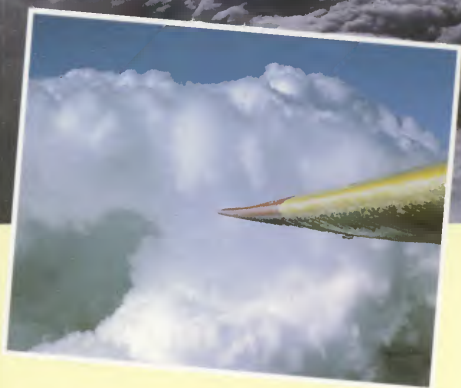


Understanding Flying Weather

Derek Piggott



Second edition

Understanding Flying Weather

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Understanding Flying Weather

Second edition

Derek Piggott

To Wally
Best wishes
Derek Piggott

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Author's Note

My aim in writing this book has been to provide a simple introduction to Meteorology for people learning to fly gliders or other kinds of aircraft. Hopefully, the book should help the reader to understand the current weather, to interpret and make better use of forecasts, and to recognise the better days for flying and the ever present hazards associated with flying into bad weather.

Although the book is largely glider and soaring orientated, I am sure that all pilots would be safer and have more fun from their flying if they understood more of the subtleties of soaring conditions. On many days any knowledgeable pilot can use thermals and hill or wave lift to improve the climbing ability and even to increase the average cruising speed and economy of a light aircraft.

With this in mind, I have included some notes on how to make use of thermal activity when flying a light aircraft and also some advice for the less experienced glider pilot who may be having difficulties in staying up.

For a long time I have known how difficult it is for glider pilots reading for their Bronze C. It usually involves searching through a number of books, never knowing what is essential for the test. No one meteorology book seems to cover what the pilots really need to know in an easily understandable manner. I hope that this book will solve their problems and I have included questions and answers covering that syllabus. These should also be useful to the reader who is starting to study for a Private Pilot Licence.

I would like to thank John Finlater and Tom Bradbury, both very experienced forecasters, for their encouragement and for their help in checking my text and suggesting what should be included.

Derek Piggott

INTRODUCTION

Meteorology is a complex subject and therefore to simplify it means discussing only the basic factors. Each is affected and modified by the others so that all of them need to be taken into account when considering what is happening to the weather.

In trying to understand the weather from a pilot's point of view the main factors involved are:

- 1 where the airmass has come from and the type of terrain over which it has travelled;
- 2 the pressure distribution and the significance of the pressure pattern;
- 3 the characteristics of depressions, fronts and anticyclones;
- 4 the stability of the airmass;
- 5 the local topography;
- 6 the time of year and the time of day.

All of these factors and many others have to be considered by a forecaster if a reasonable prediction is to be made. However, pilots do not normally have detailed information and must rely mainly on the professional forecaster to interpret the reports and measurements available to him. Although this information is updated every few hours, many of the weather changes are rapid, making the forecasts uncertain. Even a patch of high cloud or an unexpected shower can change the soaring conditions and wreck an otherwise accurate forecast. This makes it particularly important for the soaring pilot to make a good assessment of the likely conditions by looking at the forecasts available in conjunction with his own observations.

THE AIRMASS

An airmass is a body of air in which horizontal changes of temperature and humidity are slight. It may extend for many hundreds of kilometres. Its characteristics are acquired by moving over a distant source region for a long period before being moved on to affect other areas. Different airmasses are separated by fronts, where horizontal changes of temperature and humidity may be sharp.

A **front** is a sloping surface separating two airmasses having a different temperature and humidity. Surprisingly, even slightly different airmasses do not easily mix together. The frontal zone where the two airmasses meet is sometimes only a few miles across, although it may on occasion stretch for 50 miles or more.

The source of the airmass determines its characteristics and in particular its temperature. However, the path over which the airmass has travelled determines how much the airmass is modified before it reaches us. Unfortunately TV and newspaper weather maps seldom give any detail on the airmasses.

Polar airmasses come from the north and start cold or cool. Cold air cannot hold much moisture and therefore polar airmasses are likely to be relatively dry.

Arctic maritime (Am). This is polar air which has only had a short sea track. The warming over the sea makes it very unstable, producing frequent showers in the north of England.

A polar airmass which has travelled over large areas of sea will be called a **Polar maritime** airmass (Pm). By originating in the north, Polar maritime air reaches us by moving southwards over a progressively warmer sea, thus warming and moistening the lower layers of air and generating instability and showery weather with good visibility.

A **returning Polar maritime (rPm)** airmass is a polar maritime airmass which has moved south over the Atlantic to a latitude south of the UK and then returned northwards round a depression

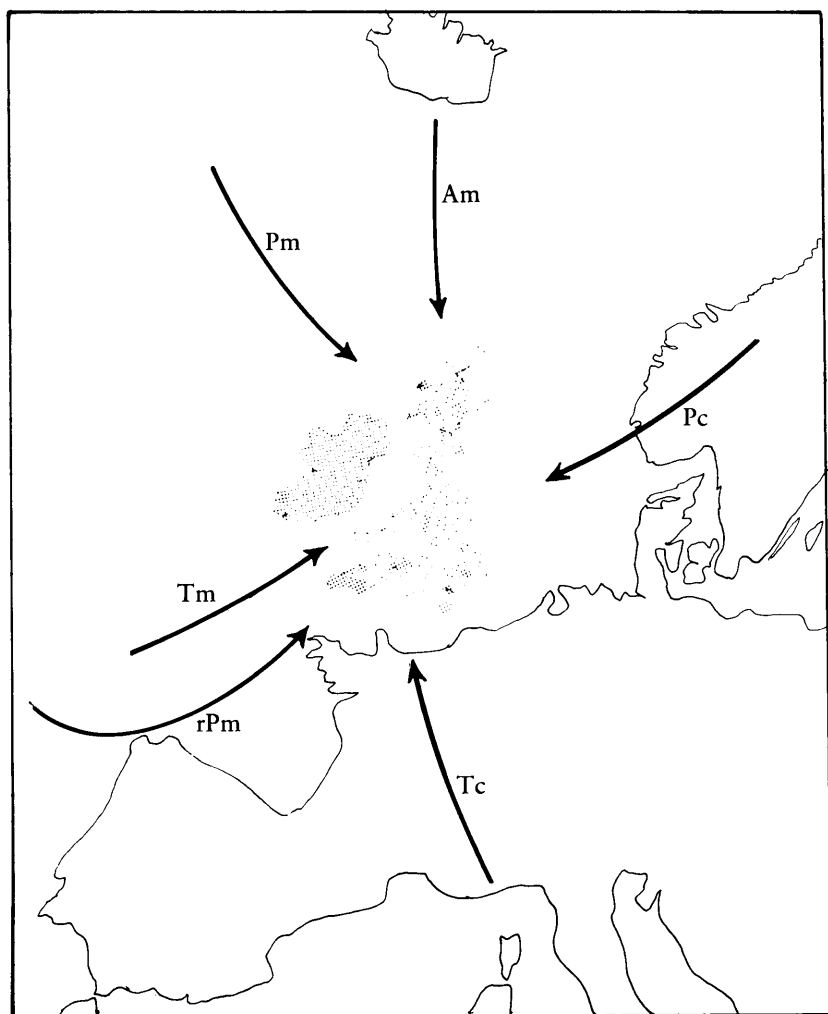


Fig 1 The origin of the airmasses. *Am* Arctic Maritime; *Pm* Polar Maritime; *Pc* Polar Continental; *Tc* Tropical Continental; *rPm* Returning Polar Maritime.

over a colder sea which stabilises the lower layers, giving stratus clouds. When this air reaches the UK it may then be heated as it moves overland. The low level stability is destroyed causing deep instability with very showery weather in the southwesterly winds.

A **Polar continental** (*Pc*) airmass is very cold air which comes from the east or northeast and has travelled over a large land mass. In winter the relatively warm sea may warm the lower layers resulting in cloudy, wintry conditions.

A **Tropical** airmass will be warm, but since warmer air can hold

more moisture, it can be dry or have a high humidity, depending on the route it has taken to reach us.

A tropical airmass which has moved over large areas of sea will have picked up a large amount of moisture. The relatively low sea temperatures will have cooled the lower layers producing stable, cloudy conditions. Near windward coasts low cloud is liable to persist all day. This kind of airmass is then known as **Tropical maritime** (Tm) and where it travels over land in summer, the cloud will break up leaving rather stable muggy weather and poor visibility.

Where tropical air moves in from the continent in summer it will be hot, hazy and dry and known as a **Tropical continental** (Tc) airmass.

On a much smaller scale the airmass is being continuously modified during the day and night. Even a slight change in the wind direction, so that the air has travelled over more land, will often result in a dramatic change in soaring conditions. The air will be drier, giving a high cloud base and better thermals. For example, in England a small change in the wind direction of northerly winds can result in marked improvement and better soaring. Instead of blowing in almost directly from the sea, the rather moist cool air will have dried out by travelling over the length of the country before it reaches central England. This will reduce the amount of cloud cover and raise the cloud base.

With such a small island the proximity of the coastline is always a limitation for long distance glider flights. The coast line is only 20 miles or so from the Lasham Gliding Centre in Hampshire (midway between London and Southampton) and with south or southwest winds, cloud base will remain low all day and thermals will usually be weak unless good cloud streets are formed. 20 miles further inland at Booker and Dunstable the cloud base will be several thousand feet higher, giving far better conditions. Similar conditions occur near most coastlines all over the world, and have a significant effect on soaring conditions whenever the winds are coming inland off the sea, particularly in summer. In winter the sea and land temperatures are much closer to each other and sea breeze effects are insignificant.

2

THE PRESSURE PATTERN

Since the air itself has weight, the air near the surface is compressed by the weight of all the air above it. The greater the height, the less weight of air above that level and therefore the lower the pressure. Below about 5000 feet the pressure is reduced by about 1 millibar for every 30 feet of extra height. This is an average figure and is important to remember for calculating heights when using an altimeter. (*See fig. 2.*)

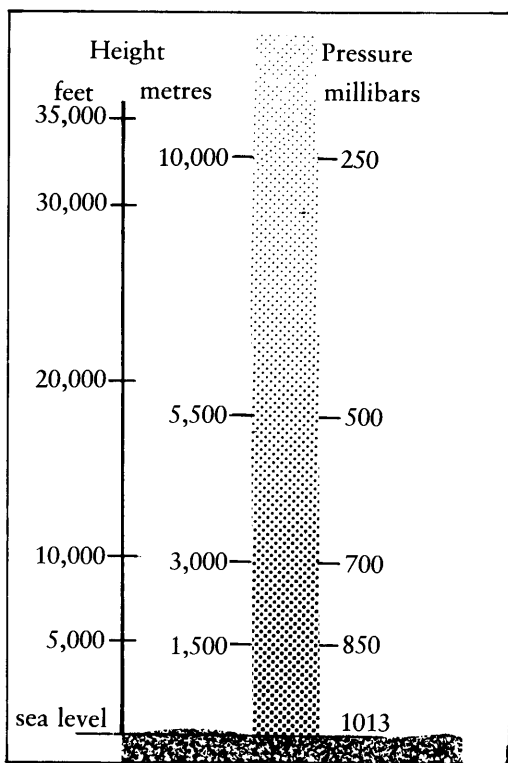


Fig 2 The reduction of pressure with height.

Lifting the air causes cooling because the atmospheric pressure decreases with height, and any reduction in pressure of a gas results in an expansion so that the same amount of heat is contained in a larger volume. This principle is demonstrated in many types of refrigerator where a gas is allowed to expand, lowering the temperature; conversely, with a bicycle pump, compressing the air into a smaller volume results in a rise in temperature.

Variations of pressure in the upper atmosphere cause a gradual ascent or subsidence in the lower levels resulting in changes in the pressure at the surface.

If air is heated, it expands when free to do so. This results in a reduction of its density and pressure. Uneven heating of the earth's surface will therefore give rise to pressure variations from place to place. Winds are the result of the movements of the air as it tries to even out these differences in pressure.

High and low pressure areas

The pressure distribution determines the direction and strength of the winds. Without the earth's rotation, air would always tend to flow directly from any higher pressure region to even out any pressure differences. (This does happen near the Equator). However, the Earth rotates and this causes air moving from high to lower pressure in the Northern hemisphere to be deflected to the right until a balance is achieved between the pressure gradient force and the deflecting force due to the rotation of the earth. This is known as the Coriolis effect, and it causes the air to flow in a clockwise direction around an anticyclone or high pressure area, and in an anticlockwise direction around a depression or low pressure area. (*See fig. 3.*) In the southern hemisphere the reverse is true and the air moves clockwise round the depressions. Since the winds are the result of these pressure patterns, to understand them and the movements of the weather systems we need to know more about pressure systems.

The readings of the local pressure are recorded by stations all over the world but it is only over the land masses that there are enough stations to form a fairly accurate picture of the ever-changing pressure patterns. In recent years the changes in pressure over the surface of the earth have been predicted largely by computer. Given the data from all the reporting stations, the computer is able to predict the most likely movements and changes in pressure patterns, enabling better forecasts to be made.

The newspaper and television charts often show the **isobars**, lines joining places of equal pressure at mean sea level (msl), and

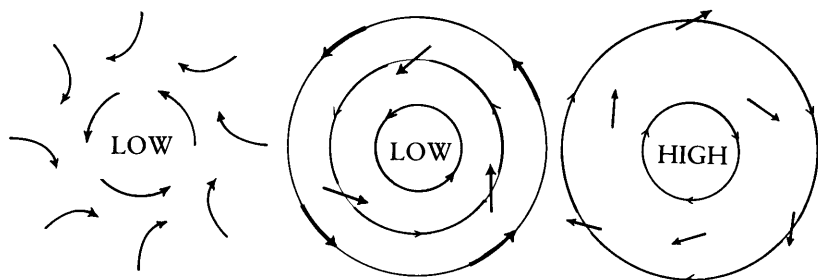


Fig 3 The earth's rotation causes the air to circulate anti-clockwise round a *low* pressure and clockwise round a *high* pressure with the surface winds at about 30 degrees to the isobars.

it is well worth while learning to interpret these charts.

It may be surprising to learn that for all practical purposes the winds at 2–3000 feet above the surface blow along these lines of equal pressure. The reason for this is not simple to explain and the average reader need only remember that this is a fact.

Near the surface, however, air is retarded by surface friction caused by trees, vegetation, structures and topography so that the wind speed and therefore the deflecting force caused by the earth's rotation are reduced. This makes the surface wind flow at an angle across the isobars towards the low pressure, often about 30 degrees overland and 10 degrees over the sea where the friction is less.

When the isobars are close together the pressure gradient and the wind are strong. When the isobars are widely spaced and the pressure gradient is weak, the winds are light.

Buys-Ballot's law

(See fig. 4.) This useful law states that: in the northern hemisphere, if you stand with your back to the wind, the low pressure will always be to your left and high pressure to your right. It is also useful to note that if you stand with your back to the surface wind, the upper wind at about 2000 feet will be blowing about 15-20 degrees further round in a clockwise direction.

Veering and backing

(See fig. 5.) The wind is said to **Veer** if it changes in a clockwise direction, and to **Back** if it changes in an anticlockwise direction. An easy way to remember these terms is that *backing* is like turning the clock *backwards*.

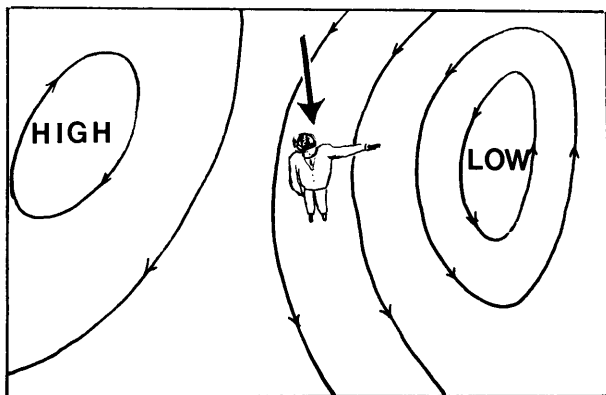


Fig 4 Buys-Ballot's Law. Standing back to the wind, low pressure is always to the left (in the northern hemisphere).

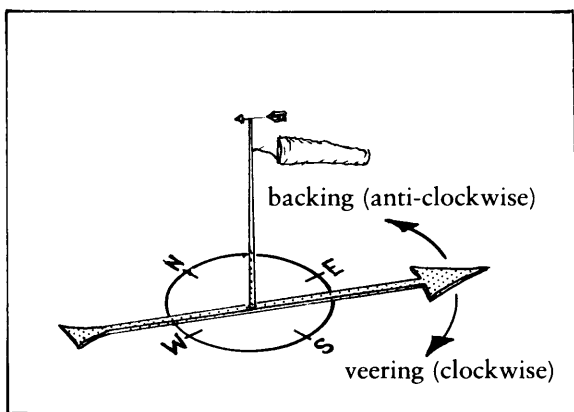


Fig 5 Veering and backing.

Interpreting the isobars

Fig. 6 (see next page) shows a weather map with only the isobars drawn in. Each line connects places with equal mean sea level pressure and in this case is marked with the pressure in millibars. The main feature is the depression centred over Northern Ireland with a weak ridge of high pressure over Europe.

Which way is the wind at Bristol? Well, the wind always blows anticlockwise round a low pressure area so we can mark in the general circulation. At Bristol, therefore, the gradient wind at 2000 feet or so would be along the isobars and in a southwest direction.

We could also predict that at the surface the wind would be

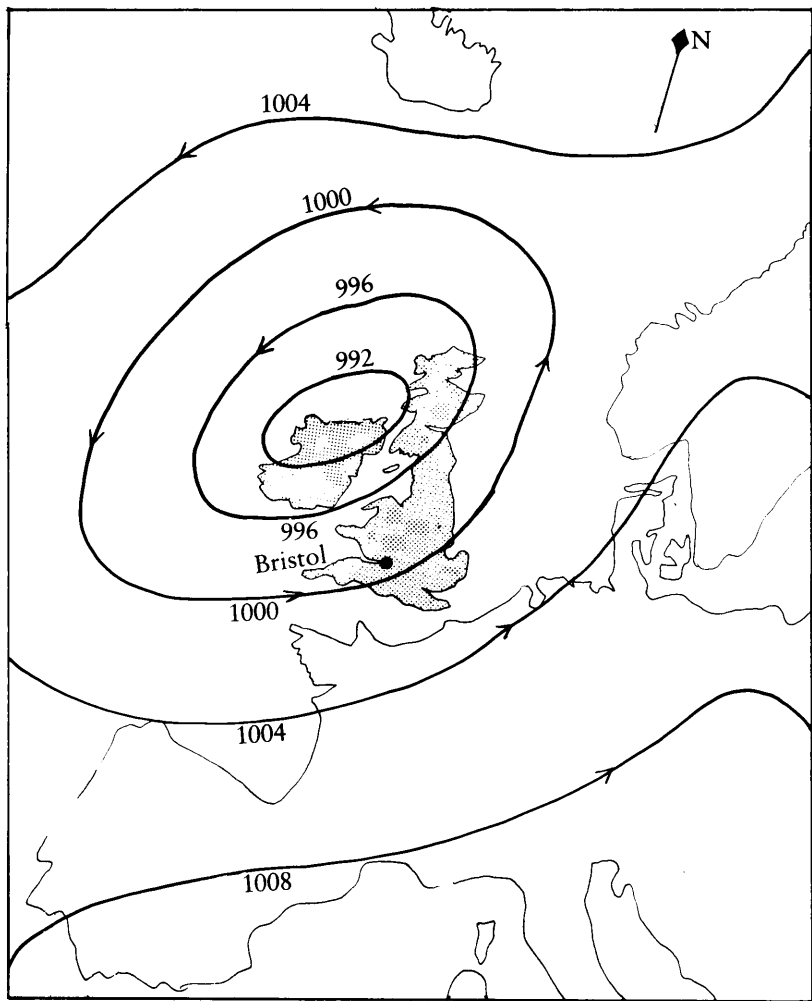


Fig 6 Interpreting the isobars. Isobars link places with equal pressure and are usually spaced at 4 millibar intervals. Which direction are the surface and upper winds at Bristol?

more southerly because it would be flowing a little more towards the centre of the low. Try the Buys-Ballot's law for Bristol. Imagine your back to the wind. Yes, the low pressure is to your left.

Wind strength

As already mentioned, where the pressure changes rapidly over a short distance, i.e. the isobars are very close together, the winds will be very strong. The Met. man can predict the wind strength

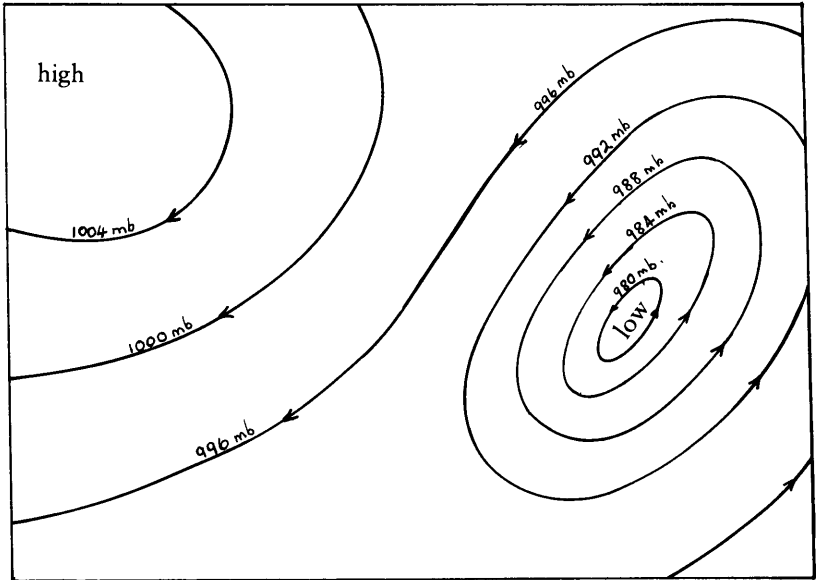


Fig 7 High and low pressure areas (anticyclones and depressions).

at a certain height by measuring this pressure gradient. A specially calibrated scale is used to measure the distance between these lines and gives him an estimate of the wind speeds at about 2000 feet. (This is known as the **geostrophic** wind.) At this height the actual wind blows along the isobars but varies from the geostrophic wind in some circumstances and this is known as the **gradient** wind. Note that this is nothing to do with vertical wind gradients which are caused by the friction of the ground on the wind and cause us so much trouble during take-off and landing in strong winds. In fact, the gradient wind is the wind *above* the influence of the surface friction. At low levels the airflow is disturbed by trees, buildings and hills, so that it is never steady. In strong winds, gusts of at least the strength of the upper wind should be expected because some of the momentum of that upper wind is brought down by the effects of convection and turbulence.

Fig. 7 shows a low and high pressure region. In the high pressure area (an **anticyclone**) the isobars are further apart indicating much lighter winds. Winds always blow clockwise round a high.

It is usual to have a much lighter surface wind in the early morning and late evening than during the middle of the day because the cold dense surface air increases the friction effect. When the surface air warms and thermal activity begins it mixes the surface wind with the upper winds. Some air is taken up and some brought down, with the result that the lower winds increase and

20 THE PRESSURE PATTERN

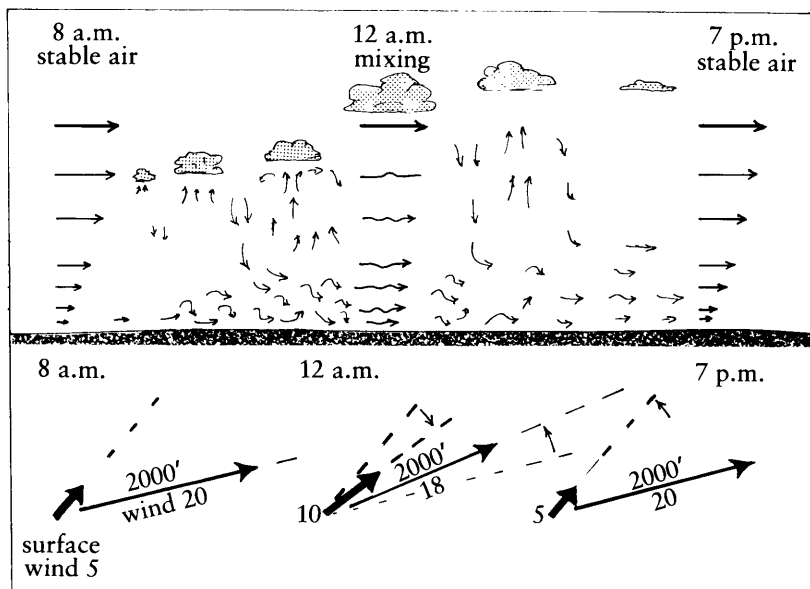


Fig 8 Changes in the surface and upper winds during the day. The surface winds increase and veer as the thermal activity causes mixing, and decrease and back in the evenings as the air becomes stable.

swing a little closer in direction to the wind at 2000 feet or so. (See fig. 8.) A knowledgeable Duty Instructor at a gliding site will allow for this inevitable veering and strengthening of the surface wind when he sites the position of the winches in the early morning.

For example, if the surface wind is a light westerly at 8 a.m., it will most likely increase by 5 knots or so and swing to a more northwesterly direction later in the morning. However, this effect can be completely swamped by any rapid change in the weather, such as the approach of a depression.

The surface wind may also increase and change in direction if it is reinforced by the sea breeze. The timing of this increase will depend on the distance the air has to come from the coast. For example, about 25 miles from the coastline an onshore wind can be expected to increase sometime after mid-day, bringing in cooler, moister air and probably spoiling any thermal activity. Sea breezes may also advance inland against a generally light but opposing wind, resulting in changes in the wind direction as well as in strength.

During the daytime the high ground heats up more rapidly than the valleys and this sets up winds, known as **anabatic** winds, blowing up the slopes. (See fig. 9.) This flow up the mountainsides is confined to quite a shallow layer so that using it involves flying

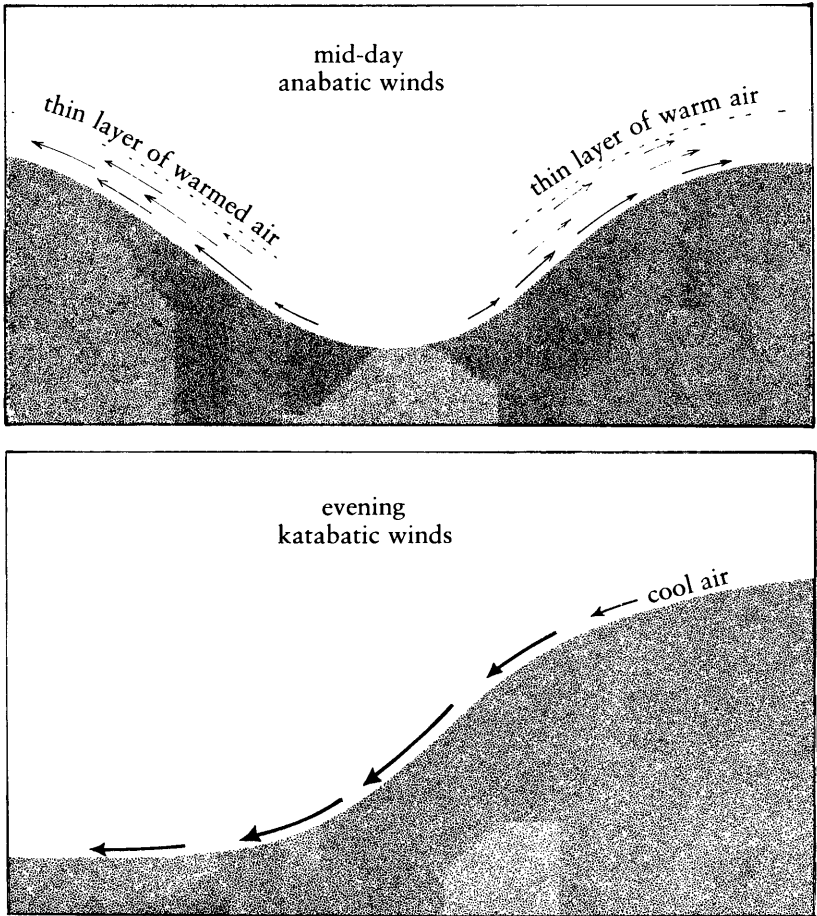


Fig 9 Anabatic and katabatic winds.

very close to the hill slope. Anabatic winds are most evident on sun-facing and lee slopes where the surface gets the greatest heating.

Conversely, in the evening and particularly on a clear night, the earth radiates heat out into space, cooling the ground and the air close to it. In hilly country this cooler air flows down the sides of any hills or mountains into the valleys. This is known as a **katabatic** wind.

Low-level winds will always tend to blow round obstructions such as hills, causing quite large variations in both the direction and strength near the surface.

In the lee of hills and mountains the surface wind strength will vary considerably if lee waves are formed. Below the crests of the waves the winds may be very light or even reversed, whereas only

22 THE PRESSURE PATTERN

a short distance up or downwind of these areas the wind can be very strong indeed. Even if it is a light wind on the ground precautions always need to be taken to tie down gliders properly, as the position of the wave may change without warning, resulting in a sudden unexpectedly strong wind. (Lee waves are explained in a later chapter.)

Wind gradient

(See fig. 10.) The layers of air close to the ground are slowed down by the friction between the air and the ground. Obviously, the stronger the wind, the greater the change in the wind speed which is possible due to this effect. The friction will also be greater if the ground is rough or covered by obstructions. If the air is unstable and the area is in the lee of obstructions such as trees or buildings, some of the faster moving air from above may be brought down to ground level, causing momentary stronger winds or gusts. These rapid changes in wind speed combined with the wind gradient often make take-offs and landings critical in windy weather. Flying down into a rapidly decreasing wind speed during the final stages of an approach causes a sudden loss of airspeed and a rapid loss of height which can be dangerous in a glider or light aircraft. This effect is caused by the **wind gradient**. Turbulence near the ground always indicates rapid changes in wind speed and direction and extra flying speed is essential to ensure that there is adequate speed and control at all times.

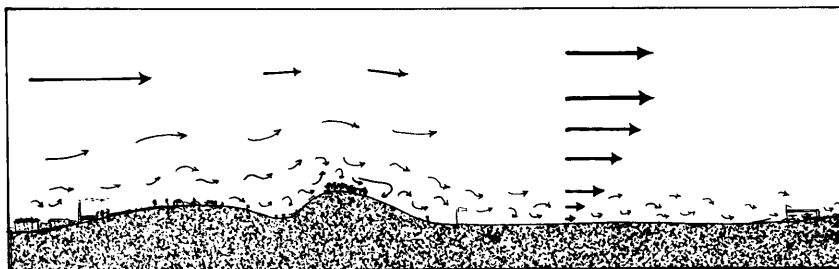


Fig 10 The wind gradient. Surface friction reduces the wind speed near the ground.

DEPRESSIONS AND ANTICYCLONES

In the past few years, with the developments in radar and the use of powerful computers and weather satellites, the mechanisms by which the depressions develop have been studied in much more detail than was ever possible in the past.

It is now known that movements occurring in the upper atmosphere are the cause of the high and low pressure systems forming near the surface which dominate our weather.

With the air circulating round the low pressure area, air must be rising and being removed at high level or the low would fill in very quickly. Similarly, for a **high** pressure system to persist there has to be a descent of the air to maintain the higher pressure. It is these general movements up and down, started at high level, which dictate where systems will form and which cause the characteristic weather associated with them.

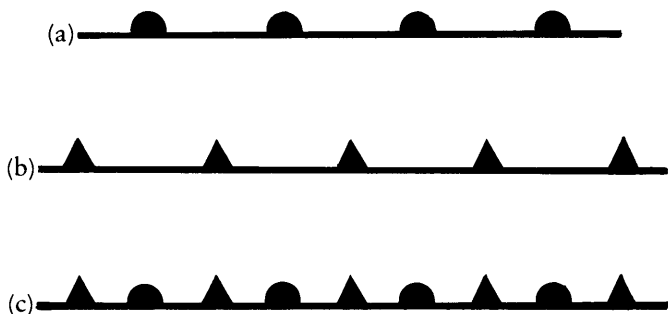


Fig 11 Symbols used on weather maps. (a) A warm front. (b) A cold front. (c) An occlusion.

Depressions

The weather systems moving into Europe originate in the Atlantic and generally move from west to east. The cold air mass from the

24 DEPRESSIONS AND ANTICYCLONES

polar regions meets the warmer tropical air along a **front** and depressions form along this boundary.

It is known as a **warm front** if the warmer air mass is moving forward over the surface, and a **cold front** if it is the cooler air mass moving forward over the surface. In some circumstances the movement of a front may be reversed so that a warm front becomes a cold one.

The majority of our weather systems form out in the Atlantic along the frontal zone between the Arctic air mass and the warmer Tropical maritime air to the south.

When two air masses of different density lie side by side they induce a strong current of air to flow parallel and on the cold air side of the front at very high altitudes. This is known as a **jet stream** and is several miles deep and travels at speeds of 100 to 200 miles an hour. (*See fig. 12(a).*)

Disturbances in this upper flow cause the jet stream to change direction and swing from side to side and this results in areas where the flow is speeded up or slowed down. (*See figs 12(b) and (c).*) Where the flow speeds up because of divergence, the pressure drops slightly inducing an upward flow of air.

This continuing upward movement results in a change of pressure at the surface which forms the depression. During the development of a depression air is flowing in near the surface, though not fast enough to stop the depression deepening. (*See fig. 13(b).*)

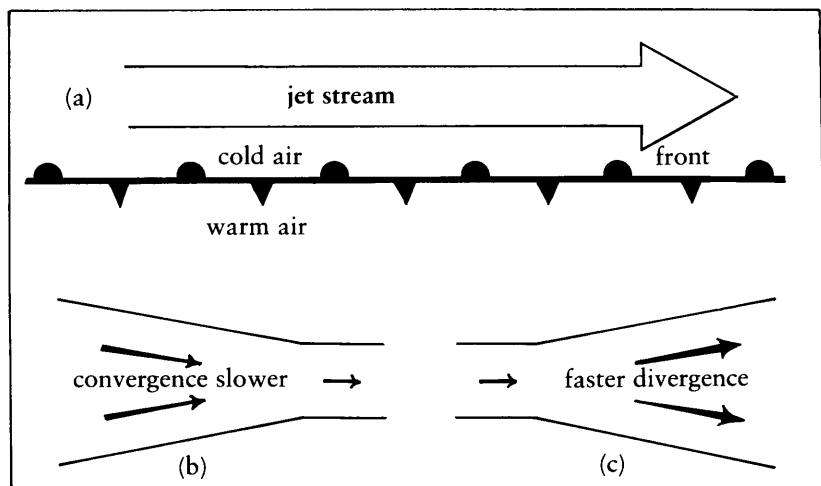


Fig 12 (a) Upper airflow along a front. (b) Convergence. As the speed of flow decreases, the pressure rises. (c) Divergence. As the speed of flow increases, the pressure decreases.

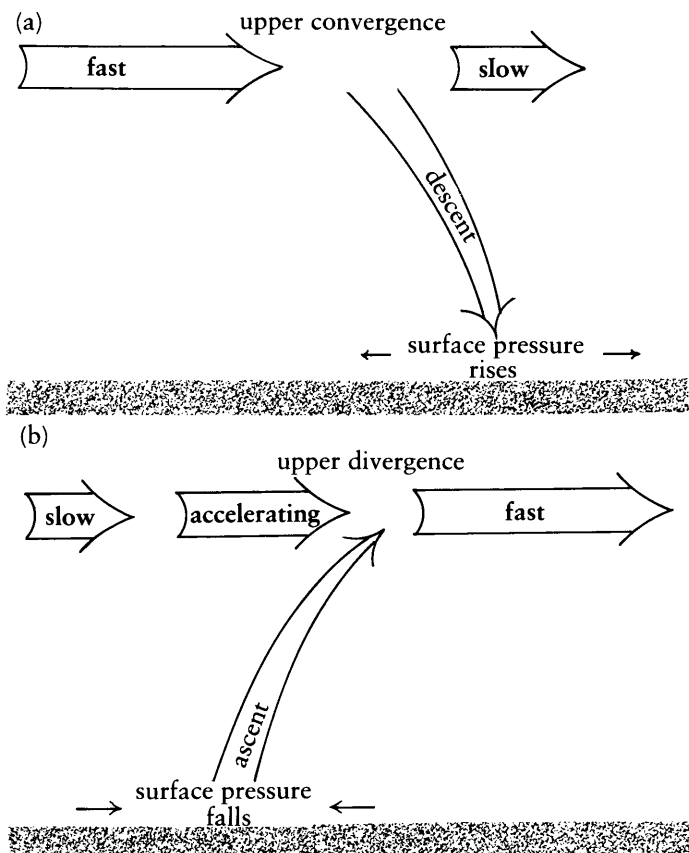


Fig 13 (a) Upper convergence causes an increase in pressure and a descending flow forming an area of high pressure (anticyclone). (b) Upper divergence causes a drop in pressure and an upward flow, reducing the surface pressure and forming an area of low pressure (depression).

Similarly, anticyclones start with convergent flow slowing down the airflow at height and causing an increase in pressure and a downward movement of air. This results in an area of higher pressure and an outward flow at low levels. (See fig. 13(a).)

The life of a depression

In figs 14(a) and (b) the increase in the speed of the upper flow caused by a divergence of the air at height has reduced the pressure. This starts a flow upwards, reducing the pressure at the surface, and induces an inflow of air trying to fill in the area of lower pressure.

26 DEPRESSIONS AND ANTICYCLONES

(See *figs 14(c) and (d)*.) Because of the effects of the rotation of the earth, this inflow is diverted into a circulation in an anti-clockwise direction.

Whereas at first the frontal surface was more or less stationary, the circulation starts a wave in the front. The cold dense air moves and starts to undercut the warmer tropical air forming a **cold front**. At the same time the warmer air is moved up over the colder air mass forming a **warm front**. (d)

(See *figs 14(e) and (f)*.) As the air is continuously extracted at the top of the system, so the pressure at the surface continues to drop, increasing the circulation and the wind speeds. The anticlockwise circulation is gradually spread up to higher levels and the upward movement of the warmer moist air causes adiabatic cooling and the formation of clouds, releasing more heat energy as the moisture condenses into water droplets.

The cold front moves more quickly than the warm one and catches it up forming an **occlusion**, with the **warm sector** at the surface being reduced in size.

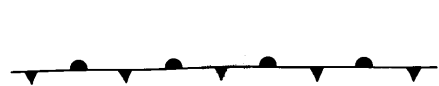
See *figs 14(g) and (h)*. The warm air continues to be carried round in a spiral by the winds but the upper extractor effect has ceased, so that the circulation runs down with the surface low pressure area gradually filling. However, the changes in the upper flow caused by the last stages of the life of this depression often create a further acceleration of the flow in the jet stream. This sets off the process again, forming a new depression.

Sometimes a whole family of depressions forms, giving a period of almost continuous unsettled or bad weather. On other occasions the upper flow will be slowed down, causing an increase in pressure and a gradual descending flow which starts the formation of an anticyclone and more settled weather.

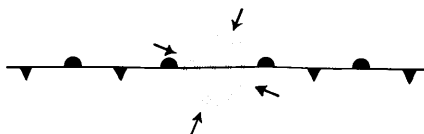
The meandering of the jet stream to the north and south as it flows across the Atlantic largely determines the pattern of our weather and the position and intensity of the areas of high and low pressure.

Warm and cold fronts

Both warm and cold fronts may vary in the weather conditions they produce, and may differ considerably from the idealised examples shown in the illustrations. The slope of the front will vary, causing changes in the cloud and the amounts and intensity of the rainfall along the front. Some warm and cold fronts may even have gradually descending air and this will reduce the amount of activity on them. Some warm fronts will have active



(a)



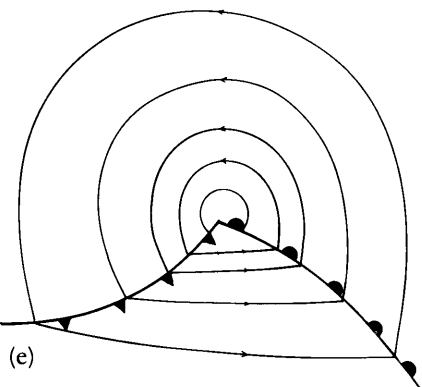
(b)



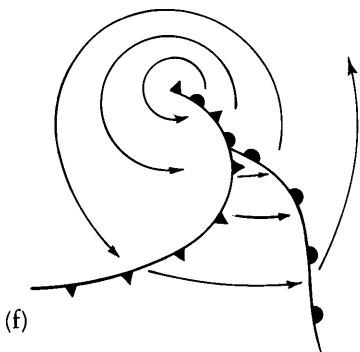
(c)



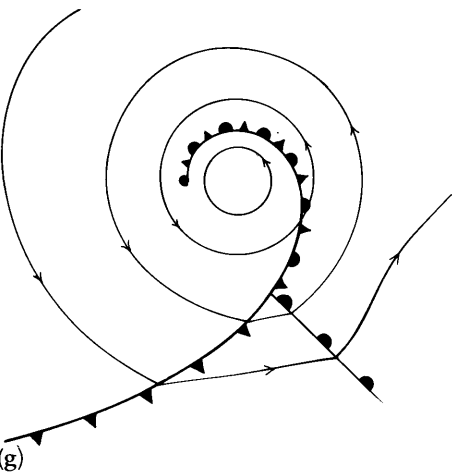
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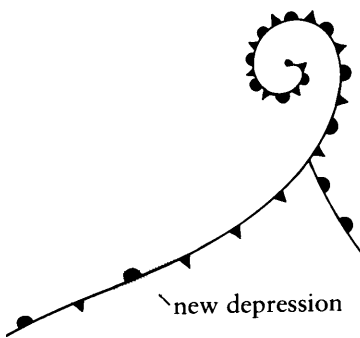
(e)



(f)



(g)



(h)

Fig 14 The life of a depression.

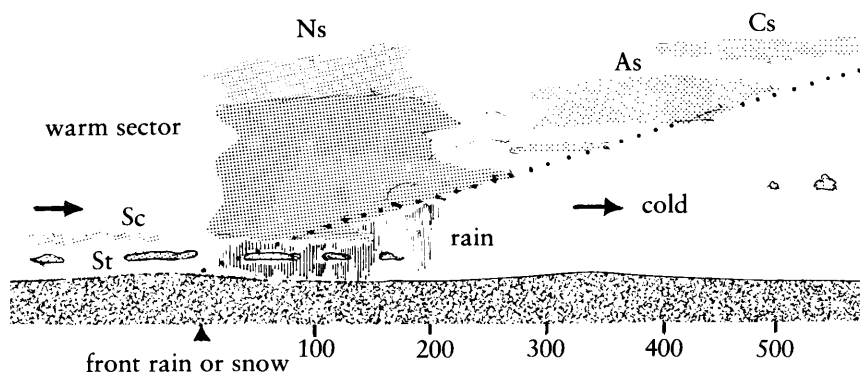


Fig 15 A section through one type of warm front.

thunderstorms and many of the characteristics of a cold front. Because of the many variations in fronts and depressions, I have not attempted to explain all the types of front.

It is important to realise that it is very rare indeed to have both an active warm front and an active cold front on the same depression. This means that if there is a large amount of rainfall on the warm front there will be little activity on the cold one.

The normal warm front has a shallow slope with the air rising very gradually over a distance of many hundreds of miles. This lifting produces the gradually thickening layer of cloud which results in steady rain near the front. (*See fig. 15.*)

Usually the high cloud cuts off the sun's heating, but if the high cloud arrives after the thermal activity has become well established, it is not uncommon for soaring conditions to persist for several hours after the sun has become partially obscured.

The warm front drizzle and rain sometimes start sporadically, but once the cloud has thickened and continuous rain begins, it is usually the end of flying for many hours, if not for the whole day.

Fig. 16 shows a typical depression with warm and cold fronts and their probable rain areas. In reality only one of the fronts is likely to be active. The first indication of the approaching bad weather will be the high cirrus cloud, possibly creating a halo around the sun or moon. The cloud will gradually thicken to altostratus and nimbostratus, with rain beginning 5–10 hours before the passage of the warm front. At this stage the winds will usually strengthen and back to become more southerly as the pressure falls. At the front the rain will ease off, the wind will veer 50 degrees or so, and the temperature and humidity will rise noticeably. The warmer, muggy weather is usually quite obvious after the front has passed. On the weather map the distinct kink

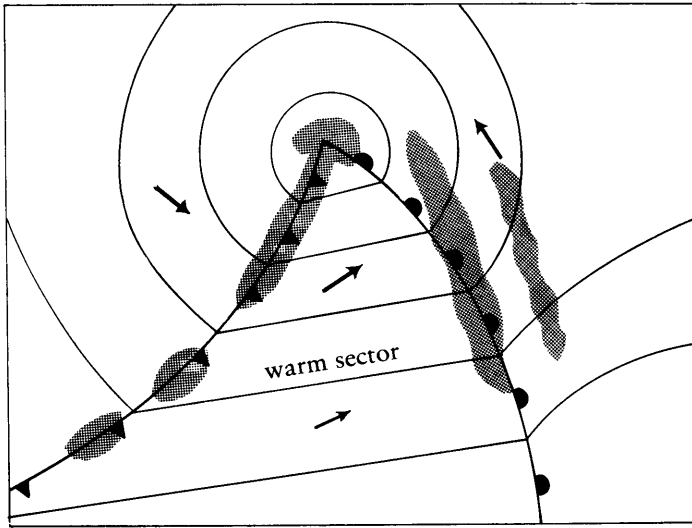


Fig 16 Warm and cold fronts on a depression, showing areas of probable rain and the surface winds.

in the isobars at the front indicates the change in wind direction.

The **warm sector** between the warm and cold fronts is typified by relatively warm humid conditions and low cloud. It may produce drizzle, especially in winter, but there are often good breaks in the cloud allowing training flights to continue although there will be few if any thermals. The warm sector may also have suitable conditions for usable waves to form in the lee of hills and mountains. (Lee waves are explained later.)

Notice that the cold front is a relatively steep wedge of air shovelling up the warmer air rapidly. (See fig. 17.) The passage of

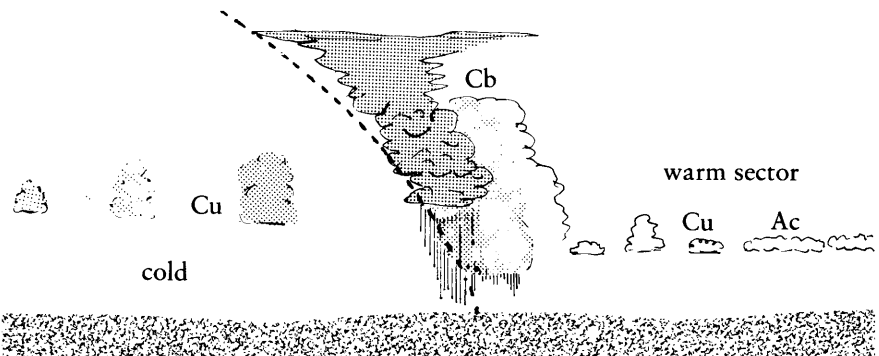


Fig 17 A section through one type of cold front.



Above A squall line below an active cumulonimbus. (Photograph courtesy of John Simpson)

Below An active sea breeze front, showing the double cloud base and wispy 'curtain' clouds. (Photograph courtesy of Lorna Minton)

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