CHAPTER 9

ANALYSIS OF SURFACE CHARTS

CHAPTER 9
ANALYSIS OF SURFACE CHARTS

Contents

CHAPTER 9

ANALYSIS OF SURFACE CHARTS

9.1 INTRODUCTION

The surface weather map, or synoptic chart, properly analysed, is the basic tool in meteorology which enables the forecaster to start to build up an understanding of the state of the atmosphere at a given time. The word 'synoptic' means 'viewed together'. A surface synoptic chart is a 'snapshot' of weather observations which are made from ground level or from ships at sea. It is the skilful analysis of these observations which constitutes a firm foundation upon which all forecasts of the weather must ultimately depend.

Actually, the individual 'surface' observations are not entirely confined to a point on the earth's surface. The observations of the state of the sky give a great deal of information about upper levels while those of the state of the weather and, in particular, of the visibility can give information of conditions within a range of considerable distance from the point at which the observation is made.

9.2 THE OBSERVATIONS

A large amount of data is plotted on the surface synoptic chart. The data consist of observations made at different reporting stations. Automatic chart plotting, together with facsimile transmission of the plotted charts to outstations, has reduced the need for manual plotting, but, where the latter is necessary, neatness and speed are both essential. The task of the forecaster is simplified if all the data on the chart are made rapidly available to him in a clear, neat and tidy form so that he can assimilate them at a glance.

The observations which are plotted around a station circle on the chart may be divided into those which are measured by instruments, and those which are normally estimated by eye. Some of the latter are also measured by special instruments at a few of the larger stations.

9.2.1 Instrumental or measured observations

(i) Barometric pressure.
(ii) Amount and characteristic of the barometric tendency during the three hours preceding the observation.
(iii) Dry-bulb temperature.
(iv) Dew-point (derived from the difference between the dry- and wet-bulb temperatures).
(v) Direction and speed of the surface wind.
(vi) Visibility (particularly at night).
(vii) Height of base of low cloud.

Also, where applicable,

(viii) Sea temperature.
(ix) Direction and speed of the ship's movement.
(x) Period of the swell.

9.2.2 Visual observations

(i) Types of clouds in the sky.
(ii) Total amount of the sky covered by cloud.
(iii) Height of the base and amount of the sky covered by various layers of cloud.
(iv) Present and past states of the weather.
(v) Visibility.
(vi) Direction and height of the swell (for ships at sea).

9.2.3 Times of the observations

The observations are made at the main synoptic hours of 0000, 0600, 1200 and 1800 GMT, and at the intermediate synoptic hours of 0300, 0900, 1500 and 2100 GMT. Observations are made at some stations every hour: these are normally plotted on open-scale charts and they may not include all of the elements observed at the main and intermediate synoptic hours. Synoptic charts covering the full area required are normally plotted and analysed for the main synoptic hours. Charts are also plotted and analysed for the intermediate synoptic hours, but these charts often cover a smaller area than those for the main hours. Some characteristics of some of the elements are, in part, dependent on the time of day. More will be said about this aspect of the synoptic analysis in a later section in which the diurnal variation of the elements is discussed.

9.2.4 Representativeness of the observations

The observations provide the basis for the analysis of the synoptic chart. It is important that the analysis is as objective as possible. Thus, if a hundred analysts were each given a fully plotted synoptic chart referring to the same date and time of day and they prepared their analyses in complete isolation from their colleagues, there would be a hundred solutions of the situation, each of which would be different in some degree. If the analysts were expert and experienced and if the data plotted on the chart were accurate and complete, the differences between the individual solutions would probably be quite small.

Different solutions of the analysis would be achieved by different individuals because each individual attaches a varying amount of importance to different aspects of the observations. If there are actual discrepancies in the observations, that is if the observations do not give consistent information, they may be erroneous, or merely unrepresentative. It is sometimes difficult to decide if a particular observation which might appear suspect at first glance, is quite erroneous, unrepresentative or accurate after all. The decision is one that must be made by the analyst for every observation that appears on the chart. An observation is erroneous if there is a real error in one of the elements reported. This may be due to an error in estimating or reading the value of the element, an error in coding it, in transmitting it on the teleprinter network, or in decoding it or plotting it on the chart. An unrepresentative observation may be correct and record the true conditions which prevail at the place of observation at the time, but these conditions may be very local and unrepresentative of the free air a short distance away.

When an observation does not appear consistent with neighbouring observations or indicates an unexpected development its representativeness should be carefully considered. If details of the site and exposure are available these can be consulted, but some possible causes of unrepresentativeness may be seen immediately from a large-scale map (adjacent lakes, coasts or rivers, strongly marked relief, etc.). Forecasters should note any recurring abnormalities of observations at particular stations in order to be on the alert for unrepresentative observations from these stations on later charts. It is important that all observations should be as nearly representative as possible in order that the analysis conveys an overall picture on the synoptic scale. Objectivity of the analysis can be achieved only if the observations are accurate and representative of the natural conditions which actually exist at the place and time of the observation.

Objective analyses of surface charts are carried out by computer, but these have not yet replaced the subjective products. Some degree of subjectivity enters into the objective analyses, however, for it is sometimes necessary to remove doubtful observations from the data being analysed, or to insert 'bogus' observations to improve the analysis in some areas.

9.3 SCALE OF THE CHART

The scale of the chart used for synoptic purposes varies from about $1:2 \times 10^6$ for open-scale charts of a local region to $1:30 \times 10^6$ for circumpolar charts covering most of a hemisphere. Although the general principles of the analysis techniques are essentially the same for all scales of chart, there are differences of emphasis depending on the scale.

9.4 STEPS IN THE ANALYSIS

The basic analysis of the surface synoptic chart may be divided briefly into two major steps. These are:

(i) frontal analysis, and
(ii) construction of the pressure pattern.

After these two steps have been satisfactorily accomplished there are a number of secondary steps which may be taken in order to extract the maximum amount of information from the available data. These subsequent steps will be discussed later. The two main steps mentioned above need not be taken rigidly in this order. However, although there is no hard and fast rule many analysts will find it convenient to place the fronts in that area of the chart to which their attention is first directed, before attempting to construct the isobars. This area would usually probably be over or within the near vicinity of the British Isles for analysts working in this country. The exact drawing of the isobars is determined to a considerable extent by the fronts. Of course, the pressure pattern itself may occasionally give valuable information about a front, but this criterion should be used to settle an otherwise inconclusive argument rather than serve as a primary reason for the identification of a front.

If, however, a large anticyclone or ridge of high pressure is clearly seen to cover that region of the synoptic chart in which the analyst is primarily interested, then isobars can be drawn at once without the need to consider the frontal analysis in areas some distance away.

9.4.1 Frontal analysis

The nomenclature of the various fronts or frontal systems which may exist on a surface synoptic chart are:

(i) warm front,
(ii) cold front,
(iii) warm-type occlusion,
(iv) cold-type occlusion,
(v) secondary cold front,
(vi) quasi-stationary front,
(vii) warm- and cold-front waves.

The reader may imagine that he has a fully plotted chart in front of him. In practice, it may often be necessary to start the analysis on a part of the chart (for example, the British Isles) before the data for the remainder of the chart are ready for plotting. The task is to analyse this chart. What is the first step? The answer to this question is that the analyst must first ensure that continuity is maintained. Above all else the changing pattern of the weather, as represented by the numerous sets of observations plotted on the chart, must be a continuous moving picture in time. It is therefore essential for the analyst to have at least one, and preferably two or more consecutive synoptic charts beside him relating to the previous synoptic hour or hours. Continuity of the frontal pattern is of paramount importance and the aim to maintain such continuity therefore provides a good starting point. The analyst should examine the continuity of the two earlier charts and extrapolate an approximate position of the fronts, making use of the advection rules that warm fronts and warm occlusions move with about 2/3 of the geostrophic wind speed in the warm air, and cold fronts and cold occlusions move with nearly geostrophic speed. Warm fronts may move somewhat faster over the ocean. An attempt at such extrapolation can often be done on a blank chart with the help of a light-table long before the new chart is ready for the analyst. It may be useful at this stage also to extrapolate the movement of the centres of any relatively fast-moving depressions from the tracks indicated on the preceding charts.

9.4.1.1 Warm and cold fronts. The next step is to examine the plotted observations on the new chart with a view to identifying any fronts in the areas where they are expected to be found. The observation at any point will give information about the type of air mass which is present at that point. Discontinuities in the values of the instrumental measurements, as well as those of the visual measurements, between neighbouring stations will signify the existence of a front dividing one air mass from another. The two fundamental properties which identify an air mass are its temperature and its dew-point. Sometimes, usually on occasions of light wind and little or no cloud, the identification cannot be made on the basis of temperature and dew-point at the surface and in such conditions the values of these elements at a higher level should be examined on an upper-air diagram. The other elements of a station observation, although less fundamental than temperature and dew-point, give valuable information about the air mass and about changes, from one type of air mass to another, which may have occurred during the past hour or two. If such changes in any of the elements of the observation are observed to have occurred, it can be deduced that a front has passed the station. Confirmation of such changes can be obtained by comparing the observations at the stations concerned with those reported at the same stations one, two or more hours previously.

The identifying features of warm and cold air masses which are immediately adjacent to one another are listed in Table 9.1 for the warm front and in Table 9.2 for the cold front.

In many cases, all the identifiable features listed agree for adjacent stations in the vicinity of a front. In such cases, there is little difficulty in sketching a smooth line which separates the cold air from the warm.

The criteria which are listed in Tables 9.1 and 9.2 for the identification of warm and cold fronts may, however, not always exist to a degree which can be recognized at all easily. In some cases, in fact, the analysis is extremely difficult because the usual identifying features appear to be absent altogether or to conflict with one another. For example, the pressure at one station where the passage of a cold front is expected to have occurred may show a sudden rise of the barograph tendency after a fall and precipitation may have ceased, yet the wind may not have veered and the temperature and dew-point may not have fallen. On the other hand an adjacent station, through which the front might also have been expected to have passed, may indicate a veer of the wind and a small fall of temperature yet the barograph tendency may still record a continuous fall and there might be light drizzle. On many occasions, there seem to be anomalies and conflicts of the evidence which make it impossible to come to a quick decision. In cases such as these it may be necessary to give some priority of importance in assessing the different elements of the observation.

Although no hard and fast rules can be given, the dew-point is an element towards which considerable weight should be attributed since it is a fairly conservative property. However, a dew-point might be unrepresentative of a cold air mass if there is a sea-breeze, in which case damp air of higher dew-point may have been advected from the sea in a shallow layer along a narrow coastal belt. A dew-point may also be unrepresentative if it is in the cold air behind the cold front on occasions when there is little wind, if the ground is wet from rain associated with the cold-front passage.

Temperature, although defining whether an air mass is cold or warm, may also be unrepresentative at the surface inland in summer and also, more generally, in conditions where there is a little or no wind. Under such conditions, solar insolation can cause higher day temperatures in the cold air than in the warm air where skies may be overcast. This may apply to the cold air adjacent to both warm fronts and cold fronts. In winter the effect may be observed in fresh polar maritime air.

The pressure tendency may be the most useful evidence in cases of light surface wind since this observation incorporates the changes that are occurring at upper levels in the atmosphere where the wind may be stronger. The change in surface wind direction is also a most important guide. So is the change in cloud type, although it should be remembered that it is often difficult to judge cloud types or estimate cloud amounts accurately during the hours of darkness. The identification of cumuliform clouds, particularly if the vertical development is pronounced, is an excellent indication of the

Analysis of surface charts

TABLE 9.1 Identification of a warm front

Weather element	Observation in the warm air	Observation in the cold air
Pressure	Does not identify directly although a trough in the pattern may assist the identification.	Does not identify directly although a trough in the pattern may assist in identification.
Air temperature	Warmer behind the front.	Colder ahead of the front.
Sea minus air temperature	Less behind the front.	Greater ahead of the front.
Wind direction	Blows from a point several degrees veered from the wind in the cold air.	Blows from a point several degrees backed from the wind in the warm air.
Dew-point	Higher in the warm air.	Lower in the cold air.
Dew-point depression	Often less than in the cold air.	Often greater than in the warm air, except in precipitation, when it may be about the same as or even less than in the warm air.
Pressure tendency	Falls less sharply than in the cold air; occasionally rises slowly.	Falls, or falls more sharply than in the warm air.
Weather	Overcast sky, except inland in summer; occasionally rain and particularly drizzle, which may be heavy on coasts exposed to the wind; fog on exposed coasts and covering hills.	Usually continuous rain or snow, but sometimes only light and intermittent; occasionally no weather, particularly inland in summer.
Cloud amount	Usually 8/8 low cloud but sometimes broken low cloud inland in summer.	8/8 low cloud in precipitation; occasionally only broken low cloud inland in summer; usually 8/8 medium and high cloud.
Cloud type	Stratiform clouds.	High, medium and stratiform clouds, nimbostratus in precipitation.
Visibility	Often good but poor on coasts exposed to the wind and elsewhere in drizzle and fog.	Often good but poor in precipitation.

TABLE 9.2 Identification of a cold front

Weather element	Observation in the cold air	Observation in the warm air
Pressure	Does not identify directly although a trough in the pattern may assist to identify.	Does not identify directly although a trough in the pattern may assist to identify.
Air temperature	Colder behind the front.	Warmer ahead of the front.
Sea minus air temperature	Greater behind the front.	Less ahead of the front.
Wind direction	Blows from a point several degrees veered from the wind in the warm air.	Blows from a point several degrees backed from the wind in the cold air.
Dew-point	Lower in the cold air.	Higher in the warm air.
Dew-point depression	Greater than in the warm air, except in precipitation.	Less than in the cold air.
Weather	Continuous precipitation near front; further behind front, showers of rain, hail or snow, broken sky, occasionally thunderstorms.	Continuous precipitation near front; overcast sky, except inland in summer; occasional drizzle, which may be heavy on coasts exposed to the wind; fog on exposed coasts and covering high ground.
Pressure tendency	Rises rapidly or more rapidly than in the warm air, sometimes continues to fall, but at a slower rate than in the warm air.	Falls, or rises more slowly than in the cold air.
Cloud amount	Broken low cloud, but 8/8 in precipitation.	Usually 8/8 low cloud; occasionally only broken cloud inland in summer; usually 8/8 medium and high cloud near front.
Cloud type	Cumuliform clouds, cumulonimbus and nimbostratus near front.	Stratiform clouds, nimbostratus near front.
Visibility	Very good except in precipitation.	Often good but poor in precipitation and on coasts exposed to the wind, and elsewhere in drizzle and fog.

existence of cold air. All the criteria should, however, be studied very closely and the decision made to place the front only after all the available evidence at all stations in the vicinity has been most carefully weighed in the balance.

A study of the temperature and humidity observations, as reported by the nearest upper-air radiosonde ascents, will be found most useful in doubtful cases where the surface information is unrepresentative of the air mass for one reason or another. The upper air is less likely to be influenced by local orographic or diurnal effects. In addition a further parameter, the relative stability of the air at the various stations on either side on the front's expected position, can be compared.

Storm-warning radar reports are often a useful supplementary guide in the placing of cold fronts. The coverage provided by individual radar stations varies according to local conditions but, in general, a 'picture' of the cloud within a 50 to 100 kilometre radius of the station is obtainable. The orientation of main cloud sheets may be determined by plotting the reports received from such stations on a polar diagram having the station as its central point. Some examples are given in Chapter 19—Clouds and precipitation.

Another valuable tool is the hodograph or vector wind diagram prepared from radar-wind reports. The hodograph will indicate the level of the frontal surface above the station. If an average value of the slope of the frontal surface is assumed, and if the orientation of the front is known approximately, the position of the front at its nearest point to the station can be extrapolated.

Although surface fronts are usually placed on the evidence of air-mass distribution at the surface, it will be found that the upper-air chart of the 1000 - 500-millibar thickness is an extremely useful guide. The important question of the three-dimensional consistency of the analysis will be discussed at greater length in Chapter 11—Upper-air charts. It is clear that if a front is an active one it will be reflected in the thickness pattern as a strong baroclinic zone. Weak fronts may not be reflected in the upper-air pattern at all.

Satellite pictures, and nephanalyses derived from them, can often be very valuable in locating frontal zones and in assessing the properties of the front. Well-defined cloud bands, often thousands of kilometres long and from one hundred to a few hundreds of kilometres wide, indicate active frontal zones and strong baroclinicity.

Cold fronts are generally more readily recognizable and easier to locate on satellite photographs than are warm fronts. Active cold fronts appear as comparatively narrow, continuous bands and give bright images in both the visible and the infra-red regions of the spectrum. Less active cold fronts have narrower, often discontinuous, cloud bands which appear bright in the visible but grey in the infra-red pictures.

The cold-front cloud band may be predominantly stratiform (for example, nimbostratus) or it may be mainly cumuliform. In the former case, the cold front at the surface is likely to be near the leading edge of the band, whereas for mainly cumuliform bands the surface cold front is usually near the rear edge.

The area of cloud associated with a warm front is usually broader (a few hundred kilometres wide) and shorter (several hundred kilometres long) than that of a cold front. The top surface of the cloud is usually uniform, but cumuliform clouds may be embedded in the layer cloud, and this indicates the existence of potential instability in the warm air and the likelihood of heavy precipitation. Often in summer the warm air behind the surface front may be relatively clear of cloud, and the warm front may, with a fair degree of confidence, be placed near the rear edge of the cloudy zone. In winter particularly, and sometimes in summer, stratus is present in the warm air; the boundary between the frontal and the non-frontal clouds may be indistinguishable in the visible, although the difference can often readily be seen on the infra-red pictures, where the frontal clouds appear bright and the low clouds grey.

Further information on the properties of fronts is given in Chapter 5 – Fronts and frontal weather, and more detail about the use of satellite pictures will be found in WMO Technical Note No. 124.[1]

9.4.1.2 Occlusions. The features which identify warm- and cold-type occlusions are similar in many respects to those which identify warm and cold fronts as listed in Tables 9.1 and 9.2. The contrasts are, however, often less marked since the true warm air mass is no longer present at the surface. The identification of old occlusions is one of the analyst's most difficult tasks.

The triple point at which the occlusion starts may be identified by following the warm and cold fronts to the point at which the warm air vanishes at the surface. The vicinity of the triple point is often marked by larger falls of barometric pressure than elsewhere along the front. In fact, small separate depressions occasionally form at this point and subsequently break away from the parent. Once the triple point has been found, the remainder of the occlusion can usually be traced to the centre of the depression where it would normally end.

Often there is a well-marked trough in the cold air in the rear of a depression; in the early days of frontal analysis 'back-bent' occlusions were drawn readily along the trough. However, when data from upper-air ascents became regularly available, they showed little evidence for such features; the concept of the back-bent occlusion became less popular and was probably finished off when satellite photographs failed to reveal such cloud systems. Instead, the clouds associated with the occlusion are seen to spiral into the centre of the depression. They appear in the early stages as a band of higher cloud in a generally cloudy area, but later the cloud begins to dissipate until only the frontal cloud is seen as a spiral against a background of mainly cloud-free air. Normally, only the portion of the outermost loop of the spiral lying poleward of the centre is drawn on the synoptic chart. On infra-red pictures it can be seen that the cloud tops associated with the occlusion become lower as the depression centre is approached. Often the rear portion of the frontal cloud is seen to be lower (less bright) than the central portions. If the rear edge is well defined, the surface front is probably near that edge.

The point of occlusion may at times be identified by a bulge of warm-front cloud ahead of it. The jet stream (see Chapter 8) often crosses the frontal system near the triple point: the axis of the jet is closely associated with the poleward edge of the cirrus sheet.

9.4.1.3 Secondary fronts. Secondary fronts of both warm and cold type may exist but the secondary cold front is more frequent. If there is a secondary warm front it is usually found in a weak trough in the isobars in the warm air between the main warm front and the following cold front. It normally forms in association with a deep or deepening and perhaps fast-moving low-pressure system. Frontogenesis may occur because of convergence within the warm sector. The identifying features are similar but rather weaker than for the main primary front.

Secondary cold fronts may sometimes form in a fast-moving cold airstream. Although these fronts are often to be found behind depressions they may occur in any strong cold current. A mere trough in the cold air need not necessarily mean the existence of a front: it often indicates the existence of marked convergence and an area of enhanced convective activity. There should be a distinct discontinuity in air-mass characteristics on either side of the trough before a front is marked on the chart.

9.4.1.4 Quasi-stationary fronts. As the name implies, a quasi-stationary front is a front which is practically stationary, but which may oscillate slowly in either one direction or the other. A front tends to become quasi-stationary when the pressure gradient along it, and the isallobaric gradient across it, become weak or disappear altogether. A front will also become quasi-stationary if the geostrophic and isallobaric components of the wind normal to the front act with equal strength in opposite directions.

Quasi-stationary fronts are often weak features which occur during the final stage of the life of a front. They may not be associated with precipitation.

9.4.1.5 Young waves. Waves may form on both warm and cold fronts. The former are called warm-front waves and the latter cold-front waves. Warm-front waves as a whole are relatively minor features of the analysis compared with cold-front waves. The condition necessary for the development and deepening of a wave into a depression centre is a strong baroclinic zone, in other words adjacent cold and warm air masses of very different temperatures. A warm-front wave has no access to the really cold air which is behind the cold front of the major low-pressure system. In addition, the slope of a warm front is less than the slope of a cold front so that the cold air immediately ahead of the warm front may only be of relatively shallow vertical extent. As a result of these conditions a warm-front wave is often translated along the warm front without much deepening. Such a wave can be identified by two distinguishing features. The first is an area of falling barometric tendencies, of greater magnitude than elsewhere along the warm front, which may extend around the tip of the wave, particularly on the forward side of the wave. This area will bulge away from the wave tip in the direction of movement of the wave. Secondly, the incipient wave will be marked by a bulge in the belt of precipitation which would normally mark the warm front. This bulge in the precipitation area may broadly cover the area of increased falls in barometric tendency.

The formation of cold-front waves is more frequent than that of warm-front waves and they are of greater importance in the analysis owing to their greater susceptibility to development. They are distinguished by an area of falling pressure, particularly on the cold side of the front where pressure should be expected to be rising, and also by a bulge in the precipitation areas in the direction of motion of the wave. A wave should not be drawn unless the observations give evidence of one. A wave should not be constructed on a front to fill an apparent empty space in the pressure field where there are no observations, or where the observations do not indicate the formation of a wave.

Nevertheless the analyst should particularly watch out for a cold-front wave if the gradient along the front becomes very weak across a front of over 2000 kilometres in length, or if such a front is likely to be distorted by any orographic features which it is approaching.

When a wave is indicated, the tip of the wave should normally extend to the point where pressure is estimated to be the lowest. However, this is not always so. The pressure distribution, rain and cloud areas during the earliest stages of wave formation do not always agree with the accepted model of a young wave. The identification or construction of a wave need not be greatly amended when the low-pressure or precipitation area appears to be detached from the frontal wave tip in the initial stages of its formation and development.

Some remarks on the appearance and characteristic cloud patterns associated with developing waves are made in Chapter 6 - Depressions and related features.

9.4.2 Some general remarks

It is most important that the analyst pays careful attention to the time of day to which the chart he is analysing refers. Most of the meteorological elements observed are characterized by a diurnal variation of some kind. Temperature obviously shows the largest diurnal variation but wind speed and direction, cloud amount and height, visibility and barometric tendency are all affected. Mention has already been made of the cases where the cold air associated with a clear sky behind a cold front in summer may have a higher temperature at midday than the cloudy warm air ahead of the cold front. The same effect may sometimes be observed in the cold air ahead of the warm front if the air has become warm from insolation prior to the covering of the sky by cloud, or if the clouds in the drier air ahead of the warm front are broken. In this case, mechanical turbulence in the damper air in the warm sector may cause a layer of stratus or stratocumulus cloud too thick to break so that the temperature is lower in the warm air than in the cold. If, on an occasion when the pressure gradient is weak, the wind is light during the night or early-morning hours, air-mass identification may be difficult since mist or fog or low stratus may have formed in a cold air mass. Later in the day the wind may become stronger and clear away the fog or cloud. Mixing of the damper surface air with drier air aloft will then cause the surface dew-points to become more representative of the cold air mass. Sea-breezes may cause surface temperatures to be considerably lower along coasts than inland although there is no difference in air mass. Such breezes may also bring low cloud or sea fog and cause higher dew-points than in areas inland where a warm air mass may become hot and cloudless on a fine, summer day.

Attention should also be paid to the diurnal variation of pressure, particularly in summer when falling pressures are often very noticeable on the midday or 1500 GMT chart. Such falls may not in themselves necessarily be indicative of any synoptic development. Similarly, the noticeable rises in pressure which are often observed, for example, on the 0900 GMT chart may only be short lived. Frontal identification should be made with these considerations in mind.

Sferic observations may be a useful guide to the placing of a cold front, occlusion or trough of low pressure over the ocean where observations are sparse.

One of the more difficult problems for the analyst is to know when to drop a front. The problem usually arises when an old front becomes slow moving and does not appear to have any weather or substantial cloud associated with it. If the gradient is weak or the isobars are parallel to the front the absence of noticeable weather or cloud may be deceptive. If the pressure pattern changes in such a way that there is a component of wind across the front, the front may become reinvigorated and move onwards in its former direction or perhaps reverse its direction. On the other hand, it is poor analysis to carry on fronts on the chart long after they have obviously completely frontolysed. Bearing in mind that fronts tend to frontolyse in anticyclones or ridges of high pressure, it may be useful to examine the upper-air chart and representative tephigram ascents when there is any doubt about the existence of an old or inactive front.

It may sometimes be necessary to insert a new front where one has not existed on previous charts. This should be done if the evidence suggests that frontogenesis is taking place.

9.5 THE PRESSURE FIELD

After the major frontal systems have been identified from the observations and marked in light pencil on the chart, the analyst can start to draw the pressure pattern. The frontal analysis may not be complete at this stage. New fronts may have been formed in areas of frontogenesis since the previous chart and the extrapolated analysis over any wide ocean areas, where observations are sparse, may not be accurate. Other new fronts may have been advected into the area covered by the chart from regions outside the boundaries of the chart during the interval of time between the two charts. As the pressure field takes shape it may help to locate such new fronts, as well as confirm the location of those already identified in the preliminary frontal analysis.

9.5.1 Isobars

There is no hard and fast rule concerning the best place to start to draw isobars. Usually the analyst draws his first isobars over the British Isles where the observations are closely packed and in which region the forecaster is probably most interested. The exact technique for drawing isobars will vary from person to person. Many analysts may, however, prefer to start with the 1012-millibar isobar, if it is a convenient one. This isobar usually separates anticyclonic from cyclonic systems. He can then work inwards towards lower pressure or outwards towards higher pressure, whichever is the more convenient. It may be found convenient to draw isobars at 8-millibar intervals and then fill in at 4-millibar or 2-millibar intervals. Isobars should be smoothly drawn except at fronts where they may show a sharp, or sometimes slightly rounded kink with the point of the V directed towards high pressure.

Eventually the isobars on the land areas over which observations are plentiful will be completed. The analyst may then concentrate his attention on the ocean where observations may be rather sparse. Here the ocean weather ship observations will provide the most reliable guide. The analysis over the ocean will normally prove considerably more difficult than over land. The analyst may encounter the difficult problem of judging the reliability of observations which at first sight do not seem to fit the synoptic pattern which is emerging. If an observation's pressure seems to be erroneous by several millibars, the first thing to do is to examine the original report. If the ship's observation has been plotted correctly from the figures in the message, the possibility of an error in the ship's reported position should be considered. The usual mistake in this respect is to plot the ship's position 5 degrees or 10 degrees in error, either in latitude or longitude, because of an error in the figures giving the position. If this test fails, the possibility of the pressure figures being interchanged can be considered. Often the figure may be out by one or more units of ten. The other elements of the observation may all help the analyst to reach a conclusion as to whether the observation is plotted wrongly, or is partly or wholly erroneous. In the latter case it must, of course, be totally disregarded. If the ship's identification letters are plotted, they can be used to verify the ship's position by reference to previous charts in cases of doubt.

In drawing isobars, care should be taken to place them accurately to one side or the other of each pressure reading. The latter are given to tenths of a millibar so that if 2-millibar intervals are used one may imagine the distance between isobars to be divided into 20 units of one-tenth of a millibar. An estimate of the distance of each isobar from the observations upon which it is based can then be made.

The surface wind direction also provides a most valuable guide to the accurate drawing of isobars, provided that the wind speed is at least eight knots and pressure tendencies are not large, that is, not greater than 2 millibars in 3 hours. The isobar should continuously intersect an imaginary line drawn tangentially to the wind direction at an angle of 12° to 15° over the sea, but at a greater angle over the land. The wind should blow across the isobars towards lower pressure. Over the land, where observations are well distributed, the isobars can often be drawn without specific reference to this rule since the pressure readings alone will suffice. It will be noted, however, that the completed pattern will show that the wind does, in effect, intersect the isobars towards lower pressure. Over the ocean, where observations are less evenly distributed, the angle of intersection will provide a useful rule to follow to assist in the direction of the isobars in areas near ships' observations. An even more fundamental rule to use in the oceanic regions is to space the isobars in accordance with the geostrophic or gradient wind equations by means of the appropriate transparent wind scales (see Chapter 16 – Wind),at those points where ships' observations are to be found, on the assumption that the observed surface wind is two-thirds of the gradient wind. The spacing of the isobars in an accurate manner is vital in the technique of analysing a synoptic chart in all regions and at all levels.

The isobars in their final state on the chart should be smoothly drawn. It may be necessary to have several attempts at drawing different sections of the chart before a satisfactory solution of the pressure pattern is produced. Clearly, a compromise must be reached in the process of smoothing. On the one hand, significant differences in the pressure of the isobars and the pressures at adjacent stations must be reconciled. On the other hand, the picture must be smoothed and the isobars must not be erratic lines which wander all over the chart in an attempt to chart the pressure field on a mesoscale, unless the scale of chart is chosen specifically for that purpose, in which case the operation of smoothing may not be desirable at all.

9.5.2 <u>Pressure patterns</u>

As the construction of the pressure field proceeds it will be noted that definite patterns slowly emerge. Although it is not intended to include here a detailed treatment of the synoptic features of the different pressure patterns, mention should be made of these patterns in relation to their construction on the chart by the analyst.

The isobaric field will normally be separated into regions of high pressure and regions of low pressure. As already stated, the 1012-millibar isobar often divides the high-pressure areas around which the isobars are curved anticyclonically from the low-pressure areas around which the isobars are curved cyclonically.

The high-pressure patterns are:

(i) the anticyclone, and
(ii) the ridge.

The low-pressure patterns are:

(i) the frontal-wave depression in various stages of its development,
(ii) the occluded-depression vortex in which the occlusion often no longer extends into the low-pressure centre,
(iii) the polar depression,
(iv) the tropical depression,
(v) the thermal or heat low,
(vi) the orographic or lee depression, and
(vii) the trough.

In addition to areas of high and low pressure the pattern may take the form of a col or saddle-shaped feature which connects adjacent high- and low-pressure systems. Finally, usually in summer, there may be either no pressure field at all or at most a few straggly isobars which do not make up any kind of recognized pattern. In such cases the pressure field is called flat, or slack.

9.5.2.1 Anticyclones. The process of drawing up that part of the chart where pressure is high should not involve many difficulties. Anticyclones are usually of relatively large extent and have gradients which are normally weaker than those in depressions. Fronts are seldom found in anticyclonic areas; if they do exist they will usually be weak. For these various reasons it will often appear most convenient to commence drawing isobars around an anticyclone, particularly over land where observations are plentiful. The anticyclone generally takes the form of a smoothly elongated central body with extensions in the form of ridges or wedges.

9.5.2.2 Ridges. The ridge of high pressure in its well-developed form takes the form of a long tongue which pushes outwards from the anticyclone centre, or it may be simply an elongated area of high pressure which connects two separate anticyclones. Small ridges may be little more than wave-like irregularities in the airflow which are unconnected with any major centre of high pressure.

9.5.2.3 Frontal-wave depression. The frontal-wave depression will take up a variety of forms depending on the stage of its development. In the early stages of its life the wave depression possesses a wide warm sector which narrows as the depression occludes. Isobars should be drawn as straight as possible in the warm sector. Pronounced kinks of the isobars which point towards higher pressure frequently occur at the fronts. But they should not be overemphasized. The kinks are seldom cusped in nature. The isobars in the cold air should be smoothly curved in a circular or elliptical shape as the low-pressure centre is approached, as indicated by the pressure observations.

9.5.2.4 Occluded vortex. During the final stage of the life history of a depression the low-pressure centre may have lost its frontal system. The central area should then emerge as a smoothly drawn circular or elliptical vortex, perhaps possessing the remains of a trough.

9.5.2.5 Polar low. An area of low pressure often forms when unusually cold air is pouring southwards over warmer seas. It is frequently difficult to identify the centre owing to lack of observations. Identification signs are falling barometric tendencies, a tendency to general precipitation, or widespread shower activity associated with winds which, particularly over the oceans, may appear too strong for the apparent gradient in some parts of the flow and too weak in other parts. A polar low usually takes a roughly circular form. A polar depression does not normally possess a front but there may be numerous troughs, particularly on its western flank; however, sometimes when the depression becomes particularly well developed, air of such differing characteristics may be drawn in that effectively the depression becomes frontal.

9.5.2.6 Tropical depression. On rare occasions, the remains of a tropical-type depression approaches the British Isles after a long journey from its source in the tropical ocean. This type of depression is usually a near-circular vortex in the warm air and does not possess any fronts, although it may sometimes capture pre-existing fronts, or frontogenesis may occur as cold air is 'fed into' the system.

9.5.2.7 Orographic or lee depressions. An area of low pressure usually occurs to the lee of a mountain range when the gradient wind is strong. Over the British Isles such orographic depressions are usually weak and of small extent. In other areas as, for example, to the north of the Pyrenees during occasions of strong southerlies or to the lee of the Alps either to the north or south, substantial lows may form. A lee depression usually takes up an irregular shape.

9.5.2.8 Troughs. A trough of low pressure is usually found to coincide with the position of a front. All such troughs are marked by V-shaped, or at least by kinked, isobars. The front passes through the point of the V. Occasionally, a cold front or occlusion moves more rapidly than the trough in which it originally lay. The isobars will then be rounded as they cross the trough-line. There may be troughs in the cold air: it is important that the analyst identifies such patterns for the arrival of a trough may be accompanied by quite violent squalls, showers, etc.

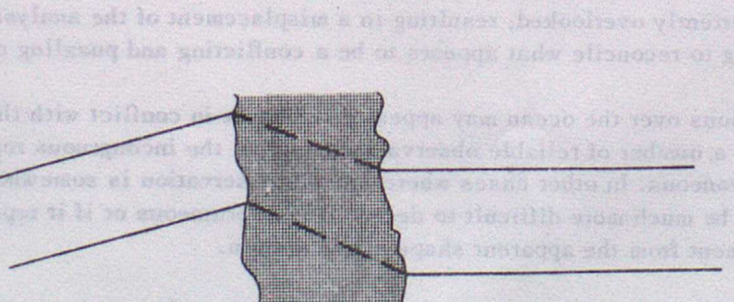
9.5.2.9 The col. The col is a neutral area lying between adjacent anticyclones and depressions. The col, like the ridge, is derived from topographical terminology as applied to ordinary maps of the earth's surface.

9.5.3 Isobars over high ground

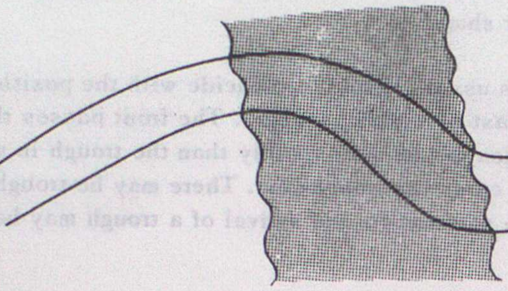
Barometric pressures are normally reduced to mean sea level. If the altitude of the station is high, the reduction process introduces significant errors, so that the pressure value at the station cannot be compared with neighbouring low-level stations. Stations situated in the midst of an appreciable area whose average height above sea level is more than 500 metres do not usually reduce their station-level pressures to mean sea level, but to some other reference level which is the subject of regional agreement. This reference level may be, for example, 1000 metres. Isolated stations more than 500 metres above the reference level used in the surrounding area normally do not reduce their readings but report the station-level pressure.

In drawing isobars over a large plateau or area of high ground there will be a discontinuity between the sea-level pressures and those reduced to the higher level. In such cases care must be taken to ensure the regularity of the pattern. It may be useful to draw the high-level pattern with dashed lines as a separate pattern which is not connected with the main sea-level pattern.

Where a high mountain range exists (for example, the Alps or Apennines) sea-level isobars on the two sides of the range need not be continuous one with the other. The effect is particularly pronounced if there is a marked difference in air temperature between the two sides of the mountain range. On these occasions, it may be desirable to omit the isobars over the high ground or draw them discontinuously rather than imply fictitious curvatures in the isobars over the adjacent lowlands. Thus:



is preferable to:



9.5.4 Pressure patterns over the ocean

With a reasonably dense network over the land the final analysis will take its shape fairly soon. It is, of course, of great importance to complete the analysis as soon as possible. Nevertheless, accuracy should never be sacrificed for speed. Rapidity and skill are attributes which come slowly with time and experience.

Over the ocean the task may be more difficult owing to a less dense network of observations. Considerable ingenuity is often required to construct an analysis that fits all the available data. Mention has already been made of some helpful guides that can be used; the extrapolation of fronts and pressure systems from a previous chart or charts, and the use of the geostrophic or gradient wind scales for spacing the isobars. A particular point to remember is that the pressure tendency reported by a ship is the total change of pressure reported by the moving ship. This total change is composed of two parts: that part caused by the component of the ship's motion normal to the pressure field and the part which is the change of pressure with time. It is the second part which is comparable with the tendency measured over the land. It is not exactly the same since this temporal change is really a mean tendency covering the track of the ship during the past three hours. This second part is the component of the tendency required by the analyst. It is obtained by subtracting the first part, due to the ship's motion through the pressure field, from the change reported and plotted on the charts. The speed and direction of the ship's movement across the ocean is also plotted so that the necessary subtraction can be made quite easily and an estimate of the time change made. It is essential that the correct value of the tendency be known and carefully considered in order that the frontal analysis may be correctly placed over the ocean. The danger is that, in transferring his attention from the land areas to the ocean, this composite nature of the ship's tendency observation may be inadvertently overlooked, resulting in a misplacement of the analysis or a waste of valuable time in attempting to reconcile what appears to be a conflicting and puzzling observation.

In some cases, observations over the ocean may appear puzzling or in conflict with the general shape of the pattern. If there are a number of reliable observations nearby, the incongruous report may be identified as definitely erroneous. In other cases where the odd observation is somewhat isolated from neighbouring ones, it will be much more difficult to decide if it is erroneous or if it represents a real alteration or new development from the apparent shape of the pattern.

There is a need for a most detailed examination of all elements of an observation at sea which at first sight does not appear to fit the analysis as it stands. Such observations may hold the key to future development, and future observations from the area in question should be scrutinized with the utmost care. It is, in particular, fatal for an analyst to hold inflexible ideas of the analysis. He should be ready to change different parts of the analysis if the evidence weighs the balance in favour of such a change.

9.6 ISALLOBARS

Isallobars, as they may be drawn on a synoptic chart, represent isopleths of equal barometric change during the past three hours. Although it has not been the practice in the past to draw the isallobaric pattern as a standard procedure in the Meteorological Office, this element of barometric change gives most important and valuable information to the analyst.

The technique of synoptic chart analysis is concerned with the slow evolution of the pressure pattern with time. This change is directly indicated by the pressure changes which are going on all the time over the entire area of the chart. These changes represent the integrated result of the convergence and divergence occurring throughout the whole atmospheric column. There is, therefore, no better guide to the future short-term evolution of the synoptic analysis than the isallobaric pattern. It will therefore be found most useful on occasions to indicate the principal features of the isallobaric pattern. Isallobars may be shown in pencil by dashed lines and should normally be drawn at intervals of one millibar.

9.7 THE FINAL PRODUCT

When the analyst is satisfied with his work and reasonably confident in his own mind that no further changes need be made, he may give the finishing touches to the chart. Warm fronts at the ground should be coloured as a solid line in red pencil, cold fronts at the ground as a solid line in blue pencil and occlusions at the ground in a solid line in purple pencil. Quasi-stationary fronts should be marked with an alternate red and blue solid line. The centres of anticyclones should be neatly labelled with an 'H' in red, and the centres of depressions with an 'L' in blue; there is no need to label any other features specifically, except for historical identification. This may be accomplished by allotting a letter to each front and pressure centre and thus carrying on the continuity of identification of each individual system from chart to chart. At this stage, the tracks of the pressure centres may be marked in pencil with a broken line joining small crosses indicating the position of successive 3- or 6-hour intervals. Isobars should be numbered at even intervals, namely, 992, 996, 1000, etc. for 4-millibar intervals.

Zones of continuous precipitation may be shaded solidly in green. Zones of intermittent precipitation may be shaded in single hatching in green. The analyst should be careful to ensure that the shading or hatching does not obliterate the plotted data. The extent of the area of precipitation may be delineated with a thin boundary line. Areas of fog may be shown by yellow shading and areas of duststorm, sandstorm or haze by brown shading. Appropriate symbols from the past-weather code may be superposed on the shaded area to indicate the nature of the weather in the area. Thus areas of showers, snow showers, etc. may be shown by distributing large, green past-weather symbols for the appropriate element over the area. The past-weather symbols for thunderstorms should be marked in red. The extent of these areas may also be delineated by a thin boundary line.

If areas of precipitation or fog are indicated, careful consideration should be given to the extension of the area into regions without observations. Historical continuity, observations of past weather, and evidence of the duration of precipitation will assist in this. If areas of rain are shaded over land, areas over the ocean where rain is believed to be falling should also be shaded, otherwise the misleading impression of fair weather may be given by the absence of shading.

The analyst may not wish to mark his chart with too much colour and symbol marking, particularly if the final product appears as a maze of irregular shading which detracts from the vital information given by the frontal and pressure-field analysis. The practice of including these extra effects is usually left to individual choice; it is more generally employed on open-scale charts for a limited area, such as the British Isles and adjacent regions. Changes from hour to hour can be noted and the charts provide a useful aid for the local forecaster. Often, fairly detailed analyses of mesoscale pressure patterns are possible: some examples have been discussed by Findlater[2] (see Chapter 7 - Anticyclones and related features), Pedgley[3] and Aanensen[4] (see Chapter 6 - Depressions and related features). Findlater showed, for example, that in an anticyclone individual cells, perhaps

200-400 kilometres across, could be identified and followed from chart to chart – on some occasions the boundaries or minor troughs between the cells were associated with changes of cloud amount and type, or of visibility. The paper by Aanensen deals with the damaging Sheffield gales of February 1962, and shows a striking example of the difference between the broad-scale analysis appropriate to a chart covering a large portion of a hemisphere and the more detailed analysis for a fraction of the British Isles. The latter included several pressure observations from climatological stations, not normally available to the operational analyst, but even the normal hourly charts showed a well-defined trough to the lee of the Pennines, with some suggestion of a small depression in the trough, features missed by the broad-scale analysis.

The aim of the process of analysis is not just to draw sets of lines on the chart which fit the observations, but to build up a three-dimensional picture of the weather systems and to acquire an understanding of the way in which the observed features have come about. It is essential, therefore, that all the relevant detail is thoroughly studied, including the upper-air analyses and charts for earlier times. By developing an understanding of the current situation in this way the forecaster will be building a firm foundation on which to base forecasts of the changes likely in the future.

BIBLIOGRAPHY

1. Geneva, World Meteorological Organization. The use of satellite pictures in weather analysis and forecasting. Tech Notes, Wld Met Org, Geneva, No. 124, 1973.

2. FINDLATER, J.: A note on the analysis of anticyclones. Met Mag, London, 96, (March) 1967, pp. 69-73.

3. PEDGLEY, D. E.; A meso-synoptic analysis of the thunderstorms on 28 August 1958. Geophys Mem, London, 14, No. 106, 1962.

4. AANENSEN, C. J. M.; Gales in Yorkshire in February 1962. Geophys Mem, London, 14, No. 108, 1965.