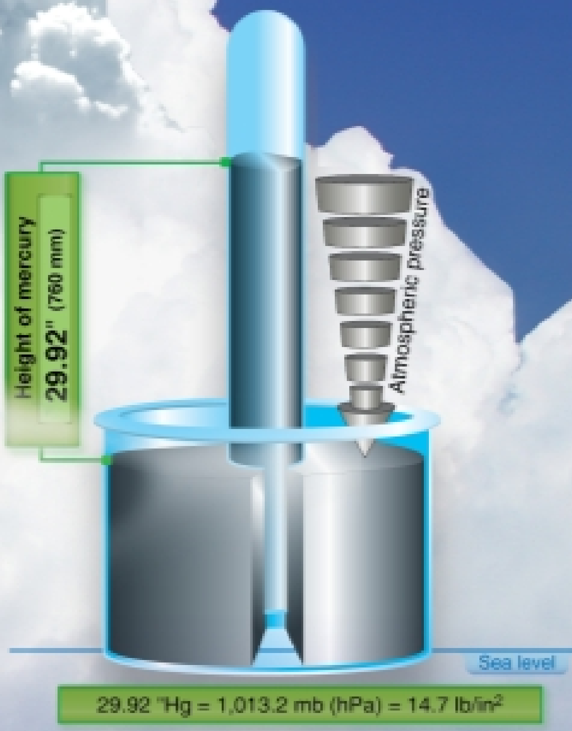
Weather Theory

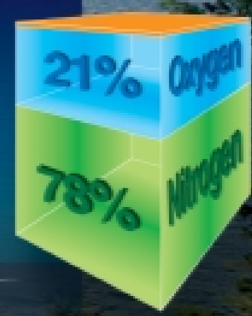
Introduction

Weather is an important factor that influences aircraft performance and flying safety. It is the state of the atmosphere at a given time and place with respect to variables, such as temperature (heat or cold), moisture (wetness or dryness), wind velocity (calm or storm), visibility (clearness or cloudiness), and barometric pressure (high or low). The term "weather" can also apply to adverse or destructive atmospheric conditions, such as high winds.

This chapter explains basic weather theory and offers pilots background knowledge of weather principles. It is designed to help them gain a good understanding of how weather affects daily flying activities. Understanding the theories behind weather helps a pilot make sound weather decisions based on the reports and forecasts obtained from a Flight Service Station (FSS) weather specialist and other aviation weather services.

Be it a local flight or a long cross-country flight, decisions based on weather can dramatically affect the safety of the flight.





PPL 4 : METEOROLOGY

Ever since birth you have been IN the air. Most of us spend quite a bit of time at about five to six feet up while we are awake. You wouldn't be able to breathe if you weren't! Now that you have decided to fly you will find that you will be UP in the air - very different from just being in the air. Meteorology is a word derived from the Greek word metéo-ros, which means "high in the sky", and is very appropriate to where the pilot does his or her thing in an aircraft.

Meteorology itself is the scientific study of the atmosphere that focuses on weather processes and forecasting. Things like temperature, pressure, density and humidity all change very quickly as you climb. All these changes mean that the phenomenon that we know as "weather" becomes far more significant than ever before. Gone are the days when you dress in a light shirt, jersey, or take a raincoat - "just in case". Weather takes on a whole new meaning when you fly. You have to be aware of the conditions that you will be flying in, as well as those that you are flying to, as weather affects your aircraft and your flight planning in many ways. And to make matters worse, your office is moving a little faster than the one you have grown accustomed to.

The sun is the start of it all, and is the main contributor to what we term weather. Weather systems are formed due to uneven heating at the surface of the Earth - the sun warms the equator more than it does the poles - and this gives rise to pressure patterns, which in turn lead to wind, which eventually leads to the weather we experience. In fact the atmosphere could be called a giant weather engine driven by the sun.

Even if the sky is a beautiful blue there are things such as temperature, pressure, wind, etc., that we cannot see. We need to know about these things to ensure that our flights are safe and enjoyable.

Remember that it is better to be on the ground
wishing you were up in the air than up in the air
wishing you were on the ground!

CHAPTER 4 : METEOROLOGY

THE ATMOSPHERE
PRESSURE, DENSITY AND TEMPERATURE
HUMIDITY AND PRECIPITATION
PRESSURE AND WIND
CLOUD FORMATION
FOG, MIST AND HAZE
AIR MASSES
FRONTOLOGY
ICE ACCRETION
THUNDERSTORMS
FLIGHT OVER MOUNTAINOUS AREAS
CLIMATOLOGY
ALTIMETRY
WEATHER ANALYSIS AND FORECASTING
WEATHER INFORMATION FOR FLIGHT PLANNING
TYPICAL EXAM QUESTIONS

The Atmosphere

Composition and Structure

The atmosphere is the air surrounding our home, the third rock from the sun, Earth. It is the world of the pilot. It is a colourless sea of gases, mainly Nitrogen, which makes up 78 % of the total, Oxygen a further 21%, and a number of others making up the remaining 1%. It is some of these other gases that play a very important role in Meteorology. To give an idea of the size of our atmosphere, take an apple. If one considers the apple to be the earth, the skin would represent the atmosphere. All of our weather takes place in the lower regions of this very thin layer, which is called the Troposphere and varies in depth from about 8 to 18 kilometres above sea level.

The atmosphere is constantly in motion and plays a vital role in the creation of weather. In short, as mentioned earlier, it is a giant weather engine powered by the sun. The weather we experience is due largely to the minor gases in the atmosphere, namely Carbon Dioxide, Water Vapour and Ozone. More about these gases later.

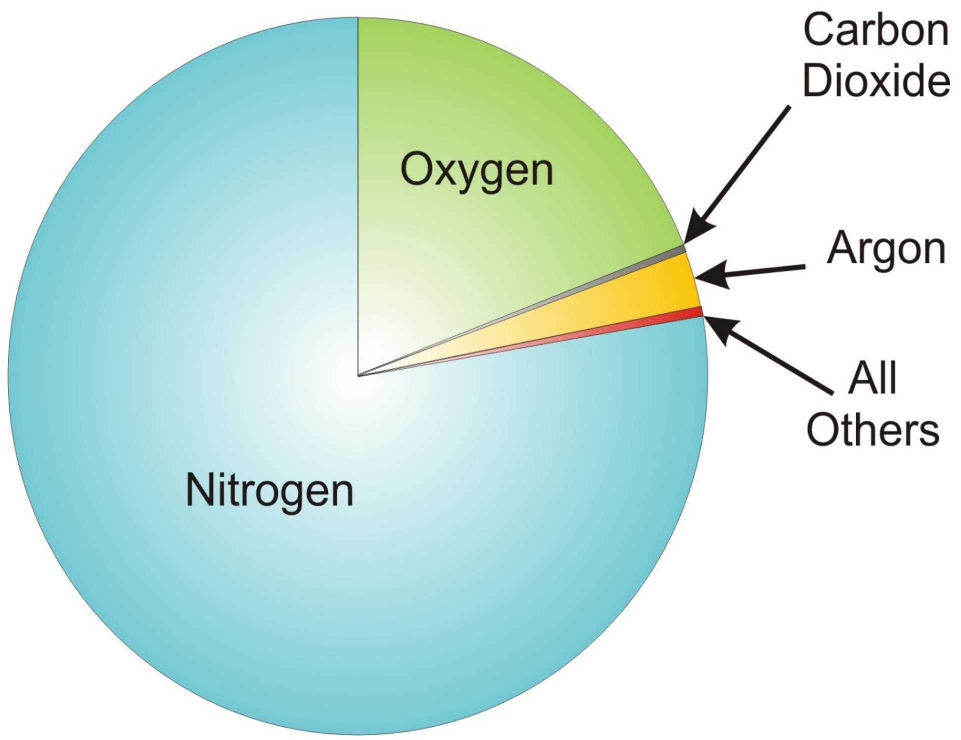


Figure 4.1

Gases in the Atmosphere

Vertical Divisions

The atmosphere is divided up into several different layers, or spheres, as one goes higher and higher. At this stage of your aviation career you are concerned only with the Troposphere. This is the domain of the private pilot (except for those who can afford their own 747s, but more of that later!).

The troposphere extends to the separation between it and the Stratosphere, known as the Tropopause. The height of the tropopause varies, depending whether one is above the poles, or above the equator. For comparative purposes it has been accepted that the average height of the tropopause is 39 000 feet above mean sea level (more of this in the International Standard Atmosphere). In actual fact it varies between about 26 000 feet (8 km) above the poles, and 60 000 above the equator (18 km).

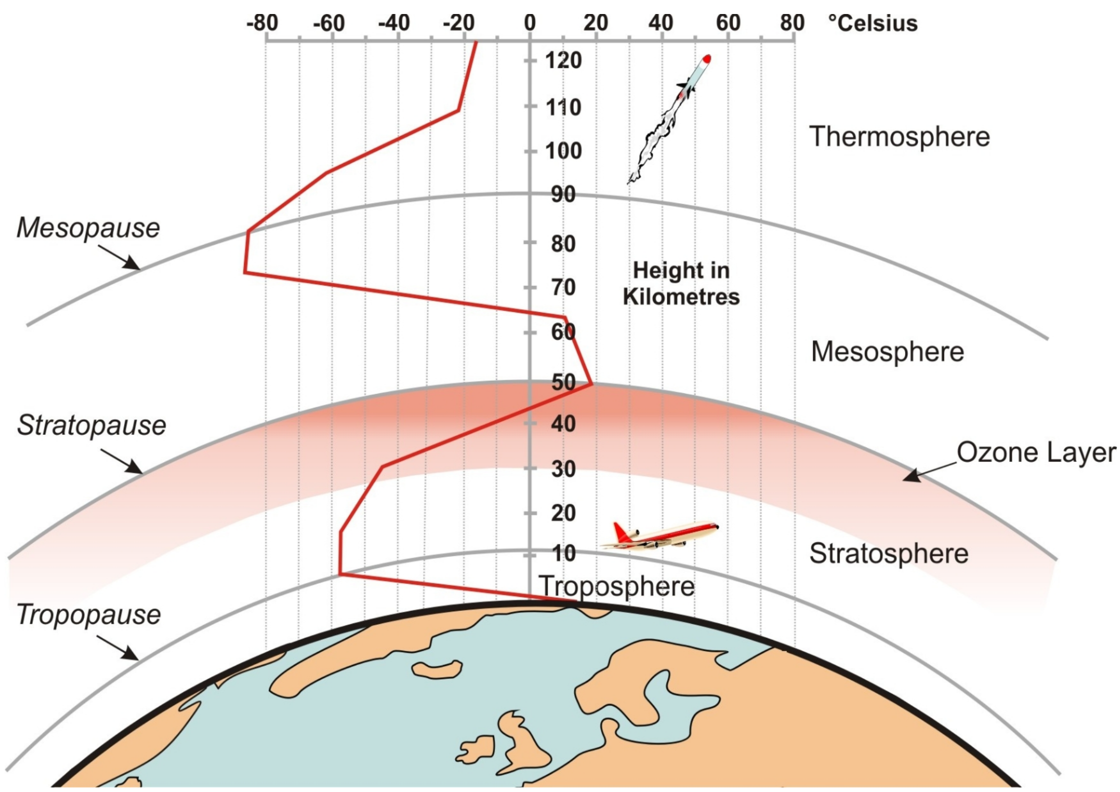


Figure 4.2

Structure of the Atmosphere

The troposphere is also characterised by a few other factors. These are:

- A decrease in temperature takes place at a rate of 1,98°C for every 1000 feet increase in altitude. This reduction continues until a minimum temperature of -56,5°C, reached at 36 090 feet. After that the temperature is regarded as remaining constant. These somewhat strange values are explained in more detail in paragraph 7.

- There is a reduction in atmospheric pressure with any increase in altitude. This is simply because there is less air being supported in a column above a point higher in the column.

- Water vapour is present in the tropopause, and is concentrated in the lower regions. For this reason, most of the weather which we experience is found in the troposphere.

- Movement of air is both vertical and horizontal within the troposphere, relative to the earth's surface, whilst above the tropopause it is usually only horizontal.

A simple way of remembering the height of the tropopause:

HIGH TEMP - HIGH TROP
LOW TEMP - LOW TROP
(Temperature being surface temperature)

Above the tropopause we find the stratosphere, then the mesosphere, and thermosphere or ionosphere. Between the spheres there is a break, similar to the tropopause, known, in ascending order, as the stratopause, and the mesopause. As mentioned earlier, all you need to concern yourself with at this stage is the lowest of the spheres, the troposphere.

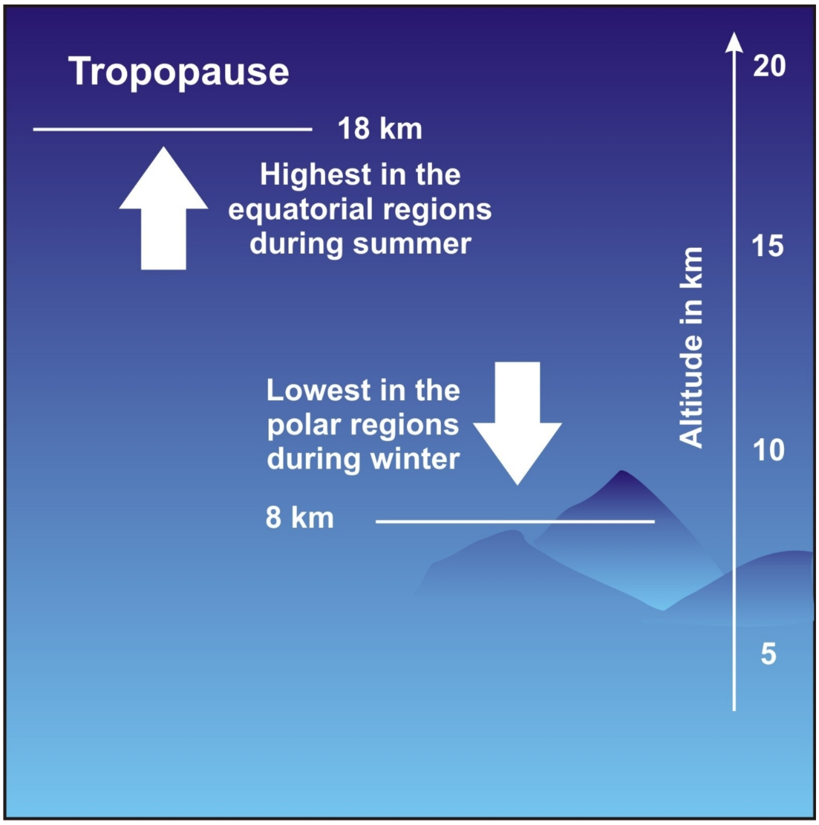


Figure 4.3

Heights of the Tropopause

ICAO Standard Atmosphere

In real life the changes in temperature and pressure in the troposphere vary greatly due to seasonal and daily changes. In order to have a standard set of conditions, ICAO decided that a few artificially created conditions would be used in order to test and compare aircraft systems. One fine day, they calculated the averages that would apply to the entire earth, and they called it the International Standard Atmosphere (ISA). Because of this, ISA is most representative of mid-latitude conditions. The following conditions relate to the standard atmosphere at sea level:

- The temperature is 15°C.

  The temperature lapse rate is 1,98°/1000 feet up to 36 090 feet, after which it is regarded as remaining constant at -56,5°C. Using a figure of 2°C/1000' is quite acceptable.

- These rather odd values derive from the original metric values which were used. The height of the tropopause is given as 11 kilometres, which converts to 36 090 feet, and the lapse rate is 6.5°C per kilometre, converted to 1.98°C per 1000 feet. Losing 6.5°C per kilometre for 11 kilometres gives the ISA tropopause temperature of -56.5°C. Be on the lookout for another value found in examinations - 0,65°C per 100 metres.

- The air pressure is 1013,25 hectopascals (hPa). The old term used was millibars, and is still sometimes found, especially in British publications, and is also the unit given by the Pathfinder CX2 navigation computer. This is sometimes expressed in other forms, but they all mean the same:

  - 14,7 pounds per square inch
  - 29,92 inches of mercury (Hg)
  - 760 millimetres of Hg

- The density of the air is 1,225 kg/m^3, or 1225 grams per cubic metre.

- Gravity is 9,81 metres per second^2 (or 32,2 ft/sec^2).

- The air is dry and uniform throughout.

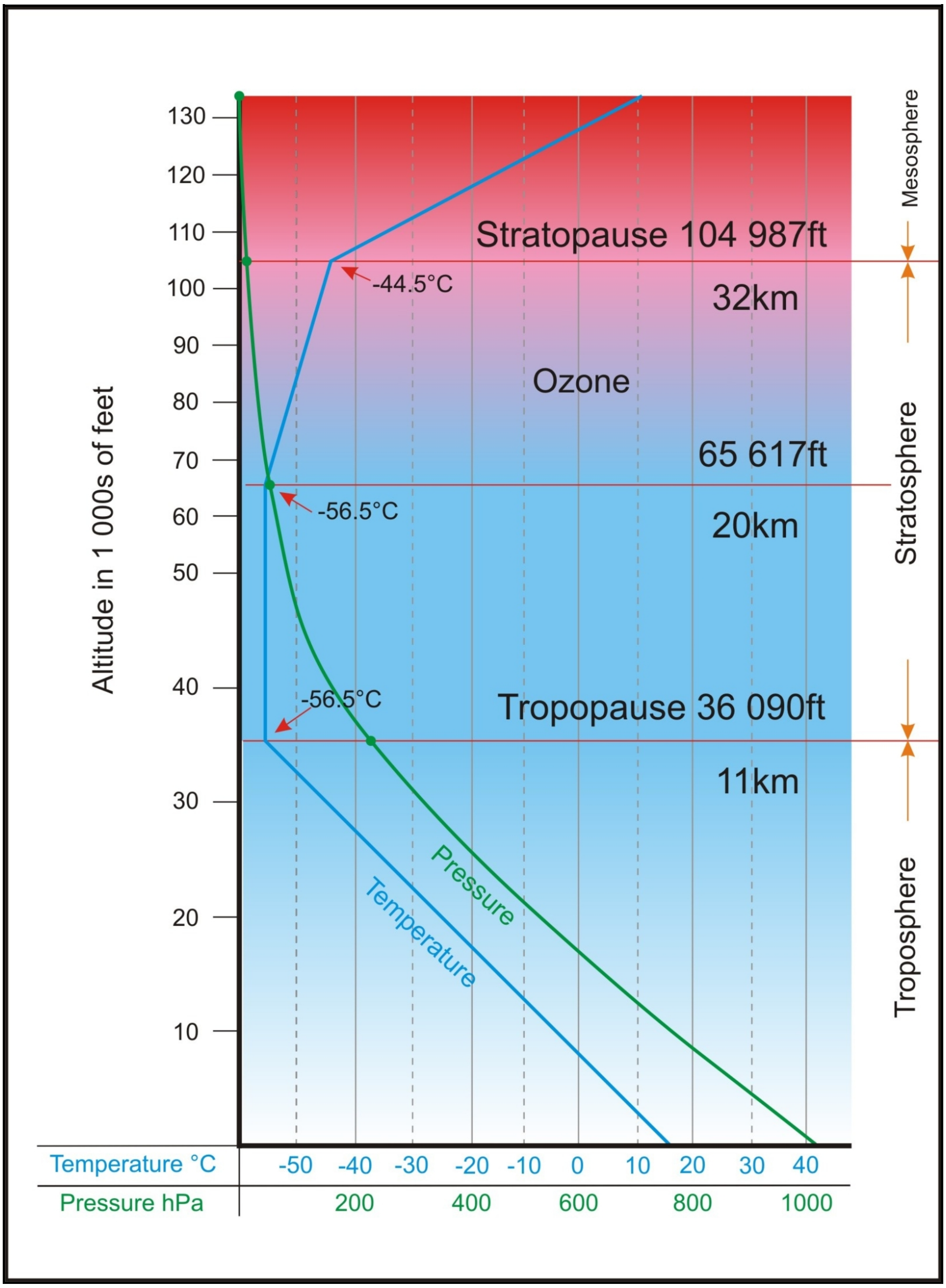


Figure 4.4

The International Standard Atmosphere

Pressure, Density and Temperature

Pressure

Pressure is the weight of a given column of air measured at the earth's surface. As you go higher the amount of air above you is decreasing until air ceases to exist. At this point the pressure will be zero. As traces of the atmosphere have been traced to heights of up to 800 kilometres above sea level, it is highly unlikely that zero pressure will be of any consequence in a Cherokee (except in the tyres, of course!).

The height of the column of air will vary with temperature, as any increase in temperature will result in the column expanding, but the weight of the column remaining constant. Figure 4.5 shows a column of cold air (on the left) alongside a column of warmer air (on the right). Each has the same number of molecules, and therefore the same weight. The pressure at the base and at the top of each column will therefore be the same.

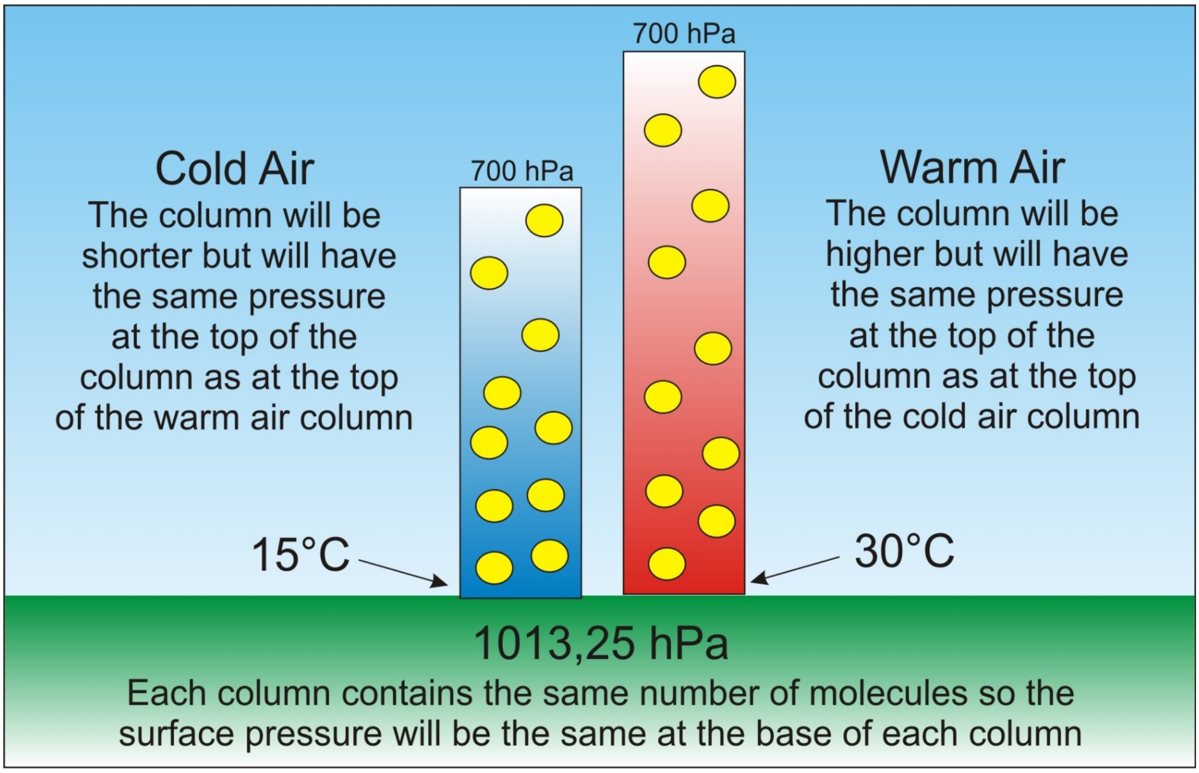


Figure 4.5

Atmospheric Pressure vs Temperature

Pilots and meteorologists need to know the horizontal distribution of pressure, as these differences at the surface (or at any level) will give rise to a movement of air from an area of higher pressure to one of lower pressure, much in the same way as water, and this gives rise to the development of wind. Areas of different pressure have different weather characteristics, and storms have very distinctive pressure patterns. If you have just a very basic understanding of the weather, by looking at weather charts you will be able to form some idea of what to expect.

To measure pressure, there are several instruments available to the met boffin. We have the mercury barometer which consists of a transparent glass tube in which a column of mercury extends up from a reservoir. As the pressure rises or falls, the mercury moves up and down along a calibrated scale according to the increase or decrease in the outside air pressure. This would have to be more than 76cm long and would be rather impractical in a cockpit.

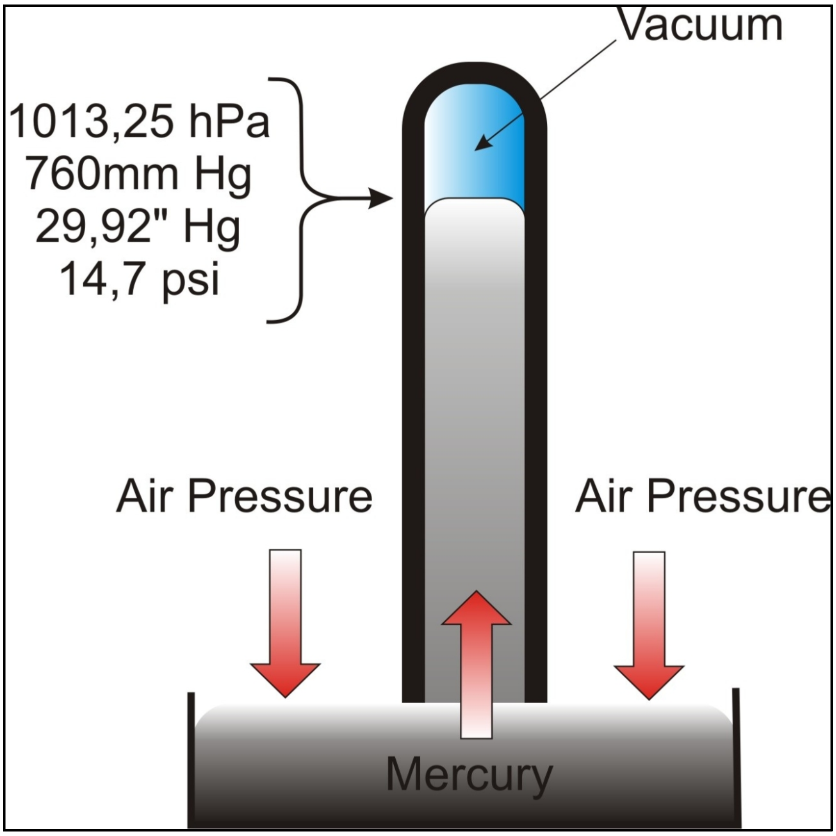


Figure 4.6

Mercury Barometer

A more common unit is the aneroid barometer (see Figure 4.7) which has a sealed metal capsule with a fixed pressure inside. The word “aneroid” means ”without water, so no liquids are used. As the pressure rises or falls, the capsule contracts or expands, and the movement is transmitted to a dial. Nowadays you will find them with a digital readout.

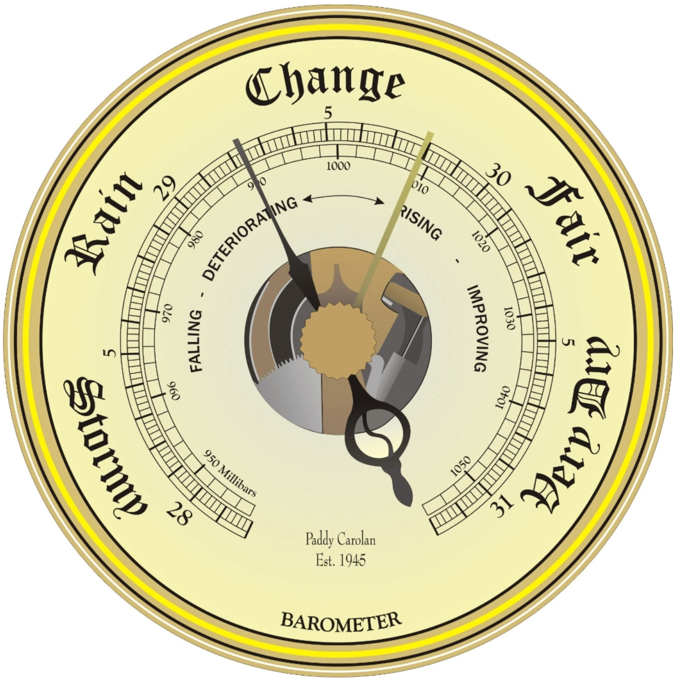


Figure 4.7

Aneroid Barometer

Shown is Figure 4.7 is an old aneroid barometer. On the face are indications of weather based on pressure. High pressure is usually an indicator of improving weather, while low pressures are associated with worsening weather. Instruments used to measure temperature and pressure are housed in what is known as a Stevenson Screen. This is a screen to shield the instruments against precipitation and direct heat radiation from outside sources, while still allowing air to circulate freely around them. It forms part of a standard weather station. Pressure is indicated on the barometer in inches of mercury (Hg) on the outside scale, and hectopascals (hPA) on the inside scale. Nowadays pressure is measured by more sophisticated instruments and data is retrieved digitally.

The information from the aneroid barometer can be transmitted to a revolving drum where a continuous trace of pressure is drawn onto a graduated sheet of paper. In this way, a 24-hour period, or in some cases a week or month, can be recorded in graphical form (see Figure 4.8). This type of barometer is called a barograph. It allows the forecaster to observe the pressure tendency over the specific period. These changes in pressure are a good indication of weather to follow. An increasing pressure usually indicates improving weather, while a drop in pressure usually suggests a deterioration. The indications in Figure 4.7 give an idea of the effect of pressure on weather.

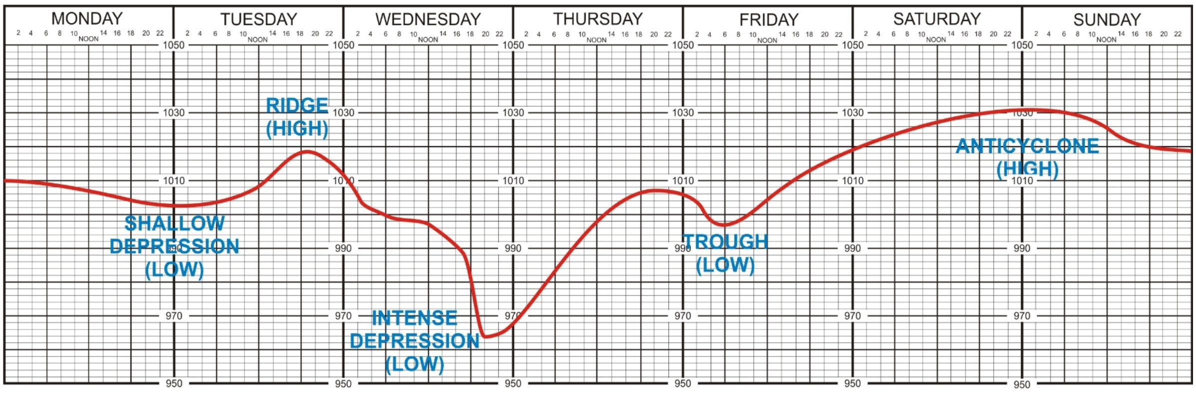


Figure 4.8

Pressure Changes as Shown on a Barograph

Pressure Changes With Increase in Height

As mentioned in para 5.b, there is a reduction in pressure with increase in height. The ISA standard for a change in height is 27 feet per hPa. The generally accepted value is rounded off to 30 feet, and this is used by everybody (including the CAA examination section for those of you who intend to go on to CPL or ATP). If we consider this accepted decrease in pressure with increase in height, a surface pressure of 1020 hPa will mean a pressure of 1010 hPa at the top of a 300 ft building (300 ÷ 30 = 10), and the pressure at a height of 3000 ft would be 920 hPa (3000 ÷ 30 = 100). Due to the constant change of pressure at varying levels it would be very difficult to get a meaningful pressure at any given time.

This problem is solved by converting all pressure readings to sea level. The pressure is then given as the pressure at Mean Sea Level (MSL). The ISA standard is accepted as 1013,25 hPa.

Pressure readings are taken all over the world at regular time intervals and sent to major meteorological centres. Here the information is used to compile drawings, known as synoptic charts. The met boffin connects all places with equal pressure with lines called isobars, and a picture emerges showing the pressure patterns existing at any place at the time of the chart's construction.

PRESSURE SYSTEMS

HIGH — A centre of high pressure known as an anticyclone

RIDGE — A wedge of high pressure extending out from the centre of an anticyclone

LOW — A centre of low pressure known as a depression or a cyclone

TROUGH — A wedge of low pressure extending out from the centre of a depression

COL — A neutral area between two highs and two lows

On a surface pressure chart, the spacing of the isobars is an indication of the pressure gradient. The closer the isobars are to each other, the stronger the pressure gradient. A strong pressure gradient is an indication of strong winds and a rapid change in weather conditions.

Figure 4.9 shows a typical arrangement of isobars for a given situation. Each of the lines represents a particular pressure, and a typical chart would have isobars with a separation of 4 hectopascals. The two semi-permanent high pressure systems (anticyclones) can be seen to the left and right of the country. The low pressure to the north is pushing down to the south, while the low pressure systems to the south (in this case mid-latitude cyclones) are very far down due to the fact that it is summer (chart is dated 28 December). Some of the many troughs and ridges are indicated, and to the right of the country in the southern Indian Ocean a Col can be seen.

On a world wide scale, the pressure patterns which exist follow a fairly regular pattern (see Figure 4.9). To a large extent this determines the weather that can be expected anywhere on earth. As you are all aware, weather does change, and this is due to influences that modify or change the simple behaviour of the patterns. The met boffins refer to these disturbances as perturbations.

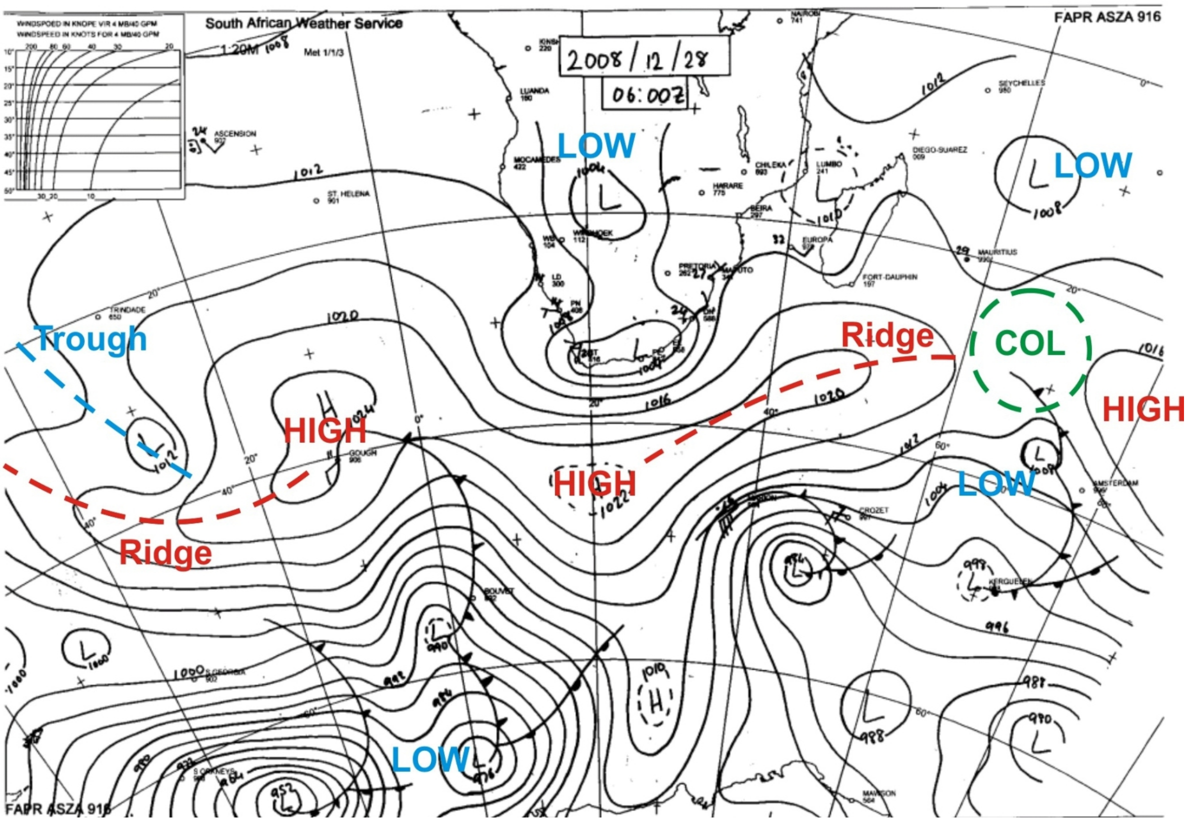


Figure 4.9

Sea Level Synoptic Chart

The rotation of the earth causes the flow from high to low to deflect, and not flow directly as you might expect.

From Figures 4.10 and 4.11, it can be seen that South Africa is situated in a position where the pressure is generally high, and the mean upper winds are westerly. More about the winds later on.

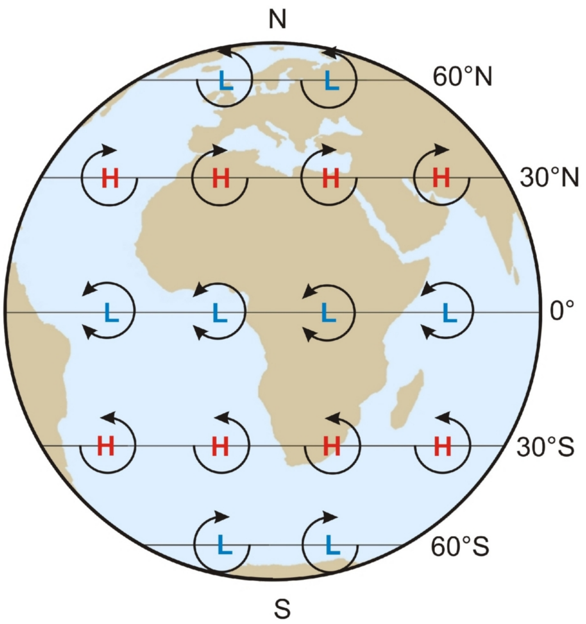


Figure 4.10

World Pressure Distribution

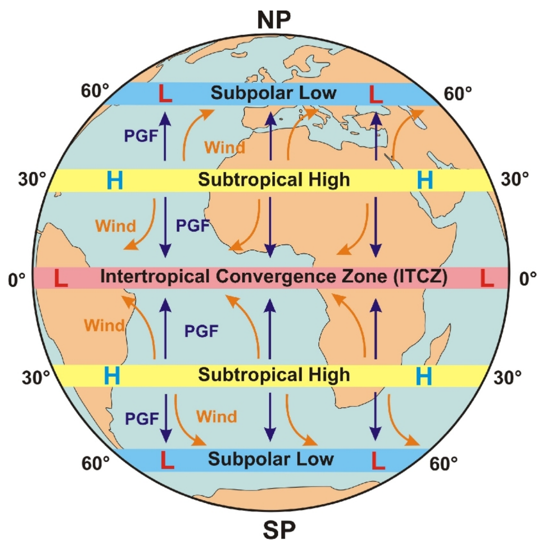


Figure 4.11

Mean Global Winds Due to Pressure Distribution

Effect of Changing Pressure on the Altimeter

The altimeter can best be described as a sensitive aneroid barometer, calibrated in feet rather than in hectopascal. As we climb the altimeter gives an indication of height above the selected datum pressure, starting off with QNH, which is the pressure at MSL at that time. If we then fly to a destination where the MSL pressure has changed, the altimeter will be giving an incorrect indication of true altitude.

This could also be illustrated by a situation where an aircraft is parked on the ground with the QNH at, say, 1010 hPa. If the airfield elevation is 1000 feet MSL, and the QNH is set to 1010 hPa, the altimeter will read 1000 ft. The pressure then rises to 1020 hPa which, at the rate of 30 ft per hPa, is the equivalent of 300 ft.

Even though the aircraft has gone nowhere and is still on the ground, the altimeter will be reading 700 ft MSL, or 300 ft below ground!. Resetting the QNH to 1020 hPa will bring the altimeter reading back to 1000 ft.

It is very important to remember this. In real life, the aircraft could have been flying from departure (1020 hPa) to destination (1010 hPa), the aircraft will be LOWER than you think to the tune of 300 ft. That could be a whole new ball game if clouds are present, or visibility is poor. You may not see the high ground which you thought was 300 ft below you, with disastrous results.

If two aircraft depart from two airfields with very different QNHs, they may pass each other with several hundred feet separating them vertically, but both aircraft may be at the same indicated altitude! For this reason, aircraft flying above a certain height, called the Transition Altitude, all use the same pressure setting in the altimeter. This way all aircraft will be flying at a specific height above a standard datum, which is 1013,25 hPa. When flying on this setting, the aircraft is no longer flying at "x feet above sea level", but rather at "flight level x". This standard setting is called QNE.

When descending from a flight level back to earth, there is a point at which you have to change from the Standard setting of 1013,25 hPa to the QNH of your destination. This point is called the Transition Level. The difference between the Transition Altitude and Transition Level is called the Transition Layer, with Transition Altitude being the lower of the two.

Summary of Altimeter Settings

Here is a summary of the more important altimeter settings which you will be using:

QNH This is the pressure setting at MSL. The reading you will get will be altitude, and registers the elevation of the airfield above mean sea level. Used for take-off and landing. Sometimes referred to as Local QNH.

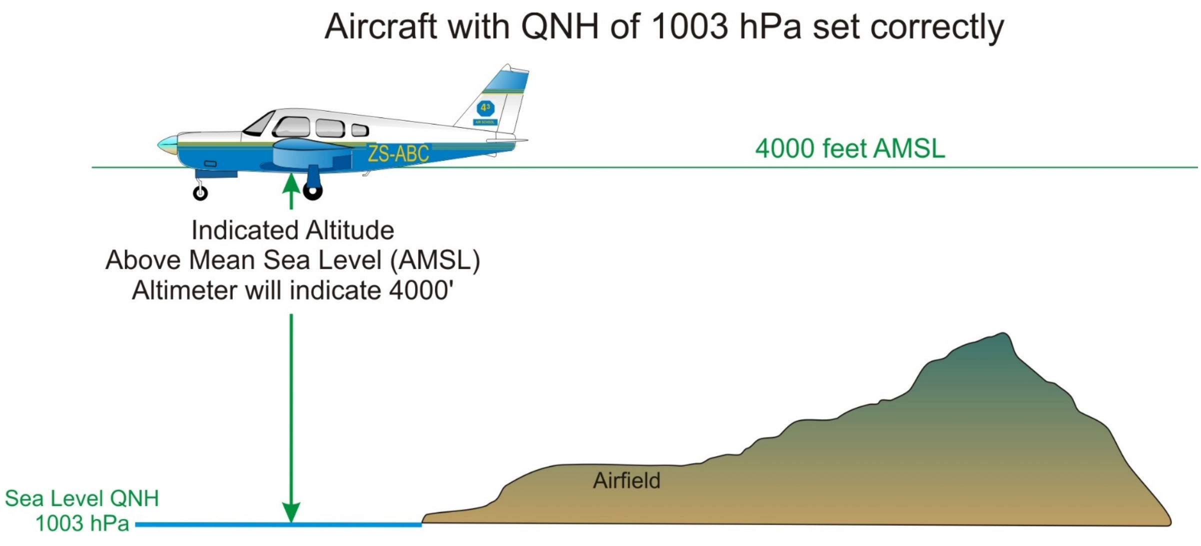


Figure 4.12

QNH

QNE This is the ISA Standard Pressure Setting, sometimes referred to as SPS. 1013 hPa is set on the altimeter scale, and the altimeter reading will be Pressure Altitude, which is expressed as Flight Level (FL). This is set as the aircraft passes through Transition Altitude. Flight levels are the pressure altitude of the aircraft with the hundreds deleted. A pressure altitude of 10 000 ft will be FL100. Using QNE ensures that adequate separation between aircraft flying under Instrument Flight Rules (IFR).

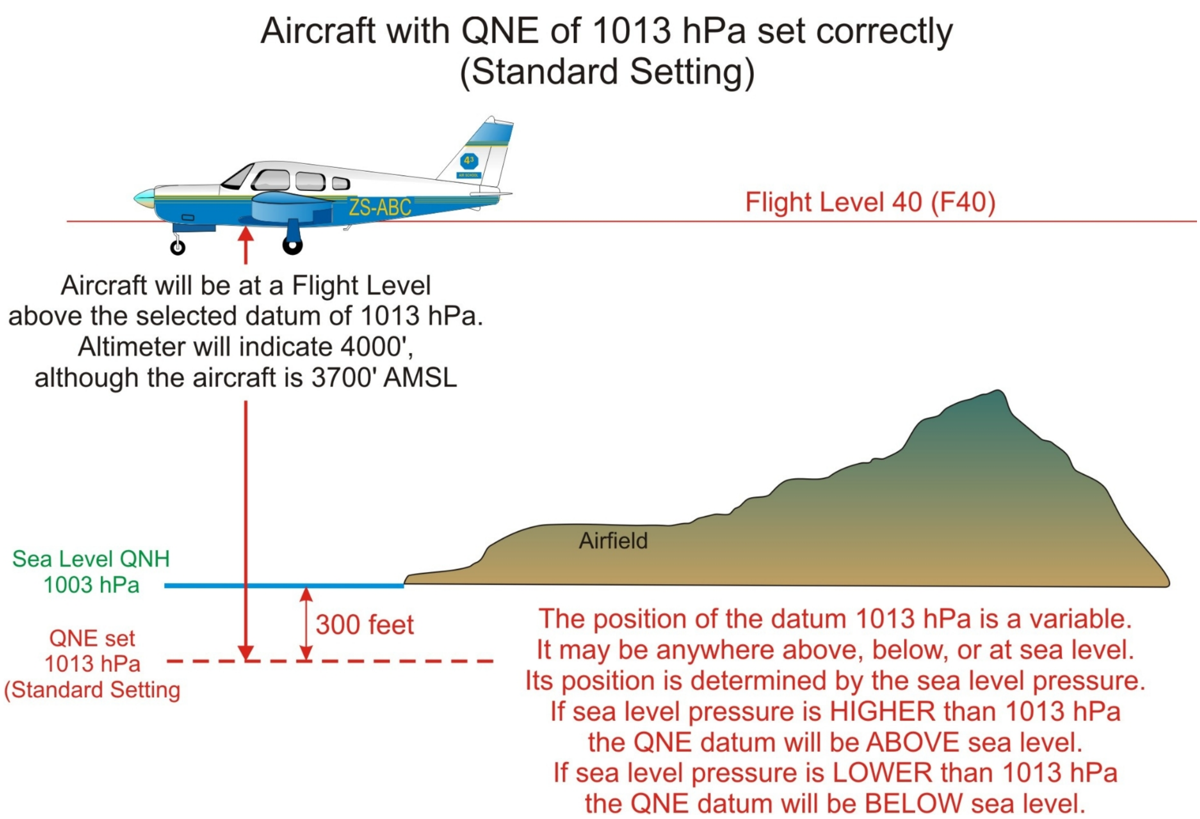


Figure 4.13

QNE, or Standard Setting

QFE This is not in use in South Africa, but you may hear it from time to time. It is used in the UK, and is the pressure setting at airfield level. The reading on the altimeter is height and will indicate 0 ft on landing. I suppose you could call it the poor man's radio altimeter.

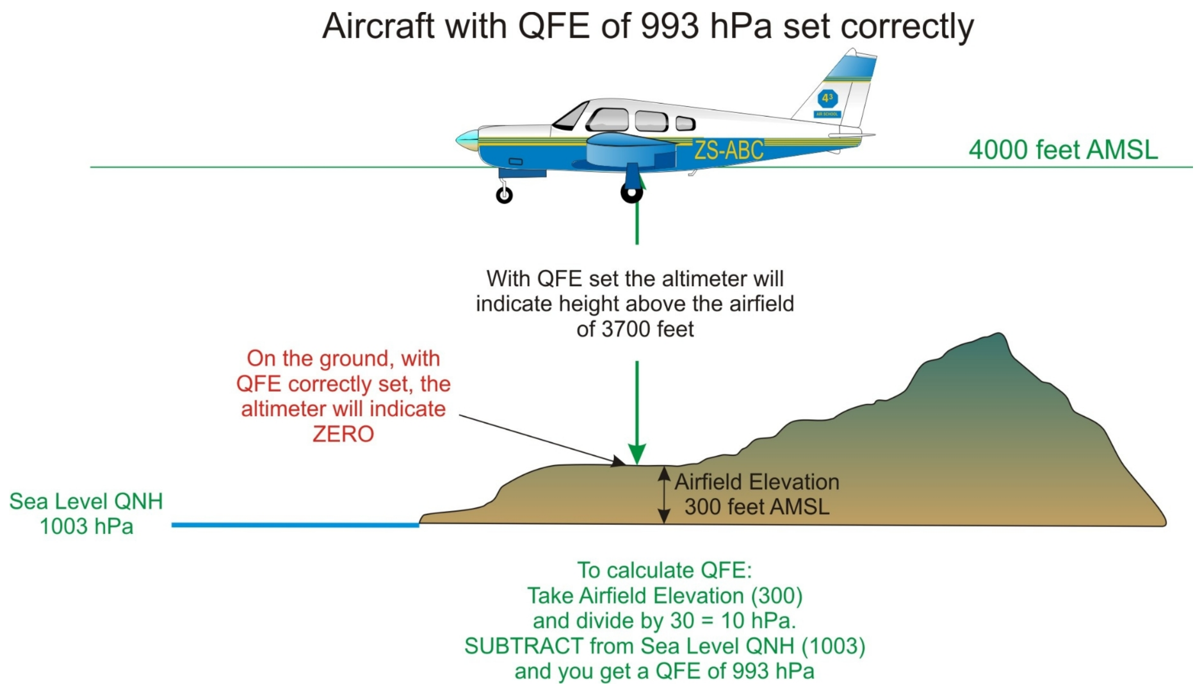


Figure 4.14

QFE

REGIONAL QNH Also not a common one. If used at all, it is a setting for a specified region, and is based on the lowest forecasted QNH in that region. Use of this will give altitude and would be used en route during low level VFR (Visual Flight Rules) flight.

It is essential that you understand the difference between the various settings and what they indicate to you, the pilot. More importantly, you must understand what could go wrong if incorrect settings are used.

It has happened often before, and it will happen often in the future, that a pilot sets the pressure on his altimeter using the correct digits passed on by ATC, but using them in the incorrect order. An example of this is setting 1013 when the actual QNH was passed on as 1031. Or vice versa. Which would be the worst case scenario? Let’s take a look and see.

Here are a few examples of what the result could be if incorrect settings are made; in the first example the QNH value is set too high, whilst in the second, it is set too low.

REMEMBER THAT A PRESSURE ALTIMETER WILL NOT AUTOMATICALLY SHOW YOUR EXACT ALTITUDE IN FLIGHT. IT IS THEREFORE YOUR RESPONSIBILITY TO ENSURE TERRAIN AVOIDANCE.

Sea level QNH LESS than 1013 hPa

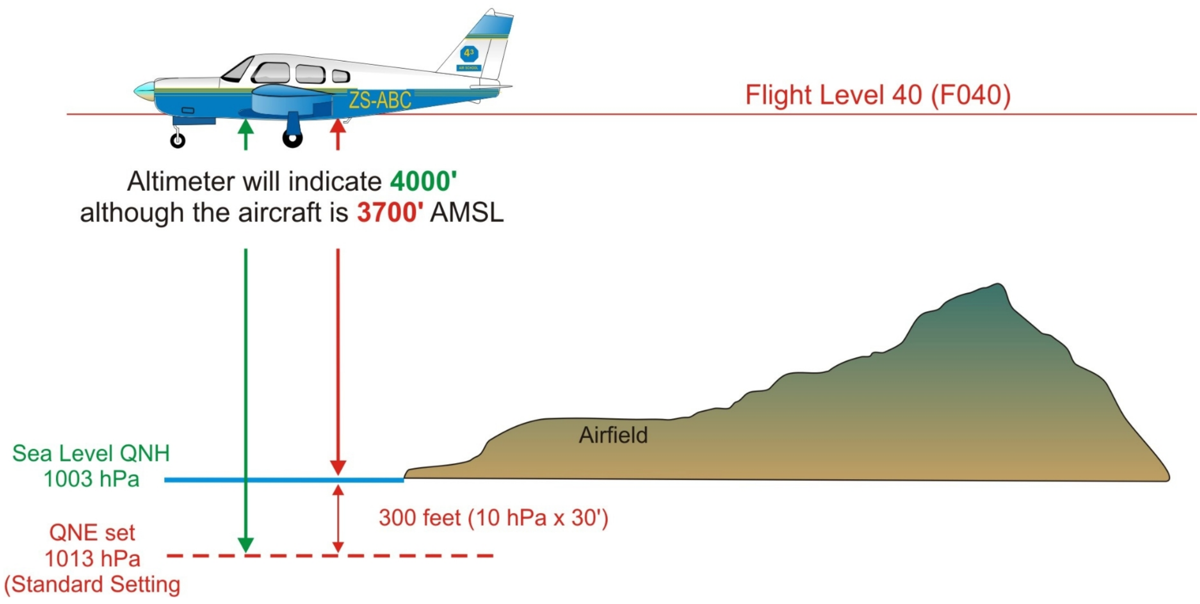


Figure 4.15

QNH LESS than 1013 hPa

When the altimeter is set at the standard setting of 1013 hPa, and the QNH is LESS than the ISA datum, then the TRUE altitude will be LESS than that indicated by the altimeter.

In Figure 4.15, it can be seen that with a QNH LOWER than the Standard Setting, the actual sea level surface is ABOVE the ISA MSL datum. In this case the difference is 10 hPa (10 x 30 ft = 300 ft). With 1013 hPa set the altimeter will indicate an altitude of 4000 ft. With the correct QNH of 993 hPa set, the altimeter indicates 3700 ft.

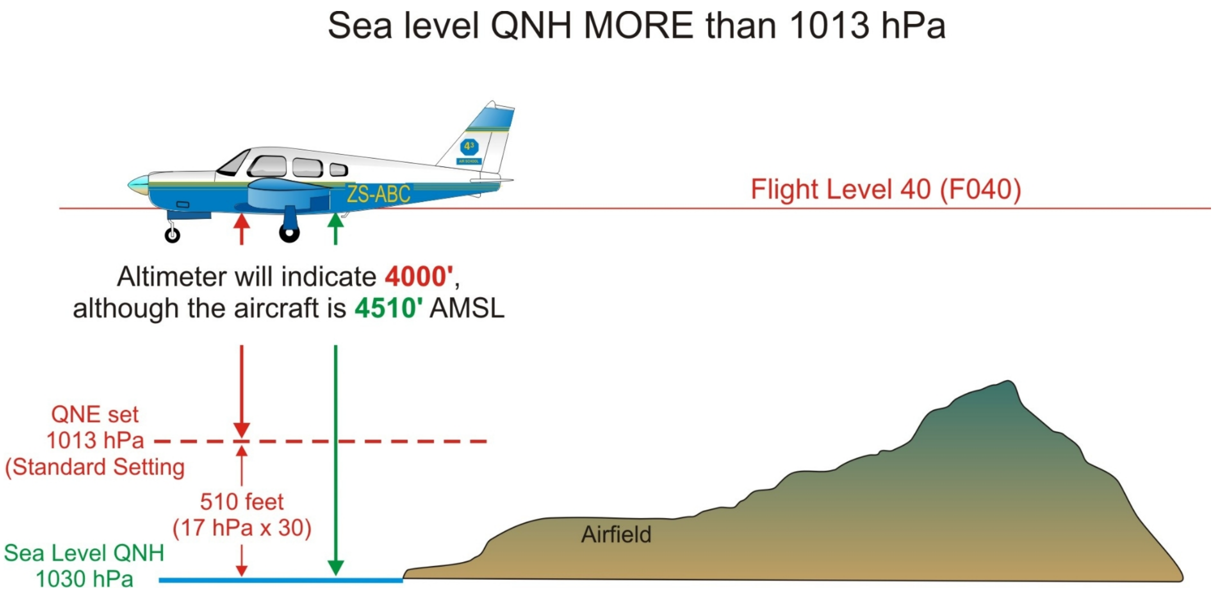


Figure 4.16

QNH MORE than 1013 hPa

When the altimeter is set at the standard setting of 1013 hPa, and the QNH is MORE than the ISA datum, then the TRUE altitude will be MORE than that indicated by the altimeter.

In Figure 4.16, it can be seen that with a QNH HIGHER than the Standard Setting, the actual sea level surface is BELOW the ISA MSL datum. In this case the difference is 17 hPa (17 x 30 ft = 510 ft). With 1013 hPa set the altimeter will indicate an altitude of 4000 ft. with the correct QNH of 1030 hPa set, the altimeter indicates 4510 ft.

Therefore, in summary:

QNH LOWER THAN ISA = TRUE ALTITUDE
LOWER THAN INDICATED

QNH HIGHER THAN ISA = TRUE ALTITUDE
HIGHER THAN INDICATED

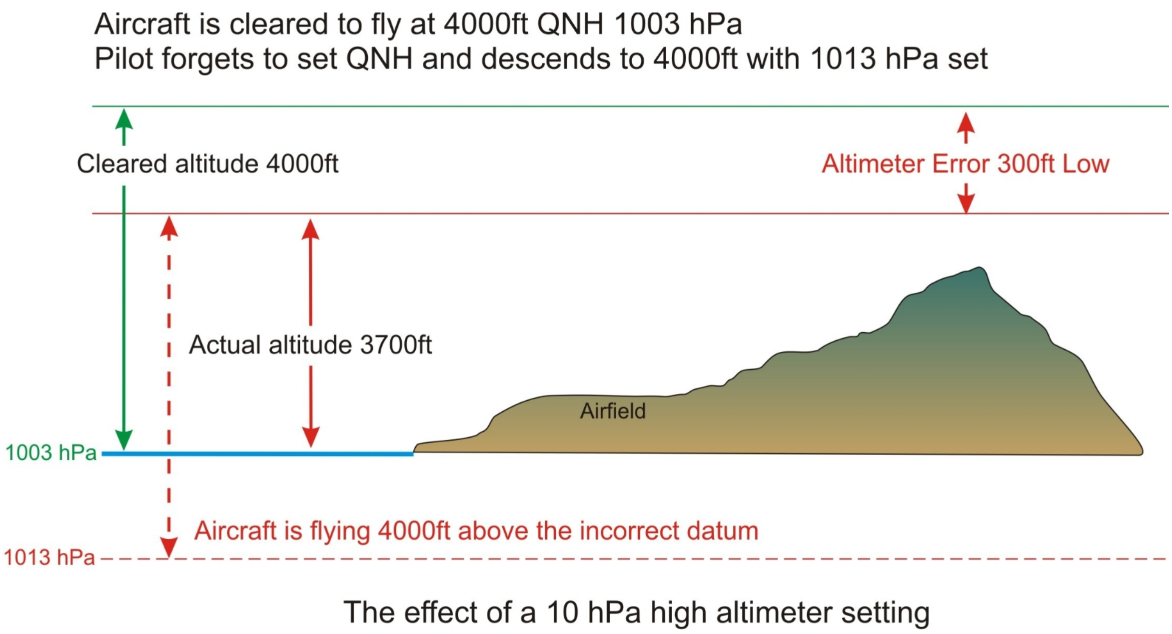


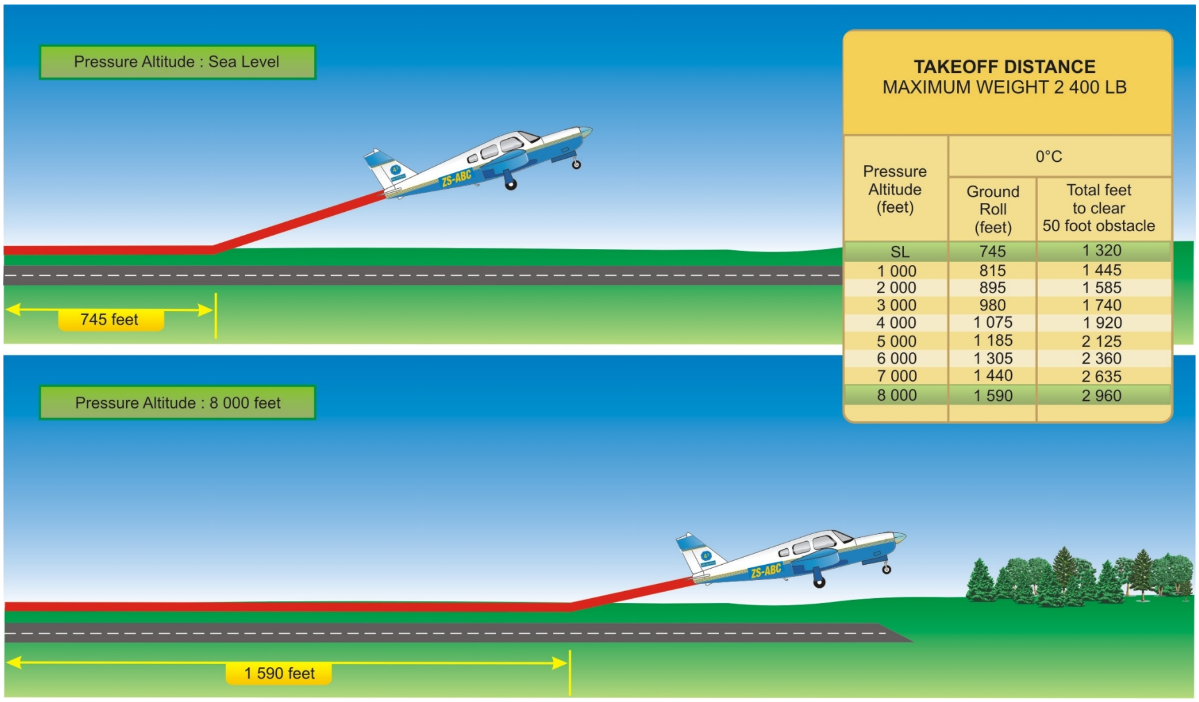
Figure 4.17

Typical Altimeter Error Made By Pilots

Density

Altitude affects every aspect of flight from aircraft performance to human performance. At higher altitudes, with a decreased atmospheric pressure, takeoff and landing distances are increased, as are climb rates.

When an aircraft takes off, lift must be developed by the flow of air around the wings. If the air is thin, more speed is required to obtain enough lift for takeoff; therefore, the ground run is longer. An aircraft that requires a 745 foot ground run at sea level will require more than double that at an airport 8,000 feet above sea level (Figure 4.18). It is also true that at higher altitudes, due to the decreased density of the air, aircraft engines and propellers are less efficient. This leads to reduced rates of climb and a greater ground run for obstacle clearance.



Pressure Altitude (feet)	0°C	
	Ground Roll (feet)	Total feet to clear 50 foot obstacle
SL	745	1 320
1 000	815	1 445
2 000	895	1 585
3 000	980	1 740
4 000	1 075	1 920
5 000	1 185	2 125
6 000	1 305	2 360
7 000	1 440	2 635
8 000	1 590	2 960

Figure 4.18

Effect of Altitude on Take-off Performance

Differences in air density caused by changes in temperature result in changes in pressure. This, in turn, creates motion in the atmosphere, both vertically and horizontally, in the form of currents and wind. Motion in the atmosphere, combined with moisture, produces clouds and precipitation otherwise known as weather.

There are several methods available to you if you wish to calculate density altitude. A simple rule of thumb is that for every degree in Celsius that the temperature differs from ISA, you add 120 feet to pressure altitude if the temperature is higher than it should be, or subtract it if the temperature is lower than standard. An example: the temperature at OR Tambo International is 35°C. The airfield elevation is 5558 feet AMSL. Bearing in mind that the ISA temperature in Johannesburg should have been 15° - 1,98° for every thousand feet above sea level, the temperature above feet, so

$$15 - (1.98 \times 5.558) = 3.995°C \text{ (let's say 4°)}$$

The temperature is therefore 31°C higher than it should be in ISA conditions, so we add 31 x 120 = 3720 to 5558 and the density altitude on the day will be 9728 feet. This means that your aeroplane will perform as if it were at 9278 feet above sea level. The whizzwheel can also be used.

A more accurate method is to use the CX-2 Pathfinder, going to Flight > Altitude > Density Alt and entering the values at each prompt (see Figure 4.19).

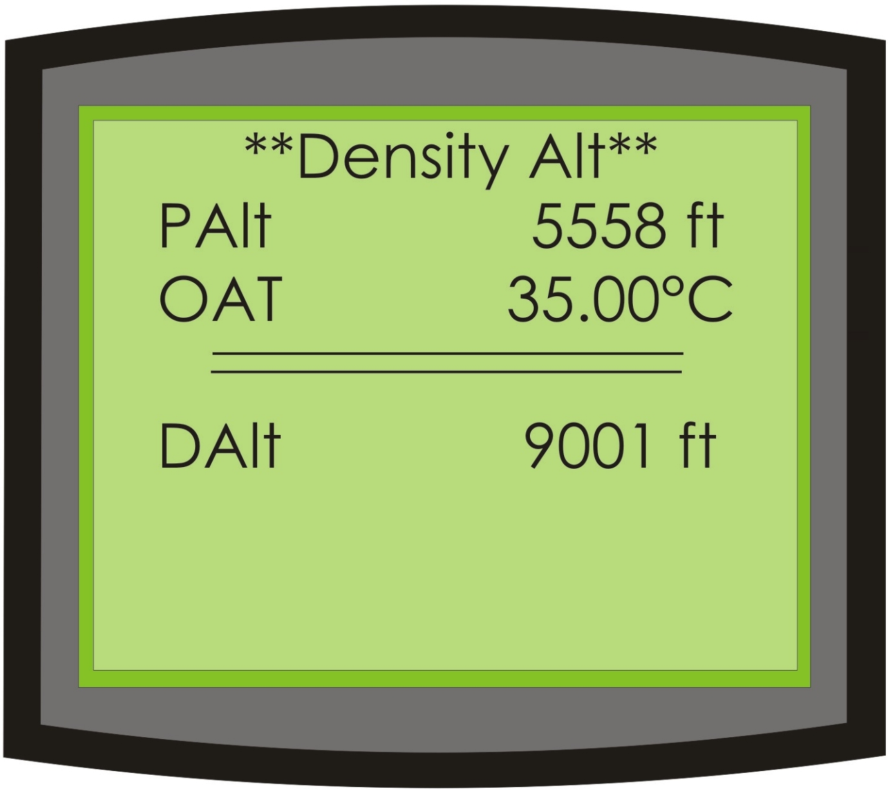


Figure 4.19

Density altitude calculation on the CX-2 Pathfinder

Temperature

Temperature plays a very important part in what goes on in the Troposphere, and therefore has a marked effect on the weather we may expect.

Many people are under the false impression that the sun heats up the atmosphere. This is not quite true, as the sun heats up the surface of the earth, and this in turn heats up the atmosphere. The incoming radiation from the sun, which has a short wavelength, is called insolation. The earth then gives off long wave radiation and it is this that warms the atmosphere.

The position of the sun relative to the latitude at which you are situated determines the amount of this insolation. That is why the temperature at the poles is so low. The amount of heat has to be spread over a greater surface area, and the result is that the ground does not heat up as effectively as at the equator. In fact, during the Southern Hemisphere winter, the sun does not even shine on the South Pole for months on end.

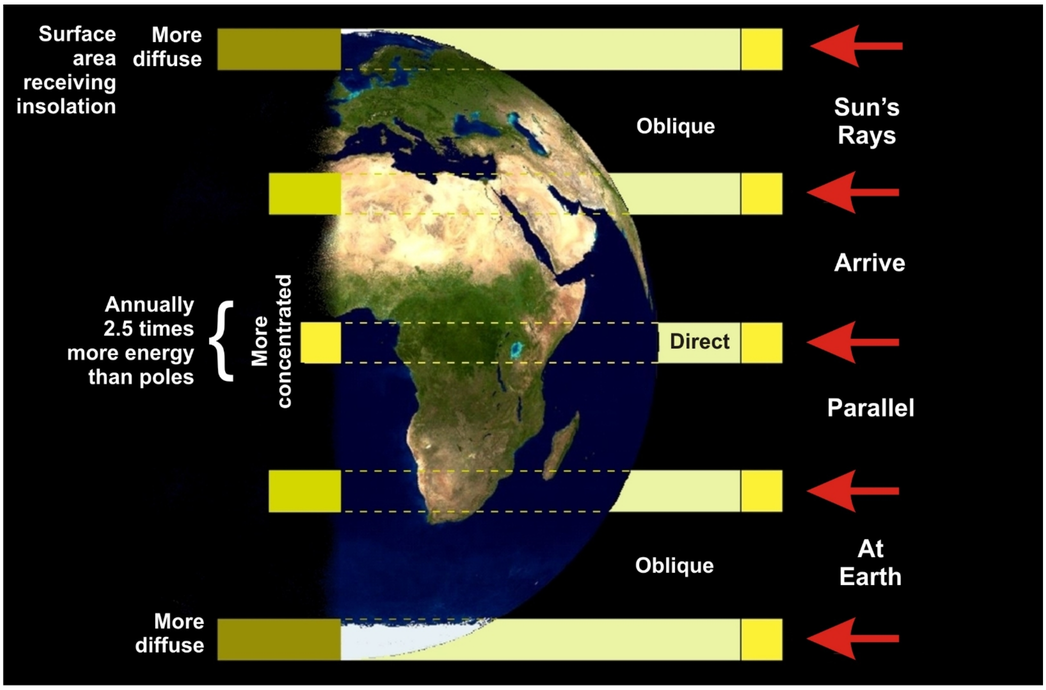


Figure 4.20

Effect of Latitude on Incoming Insolation

Any object which has a temperature above absolute zero will radiate heat. Because the earth's surface is well above absolute zero, it is continuously losing its heat. During the day the incoming heat from the sun offsets the earth's loss, so the temperature increases, reaching a maximum soon after midday. At night, when there is no incoming solar energy, the earth continues to radiate its energy, and cools quite considerably. This change of temperature which takes place on a daily basis is called diurnal variation and plays a major role in the creation of wind and clouds.

The amount of insolation received by the surface will be maximum at local midday. This is not a clock time but happens when the sun is directly overhead. This will not be the hottest time of the day, as the warming of the atmosphere is delayed. The incoming solar radiation will warm up the earth. The total radiation received by the earth is made up of the following:

- reflected by clouds: 20%;
- scattered by the atmosphere (reflection off CO_2, water vapour, etc: 6%;
- absorbed by the atmosphere (ozone): 19%;
- reflected by the earth's surface: 4%; and
- absorbed by the earth's surface: 51%.

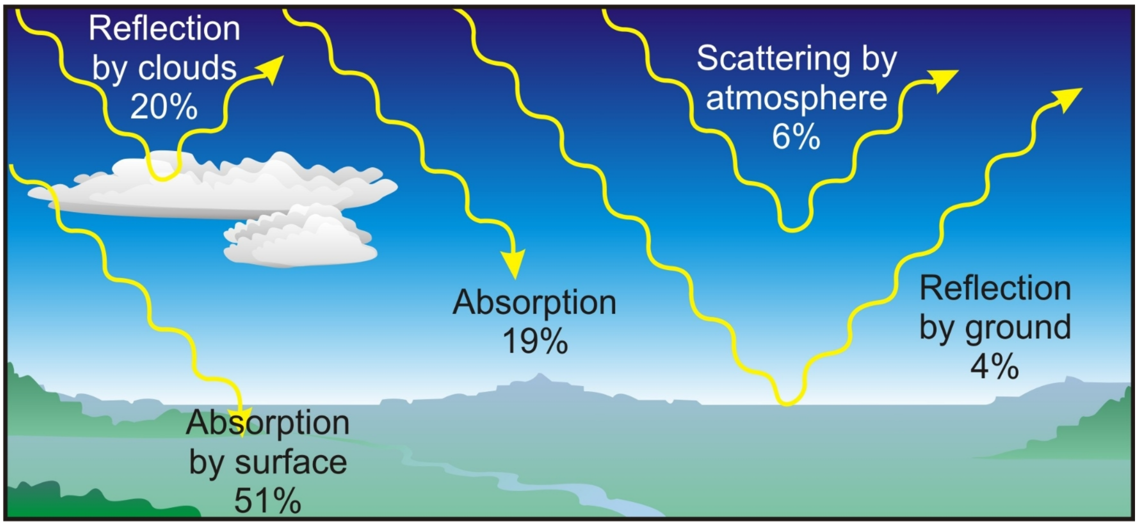


Figure 4.21

Incoming Solar Radiation

Once the earth has absorbed the incoming radiation, it will have warmed up, and will also radiate heat. The heat radiated by the earth is much less than that of the sun (15°C vs about 6000°C) and will be of a longer wavelength. This is what contributes to a major part of the warming of the atmosphere. There will be a delay of about two hours before the atmosphere will reap the benefit of the radiation from the earth, known as terrestrial radiation. It also explains why temperature decreases with an increase in height - you are moving away from the source of heat, namely the earth.

When the sun sets, the incoming radiation reduces, and the air will slowly cool. This cooling will continue during the night, and the earth will only start warming the atmosphere after the sun risen. This is the diurnal variation referred to in para 45, and shown in Figure 4.22.

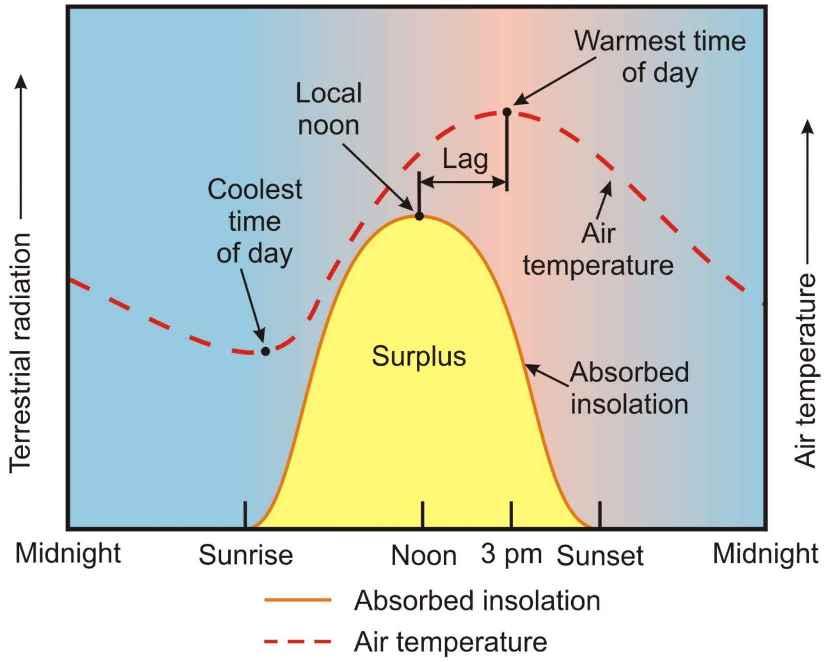


Figure 4.22

Diurnal Variation

To add the changes in temperature which takes place, the surface of the earth is made up of various substances with different rates of heat absorption. This also contributes to the fact that surface temperatures will vary, not only because of the time of day, but also because of the surface texture.

Adiabatic Process

It is a fact that as altitude is gained, pressure will decrease. As pressure decreases, volume will increase. Let us consider the air to be dry and uniform throughout. If no heat were to enter or leave the system, a parcel of air which is rising would retain the same total heat energy, but the temperature within the parcel would decrease as the parcel expands. Similarly, it will heat up if it is compressed (see Figure 4.23). The front of a bicycle pump is an example of heat increase with compression. In the atmosphere, when a parcel of air expands due to an increase in altitude, the resultant pressure drop will cause a decrease in temperature. The rate at which the air temperature decreases with altitude is known as the lapse rate.

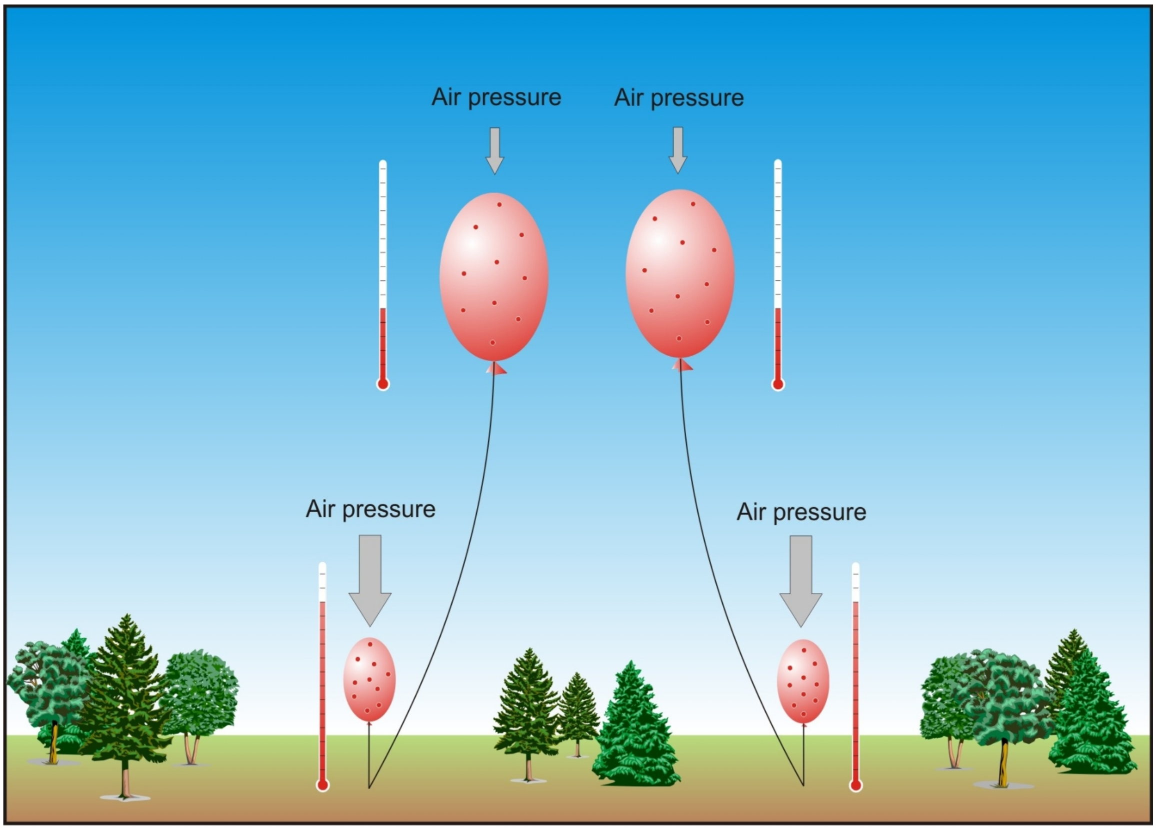


Figure 4.23

Adiabatic Heating and Cooling

As the chief source of heat is the earth's surface, the lapse rate in air close to the ground often far exceeds the normal rate. The first hundred millimetres or so tends to have a micro-climate of its own. A temperature fall of 20°C in the first metre above a hot desert surface is usual, compared with the average figure for the normal lapse rate of 1,98°C per 1000 feet. On a sunny afternoon in the tropics a steep gradient may exist up to several hundred metres above the surface.

The lapse rate varies from place to place with the season, the time of day, the water vapour content, and there is almost always a variation in lapse rate with altitude. The actual temperature decrease with height in the air about you, or in the air surrounding a particular mass of air under observation, is the environmental lapse rate (ELR).

Now consider an unsaturated, or dry, parcel of air in contact with the surface and what happens when, for some reason, it is displaced and rises through the surrounding atmosphere. We may assume that no heat is transferred between this air and the environmental air, a circumstance known as adiabatic.

The atmosphere is never completely dry; but unsaturated air is described as "dry" if its moisture content does not condense, and so affect the lapse rate. Its cooling rate, the dry adiabatic lapse rate (DALR) is about 3.0°C per 1000 feet, or 10°C per 1000 metres.

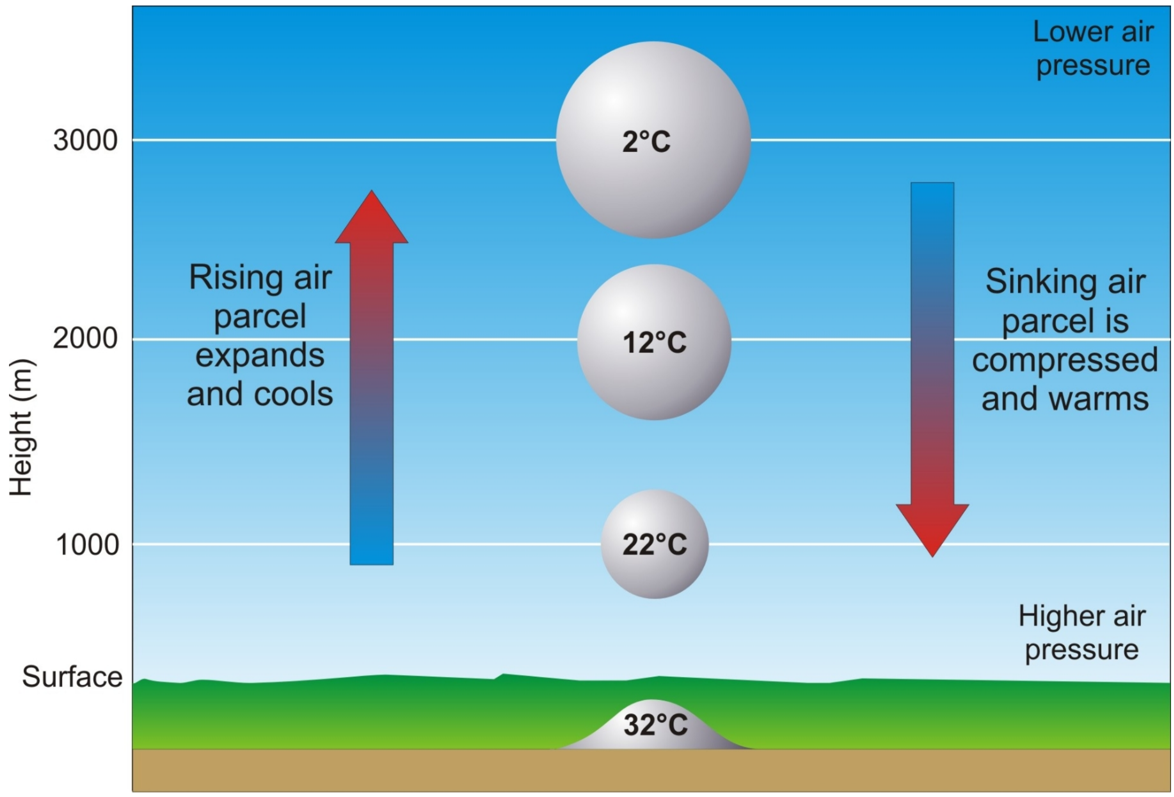


Figure 4.24

Dry Adiabatic Lapse Rate

As this air rises and is chilled to saturation point (its dew-point), much of the water vapour condenses to form droplets. This releases latent heat energy into the parcel (from the Latin word latere - be hidden). Heavy condensation thus has a considerable heating effect, which acts against the adiabatic cooling. The rising, now saturated, air thus cools at a slower rate of an average of 1,5°C per 1000 feet or 5°C per 1000 metres - the saturated adiabatic lapse rate (SALR).

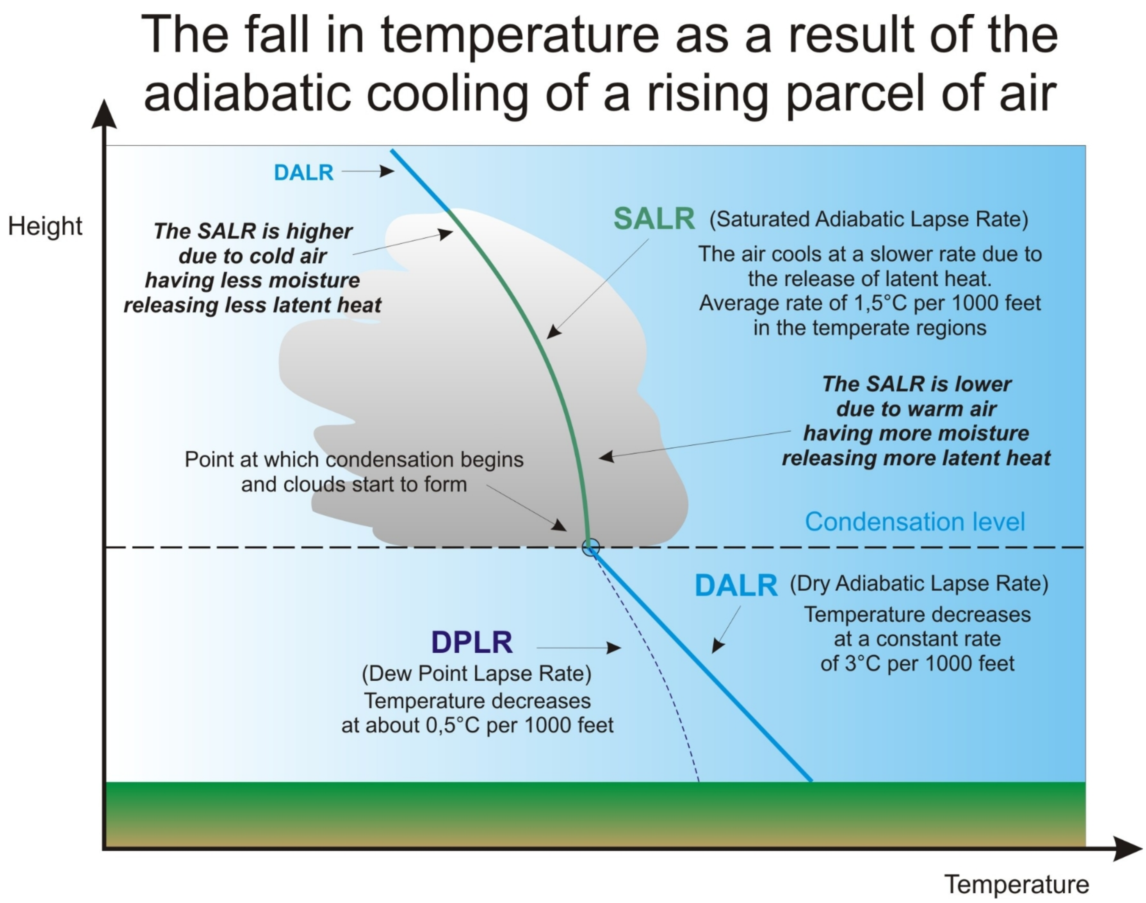


Figure 4.25

Temperature Changes Due to Adiabatic Cooling

The SALR depends on the amount of water vapour present in the parcel. If the water vapour content is high, then more latent heat is released and the cooling process is slowed quite considerably. At the equator this could drop to as little a 1°C per 1000ft. If the air is very cold, ie. at the poles, or in sub-zero conditions, the amount of water vapour present in the parcel would be very low. Less water vapour condensing means less latent heat being released into the parcel. The result of this is that the parcel's cooling rate is not slowed by much and can be 2 - 2,5°C per 100ft. In the temperate zones where we find ourselves, the average SALR is regarded to be 1,5°C per 1000ft. In Figure 4.25 it can be seen that this value of 1,5°C is not constant throughout the process but changes depending on the temperature. At the base of the cloud the SALR is low compared to the top of the cloud where it is much higher. This is due to the colder air at the top of the cloud holding less water vapour that what would be found at the warmer base.

We have already considered inversion conditions, where warmer air overlies cooler and produces a negative lapse rate, ie the temperature increases with increase in altitude. This occurs on a large scale in the relatively stationary high pressure systems in the sub-tropics where we live, above the great deserts. Air from the two permanent high pressure systems over the Indian and Atlantic oceans gradually sinks over a wide area and being warmed by adiabatic compression, results in air temperatures being higher at a higher level than those at the surface. Over the continental interiors in winter surface temperatures drop as the earth's surface cools, resulting in surface temperatures being lower. Johannesburg is well-known for its night-time winter surface inversions (see Figure 4.26).

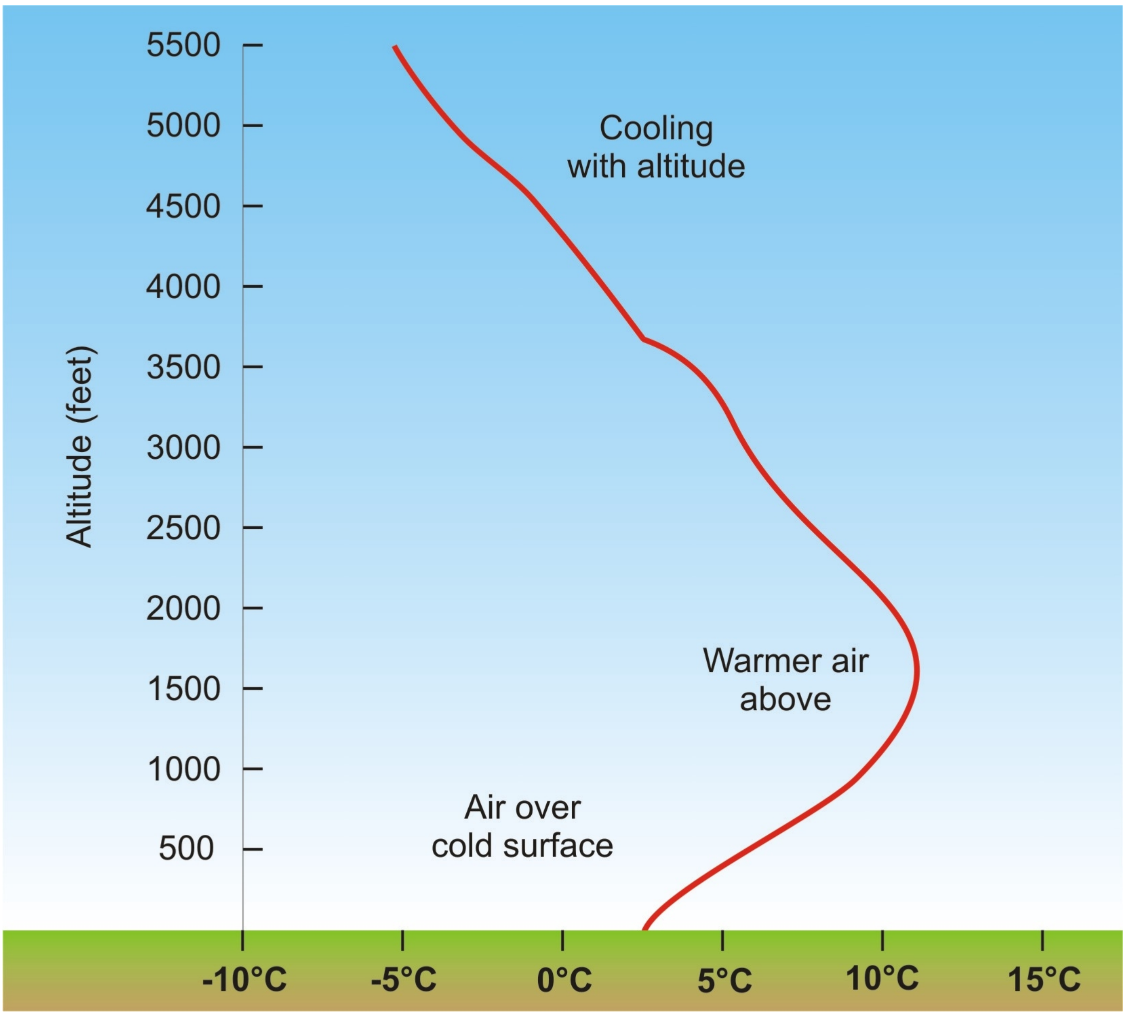


Figure 4.26

Surface Inversion

Large scale inversion also occur at high altitudes in the stratosphere where the temperature increases with height above the tropopause (see Figure 4.27).

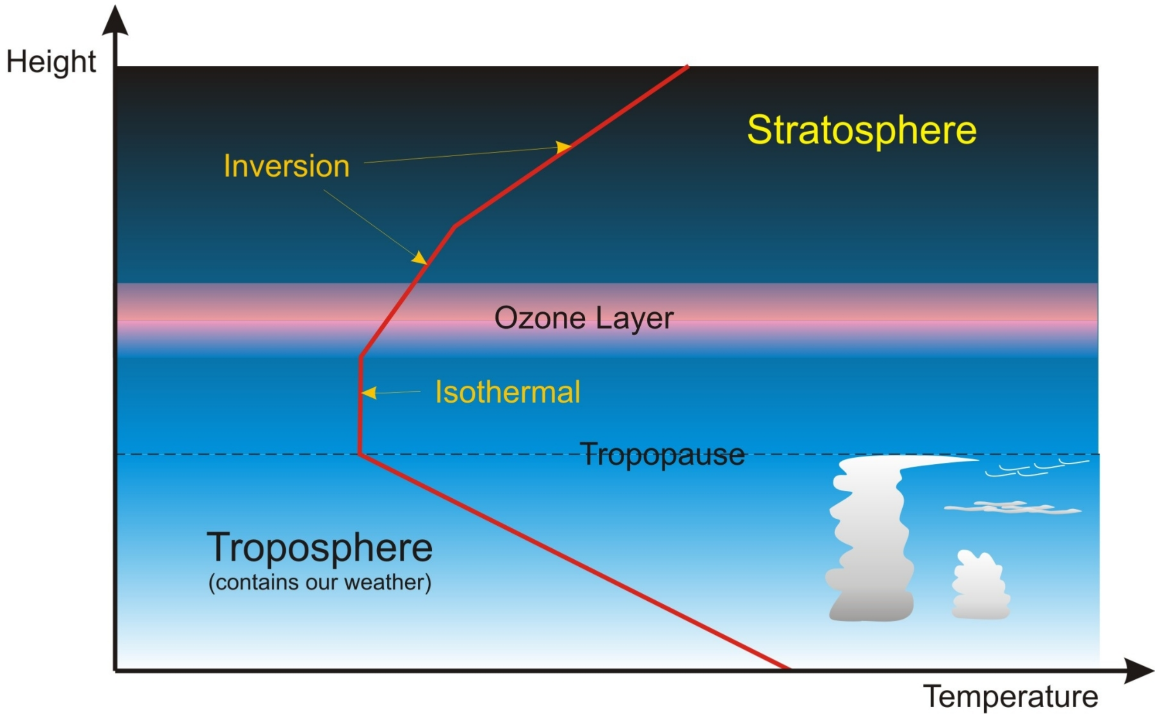


Figure 4.27

Stratospheric Inversion

Advance knowledge of the lapse rates within advancing air masses is essential to weather forecasting. They may indicate the likelihood of strong vertical movements, with possible condensation, cloud formation, and rain; or may point to more stable conditions. Knowledge of the ELR is especially important as the stability of the air mass can be determined. With this knowledge, the weather forecaster can begin to do his/her work.

Stability

Vertical air movements are involved in changing weather conditions. Consider again a parcel of air which is caused to move vertically. Should the differences between its properties and those of the surrounding air result in its further upward movement, the local atmosphere is in an unstable condition. Should it be forced to rise vertically, but the vertical movement is so resisted so that it tends to return to its former level, then the local atmosphere is stable.

Figure 4.28 shows air forced to rise, but cooling at the dry adiabatic rate. It remains cooler, than the surrounding environment, and is therefore denser than the surrounding air. After displacement it sinks to a lower level: a state of stability.

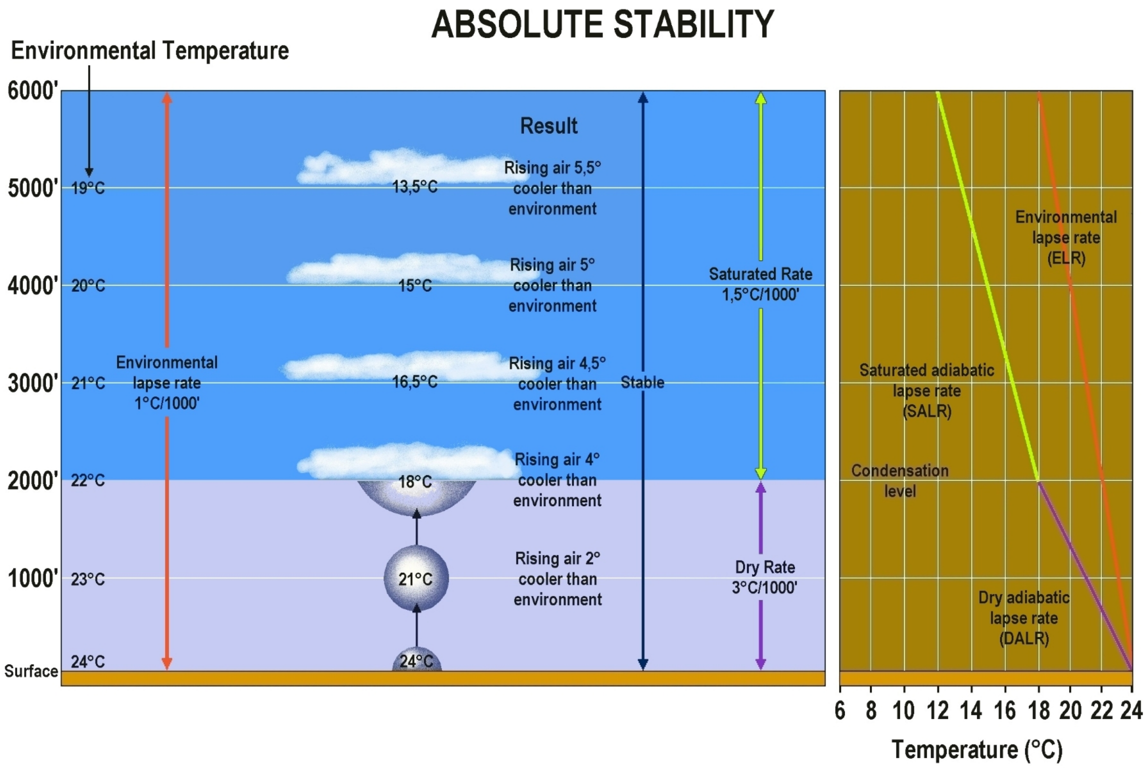


Figure 4.28

Absolute Stability

Flight conditions in stable air will be as follows:

- Visibility will be poor due to the descending tendency of the air. Impurities in the air will sink, causing visibility problems due to haze, etc.
- Winds will be light
- There will be very little turbulence
- Any cloud which may form will be of the stratiform, or layer, type

The weather conditions found in an inversion are generally of this type. The descending. Warming air will trap the impurities resulting in poor visibility. Figure 4.28a shows the temperature profile in more detail.

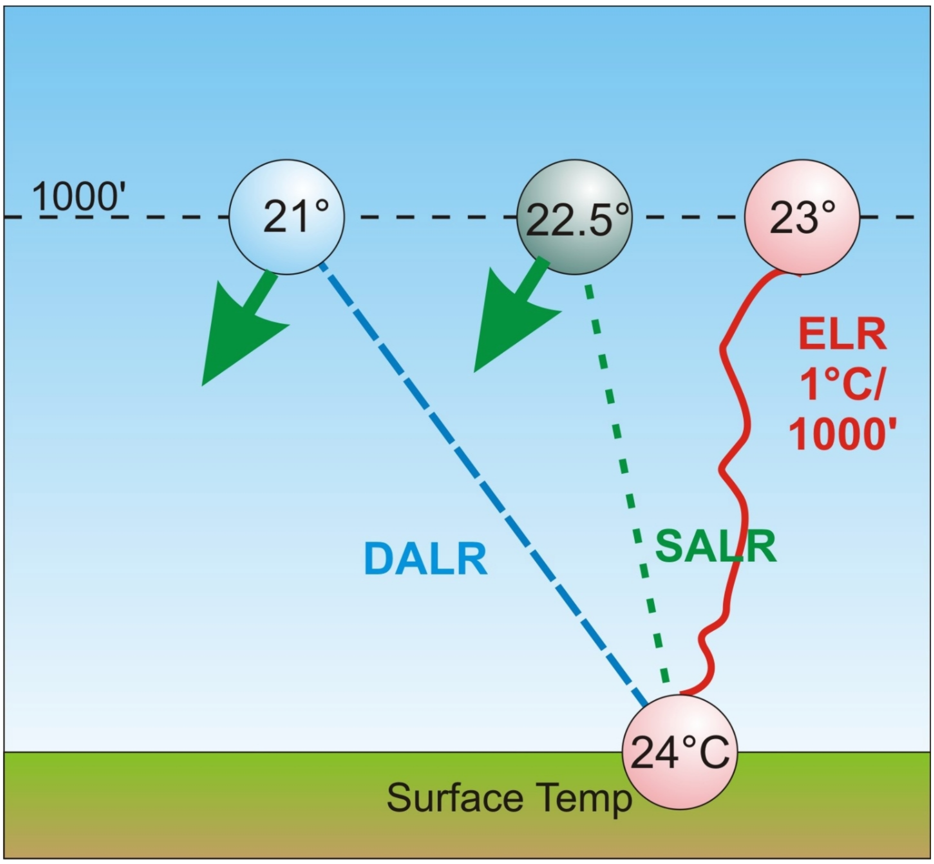


Figure 4.28a

Tendency of Rising Parcel of Air in a Stable Atmosphere

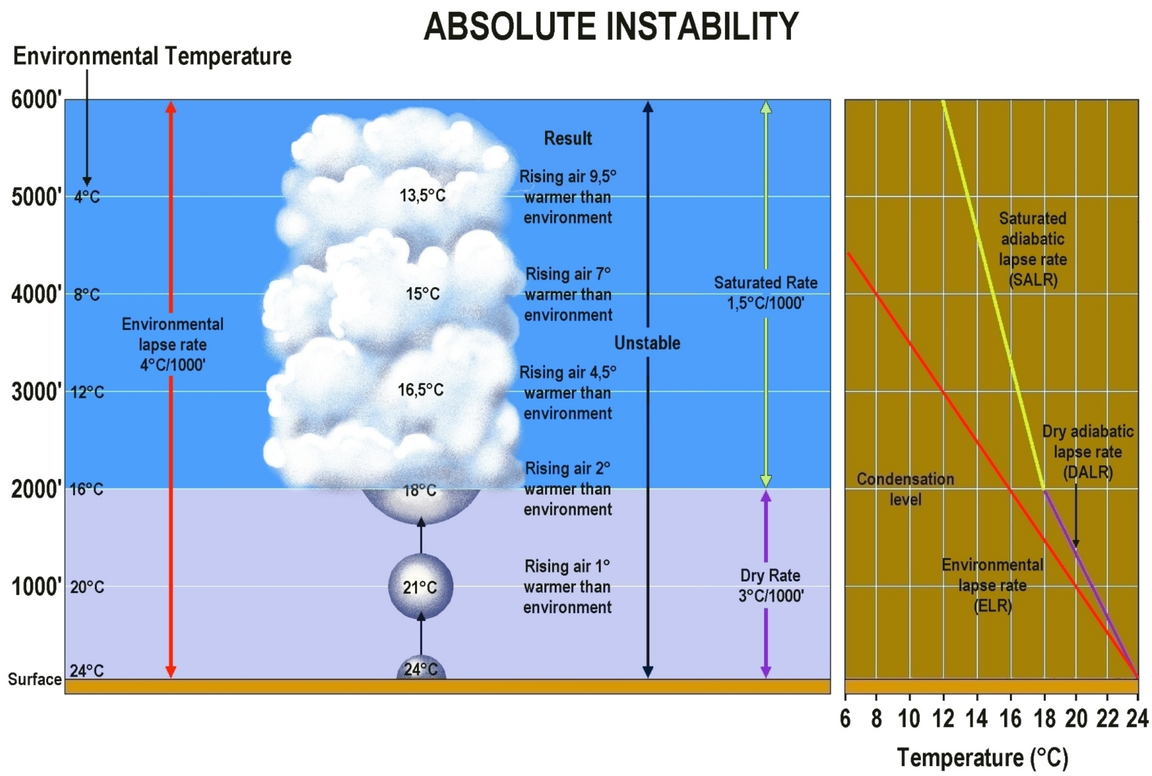


Figure 4.29

Absolute Instability

Figure 4.29 shows rising air which has a lower lapse rate than the surrounding air. As long as it remains warmer and less dense than the environmental air, it will continue to surge upwards. This is absolute instability.

Flight conditions in unstable air will be as follows:

- Visibility will be good, due to dust and haze rising to the upper atmosphere
- Winds will be gusty
- There will be turbulence
- Any cloud which may form will be of the cumuliform, or heap, type

These conditions will be found if there is convergence at the surface, or divergence aloft. This will give rise to a low pressure system forming at the surface. Figure 4.29a shows the temperature profile in more detail.

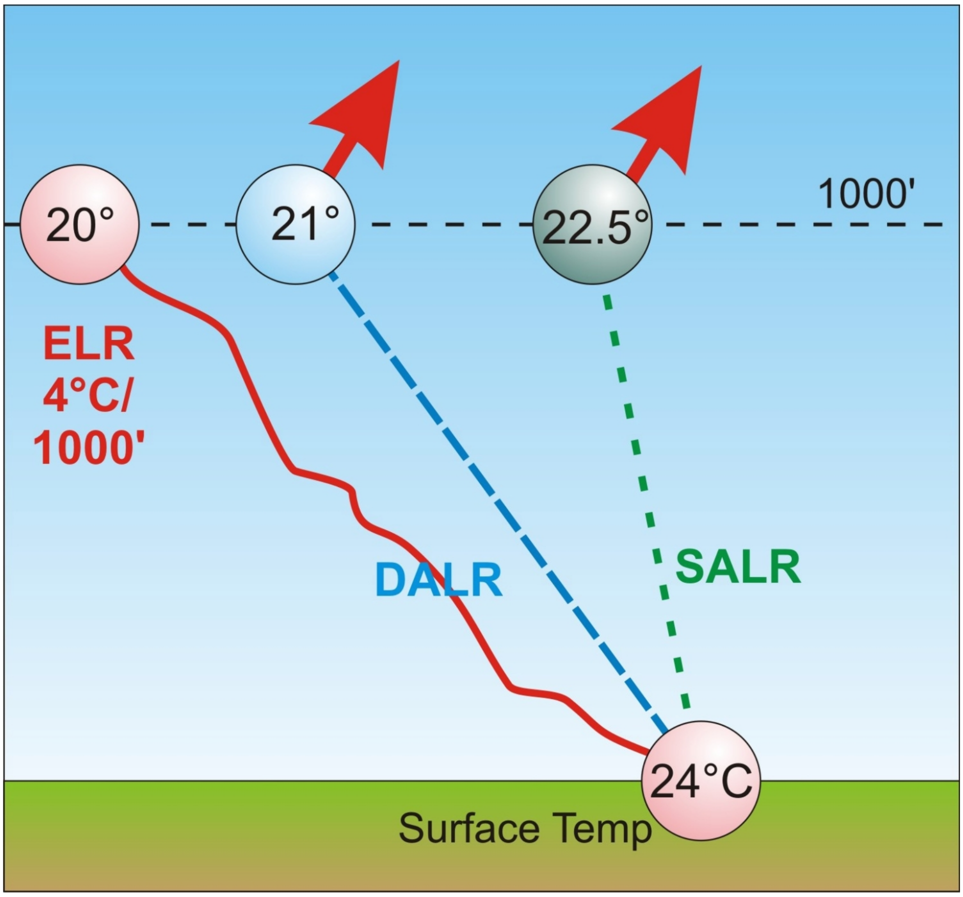


Figure 4.29a

Tendency of Rising Air in an Unstable Atmosphere

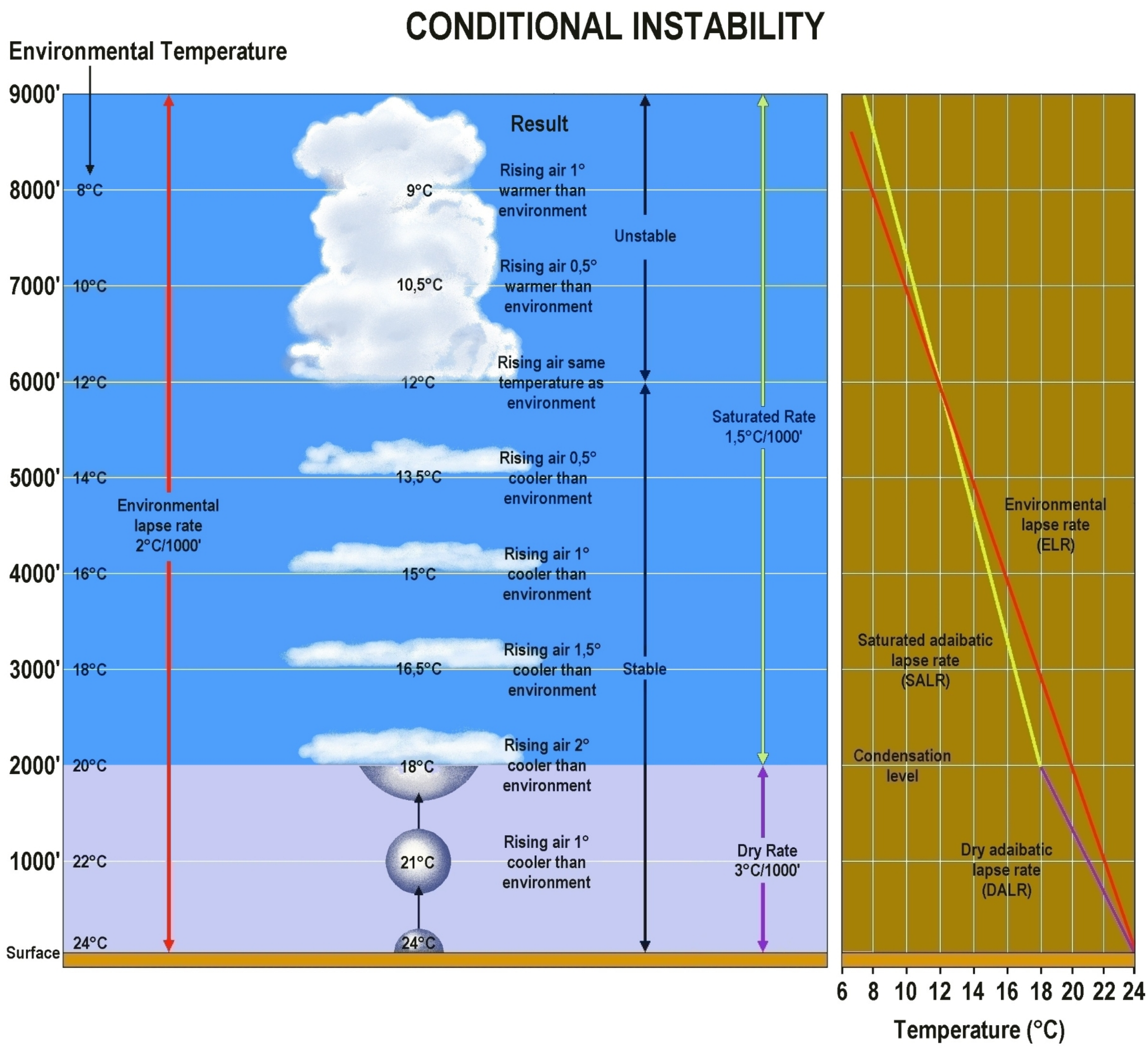


Figure 4.30

Conditional Instability

Figure 4.30 shows air which is forced to rise, perhaps by encountering a mountain side or having to rise over a mass of cold dense air. It begins to rise and cool at the DALR, and remains cooler than the surrounding air. But at a certain height condensation occurs. This releases heat, with the result that the air cools less rapidly. Eventually it becomes warmer than the environment, and hence unstable. It now continues to rise by its own buoyancy. Such conditional instability occurs much more frequently than absolute instability. In fact air with only moderate potential instability may not begin to rise until it encounters an obstacle. Figure 4.30a shows the temperature profile in more detail.

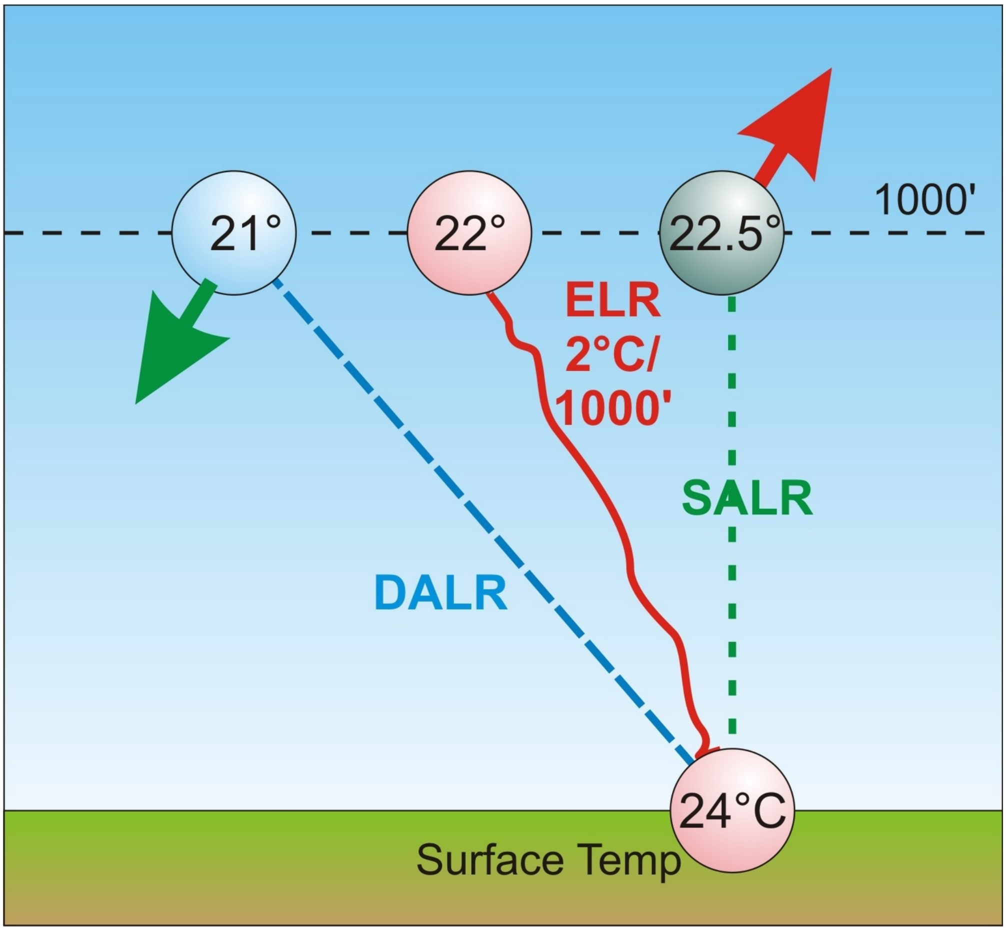


Figure 4.30a.

Tendency of Rising Air in Conditionally Unstable Air

In general, air approaching saturation, when it would be subject to a lower rate of cooling, is likely to be less stable than unsaturated air. Also, air containing water vapour is lighter than the same volume of dry air (water vapour being lighter than the atmospheric gases). Such warm, damp air, rising to great heights may well create the towering clouds we see on a hot summer's day, and so frequently in humid conditions on the Highveld.

To summarise, the stability of the air is dependent on the environmental lapse rate (ELR):

- If the ELR is low, ie. less than the SALR of 1,5°C per 1000ft, the environmental air will be warmer than a rising parcel, and the parcel will sink back to earth as soon as the lifting force is removed

- If the ELR is greater than the dry adiabatic lapse rate (DALR), ie. more than 3.0°C per 1000ft, then the environmental air will be colder than the rising parcel. Because the parcel is warmer, it will continue to rise after the lifting force has been removed.

- If the ELR falls between the DALR and the SALR, ie. between 1.5° and 3,0°C per 1000ft, the stability will depend on the condition of the air in the parcel. If the air is dry, the parcel will be cooler than the surrounding, with a tendency to sink. However, if the air in the rising parcel is saturated, the parcel will be warmer than the surrounding air, and the tendency will be to rise under its own steam.

- this can also be presented in the following form:

ELR<SALR	=	Absolutely Stable
ELR>DALR	=	Absolutely Unstable
DALR>ELR>SALR	=	Conditionally Unstable

Figure 4.31 shows the relationship between ELR and both DALR and SALR to give an indication as to what conditions may be expected. An ELR out to the right means stable air, out to the left is unstable, while ELR between the DALR and SALR will mean conditional Instability. The condition is whether the air is dry or saturated. If the air is dry, the ELR is right of DALR and therefore stable, if it is saturated, ELR is the left and therefore unstable.

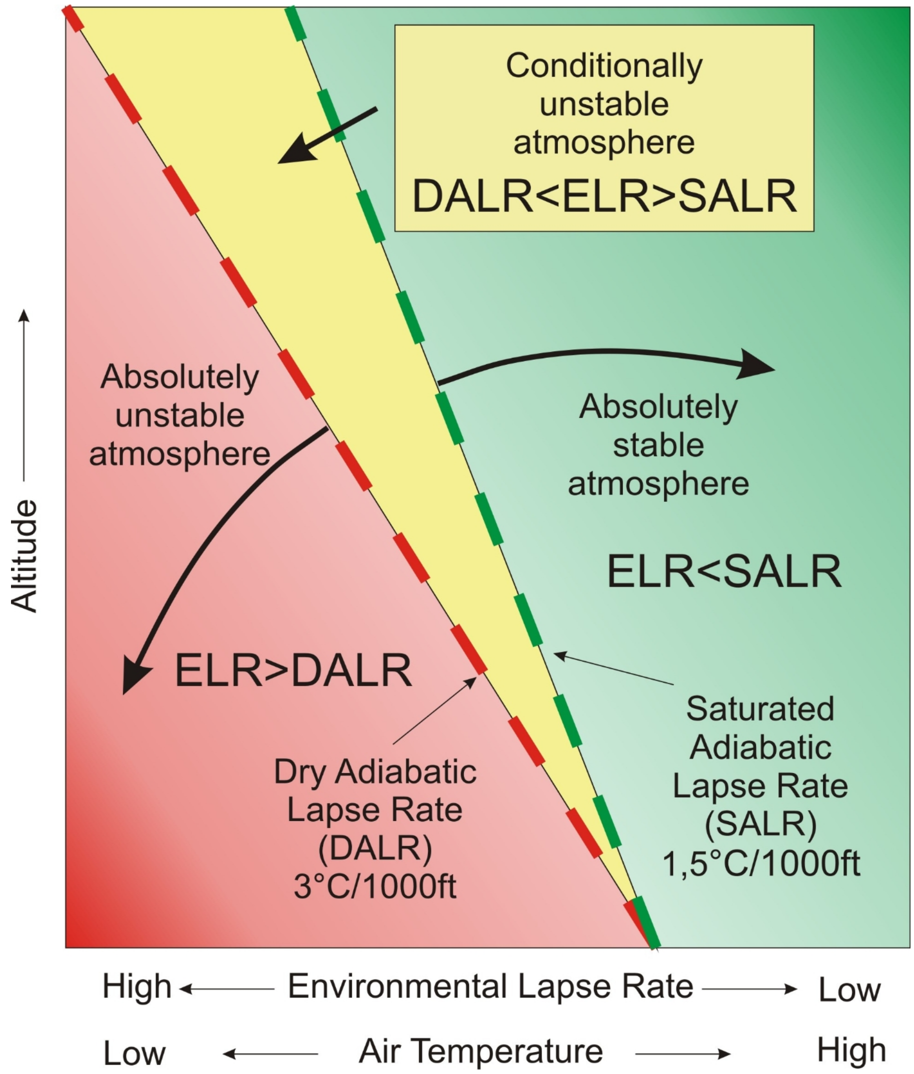


Figure 4.31

Lapse Rates vs Stability

In Figure 4.32 you get an idea of what a typical temperature profile would look like in the real atmosphere. With the ELR (in red) out to the left the air is unstable, out to the right it is stable, and when the ELR falls between the two (DALR and SALR) the air is conditionally unstable. The "condition" referred to is the moisture state of the parcel.

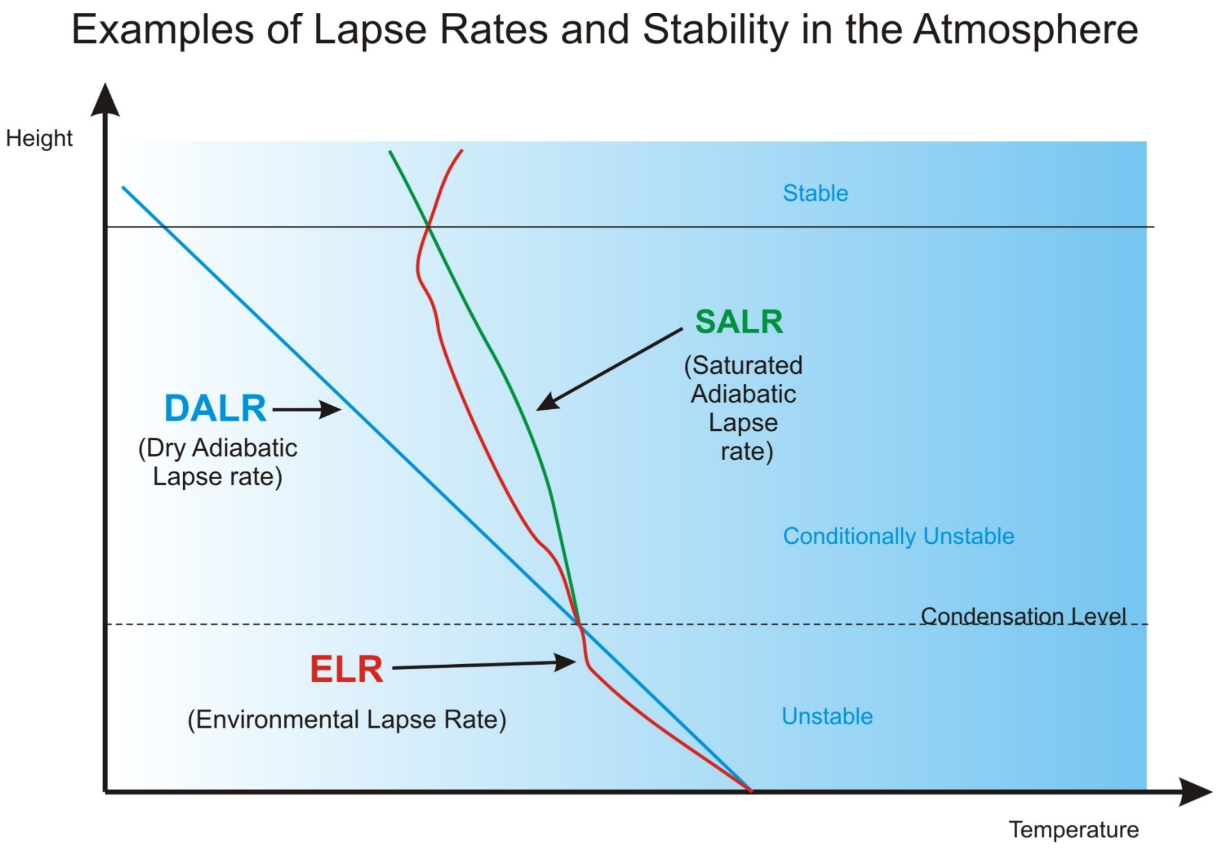


Figure 4.32

Stability in the Atmosphere

Humidity and Precipitation

Before venturing into the processes involved, there are a few words that need to be understood. H_2O exists in three forms or states in the atmosphere: solid ice, liquid water, and water vapour (gas). It can change from one to the other when certain conditions are met. These changes are as follows:

- Melting - solid to liquid, heat is absorbed
- Evaporation - water to gas, heat is absorbed
- Condensation - gas to liquid, heat is released
- Freezing - liquid to solid, heat is released
- Sublimation - solid to gas without going through the liquid state, heat is absorbed
- Deposition - Gas to solid without going through the liquid state, heat is released (see Figure 4.33)

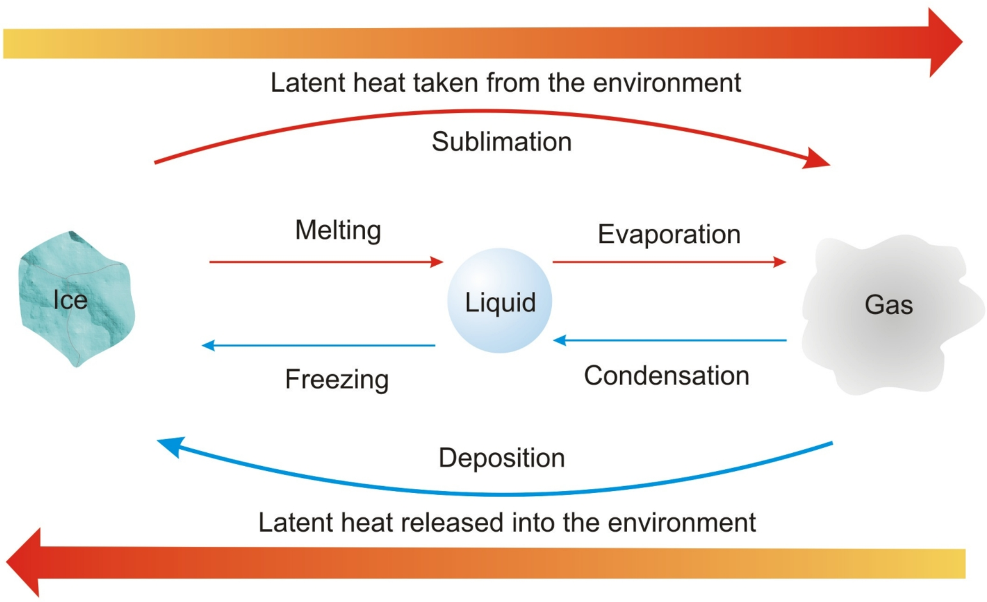


Figure 4.33

Changes of state of H_2O

The heat referred to is latent, or hidden, heat and this plays a very important role in managing the temperature of the atmosphere.

The amount of the invisible gas called water vapour is only a few percent of the total air mixture making up our atmosphere. In ISA the atmospheric air is regarded as dry, but in reality the amount of water vapour varies from almost zero to about 4 per cent of the total. Despite the small amounts, water vapour is very important to us. When it condenses or freezes it transforms into minute cloud droplets or ice crystals which grow and can eventually fall to the earth as precipitation. The term humidity is used to describe the amount of water vapour in the air. There are several adjectives relating to humidity and we will look at some of them. What may be interesting to note is the fact that hot “dry” usually holds more water vapour than cold “moist” air.

The air over the Namib and Kalahari deserts holds more water vapour than the cold, miserable air over the South Pole. This is due to the fact that the amount of water vapour that can be held in the air depends largely on the temperature of the air. The amount of water vapour present in the air at any place varies, greatly. The water vapour content of the lower reaches of the atmosphere air tends to be about 2 per cent of its volume, but, as mentioned earlier, varies from very little to about 4 per cent. The amount present also tends to decrease as we climb higher, so that the mean vapour content at 4000 feet is only about a tenth of that near sea level. This too is variable.

Within the atmosphere there is a finite amount of water available to us. If all the water vapour in the atmosphere were to condense at the same time and fall as rain, it would only cover the earth’s surface with about 2.5 cm of water. To keep the supply going there is a never-ending cycle known as the hydrologic cycle. This is constant circulation of water, and because it is a cycle, there is no beginning or end, and the water is re-used over and over again. Water can change states among vapour, liquid, and ice at various places in the hydrologic cycle.

The sun, which drives the water cycle, heats water in the oceans. Water evaporates as vapour into the air. Ice and snow can sublimate directly into water vapour. Evapotranspiration is water transpired from plants and evaporated from the soil. Rising air currents take the vapour up into the atmosphere where cooler temperatures cause it to condense into clouds. Air currents move clouds around the globe, cloud particles collide, grow, and fall out of the sky as precipitation. Some precipitation falls as snow and can accumulate as ice caps and glaciers, which can store frozen water for thousands of years. Snow and glaciers can thaw and melt, and the melted water flows over land and into rivers. Most precipitation falls back into the oceans or onto land, where the precipitation flows over the ground as surface runoff. A portion of runoff enters rivers in valleys in the landscape, with streams and rivers moving water towards the oceans. Run-off and groundwater are stored as freshwater in lakes. Not all runoff flows into rivers. Much of it soaks into the ground as infiltration. Some water infiltrates deep into the ground and replenishes aquifers, which store huge amounts of freshwater for long periods of time. Some infiltration stays close to the land surface and can seep back into surface-water bodies (and the ocean) as groundwater discharge. Some groundwater finds openings in the land surface and emerges as freshwater springs. Over time, the water re-enters the ocean, where the water cycle started.

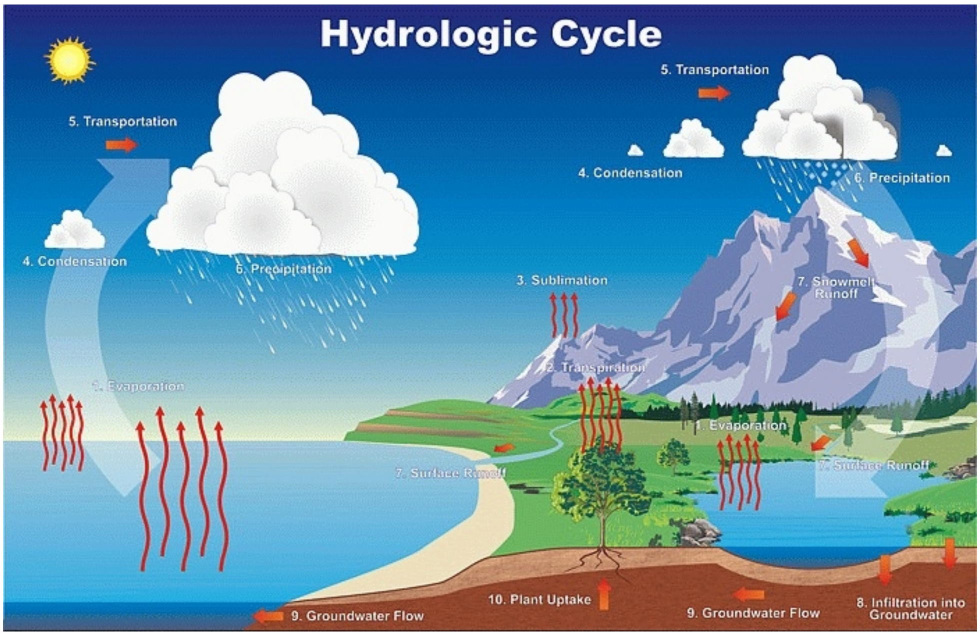


Figure 4.34

The Hydrologic Cycle

Different Processes in the Hydrologic Cycle

There are several processes which take place continuously and each plays an important part in the hydrological cycle.

- Precipitation

  Condensed water vapour that falls to the Earth's surface. Most precipitation occurs as rain, but also includes others such as snow, hail, and sleet. Approximately 505,000 km^3 (121,000 cu mi) of water fall as precipitation each year, 398,000 km^3 (95,000 cu mi) of it over the oceans.

- Runoff

  The variety of ways by which water moves across the land. This includes both surface runoff and channel runoff. As it flows, the water may infiltrate into the ground, evaporate into the air, become stored in lakes or reservoirs, or be extracted for agricultural or other human uses.

- Infiltration

  The flow of water from the ground surface into the ground. Once infiltrated, the water becomes soil moisture or groundwater.

- Subsurface Flow

  The flow of water underground and aquifers. Subsurface water may return to the surface (eg. as a spring or by being pumped) or eventually seep into the oceans. Water returns to the land surface at lower elevation than where it infiltrated, under the force of gravity or gravity induced pressures. Groundwater tends to move slowly, and is replenished slowly, so it can remain in aquifers for thousands of years.

- Evaporation

  The transformation of water from liquid to gas phases as it moves from the ground or bodies of water into the overlying atmosphere. The source of energy for evaporation is primarily solar radiation. Evaporation often implicitly includes transpiration from plants, though together they are specifically referred to as evapotranspiration. Total annual evapo-transpiration amounts to approximately 505,000 km^3 (121,000 cu mi) of water, 434,000 km^3 (104,000 cu mi) of which evaporates from the oceans.

- Sublimation

  The state change directly from solid water (snow or ice) to water vapour.

- Advection

  The movement of water - in solid, liquid, or vapour states- through the atmosphere. Without advection, water that evaporated over the oceans could not precipitate over land.

- Condensation

  The transformation of water vapour to liquid water droplets in the air, producing clouds and fog.

- Transpiration

  The release of water vapour from plants into the air. Water vapour is a gas that can not be seen.

The sea contains about 70% of the Earth's water, so it is a major player in this on-going cycle.

The water vapour content may be stated as the proportion of the atmospheric pressure due to the water vapour content, say 20 hPa out of a total atmospheric pressure of 1000 hPa. Cold, dry air might have a water vapour pressure of less than 2 hPa; whereas in warm, moist, tropical air water vapour might exert a pressure of 15 -20 hPa.

At any given air temperature there is a limit to the amount of water that can be held as vapour. Once this limit of saturation is exceeded, condensation usually occurs. This can also happen if the temperature of the parcel of air was cooled in any way.

The absolute humidity of the air does not change unless water is added to, or taken from, the body of air concerned; but the relative humidity varies with the temperature. Relative humidity is defined as the proportion of the actual mass of water vapour contained in a given volume of air to the maximum amount that could be contained at that temperature. It can be expressed as a percentage. If the air is gradually cooled while maintaining the moisture content constant, the relative humidity will rise until it reaches 100%. This temperature, at which the moisture content in the air will saturate the air, is called the dew point . If the air is cooled further, some of the moisture will condense. Relative humidity is the amount of moisture in the air compared to what the air can "hold" at that temperature. When the air can't "hold" all the moisture, then it condenses as dew.

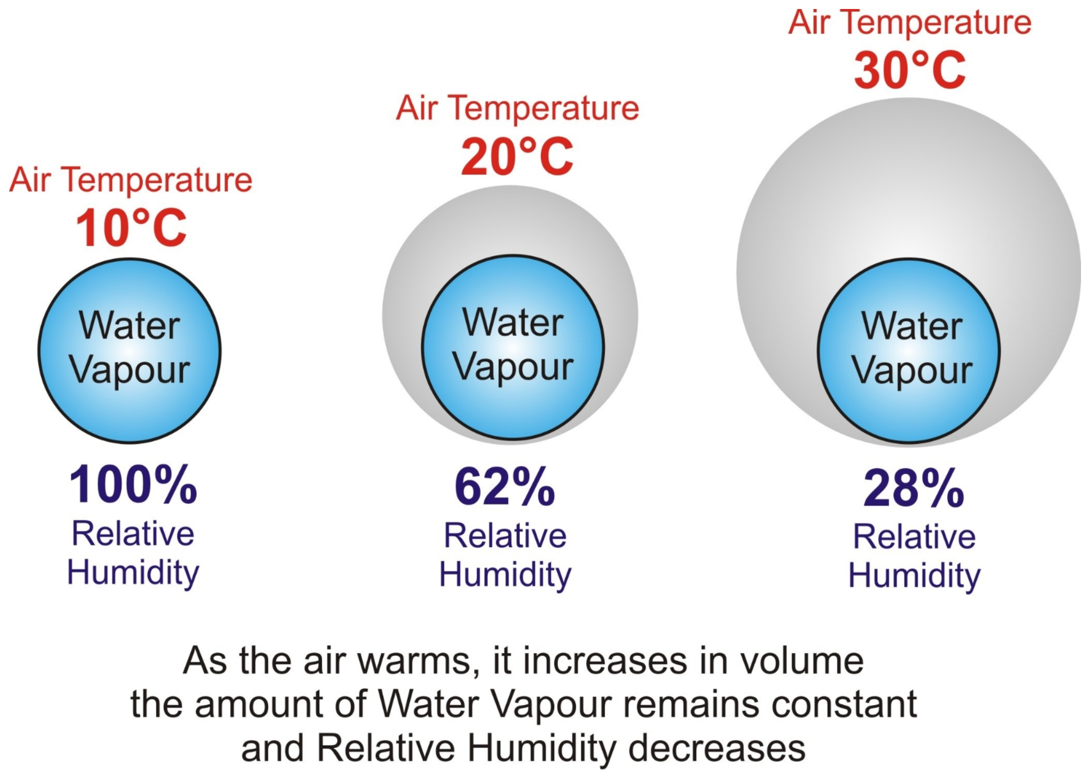


Figure 4.35

Relative Humidity: Variations with Temperature

As the water vapour may be expressed in terms of the pressure it exerts, a comparison of the actual vapour pressure with that which would be exerted if the air were saturated at that temperature also gives us the relative humidity.

Consider air which is saturated at 10°C: its relative humidity is 100 per cent. As it warms the value falls to 62 per cent at 20°C, and to 28 per cent at 30°C (Figure 4.35). So very dry air over a hot desert may contain as much, or more, water vapour as saturated air over Arctic waters. The actual amount of water vapour in the parcel is known as the absolute humidity, and is expressed as a unit volume, usually grams per cubic metre. In Figure 4.35 the absolute humidity remains constant as no water vapour is added or removed from the parcel.

Saturation levels at any temperature are fixed, and as the temperature rises, the parcel can hold more water vapour. An example of this:

- At sea level pressure air at 20°C can hold 17 grams of water vapour per cubic metre. At this point the parcel is regarded as saturated, or has 100% relative humidity. Any cooling of the parcel will cause condensation (clouds, fog, dew) to form. 20°C would then be known as the dewpoint for that situation.

- At sea level pressure air at 10°C can only hold 9 gm/m^3. If the temperature of our one cubic metre parcel were to be cooled to 10°C, the air can only hold 9 gm of water vapour, so 8 gm would have to condense as water droplets. The relative humidity of the parcel would still be 100%.

- At sea level pressure air can hold 30 gm/m^3 If our parcel in para a were to be heated to 30°C and no water vapour added, the parcel would still contain 17g of water vapour. This would mean that the relative humidity of the air will have dropped to 57%. 17g of the 30g that the air could have held at 30°C is 17/30 x 100 = 56,67%.

The process of condensation

Unsaturated air may become saturated by decreasing the temperature; or, if the temperature remains constant, by increasing the water vapour content.

When unsaturated air is cooled, the relative humidity increases until it is completely saturated. This is the dew-point. Any further cooling leads to condensation. If the dew-point is below 0°C, some of the condensation may appear as ice crystals, as snow, white frost, or high (cirrus) clouds. In practice liquid condensation often occurs at temperatures well below freezing point. This is due to the purity of the water at altitude. The purer the water, the lower the freezing point, with the purest water only freezing at -40°C. In order for water droplets to form in the atmosphere, it is necessary for tiny particles to act as condensation nuclei. These may be microscopically small (see Figure 4.36), such as dust particles or salt crystals, which are common in the lower troposphere. Particles with an affinity for water (hygroscopic substances) are the most effective nuclei of condensation. Salt particles over the ocean are particularly suitable, and, of course, plentiful.

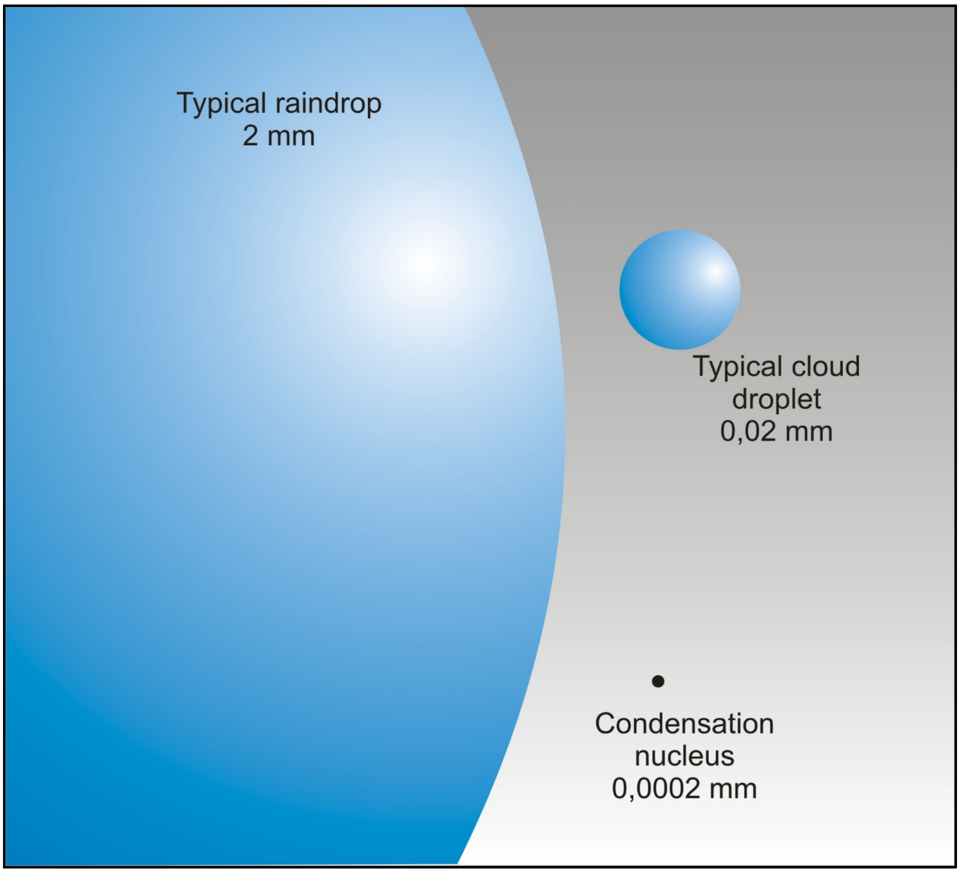


Figure 4.36

Comparative Sizes of Droplets and Condensation Nuclei

Where nuclei are absent, cooling may continue far below the dew-point without condensation, and the air becomes super-saturated with water vapour. Such conditions are obviously less likely to occur below, say 20 000 ft m, than in the higher, purer atmosphere.

The nature of precipitation

The term "precipitation" includes such condensation forms as rain, drizzle, snow, sleet, hail, dew, hoarfrost and rime ice.

When air is caused to rise it expands and cools. At a certain height it becomes saturated with water vapour and condensation occurs. But condensation releases heat energy, which counteracts the cooling by expansion. This may keep the air warmer and more buoyant than the surrounding air, so it continues to rise. Condensation may occur on a scale sufficient to bring precipitation to ground level.

Droplets are formed, usually of radius between 0.001 - 0.05 mm. Very small droplets tend to avoid one another if set in motion. But slightly larger ones may collide and coalesce into larger and larger drops (see Figure 4.37). Eventually they are able to fall to earth as rain, often against considerable up-draughts. The maximum size of a raindrop is of the order of 5 mm radius.

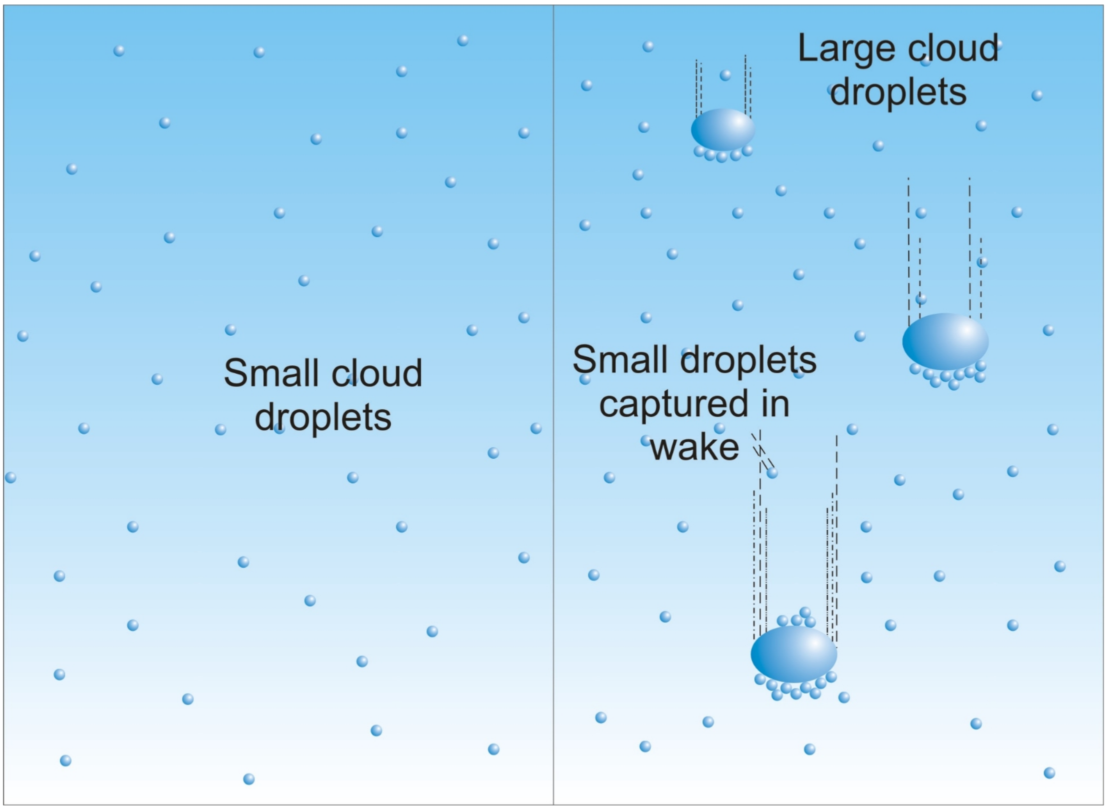


Figure 4.37

Coalescence or Collision

The rate of fall of droplets varies. The larger the droplet, the faster it falls. A drop of 0.5 mm may take up to four minutes to fall one kilometre; one of 2.0 mm radius may take less than two minutes. Very fine rain may evaporate below the cloud base before reaching the ground.

Hail is usually formed in towering cumulonimbus clouds. Strong updrafts carry droplets to high altitudes, where they freeze within the cloud. As they fall, further condensation takes place on the particles before they are again carried up by air currents. The process may be repeated many times before the resulting hailstones escape the main updraft and become large enough to fall to earth. When they do fall they are cushioned to some extent by the uprush of air. The hailstone*s interior shows concentric shells of ice, much like the rings of a tree.

Dense masses of droplets formed by condensation and held in air close to the ground comprise mist or fog. (When the droplets restrict visibility to less than 1 000 metres, this is regarded as fog rather than mist.) They form when moist air is cooled below its dew-point, or sometimes when extra water vapour is added to a mass of air from a surface water source - a lake or river, or moist vegetation.

When clear skies freely allow radiation loss and the air in contact with the ground is chilled to below dew-point, condensation occurs as radiation fog. Gravity plays a part in building up such fog belts, as when valleys receive cold, dense air from higher ground. The fog develops and thickens from the bottom upward. Here, again, there is local inversion, with cold air close to the ground and warmer air above.

Sometimes meteorological conditions cause air to subside from high altitudes and warm by compression. This gives rise to more general temperature inversion, and any fog formed in the colder air beneath may persist for long periods.

At other times fog may lift and form low cloud layers during the day, before lowering and thickening again at night. Much of what is known as “upslope fog” is in fact cloud at hill level.

Masses of air moving horizontally above the surface, as advection currents, transfer heat energy and moisture, so that fog may form where warm, moist air moves over a cold surface.

Hoar frost occurs when the temperature is well below freezing and the water vapour is supercooled. Minute ice crystals are deposited on grass, leaves and cold surfaces, though there may also be frozen drops of super-cooled water. You have probably gone to your car on a cold winter's morning, only to find the windshields covered in a thin ice layer. This is hoar frost. The cold temperature of the car's surface causes the water vapour to freeze directly onto the car.

Rime is usually a heavier deposit (ice crystals which build up on the windward side of objects), formed when the air is moving very slightly, often when foggy conditions occur under clear skies.

Clouds, too, are masses of tiny suspended droplets. But the form of clouds varies a great deal and reflects conditions in the lower atmosphere. So, before considering cloud forms in detail, it is necessary to appreciate how the properties of air change from the surface upward through the troposphere - the vertical distribution of temperature and humidity.

Cloud Formation

In order for clouds to form, air must be cooled to the dew point temperature so that, if any further cooling takes place, condensation will occur. Clouds are simply visual confirmation of the condensation process. The temperature at which condensation takes place will determine whether the clouds are made of ice particles, water droplets, or a combination of both.

This cooling may take place as a result of advection, radiation, or adiabatic expansion due to air being lifted, ie. convection.

Advection occurs when air is moved horizontally, and passes over a warmer or colder surface. A colder surface will result in the air being cooled, and if it is cooled sufficiently, then condensation could take place. This is found along the West coast of Southern Africa, when air from the Atlantic high pressure system passes over the cold Benguela current, resulting in advection fog. Fog is simply clouds at ground level.

Radiation on a cold night can result in the air temperature falling sufficiently to cause condensation. This is the reason for the radiation fog found on the Gauteng Highveld, usually during cold winter nights.

Adiabatic cooling is the reason why a vast amount of clouds form. When a parcel of air is lifted, it will cool due to the expansion of the parcel as pressure decreases with increasing altitude. The amount of heat energy in the parcel remains unchanged, and as the parcel grows in size, the overall temperature within the parcel drops. If the parcel descends, the parcel 's size reduces, and the parcel temperature increases. This process is called adiabatic, as no energy is lost or gained. A dry parcel will cool at the Dry Adiabatic Lapse Rate (DALR), which is about 3°C per 1000ft, or 10°C per 1000m. This is a fixed value and applies at any latitude. A saturated parcel will cool at the Saturated Adiabatic Lapse Rate (SALR) which averages out at about half of the DALR in the mid-latitudes where we live.

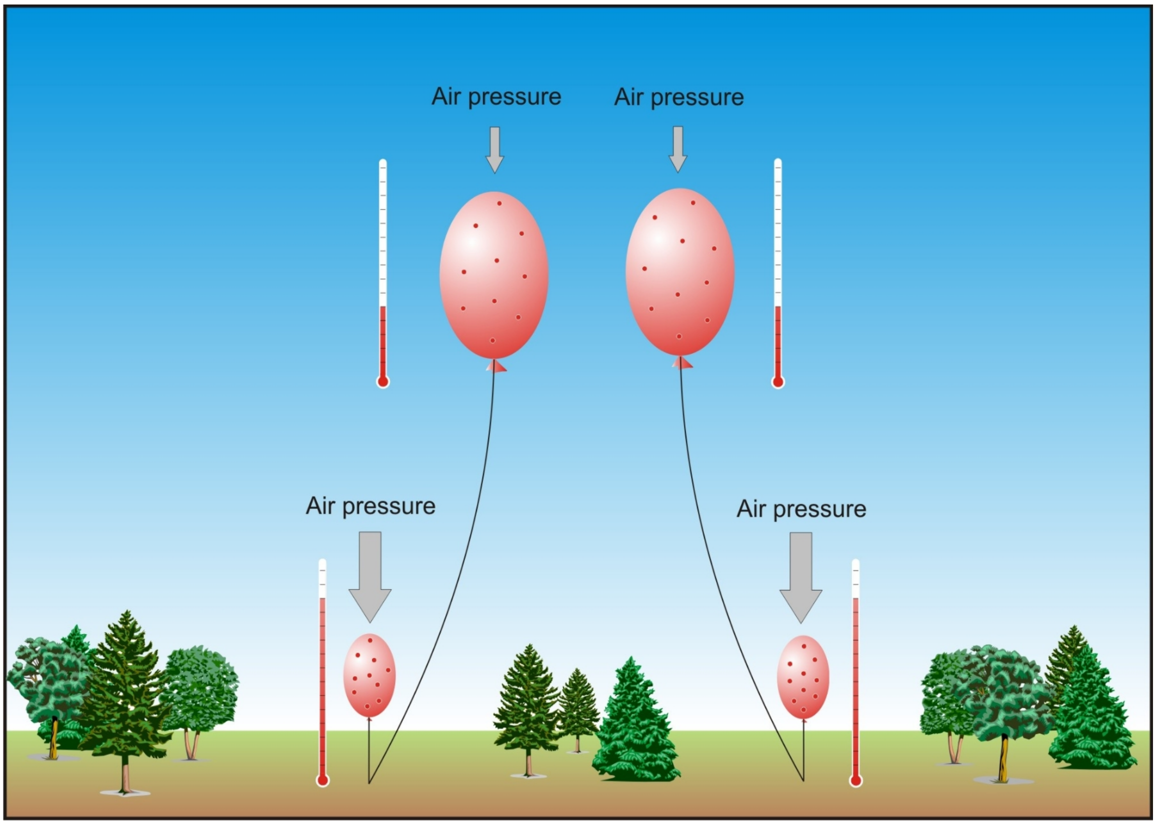


Figure 4.38

Adiabatic Process

There are several ways in which a parcel may be lifted. The primary causes are Convection, Convergence, Orographic and Frontal:

- Convection occurs when the surface of the earth is warmed, causing the air above it to rise (see Figure 4.39). As the air rises it will be subjected to a lower pressure, and adiabatic cooling will take place.

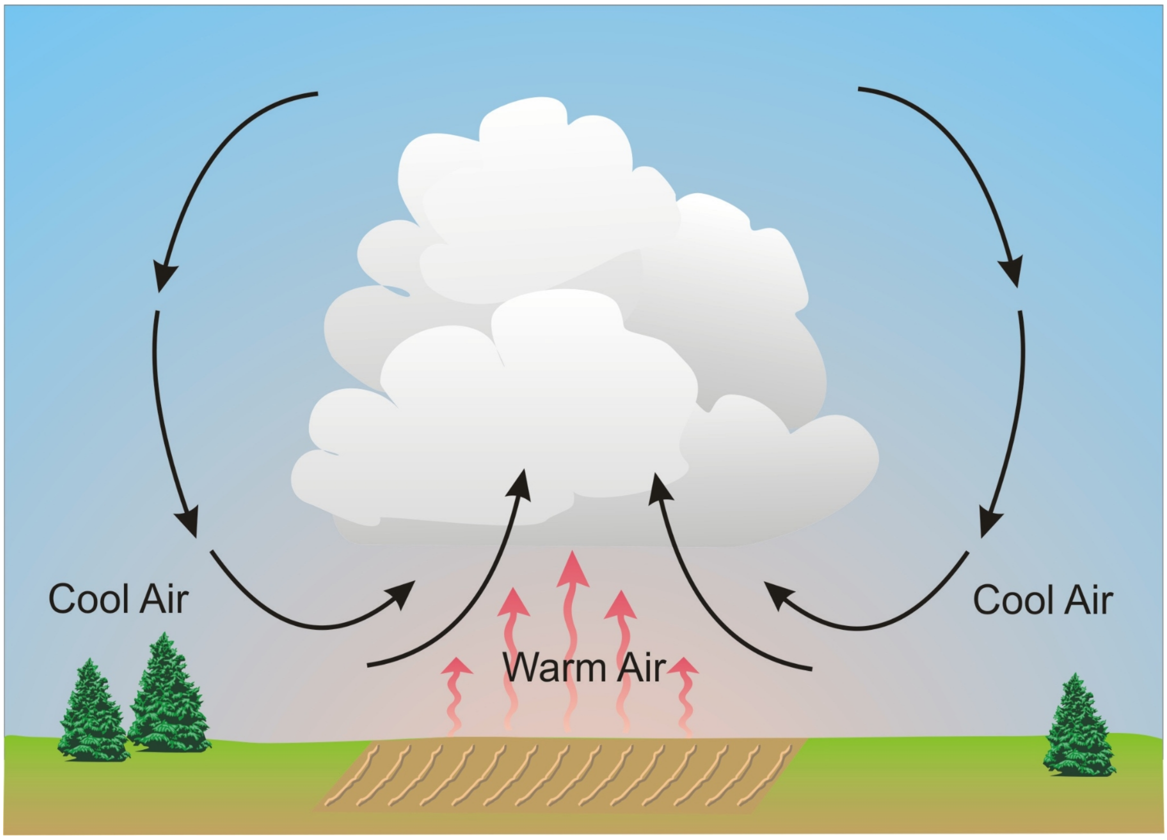


Figure 4.39

Convective Lifting

- Convergence occurs when two air parcels with similar temperature and humidity characteristics converge on each other (see Figure 4.40). This occurs along the equator, or more specifically the Intercontinental Convergence Zone (ITCZ) which moves north or south depending on the seasonal position of the sun. The only option open is for the two to rise resulting in cooling over a widespread area.

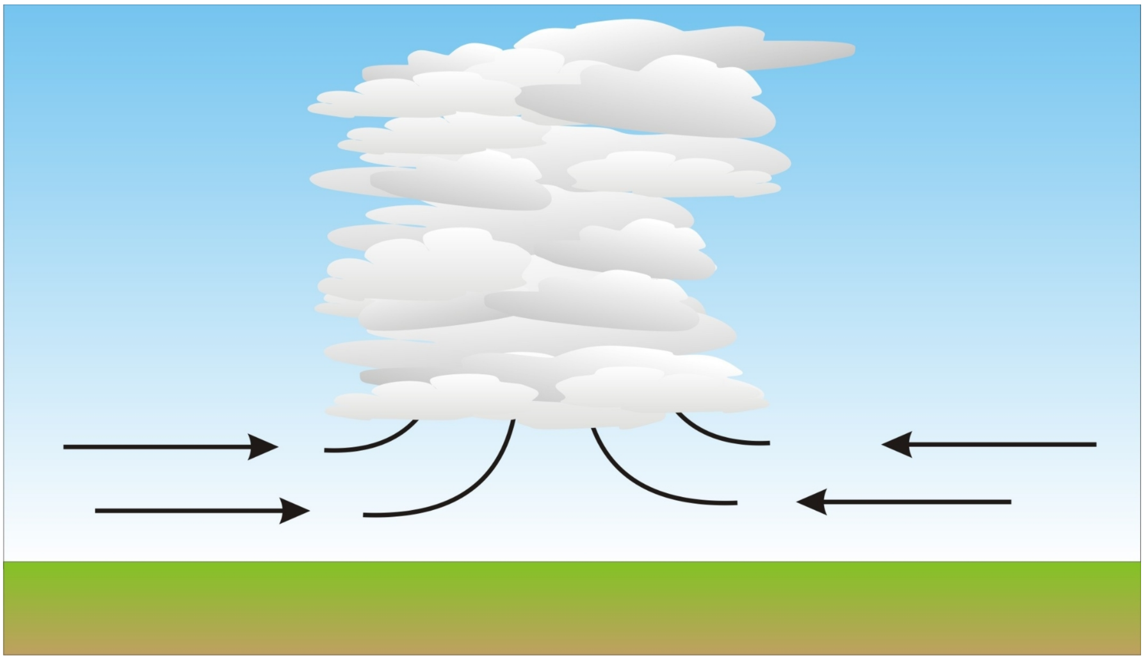


Figure 4.40

Convergent Lifting

- Orographic lifting occurs when a moving air parcel encounters a land mass or mountain in its way (see Figure 4.41). The parcel could pass around the obstruction, but if forced to rise over the obstruction, cooling will occur.

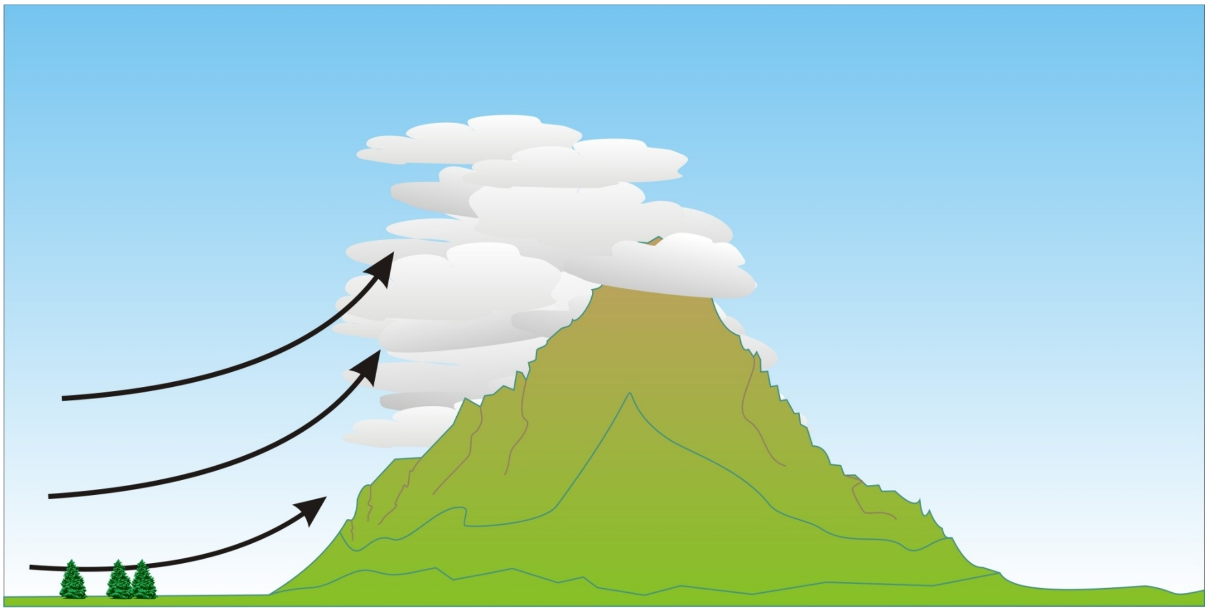


Figure 4.41

Orographic Lifting

- Frontal lifting occurs when two parcels of different temperature and humidity characteristics meet up with each other (see Figure 4.42). If a moving cold parcel meets up with warmer air, the cold will push the warm air upwards, causing it to cool quite rapidly. If a parcel of moving warm air meets up with cold air, the warm air will rise gently over the cold air, resulting in a more gentle cooling.

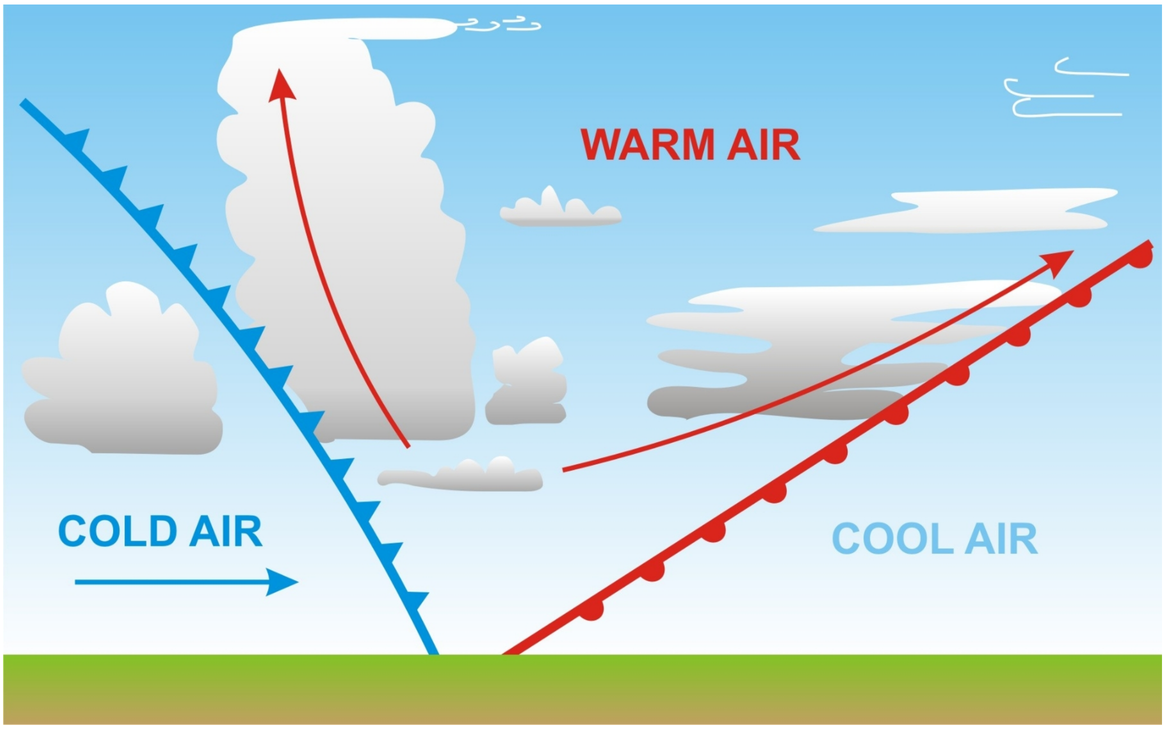


Figure 4.42

Frontal Lifting

Clouds consist of countless millions of very tiny droplets or minute ice crystals, maintained in the atmosphere by slight upward movements. When the sun shines on their outer surfaces, or through thin layers, they appear white by reflected or refracted light. The sides appear grey, or black when the cloud is dense.

Cloud forms tell us a great deal about atmospheric conditions, and we may be able to estimate whether clouds in the lower atmosphere are building or dispersing by observing their outer edges. Sometimes clouds form in an up-current and disperse in a down-current, as turbulent conditions with eddying may cause humid air to rise and fall above and below condensation level. In other words, behaviour as well as shape can also reveal a great deal about the atmosphere. There are two basic cloud types, namely stratiform and cumuliform. They are classified according to the height of the cloud base. Figure 4.43 shows what each of the cloud types generally looks like.

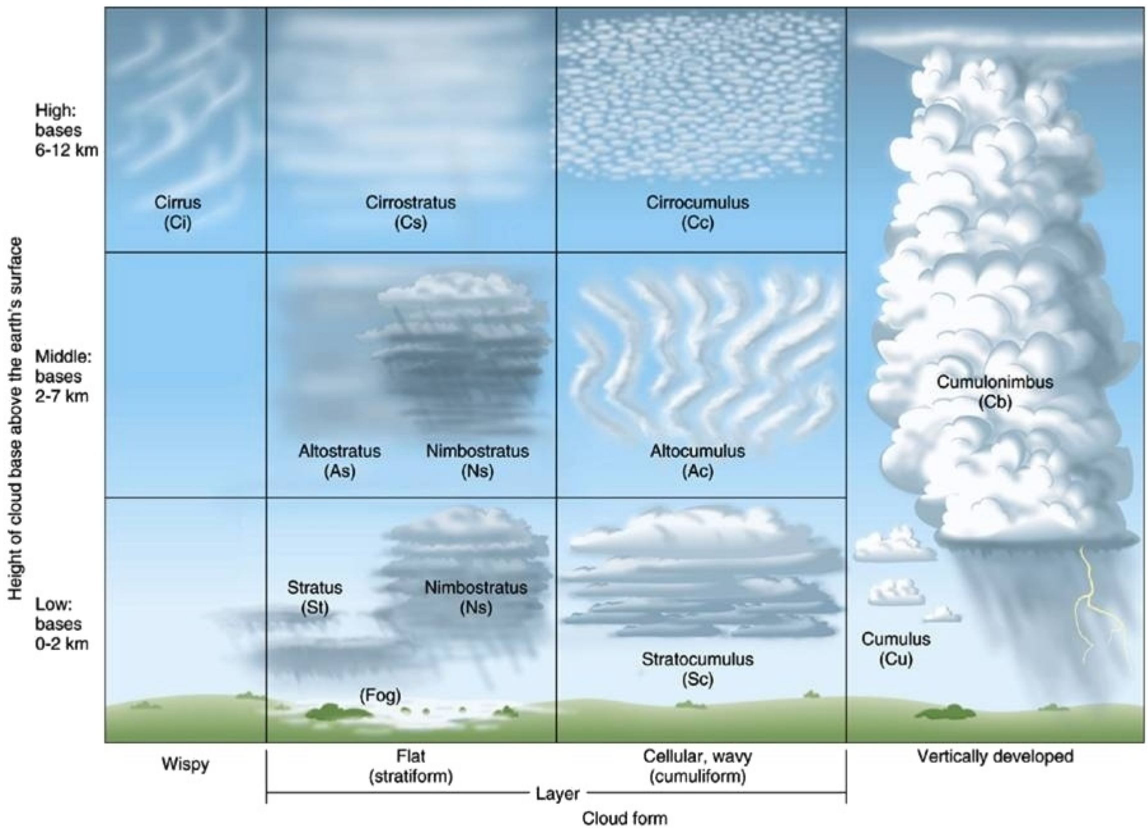


Figure 4.43

The Major Cloud Types

High clouds (bases forming generally above 20 000 ft)

These clouds are not really of too much concern to the private pilot, as they are too high. They do however, give some indication of what type of weather is on the way.

Cirrus clouds are composed of ice crystals and are usually wispy or feather-like in appearance. They may be seen in isolated groups in fair weather conditions. But when they occur in long regular bands of "mares* tails", or are associated with cirrostratus, they are usually caused by warm air moving high up over a mass of cold air, far in advance of a warm front and therefore an indication of bad weather on the way. This is because a cold front always follows a warm front.

Cirrostratus is a thin sheet of ice crystals covering the sky. Instead of a deep blue, there is a hazy or milky appearance. A halo may be seen around the sun or moon, as light is refracted through the crystals. Such clouds are also likely to have been formed in warmer air from moisture ascending over a mass of cold air in advance of a warm front. Precipitation is likely to follow as this layer thickens.

Cirrocumulus. If the warm air overriding the cold air is unstable, small globular cloud masses may be formed at this height, showing vertical development. They are often in lines, giving the appearance of a "mackerel sky", and hinting at unsettled conditions.

Middle clouds (usually formed between 7000 and 20 000 ft)

Altostratus is a thick cloud layer, which may merge with higher cirrostratus; but at this lower level the more abundant water vapour gives a dense dark cloud, through which the sun may faintly gleam. It forms most frequently where uplift and condensation occur in advance of the warm front of a depression, and usually blankets the sky. Fairly steady precipitation follows its development.

Altocumulus generally forms under fair weather conditions, and the cloud masses have some vertical development. Blue sky appears between lines or layers of individual clouds. These can be caused by layers of air of different density and humidity flowing over one another, producing a billowing effect. The clouds appear white, or grey on the shaded sides.

Low Clouds (from the surface to about 7000 ft)

These are the clouds that can affect you in a big way. Notice that the biggest of all the cloud types, the cumulonimbus, although they tower up to heights of 40 000 feet and more, are regarded as low clouds. And they eat aeroplanes!

Stratus is a low, dense, uniform, dark grey layer of droplets, similar to blanketing ground-level fog. It does not rest on the ground, and often forms well above the surface. Ragged in appearance, and usually shallow, it may drift swiftly along. Stratus may form locally in moisture-laden air, even when weather conditions are otherwise fair, blotting out a hillside or hanging close to a summit. Thick stratus associated with rain or snow is known as nimbostratus.

Stratocumulus clouds are usually low, soft-looking masses, with a somewhat globular or roll-shaped appearance. Open sky shows between them. There is often a regular pattern, particularly when rolls of cloud form at right angles to the general direction of cloud movement. This type of cloud is mostly associated with clearing weather.

Clouds with marked vertical development (rising to higher levels)

Cumulus of the fair weather type is formed when convection is strong. Bubbles of warm air (thermals) rise from the heated surface. In some the water vapour condenses at a particular height, indicated by the flat base of the small billowing cloud. A few may grow in size and develop vertically until more stable conditions occur at higher levels. Individual thermals form separate updrafts within the cloud, so that the billowing, domed masses of the upper surface resemble a cauliflower. Where illuminated by the sun, they appear white, but grey on the shaded sides. As convection currents lose their strength, usually towards evening, the clouds tend to die away.

Cumulonimbus. In these the air remains unstable to considerable heights. The vertical development is great. Clouds may extend from about 1 500 ft to towering summits at over 35 000 ft, their tops dazzlingly white. The thick shaded masses give the threatening appearance of a thunder-cloud seen from the ground.

Super-cooled droplets and ice crystals form in the higher parts of these clouds, releasing more latent heat. This helps to increase the rate of upward movement. Strong, cold downdrafts about the cloud contrast with the warmer air within and also accelerate the updrafts. Eventually a layer of ice crystals (cirrostratus) forms at the top, spreading out in the typical anvil shape as it encounters the strong inversion of the tropopause. Winds carry the ice particles forward.

Torrential rain and hail often result from these movements. The downdrafts reach the cloud base and spread out in cold gusts, often against the surface wind.

Lightning and thunder frequently occur, with discharges of accumulated static electricity between cloud and cloud, or cloud and earth. The discharge heats the air and causes great expansion. The resultant contraction produces the initial sound of thunder. The charges result from the updraft. These tend to separate positive and negative charges. The charges become concentrated in certain parts of the cloud.

Cumulonimbus clouds do not only build up in unstable air on hot sunny days. Sometimes a stream of cold air receives energy and moisture from a warm sea. There is then a high lapse rate and vigorous convection. If a warm land surface, or outstanding relief, then provides additional uplift, very heavy rain may occur.

Fog, Mist and Haze

Fog and mist are really just clouds that have their bases at the surface, or within 50 feet of the surface. The difference between fog and mist is a matter of visibility. If the visibility is less than 1000 metres, it is fog. More than 1000 metres, it is mist. More than 3000 metres, it is distant fog or mist.

Radiation fog is formed when clear skies allow radiation loss, and the air which is contact with the cold surface of the earth is cooled below its dew point. The condensation which then occurs is called radiation fog. A gentle wind of about 2 - 10 knots will help, as will a high moisture content (relative humidity). Clear skies at night will assist in cooling the ground down much quicker. This is quite common during winter nights and mornings over the Highveld areas of the country, eg. Gauteng and the Free State.

Figure 4.45

Radiation Fog

Gravity also plays a part in the formation of radiation fog when heavy cold air sinks into valleys. This can result in very dense fog in the valley, thinning out as you move upwards. When this occurs it is known as valley fog. This is fairly common in the valleys of Kwa-Zulu Natal.

In the morning, as soon as the wind picks up, radiation fog starts to disappear, and lifts to become low stratus cloud, finally dispersing altogether.

Fog forms in stable air when the air is cooled to saturation point by contact with cold ground or a cold water surface. This is called advection fog. This is a common occurrence along the West coast of the country, especially up towards the Namibian border.

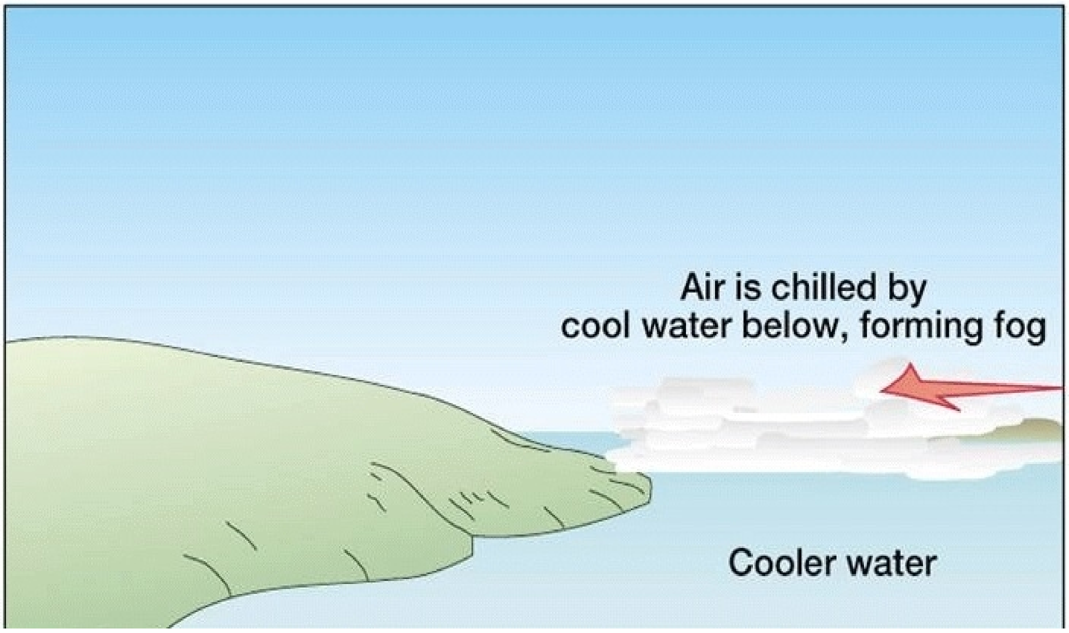


Figure 4.46

Advection Fog

Upslope fog is a situation where you find yourself IN low stratus cloud, rather than under it. It forms when warm air is forced upslope and cools to below dew point. The cloud on top of Table Mountain would be called mist if you were in it (or fog if the visibility was less than 1 km).

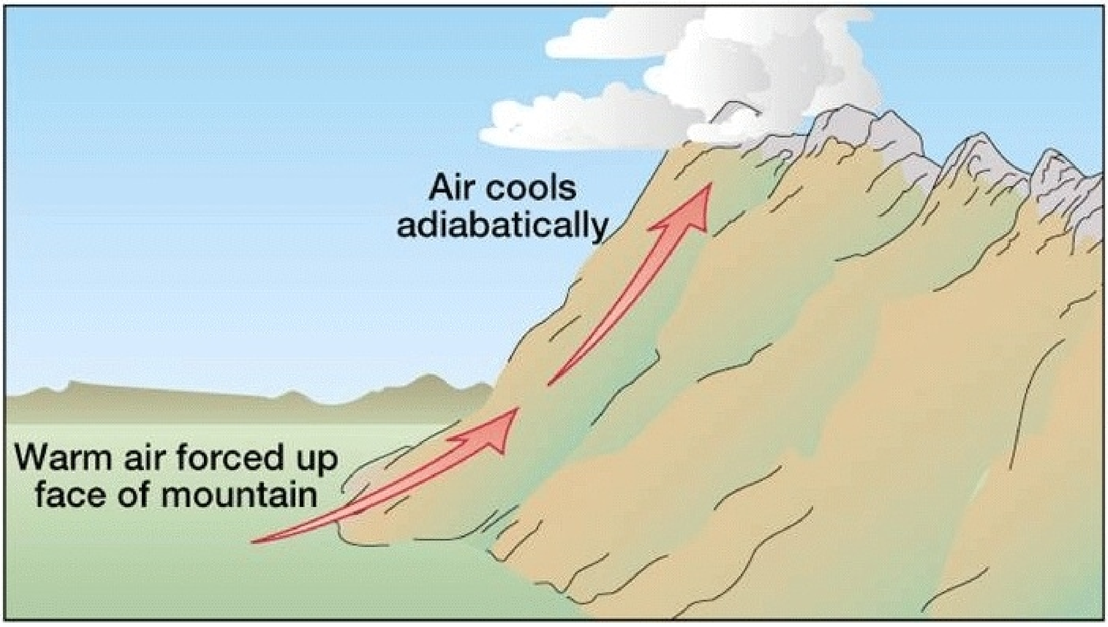


Figure 4.47

Upslope Fog

Evaporation fog occurs when rain strikes a warm surface, ie a runway, and this causes the rain to evaporate. The cool air which falls after the rain, together with cooling from the evaporation, can result in a low, thin layer of fog just above the surface. This can also happen over surface water, usually early in the morning when the heating by the sun's rays causes the evaporation to take place.

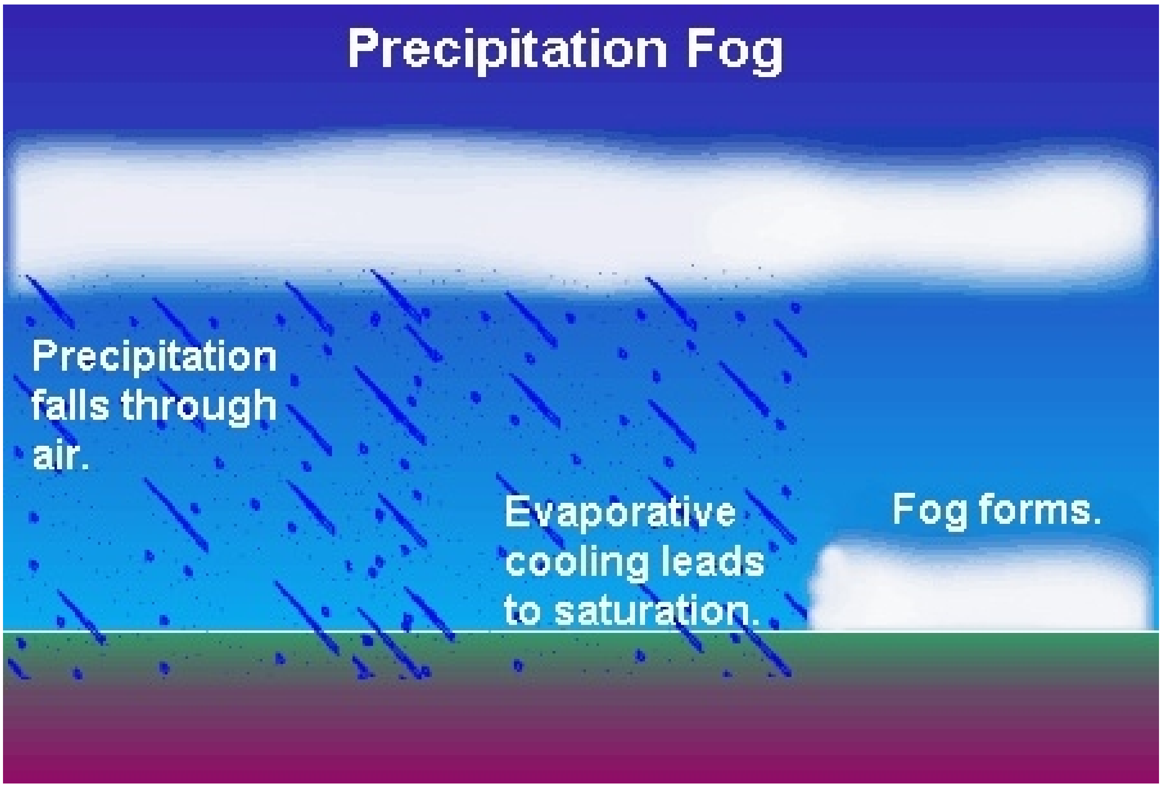


Figure 4.48

Evaporation Fog

Smoke is the suspension of combustion particles in the air. a red sky at sunrise and sunset is a good indication of smoke in the air. During the day, the sky will take on a grey appearance. The result is that visibility will be affected. If the air is stable (not rising) then the problem is worse. If air is unstable and rises, it takes the smoke particles up an away, resulting in improved visibility.

Haze is the presence of very small dry particles suspended in the air. this is usually from dust, salt or distant fires. Colours tend to be a bit subdued, distant mountains take on a bluish tinge, and even the sun can appear to be a dark orange.

Smog is the name given to a mixture of smoke and fog.

One has to be careful when encountering smoke and haze as the vertical visibility is usually quite good. Looking down at a runway from 1000 feet through a layer of smoke or haze which is only about 200 feet thick, will usually allow you to see everything quite clearly. But once you get to your finals turn, at say 2 miles, you will have the problem of looking through a lot more than 200 feet of poor visibility. The oblique distance through the 200 foot layer is now more than 3000 feet! (See Figure 4.49)

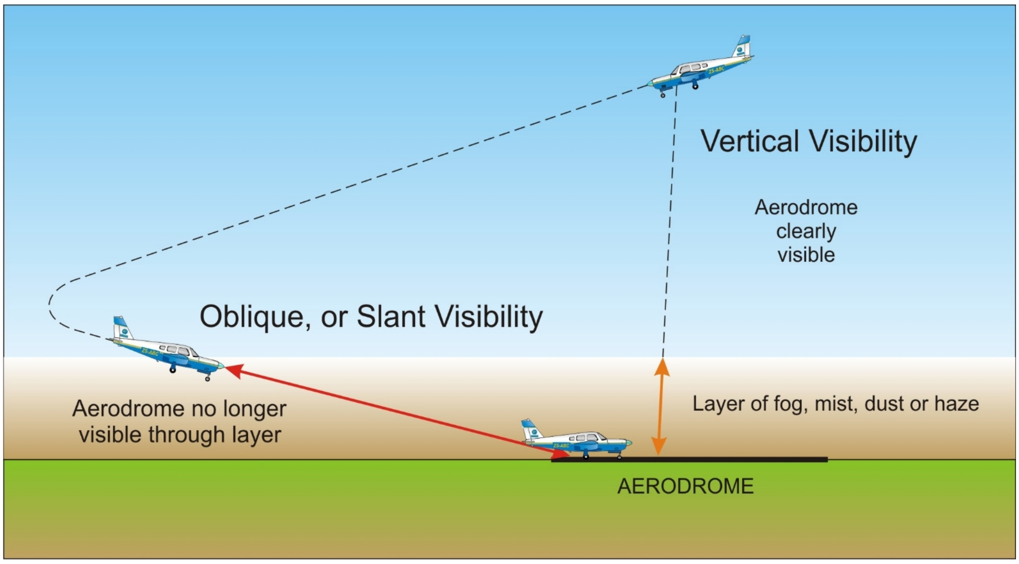


Figure 4.49

Oblique Visibility Through Fog, Mist or Haze

Pressure and Wind

In Chapter 1 we saw that, for all practical purposes, air is regarded as an ideal fluid. And we know that fluid will flow downhill. The same thing happens with air, the only difference being that instead of having high or low ground, we have high and low pressure areas. In the same way that water flows from high to low, air will flow from a high pressure area to one of low pressure. Once air starts moving we call it wind.

Once the air starts to move from the high pressure towards the low pressure, it is called pressure gradient force (PGF). Due to the rotation of the earth, to an observer watching this flow in the southern hemisphere, it will appear to be deflected to the left. Think of a roundabout in a park. If you were on the roundabout, spinning clockwise, and you threw a ball at someone standing off the roundabout, what would happen? To you it would appear that the ball deflected to the left, while to the other person it would appear that the ball came straight. This is called the Coriolis Effect, or force, and is due to the rotation of the roundabout, or in the case of wind, to the rotation of the earth. If you had been spinning anti-clockwise, the ball would appear to have deflected to the right, which would be the case with wind in the northern hemisphere. To a person on the south pole, the equator will be turning in a clockwise direction, while to an observer on the north pole, the equator would appear to be rotating anti-clockwise. The direction of the wind has nothing to do with Coriolis, it is dependent on the hemisphere.

The formula for Coriolis Effect is:

CF = 2 V ñ ù sin è

where: V = Velocity of the air
ñ = Density
ùù = Angular velocity of the earth
èè = Latitude in degrees

Don't worry too much about the formula, it is only to show that Coriolis is dependent on the rotation of the earth, the speed of the wind, and the latitude at which the process is taking place. The greater the wind speed, the higher the Coriolis, and the greater the latitude the greater the Coriolis. As the sin of 0° = 0, there is no Coriolis at the Equator, while it will be maximum at the Poles (sin 90° = 1).

The result of all of this is that instead of the wind actually flowing into the high pressure area, it takes up a path between the two pressure systems, with the low pressure on the right, and the high pressure on the left. It will then be flowing parallel to the isobars between the two pressure systems. When this happens, the wind is called Geostrophic Wind, and this is as a result of the Pressure gradient force and the Coriolis force balancing each other out (see Figure 4.50).

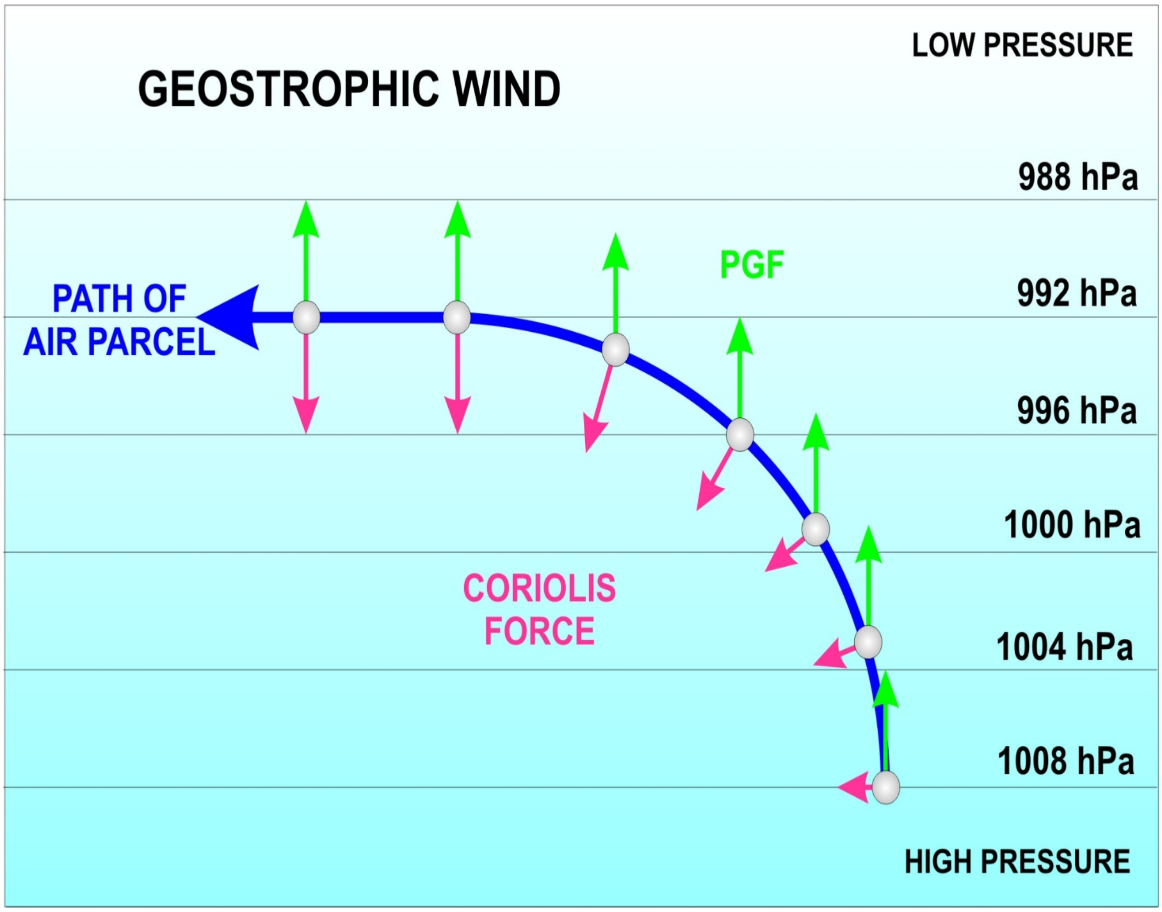


Figure 4.50

Coriolis Effect

Because the pressure patterns have a fairly circular shape, the wind will then tend to flow around the pressure patterns, keeping the balance between the two forces. This results in the flow around a low pressure system being clockwise, while around a high, the flow is anticlockwise. If you read anything on the flow in the northern hemisphere, the flow is reversed.

Many years ago, a Dutchman by the name of Buys Ballot came up with a simple way of determining the position of the low pressure area. Modifying his theory for the southern hemisphere (he was in the north, after all) if you stand with your back to the wind in the southern hemisphere, the low pressure system will be to your right (Figure 4.51). This is good to know as most lousy weather is associated with low pressure systems.

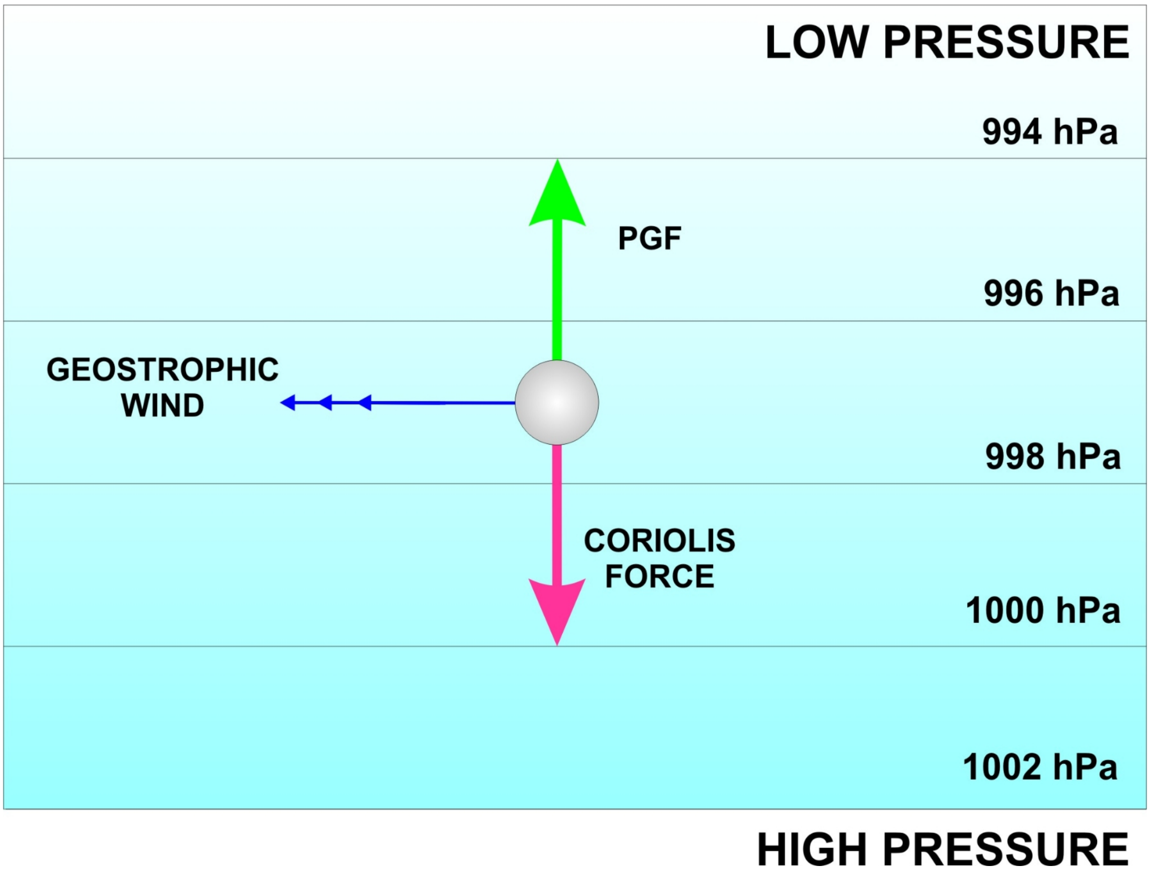


Figure 4.51

The Creation of Geostrophic Wind

Because of these pressure patterns (Fig 4.52), air will tend to flow from the high pressure areas towards the low pressure areas (PGF). Coriolis will then come into play due to velocity (V) and the winds will deflect depending on the hemisphere. This will result in winds which start flowing north or south deflecting to become easterly of westerly (see Fig 4.53).

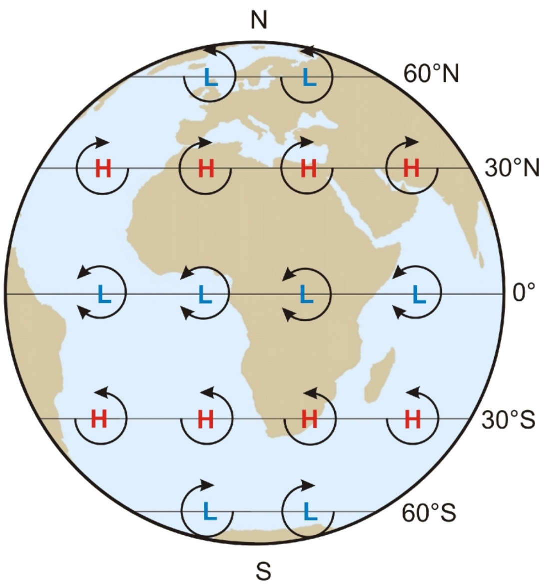


Figure 4.52

Basic Global Pressure Patterns

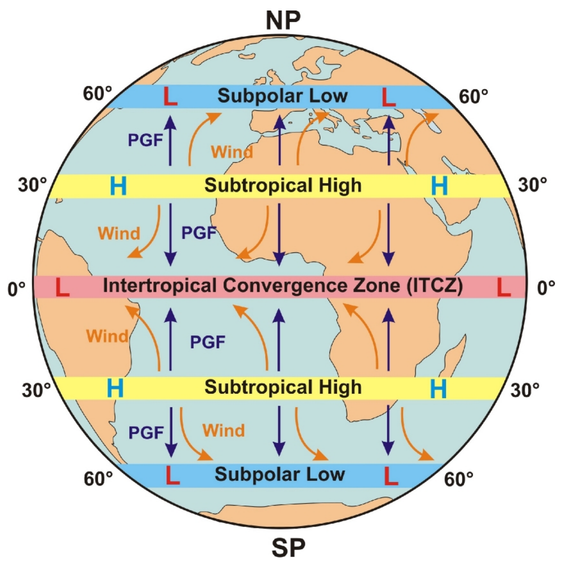


Figure 4.53

General Upper Air Winds Due to Coriolis

The winds discussed in the preceding paragraphs relate to those found at higher altitudes. What happens closer to the surface is that the wind speed will reduce due to surface friction - the rougher the surface, the greater the effect. This means that the Coriolis force, which is directly proportional to sped, will reduce, and PGF will dominate. This results in a wind direction change towards the low pressure system(see Figure 4.54). This change will be clockwise in the southern hemisphere, and is called veering. A directional change in an anti-clockwise direction is known as backing.

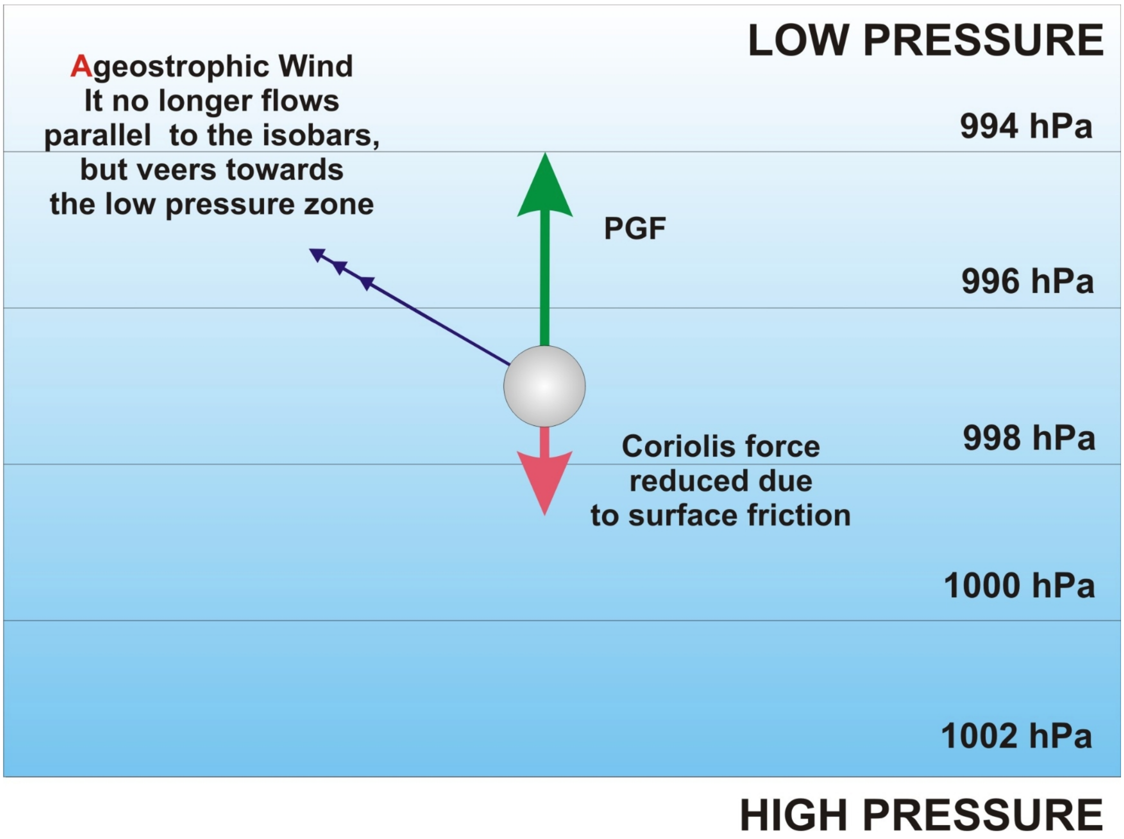


Figure 4.54

Effect of Surface Friction

There is also vertical motion of air in the atmosphere, and this is due to the basic pressure systems shown in Figure 4.55. Where two large air masses move towards each other, such as at the equator, there is only one place to go and that is upwards. This is referred to as convergence, or "drawing together". Convergence in the atmosphere is associated with vertical motion, and hence development (or weakening) of weather systems. For example, convergent flow near the surface is coupled to, and may be the primary cause of, upward motion, leading to cloud formation/ precipitation etc. This rising air will result in a low pressure system forming at the surface, which is exactly why the equator is an area of low pressure. As air is forced upwards, adiabatic cooling will take place, and if the air is cooled to it's dewpoint and below, clouds will form and precipitation is possible.

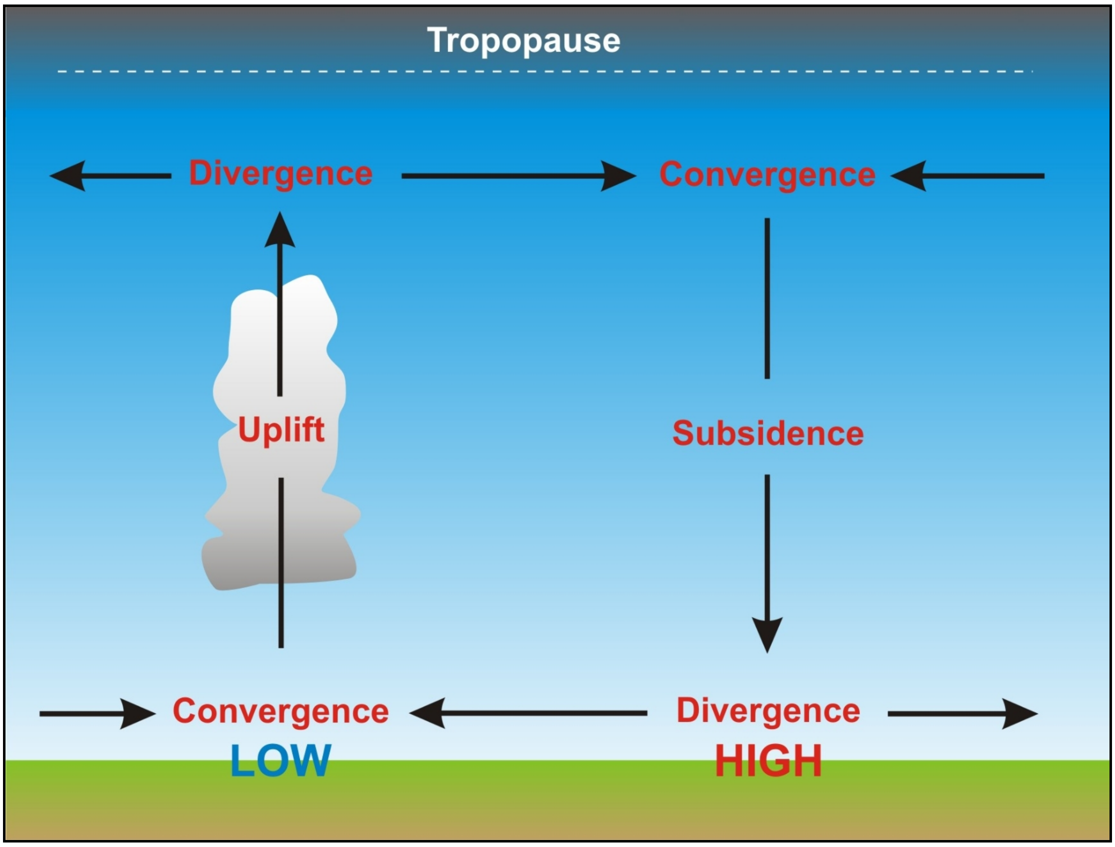


Figure 4.55

Areas of Convergence and Divergence

At about 30° South (were we live) and 30° North, there is a general outflow of air to the equator and about 60°N/S. This is called divergence, or ”spreading apart”. Divergence in the atmosphere is also, like convergence, associated with vertical motion, and the development (or weakening) of weather systems, depending upon the level where the divergence is dominant in a particular atmospheric column. For example, divergent flow aloft is coupled to, and may be the primary cause of, upward motion, leading to widespread cloud formation as well as frontal systems and cyclones. When divergence takes place, there will be a corresponding increase in pressure, creating a high pressure system at the surface. And this is why South Africa is mainly affected by high pressure systems.

This vertical movement of air is generally slower than the horizontal movement.

The low and high pressure systems which are caused by this convergence and divergence give rise to the surface winds we experience. An area of low pressure is quickly filled up by air from a high pressure system. Think of taking a bucket of water out of a dam. The hole does not remain in the surface, but quickly fills up. Upper winds are also formed in this way, but will be of little interest to you at this stage of your flying.

Weather charts give some indication of the pressure gradient. The lines drawn on the chart are called isobars, and represent lines of equal pressure. The middle of a High pressure system, for example, is where the pressure at sea level is high when compared to its surroundings. The closer these isobars are to each other, the steeper the pressure gradient. The closer these lines are to each other, the stronger the winds that can be expected. The further apart they are, the calmer the wind.

From Figure 4.56 it can be seen that stronger winds are usually associated with low pressure systems, while the high pressure areas have weaker winds. Yet when you look at the trough of low pressure over the central parts of South Africa, even though it is a low pressure area, the gradient is very slack, and the winds therefore will be light.

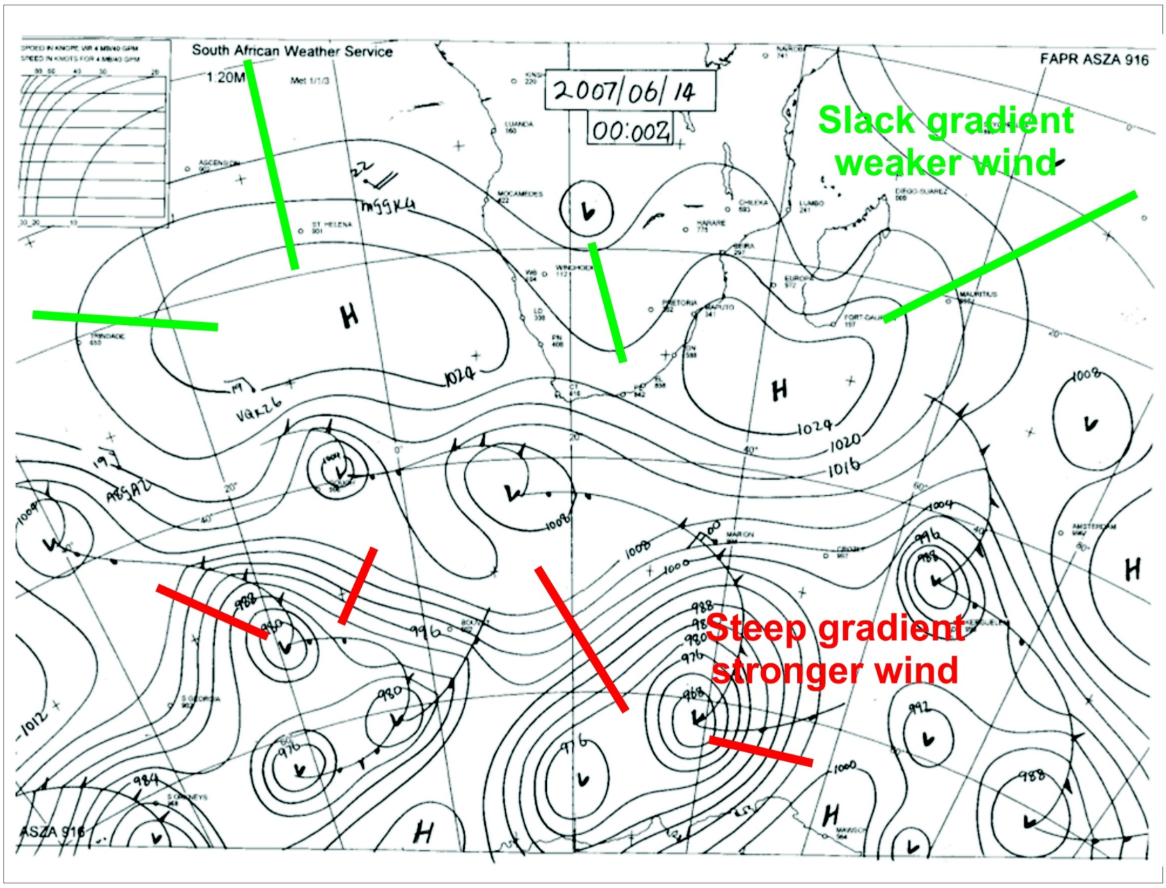


Figure 4.56

Pressure Gradients Giving an Idea of Wind Speed

Turbulence

Wind can be problematic for the pilot. If obstructions are encountered, wind will change direction and/or speed. This will lead to wind shear which is a change in wind speed or direction. It can also give rise to turbulence. Turbulence is air movement in the vertical as well in the horizontal that normally cannot be seen. It may occur when the sky appears to be clear and can happen unexpectedly. It can be created by any number of different conditions, including atmospheric pressures, jet streams, mountain waves, cold or warm fronts, or thunderstorms.

There are two main types of turbulence:

- Mechanical. Disruption to the smooth horizontal flow of air. Land masses, mountains and buildings are examples (see Figure 4.57). The severity of the turbulence depends on the strength of the air flow, the roughness of the terrain, the rate of change and curvature of contours, and the elevation of the high ground or obstruction above surrounding terrain.

- Thermal. Turbulence caused by vertical currents of air in an unstable atmosphere. Thermals are found mainly at low level and can cause a very bumpy ride.

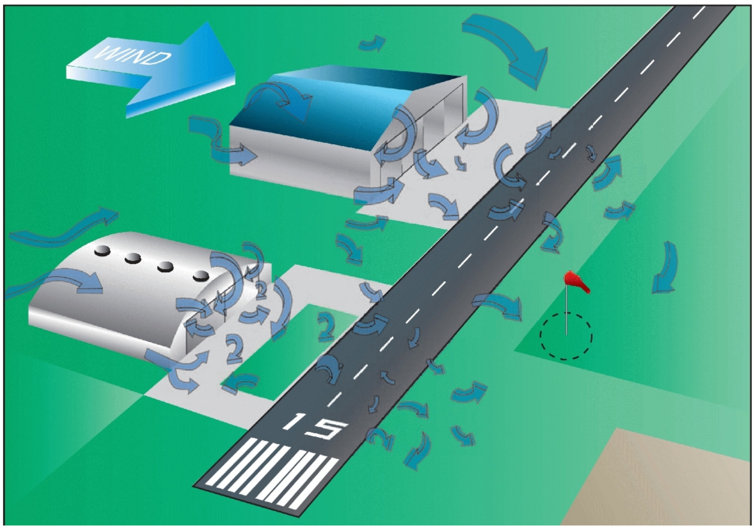


Figure 4.57

Mechanical Turbulence Caused by Man-made Obstructions

In an aircraft, there are different intensities of turbulence that you may encounter:

- Light turbulence - briefly causes slight, erratic changes in altitude and/or attitude.

- Light chop - slight, rapid and somewhat rhythmic bumpiness without noticeable changes in altitude or attitude.

- Moderate turbulence - similar to light turbulence, but greater intensity. Changes in altitude/attitude occur. Aircraft remains in control at all times. Variations in indicated air speed.

- Moderate chop - similar to light chop, but greater intensity. Rapid bumps or jolts without obvious changes in altitude or attitude.

- Severe turbulence - large, abrupt changes in altitude/attitude. Large variation in indicated airspeed. Aircraft may be temporarily out of control.

- Extreme turbulence - aircraft is violently tossed about and is impossible to control. May cause structural damage.

The reactions inside aircraft vary from occupants feeling slight strain against their seat belts and unsecured items being slightly displaced, through to occupants being forced violently against seat-belts, and unsecured items being tossed about.

Local Winds

Although global winds are important in determining the prevailing winds in a given area, local climatic conditions may have quite an influence on the most common wind directions. We expect winds in Southern Africa to be westerly in the southern parts during most of the year, with a bit of an easterly flow in the north during the summer.

Local winds are so named because of the effect that local conditions and terrain have in its creation. Local winds are always superimposed upon the larger scale wind systems, i.e. the wind direction is influenced by the sum of global and local effects. When larger scale winds are light, local winds may dominate the wind patterns.

Examples of local winds are the föhn wind, land and sea breezes, and anabatic and katabatic winds.

Föhn Wind

A föhn wind is a type of dry down slope wind which occurs in the lee of a mountain range. It is a rain shadow wind which results from the subsequent adiabatic warming of air which has dropped most of its moisture on windward slopes. As a consequence of the different adiabatic lapse rates of moist and dry air, the air on the leeward slopes becomes warmer than equivalent elevations on the windward slopes. Föhn winds can raise temperatures by as much as 30°C in just a matter of hours.

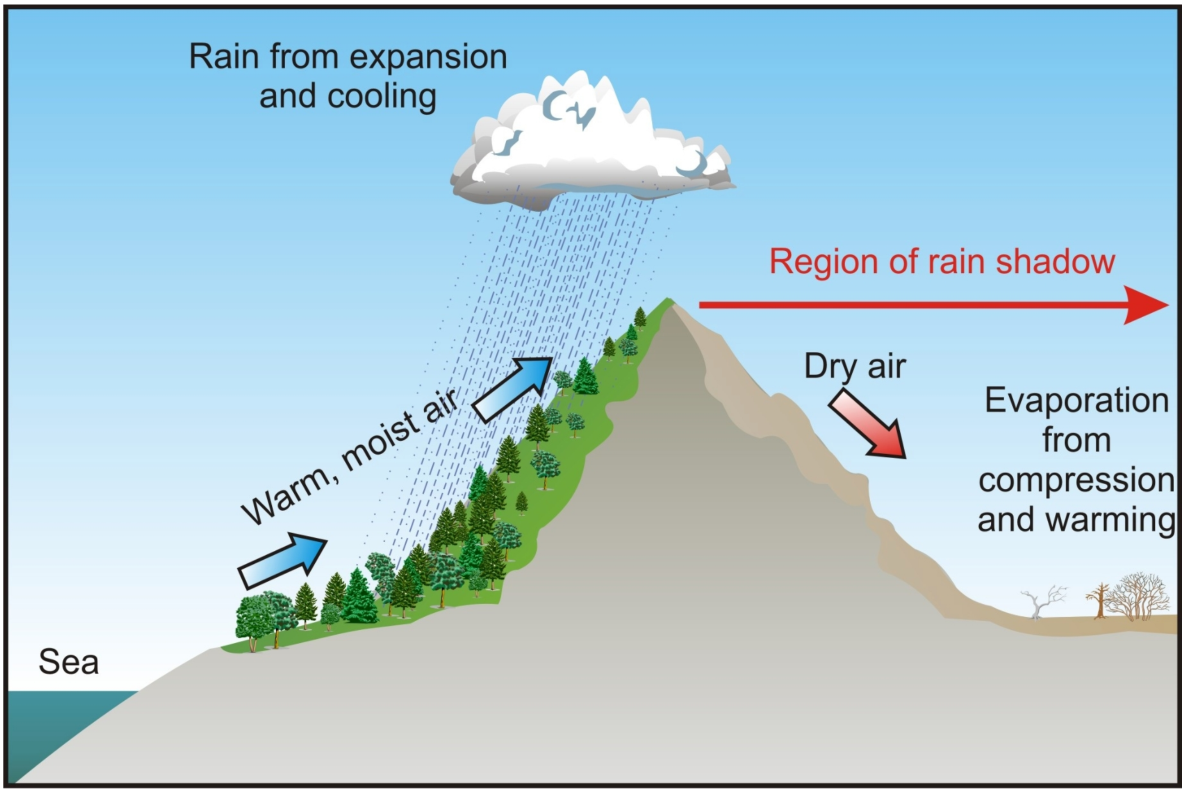


Figure 4.58

The Föhn Effect

The name föhn applies to the effect found in the Alps. Regionally these winds are known by many names, for example in the USA it is called the Chinook, while in South Africa it is known simply as the Berg Wind. The warm air flowing in over the Drakensberg and is forced to rise. The air then cools at the DALR and once the air starts condensing, any further rise will lead to precipitation on the eastern side of the Drakensberg. This makes the air drier, so when the air passes over the top of the mountain, provided the air is stable, it will descend and warm up again. Due the loss of moisture on the upwind side, the cloud base on the lee side will be higher. The air then returns to the base of the mountain, warming at the DALR through a greater height, resulting in warmer, drier air at the base on the lee side. The wind then continues to move in an anti-clockwise direction and passes over the south and south-eastern parts of the country as a hot, dry wind known as the Berg Wind.

The word föhn in German means hair dryer, which describes the effect rather aptly.

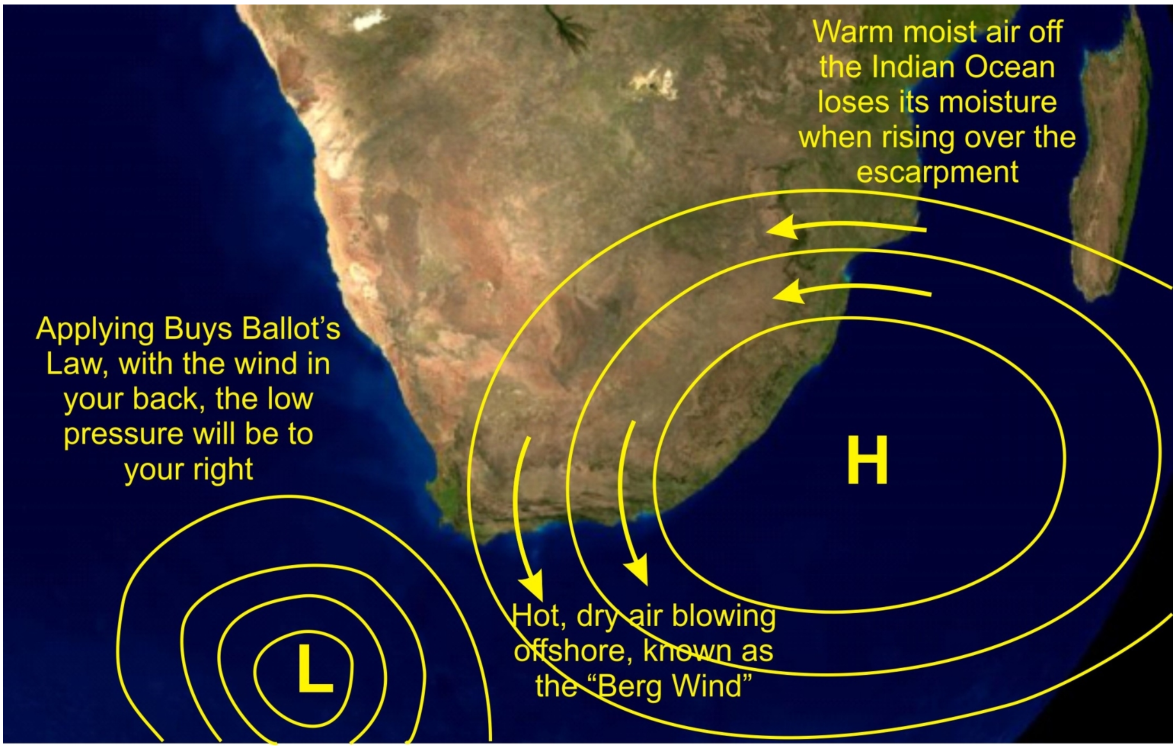


Figure 4.59

Berg Wind

Land and Sea Breezes

Land and sea breezes are local winds and weather phenomena associated with coastal areas. A land breeze is a breeze blowing from land out toward the sea. A sea breeze is a wind blowing from the water onto the land. Land breezes and sea breezes arise because of differential heating between land and water surfaces. Land and sea breezes can extend inland up to 100 miles, or could simple be local phenomena that quickly weaken with a few hundred yards of the shoreline. On average, the weather and cloud effects of land and sea breezes dissipate 20-30 miles inland from the coast.

Air above the respective land and water surfaces is warmed or cooled by conduction with those surfaces. During the day, the warmer land temperature results in a warmer and therefore, less dense and lighter air mass above the coast as compared with the adjacent air mass over the surface of water. As the warmer air rises by convection, cooler air is drawn from the ocean to fill the void (see Figure 4.60). The warmer air mass returns to sea at higher levels to complete a convective cell. During the day there is usually a cooling sea breeze blowing from the ocean to the shore. Depending on the temperature differences and amount of uplifted air, sea breezes may gust up to about 15 knots. The greater the temperature differences between land and sea, the stronger the land breezes and sea breezes. Because the greater temperature difference is found during the day, sea breezes are generally stronger than land breezes.

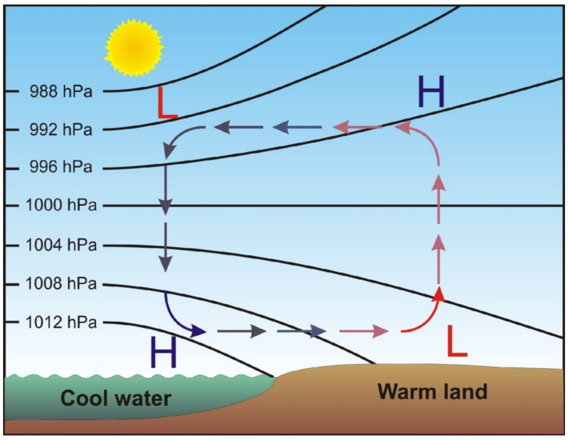


Figure 4.60

Sea Breeze

After sunset, the air mass above the coastal land quickly loses heat while the air mass above the water generally remains much closer to it's daytime temperature. When the air mass above the land becomes cooler than the air mass over water, the wind direction and convective cell currents reverse and the land breeze blows from land out to sea (see Figure 4.61).

Note that in both the land and sea breezes the wind flow higher up is in the opposite direction to the surface wind. When doing a circuit at a coastal airfield during mid-afternoon, the surface wind will be a sea breeze, but on downwind you will have to contend with a wind from the landward side.

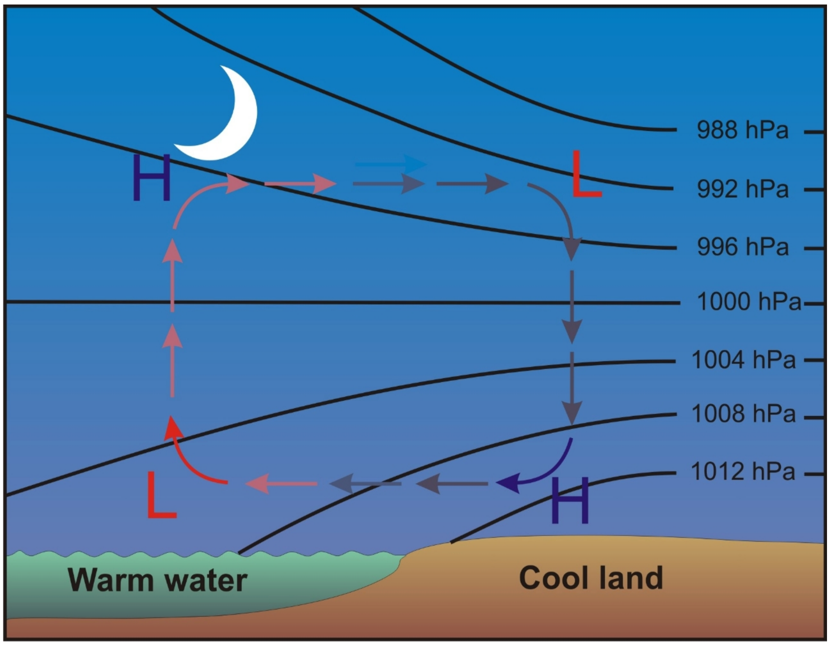


Figure 4.61

Land Breeze

Anabatic and Katabatic Winds

Local wind conditions also take place on land where differential effects of heating and cooling occur. In mountainous areas, the general pattern is upslope winds during the day and downslope winds at night.

Anabatic wind

An anabatic wind is a wind which blows up a steep slope or mountain side, driven by heating of the slope through insolation. It is also known as an upslope flow, or valley wind as it comes from the valley below. These winds typically occur during the daytime in calm sunny weather. A hill or mountain top will be warmed first by the sun which in turn heats the air just above it. The lower reaches of the hill will only receive insolation much later in the day, and this effect may be enhanced if the lower lying ground is shaded by the mountain and so receives less heat.

The air over the hill top is now warmer than the air at a similar altitude around it and will rise through convection. This creates a lower pressure region into which the air at the bottom of the slope flows, causing the wind. It is common for the air rising from the tops of large mountains to reach a height where it cools adiabatically to below its dew point and forms cumulus clouds. The wind speed is usually quite gentle and can be termed a breeze.

Katabatic Wind

Katabatic winds are down-slope winds, frequently produced at night by the opposite effect, the air near to the ground losing heat to it faster than air at a similar altitude over adjacent low-lying land. Cool air is much heavier so it will flow down the slope. The result is a much faster flow down the slope. This can be as much as 50 knots, and its effects can be felt up to 100 miles from the slope. If there is snow on the peaks, the effect will be greater. Also called a mountain wind.

Airmasses

An airmass is a large body of air that has fairly uniform characteristics with regard to temperature, the stability of the air, and the moisture content. They are large and can quite easily cover more than 1000 nm. Airmasses play a very important role in the weather found anywhere around the globe.

Airmasses are formed when winds are light and the conditions at the surface are fairly uniform. This gives an airmass over the land time to warm up. Conversely, an airmass over the cold sea to the south of us will be cold. When the airmass starts to move, it gives us the two basic descriptions in terms of temperature - an airmass is either a warm airmass (w, for warm) or a cold airmass (k, for "kalt" the German word for cold)when measured to the ground over which it is moving - so if the moving air is colder than the surface, the mass is described as a cold airmass.

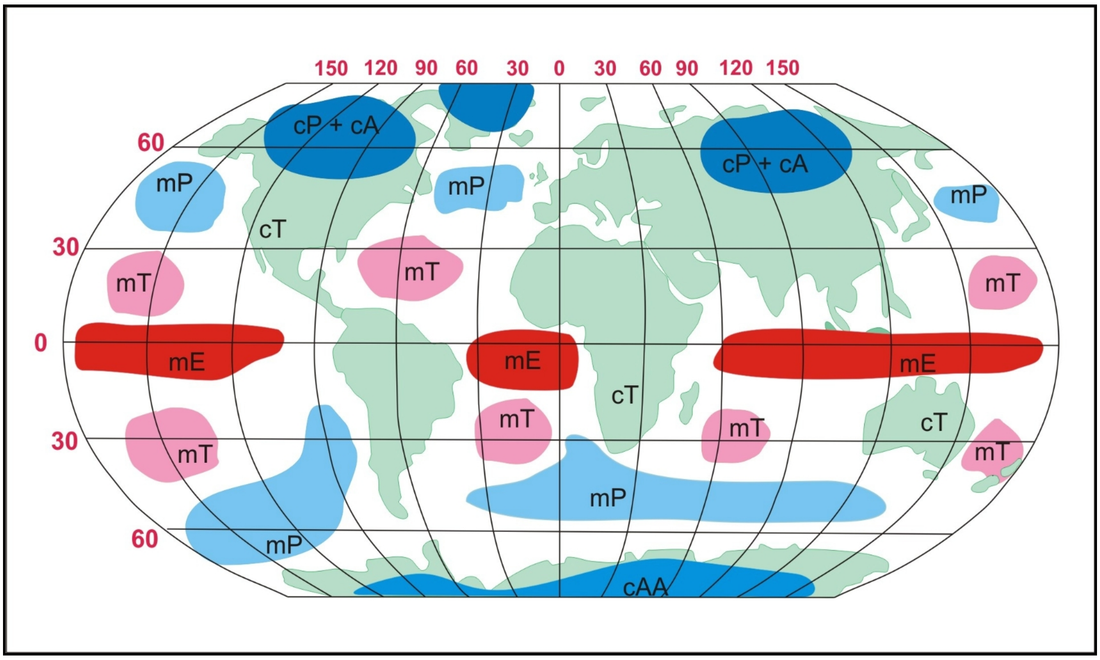


Figure 4.62

Global Airmasses

Airmasses are also identified by the source region. If it develops over the equator it is called Equatorial (E), over the tropics, Tropical (T), over the Antarctic it is Antarctic (A), and over the poles it will be called Polar (P).

Finally, airmasses are also identified by the moisture content. If an airmass develops over the sea it is called Maritime (m), and over land would be known as Continental (c). The letter "k" is used for cold to avoid confusion with the "c" for Continental.

Typical airmasses affecting Southern African weather would be Continental Tropical (cT), warm air pushing down in the summer; Maritime Tropical Warm (mTw) coming in from the Indian Ocean; Maritime Tropical Cold (mTk); or Maritime Polar Cold (mPk), pushing up from the south during winter. It is not necessary to include the temperature indicator (w or k) unless it is necessary, as in the two mT airmasses east and west of the country. Usually the Polar air is referred to as mP. The fact that it comes from a polar region would automatically suggest cold air, just as Equatorial air would suggest warm. When two different airmasses meet up we have what is called a front, and we have the weather associated with that front.

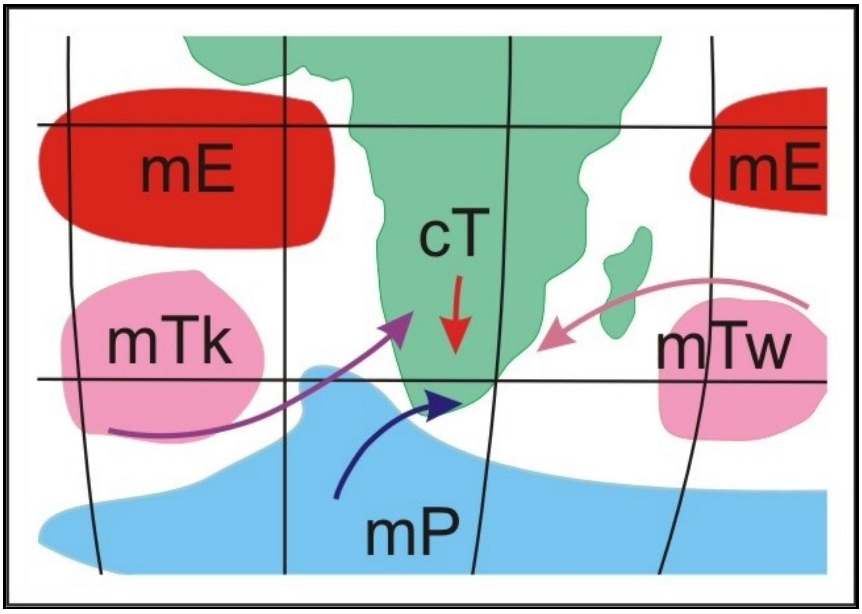


Figure 4.63

Airmasses Affecting Southern Africa

Modification of Airmasses

Airmasses will also change their characteristics if the mass remains fairly static over a region different to its source. For example, a cold airmass will be dry, but if it settled over South Africa for a length of time, it would gradually heat up. When air is heated it can hold much more moisture, so the airmass characteristics would have changed.

The speed at which an airmass moves also plays a part in the weather we experience. A cold airmass moving in quickly from the south of the country will stay very cold over the southern parts of the country because the airmass would not have had a chance to adjust to the conditions overland. This gives rise to the very cold spells that we experience during the winter. If the airmass had been moving slower, there would have been a chance for the characteristics to change slowly, and the cold would be less severe.

Cold air airmasses carry very little moisture, and this explains why the western side of the country is as dry as it is. The movement of the air is generally in an easterly direction, so when an airmass, cooled by the cold ocean, hits the west coast, there is not much moisture to deposit in the form of precipitation. On the eastern side of the country, the air flowing anti-clockwise around the high pressure system in the Indian Ocean, will warm up as the sea is warm. this allows the airmass to carry much more moisture, and when reaching the coast, deposits a lot of rain over the Kwa Zulu Natal and Mpumalanga coastal regions.

Frontology

173. Airmasses tend to retain their characteristics for quite some time, and if two airmasses with different characteristics come into contact with each other, they do not mix very well. The boundary between the two airmasses is called a front. The airmass that is moving is the one by which the front is named. If a cold airmass moves in on a static or slower moving warm airmass, the front is called a cold front. If a warm airmass moves in on a static or slower moving cold airmass, the result is a warm front. We also have a stationary front if there is little movement by either of the two airmasses. The other type of front is an occluded front, and this occurs when a cold front, which moves faster than a warm front, overtakes the warm front. Figure 4.64 shows the symbols used to depict the various fronts on a weather chart.

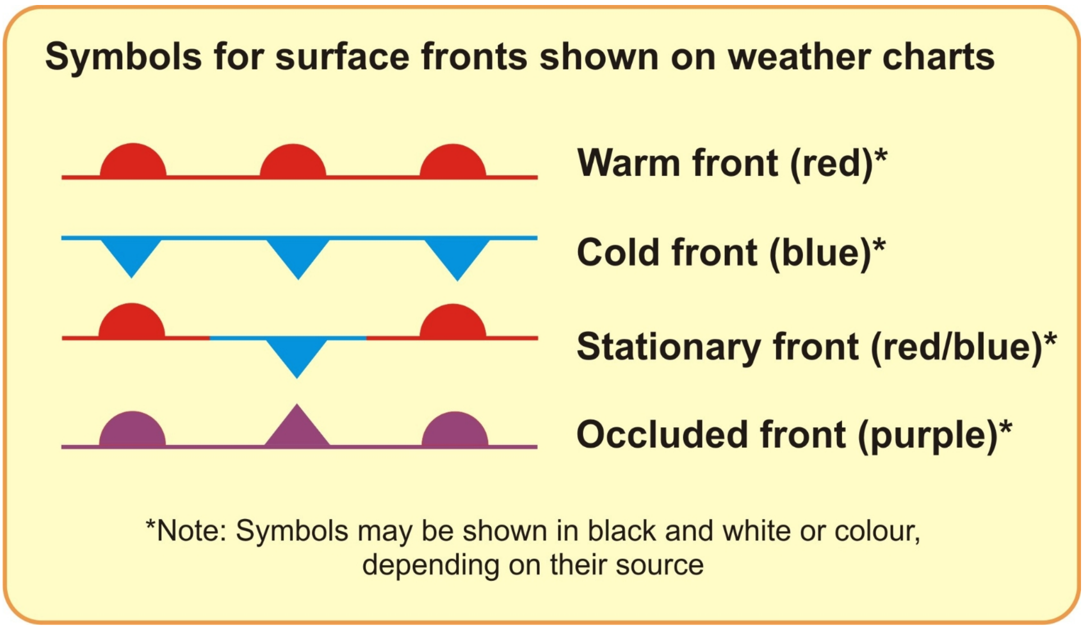


Figure 4.64

Frontal Symbols

What usually happens when two different airmasses meet, the moist air (in the warm airmass) is lifted, and this gives rise to cloud formation and the possibility of precipitation. If warm air rises gently over cold air, the clouds will be of the stratiform type, but if the warm air is forced to rise by cold air pushing underneath it, the cloud is likely to be cumuliform.

If the warm air moves in and rises over the cold air (a warm front) the slope will be about 1:200 to 1:400. This means that for every 200 (or 200) feet horizontal movement, there will be a 1 foot vertical gain. This makes for a shallow slope. However, id cold moves in under warm air (a cold front) the slope will be in the region of about 1:50 and 1:100. This is regarded as a steep slope. The steeper the slope, the more intense the weather.

In Figure 4.65 we see both a cold and a warm front. Taking a look at the cold front first, you will notice that it has a much steeper slope than the warm front (the bold line showing the boundary between the two airmasses). The moving cold airmass forces it way under the warm air, shoving it upwards at quite a rate. The clouds that are associated with a cold front are the type that develop vertically and are mainly of the cumuliform family, with cumulonimbus (Cb) being likely. This means that if there is precipitation, it will most likely be heavy and of a relatively short duration. Turbulence and icing are also usually associated with a cold front. The cirrus ahead of the front is actually the "anvil" at the top of a thunderstorm. Ahead of the cold front you can see altocumulus (Ac), stratocumulus (Sc) and cumulus (Cu). The cold front is the more common of the two, and a large number of them affect our weather systems each year.

The warm front on the right has a shallower slope, and because the warm rides up slowly over the cold air, the clouds that are associated with a warm front are of the stratiform type, cirrostratus (Cs), altostratus (As) and nimbostratus (Ns). Rainfall will tend to be of longer duration and will be fairly steady and heavy. Warm fronts are not a common occurrence over land in Southern Africa.

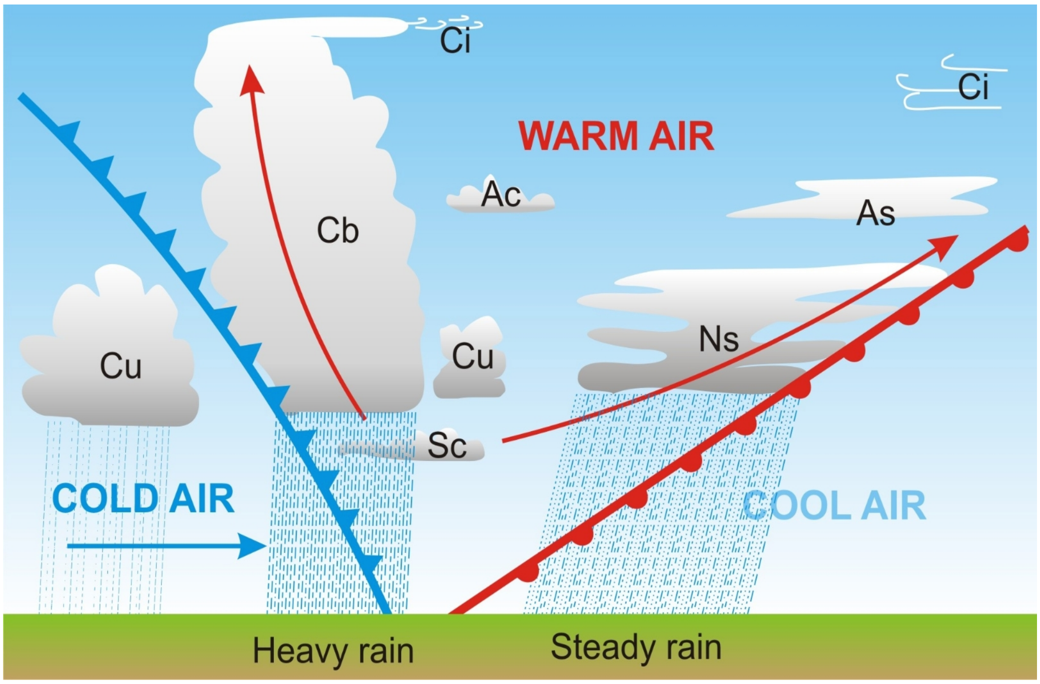


Figure 4.65

Warm and Cold Fronts

The formation of the frontal system, known as mid-latitude cyclone, occurs at about 60° North and South, but this position is not fixed, and the source region covers quite a wide band (see Figure 4.66). As the seasons change the source region will move closer to Southern Africa during the southern hemisphere winter, and moves southwards during our summer.

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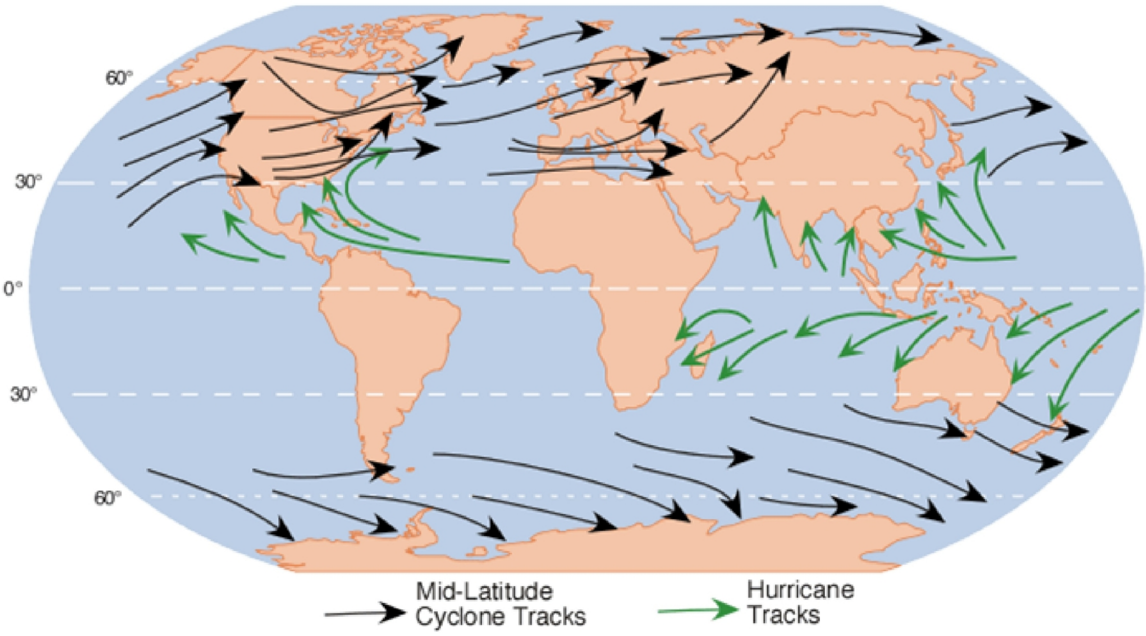


Figure 4.66

Source Regions of Mid-Latitude Cyclones

179. Warm air to the north is flowing in a generally westerly direction, while to the south the colder easterly winds are found. Where these two airmasses meet a stationary front exists. This state of balance can be seen in Figure 4.67A. The greater the temperature gradient between the two airmasses, the greater the potential energy the atmosphere contains.

In Figure 4.67B there is a kink in the stationary front line due to instability in the middle and upper air. A low level north westerly flow from the warm air converges with the cold air to the south to replace the air rising in the middle and upper atmosphere. This sets up a cyclonic flow and the whole mass starts to rotate in a clockwise direction.

In Figure 4.67C the warm front can be seen moving to the southeast, while the cold front moves to the northeast. The air between the two fronts is known as the warm sector. The central low pressure formed by the cyclonic (clockwise) flow intensifies. Warm air moves over the cold at the warm front, and cold air moves in from the southwest behind the cold front (Figure 4.67D). Winds speeds start to increase, especially in the cold air as it moves faster than the warm air. There will be widespread precipitation ahead of the warm front, while precipitation band along the cold front will be narrow. The formation of clouds and precipitation releases more energy into the system as latent heat is released.

In Figure 4.67E the cold front moves quickly eastwards and the two systems start to occlude. This is the most intense stage.

Figure 4.67F shows the warm front getting smaller and the storm starts to dissipate as most of the energy has been used. The warm air has been lifted upwards and cloud formation and precipitation cease. At the surface the cold air dominates and the conditions become stable again.

Figure 4.67G shows the system almost back to A and the stationary front is back in place until the next interference (called perturbation by meteorologists) takes place, when the whole process repeats itself. This is an ongoing process throughout the year and is unaffected by season. Only the latitude where it occurs will change.

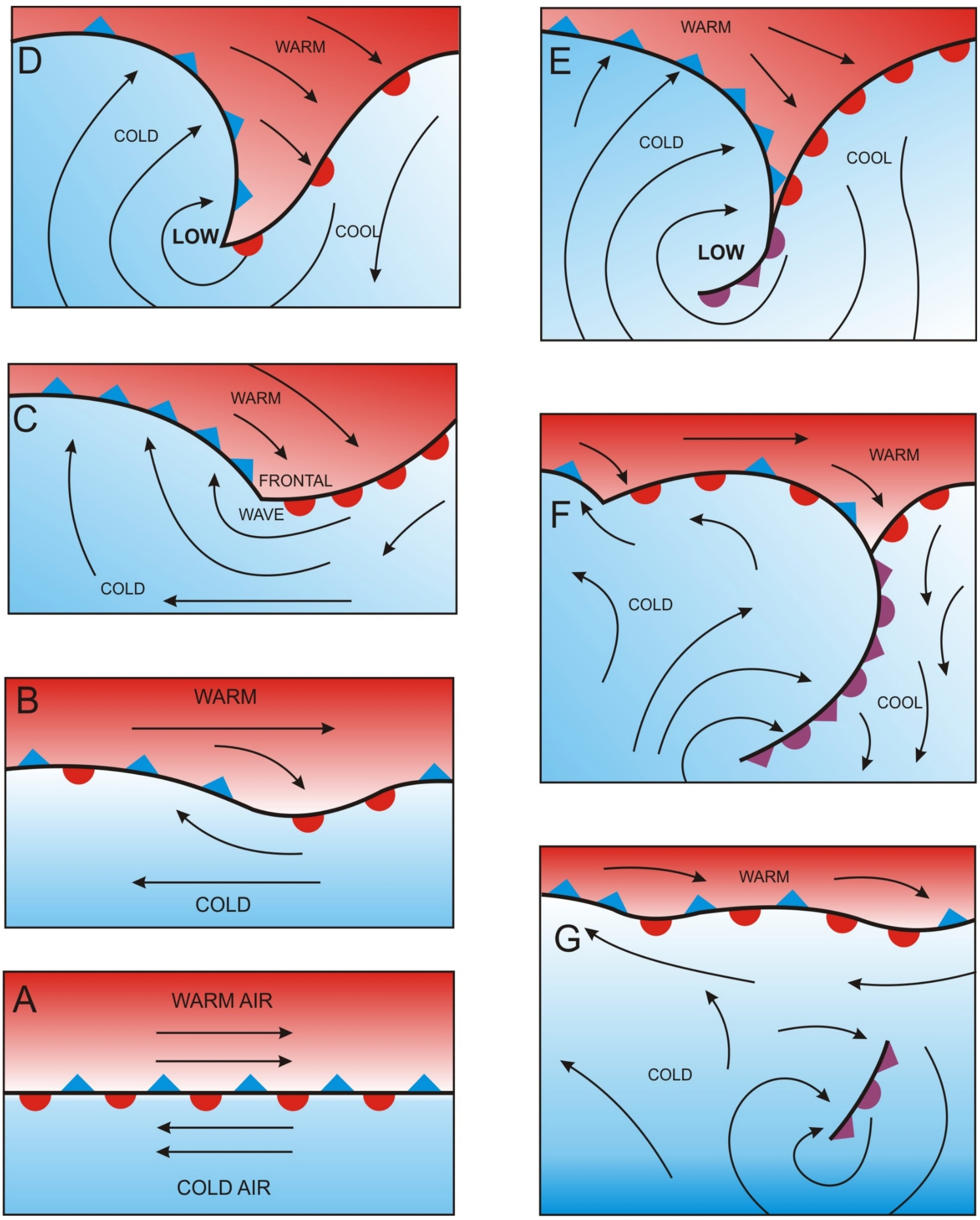


Figure 4.67

The Formation of a Mid-Latitude Cyclone in the Southern Hemisphere

Looking at Figure 4.68 you have a side view and summary of all the weather conditions associated with the passage of the whole system. Figure 4.69 gives you a bird's eye view. The line A- B represents the passage from right to left in Figure 4.68.

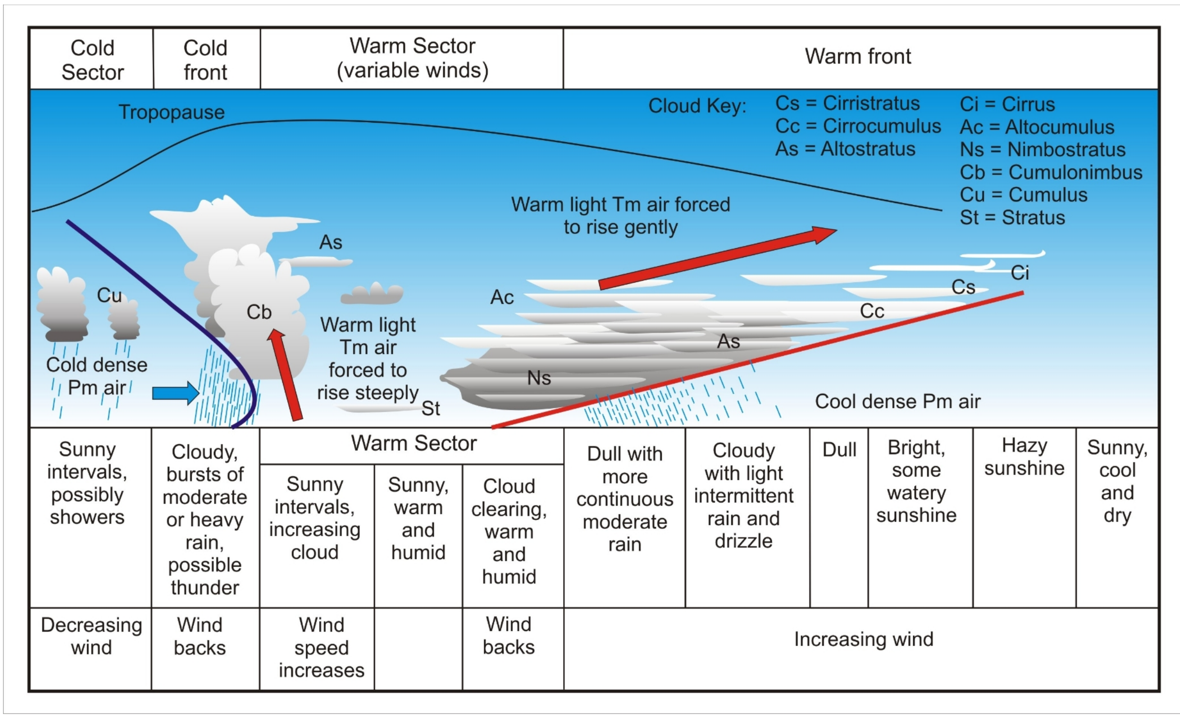


Figure 4.68

Weather Conditions Associated with the Passage of a Mid-latitude Cyclone

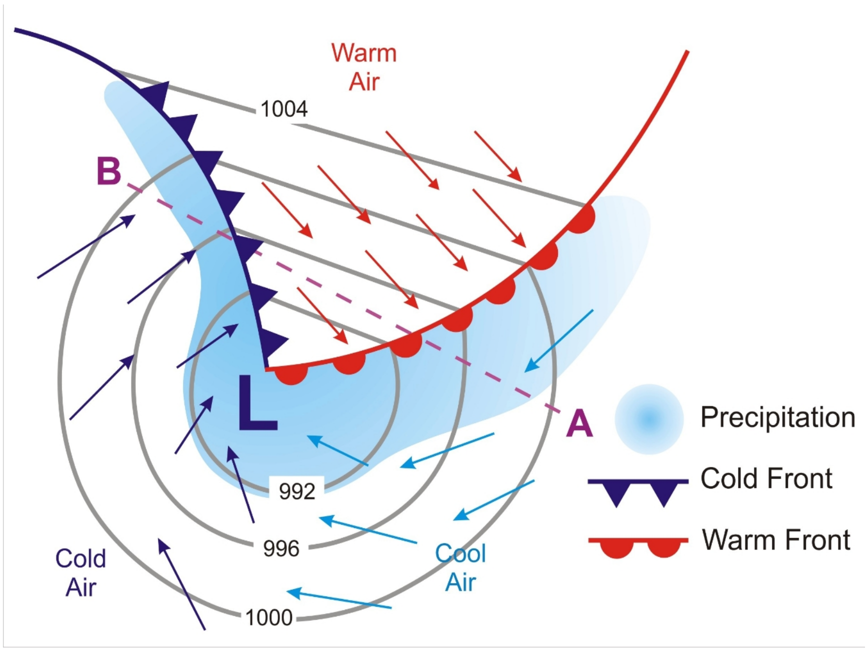


Figure 4.69

Top View of a Frontal System

Occluded Front

An occluded front occurs when a fast-moving cold front catches up with a slow-moving warm front. As the occluded front approaches, warm front weather prevails, but is immediately followed by cold front weather. There are two types of occluded fronts that can occur, and the temperatures of the colliding frontal systems play a large part in defining the type of front and the resulting weather. A cold front occlusion occurs when a fast-moving cold front is colder than the air ahead of the slow-moving warm front. When this occurs, the cold air replaces the cool air and forces the warm front up into the atmosphere. Typically, the cold front occlusion creates a mixture of weather found in both warm and cold fronts, providing the air is relatively stable. This is the type of occlusion experienced in Southern Africa.

A warm front occlusion occurs when the air ahead of the warm front is colder than the air of the cold front. When this is the case, the cold front rides up and over the warm front. If the air forced up by the warm front occlusion is unstable, the weather will be more severe than the weather found in a cold front occlusion. Embedded thunderstorms, rain, and fog are likely to occur. It is unlikely that the coldest air in a Southern African system would be in front of the system, so the warm occlusion is included for information purposes only.

Figure 4.70 depicts a cross-section of a typical cold front occlusion. The warm front slopes over the prevailing cooler air and produces the warm front type weather. Prior to the passage of the typical occluded front, cirriform and stratiform clouds prevail, light to heavy precipitation is falling, visibility is poor, dewpoint is steady, and barometric pressure is falling. During the passage of the front, nimbostratus and cumulonimbus clouds predominate, and towering cumulus may also be possible. Light to heavy precipitation is falling, visibility is poor, winds are variable, and the barometric pressure is leveling off. After the passage of the front, nimbostratus and altostratus clouds are visible, precipitation is decreasing and clearing, and visibility is improving. Bear in mind that this is happening way to the south of us. A warm occlusion (see Figure 4.71) is not something we experience in Southern Africa. The air at the rear is warmer than the air ahead, hence the name "warm".

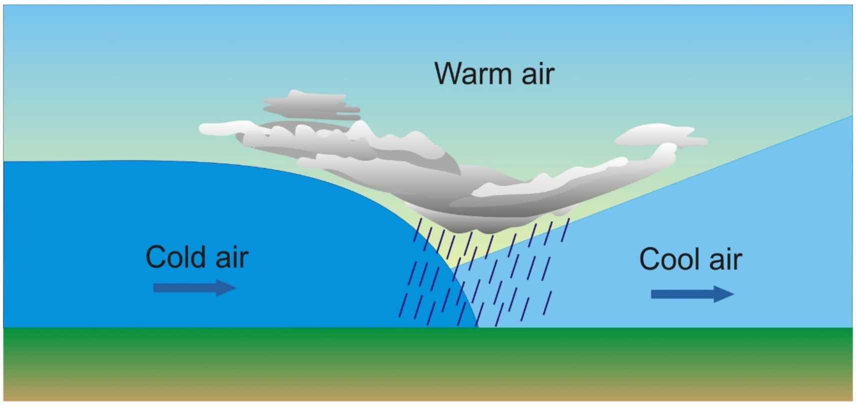


Figure 4.70

Cold Occlusion

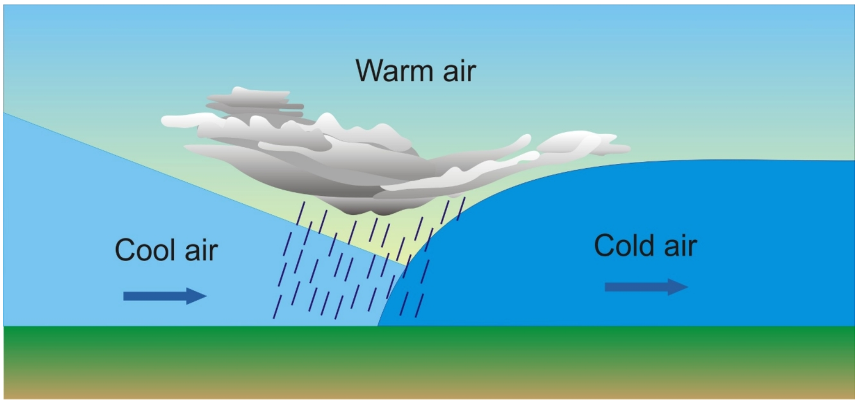


Figure 4.71

Warm Occlusion

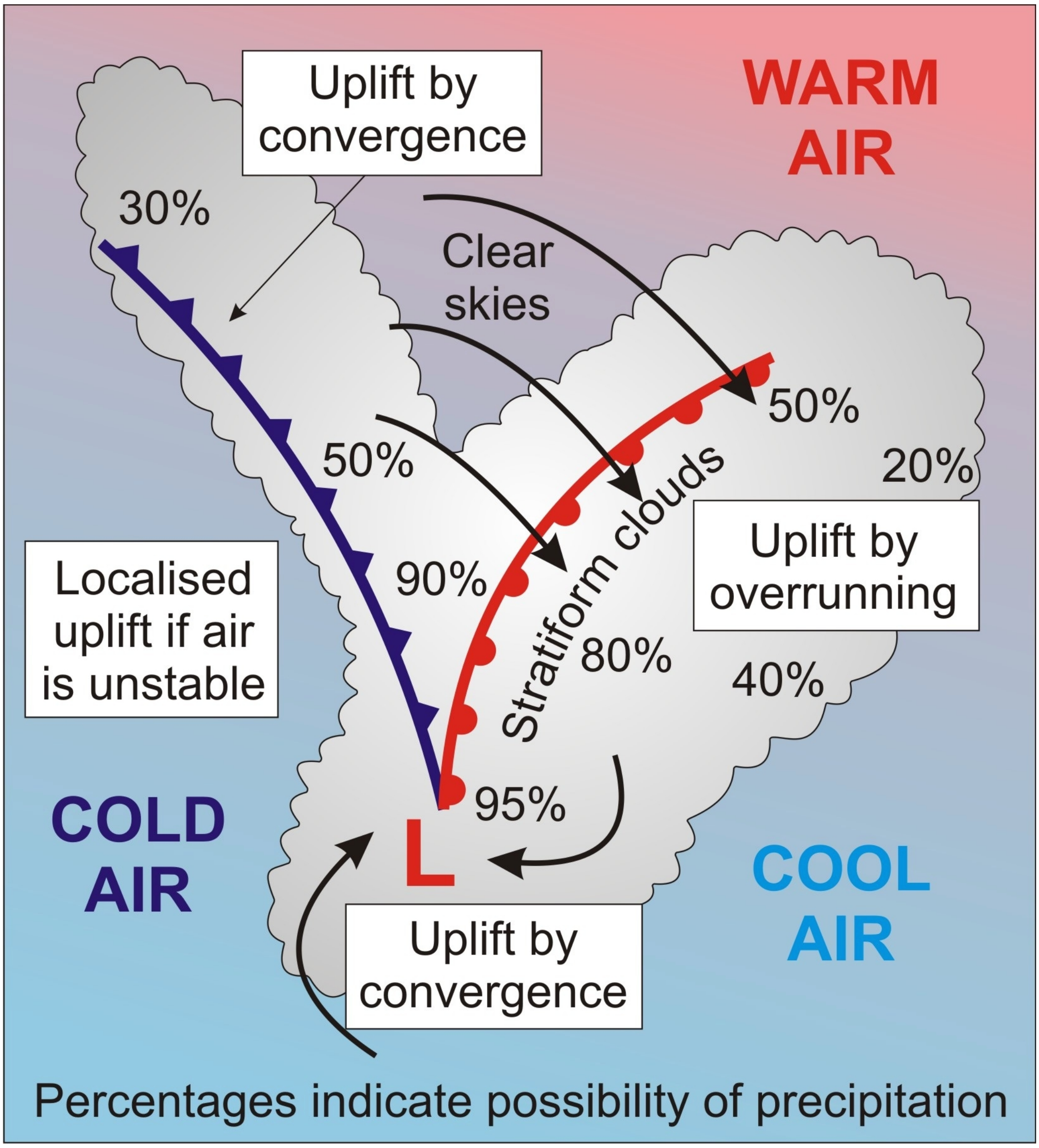


Figure 4.72

Frontal Clouds

Ice Accretion

Icing can occur at any time when you fly an aeroplane in clouds when the temperature is below 0°C. Water droplets can still be found at temperatures well below 0°C and are known as super-cooled droplets. This happens as a result of the purity of the water. Pure water freezes at -40°C, and the water found in the atmosphere becomes purer with increasing altitude. On impacting with the airframe, windshield, wings, intakes or propellers, they freeze immediately. As the temperature decreases, so does the threat of icing, due to the fact that the colder the air, the less moisture present. At temperatures below -40°C icing is unlikely.

Whenever ice forms on an aircraft, the performance of the aircraft will deteriorate. As far as the wings are concerned, ice will change the shape of the aerofoil which provides lift. Lift will be decreased, and the stalling speed of the aircraft will increase, but the danger is that you will not know what that new stall speed is until it actually happens. Control surfaces and their hinges may also be affected, and may not operate properly. Drag will increase, and the weight of the aircraft will also increase, further affecting the stalling speed.

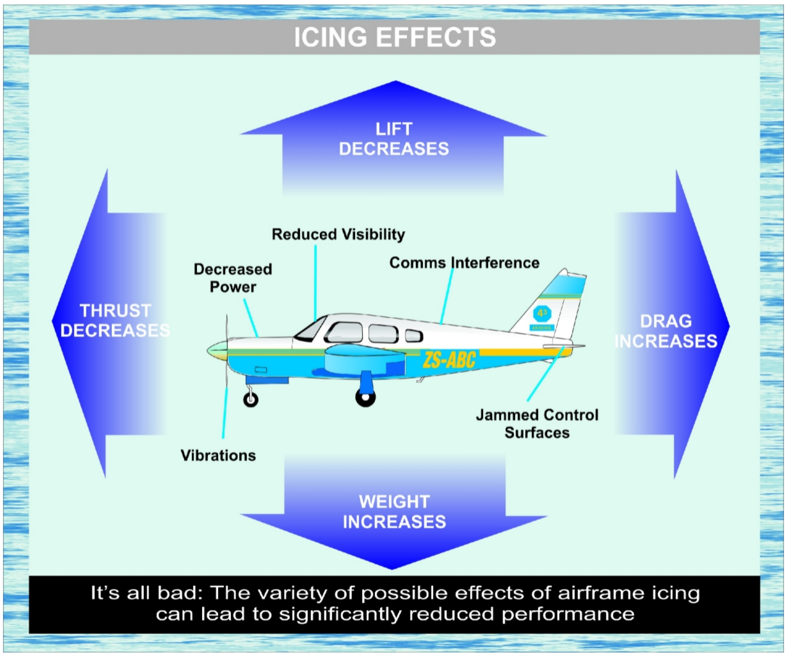


Figure 4.73

Icing Effects

Icing can occur on the pitot-static system, affecting the readings of the pressure instruments such as the altimeter, airspeed indicator and the VSI. Antennas can become coated with ice and radio reception can be affected, as well as other systems such as the ADF, VOR, etc. It goes without saying that if the windshield iced up, you would not be able to see very much!

Carburettor icing will affect the performance of the engine, and ice on the propeller will not only affect the thrust produced by the propeller, but can give rise to severe vibrations.

The are two main forms of aircraft icing, namely clear, or glaze, ice, and rime ice. You can also encounter situations where both types are present at the same time.

Clear ice forms on the aircraft when water droplets freeze onto the surface of the aircraft as it passes through them. Remember that the temperature must be below freezing and visible moisture must be present. The larger the droplet, the greater the problem. This is because only a small portion of the droplet will freeze on impact, and the rest of the water droplet spreads over the surface before freezing. This results in a complete covering of the surface. You can usually see through the ice, much like an ice cube, hence the name clear ice.

Rime ice occurs when the droplets are smaller and freeze completely on impact. Air is trapped between the frozen particles of ice, and rime ice grows out into the airflow as opposed to clear ice which spreads over the surface. It has a much rougher appearance and because it is made up of small ice particles, it is opaque. This type of icing is found in colder temperatures.

There is also the danger of frost on the aircraft on a cold winter’s morning. This is known as hoar frost and is formed when the surface temperature is below zero and ice forms directly onto the frozen surface. Residents of higher lying regions will know this from those winter mornings when a car will be covered in a very thin layer of ice. A jug of lukewarm water usually does the trick.

Tests have shown that ice or frost which has the thickness and texture similar to medium or coarse sandpaper on the leading edge and upper surface of a wing can reduce lift by as much as 30% and increase drag by 40%.this will play havoc with your take-off performance, and even if you were to get airborne, your aircraft's stalling speed can increase by as much as 10%. If you have icing and a wind shear at low speeds you are going to have a serious problem. Make sure that all frost is removed from your aircraft before take-off.

As far as carburettor icing is concerned, there does not have to be visible moisture present, and icing can occur at temperatures into the mid-20's. This is due to the structure of the intake which causes the air to speed up. As it speeds up, the pressure will drop, as will the temperature (by about 20°C), and if sufficient moisture is present, it will condense and freeze in the intake of the carb. Check your Aircraft Operating Manual for details of the use of carb heat.

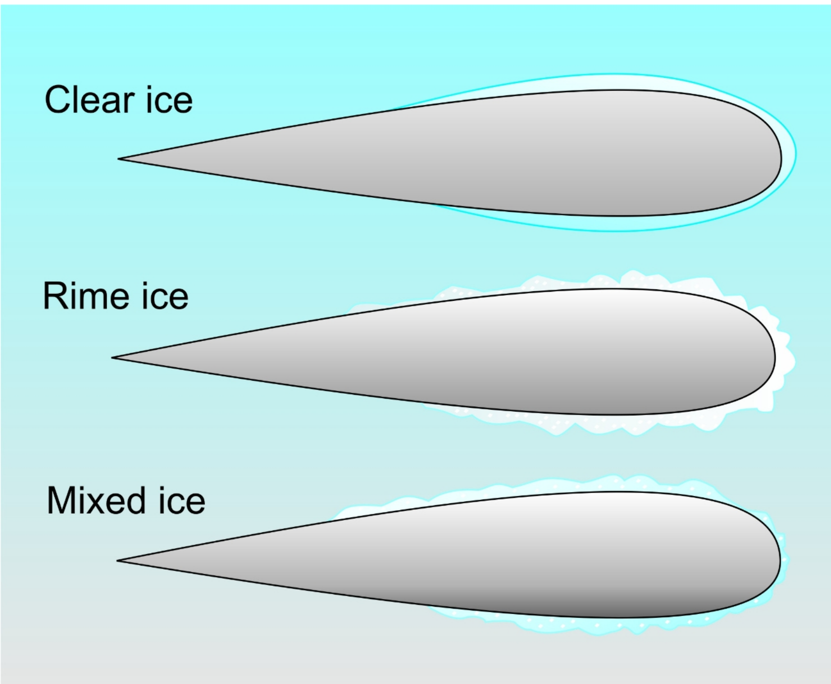


Figure 4.74

Types of Icing

Avoid cumuliform clouds if at all possible. Without an Instrument Rating, you shouldn't be going there anyway. It is great fun going into clouds for a "look see", but remember that if you are above the freezing level, even a short venture into cumulus could cause icing. The worst case will be from 0°C to -15°C. Icing is also possible in stratiform clouds - after all, they are also visible moisture. In stratiform clouds the area to avoid is between 0°C and -10°C.

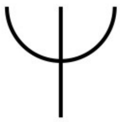
<table>
<tr><th>Temperature</th><th>Stratiform</th><th>Cumuliform</th></tr>
<tr><td>-15° to -20°C</td><td rowspan="2">Rime</td><td>Rime</td></tr>
<tr><td>-10° to -15°C</td><td rowspan="2">Clear</td></tr>
<tr><td>0° to -10°C</td><td>Clear</td></tr>
</table>

Figure 4.75

Temperature Ranges to Avoid

Significant Weather Charts will show areas were icing can be expected, but that does not mean that icing won't be found elsewhere. The chart will indicate the expected severity of the icing - Light, Moderate, or Severe. The Table 4.1 gives you the symbols used on the charts, and some idea of the effects of icing:

Table 4.1 : Icing Intensity, Effects and Pilot's Action

Icing Intensity and Chart Symbol	**Effect on Aircraft**	**Pilot's Action**
Trace (not indicated)	Ice becomes noticeable on surface, rate of accumulation is very low	No action required unless it persists for more than an hour
Light 	If you find yourself in this situation for more than an hour it could become problematic	Use de-icing or anti-icing from time to time to remove or prevent further accumulation. You may consider a heading or an altitude change
Moderate 	Ice will accumulate in a short time and becomes potentially dangerous	You need to use de-icing or anti-icing, or you must make a heading or altitude change
Severe 	Ice accumulation in such a way that de-icing or anti- does not cope	Immediate heading or altitude change

Induction System Icing

Introduction

Piston engine induction system icing, commonly, but not completely accurately, referred to as 'carburettor icing' may occur even on warm days, particularly if they are humid, IT CAN BE SO SEVERE THAT, UNLESS CORRECT ACTION IS TAKEN, THE ENGINE MAY STOP. Induction system icing is more likely at low power setting such as those used during descent, holding, on the approach to a landing or during auto-rotation on a helicopter.

Statistics continue to show an average of 10 occurrences, including 7 accidents, per year, which were probably caused by engine induction icing. After a forced landing or accident the ice may well have disappeared before an opportunity occurs to examine the engine, so that the cause cannot be identified positively.

Some aircraft and engine combinations are more prone to icing than others and this should be borne in mind when flying various aircraft types.

There are three main types of induction system icing:

- Carburettor Icing:

  The most common type of induction system icing is carburettor icing which is caused by the sudden temperature drop due to fuel vaporisation and reduction in pressure at the carburettor venturi. The temperature reduction may be as much as 20°-30°C and results in moisture in the induction air forming ice. The ice gradually builds up, constricting the venturi and, by upsetting the fuel/air ratio, causes a progressive decrease in engine power. Engines which have a conventional float type carburettor are more prone to this type of icing than are those which have a pressure jet carburettor, i.e. the Stromberg type of carburettor. Engines with a fuel injection system are not, of course, subject to carburettor icing.

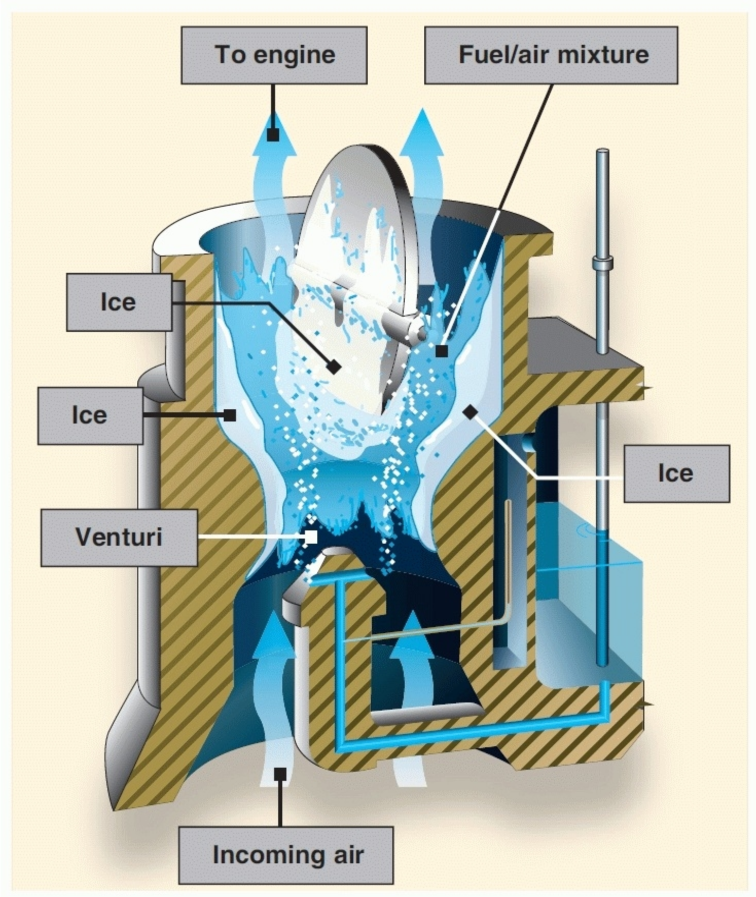


Figure 4.76

Carburettor Icing

- Fuel Icing:

  Fuel Icing is the result of water, held in suspension in the fuel, precipitating and freezing in the induction piping, especially in the elbows formed by bends.

- Intake or Impact Ice:

  Ice which builds up on air intakes, fitters and on carburettor heat or alternate air valves etc is known as Intake or Impact ice (for consistency the term Impact ice is used throughout this chapter). Impact ice can accumulate in snow, sleet, sub-zero temperature cloud or in rain when the temperature of the rain or the aircraft is below 0°C. This type of icing affects fuel injection systems as well as carburettor systems.

Testing has shown that, because of the greater volatility and possible greater water content, carburettor and fuel icing is more likely to occur with MOGAS than with AVGAS.

Reduced power settings are more conducive to icing in the throttle area because there is a greater temperature drop at the carburettor venturi and the partially closed butterfly can more easily be restricted by the ice build-up.

Atmospheric Conditions

Carburettor icing is not confined to cold weather and will occur in warm weather if the humidity is high enough, especially when the throttle butterfly is only partially open as it is at low power settings. Flight tests have produced serious icing at descent power with the ambient (not surface) temperature above 30C, even with a relative humidity as low as 30%.

At cruise power, icing can occur at 20°C with a relative humidity of 60% or more. Ice accretion is less on cold, dry, winter days than on warm, humid, summer days because the water vapour content of the air is lower. Thus, where high relative humidity and ambient temperatures of between -10°C and +25°C are common, pilots must be constantly alert to the possibility of icing and should take the necessary steps to prevent it. If the appropriate preventive action has not been taken in time it is vital to be able to recognise the symptoms. Corrective action must be taken before an irretrievable situation develops. Should the engine stop due to icing it may not re-start or, even if it does, the delay may result in a critical situation.

Carburettor or fuel icing may occur even in clear air and these are, therefore, the most insidious of the various types of icing because of the lack of visual clues. The risk of all forms of induction system icing is higher in cloud than in clear air but because of the visual clues the pilot is less likely to be taken unawares.

Specific warnings of induction system icing are not included in standard weather forecasts for aviation. Pilots must use knowledge and experience to estimate the likelihood of its occurrence from the weather information available. When information on the dewpoint is not available, pilots should assume a high relative humidity, particularly when:

- the surface and low level visibility is poor, especially in the early morning and later evening and particularly when near a large area of water;

- the ground is wet (even with dew) and the wind is light;

- just below the cloud base or between cloud banks or layers;

- in precipitation, especially if it is persistent;

- in cloud or fog – these consist of water droplets and therefore the relative humidity should be assumed to be 100%;

- in clear air where cloud or fog has just dispersed.

The chart in Figure 4.77 shows the wide range of ambient conditions conducive to the formation of induction system icing for a typical light aircraft piston engine. Particular note should be taken of the much greater risk or serious icing with descent power. The closer the temperature and dewpoint readings the greater the relative humidity.

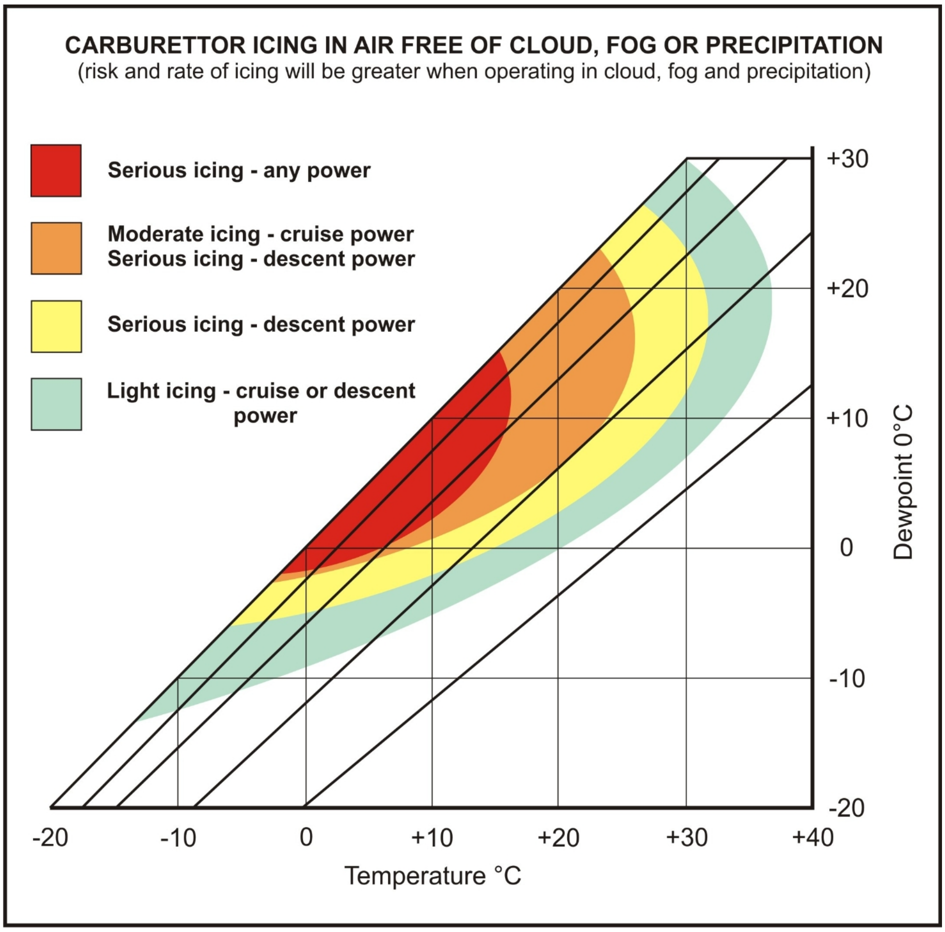


Figure 4.77

Carburettor Icing - Temperature Ranges

Impact icing occurs when flying through snow or sleet, or in cloud in which super-cooled water droplets are present. It can occur, but is less frequent, when flying through supercooled rain or to an aircraft which has a surface temperature below 0°C when flying through rain which is above freezing temperature. The ambient temperature at which impact ice may be expected to build up most rapidly is about -4°C in conditions in which visible ice is forming on other parts of the aircraft.

Prevention, Recognition and Remedial Practices

Prevention

Whilst the following provides a general guide to assist pilots to avoid induction system icing, the Pilot's Operating Handbook or Flight Manual must be consulted for specific procedures applicable to a particular airframe and engine combination. The procedures are likely to vary between different models of the same aircraft type:

- heating the intake air in an exhaust heat exchanger before it reaches the carburettor prevents carburettor icing, (Design Requirements typically demand a temperature rise of 50 °C at 75% power). This is usually achieved by use of a manually operated carburettor heat control, marked HOT or COLD and which, in the HOT position, by-passes the normal intake filter and derives the induction air from a heated source. The HOT position should be selected in time to prevent the formation of ice, because if the selection is delayed the use of hot air might be too late to melt the ice before the engine stops;

- engines with fuel injection normally have an alternate air intake, marked ON or OFF, located within the engine cowling and operated by a valve downstream of the normal intake. Although the air does not pass through a heat exchanger it derives some heat from the engine. Some engine installations have automatic alternate air selection activated by pressure sensitive valves;

- other than on take-off, the HOT position should be selected periodically when icing conditions are suspected or when flying in conditions of high humidity with the outside air temperature within the high probability ranges indicated on the chart. Unless expressly permitted the continuous use of the HOT position should be avoided, especially during hovering flight in a helicopter. It should be selected intermittently for long enough to pre-empt the loss of engine power; this time period will vary dependent on the prevailing conditions;

- as a consequence of the increased susceptibility to carburettor icing at reduced power settings, the HOT position should be selected prior to descent, approach and landing.

Recognition

Should no preventative action have been taken, or was taken too late, or was insufficient, the onset of induction icing may be recognised in the following ways:

- with a fixed pitch propeller, a slight drop in RPM is the first sign which may indicate the onset of icing in the induction system. If not rectified there will be a loss of airspeed and possibly height. The loss of RPM may be gradual with no associated rough running. The usual reaction is to open the throttle slightly to restore the RPM and this action masks the early symptoms. As the icing increases there will be rough running, vibration and further RPM reduction; a loss of airspeed or height will result and ultimately, THE ENGINE MAY STOP. Thus the main detection instrument is the RPM gauge used in conjunction with the Air Speed Indicator;

- where a constant speed propeller is fitted and in a helicopter the loss of power would have to be large before the RPM reduced, hence the onset of induction system icing could be even more insidious. However, the effect of icing will be shown by a drop in manifold pressure and then by a reduction of airspeed or height. The primary detection instrument is, therefore, the manifold pressure gauge. Engine rough running may provide an additional indication;

- an exhaust gas temperature indicator will show a decrease in Exhaust Gas Temperature (EGT) with the onset of icing but engine rough running would, probably, have already been detected.

Remedial Action

When the presence of induction system icing is suspected the HOT or alternate air ON position must be selected immediately:

- the recommended practice with most engines is to use full heat whenever carburettor heat is applied. The control should be selected fully to the HOT position. Partial heating can induce induction system icing because it may melt ice particles, which would otherwise pass into the engine without causing trouble, but not prevent the resultant mixture from freezing as it passes through the induction system. Alternatively partial heat may raise the temperature of the air into the critical range.

- with some engine installations the use of partial carburettor heat may be considered, particularly where an intake temperature gauge is fitted, An intermediate position between HOT and COLD should only be used if an intake temperature gauge is fitted and appropriate guidance is given in the Flight Manual.

  Note: Remember that the selection of the HOT position, after ice has already formed may, at first appear to make the situation worse. This is due to the reduction in power because of the hot air, and to an increase in rough running as the ice melts and passes through the engine. If this happens the temptation to return to the COLD position must be resisted in order that the hot air may have time to clear the ice. This may take 15 seconds or more and may seem a very long time in difficult circumstances.

Air intake blockage: Fuel injected engines have no carburettor. However, when conditions are favourable for structural icing, fuel injected engines can lose power and even fail if the air filter and intake passages are blocked by ice. (This can also occur in aeroplanes with carburettors.) At the first sign of power loss, activate the alternate induction air door or doors. Intake air routes through them, bypassing the ice-blocked air induction pathway.

Many alternate induction air systems activate automatically; these designs use spring-loaded doors. Suction in an ice-blocked air intake draws these alternate air doors open. Some older fuel-injected aeroplanes have alternative air doors that must be manually opened. Knobs or levers have to be physically moved to the open position in order for alternate air to reach the engine. Check the pilot operating handbook to find out how and when to use this system.

Thunderstorms

Southern Africa is quite famous (notorious?) for its thunderstorms. You need to know a little about them in order to realise that the only way to treat them is to stay away from them. All thunderstorms start off as cumulus clouds, but not all cumulus clouds become thunder-storms, or cumulonimbus (Cb - Charlie Bravo’s as they are commonly called).

The name “thunderstorm” comes from the fact that lightning is always associated with such a storm. Lightning causes the air to heat up and expand at a very rapid rate. The speed of this expansion is greater than the speed of sound, and the thunder that you hear is the shock wave formed by this fast moving air. one hears stories from people saying: “We had a thunderstorm yesterday, but we were lucky that there was no lightning”. Not possible. Due to the vast amount of cloud found in a thunderstorm, they simply did not see the lightning, and only heard the thunder. A bit of good news - if you hear the thunder, the lightning missed you!

If you see a flash of lightning, and then hear the clap of thunder some seconds later, you can quickly work out how far the storm is from you. In ISA conditions the speed of sound at sea level is about 660 knots (1 220 kph). This means that the shock wave is travelling at about 0,18 nm/sec, or 0,34 km/sec. If you count slowly (Thousand-and-one, thousand-and-two, etc) from the time you see the flash until you hear the thunder, you will be counting the number of seconds between the two. Every 3 seconds = 1 kilometre, or every 5 seconds = 1 nautical mile.

Conditions Required for Thunderstorm Formation

If you watch a cumulus cloud growing, you will notice that the vertical development is very rapid. This is one of the three major factors in the formation of a Cb. The three are:

- Instability. A deep layer of instability over 10000 feet vertically will allow the air to rise, and continue to do so.

- Moisture. There must be an adequate supply of moisture, particularly at low level.

- Trigger Action. This is the action which starts the air rising, and may be as a result of two air masses coming together (airmass type thunderstorm), at the line of a front (frontal type), an escarpment or mountain range over which the air is forced to rise (orographic type), or surface heating resulting in thermals (convective type).

When all of these three factors are present, thunderstorm formation is possible.

Thunderstorms may be a single cell (one cumulus growing into a single Cb), or multi-cell, where two or more Cbs are blended together into one very large mass of cloud. It is very difficult to tell the difference between the two from their outside appearance, but the multi-cell is by far the worse of the two. And they are very prevalent in the Highveld regions of Gauteng.

Development Process

As mentioned before, all Cb’s start off as cumulus clouds. Watch out for them, especially if there is a lot of vertical development of the cloud. Thermals are also an indication of air which is being heated and lifted. As the rising air cools, visible moisture becomes evident as cumulus clouds. If the tops are fairly uniform, and appear flattened, it is an indication of an inversion. Due to the temperature rising in an inversion, the air is then cooler than the surrounding air, and the rising stops. Cloud tops with irregular heights are a good indication that things could get worse in terms of cloud growth.

If the growth continues, the cloud virtually starts feeding itself, drawing air in from all directions around it. This results in fairly rapid growth of the cloud, and very strong updrafts. This growth of cloud is known as the cumulus, or developing stage of the thunderstorm. Clouds tops will usually be in the vicinity of about 20000 feet, and the cloud will be about 3 to 5 miles in diameter. This stage of the thunderstorm is characterised by strong updrafts. These have been measured at speeds as high as 30 metres per second, or roughly 6 000 feet per minute. You don’t want to be there in a light aircraft!

As the air rises and cools, droplets form. They become bigger and bigger, a point will be reached when the updraft is no longer capable of supporting the droplet, and the droplets start to fall from the cloud. As the droplets fall out of the cloud, they drag air down with them, and the updraft becomes a downdraft. This gives rise to turbulence within the cloud, and values can reach quite frightening proportions. Values of 2000 feet per minute are quite usual, but can be as much as 12000 feet per minute in extreme cases. The downdrafts will slowly overtake the updrafts, and soon only downdrafts will be present. The thunderstorm is regarded as reached the mature stage when the precipitation falling out of it reaches the ground. This happens about 30 minutes after the start of the developing stage.

At this stage of the storm, airflow is now not only vertical (up) into the cloud, but vertical (down) out of the cloud. These downdrafts are particularly dangerous as they cannot blow into the surface, and spread out in all directions as soon as they make contact with the surface. This sudden change in wind direction and speed is known as windshear, and plays havoc with any aeroplane, more so with a light one.

Once the updrafts stop, the thunderstorm reaches what is called the dissipating stage. The source of energy, the updraft, has been removed, and no more heat and moisture can be drawn into the storm. This is the end of the storm, and since there is no more moisture being drawn into the storm, precipitation decreases, and the top of the cloud starts to spread out in a stratiform appearance. This is called the anvil, and consists of ice crystals. The cloud below gradually dissipates, and sometimes only the ice cloud remains. The whole process from start to finish lasts for about one hour.

Thunderstorms do last for longer, but they are most likely multi-cell storms. A bit more about them later.

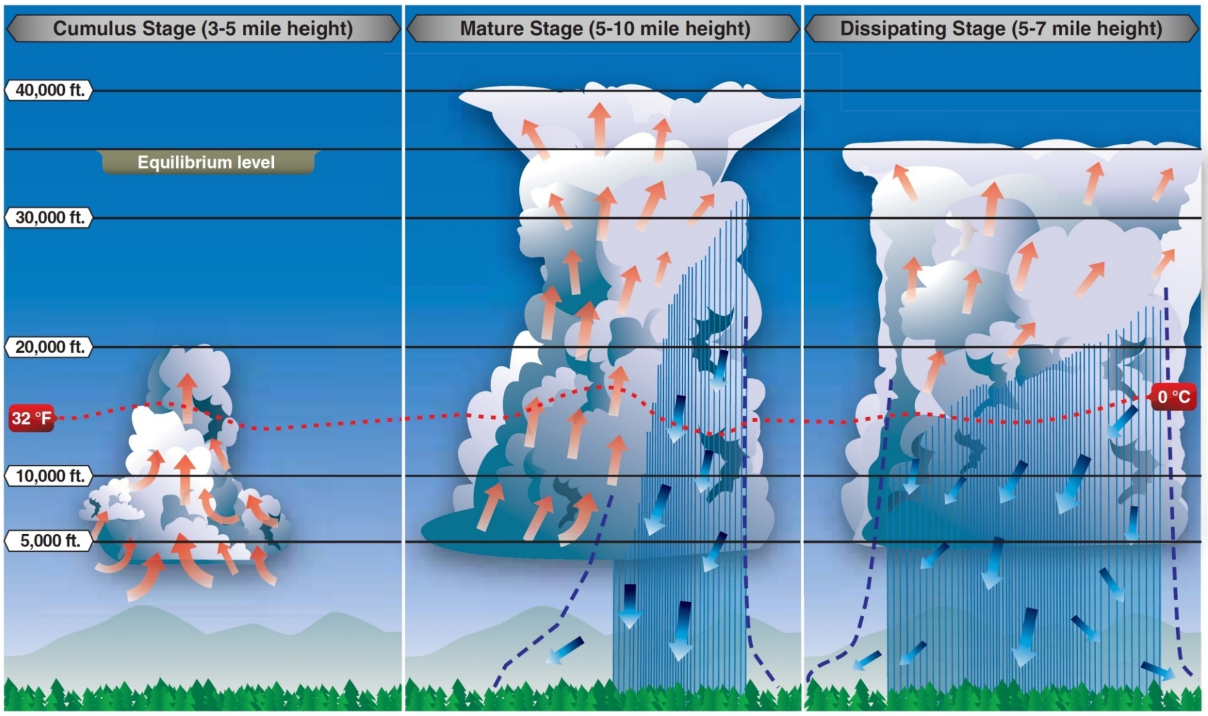


Figure 4.78

Stages of Development of a Thunderstorm

Hazards Associated with Thunderstorms

Apart from the dangers of downdrafts under a thunderstorm, there are other factors which make a thunderstorm something to be avoided. These are turbulence, lightning, hail, icing, downdrafts outside the thunderstorm, and the possibility of a multi-cell storm.

Turbulence. Turbulence in a thunderstorm can be frightening, and of sufficient strength to break up even the largest of aeroplanes. During the cumulus stage, most currents are up, but once the mature stage is reached, very strong downdrafts occur. These up and down currents are closely located and structural failure is possible. These currents can reach speeds of up to about 7000 feet per minute, and when 7000 fpm up becomes 7000 fpm down, something has to give! And remember that it does not have to be a fully fledged thunderstorm to give you dangerous turbulence. Medium to large cumulus clouds can also contain up draughts that can cause structural failure in a light aircraft. even flying through underneath a small cumulus cloud can give a very uncomfortable ride due to the updraft.

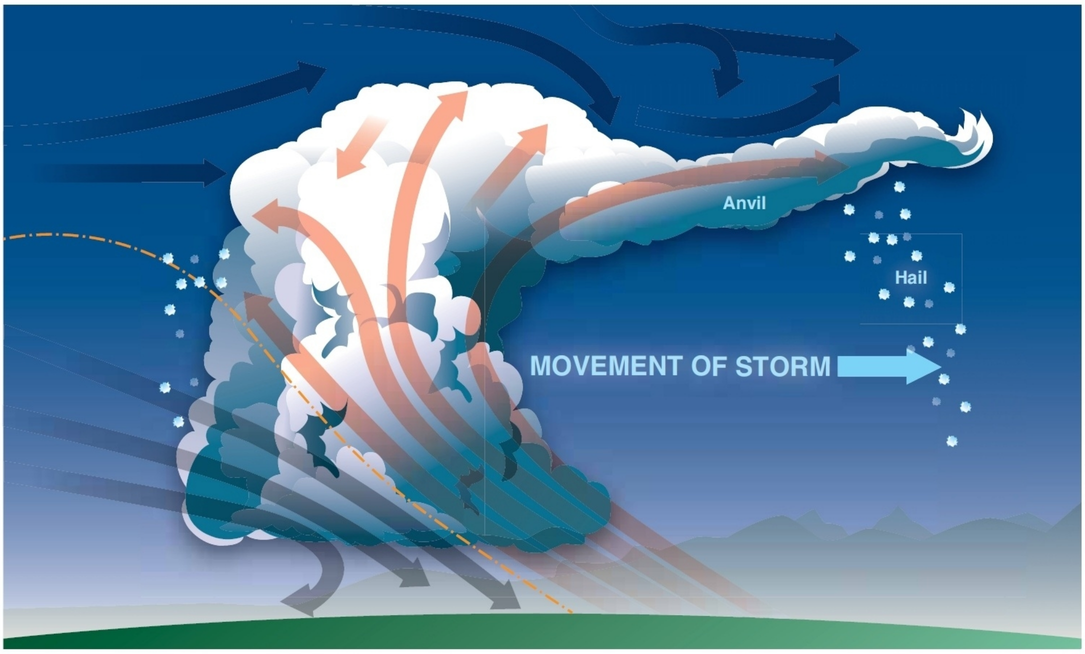


Figure 4.79

Vertical Currents in a Thunderstorm

Lightning. Lightning is not normally associated with visible damage to an aeroplane, but can play havoc with electrical systems, instruments, avionics and navigational systems can be affected by a lighting strike, and aerial damage may occur. Structural damage is usually limited to small holes in the fuselage. Another problem with lightning is that it is incredibly bright, and a pilot may suffer from temporary blindness if exposed. To lessen the effects of temporary blindness, avoid looking at a thunderstorm, and turn up cockpit lighting, even during the day. The area to avoid is about 5000 feet on either side of the freezing level.

Hail. Hail is associated with thunderstorms. This is because the strong updrafts keep water an ice up in freezing conditions for as long time, allowing the hail stones to grow in size. As they start to fall, they be re-circulated back up into the cloud by a stronger updraft, and grow even larger. For this reason, hail may be found at any level in a thunderstorm, above the thunderstorm, and even as far as 10 nm outside of the storm in the clear air under the anvil.

Icing. The cumulonimbus (or Charlie Bravo, from the abbreviation Cb) is a very good source of icing. These clouds carry an immense amount of super-cooled water droplets and any aircraft making contact with these droplets causes instant freezing of the droplets. Accumulation of ice can be so rapid that in severe icing, even de-icing/anti-icing equipment is unable to cope. The bad news is that most light aircraft don't even have icing protection. As the ice accumulates, the aerodynamic efficiency of the aircraft changes quite dramatically. The shape of the wing surface could change completely, the weight of the aircraft increases rapidly, and the stalling speed goes up. Carburettor icing can cause total engine failure.

Downdrafts Outside the Storm. As the air is sucked into a cumulonimbus, it must come down again sometime (Remember the old adage : What goes up, must come down?). For many miles around a thunderstorm air can be subsiding. The intensity of the downdraft will not be as great as that of the downdraft under the storm, but it can cause problems. Because the air is warming as it descends, there may not be any visible moisture to give you any indication of the downdraft. Your power setting and speed may appear to be correct, but the VSI will show a rate of descent. when this happens, move further away from the thunderstorm (see Figure 4.80).

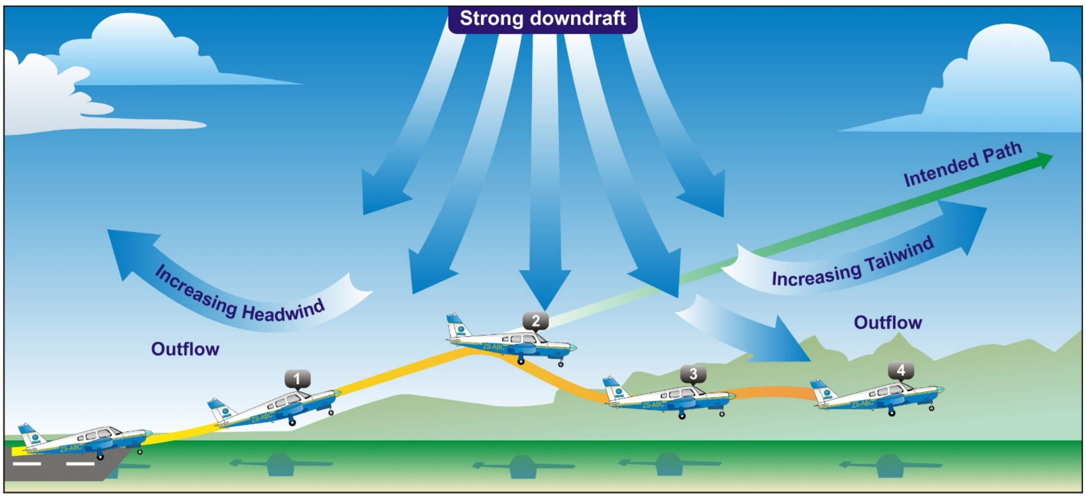


Figure 4.80

The Effects of Downdraft on the Flight Path

Multi-cell Thunderstorms. Up till now we have only considered the thunderstorm to be a single-cell type storm. The reality of it all is that many multi-cell storms are found in South Africa, especially on the escarpment, and very common over the Pretoria/Johannesburg region. The danger is that a single cloud mass may contain many different cells, each at a different stage in the cycle of a single-cell storm. Up to 30 cells may develop during the life-span of a storm, and the storm may last for several hours. One such storm over the Pretoria - Witwatersrand area was observed to move over a distance exceeding 100 nm in four hours. The appearance of an anvil is no guarantee that the storm has reached its dissipating stage - only one of the cells has. The lesson to be learnt from all of this is simple:

AVOID SUCH CLOUDS AT ALL COSTS!

This also applies to a large cumulus cloud with its distinctive cauliflower shape. Remember that it could be a cumulonimbus in the making.

Flight Over Mountainous Areas

You must always exercise caution when flying near mountains. If you are approaching a mountain range from the up-wind side (with the wind at your tail), the airmass you are in will have to move up and over the mountain in the same time that the air passing over the mountain does. This means that there will be an increase in the wind speed (see Figure 4.81), as well as an updraft. Those of you who have been to Cape town may have seen the para-gliders making good use of this type of wind at Sir Lowry's Pass, so it does have a beneficial effect for some aviators.

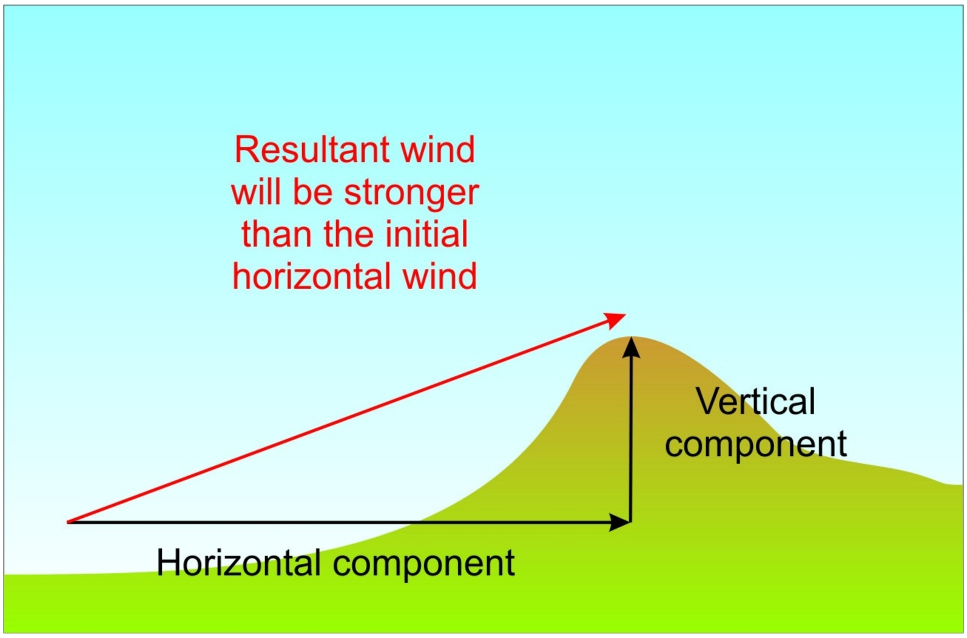


Figure 4.81

Wind Over Mountains

The picture is somewhat different on the downwind, or leeward side of the mountain. The airmass descends suddenly, and the result is an unhealthy increase in a rate of descent. If the wind speed is high enough, this descending air can actually curl back under itself, and this is called rotor turbulence. If there is sufficient moisture present in the air, a rotor cloud may form at the crest of the mountain, and can be seen to be rotating. If there is no cloud present, it most certainly does not mean that no rotor turbulence is present. It simply means that the air is too dry to form cloud.

The danger for any aircraft, apart from the possibility of exceeding the permitted load factor, is that the airflow from under the wing effectively increases the angle of attack of the wing. You may not have the power available to recover from the resulting stall.

At a higher level you will find what are known as mountain waves (see Figure 4.82). These are also called lee, or standing waves. The term “lee” represents the leeward or downwind side of the mountain, and “standing” comes from the fact that to an observer on the ground, these waves appear to be stationary. How can one see waves of air? Air is forced up and over the mountain, pushing air above it up as well, and, If there is sufficient moisture present, clouds may form due to adiabatic cooling. These clouds are known as lenticular clouds due to there shape which resembles a lens from the side. Other clouds associated with mountain wave activity are cap cloud, the cloud that may occur mainly on the windward side (the side that the wind is coming from) of the mountain, with a higher cloud base on the leeward, or downwind, side. Rotor cloud is also possible, and is an indication of possible severe turbulence on the leeward side. These occur due the very turbulent mixing of the air, and are found at about the height of the crest of the mountain (see Figure 4.82).

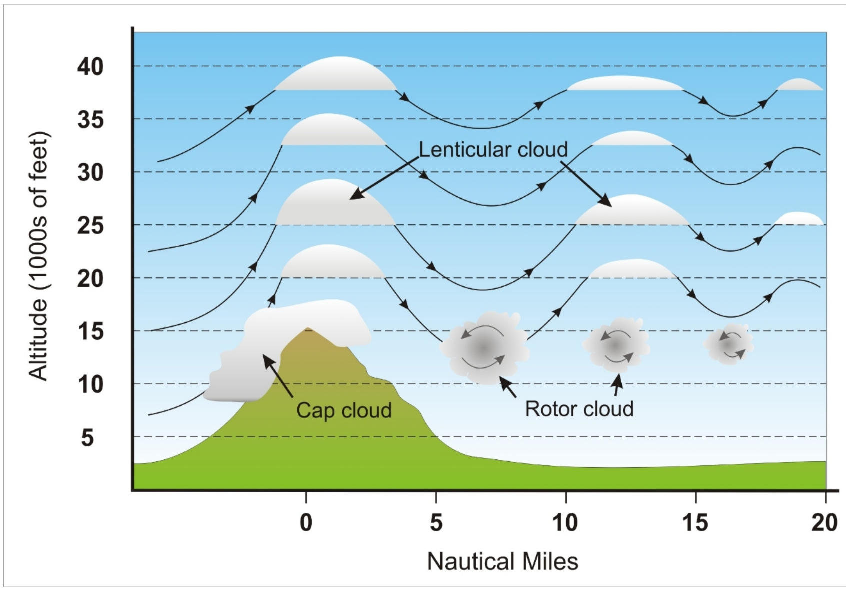


Figure 4.82

Mountain Waves

For mountain waves to form the following conditions are required:

- the wind must be blowing at 90° to the mountain range, ±30° (see Figure 4.83).

- the air above the mountain must be stable. If not, the air would simply continue to rise and form cumuliform cloud and not mountain waves.

- the wind speed at the crest of the mountain should be about 15 knots for small ranges and about 30 knots for larger mountains.

- the wavelength of the wave must be greater than the mountain (see Figure 4.84).

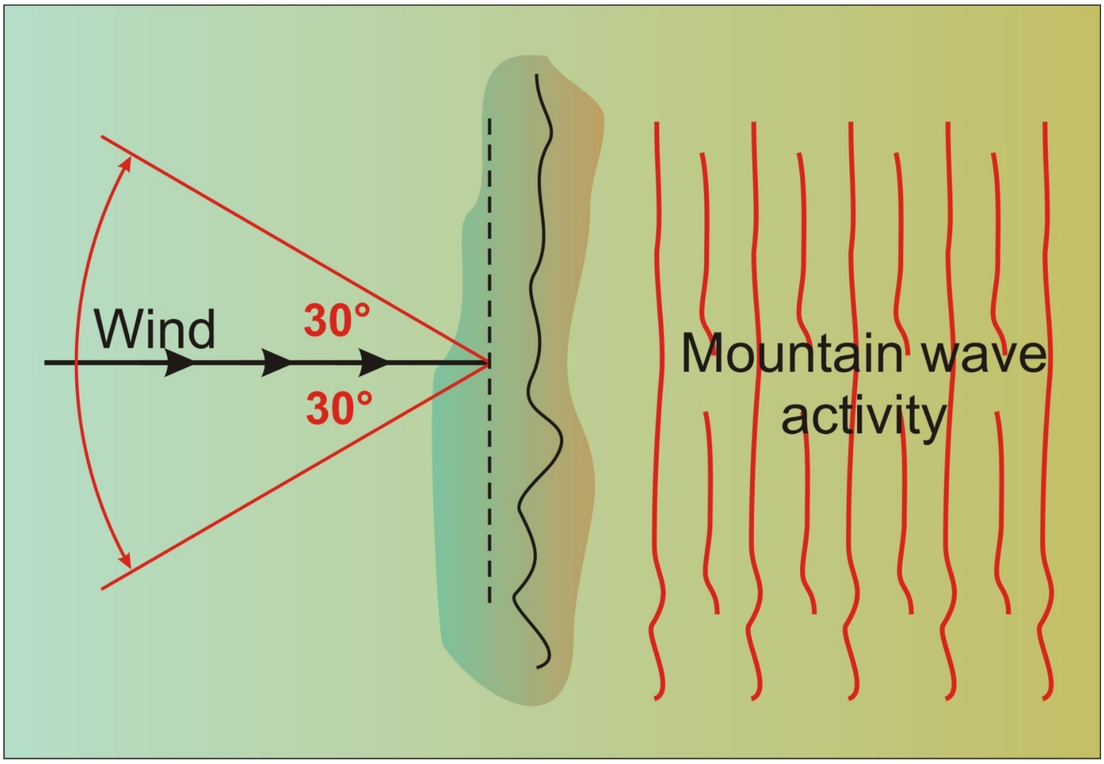


Figure 4.83

Wind Requirements for Mountain Waves

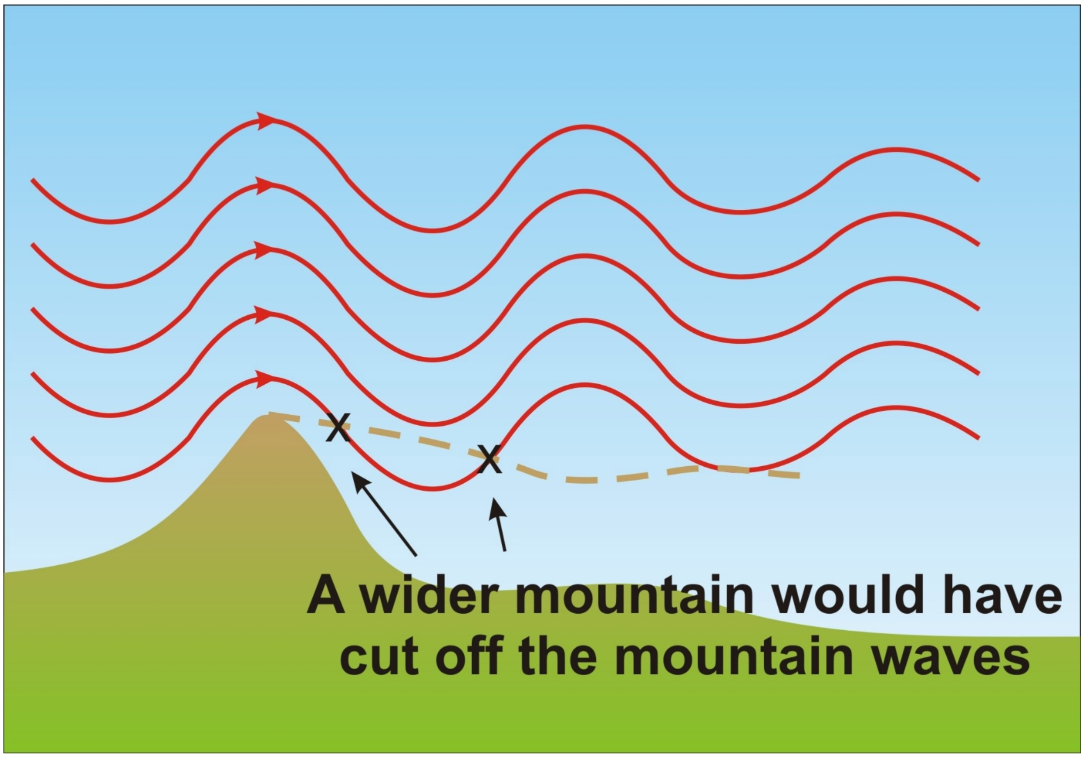


Figure 4.84

Wavelength of Mountain Waves

Mountain waves can exist up to about 300nm on the downwind side of a mountain range, and the area to avoid is the downwind side close to the range at about the height of the crest. To reduce the effects of the waves, plan your track in such a way as to cross the wind line at an angle, or fly as high as possible. They wont go away, as the can stretch all the way up to the tropopause, but the intensity reduces with increasing altitude.

Valley Winds

Exercise caution when flying in a valley. One side of a North/South valley will receive more direct sunlight than the other (except at midday) and this will result in different flows of air up the sides of the valley. On the warm side the air will be rising causing an updraft, while on the cool side the air will be cooler and descending. In the morning the western side of the valley will receive more solar radiation than the eastern side resulting in an easterly wind in the valley. During the afternoon the eastern side will be warmer and the wind will change westerly.

This also applies to valleys which lie East/West. Because the sun is generally to the north, the southern side of the valley will receive more radiation resulting in a northerly wind in the valley.

Climatology

The weather that is experienced at any place on earth varies from day to day, and even hour to hour. If records are kept for a particular place over an extended period of time, then a pattern of the weather conditions starts to appear. This pattern is referred to as the climate of that particular place or region, and climatology is the term given to the study of the differing weather patterns, as well as the causes. Weather is what we actually get, climate is what we expect to get.

The climate of any region is determined by the prevailing air masses over the region, and the air masses are determined, to a large extent, by the latitude of the region.

The world is divided into a few very basic climate zones. These are the Tropical Zone, the Temperate Zone and the Polar Zone (Figure 4.85).

- The Tropical Zone. This is the belt of low pressure at the equator. Because it a low pressure area, the natural tendency of air will be to flow towards it. Winds are generally light, but there are normally heavy showers of rain due to the two airmasses converging on each other, being forced up, cooling off, condensation occurring, followed by precipitation. This is also known as the Doldrums. The tropical zone is also home to the Trade Wind belt. This area extends about 30° north and south of the equator. Due to the low at the equator the winds will blow towards the equator, and due to the rotation of the earth, there will also be an easterly component. In the southern hemisphere the wind will be south-easterly.

- The Temperate Zones. These are areas of high pressure situated at about 30° north and south of the equator. Air movement in a high is downwards, and this results in very little clouds or rain in the region. The region is also known as "The Horse Latitudes" and there are many stories about the choice of the name "Horse Latitudes", but they are unimportant. A feature of this region is that most of the world's deserts are found there. Bordering on the temperate zones are the Westerlies. These regions fall between 30° and 60° north and south, and get their name from the fact that the prevailing winds are westerly. This is the home of the moving cyclones (cold fronts) and weather is very changeable. Those of you who are familiar with yachting will know the region as the "Roaring Forties" in the southern hemisphere.

- The Polar Zones. Situated between 60° and 90° latitude, these zones are dry with little precipitation. They are also known as the cold deserts.

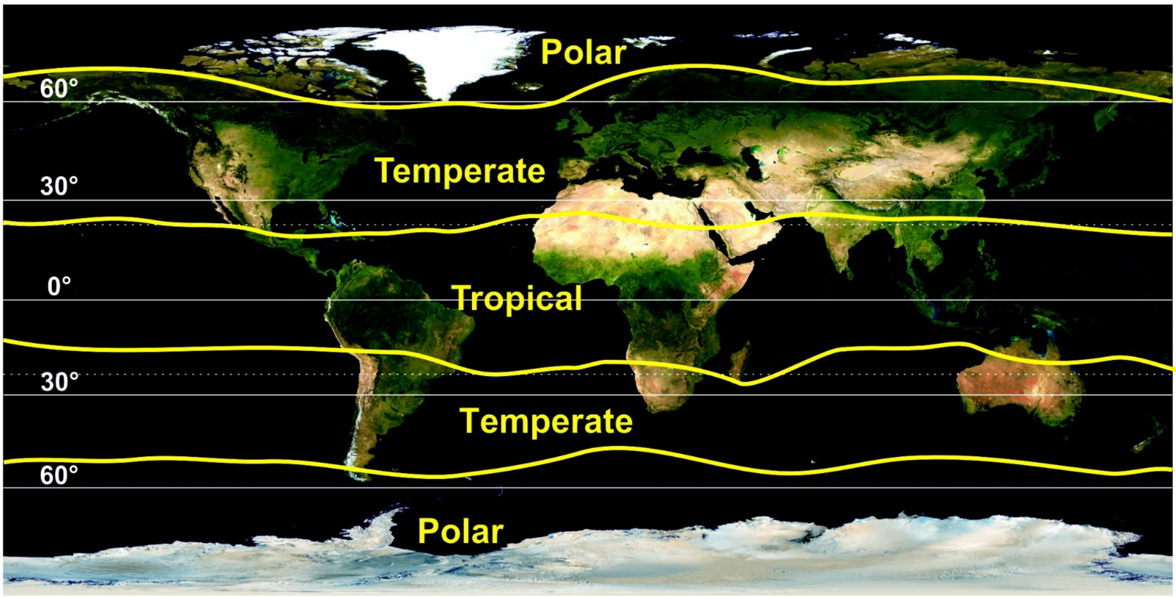


Figure 4.85

Basic Climate Zones

The boundary lines between the different zones are not fixed and move with the seasons. When these seasonal changes take place along the boundaries, the weather is quite different and seasonal weather changes occur. The boundary zones are known as the transitional zones. An example close to home is the Western Cape. The region experiences a dry summer but has a wet winter whereas most of the rest of the country has wet summers and dry winters.

Southern Africa finds itself situated in the sub-tropical dry zone which is influenced by the trade winds and the subtropical high pressure systems with predominantly dry conditions (most of South Africa); the transitional tropical zone which is affected by the trade winds in winter and the equatorial low which brings summer rainfall (the northern part of the region); and the southernmost tip, the transitional sub-tropical zone which is dominated by the sub-tropical high pressure belt in summer, and the westerlies of the temperate low pressure belt in the winter which brings winter rainfall. The southernmost part of the region (Cape Peninsula) is sometimes referred to as having a Mediterranean climate. This is because it has the same climate as the Med, being at the same latitude.

The weather patterns in the southern hemisphere are almost a mirror image of those in the northern hemisphere. Small differences do occur due to the relationship between land masses/sea surfaces, and the effect of ocean currents - warm currents will allow the air to carry more water vapour.

Southern African Weather

The subtropical high-pressure belt dominates the weather over Southern Africa, which is, except during a few winter months, split by the continent to become the Atlantic Ocean High (AOH) and the Indian Ocean High (IOH). Variations in position and intensity of the two high-pressure systems play an important role in the rainfall distribution over South Africa. The mid-latitude westerly circulation, extending northwards to, and in association with, these two high-pressure systems, controls to a large extent, the weather of South Africa. During the summer months, as the high-pressure systems migrate southwards, the influence of the westerly circulation is diminished. South African weather is affected by three major factors:

- The sub-tropical anticyclones: the South Atlantic, South Indian and Continental high pressure systems.
- The easterly wind waves and lows (summer).
- The westerly wind waves and mid-latitude cyclones (winter).

In January (summer) there is a dominant thermal low pressure system over the interior of South Africa, with high pressure systems present over the coastal areas, the Southern Atlantic high to the west, and the Southern Indian Ocean high to the east. The low leads to the summer rainfall over the interior.

- The sub-tropical anti-cyclones are the high pressure systems over the Indian and Atlantic oceans during summer. Warm, moist air is brought over the eastern coastline by the Indian Ocean high, bringing summer rainfall. The air from the Atlantic high is cooler and drier, resulting in little, if any, rain on the west coast, with advection fog being more dominant.

- During summer, the Atlantic Ocean high ridges in south of the country, advecting warm moist air from the Indian Ocean onto the East coast. This can cause orographic lifting over the Drakensberg, bring rain to the eastern and southeastern regions. The high pressure over the west coast causes stable conditions with descending air over the Cape. This anticyclonic flow results in southeasterly winds, which are a very prominent condition over the western cape during summer.

- During summer the easterly flow over the ITCZ is disturbed by the thermal heating which takes place over the continent. This is a summer seasonal condition and gives rise to the low pressure troughs which bring rain to the interior during summer. In winter the ITCZ and its accompanying easterlies are too far north to have any effect on the interior, resulting in dry winters in the interior.

- In summer the air over the interior is heated by the sun, causing the air to rise. As it rises it results in a thermal low pressure at the surface. This brings the warm moist air from the South Indian High into the interior towards the low pressure. This is aided by the anticlockwise flow around the high, and this convergence on the eastern side of the country results in convergence which causes the air to rise. This rising air will cool and eventually condense as it gets higher, resulting in rain. This rain can be in the form of intense thunderstorms due to the high convective activity taking place. On the western half of the country that air is diverging because the South Atlantic high is rotating anticlockwise and moving air away from the interior. This divergence causes the air to subside, resulting in stable conditions with no rainfall.

- Thunderstorms require a lot of moisture and strong convectional heating and are strong feature of our summer weather.

- In the summer the inter-tropical convergence zone (ITCZ), identified by large convective cloud structures, moves southwards to approximately 17°S bringing tropical weather to South Africa's northern regions. During this time of the year tropical weather systems invade Southern Africa in the form of tropical cyclones, tropical lows and easterly waves

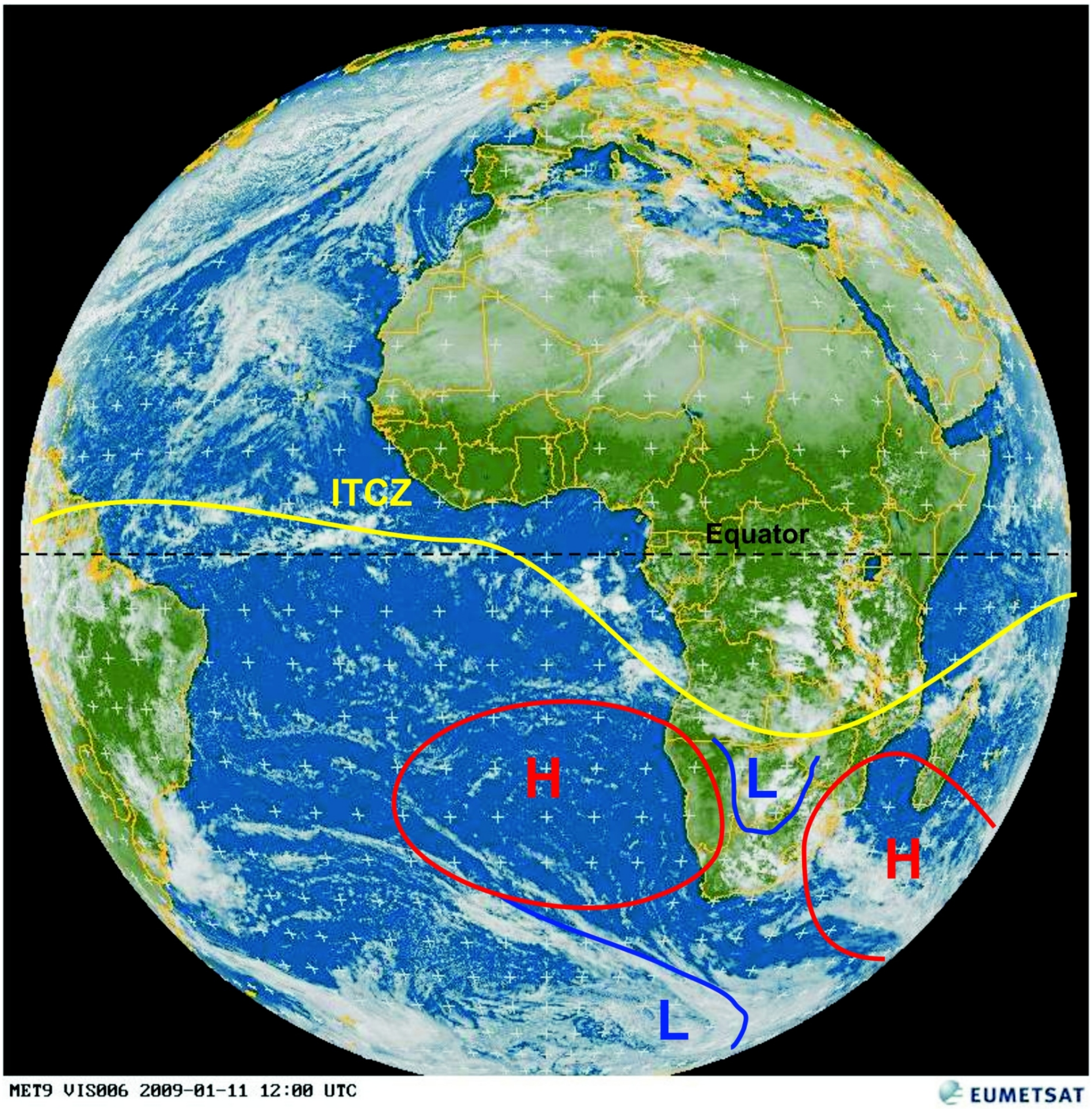


Figure 4.86

South African Summer Weather

During winter (July) the high pressure systems east and west of the country join together, giving a predominant high over the interior. The cooler winter temperatures at the surface give rise to this subsiding air, resulting in stable dry conditions.

- The Kalahari high pressure system over the interior in dominant in winter. This descending air prevents any movement of warm, moist air from the Indian high, and suppresses any convection. This results in the interior of the country being predominantly dry during winter.

- Westerly wind waves. This more commonly referred to as a cold front. During winter the belt of low pressure which is usually at about 60°S during summer moves northwards with the northerly migration of the ITCZ. The northernmost sections of the low pressure systems can now influence the weather in the southern parts of South Africa. The passage of each of the low pressure systems (or the cold fronts) is associated with sharp drops in temperature, and wind and rain. These systems seldom cause heavy rain inland of the escarpment. They move from west to east, moving up the East coast, usually dissipating around Port Elizabeth and Port Alfred.

- If a high pressure system follows a cold front, the anticlockwise flow results in air being drawn up in a south to north direction. This results in a sharp temperature drop as cold polar maritime air is advected onshore. This can occur all year round.

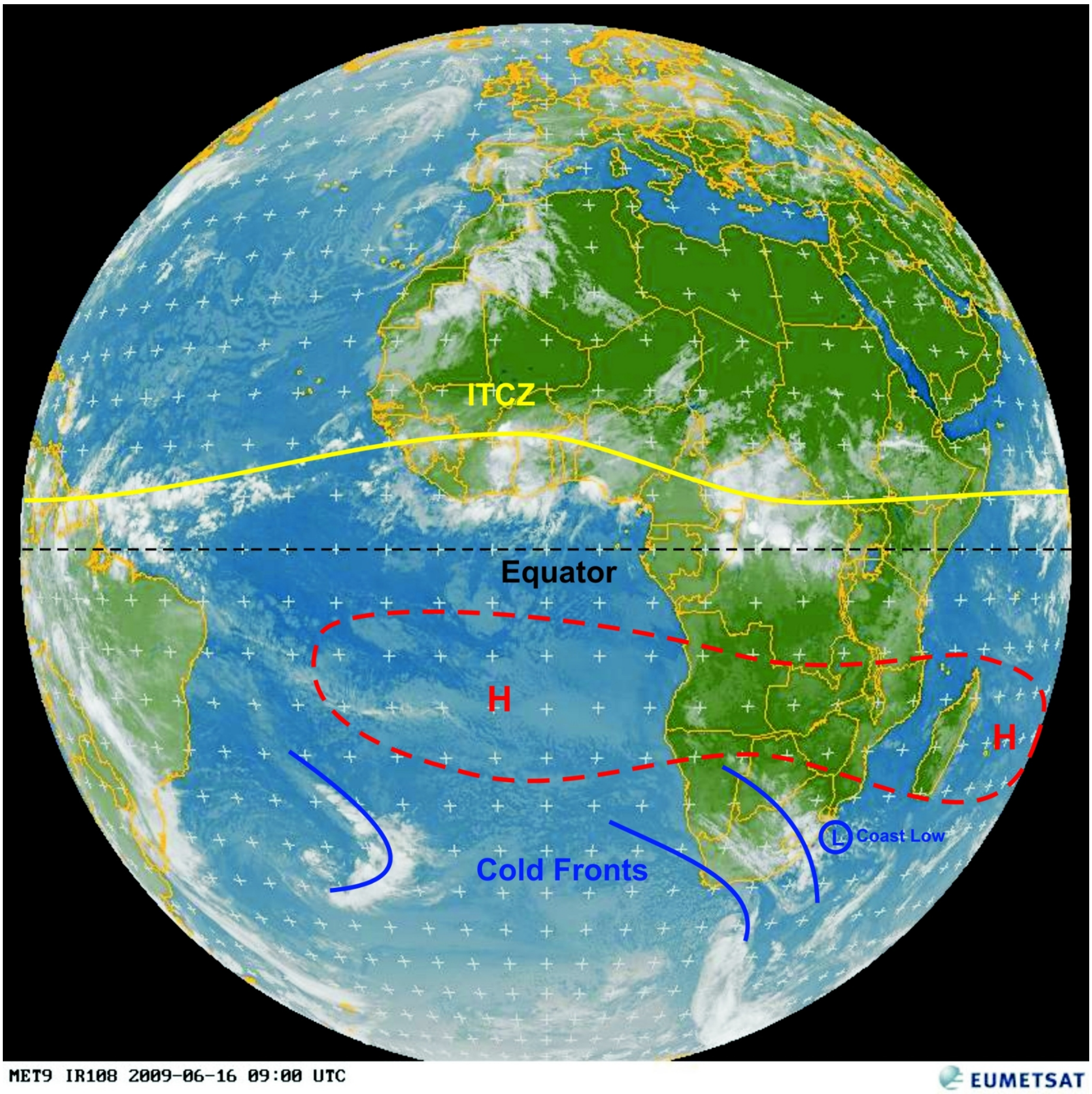


Figure 4.87

South African Winter Weather

Apart from the general weather pattern, there are a few localised systems that you should be aware of, as they may affect any flight you wish to undertake in their vicinity.

The South-Westerly Buster. This is found along the Kwa-Zulu Natal coast and is associated with a passing low pressure system. as the wind around a low is clockwise, the wind to the rear of the low, also moving eastwards, will be onshore. This results in a sudden deterioration of the conditions, rain, a 180° change in the wind direction, an increase in the wind speed, and a drop in temperature.

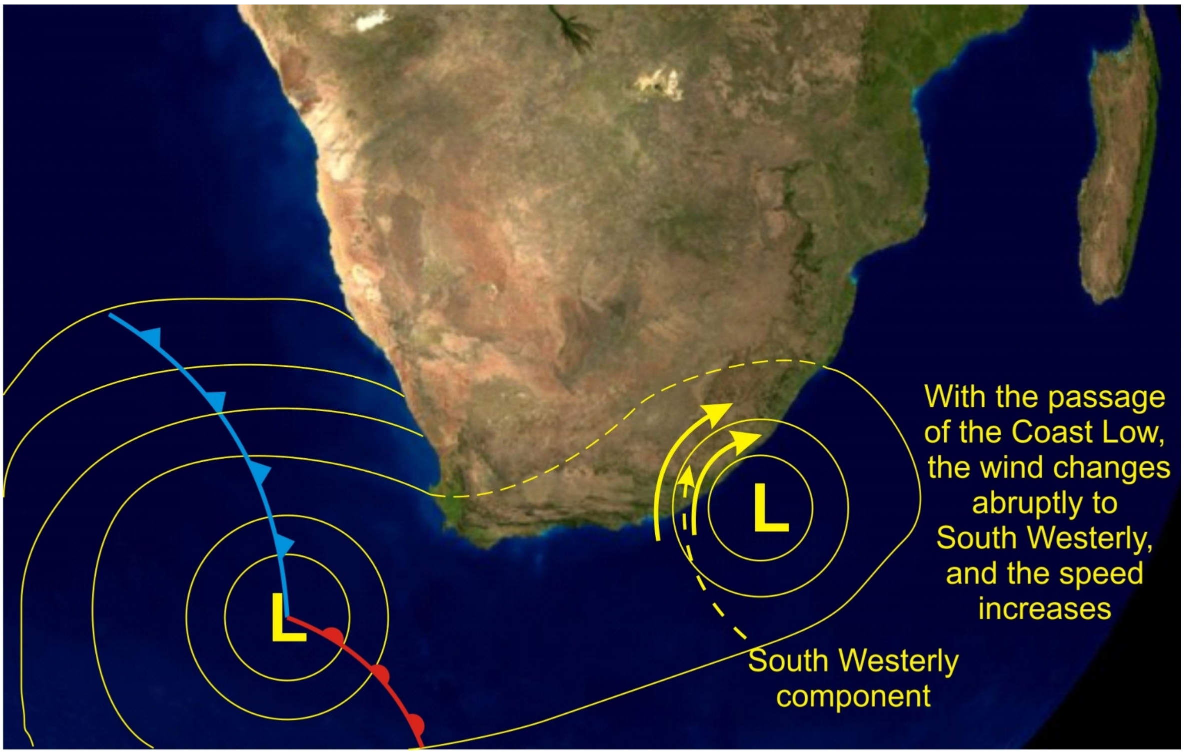


Figure 4.88

South-Westerly Buster

The Cape Doctor. This is a strong south easterly wind which is found over the Cape peninsula during the summer months. Skies are generally quite clear, and the wind gets its name from the fact that tends to blow away all the pollutants and insects. It is associated with a well developed high pressure system west of the Cape Peninsula, and is basically a trade wind. The South Atlantic High moves southwards during summer and ridges in south of the country, joining up with the South Indian High, and giving a band of high pressure to the south of the country during summer The South Easterly wind varies from about 10 kts to about 70 kts during gale force winds. The well-known "tablecloth" over Table Mountain is a good indicator of this condition.

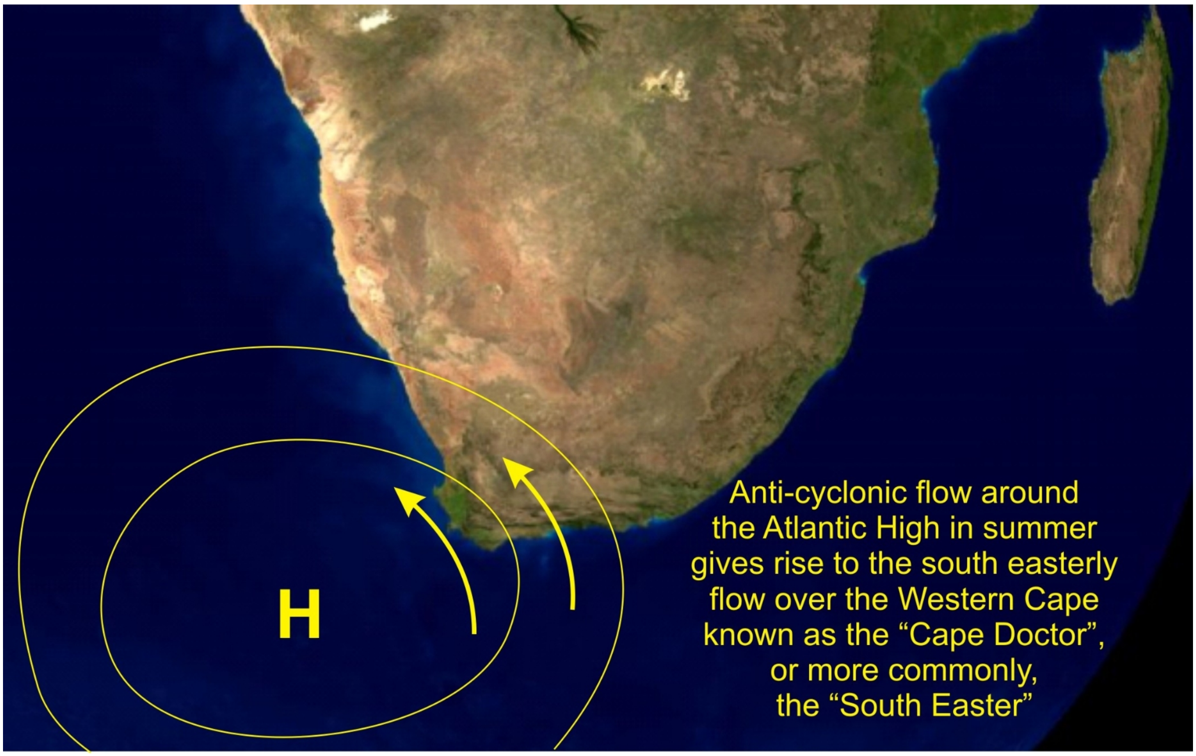


Figure 4.89

The Cape Doctor

Figure 4.90 is a synoptic chart showing typical Cape Doctor conditions. The TAF for the day looked like this:

> FACT 040400Z 0406/0512 17018KT CAVOK TEMPO 0409/0419 17028G40KT PROB40 TEMPO 0509/0512 17025G35KT TX27/0511ZTN17/0504Z=

CAVOK is reported due to the clear skies thanks to the stable high pressure air, and the highest wind gusts for the forecast period are up to 40 knots.

Another interesting feature of the chart is the presence of tropical storm "GAEL" to the east of Madagascar.

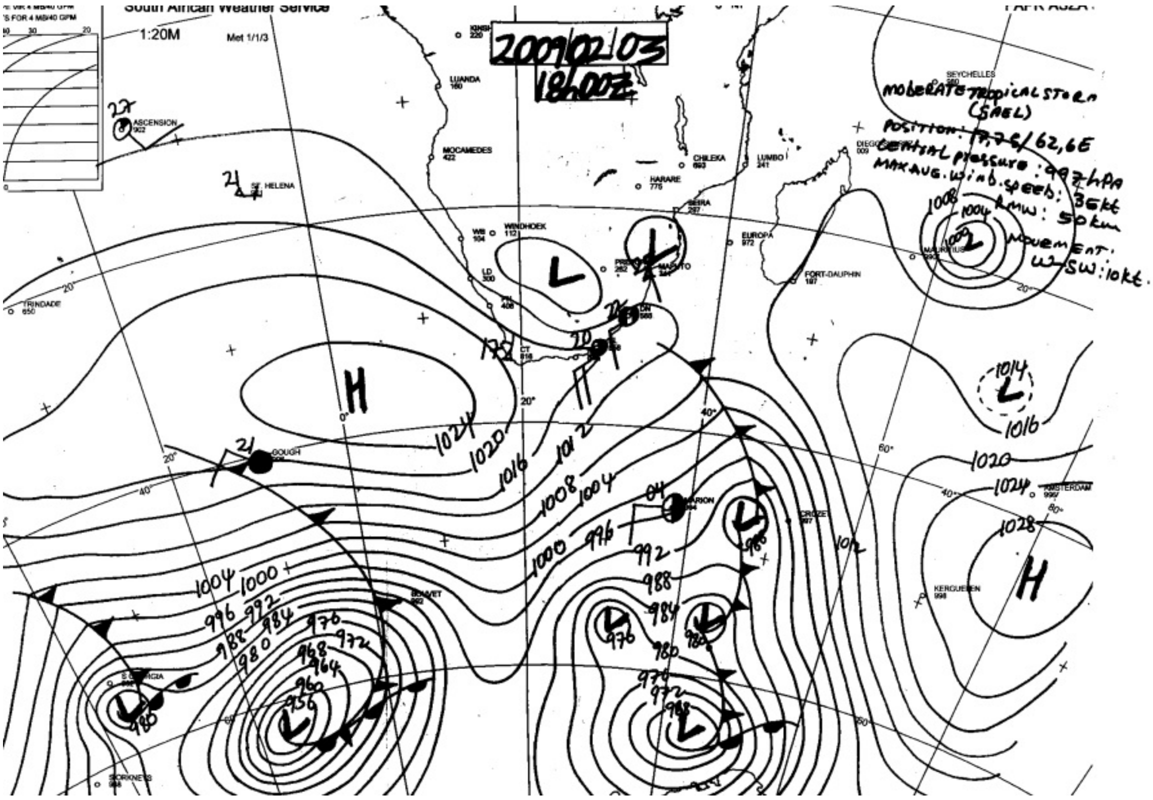


Figure 4.90

Synoptic Chart Showing Cape Doctor Conditions

The Black South Easter. The Cape Doctor is associated with dry conditions. When the South Easter is blowing, usually strongly, and it is accompanied by rain, it is referred to as the "Black South Easter". It is usually caused by a deep low pressure system over the South Western Cape, both in the upper air and on the surface, and a very strong, intense South Atlantic High to the south of the country. The steep pressure gradient between the systems causes the wind, and the low pressure system produces the rain. They occur mainly during spring and autumn when cut-off low pressure systems are usually found. These rains can at times be very heavy, as evidenced by the Laingsburg Floods in 1981 and the Easter of 1994 in Cape Town.

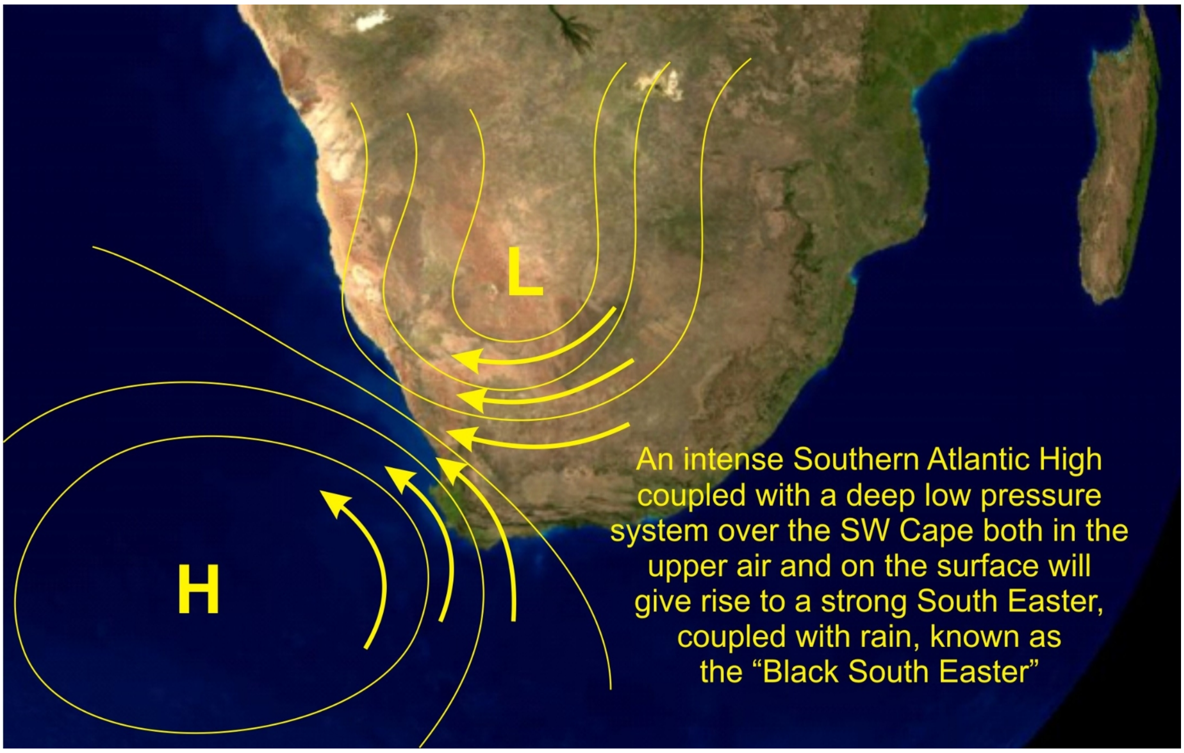


Figure 4.91

The Black South Easter

Bergwind

Bergwind is the South African name for fohn wind or mountain wind. It is a hot, dry wind that blows from the interior of South Africa to the coast and usually is blustery. Most people find it rather unpleasant. It can be mild at times blowing at about 10km/h, but sometimes it can be really strong and may gust up to 100km/h causing some structural damage to buildings and uprooting trees.

Bergwinds usually occur when a strong high pressure exists south or south-east of the country and when a high pressure is also situated over the country. These conditions usually only occur in winter, but sometimes in summer too, hence bergwinds are mainly a autumn-winter-spring phenomenon.

Because air rotates anti-clockwise around a high pressure in the southern hemisphere the wind direction to the north of the high pressure will be easterly or north-easterly, especially along the west coast of southern Africa. The bergwinds will usually start blowing along the Namibian coast and the first indication of bergwinds is a rise in temperature, sometimes this rise can be rapid. In winter of 1985 in Cape Town, the temperature rose from 3°C at 07:00 in the morning to 27°C by 07:35 that same morning. This is not a common occurrence, but rather an extreme case.

Air in a high pressure descends and warms up as it descends, so it stands to reason that the off-shore winds will be warm to hot and the temperature will usually rise about 10°C from the interior of the country to the coast. So the temperate at Bloemfontein may be 20°C, while at Port Elizabeth it may be over 30°C.

At the same time a coastal low will develop along the coast. Off-shore flow ahead of the coastal low is usually easterly to north-easterly in direction along the west coast and north-westerly along the east coast. Humidity levels are usually very low, sometimes as low as 5%, usually between 10-40%. The temperatures vary from 25°C to 35°C in winter and over 40°C in summer. Behind the coastal low the wind is on-shore and usually south to south-westerly in direction. It is cool and moist and usually associated with fog.

The coastal low moves up the east coast of South Africa until it fills in the high pressure system near Maputo in Mozambique. The bergwinds obviously follow the same pattern. The highest official temperatures recorded in South Africa (51.5°C) was recorded one summer during a bergwind occurring along the Eastern Cape coastline.

The bergwinds are usually followed by a cold front in winter.

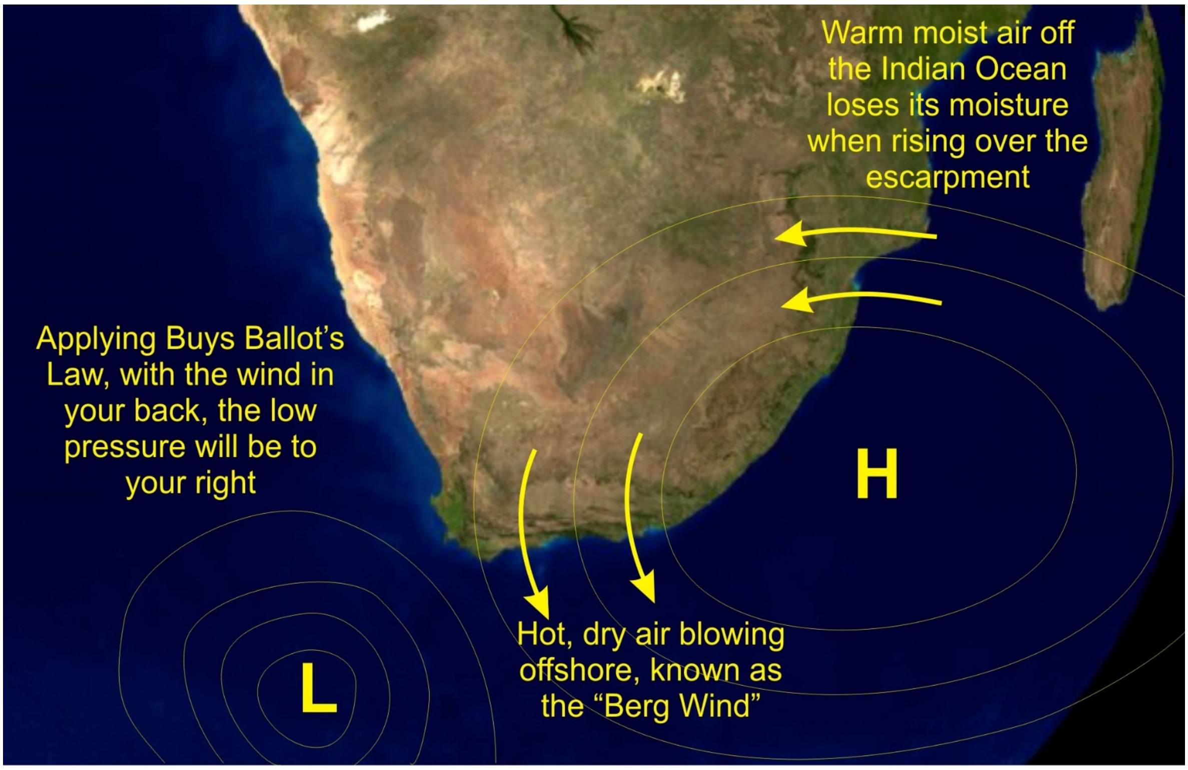


Figure 4.92

The Berg Wind

Coast Low

A coast, or coastal low is a shallow low pressure system limited to the lower layers of the atmosphere and is formed when the wind blows from the land TO the sea, usually during bergwinds. These coastal low pressure systems usually form off the Namibian or West Coast, and off the South-Eastern Coast of SA. They then slowly move down the coast and round the SW Cape and then move up the East Coast of SA where they finally fill up along the Mozambique coast where the plateau ceases to exist.

Air moves off the coast at a height of approximately 1500m. This creates a relative "vacuum" at the surface as air rises to replace the air that is moving away from the coast. In a low pressure system, air rises clockwise in the southern hemisphere and the resultant circulation around the low pressure is the same. As a result, prior to the presence of a coastal low, the winds are usually offshore and in Cape Town they are usually in the form of hot, dry NE bergwinds. Once the coastal low moves through the area, the hot, dry winds are replaced by cool, moist NW-SW winds and usually fog. Coastal lows usually precede cold fronts in winter.

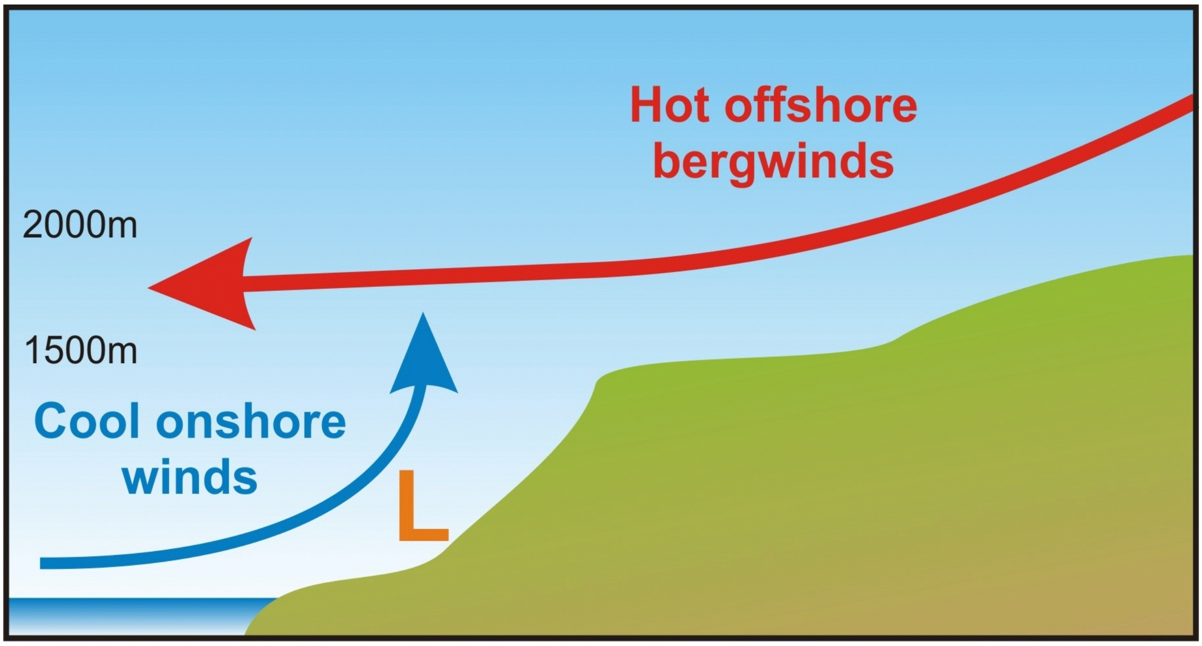


Figure 4.93

Formation of a Coast Low

Between Port Elizabeth and East London when bergwinds occur due to the high pressure system to the east feeding in over the plateau, a similar vacuum exists and this also gives rise to the formation of a low pressure system. Very heavy rains have occurred as a result of these Coast Lows being trapped and staying more or less stationary. The moist warm air coming in off the warm sea brings heavy precipitation at times.

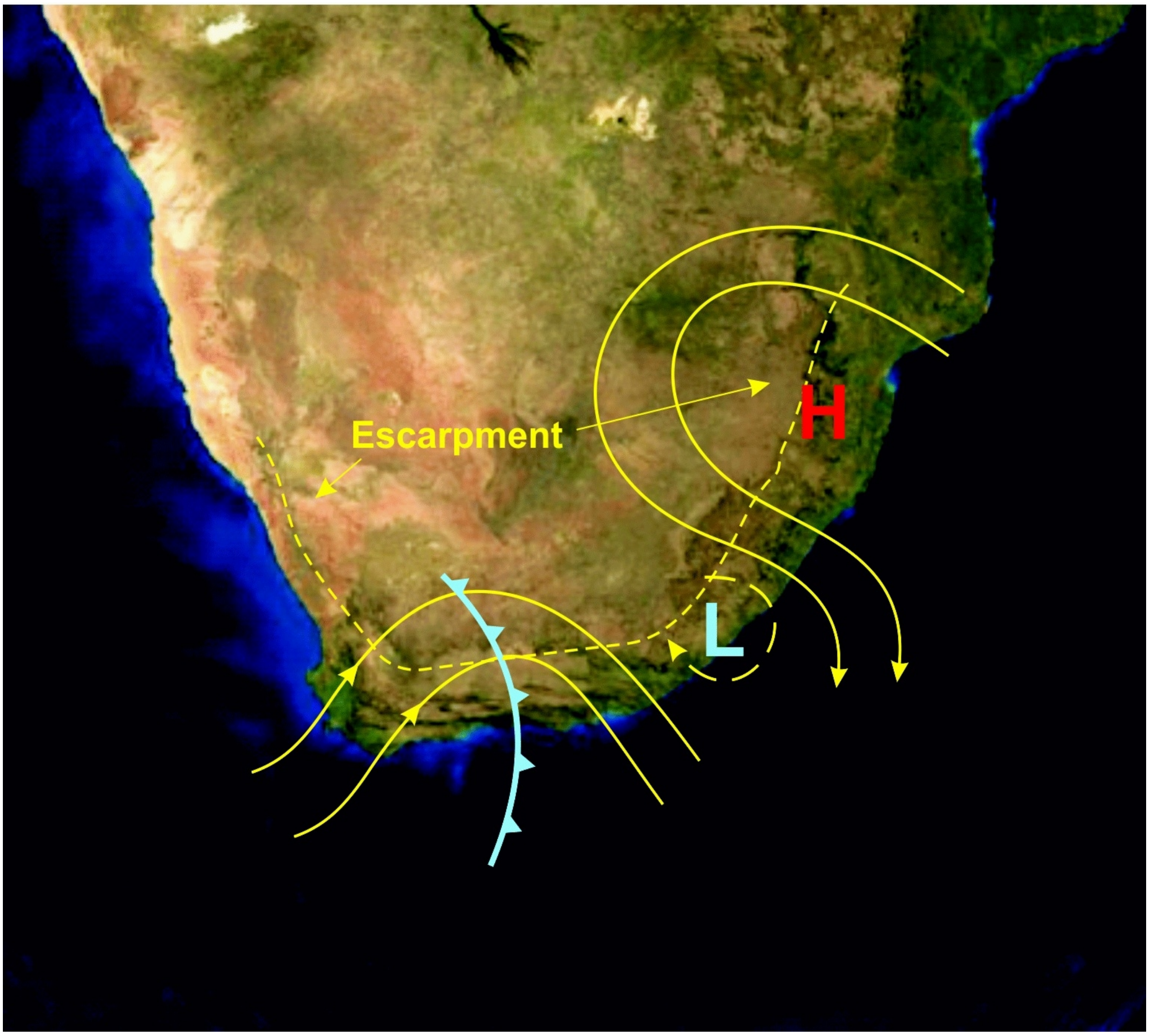


Figure 4.94

East Coast Coastal Low

The Meteorological Organisation

Throughout the world synoptic observations are taken at the same time (0000, 0600, 1200 and 1800 hrs UTC). The information is then combined at a central forecasting office under control of a body of the United Nations called the WMO. This information is than analysed and redistributed to all meteorological offices.

In South Africa the meteorological authority is the Weather Bureau which falls under the Department of Environmental Affairs. They have to supply a service to aviation in terms of several ICAO documents.

The Main weather Forecasting Offices (MFOs) are located at major airports such as Johannesburg, Durban, Cape Town, Port Elizabeth, and Bloemfontein. There are numerous other stations, ranging from weather offices, subsidiary stations and Automatic Weather Stations, such as the one behind the control tower at 43 Air School. The MFOs are responsible for collecting all the information from subsidiary stations and sending it all to the Central Forecasting Office (CFO) in Pretoria. The CFO then analyses all the data and redistributes it to the MFOs. They in turn issue more detailed weather forecasts for their own areas and are responsible for the weather services to aviation.

Weather Analysis and Forecasting

Weather forecasting is available to the pilot in printed form, or may be obtained telephonically from a forecaster at one of the weather stations located at each major airpost around the country.

There are numerous weather charts available to the aviator. Each day a selection of these are displayed in the Operations Room for use by pilots. Those displayed are certainly not all that is available, but merely a selection of those relevant to flying in South Africa at low/medium levels. They are downloaded from the Internet from the web site of the Weather Bureau. The address for their home page is: http://aviation.weathersa.co.za. You can then navigate to the Aviation Services and access what you need.

The symbols and codes used are standard, and the charts that follow are the more common ones you should get used to interpreting, so that you have an idea of the weather conditions to be expected. Whenever in doubt, phone the nearest met office and speak to a forecaster.

METARs and TAFs

These are two of the more common reports which you will see a lot of in the Operations Room each day:

- METAR is a Meteorological Aeronautical Report, also referred to as an Actual. It is a coded weather bulletin of the observed weather at a specific location or aerodrome. The same format is in throughout the world and is simple to decode.

- TAF is a Terminal Aerodrome Forecast which is a detailed forecast of expected weather elements at an aerodrome that significantly affects the movement of aircraft.

A third report of importance to all pilots is the SPECI. It is the same as a METAR but is only issued when certain changes in the weather conditions take place. The changes that result in a SPECI being sent are indicated in paragraph 298..The format used is the same as that of the METAR. The contents and examples of TAFs and METARS are provided on the next few pages.

To quote Dr Frankenfurter from “The Rocky Horror Picture Show” - Don’t get thrown off by the way I look...... this might look very confusing and difficult to understand right now, but the codes all have a very simple interpretation. You won’t remember them all at first glance, but as you will be seeing them virtually every day of your flying career you will get used to them. At this stage you need to know that they are all presented in a specific order, not all METARs and SPECIs contain all the information - only the relevant reportable information is provided - and the more often you interpret them, the easier they become to understand. The full codes are available in the NOTAMs, under Meteorological Aviation Codes.

On the following page is a more detailed table of the more important codes found in a METAR

Code Element	Example	Decode	Notes
1. Identn METAR or SPECI Location indicator Date/time	METAR FAJS 291020Z	METAR Johannesburg International ten twenty Zulu on the 29th	METAR - aviation routine report, SPECI - selected special Station four-letter indicator
2. Wind Wind direction/ speed Extreme direction variance	31015G27KT 280V350	three one zero degrees, fifteen knots, max twenty seven knots varying between two eight zero and three five zero degrees	Max only given if $10 KT than mean. VRB = variable. 00000KT = calm Variation given in clockwise direction, but only when mean speed is greater than 3 KT.
3. Visibility Minimum visibility Maximum visibility	1400SW 6000N	one thousand four hundred metres to south west six thousand metres to the north	0000 = less than 50 metres. 9999 = ten kilometres or more. Direction of minimum visibility given by eight point compass. Given when min visibility #1 500 m and max $5 000 m.
4. RVR	R21R/1100	RVR, runway two one right, one thousand one hundred metres	RVR tendency (U = increasing, D = decreasing, N = no change) may be added after figure, eg. R21R/1100D. P1500 = more than 1500 m, M0050 = less than 50 m. Significant variations: eg. R21R/0950V1100 = varying between the two values.
5. Present weather	+SHRA	Heavy rain showers	See Table of Significant Present, Forecast and Recent Weather in Figure 4.101
6. Cloud	FEW005 BKN025 SCT025CB	few at five hundred feet, broken at two thousand five hundred feet, scattered cumulonimbus at two thousand five hundred feet. Add “00" to the end and you get cloud base in feet above ground level	SKC = Sky clear (0 oktas), FEW = few (1-2 oktas), SCT = scattered (3-4 oktas), BKN = broken (5-7 oktas), OVC = overcast. There are only two cloud types reported: TCU = towering cumulus and CB = cumulonimbus. W / / / = state of sky obscured (cloud base not discernible): Figures in lieu of / / / give vertical visibility in hundreds of feet. Up to three, but occasionally more, cloud groups may be given.

7. CAVOK (Will replace visibility and cloud groups)	CAVOK	Cav-oh-kay	Visibility greater or equal to 10 km, no cumulonimbus, no cloud below 5000 ft or highest MSA (greater) and no weather significant to aviation.
8. Temp and dew point	10/03	temperature ten degrees Celsius, dew point three degrees Celsius	If dew point is missing, example will be reported as 10/ / /. M03 = minus degrees Celsius.
9. QNH	Q0995	nine nine five hectopascals	Q indicates hectopascals. Is the USA the letter A is used (QNH is in inches and hundredths).
10. Recent weather	RETS	Recent thunderstorm	RE = recent, weather codes as above. Up to three groups may be present.
11. Trend	BECMG* FM1100 23035G50KT TEMPO** FM0630 TL 0830 3000 SHRA	becoming from 1100Z 230 degrees 35 KT, max 50 KT temporarily from 0630 until 0830, 3000 metres visibility, Moderate rain showers.	BECMG = Becoming TEMPO = Temporarily NOSIG = No sig change NSW = No sig weather AT = At, FM = From, TL = Until, NSC = No sig cloud Any of the wind forecast, visibility, weather or cloud groups may be used, and CAVOK. Multiple groups may be present.

* BECoMinG is used where changes are expected to reach or pass through specified values at a regular or irregular rate.

** TEMPOrary is a temporary fluctuation in some of the elements lasting for periods of 30 minutes or more but not longer than one hour with each instance, and does not cover more than half of the total period indicated. If any information listed in Code Element 11 - Trend is provided, the METAR is known as a “Trend-type METAR”.

A few METAR examples with full explanations:

METAR FAJS 301220 24015KT 200V280 8000 -RA
FEW010 BKN05 OVC080 18/15 QI008
TEMPO 3000 RA BKN008 OVC020=

In plain language:

METAR for JOHANNESBURG INTERNATIONAL for 1220 UTC on the 30th of the month: Surface wind: mean 240 degree True, 15 knots; varying between 200 and 280 degrees; minimum visibility 8 km; light rain; cloud: 1 - 2 oktas base 1000 feet, 5 - 7 oktas 2500 feet, 8 oktas 8000 ft; temperature +18°C, dew point +15°C; QNH 1008 hPa; Trend: temporarily 3000 m visibility in moderate rain with 5 - 7 oktas 800 feet, 8 oktas 2000 feet.

METAR EGLL 301200 30025G37KT 270V360 1200NE
6000S +SHSN SCT005 BKN010CB 03/M01
Q0999 RETS BECMG AT 1300 NSW SCT015
BKN1000+

In plain language:

METAR for LONDON HEATHROW for 1200 Zulu on the 30th of the month: Surface wind: mean 300 degree True, 25 knots, maximum 37 knots, varying between 270 and 360 degrees; minimum visibility 1200 metres to the north-east, maximum visibility 6 km to the south; heavy shower of snow, Cloud: 3 - 4 oktas base 500 feet, 5 - 7 oktas CB base 1000 feet; temperature +3°C, dew point -1°C; QNH 999 hPa; Thunderstorm since the previous report; Trend: visibility improving at 1300 Zulu to 10 km or more, nil weather, 3 - 4 oktas 1500 feet, 5 - 7 oktas 10000 feet.

QUALIFIER		WEATHER PHENOMENA		
INTENSITY OR PROXIMITY 1	DESCRIPTOR 2	PRECIPITATION 3	OBSCURATION 4	OTHER 5
- LIGHT	**MI** Shallow	**DZ** Drizzle	**BR** Mist	**PO** Well-developed dust/sand whirls
MODERATE (No qualifier)	**BC** Patches	**RA** Rain	**FG** Fog	**SQ** Squalls
	DR Drifting	**SN** Snow	**FU** Smoke	**FC** Funnel cloud (tornado or waterspout)
+ HEAVY or well developed in case of **PO** and **FC**	**BL** Blowing	**SG** Snow grains	**VA** Volcanic ash	**SS** Sandstorm
	SH Showers	**IC** Diamond dust (ice crystals)	**DU** Widespread dust	**DS** Duststorm
VC In the vicinity	**TS** Thunderstorm	**PE** Ice pellets	**SA** Sand	Ice pellets
	FZ Freezing (Supercooled)	**GR** Hail	**HZ** Haze	Hail
	PR Partial covering part of the aerodrome	**GS** Small hail and/or snow pellets	Small hail and/or snow pellets	Small hail and/or snow pellets

Groups are constructed by considering columns 1 to 5 in the table above in sequence, that is intensity, followed by description, followed by weather phenomena.

An example could be: **+SHRA** (heavy shower(s) of rain).

DR (low drifting) less than two metres above ground, BL (blowing) two metres or more above ground.

GR used when hailstone diameter 5mm or more. When less than 5mm, GS is used.

BR visibility at least 1000 metres but not more than 5000. FG - visibility less than 1000 metres.

VC - within 8km of the aerodrome perimeter, but not at the aerodrome.

Figure 4.103

Significant Present Weather (Code elements 5 and 10)

SPECI - Special METAR

A SPECI uses the same codes and format as a METAR but is only issued when the following criteria is met or passed:

- Mean surface wind direction has changed by 30 degrees or more, the mean wind speed before and/or after the change being 20Kt or more.
- Mean surface wind speed has change by 10Kt or more, the wind speed before and/or after the change be 30Kt or more.
- Wind Gusts have increased by 10Kt or more, the mean wind speed before and/or after the change being 15Kt or more.
- Visibility changes to or pass:
    - 1500 or 3000m (SPECI) - 150, 350, 600, 800,1500, 3000m (TAF)
    - 5000m where significant numbers of VFR flights are operating.
- Runway visual range changes to or pass 150, 350, 600, 800m.
- When any combination of weather in the significant weather table begins, ends or changes intensity.
- Height of the base of the lowest cloud layer of BKN or OVC extent, changes to or passes:
    - 100, 200, 500 or l000ft.
    - 1500ft where significant numbers of VFR flights are operating.

- When the amount of cloud below 1500ft changes from:
    - SKC, FEW, SCT to BKN or OVC
    - BKN or OVC to SKC, FEW, SCT
- When the sky is obscured and vertical visibility changes to or passes 100, 200, 500, 1000ft.
- Increase in temperature of 2 degrees Celsius or more.

Here is a more detailed table of the more important codes you will find in a TAF:

Code Element	Example	Decode	Notes
1. Report type	TAF	TAF	Name for an aerodrome forecast
2. Location	FAJS	Johannesburg International	Station 4-letter ICAO indicator
3. Date/Time of origin	130500Z	For the 13th at oh, five, hundred, Zulu	Can be omitted
4. Validity time	1307/1316 1306/1412	Valid from oh, seven hundred, to, sixteen hundred, on the 13th. The validity period may be up to 30 hours.	Zulu
5. Wind	31015G25KT	Three one zero degrees fifteen, max twenty five knots	VRB = Variable; 00000KT = Calm
6. Min visibility or CAVOK	8000	8000 metres, or eight kilometres	9999 = 10 km or more; 0000 = less than 50 metres
7. Significant weather	-SHRA	Light rain showers	See present weather table on METAR for details; NSW = No significant weather

8. Cloud	FEW005 SCT010 SCT018 CB BKN025 CAVOK	Few at 500 feet, scattered at one thousand feet, scattered cumulonimbus at one thousand eight hundred feet, broken at two thousand five hundred feet Same as for METAR. SKC or NSC could also be used.	SKC = Sky clear (0 oktas), FEW = few (1-2 oktas), SCT = scattered (3-4 oktas), BKN = broken (5-7 oktas), OVC = overcast. (8 oktas) W / / / = state of sky obscured (cloud base not discernible): Figures after / / /will give vertical visibility in hundreds of feet. NSC = no significant cloud (none below 5000 feet and no CB) CB will be the only cloud type specified.
9. Significant changes Probability Time Change indicator Met. groups	PROB30 1416 BECMG 1416 FM 1400 TSRA BKN010 CB	30% probability from fourteen hundred to sixteen hundred or becoming from fourteen hundred to sixteen hundred or from fourteen hundred to sixteen hundred Thunderstorm with rain, broken cumulonimbus at one thousand feet	Only 30% or 40% are used. Indicates beginning and end time of forecast period in UTC or Zulu (Z) Also TEMPO = temporarily may be used. Met. group follows indicating a change in some or all of the elements forecast in the first part of the TAF
10. Expected Temp Maximum and Time Minimum and Time	TX21/1 2Z TN16/0 6Z	Maximum temperature of 21°C expected at 1200 Zulu Minimum temperature of 16°C expected at 0600 Zulu	Printed as one continuous 16 letter/digit field May also include other forecasted temperatures and times, eg T16/18Z is a temperature of 16°C expected at 1800 Zulu

TAF Examples:

TAF FAJS 102200 110624 13010KT 9000 BKN010
BECMG 0608 SCT015 BKN020 PROB30
TEMPO 0816 17025G40KT 4000 TSRA SCT010
BKN015CB BECMG 1821 3000 BR SKC=

In plain language:

TAF for JOHANNESBURG INTERNATIONAL, issued at 2200 Zulu on the 10th of the month, and valid from oh six hundred Zulu to midnight on the following day (11^{th}): Surface wind 130 degrees True, 10 knots; visibility 9 kilometres; Cloud: 5 -7 oktas at 1000 feet; becoming from 0600 Zulu to 0800 Zulu, 3 - 4 oktas at 1000 feet, 5 - 7 oktas at 2000 feet. 30% Probability, temporarily between 0800 Zulu and 1600 Zulu of wind 170 degrees True, 25 knots, gusting 40 knots; 4000 metres visibility in moderate thunderstorm with rain; Cloud: 3 - 4 oktas at 1000 feet, 5 - 7 cumulonimbus at 1500 feet. Becoming from 1800 Zulu to 2100 Zulu, 3000 metres visibility, sky clear.

TAF EGLL 300900 301019 23010KT 9999 SCT010
BKN018 BECMG 1114 6000 -RA BKN012
TEMPO 1418 2000 DZ OVC004 FM1800
30020G30KT 9999 -SHRA BKN015CB=

In plain language:

TAF for LONDON HEATHROW, issued at 0900 UTC on the 30th of the month, and valid from ten hundred UTC to nineteen hundred UTC on the same day (30th): Surface wind 230 degrees True 10 knots; 10 km or more visibility; Cloud: 3 - 4 oktas at 1000 feet, 5 - 7 oktas 1800 feet. Becoming from 1100 UTC to 1400 UTC, visibility 6 km in light rain; Cloud: 5 - 7 oktas at 1200 feet. Temporarily 1400 UTC to 1800 UTC, 2000 metres visibility in moderate drizzle, 8 oktas at 400 feet. From 1800 UTC: surface wind 300 degrees True, 20 knots gusting to 30 knots; visibility 10 km or more in light rain showers; 5 - 7 oktas cumulonimbus at 1500 feet.

From the examples above, you can see that the whole world uses the same codes. If you can interpret ours, you can interpret one from anywhere in the world.

There are numerous METARs and TAFs available to the pilot, as well as many, many other meteorological reports and forecasts. Part 91 (general Operating and Flight Rules) of the Civil Aviation Regulations, 91.02.8 : Duties of pilot-in-command regarding flight preparation, requires you to ensure that the weather at the aerodrome being operated to or from will not prevent a safe take-off and a departure or a safe landing at the destination aerodrome or alternate aerodrome.

Before filing any VFR flight plan you will have to ensure that the weather along the entire route will allow you to fly in VFR conditions for the entire duration. So get used to using the charts, and keep on using them.

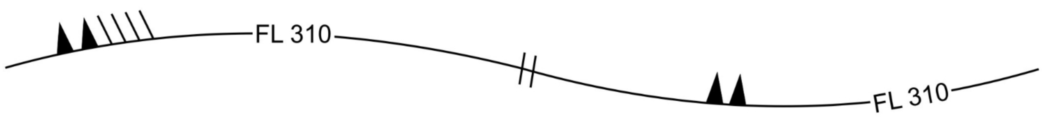
The next few pages contain some other charts that may be used to get a better picture of the weather you can expect to encounter. Note that all weather charts have a period of validity, so they have to constantly updated. Don’t ever use yesterday’s weather for today’s flight.

SIGNIFICANT WEATHER CHARTS

SYMBOLS FOR SIGNIFICANT WEATHER CHARTS

	Thunderstorm		Drizzle		Tropical cyclone
	Rain		Severe line squall*		Snow
	Moderate turbulence		Severe turbulence		Showers
	Widespread blowing snow		Mountain waves		Severe sand or dust haze
	Slight aircraft icing		Widespread mist		Widespread haze
	Moderate aircraft icing		Widespread for		Widespread smoke
	Heavy aircraft icing		Hail		Freezing precipitation**
350	Tropopause level	300	Tropopause low	520	Tropopause high
120 / 050	Cloud tops and base	12	Isotherm °C	12	Temperature at selected points
H	Centre of high altitude of the isobaric surface	L	Centre of low altitude of the isobaric surface		Cloud border
0°=090	Freezing level		Volcanic eruption		Convergence line

	Cold front at the surface		Cold front above the surface
	Warm front at the surface		Warm front above the surface
	Occluded front at the surface		Occluded front above the surface
	Quasi-stationary front at the surface		Quasi-stationary front above the surface
	Position, speed and level of maximum wind		Intertropical convergence zone
	Zone of maximum wind		Wind at selected points (half a barb = 5 kts, full barb = 10 kts and a triangle = 50 kts



The double bar denotes changes of level by 3000ft or less, and/or wind speeds by 20kts. In the example, at the double bar the wind speed is 120kts

The heavy line delineating the jet axis begins/ends at the points where a wind speed change of 80kts if forecast.

* In-flight documentation for flights operating up to FL 100, this symbol refers to "line squall"

** This symbol does not refer to icing due to precipitation coming into contact with an aircraft which is at a very low temperature

Figure 4.104

Significant Weather Chart Symbols

FORECAST WEATHER ABBREVIATIONS

VISIBILITY

BR	Mist	**FG**	Fogt	**BCFG**	Fog patches
MIFG	Shallow fog	**VCFG**	Vicinity fog	**PRFG**	Partial fog
FU	Smoke	**HZ**	Dust haze	**SA**	Dust or sandstorm

PRECIPITATION

DZ*	Drizzle	**RA***	Rain	**RASH**	Rain showers
FZDZ*	Freezing drizzle	**FZRA***	Freezing rain	**GR***	Hail
XXSH	Heavy showers	**SN***	Snow		

THUNDERSTORMS

TS*	Thunderstorm	**TSGR***	Thunderstorm with hail	**LSQ**	Line squall
ISOL	Isolated	**OCNL**	Occasional	**FRQ**	Frequent
EMBD	Embedded				

TURBULENCE

MTW	Mountain waves	**TURB**	Turbulence	**WS**	Wind shear

REGIONS

LOC	Local	**MON**	Over mountains	**ESC**	Along ecarpment
CIT	Urban areas (city)	**VAL**	In valleys	**HIV**	On highveld
LOV	Over lowveld	**MAR**	Maritime	**COT**	Coastal

CLOUD COVER

FEW	1 - 2 oktas	**SCT**	3 - 4 oktas	**LYR**	Layer
BKN	5 7 oktas	**OVC**	Overcast		

Note: Items which are marked * may be preceded by **XX**, which means ***HEAVY***

Figure 4.105

Forecast Weather Abbreviations

There is an important fact to remember when using the Significant Weather charts. There are two of them:

- S The LOW chart, indicating significant weather between Mean Sea Level (MSL) and FL180; and

- S The HIGH chart, indicating significant weather above FL1800

As a PPL you will usually only be interested in the weather on the LOW chart, but cloud tops or bottoms which are outside of the limits of any chart are shown on the next one up or down. You can get a pretty good idea of the severity of the weather by looking at the next one up. The chances of you ever using the High chart are slim as a PPL, but it is included for those who may be interested.

SIGNIFICANT WEATHER CHART: LOW (MSL - FL180)

To illustrate the indications of a large cloud mass on each of the charts, an indication of what will appear on the chart in terms of cloud cover is shown below. The actual charts follow on the next pages, and the areas in question are Johannesburg and Port Elizabeth, in the right centre of each chart, indicated as JS, and the bottom middle indicated as PE.

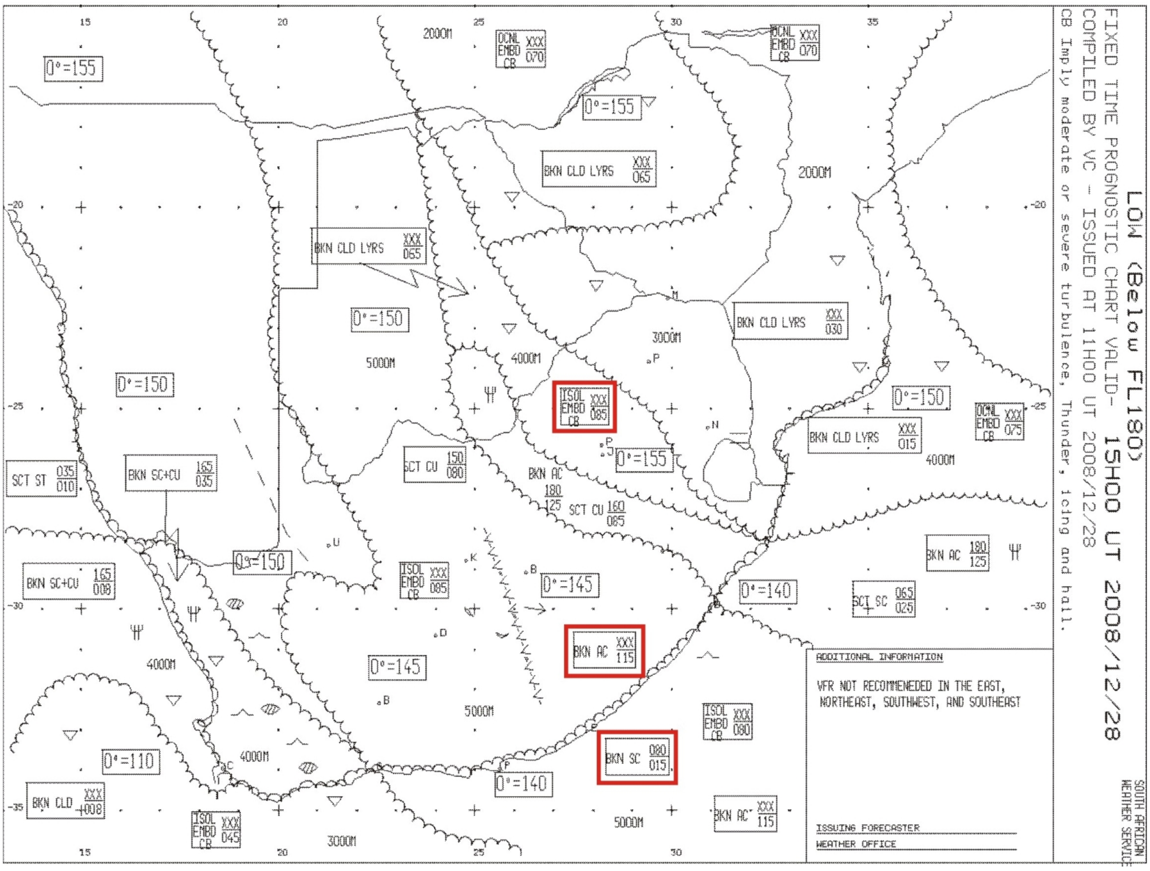


Figure 4.106

Significant Weather Chart (Low)

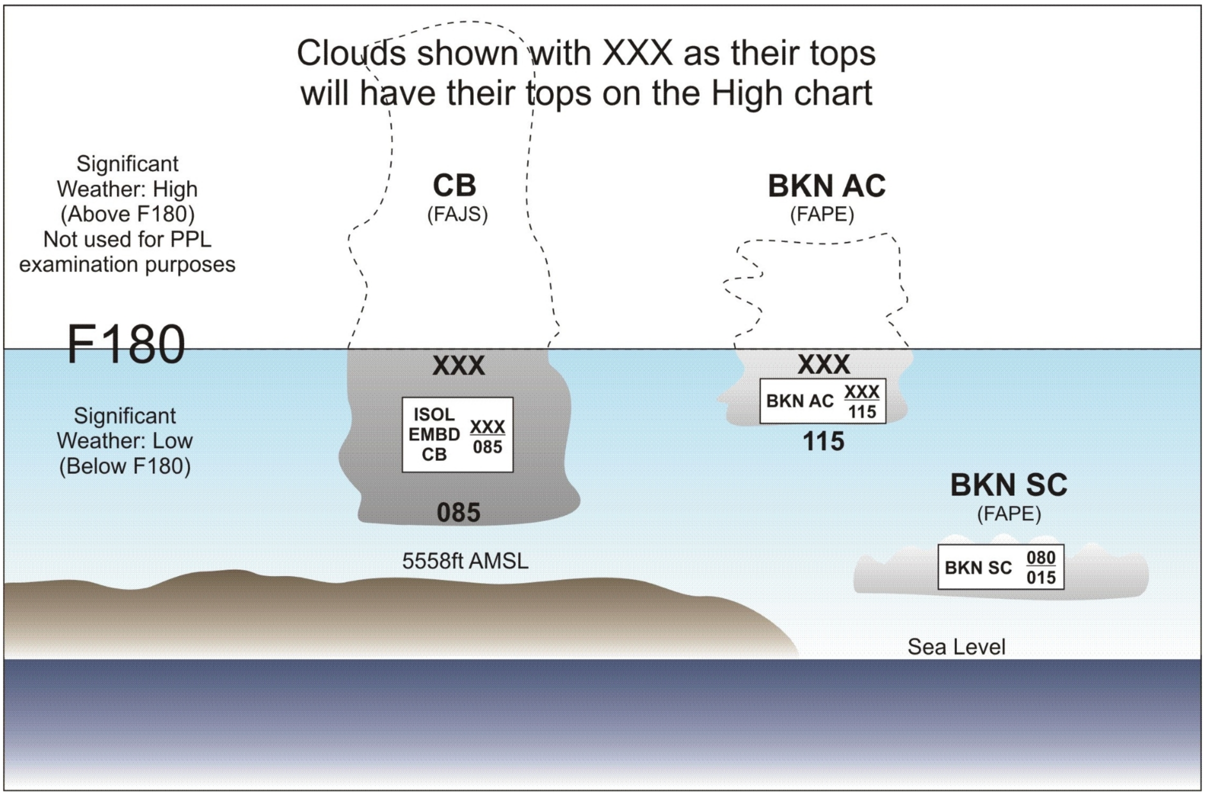


Figure 4.107

Plan View of Clouds Shown on Sig Wx Chart

General summary of the information shown on the Sig Wx Chart:

! Not a good day for VFR flying! Virtually the whole of South Africa is covered by cloud, as indicated by the scalloped lines scattered all over the country, as well the warning provided in the "Additional Information" box at the bottom right hand corner - VFR NOT RECOMMENDED IN THE EAST, NORTHEAST, SOUTHWEST, AND SOUTHEAST. The rounded edges indicate the limit of the cloud.

! Starting at the top left corner, there is scattered stratus (SCT ST) between 1000ft (010) and 3500ft (035) along the Namibian coast. Add 00 to the number in the block and you have cloud base in feet above mean sea level. Namibia itself is almost cloud free. From Alexander Bay (AB) on the border between South Africa and Namibia the cloud cover is 5-7 oktas Stratocumulus and Cumulus (BKN SC+CU) between 3500ft and 16500ft. Out sea the cloud is the same but is between 800ft and 16500ft. Out to sea off the coast at Cape Town there is 5-7 oktas cloud (not specified) from 800ft up to XXX, which means that the cloud tops are not on this chart, but on the High chart, as well as isolated embedded Cumulonimbus (ISOL EMBD CB) from 4500ft to XXX. 5-7 oktas of Stratocumulus are found all along the coast to Durban (D) between 1500ft and 8000ft.

! In the interior the clouds thin out a bit to 3 to 4 oktas of cumulus (SCT CU) in places, with bases varying between 3500 and 11500 feet MSL.

! Mountain wave activity, moderate icing, moderate turbulence and showers are indicated north and east of Cape Town, and over Botswana, Zimbabwe and Mozambique.

! There is also the presence of Isolated cumulonimbus stretching from Beaufort West all the way up into Botswana.

! The freezing level over the whole country varies from FL110 (Cape Town) to FL155 over Johannesburg, Southern Angola and Zimbabwe.

! Visibility is given in metres at several places on the chart, ranging from 2000 metres (2000M) to 5000 metres (5000M).

! The chart was issued at 11h00 Zulu (UT) on 28 September 2008 and was valid for 15h00 Zulu on the same day.

SIGNIFICANT WEATHER CHART: HIGH (Above FL180)

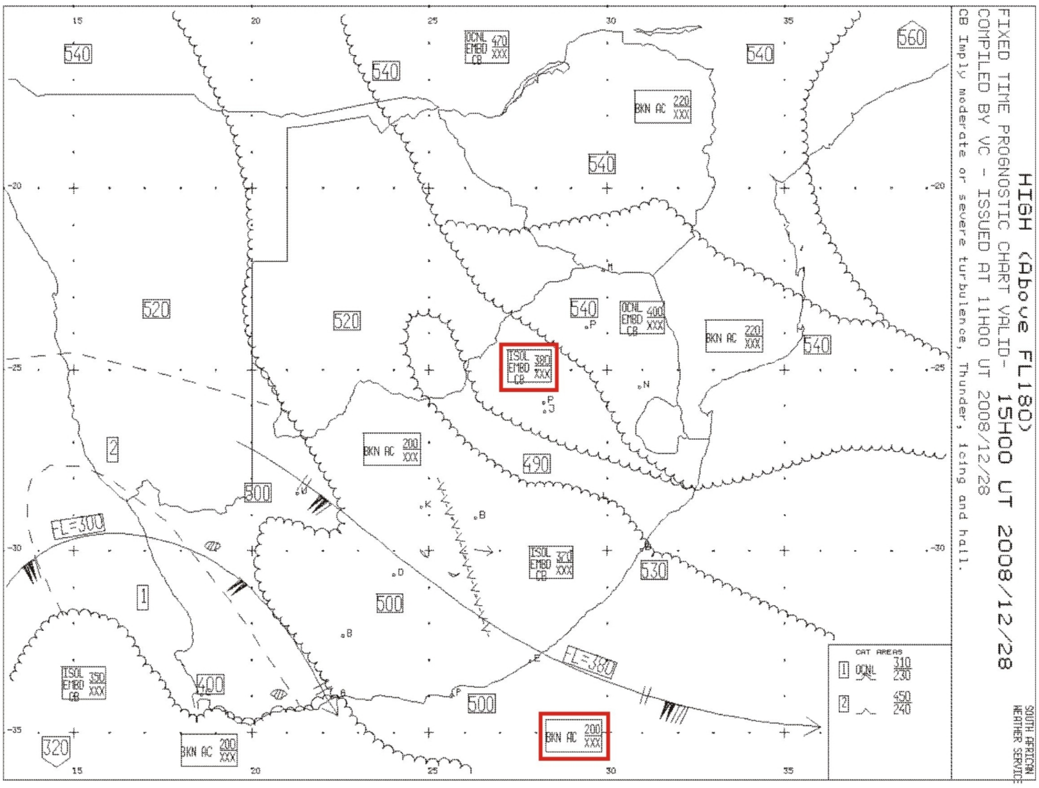


Figure 4.108

Significant Weather Chart (High)

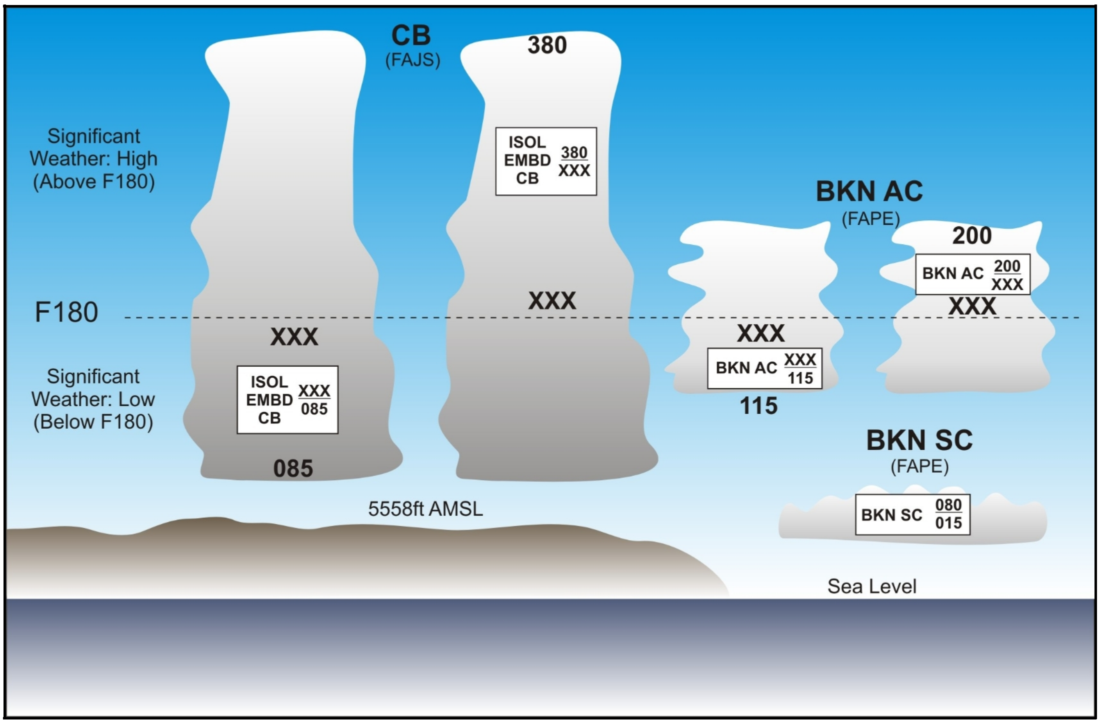


Figure 4.109

Plan View of Clouds Shown on High Sig Wx Chart

General summary of the information shown on the Significant Weather Chart:

! The final significant weather chart will obviously only contain information relating to high altitude flying, and is usually the one with the least information. This is because most of the water vapour occurs in the lower regions - up to about 18 000 feet.

! In this case the Cumulonimbus near Johannesburg extends up to FL380, and the Altocumulus south of Port Elizabeth extends up to FL200. In both cases the base is given as XXX which means you must find the base on the LOW chart. The highest cloud tops are found east of Polokwane (P) at FL400).

! The two arrows running from left to right indicates the position of the two jet streams on the chart. The altitude of the left hand jet is FL300 (FL=300), and the one on the right is FL380. The wind speed of the first starts at 110kts, 2 x pennant (50 each) and 1 x feather (10 each), reducing to 100kts, while the right hand jet starts at 11kts becoming 130. The point at which the speed changes is indicated by the two lines crossing the jet behind the 130kt indication. It is not uncommon to have speeds of 200 knots or more in these high altitude jet streams.

! In the CAT AREAS box on the right, the two areas of cat are indicated. 1 is the hatched section found south of the first jet and indicates that there is occasional severe turbulence between FL230 and FL310. The area 2 is just to the north and is moderate turbulence between FL241 and FL450. Mountain wave activity is also indicated to the east and north of Cape Town.

! The line squall on the low chart extends above FL180 and is situated in the same place as on the low chart

! The other information on the chart is the height of the Tropopause at various places. Around the coast it varies between FL400 (Cape Town) and FL560 (northern Mozambique coast), while inland it ranges between FL490 and FL540. The highest tropopause on the chart is at FL560, while the lowest is south-west of Cape Town at FL320.

!

Upper Winds and Temperatures

The Weather Bureau provides charts showing upper air winds and temperatures from 1000 feet above sea level up to 45000 feet (or FL 450). As a PPL you will only be examined on the lower levels up to FL 240. On the chart in Figure 4.xx you will see that these winds are given in what is known as the "Block" format. At points every 5° of latitude and longitude the winds and temperatures are provided for the forecast period. The forecast period is found to the right, and in the chart provided you will see that the chart was issued on 12UTC (1200 Zulu) on 20090402 (2 April 2009) and is valid for 00UTC (0000 Zulu) on 20090403 (3 April 2009).

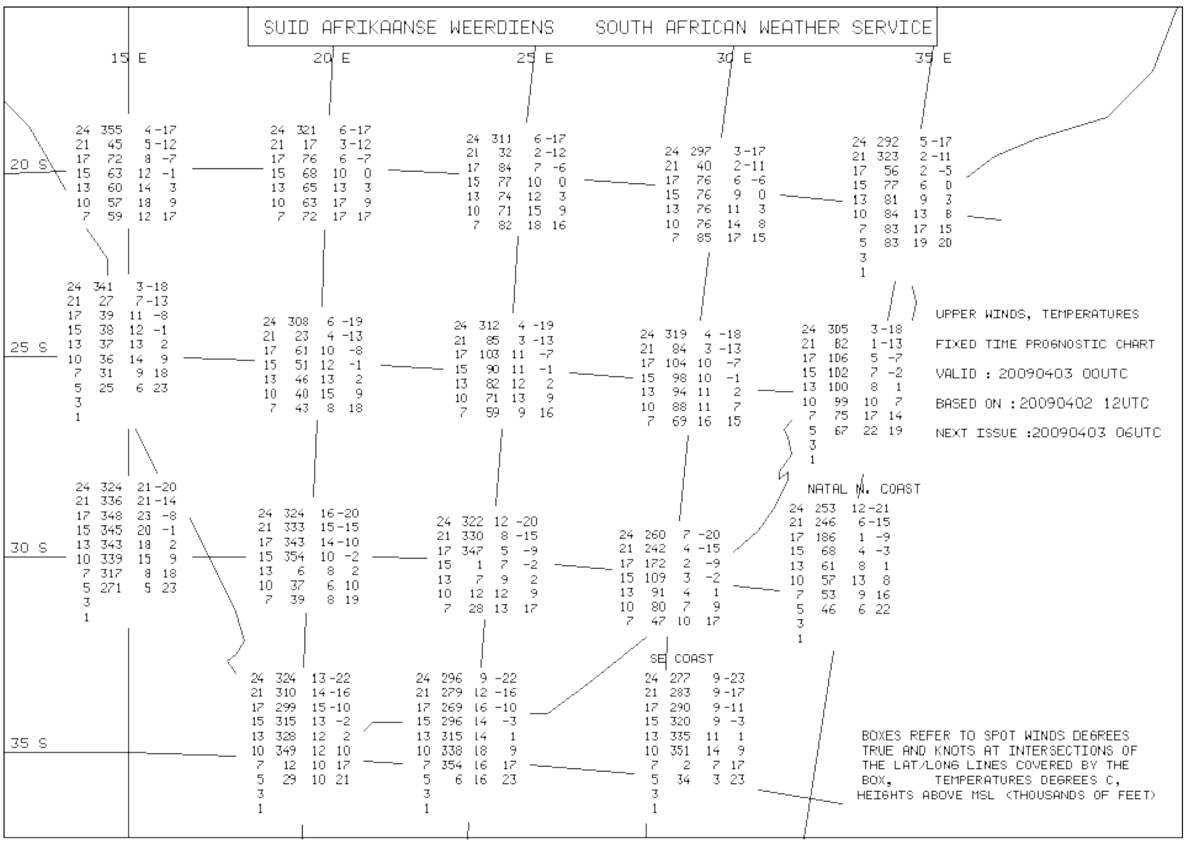


Figure 4.110

Upper Winds and Temperatures Chart (Low)

The block at the top left of the chart represents the wind and temperature at the position where the latitude of 20° South intersects the longitude of 15° East. At FL 240 the information given is

24 355 4 -17

This, as indicated in the text explanation at the bottom right, represents FL 240 (24000 feet above mean sea level), the wind is from 355° True, wind speed is 4 knots, and the temperature is -17°C.

At the intersection of 35° South and 20° East (more or less where Cape Town is located) the wind at FL240 is from 324° True, with a wind speed of 13 knots, and a temperature of -22°C.

Although not part of the PPL syllabus, the high level winds and temperatures are given in Figure 4.107 for purposes of comparison. On this chart the wind for the same position (35°S 20° East) at FL450 is 274° True at 32 knots, while the temperature is -64°C. This wind, as well as most others on the chart, is an indication of the westerly winds that prevail at altitude over the southern parts of the country, and the temperature is evidence that Mother Nature doesn't care too much about ISA, where it shouldn't be colder than -56,5°C. There will be days when the winds will be considerably stronger, and the temperatures much lower.

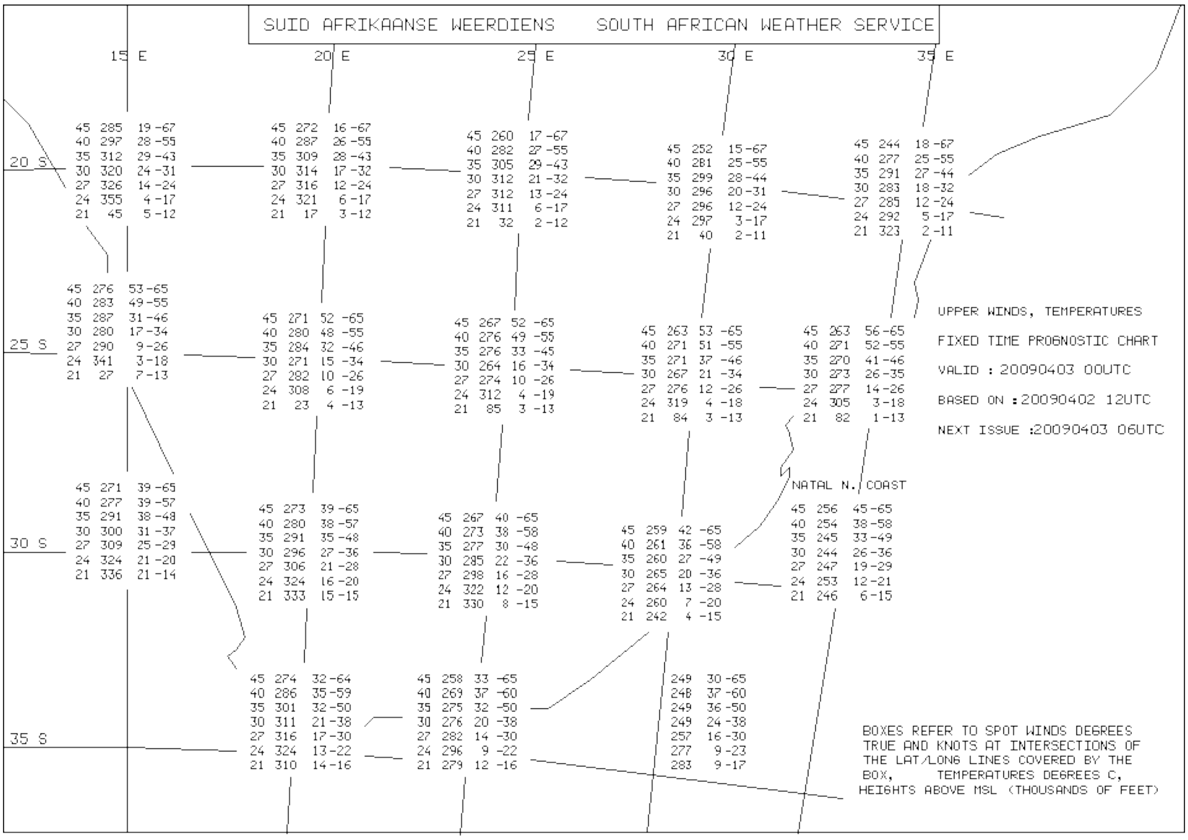


Figure 4.111

Upper Winds and Temperatures Chart (High)

The weather systems over the sub-tropical zone tend to move from west to east. A glance at the Upper Winds chart will show that a major part of South Africa lies in what is known as the Westerly Wave. Using this information we can start to do basic forecasting. If for example, the pressure in Port Elizabeth is 1023,1 hPa and the pressure at Port Alfred is 1018,6 hPa, what tendency can be expected?

> As the tendency of the weather is to move from west to east, the pressure should start rising as the higher pressure at Port Elizabeth starts to move towards Port Alfred. Knowing what is associated with a high pressure area gives you the opportunity of forecasting what changes may be expected.

Meteorological Broadcasts for Aviation

There are VHF frequencies available to the pilot near major airfields where met information may be obtained. This is called the VOLMET service, and is summarised below:

Name	Call-sign	Freq	Time	Hours	Station, Route, Area	Contents
Bloemfontein	BLV	114.1MHz	CONT	0400 - 2000	Bloemfontein	METARS & TRENDS
Cape Town	CTV	115,7 MHz	CONT	0400 - 2000	Cape Town	
Durban	DNV	112,5 MHz	CONT	0400 - 2000	Durban	
East London	ELV	114,5 MHz	CONT	0430 - 1930	East London	METARS
Johannesburg International	JSV	116,1 MHz	CONT	H24	Johannesburg International	METARS & TRENDS
Port Elizabeth	PEV	112,9 MHz	CONT	0430 - 1945	Port Elizabeth	

Note: The information provided by Johannesburg is updated at H+00 and H+30 between 0300 and 2200, and at H+00 between 2200 and 0300.

TYPICAL EXAMINATION QUESTIONS:

When taking any CAA test (or any test for that matter), keep the following in mind:

- Carefully read the instructions given with the test.
- Answer each question in accordance with the latest regulations

and guidance publications.

- Read each question carefully before looking at the answer options. You should clearly understand the problem before attempting to solve it.

- After formulating an answer, determine which answer option corresponds with your answer. The answer you choose should completely resolve the problem.

- From the answer options given, it may appear that there is more than one possible answer; however, there is only one answer that is correct and complete. The other answers are either incomplete, erroneous, or derived from popular misconceptions.

- If a certain question is difficult for you, it is best to mark it for review and proceed to the next question. After you answer the less difficult questions, return to those you marked for review and answer them. Although the computer should alert you to the unanswered questions, make sure every question has an answer recorded. This procedure will enable you to use the available time to maximum advantage.

- When solving a calculation problem, select the answer that most closely matches your solution. The problem has been checked by various individuals using different methods of calculation; therefore, if you have solved it correctly, your answer will be closer to the correct answer than any of the other choices. Also when doing calculations, remember to any conversions that may be required so that you will be solving the problem using similar units throughout.

- Make sure you have all the equipment that you are permitted to take into the examination room with you when you arrive. This includes your CX-2 Pathfinder, the E6B Whizzwheel, and a calculator that is non-programmable. Also have a ruler, protractor, dividers, pair of compasses, and a pen/pencil handy. You never know what you may need, so come prepared.

Here are some examples, the first one is a simple calculation:

When the pressure altitude is 0 feet and the temperature is 32 degrees Celsius, the density altitude will be:

a. 1,000 feet.
b. 2,000 feet.
c. 3,000 feet.
d. 4,000 feet.

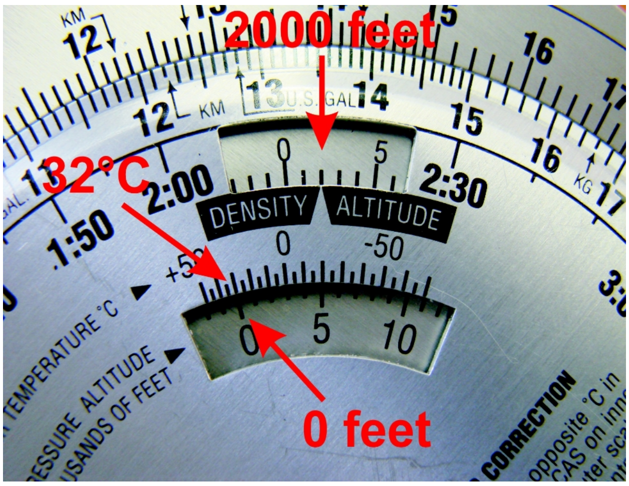
Answer and explanation:

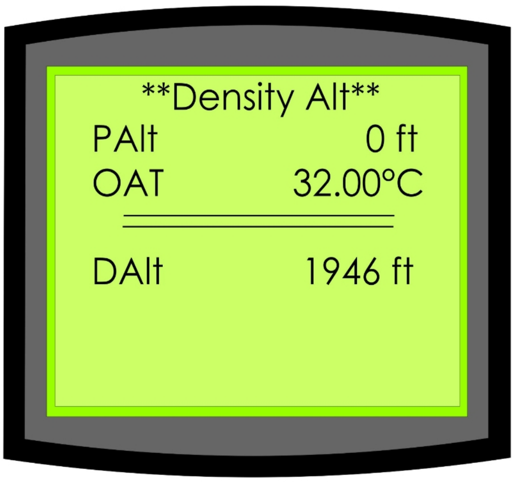
Pressure altitude is the indication on one's altimeter when the subscale is set to 1013,25hPa. Density altitude, is pressure altitude corrected for temperature. It is important to be aware of the density altitude, because a higher density altitude will degrade and aircraft's performance.

Density altitude can be:

*	calculated using the formula which is 120 feet for every 1°C deviation from ISA. At sea level the temperature should have been 15°C, but at 32°C it is 17° hotter, so add the answer to the airfield elevation to get the answer. 120 x 17 = 2040 feet density altitude.
*	computed using an E6B, when the pressure altitude and temperature is known. Using the given values, the closest is 2000 feet.
*	calculated using the CX-2 Pathfinder. This is the most accurate method and gives a value of 1946 feet.

Either way, 2000 feet is the nearest answer. Answer B.





The second question is an example of plain old theoretical fact:

What is the "thunderstorm stage of development" that consists mainly of down drafts?

a. The dissipating stage.
b. The cumulus stage.
c. The initial stage.
d. The mature stage.

Answer and explanation:

Straight fact. Thunderstorms will exist anywhere there is sufficient moisture, instability and an adequate lifting process. This lifting process can be created by a number of different means, such as: frontal lift, convergence, convection etc. Thunderstorms have three main stages:

- Cumulus stage - this is the initial stage where smaller cumulus clouds begin to group together to form one large cumulus cloud. In this stage the developing cumulus cloud is mainly comprised of strong updrafts. There is little no precipitation in this stage.

- Mature stage - in this stage the thunderstorm has fully developed and will produce extremely strong up and down drafts. These strong up and down drafts will suspend moisture for a longer period of time producing very large water droplets and/or hail. A mature thunderstorm will produce the following weather: heavy rain, hail, lightning, microbursts, macrobursts, windshear, downbursts, tornados, and icing. The mature stage generally lasts 15 to 20 minutes. The top of a mature thunderstorm can reach the tropopause.

- Dissipating stage - in this stage the thunderstorm is mainly down drafts, except at the top of the thunderstorm where the anvil structure develops.

The only correct statement is Option A. Options B and C relate to the same stage, where drafts are up, while Option D relates to the stage where up and down drafts are found

The third type of question relates to the practical application of facts:

A secondary low will orbit .... the primary low.

a. outside of
b. counter clockwise about
c. clockwise about
d. slowly about

Answer and explanation:

Low pressure systems are also known as depressions or cyclones, and their general characteristics are:

- Generally areas of poor weather, precipitation.
- An area where the lowest pressure is realized at its centre.
- An area of ascending or rising air.
- The airflow is clockwise rotating and inward, in relation to the isobars.
- The intensity of a low is dependent upon the pressure gradient, how quickly the pressure decreases towards the centre of the low.

A secondary low is an area of low pressure found within a deeper low. As the whole system of which the secondary low is part is rotating clockwise, it stands to reason that the secondary low will follow a clockwise path around the deeper low.

Option A suggests that it would rotate outside the primary low, but a secondary is found within the primary low. Option B would be correct for the Northern Hemisphere, and Option D could be proved wrong in a very intense low where rotational speeds will be high. The only correct option is Answer C.

Now with this in mind, try the following using the processes described in the preceding questions:

1. The highest density levels in the atmosphere will be recorded at sea level in:

a. high pressure systems at the poles
b. low pressure systems at the poles
c. high pressure systems at the equator
d. low pressure systems at the equator

2. The daily maximum temperature normally occurs at around:

a. 1200hr LMT when insolation is at its maximum and terrestrial radiation is at its minimum
b. 1200hr LMT when insolation is at its maximum and terrestrial radiation is at its maximum
c. 1430hr LMT when solar radiation is at its maximum and is equal to the steadily increasing terrestrial radiation
d. 1430hr LMT when solar radiation is decreasing and terrestrial radiation is at its maximum

3. In the troposphere:

a. low air mass temperatures result in low pressures aloft
b. in high temperature air masses pressure levels will be at greater heights
c. in low temperature air masses the tropopause will be lower
d. All of the above are correct

4. The stratosphere extends on average from:

a. 36,090ft to 20km above the earth's surface
b. 36,090ft to 30km above the earth's surface
c. 11km to 20km above the earth's surface
d. 11km to 50km above the earth's surface

5. The International Standard Atmosphere assumes that the following lapse rate and surface conditions exist:

	Pressure	Temperature	Lapse rate	Density
a.	1012.25hPa	+1 5°C	1.98°/1000ff	1225gm/M^3
b.	1013.25hPa	+15°C	1.89°/1000ft	1225gm/M^3
c.	1013.25hPa	+15°C	1.98°/1000ft	1252gm/M^3
d.	1013.25hPa	+15°C	1.98°/1000ft	1225gm/M^3

6. Average tropopause heights, winter and summer, would be:

a. Latitude 60° - 25,000ft and 35,000ft
b. Latitude 25° - 50,000ft and 75,000ft
c. Latitude 25° - 75,000ft and 50,000ft
d. Latitude 60° - 35,000ft and 25,000ft

7. The level in the atmosphere where the air temperature ceases to fall with increase in height is known as:

a. the troposphere
b. the stratosphere
c. the stratopause
d. the tropopause

8. Which of the following statements is not true?

a. In the lower stratosphere temperature is roughly constant with height
b. Above the stratopause the temperature falls to below minus 273°C
c. In the troposphere temperature usually falls with increasing height
d. Pressure and density always fall with increasing height

9. A SPECI, will be issued to amend

a. a TAF where the forecast conditions have changed significantly.
b. a METAR where there has been a significant change in the weather.
c. a SIGMET where the forecast conditions have changed significantly.
d. an ATIS where there has been a significant change in the weather.

10. The tropopause at 55° North is .... in winter than in summer and .... than at 30° North:

a.	higher	lower
b.	lower	higher
c.	lower	lower
d.	higher	higher

The following questions do not offer any answer options. There may be more than one correct answer, so use your knowledge and the Meteorology text to find possible solutions.

1. An aircraft is flying at FL095, OAT +5°C. The temperature deviation from ISA is:

2. Air has a tendency to flow from:

3. The average height of the troposphere:

4. In a temperature inversion:

5. The term "insolation" is used to define the:

6. In terms of visibility, the difference between fog and mist is that:

7. Adiabatic process is the term used to describe:

8 The dewpoint temperature is the temperature at which a particular air mass:

9. A sea breeze will be found at coastal areas:

10. On a clear night, light winds and moist air blowing over the land will most probably create:

11. The ideal conditions for the formation of advection fog are:

12. Polar maritime air is characterised by:

13. The factor most likely to cause a decrease in the stability of an air mass is:

14. The symbol SCT is used to indicate:

15. The information which is provided by the ATIS includes:

16. The weather condition associated with a surface temperature inversion is:

17. Whilst flying in the vicinity of a mountain range a pilot observes formations of static lenticular cloud. The pilot should expect:

18. In stable conditions, with a strong wind blowing over a mountain range or high ridge of hills:

19. A METAR is:-

20. A TAF is:

21. Air density will:

22. The flow of air from a high to a low in the southern hemisphere is deflected by the Coriolis force:

23. Following the passage of a cold front:

24. Virga is:

25. As a polar maritime air mass passes over South Africa during summer it will:

26. Convergence is associated with:

27. Following the passage of a warm front in South Africa:

28. The Black South Easter is a wind which occurs in South Africa when:

29. When the standard pressure setting, 1013 hPa, is set on the subscale of the altimeter of an aircraft on the ground at an aerodrome, the altimeter will indicate:

30. When QFE is set on the subscale of the altimeter of an aircraft on the ground at an aerodrome, the instrument will read:

ANSWERS:

1	2	3	4	5	6	7	8	9	10
A	D	D	D	D	A	D	B	B	C

ANSWERS EXPLAINED:

1. Density is directly proportional to pressure and inversely proportional to temperature. so for maximum density at sea level we are looking for high msl pressure and low msl temperature, in surface high pressure systems at the poles - or possibly in Siberia in winter, but that wasn't one of the choices. Answer A.

2. First of all, we know that maximum day temperatures occur after 1200LMT. Answers a. and b. are therefore wrong. The rate of terrestrial radiation depends on the surface temperature, so maximum temperature equals maximum level of radiation out. Equally, we know that the incoming radiation from the sun is at its maximum at 1200LMT, and both these factors point to Answer D.

3. True, all true. In cold air pressure falls more rapidly as you climb, resulting in lower pressures aloft. Likewise, in higher temperature air masses pressure is higher aloft, so pressure levels will be at higher altitudes. It is also true that 'low temp = low trap, high temp = high trop.' Answer D.

4. The average tropopause height, on which ISA is based, is 11km, which translates to 36,090ft in Imperial units. The stratosphere extends from the tropopause to about 50km. Answer D.

5. Facts. Answer D.

6. Answers B and C are way off. No trop height reaches 75,000ft, winter or summer, so the question is just about Latitude 60, low trop in winter, high trop in summer, and the figures given are about right. Answer A.

7. The troposphere is defined as the layer of the atmosphere next to the earth where temperature falls as height increases. By taking temperature soundings aloft we find the height where this stops, and where the temperature either remains constant or rises with increasing height. This marks the upper limit of the troposphere, and is called the tropopause. Answer D.

8. Temperature can never fall below absolute zero, minus 273°C, and even at great heights it does not approach this figure. Options A, C and D are all true statements. Note particularly option D. Temperature may rise with increasing height, but not pressure or density. Answer B.

9. A SPECI, is a "Special Weather Report," that will be issued where significant changes in the weather have been observed between the regular issue times of a METAR. A SPECI, will be issued whenever the following changes occur:

   - Significant increase or decrease in the ceiling.
   - Significant changes in the sky condition: i.e., a layer is observed below 1,000 feet and no layer aloft was observed in the previous METAR.
   - Significant increase or decrease in visibility.
   - An observed, dissipated, or reported, tornado, waterspout, or funnel cloud.
   - A thunderstorm either begins, becomes "heavy" in intensity, or ends.
   - Precipitation either begins or ends.
   - The wind changes direction considerably or the wind intensity doubles and is greater than 30 knots.

Answer B.

10. The rule of thumb is ‘low temp - low trop, high temp - high trop’ but do remember that it is airmass temperature this refers to, not surface temperature. The tropopause is highest in the hot air near the equator, about FL550 out to Latitude 30 on either side, and comes lower toward the poles, with a break jump at the polar front. At latitude 60 the airmass temperatures are warmer in summer and colder in winter, so the tropopause will be low in the winter - sometimes down to FL230 - 250, and higher in the summer, up to about FL300 - 350. Answer C.

Answers to the straight questions - remember that these are not necessarily the only correct answers to each of them, but those given below are all correct options:

1. +9°C

2. out of an area of high pressure and into an area of low pressure

3. is greatest at the equator

4. the temperature increases with an increase height

5. heating of the earth's surface by the sun

6. fog has a visibility of less than 1000 metres

7. the cooling of air as it rises and expands

8 becomes saturated

9. during the day

10. radiation fog

11. warm moist air blowing over a cold surface

12. stable conditions at its source

13. warming of the air mass from below

14. 3 to 4 oktas of cloud

15. the airfield's surface wind, QNH, visibility and runway in use

16. an increase in temperature with altitude

17. considerable turbulence

18. mountain wave turbulence is to be expected

19. a report of actual weather at an aerodrome

20. a weather forecast for an aerodrome

21. decrease with an increase in humidity

22. to the left

23. the pressure will begin to rise

24. rain which evaporates before it reaches the surface

25. absorb heat in the lower layers and become unstable

26. rising air and a low pressure system with instability

27. the pressure will begin to rise

28. there is a well developed high pressure system to the west of Cape Town, with strong pressure gradients and a long sea track

29. pressure altitude

30. zero (or the height of the static source above the ground