional ana-cold fronts. Douglas[2] speculated that the smaller magnitude of the air-mass temperature difference may be the main reason for this, since a large temperature difference is likely to favour the undercutting of the cold air. The mean westerly thermal wind is weaker in summer than in winter and it is therefore improbable that there can be a greater tendency for forward shearing of the upper wind over a cold front. It is probable that the difference in size and character of the sea-level isobaric system in the different seasons is a factor in the problem. A persistent warm anticyclone to south-eastward is favourable for an ana-cold front at its north-western boundary and continental heating tends to eliminate such systems (in summer) at low levels. Moreover summer cold fronts are usually complicated by small lows or troughs coming up from Spain or France ahead of them.

In winter most cold fronts crossing the British Isles are of ana-cold type but there may be an occasional kata-cold front. The seasonal distribution for the British Isles as found by Sansom is given in Table 10.1.

TABLE 10.1 SEASONAL DISTRIBUTION OF COLD FRONTS

	Winter Dec.-Feb.	Spring Mar.-May	Summer June-Aug.	Autumn Sep.-Nov.
Ana-cold fronts	8	5	0	2
Kata-cold fronts	1	3	10	9
Unclassified	3	4	1	4

Two synoptic examples, typical of ana- and kata-cold fronts were selected and illustrated by Sansom[5]. Parts of these illustrations which are relevant to this chapter are reproduced below.

10.3.1 Ana-cold front, 3 January 1945

Figure 10.1 shows the surface chart for 1200 G.M.T., 3 January 1945. There is fairly uniform post-frontal precipitation and cloud cover. The warm-sector isobars make a small angle with the cold front and there is a marked decrease in geostrophic wind speed at the front. The cold-air isobars show cyclonic curvature increasing toward the front.

Some of the autographic records for Kew Observatory are reproduced in Figure 10.2(a). These clearly show the passage of the cold front near 1700 G.M.T. There was continuous rainfall at the front lasting for some hours. The very sharp wind veer was accompanied by a marked decrease in wind speed. There was a quite considerable drop in temperature and a sudden check to the pressure fall. The discontinuities occurred simultaneously on all four charts.

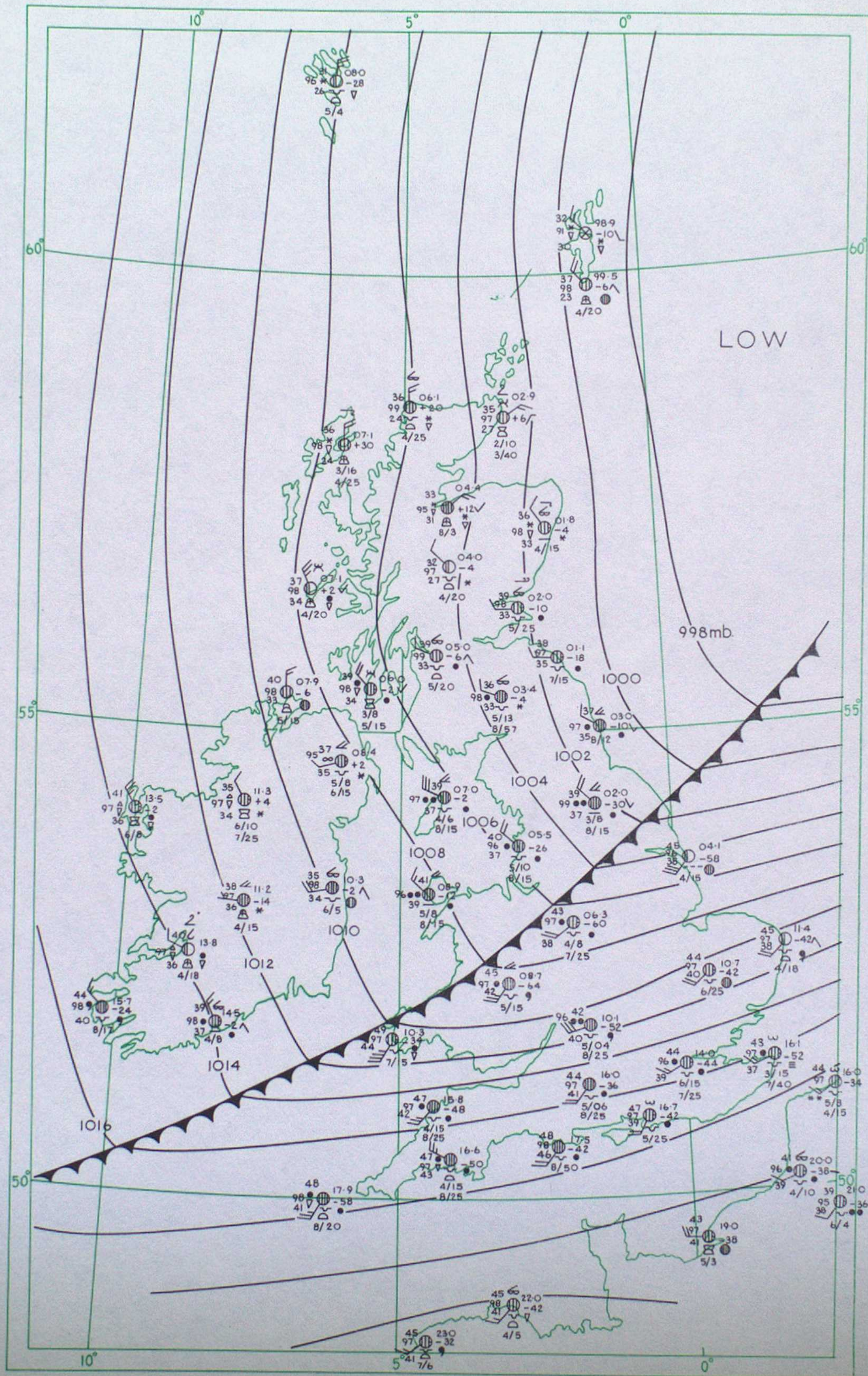
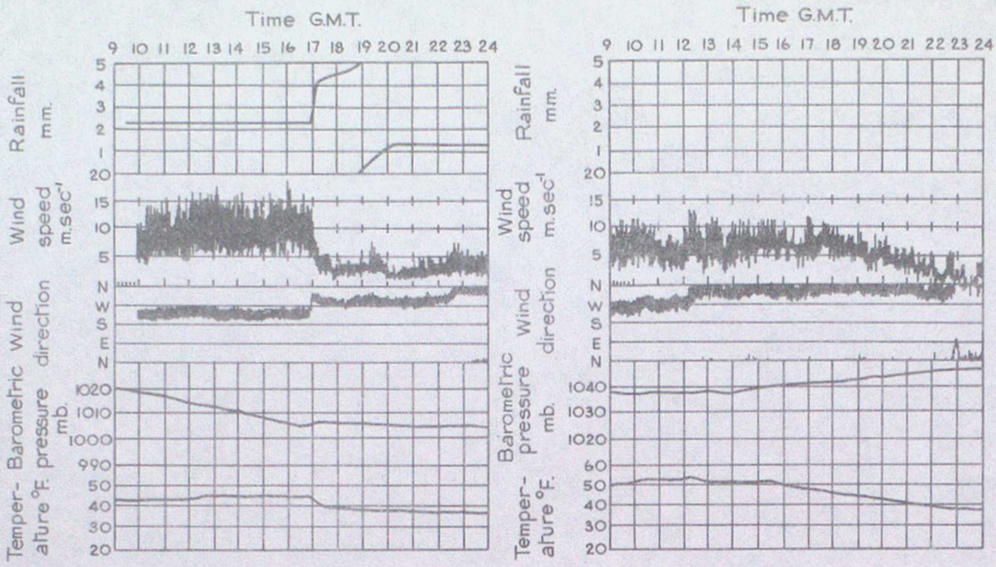


FIGURE 10.1 SURFACE CHART SHOWING ANA-COLD FRONT,
1200 G.M.T. 3 JANUARY 1945



(a) Ana-cold front, 3 January 1945 (b) Kata-cold front, 1 March 1945

FIGURE 10.2 AUTOGRAPHIC RECORDS SHOWING PASSAGE OF FRONTS AT KEW OBSERVATORY

10.3.2. Kata-cold front, 1 March 1945

Figure 10.3 shows the surface chart for 0600 G.M.T., 1 March 1945. There is a general absence of precipitation behind the front and a fairly rapid clearance of cloud. The isobars in the cold air have cyclonic curvature decreasing (or becoming anticyclonic) towards the front.

The autographic records are shown in Figure 10.2(b). There was no precipitation at the front at Kew. The wind veer, although quite sharp, was very slight and there was no appreciable change in wind speed. There was a fairly sharp temperature fall (sharper than at most kata-cold fronts) which was accompanied by a considerable decrease in relative humidity (not reproduced here). The pressure began to rise without any discontinuity.

Other synoptic examples of both ana and kata-cold fronts have been described by Freeman.[4] These indicate the conditions in the upper air in rather greater detail than Sansom could infer or deduce from the routine observations. Two examples together with Freeman's brief descriptive account are given below.

10.3.3. Ana-cold front, 11 January 1955

A complex depression in mid-Atlantic had brought mild air to the southern half of the British Isles and a depression developed between Scotland and Norway and moved slowly north-east. A cold front associated with this depression moved slowly south across the British Isles and by 1400 G.M.T. on 11 January lay along the north coast of France when it was moving south at about 12 knots. There was a surface temperature drop of some 10°F. at the frontal passage and in many parts of England the post-frontal precipitation turned to sleet or snow. A flight was made on an approximately north-south track and intercepted the frontal zone on the horizontal legs at 620 millibars and 500 millibars and on both the ascent and descent.

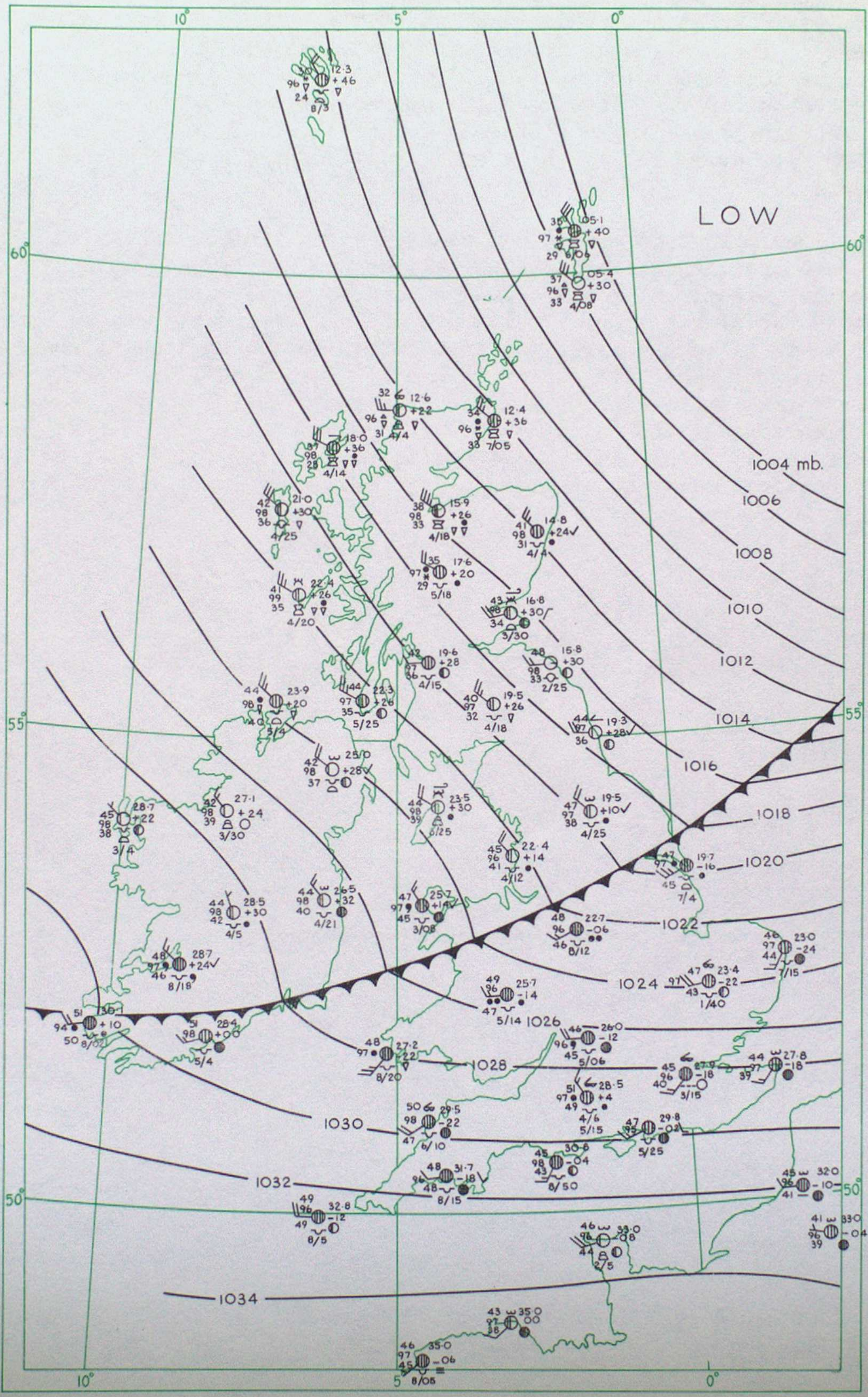


FIGURE 10.3 SURFACE CHART SHOWING KATA-COLD FRONT, 0600 G.M.T. 1 MARCH 1945

This was a good example of a slow-moving cold front with an extensive cloud sheet and broad precipitation belt behind the surface cold front. The horizontal flights at 18,000 and 13,000 feet showed a broad frontal zone about 180 nautical miles wide with a temperature drop across it of about 10°C. The slope of the front below 600 millibars was 1:140; above this level it was steeper - about 1:45. The driest air was at 6,500 feet over the descent when a frost-point depression of 31°C was recorded.

Figure 10.4 is a vertical cross-section from Stornoway to Trappes prepared from the aircraft observations and radio-sonde ascents. The vertical extent of frontal cloud should be noted and also the very dry air in the frontal zone itself. It should be remembered that the vertical scale is much exaggerated in relation to the horizontal scale. Thus the apparent near vertical profile of the cloud on Figure 10.4 does not give a true impression of the cloud sheet extending to the rear of the leading edge of the cold front. The post-frontal cloud sheet does not, according to Figure 10.4, commence to break until a distance of about 175 nautical miles to the rear of the leading edge of the front.

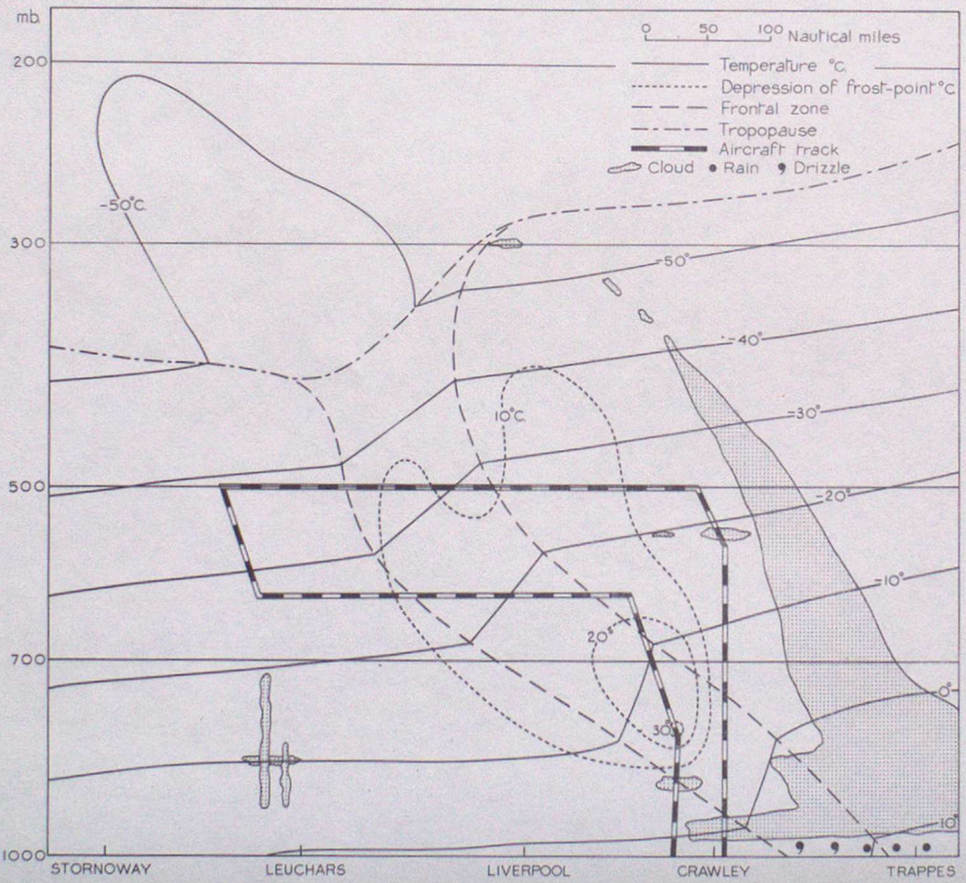


FIGURE 10.4 VERTICAL CROSS-SECTION FROM STORNOWAY TO TRAPPES, 1400 G.M.T., 11 JANUARY 1955

Below about 400 millibars the isopleths of frost-point depression are complete and fairly well fixed by the available observations. Above about 400 millibars reported observations of humidity are very sparse.

10.3.4. Kata-cold front, 16 September 1954

During an unsettled westerly type of weather a depression moved east-north-east just to the north of Scotland. The associated cold front crossed the British Isles during the morning of 16 September 1954, moving south-east across England at 28 knots. By 1400 G.M.T. the cold front was lying along a line from Denmark through the Heligoland Bight, Holland, Belgium and northern France to Lorient and thence west-south-westwards. A flight was made on a track of 310°-130° through Farnborough and intersected the frontal zone on both the horizontal legs as well as on the climb and descent. It did not, however, reach the frontal cloud which lay over France.

This occasion provided a good example of a kata-cold front with descending air at the frontal surface and very little frontal cloud. The passage of the surface front was accompanied by a rapid clearance of cloud. The frontal zone was well marked on the flight at 12,500 feet with a temperature contrast of 9°C. in 50 nautical miles. At 17,500 feet the temperature difference was only 4½°C. in about 35 miles. Below 12,000 feet the frontal surface was clearly defined and had a slope of about 1/110. Above 12,000 feet the original front was very weak and had a much smaller slope (about 1/400). The main temperature contrast aloft at the time of the flight lay above the original front and probably had a dynamical origin with very subsided air ahead and air which had subsided rather less forming the 'cold' air.

The flight was notable for the extremely dry air encountered, a frost-point depression of 45°C. being recorded in the warm air at 12,500 feet. Another very dry patch occurred at this level in the frontal zone. The whole of the flight was made in clear air, with cumulus cloud occurring in the cold air below the frontal zone. The position of the surface front was marked by a mass of cumulus and stratiform cloud with tops extending to about 14,000 feet.

Figure 10.5 is a vertical cross-section constructed from the aircraft observations and radio-sonde ascents. It should be noted that the frontal cloud mass was almost immediately ahead of the leading edge of the front at the surface, that the rear edge of this cloud mass was almost vertical and that a clearance would set in at or very close in time to the frontal passage. Any frontal precipitation was ahead of the front. The two patches of extremely dry air between 700 and 500 millibars seem to be abnormally dry and should not be regarded as typical of the magnitude of dryness associated with kata-cold fronts. However, the descending air near the frontal surface would presumably generally cause some dry patches to occur near the front in the lower troposphere.

In regard to forecasting only light rain Douglas[2] has remarked that "a confident forecast of only light rain at a cold front requires dry stable air ahead of it. This is frequent when the Azores anticyclone is well to northwards, and this is characteristic of fine summers. A thermal wind blowing forward across the front is unfavourable for rain at the front but so long as any part of the warm air is moist one must watch out for rain in that region."

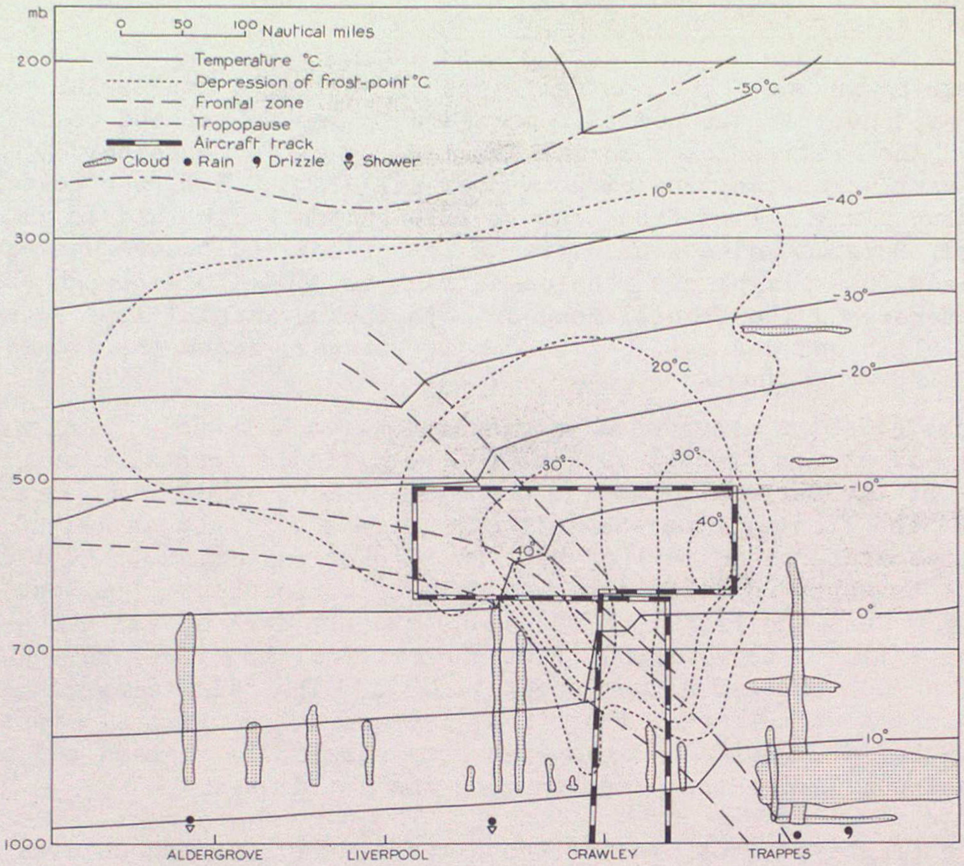


FIGURE 10.5 VERTICAL CROSS-SECTION FROM ALDERGROVE TO TRAPPES, 1400 G.M.T., 16 SEPTEMBER 1954

Below about 350 millibars the isopleths of frost-point depression are complete and fairly well fixed by the available observations. Above about 350 millibars reported observations of humidity are very sparse and the isopleths of frost-point depression are ill-defined and their location is rather indeterminate.

10.4 OCCLUDED FRONTS

It has already been mentioned in Chapter 8 that near the tip of the warm sector and at the warm front the precipitation tends to become more intense when occlusion occurs. If a secondary depression forms at the point of occlusion there is usually a considerable area of precipitation which extends on both sides of the occlusion. Near such secondaries the precipitation is probably seldom purely of frontal origin and general low-level convergence associated with the secondary must often be a factor and, at times, may be the dominant one.

Douglas[2] has remarked that "the air from the original warm sector can only supply rain for about 24 hours and further rain is maintained by the ascent of the warmer of the two air masses separated by the line of the surface occlusion, which has on average as well defined a trough with it as any other type of front. The lapse rate and humidity come into the problem. The thermal trough is often close behind an old occlusion and there may be an element of instability in the rain belt, though actual thunder is comparatively rare. Such rain bands are often narrow and, once the upper winds back, the risk of much forward spreading vanishes.

Probably the continued supply of warmth and moisture from the sea surface to the returning cold air ahead of the occlusion plays a part in maintaining the rain belt, especially in winter when the rain often decreases after the occlusion reaches land and the trough fills up.

"In summer many occlusions behave as cold fronts when they reach heated land areas".

Well within a vigorous primary depression, and away from any secondary depression at the tip of the warm sector, the precipitation associated with an occlusion is generally ahead of it. In the earlier stages of occlusion there is often a substantial pressure gradient along the occlusion so that the precipitation is in the form of a relatively fast-moving belt. However, in the later stages of occlusion, particularly with very deep slow-moving depressions, the occlusion in the region of strong winds tends to protrude ahead of the centre so that the front tends to spiral out from the centre. This forward protrusion and spiralling out from the centre usually leads to the occlusion ultimately becoming fairly closely aligned to the winds in the lower troposphere, sometimes throughout much of the troposphere. Such occlusions are slow-moving and precipitation associated with them tends to be persistent. Sometimes it is very persistent and continues even when the occlusion is difficult to identify on a detailed chart and the thermal structure is very weak. During the formation of such an occlusion a tongue of warm air is advected to the north of the centre of the depression and a tongue of cold air moves to the south and east. This leads to a reversal of the normal latitudinal temperature gradient and, although the thermal pattern associated with the occlusion may be very weak, precipitation can nevertheless be very persistent. If there is enough slowing down of the depression, rain from the occlusion can spread to westward of the centre. This is particularly noticeable in eastern districts of the British Isles on occasions when deep depressions slow down on entering the North Sea. The rain is often prolonged and on some occasions has led to historic floods. In addition rain sometimes continues for several hours even after sustained and substantial rises of barometric pressure have set in. Such long-continued precipitation is probably not entirely of frontal origin. In the later stages continued supply of warmth and moisture from the North Sea coupled with coastal convergence and/or orographic uplift are probably important factors in the maintainence of precipitation. The spread back of rain in the rear of a deep depression may occur elsewhere in the British Isles but it is then generally less well marked than in eastern districts.

When a succession of occlusions moves eastward into Europe in winter and come to rest on the fringes of an intense slow-moving continental cold anticyclone, the largest amounts of precipitation associated with such an occlusion generally occur in south-western districts and the precipitation is less intense as the occlusion moves eastwards. When the occlusion becomes stationary the precipitation is often feeble and may die out altogether, even though the thermal contrast across the occlusion between the maritime air to the west and the cold continental air to the east is probably greater than when the front was more active in western districts. Precipitation from such a stationary occlusion usually remains feeble and sporadic until a further trough advances from the west which sometimes invigorates the old occlusion and further precipitation occurs.

On the whole it is the existing rain area, the pressure distribution and the tendency distribution which have the greatest prognostic value when interpreting occlusions in terms of weather. These distributions should be most carefully studied and used for short-period forecasting. In addition it is useful to examine the characteristics of the lower cold air masses on either side of the occlusion to determine whether the front is likely to behave as a warm- or cold-type occlusion.

On some occasions a long belt of precipitation forms in a non-frontal trough in a large depression. Such a belt of precipitation often exhibits the frontal characteristics of an occlusion although there may be no previous historical evidence for the evolution of an occlusion from warm and cold fronts. When such a belt of precipitation has formed some success in forecasting its movement is usually possible by inserting a pseudo-occlusion at the pressure trough (but the initial development of the rain belt in the trough is often difficult to forecast in advance). On some occasions when there is such a trough in a primary depression and a wave cyclone, which is forming towards the periphery, subsequently moves to a position near the axis of the trough in the primary there is a mutual interaction between the trough and wave features which combine and subsequently move as one complex feature exhibiting, in its several sectors, weather characteristic of warm, cold and occluded fronts.

10.5 SECONDARY OR MULTIPLE FRONTS

When the observational data and a sequence of analysed charts show clear evidence, either at the surface or in the upper air, that the existence of secondary or multiple fronts is well founded, then there is justification for retaining such fronts on analyses and on forecasts also unless the meteorological processes are expected to lead to frontolysis. The remarks of the preceding sections of this chapter may then be applied to interpret these fronts in terms of weather.

There is, however, sometimes a tendency to identify some line of discontinuity on a weather chart (for example the rear edge of a rain area) and to regard it rather indiscriminately as a front. To identify and follow a line of discontinuity is often of great value in short-period forecasting. Experience shows that such lines retain a coherent pattern and shape, often for a few hours, as the weather moves across an area of the chart. It is legitimate to identify such lines and make intelligent extrapolation of both their movement and the change in the currently observed weather which is likely to occur with time and distance. It is wrong, however, to label such lines indiscriminately as warm, cold or occluded fronts and to associate typical weather of a model textbook front with these lines. Experience and judgement usually combine to produce a realistic and sound attitude to the use of secondary or multiple fronts in day-to-day work.

10.6 FRONTOGENESIS

Fronts are formed in areas where the horizontal temperature gradient is increasing, usually as a result of the horizontal advection of air from different directions in adjacent regions. When it can be seen from a study of the configuration of surface isobars and thickness lines that a region of strong temperature gradient will be built up in this way, frontogenesis should be forecast. The occurrence of frontogenesis usually leads to the active ascent of the warm air even before typical frontal characteristics become apparent. If it is expected that frontogenesis will take place, rain and extensive cloud should be forecast in the area where the new front is expected to appear. Old or weak fronts moving into an area of frontogenesis rapidly become active again.

Warm frontogenesis is commonly found ahead of depressions advancing from the west when the main temperature gradient as shown by the 1000-500-millibar thickness pattern has been displaced ahead and to the north-east of the old (occluded) frontal system.

10.7 FRONTOLYSIS

Frontolysis does not usually present such a difficult problem to the forecaster as frontogenesis. In many cases when frontolysis is forecast to occur the sequence of recent synoptic charts contains clear evidence that the front has weakened to some extent so that the general forecast is then partly an extrapolation of an existing trend. The problem is then often one of timing the cessation of rain or the general thinning, lifting and breaking of cloud systems. Precise timing of changes in the weather at the front is often not possible to within close limits (for example one hour or so). Natural human caution will normally incorporate some margin of safety in the timing of the improvement in frontal weather. However forecasts of frontolysis may occasionally be optimistic. For example, even though pressures are rising substantially on both sides of an old occlusion, precipitation may be slow to clear in the north-western quadrant of a deep depression which is slow-moving off the eastern seaboard (see Section 10.4). Another example which comes to mind is that of a weak, almost stationary and decaying frontwith negligible weather activity, perhaps for days. There is sometimes a tendency to frontolyse it completely and drop it from the analysed and forecast charts. However the front may be revivified - perhaps by a fresh supply of warmer or colder air, the formation of another disturbance or by the development of some suitable frontogenetic upper air configuration. These are really problems to be solved in the preparation of prebaratic and prontour charts. However they do emphasize that there should be no automatic "rule of thumb" approach to the forecasting of thinner clouds and less precipitation by a simple extrapolation from the recent past.

In a few cases it may be possible confidently to forecast frontolysis in advance of there being any direct indication from the available reports of actual weather. Such a situation may arise when there is good confidence in the general dynamical development and it is clear that a currently active front is likely to move into a strongly frontolytic region. For example, a common case of frontolysis occurs when an anticyclone forms or moves eastward in association with a confluent distribution of thickness lines as indicated schematically in Figure 10.6.

The region to the left of the confluence is anticyclogenetic and the region to the right is one of convergence and ascent. The more northerly anticyclone therefore develops whilst the previous anticyclone to the south decays. Subsidence occurring in the active anticyclone behind the front combined with slight ascent ahead of the front leads to a rapid reduction of the temperature contrast in the free atmosphere near the front and consequent frontolysis.

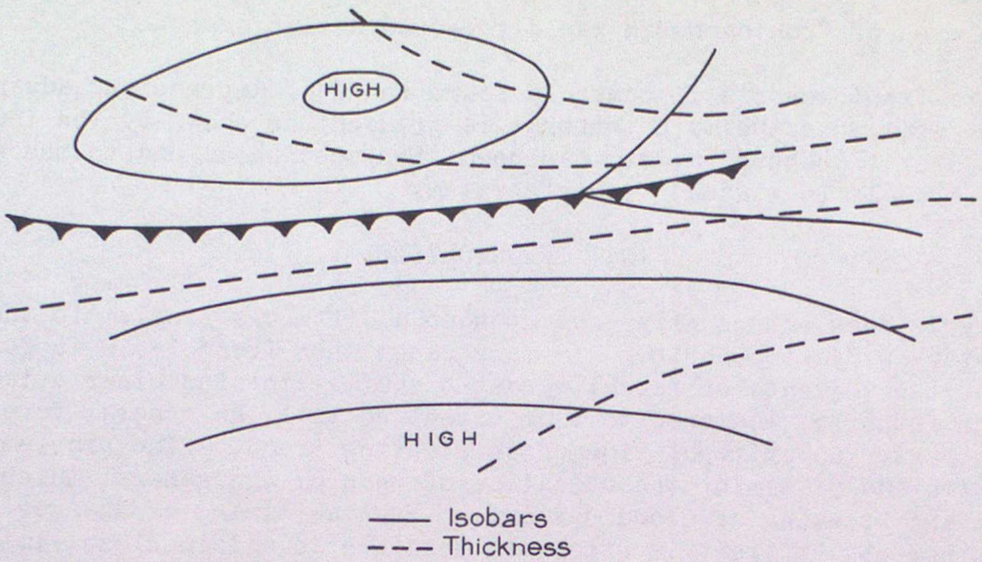


FIGURE 10.6 FRONTOLYTIC SITUATION

10.8 INFLUENCE OF OROGRAPHY

Some comments relating to the effect of orography on clouds and precipitation accompanying fronts are contained in Chapter 16, Section 16.8.

BIBLIOGRAPHY

1. CORBY, G.A.; The rainfall of individual warm fronts over England. Unpublished.

2. DOUGLAS, C.K.M.; Preliminary monograph on forecasting rainfall and thunderstorms. Unpublished.

3. SAWYER, J.S.; The free atmosphere in the vicinity of fronts. Geophys. Mem., London, 12, No. 96, 1955.

4. FREEMAN, M.W.; Fronts investigated by the Meteorological Research Flight. M.O.12. Tech. Note No. 4, 1958. Unpublished.

5. SANSOM, H.W.; A study of cold fronts over the British Isles. Quart. J. R. met. Soc., London, 77, 1951, p.96.