Meteorology and Hydrology Faculty

AVIATION METEOROLOGY

(chapter 1)

2nd Semester

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Chapter I

Meteorological aspect of Aviation

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1.2 The basic forces acting on aircraft
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Chapter I
Meteorological aspect of Aviation

Introduction

- Weather is an interesting phenomenon of nature that influence our lives.

- Most of the weather that occurs on our planet happens below 1500ft(457.2 m). That is great if you are flying a commercial jetliner at a high altitude of perhaps 30,000ft where there is hardly any weather.

- For the majority of us we are “under the weather” most of the time.

- Weather is the utmost consideration of all pilots when planning a flight. Therefor, the weather at the departure airport, all along the route and at the destination airport must be constantly monitored.

- So we consider the major weather conditions that affect flying.

The Atmosphere

- The atmosphere is essentially a mixture of gases. Within these gases **tiny solid particles of dust and smoke** are suspended. In addition, water occurs not only as a vapour, but also in solid and liquid forms.

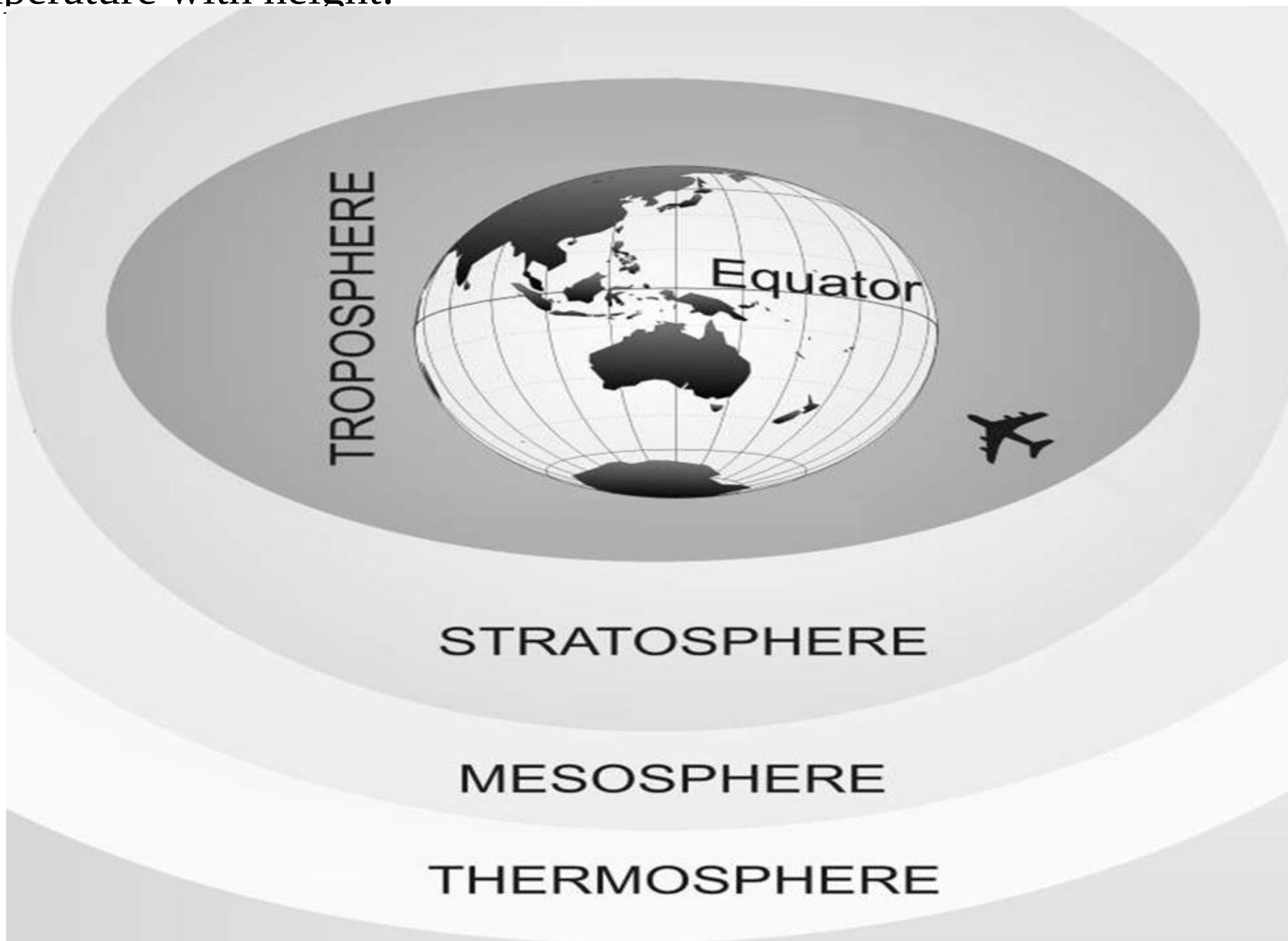
- **Water vapour** is the most important gas as far as meteorology is concerned. The amount of water vapour in the air (often expressed as humidity) varies greatly between the **oceans and deserts, between ground level and higher altitudes, and between cold and hot regions**.

- Even though water vapour makes up only a small percentage of the atmosphere, **the energy released/consumed as it changes from gas to liquid to ice and back again,** drives many **severe weather systems** such as thunderstorms, tornadoes and cyclones

- What is that energy?

Vertical divisions of the atmosphere

The atmosphere can be divided into four layers based on the **mean** variation of temperature with height:



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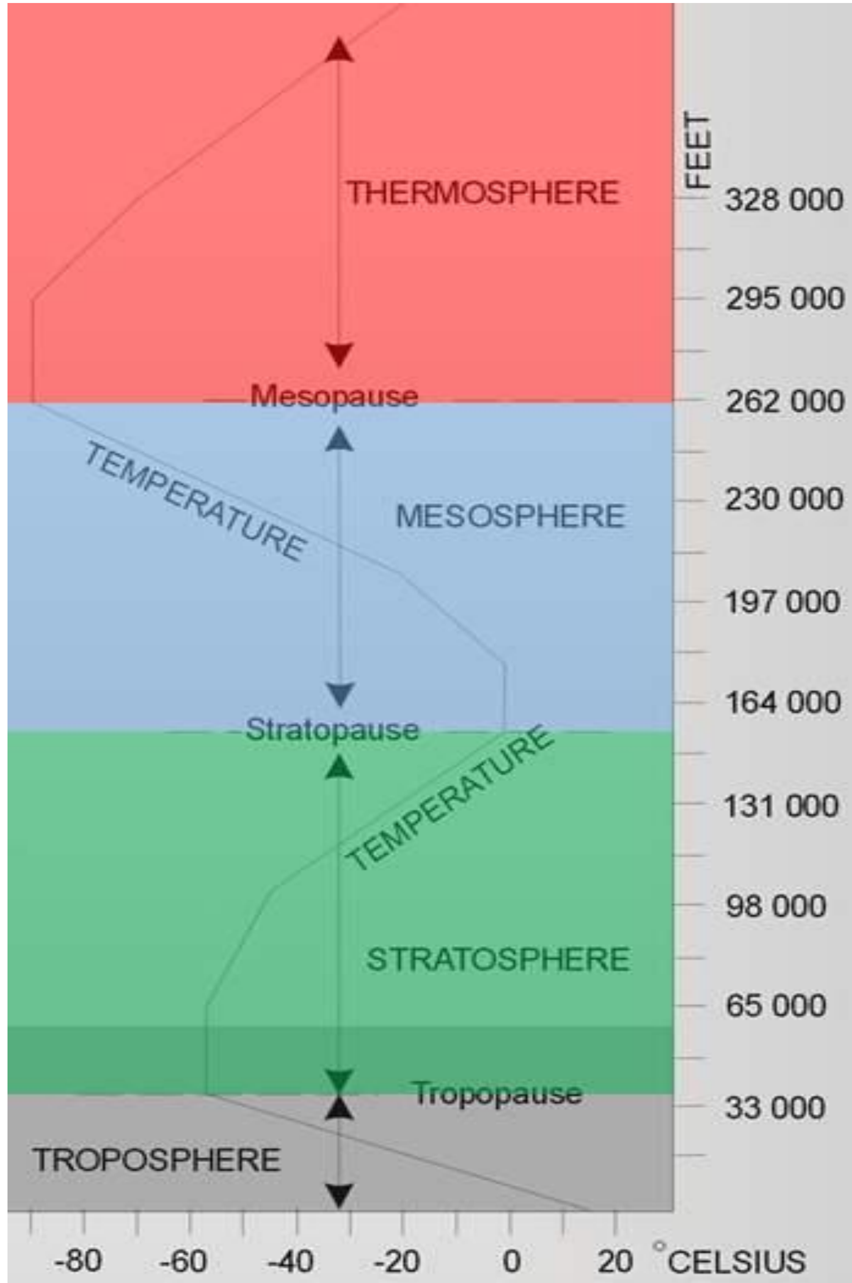
- The troposphere, the lowest layer, is **deeper over the tropics (60,000ft) than the poles(20,000ft)**.

- The boundary between the troposphere and the stratosphere is called the **tropopause**. Its height varies with **latitude, the season and the movement of weather systems.**

- The troposphere is mainly heated from below by the earth's surface, and has temperatures that generally decrease with height. (i.e T^{o} lapse Rate)

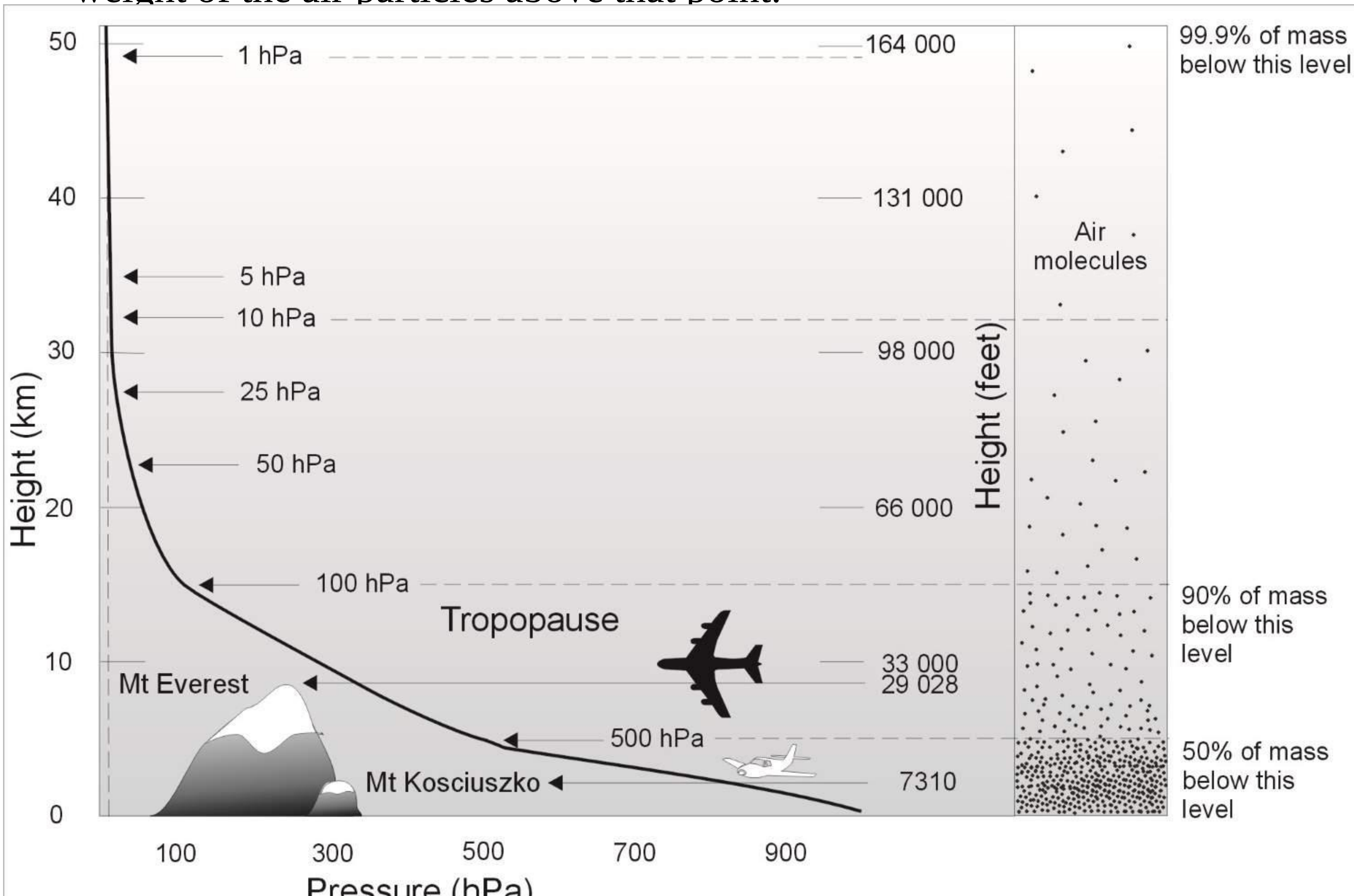
- The troposphere contains most of the mass of the atmosphere. It is characterized by marked **vertical air motions**, appreciable **water vapour**, **cloud** and **weather**.

Temperature variation with altitude in each atmospheric layer



The weight of the atmosphere

- The pressure exerted by the atmospheric gases at any altitude depends on the weight of the air particles above that point.



The weight of the atmosphere

- The diagram shows that the atmospheric pressure near mean sea level is about **1013 hectopascal (hPa)** while at an altitude of **50km** the pressure is only about **one hPa**, indicating that only about **one-thousandth** of the mass of the atmosphere exists above 50km.

- Atmospheric pressure decreases more rapidly with height in the lower layers - note the shape of the curve in the diagram.

- At an altitude of 18,500 feet (500hPa) one half of the atmosphere's molecules would already be below you. That is, half of the mass (weight) of the atmosphere is contained in the layer below this altitude.

1.2 The basic forces acting on aircraft

Airplanes: how do they fly?

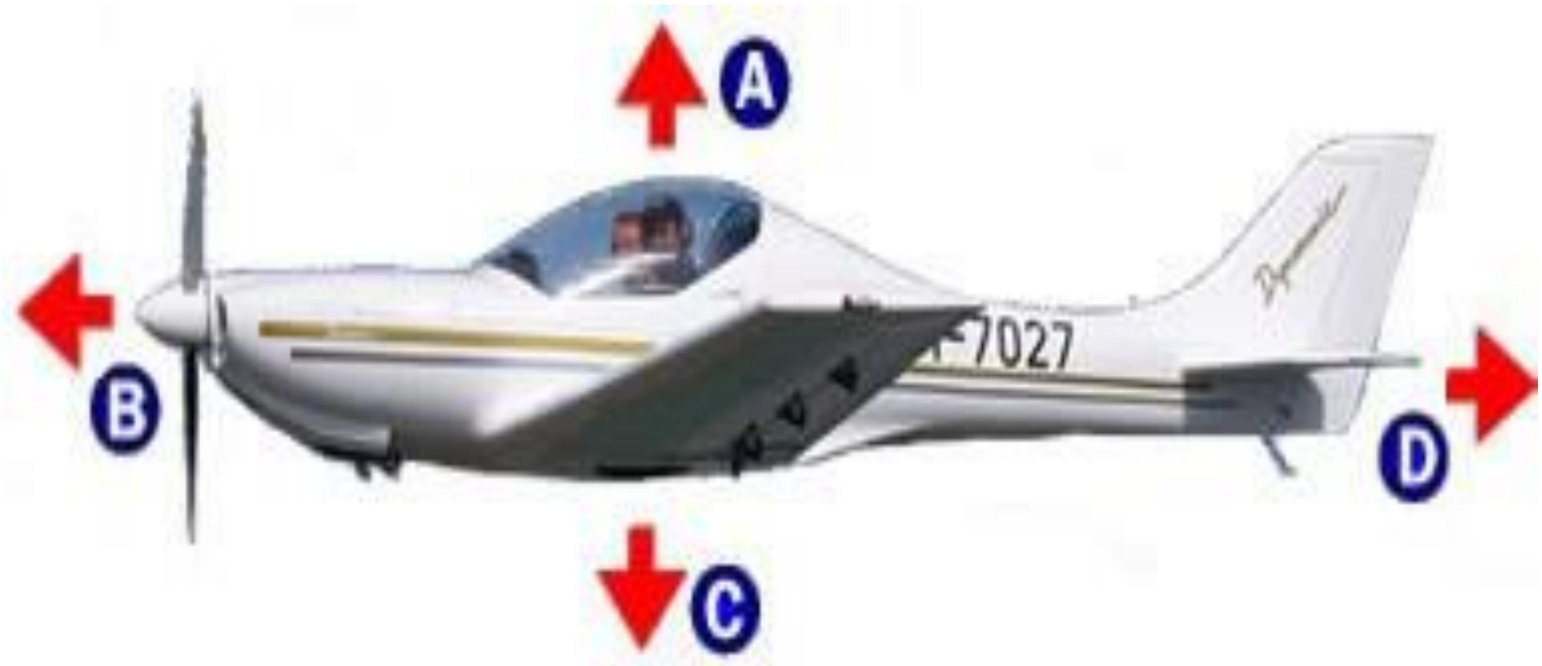
- For a moment, think of an airplane moving from left to right and the flow of air moving from right to left.

- An airplane in flight is the centre of a continuous tug of war between **four forces**: **lift, gravity force or weight, thrust, and drag**.

- **The weight or force due to gravity** pulls down on the plane opposing the **lift** created by air flowing over the wing.

- **Thrust** is generated by the propeller (Engine) and opposes **drag** caused by air resistance to the frontal area of the airplane.

The four forces acting on an aero plane



A Lift

B Thrust

C Weight

D Drag

Cont…

- **Lift and Drag** are considered **aerodynamic forces** because they exist due to the movement of **the aircraft through the air**.

- **During take-off**, thrust must be greater than drag and lift must be **greater than** weight so that the airplane can become airborne.

- **For landing,** thrust must be **less than** drag, and lift must be **less than** weight.

- Over 95 percent of all aviation accidents happen during take-off and landing phases of the flights.

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Thrust

- Thrust is a force created by a power source which gives an airplane forward motion.
- It can either "pull" or "push" an airplane forward.
- Thrust is that force which overcomes drag.
- Conventional airplanes utilize engines as well as propellers to obtain thrust.

Cont…

Drag

- Drag is the force which delays or slows the forward movement of an airplane **through the air** when the airflow direction **is opposite** to the direction of motion of the airplane.

- It is the friction of the air as it meets and passes over and about an airplane and its components.

- The more surface area exposed to rushing air, the greater the drag.

- An **airplane's streamlined shape** helps it pass through the air more easily.

Lift

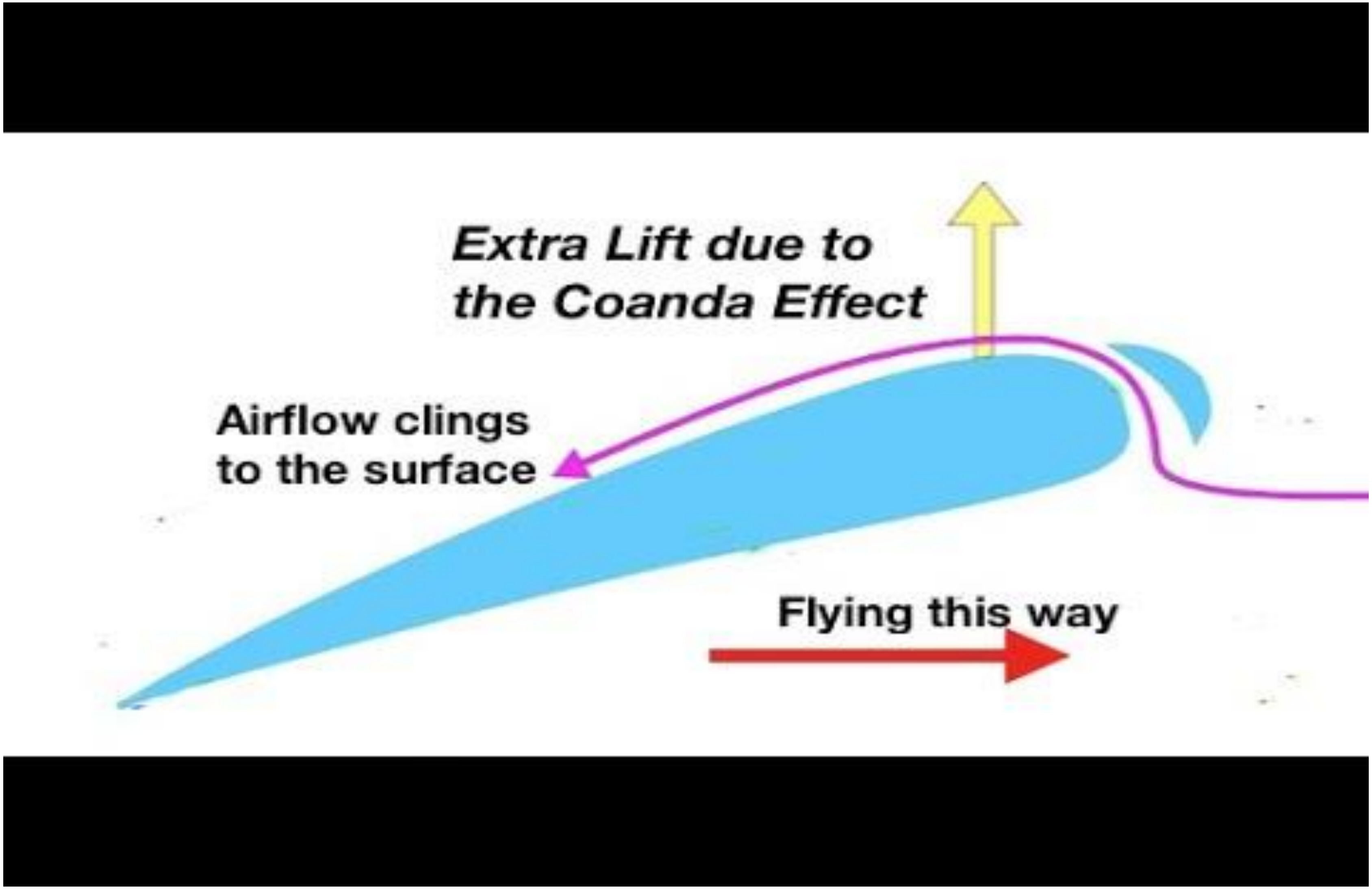
- Lift is generally explained by three theories: **Bernoulli's principle** , **the Coanda effect** , and **Newton's third law of motion .**
- Bernoulli's principle states that **the pressure of a moving gas decreases as its velocity increases.**

❑ When air flows over a wing having a curved upper surface and a flat lower surface, the flow is **faster across the curved surface than across the plane one**; thus a **greater pressure** is exerted in the upward direction.

❑ This principle, however, does not fully explain flight; for example, it does not explain how an airplane can fly upside down.

❑ Scientists have begun suggesting that the **Coanda effect** is at least partially responsible for how planes fly.

Coanda effect



Lift

- Regardless of the shape of a plane's wing, the Coanda effect, in which **moving air is attracted to and flows along the surface of the wing, and the tilt of the wing, called the angle of attack, causes the air to flow downward as it leaves the wing.**

- The greater the angle of attack, the greater the downward flow. In obedience to **Newton's third law of motion**, which requires an equal and opposite reaction, the airplane is deflected upward.

- At the same time, a force that retards the forward motion of the aircraft is developed by diverting air in this way and is known as **drag due to lift**.

Lift

- Lift is produced by a **lower pressure created on the upper surface** of an airplane's wing compared to the **pressure on the wing's lower surface**, causing the wing to be "lifted" upward.

- The special shape of the **airplane wing (airfoil)** is designed so that air flowing over it will have to **travel a greater distance faster**, resulting in a lower pressure area thus lifting the wing upward.

- Lift is that force which opposes the force of gravity (or weight).

wing shape (aero foil)

- The special shape of **the airplane wing (air foil)** is designed so that air flowing over it will have to travel a greater distance - faster - resulting in a low pressure area thus lifting the wing upward.

- Laminar Flow is the smooth, uninterrupted flow of air over the contour of the wings, fuselage, or other parts of an aircraft in flight

- Laminar flow is most often found at the front of a streamlined body and is an important factor in flight.

- If the smooth flow of air is interrupted over a wing section, **turbulence** is created which results **in a loss of lift and a high degree of drag**.

- An airfoil designed for minimum drag and uninterrupted flow of the boundary layer is called a laminar airfoil.

Angle of attack

- The angle of attack is the angle that **the wing presents to oncoming air**, and it controls the thickness of the slice of air the wing is cutting off.

- Because it controls the slice, the angle of attack also controls the amount of lift that the wing generates (although it is not the only factor).

Zero angle of attack   Shallow angle of attack   steep angle of attack

1.3 Effect of meteorological parameters on an aircraft

- Weather effect to an aircraft are in almost every action that a pilot of an aircraft takes.

- Meteorological parameters that are considered in aviation includes RH, Temperature, pressure, wind, jet stream, clouds, thunderstorm, fog, hurricanes, snow, rain etc…

- Most of these weather elements have to be considered at the aircraft parking, take-off, en-route flight and landing phase of the aircraft.

Air Temperature

- Temperature is the measure of the internal heat energy of a substance.

- If you add or subtract heat to or from an object, then provided it does not change its state, the temperature will rise or fall, dependent on the molecular make-up of the substance.

- The change in surface temperature from day to night is referred to as the diurnal temperature variation.

- Over land, diurnal variation is much **greater than** over the sea because the sea has a higher specific heat or a greater ability to retain its heat.

- Over land, variation could be as great as 25 to 30^{o}C, while ocean temperature variation may only be a degree or two.

Cont…

- Diurnal variation is greatest when there is little or no wind and no cloud cover. Why?

- If it is windy, the air will **mix** through a deeper layer, allowing daily gains and nightly losses of heat to be shared through a **greater depth** of the atmosphere.

- If there is cloud cover, the cloud behaves like a blanket and insulates the lower atmosphere. It inhibits warming by the sun during the day and inhibits heat loss by night.

- The temperature decreases with altitude in the troposphere at about 2°C per 1000 feet. This means if the temperature at sea level is 15°C, on average it will decrease to a value of -15°C at 15 000 feet (i.e. a fall of 30°C).

- **The changes in temperature also affect air density and so impact aircraft performance**. (how?)

Temperature/Air Density

- The changes in temperature affect air density and so impact aircraft performance.

- In science we learnt that when you heat air it expands and when it expands its density decreases.

- For the engines to be able to lift the huge mass of the airplane, the air density has to be considered.

- Air density is very important and will certainly determine the Takeoff weight of the aircraft.

- The higher the air temperature there is the lower the air density and the lower the Take off weight of the aircraft.

Cont…

- Naturally, when the air temperature is low then you will load a heavier take-off weight as the airplane will be able to built sufficient thrust, but only if the length of the runway will permit.

- But even after a successful takeoff, you still have to bother with temperatures.

- Remember flying in the air is like floating in the air and for the airplane to fly the air density will remain a factor to be considered from the airport of departure, en-route and up to the airport of destination.

- If we look at Boeing 777 airplane with a Long Range Cruise altitude of 37,000 feet, then you know that the temperatures at that height of 37000 feet are negatives in minus 30 degree Celsius range.

Cont…

- At such low temperatures, you will expect ice to form on the airplane.
- Ice is very dense and if it forms on the plane then it will bring it down because the whole thing will become very heavy.
- But look at the Normal cruise Speed of 900 km/h. At such speeds, there usually is a lot of friction between air and the airplane.
- With lots of friction comes heating which goes a long way to control the icing that may develop.
- The idea is to obtain an optimum equilibrium between the air density, airplane weight, air temperature, speed of the airplane among other factors.

Cont…

- How then are the temperature reports obtained for such high altitudes so that an airplane appropriate weights can be computed before takeoff from airport of departure?
- At any one time, there are thousands of planes in the air. Aircrafts do make observations of winds, air temperatures and other special phenomena at specific intervals in the atmosphere.

- These reports are called air-reports (AIREPs). These reports are then compiled by weather personnel and disseminated through out the world.
- These weather elements of wind, temperature and pressure are also observed by use of weather satellites as well as weather radiosondes.

- A radiosonde is a balloon-borne weather observing instrument with radio transmitting capabilities of weather elements of wind speed, wind direction, air temperature, air-pressure and air relative humidity.

Air Density

- Air density is a major factor in aerodynamic performance and aircraft engine efficiency.

- Air density is the mass per unit volume of the Earth's atmosphere or more simply, the number of air molecules in a given volume.

- Most of our experiences with density involve solids. We know that some objects are heavier than others, even though they are the same size.

- A brick and a loaf of bread are about the same size, but a brick is heavier; it is denser.

- For gases though, the molecules are free to move about so density can vary over a wide range. Air at the earth's surface has a very different density than air at greater heights.

Cont…

- Increases in air temperature, humidity or altitude are coupled to decreases in air density. (WHY?)

Low air density decreases aircraft performance in a number of ways:

- The lifting force of an aero-plane's wings or helicopter's rotor decreases
- The power produced by the engine decreases;
- The thrust of a propeller, rotor or jet engine decreases.

- All three of these factors reduce climb rates and can drastically reduce maximum take-off weight.

- Also, all other factors being equal, lower air densities require longer take-off and landing distances for fixed wing aircraft.

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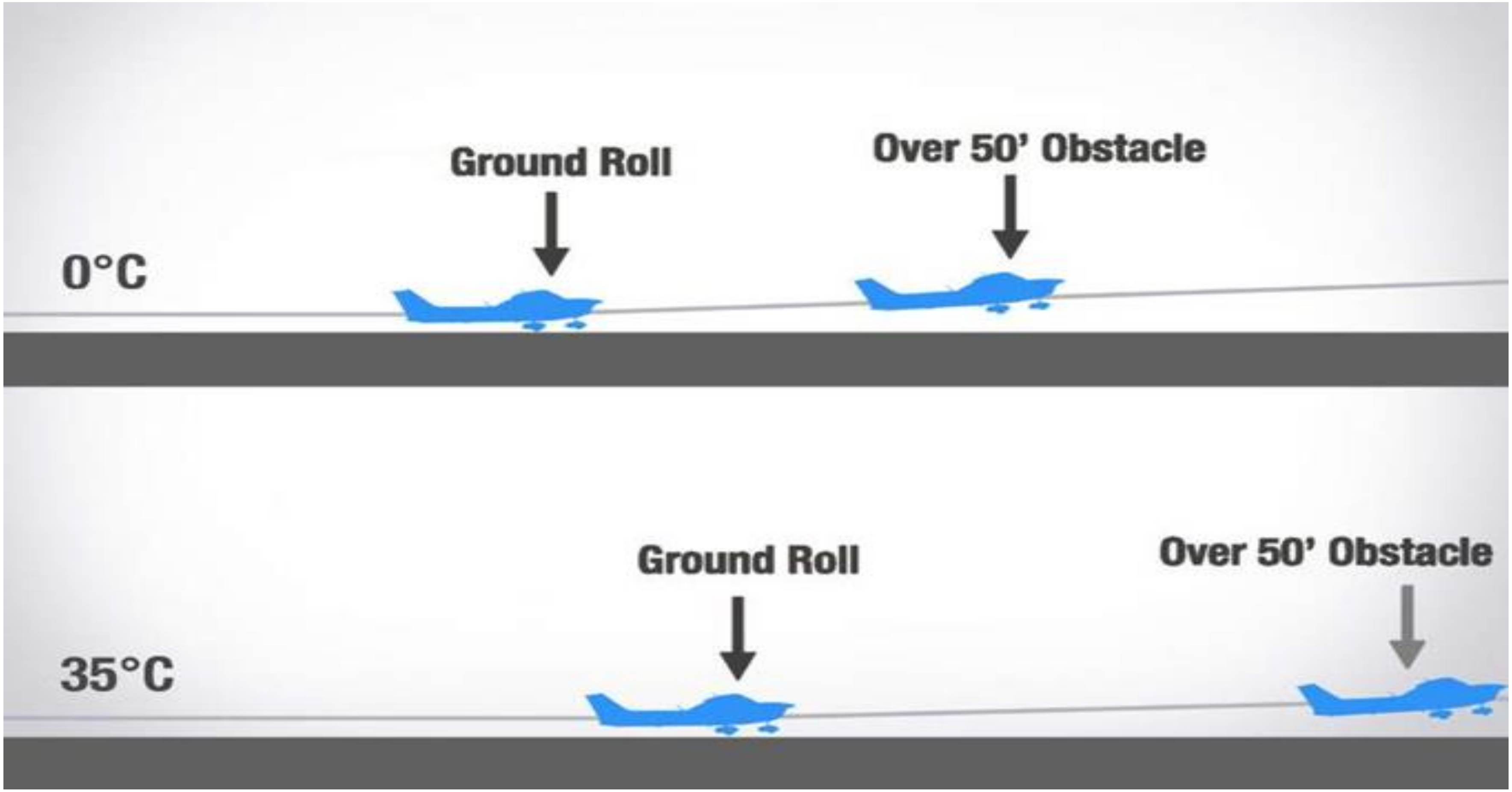

Figure: Higher air temperature, lower air density, longer distance for take-off and landing.

The density of dry air

- The density of dry air having a pressure of **1013.25 hPa** at **15°C** is **1.225 kg per cubic metre**.

- For dry air, the density is related to pressure and temperature by the **fundamental gas equation**:

$$D = P/RT$$

where:

D is the density,

P is the pressure,

T is the absolute temperature, and

R is a constant.

Cont…

The equation shows:

- ✓ For a <u>fixed temperature</u>, the density of dry air will increase as pressure increases (as air is compressed it occupies a smaller volume);
- ✓ With <u>constant pressure</u>, density will decrease as temperature increases. To retain the same pressure the air must occupy a larger volume.

Density variation

Factors other than temperature and pressure affect air density:

- **Moist air**:- Water vapour is a less dense gas than dry air, so the combination of water vapour and dry air (called 'moist air') is less dense than dry air at the same pressure and temperature.
- **Height: -** The density of air at 18,500 feet(500hp) is about half the surface value. It then drops to about one quarter at 40,000 feet, and about one tenth at 60,000 feet as depicted in the diagram.

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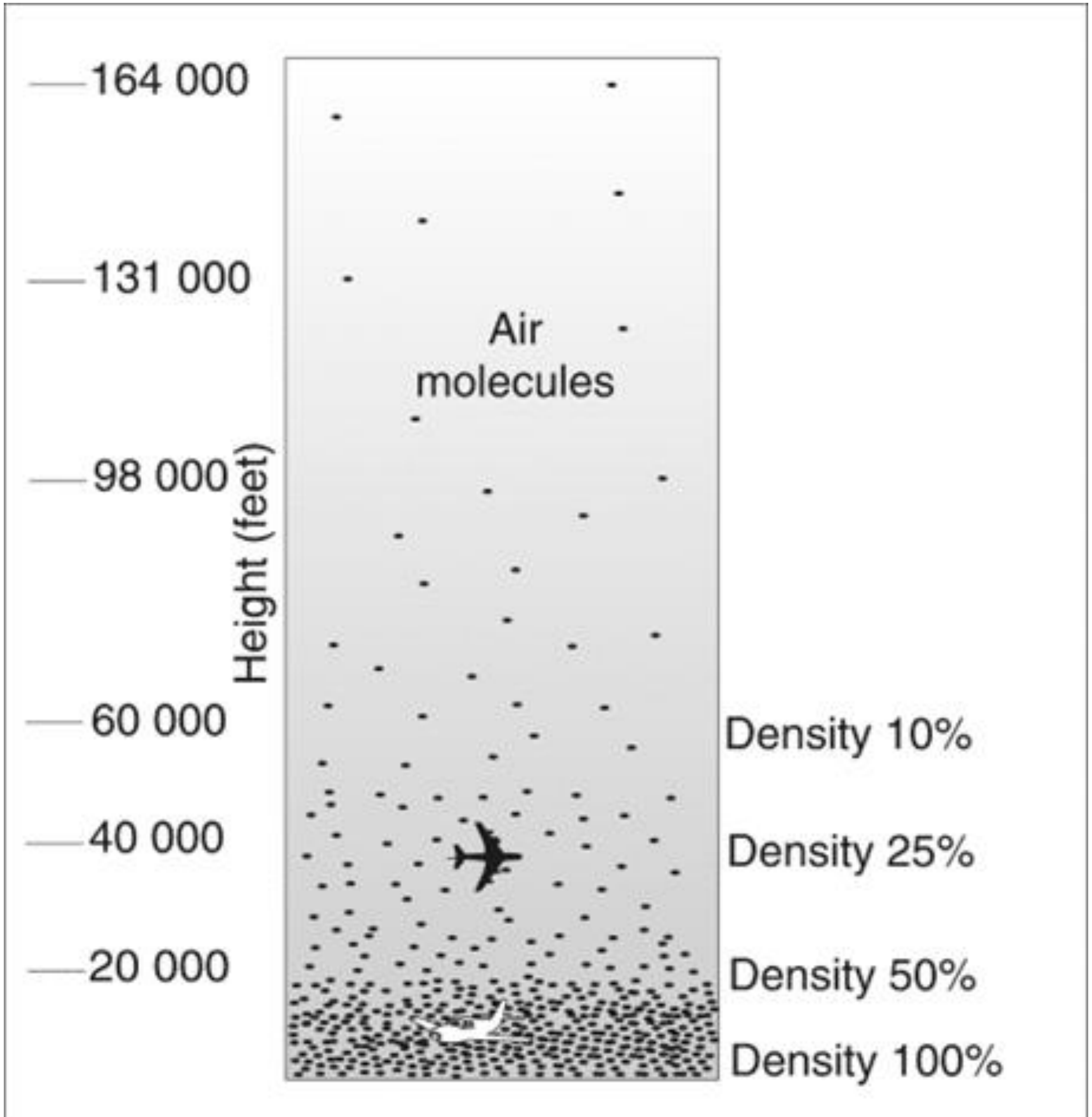


Figure: Variation of density with height

Atmospheric Pressure

- Atmospheric pressure is a measure of the total weight of the atmosphere above the point of measurement.

1hPa = 100 Pascals = 100 Newtons per square metre

- Surface pressures normally range between 1040 hPa and 970 hPa. However, extreme values of 1084 hPa and 870 hPa have been recorded.

- The variations of pressure are closely related to the generation of wind and changes in the weather.

- The intimate relationship between pressure and height is utilised by the pressure altimeter for determining the height of aircraft.

Cont…

- Surface pressures are also used for the production of weather charts.

- The weather charts comprise smooth curved lines of mean sea level pressure called **isobars** (lines of equal atmospheric pressure). Isobars depict weather systems such as highs and lows.

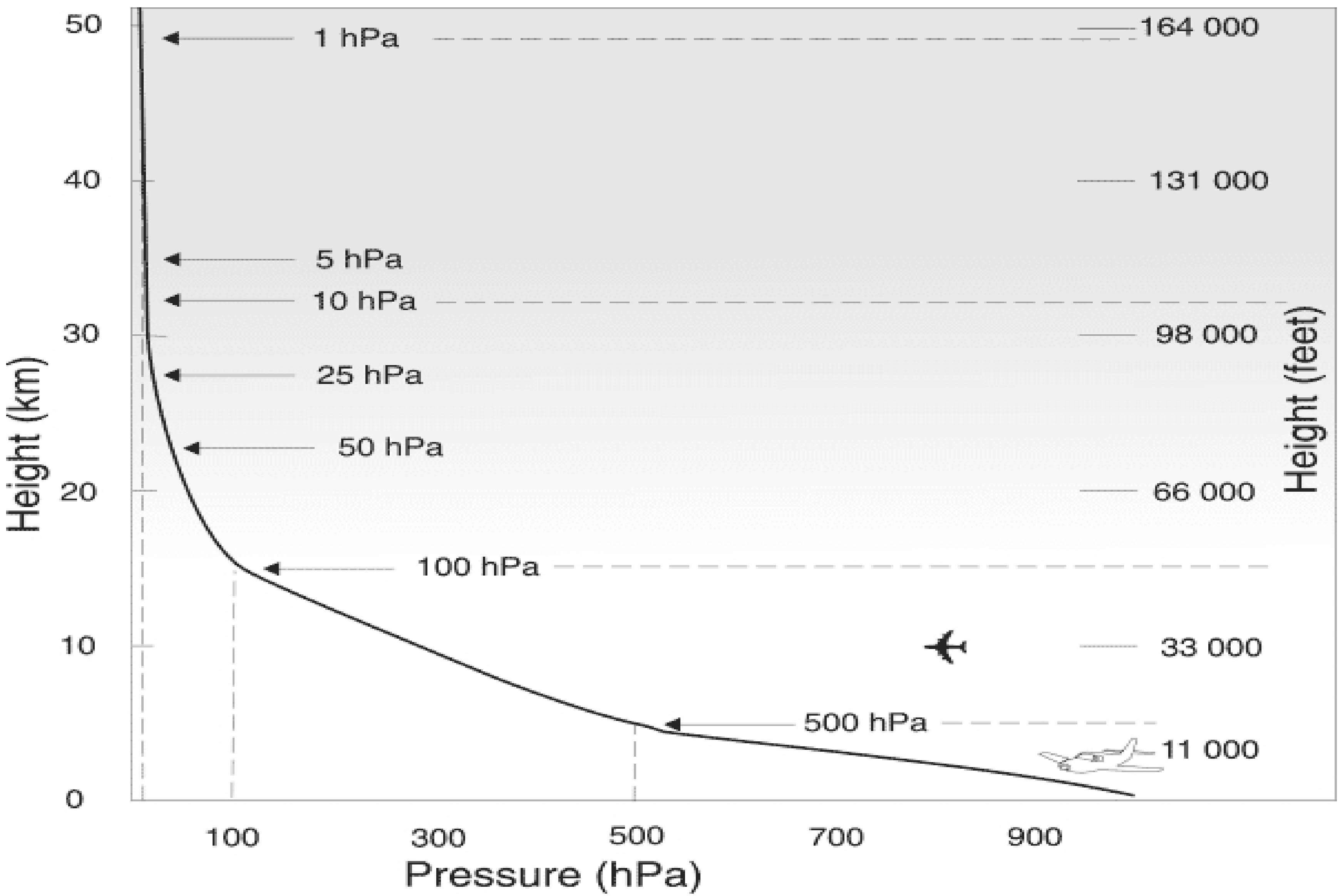
Variation of pressure with altitude

The rate of pressure decrease with altitude is not linear (as shown in the diagram).

- Near sea level, for about every 30 feet increase in height, the pressure decreases by 1 hPa.

- At about 16 000 feet the same pressure decrease is equivalent to a rise of approximately 50 feet.

Figure : Variation of pressure with altitude



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- In science we learnt that pressure is force (weight) per unit area.

- We also learnt that the higher you go the cooler it becomes and the lower the pressure becomes.

- An airport or airfield in a low altitude (height above sea-level) will naturally have a higher pressure than an airport at a higher altitude.

- Since pressure is force per unit area, then it therefore contributes to air density.

- This air pressure is another weather element that will affect an aircraft in achieving the most economical maximum take-off weight as it affects the density of air.

Cont…

- When an airplane fly or floats in air, it does so by setting its engines in such a way that the engines compresses the air below the aircraft thus creating a very high pressure below the aircraft and very low pressure above the aircraft's body.

- Once this happens, the aircraft will float higher to the area of low pressure. It continues doing so until the airplanes reaches the **Long Range Cruise altitude.**

- When the pressure or density of air is low you can compensate this by using a longer runway so that you can build sufficient thrust to lift the airplane.

- This therefore means that at the coastlines or low altitude places, there are usually shorter runways than airports situated in high altitudes where the air pressure and air density are lower.

Cont…

- If therefore you are taking off from an airport on a high altitude with a shorter runway, then you have to do it in away with some of the maximum take-off weight so that you can be able to take-off.

Adjustment of recorded pressure to standard levels

- Pressures are measured at the height of the station where the barometer is located. This is called **Station Level Pressure (SLP)**.

- Since different stations will have differing elevations, pressures need to be adjusted to a common datum so that measurements can be compared across the earth regardless of the location.

- Station level pressures are reduced to **Mean Sea Level Pressure (MSLP)** for this purpose.

Cont…

- Reduction to MSL pressure is done by adding the weight of the ISA column of air, between the recording station and sea level, to the measured pressure.

- Because the temperature and density chosen for the column are based on the imaginary ISA, the derived MSL pressures are hypothetical, however they give satisfactory results for most regions.

In the diagram bellow, the pressure is measured at point **A**. To determine what the pressure would be at point **B** (at sea level) we could either:

- Dig a hole down to sea level and lower the barometer down on a long rope (not very practical!); or
- Mathematically determine an approximate pressure using the ISA pressure lapse rate between points A and B; this is what is done.

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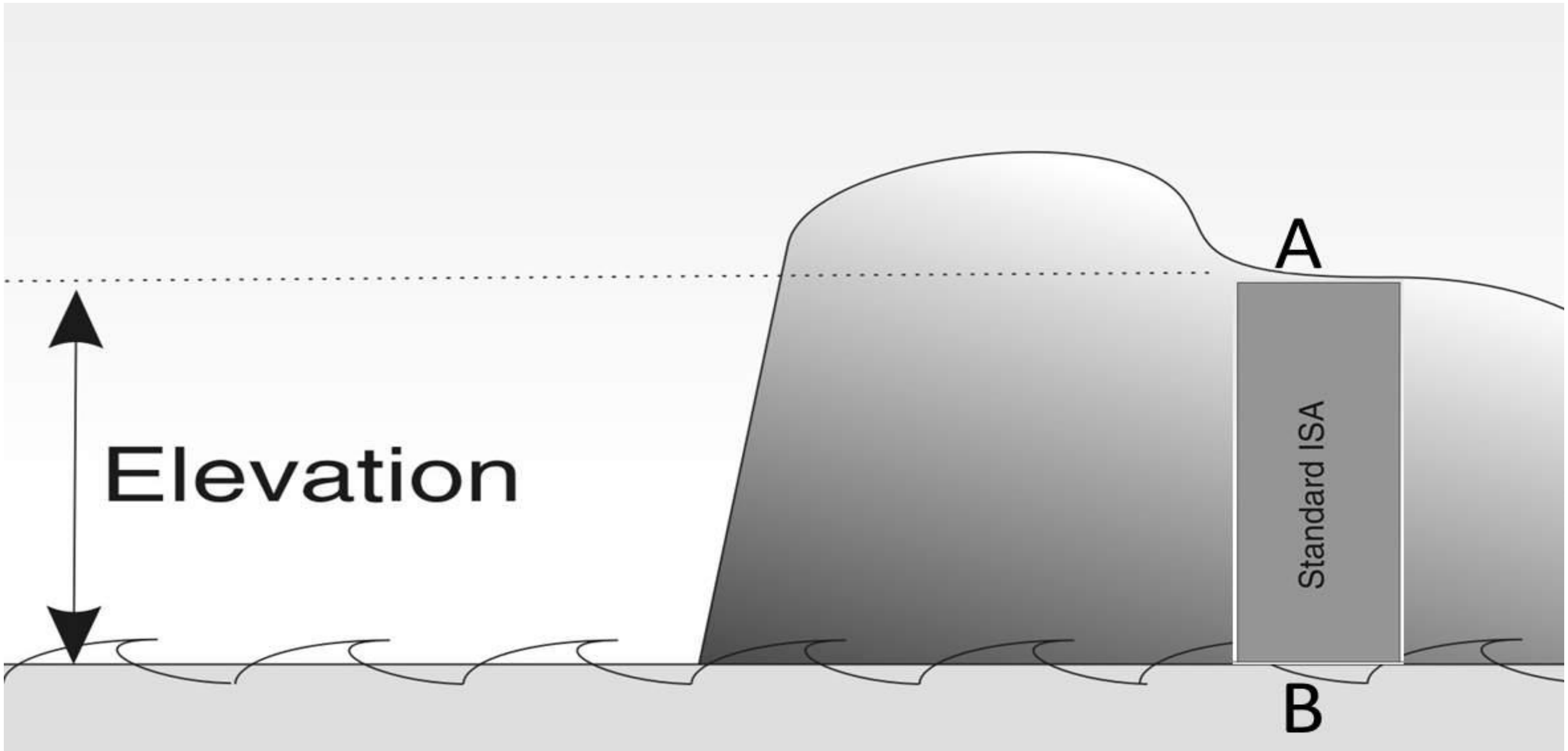

Figure: Pressure adjustment to ISA

Variations of surface pressure

Atmospheric pressure at a given locality varies continually. The variations may be **irregular** or **regula**r.

- **Irregular variations** are primarily associated with the development, decay and passage of pressure systems. Sometimes purely local effects can force irregular pressure changes. An example of such an effect is a low-pressure trough in the lee of terrain. The air movement up and over the terrain causes a pressure reduction on the lee side. Thunderstorms and temperature variations can also cause pressure changes.

- **Regular oscillations** have a period of about twelve hours generated by the alternate heating and cooling of the earth's atmosphere by the sun. This produces a rhythmic expansion and contraction of the atmosphere. The changes are not perfectly symmetrical and vary considerably with locality.

Pressure gradient

The rate of change of pressure between locations is termed the pressure gradient. **Isobar spacing** on weather maps reflects the pressure gradient.

- Isobars close together are indicative of strong-pressure gradients and strong wind.
- Isobars far apart are indicative of weak-pressure gradients and light wind.

Wind Speed and Direction

- Wind is a force. When wind hit such a voluminous object like a Boeing 777 with a volume of over 6000 cubic meters, it becomes such a significant force to be avoided or to be made use of.

- In aviation industry, the idea is to make the best use of the wind force.

- There are three main conditions of wind that have to be considered during take off and landing of an aeroplane - headwind, tailwind and crosswind

- If you look at the Boeing 777 specifications, you will see that the Empty operating weight – OEW is 133,000 kg and the Standard fuel capacity is 117,000 kg. This shows that almost 50% of a airplane’s weight is fuel.

Cont..

- All the money in an airplane comes from the payload.

- If only one can be able to increase the payload at the expense of the expensive fuel, then it won't take you long to realize that an air plane can be a very profitable business. (The revers is also true).
- One weather element that is able to do that is the **wind strength and direction.**

Cont…

- The weather meteorologists and scientists are able to obtain prognostic wind directions and wind speeds using models that involve endless approximation equations in a science called **numerical weather prediction**.

- These weather products are then made available to the aviation industry for use. If you are to fly Boeing 777 from point **A to point B** at 37000 feet above mean sea and the tailwind is flowing in the direction of point A to point B at 15 knots, then you will expect a substantial assistance from the wind and fuel consumption will drastically be reduced.
- The benefits from this have a multiplier effect in the sense that you don't have to carry the extra heavy fuel that uses a lot of fuel to carry.
- The other thing you do is that you will carry more payloads in place of fuel.
- The opposite is also true when you move from point B to point A with a headwind of 15 knots.

1.4 Altimetry

- We have seen that the higher you go the lower the pressure becomes.
- From this therefore, pressure is used as the measure of heights in the aviation industry.
- When the Long Range Cruise altitude of Boeing 777 is 37,000 feet above mean sea level, it means that height whose atmospheric pressure is about 200 to 250Mb or hpa.
- Every airport has a mean atmospheric pressure which is the measure of the height of the airport.
- This height is in pressure but can as well be converted to feet above mean sea level. This pressure is not constant and fluctuates, depending on changes of weather elements such as temperatures and wind flow.
- In every aircraft, there is an instrument called **altimeter** which is used for measuring the pressure which is converted to feet or kilometers

Cont…

- In every airport, there are meteorological personnel and automatic weather observing instruments that provides real time atmospheric pressure for the runway.

- By use of radio waves instruments, the pressure on the ground is transmitted to the pilot and his officers for them to have.

- It is by use of these pressure readings from the weather personnel and the altimeter reading in the aircraft that a pilot is able to determine the distance between the solid ground (airport) and his/her aircraft.

A clear definition of the following terms in relation to aviation is necessary:

❖ **Height** is the vertical distance above a specified datum, usually ground level;

❖ **Elevation** is the vertical distance above mean sea level (MSL) of a point on the earth's surface;

❖ **Altitude** is the vertical distance above MSL.

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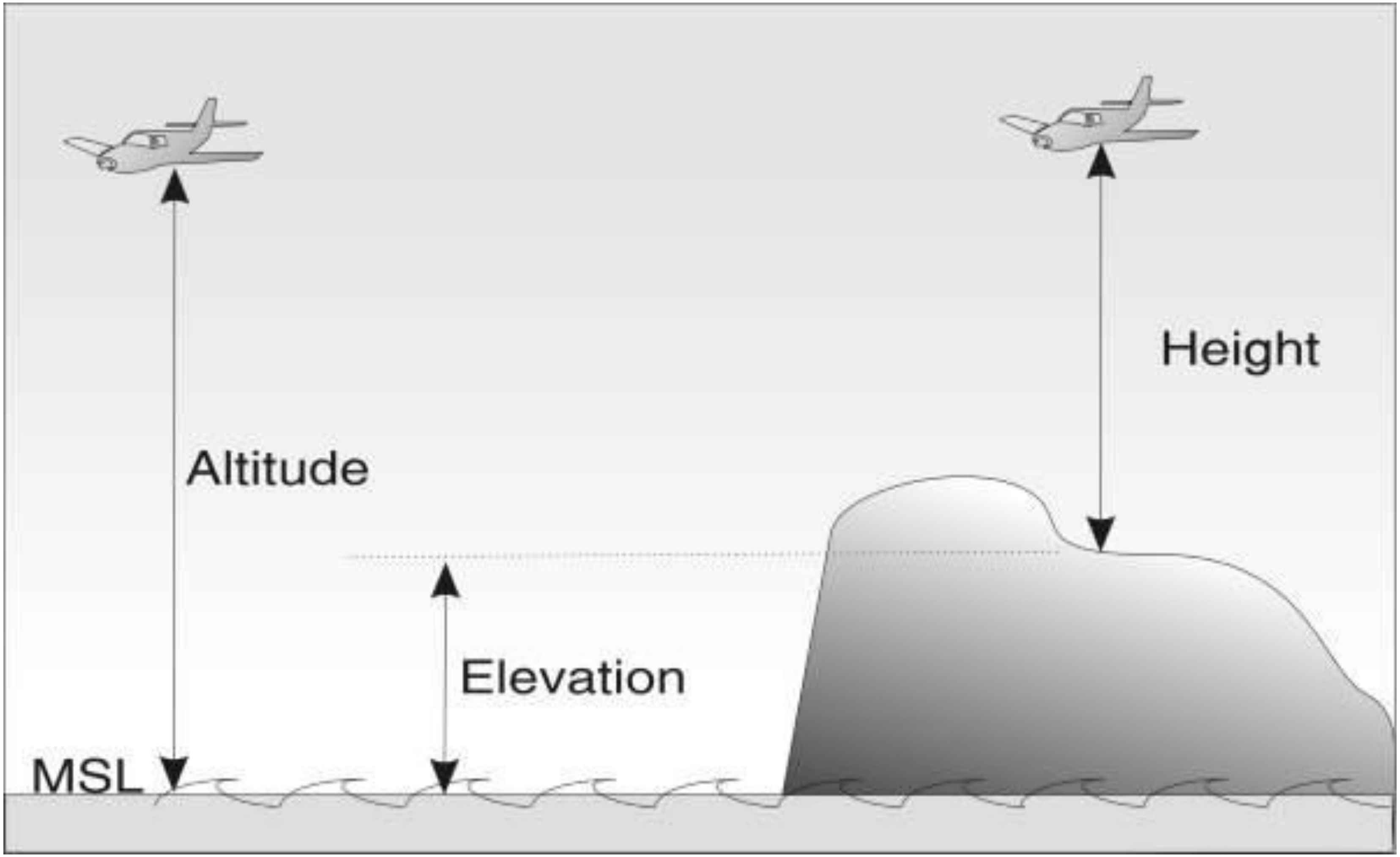

Figure: Height, Elevation and Altitude measurement

Altimeter Setting

- On the altimeter shown here, the pilot will turn the **dial (A)** to set a known pressure in the altimeter **subscale (B**) for a particular datum, and **the pointers will indicate the height above that datum.**

Figure: Altimeter setup on aircraft

Cont…

- **QNH**:- The QNH pressure setting is the mean sea level pressure for a location or area that has been calculated assuming ISA conditions.
- In flight with the QNH set on the altimeter, the needles will show the aircraft's altitude, ie. the height above mean sea level.
- For example, the QNH altimeter setting is used in Australia use when operating up to and including 10,000 feet AMSL.
- An altimeter set to QNH while an aircraft is on the ground will indicate the aerodrome's elevation.
- QNH is the pressure value given in all aviation forecasts and observations.
- When an accurate local QNH is available at an aerodrome, the pilot will perform a check of the accuracy of the altimeter prior to departure by comparing the known aerodrome elevation with that displayed on the altimeter.

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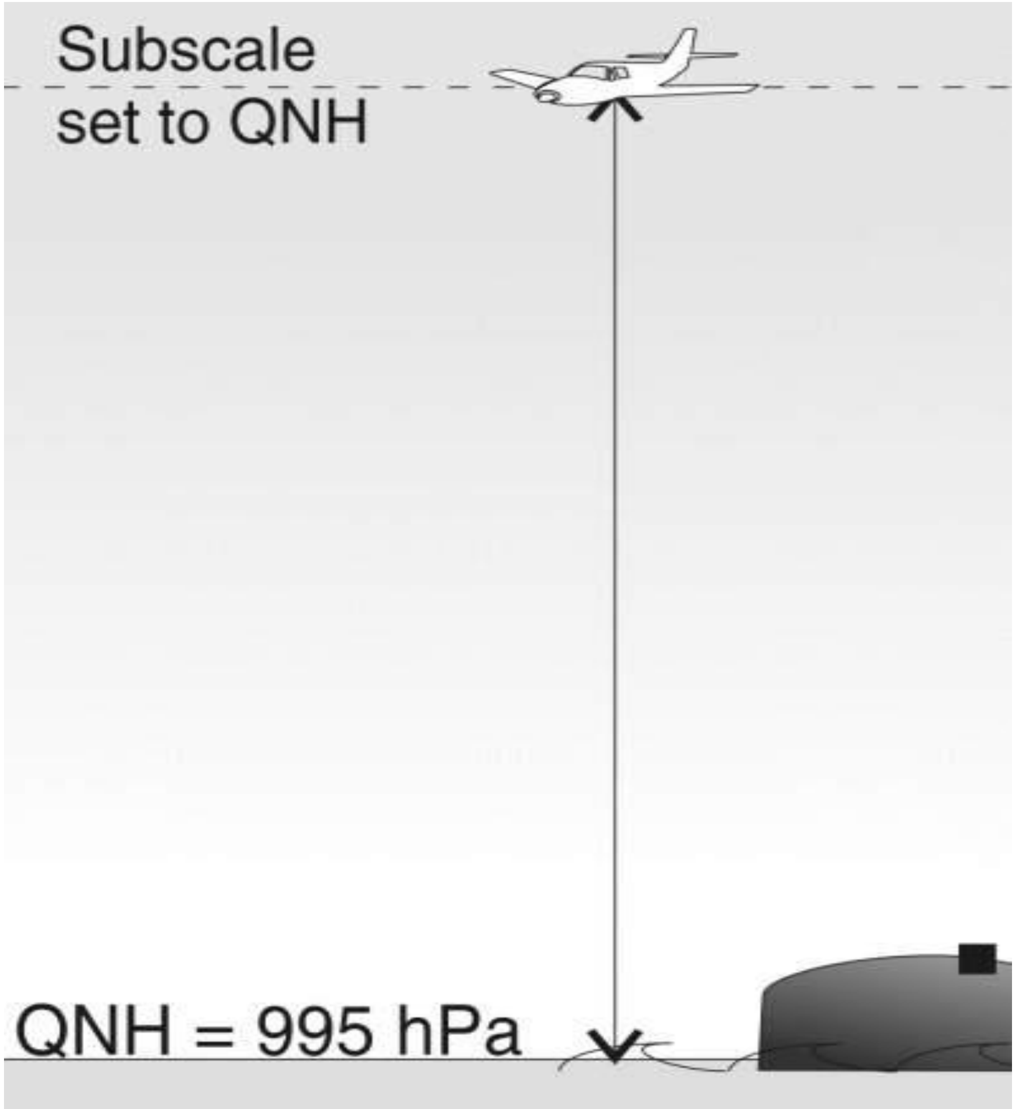

Figure: QNH Altimeter setting

Cont…

- **<u>1013</u>:** 1013 hPa is the mean sea level pressure in the ISA. An altimeter with this setting on the subscale will indicate the aircraft height above the 1013hPa level. This is known as **the pressure altitude.**
- In Australia, pilots passing through 10,000 ft on climb change the altimeter setting from the **QNH to 1013hPa**.
- Pressure altitudes above 10,000 feet are generally quoted in hundreds of feet and called **flight levels**. For example, the pressure altitude of 12,500 feet is FL125 (read as flight level one two five); 41,000 feet is FL410 (read as flight level four one zero). The 1013 altimeter setting is sometimes referred to as QNE.
- **Flight levels** are **NOT** the same as the height above sea level (altitude), unless of course the sea level pressure at that place and time happens to be 1013hPa.

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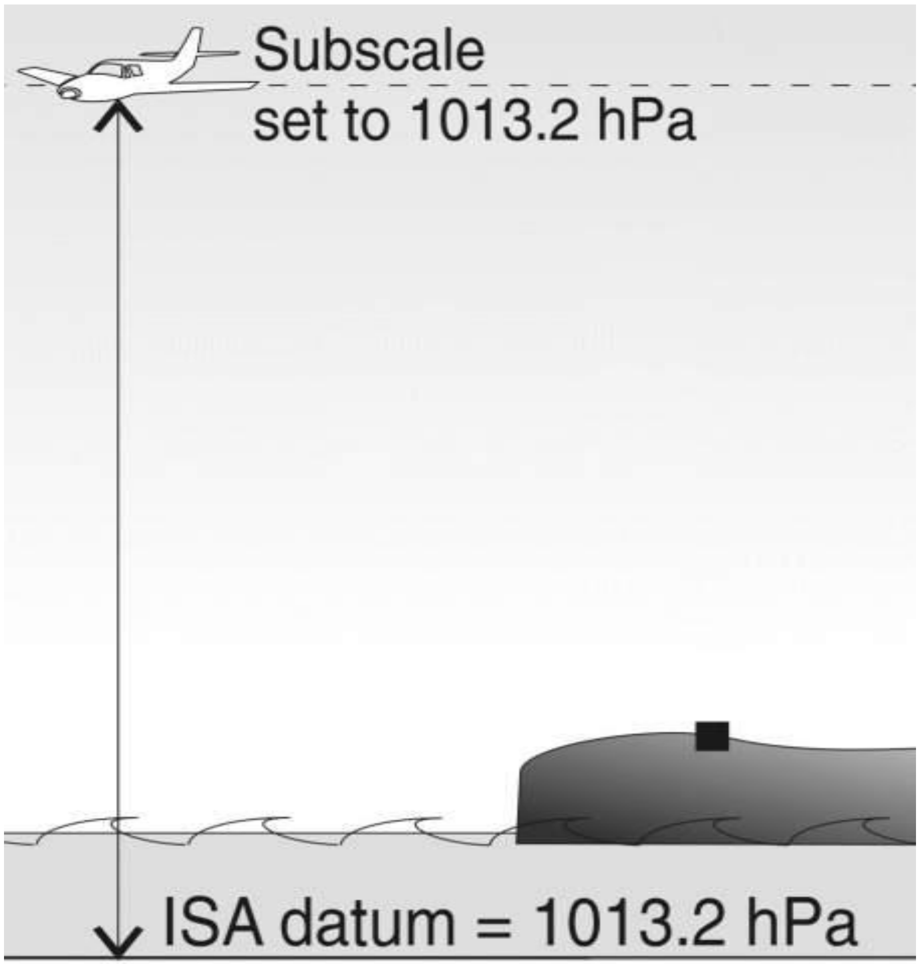

Figure: Altimeter setting of 1013 hpa.

Cont…

- **QFE:** QFE is the **station level pressure**, or more simply **the pressure at ground level**.
- An altimeter set to QFE will read zero when the aircraft is on the runway. In flight, the QFE setting will indicate the height of the aircraft above the aerodrome.
- Generally though, a barometer in an automatic weather station at an aerodrome does not provide QFE to pilots. While it does sense the station level pressure, it is converted to QNH for transmission to pilots.
- If a pilot wishes to use the QFE setting at an aerodrome, they would simply set their altimeter to read zero feet prior to departure; the pressure reading in the altimeter subscale window would then be the QFE (or near to it depending on the accuracy of the altimeter).

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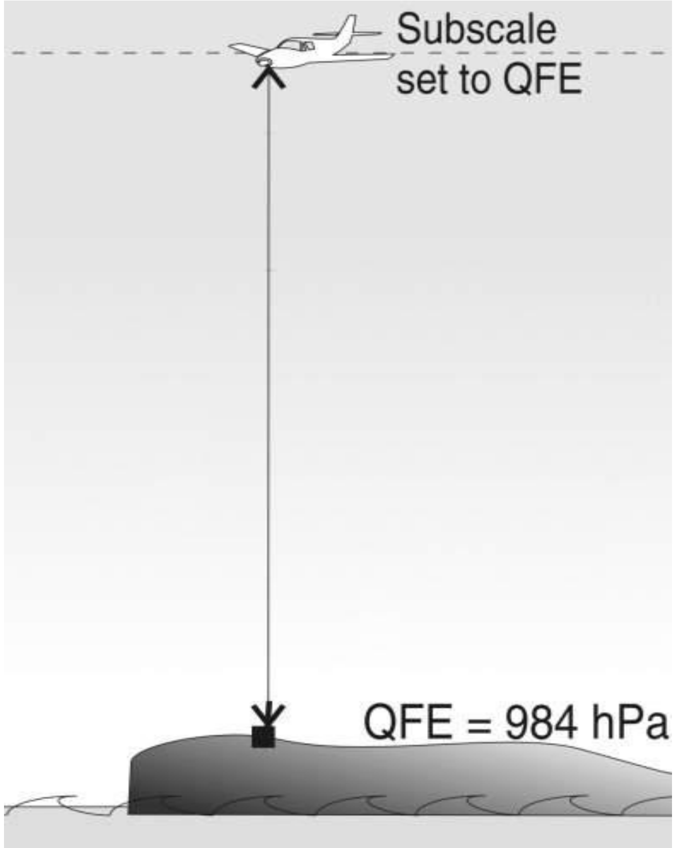

Figure: Altimeter setting of QFE.

Cont…

- **Lowest Safe Altitudes (LSALT)** on aero-nautical charts are published to ensure adequate terrain clearance exists for aircraft in flight.
- So with QNH set, pilots can compare the altimeter read-out with the LSALT to ensure they will remain clear of obstacles/terrain
- To obtain an accurate altitude, an accurate QNH must be entered or dialled on the altimeter subscale on the altimeter.
- An error of 1hPa entered on the subscale will result with about a 30 foot error in the height indicated on the altimeter.
- If a pilot incorrectly sets 1031hPa when in fact the QNH is actually 1013hPa, the altimeter would over-read by 540 feet; that is, the pilot would think the aircraft was 540 feet higher than it actually is. If the aircraft is operating close to terrain without visual reference to the surrounds, the consequences could be disastrous.

:-Accurate pressure information is vital for the safety of aircraft operations!

Altimeter settings – summary

- The following diagram shows three aircraft, all with a different altimeter subscale setting.
- **The point to note is that although they are at actual different heights, their altimeter's all indicate the same thing: 2500 feet.**
- This diagram emphasizes that an altimeter will simply show how high an aircraft is above the pressure datum that the pilot has set in the subscale.
- It is therefore important that pilots use the appropriate setting for the phase of flight they are undertaking; and it is equally important that weather services personnel ensure the correct pressure information is available.

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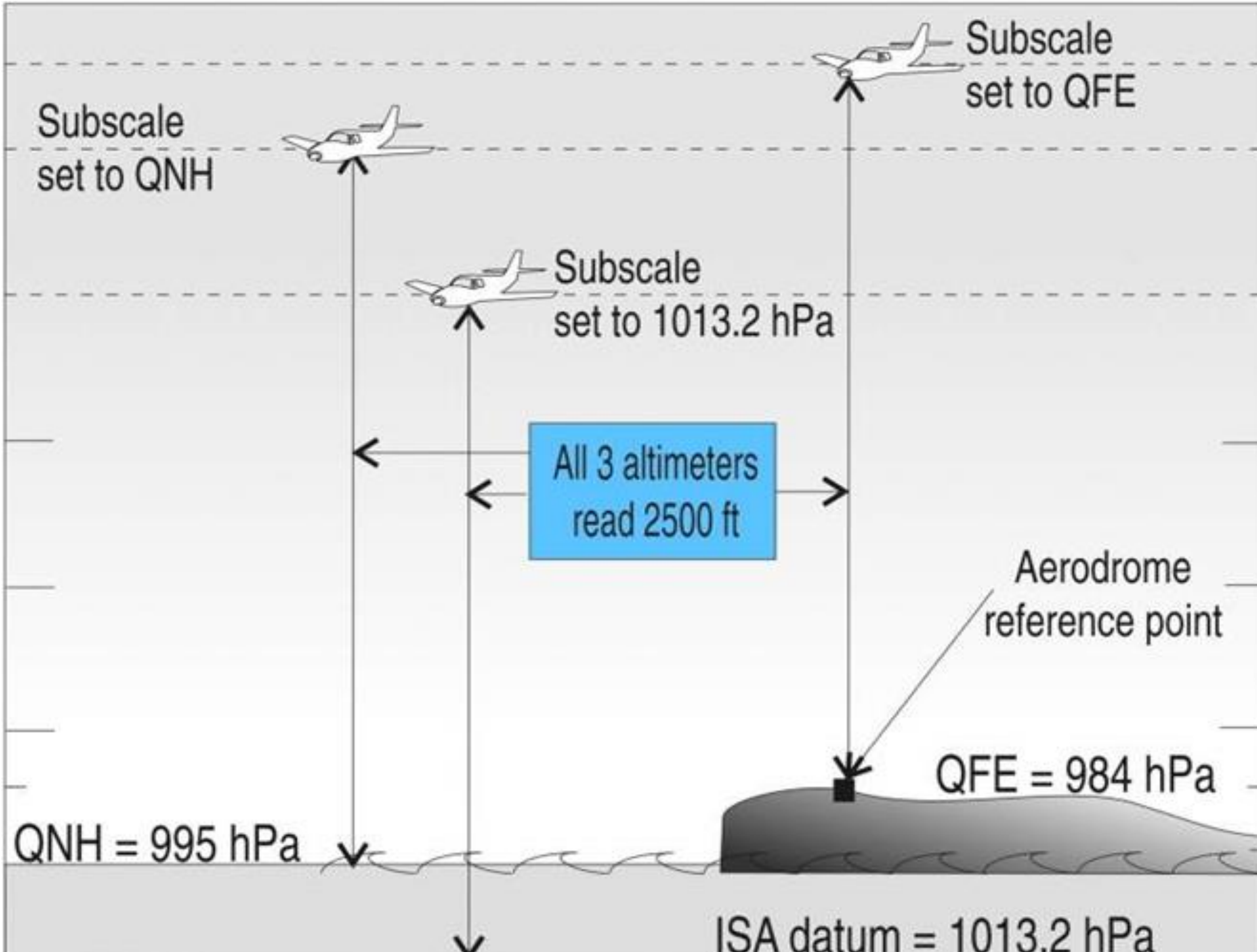

Figure: Altimeter setting with different subscale at the same altitude

Pressure Altitude & Density Altitude

- We have explained previously that aircraft performance changes when the air pressure and density change.

- Pilot Operating Handbooks have either tables or charts to calculate performance requirements under various atmospheric conditions. To use these, the Pressure Altitude must be determined.

- Pressure Altitude is simply the height above the 1013hPa datum. So if the altimeter pressure subscale is dialed to 1013, the needles will indicate the pressure altitude of the aircraft; be it on the ground or in the air.

Calculating Pressure Altitude

- For every 1 hPa variation in the ambient pressure from 1013 hPa, an approximate 30 ft change occurs to the pressure altitude. A simple formula can be used:

Pressure Altitude = Elevation + (1013 - QNH) x 30

Example: Aerodrome elevation is 550 ft, and the mean sea-level pressure (QNH) is 998 hPa.

Pressure Altitude = 550 + (1013 - 998) x 30

= 550 + 15 x 30

= 550 + 450

= 1000 ft

- **Note that** for a QNH greater than 1013 hPa, the pressure altitude will be a lower value than the elevation (or altitude) in question.

What does it mean?

- For departure at this aerodrome, the pilot will use a pressure altitude of 1000 ft in the take-off/climb-out performance calculations.
- Put simply, the aircraft will 'behave' like it is at 1000ft rather than the airfield elevation of 550ft. we also need to consider the effect of temperature

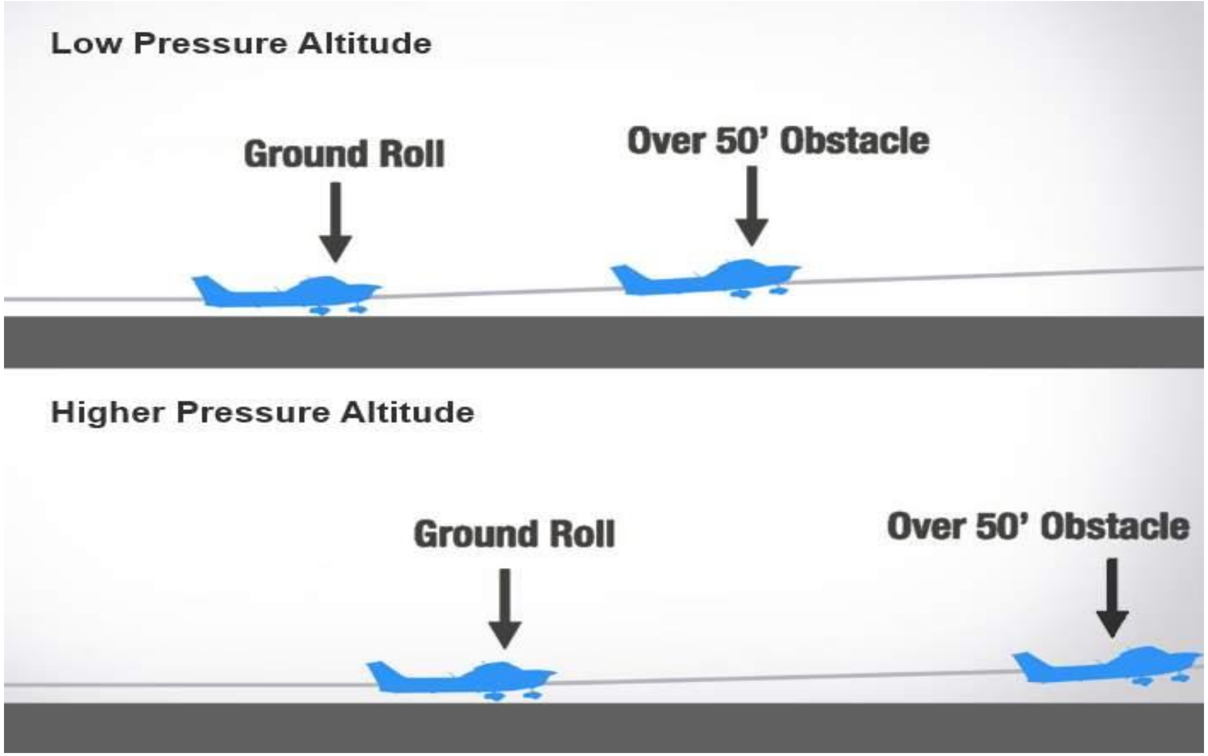

Figure: Pressure Altitude

Density Altitude

- The variation in temperature from ISA has a much greater effect near sea-level than pressure variations in terms of aircraft performance. The density altitude calculation accounts for this.

- Density altitude is the pressure altitude **corrected for temperature deviation from the ISA**.

- It is computed from the pressure altitude and the outside air temperature.

- **A high density altitude value equates to low air density, and a low density altitude value equates to high air density.**

Calculating Density Altitude

- An approximate method for calculating density altitude is to add 120 feet to the pressure altitude for each degree Celsius that the actual temperature is above the ISA standard for that level. The following formula can be used:

Density Altitude = Pressure Altitude + (ISA Temperature Deviation x 120)

- From the previous Pressure Altitude calculation: Aerodrome elevation is 550 ft, QNH is 998 hPa - Calculated Pressure Altitude is 1000 ft. Let's say the temperature at the aerodrome is 31°C.
- At a Pressure Altitude of 1000 ft, the ISA Temperature is 13°C (ISA temperature at sea-level of 15°C and a lapse rate of 2°C per 1000 ft). If the actual temperature is 31°C then the ISA Temperature deviation is 31 - 13 = 18°C.

Cont…

- Plug this into our formula:
- Density Altitude = Pressure Altitude + (ISA Temp Deviation x 120)

  = 1000 + (18 x 120)

  = 1000 + 2160

  = 3160 ft.

- For departure at this aerodrome, the pilot will use a density altitude of 3160 ft in the take-off/climb-out performance calculations.
- In other word the aircraft will perform as though it is at an altitude of 3160ft rather than the aerodrome elevation of 550ft
- **Note that** if the ISA temperature deviation is a negative value (that is, the actual temperature is colder than the ISA temperature for that pressure altitude), then the density altitude will be a lower value than pressure altitude.

1.5 Pressure Pattern flight

- There are several navigation techniques which make use of the distribution of pressure in order to determine the effect of wind on an aircraft, pressure pattern flying is the name given to those techniques.

- In other words, an aircraft flight is so planned and navigated as to take advantage of the flight altitude winds (pressure pattern) to reduce the flight time.

- Pressure Pattern flight may be grouped in to three main categories:

I. Minimal flight path
II. Altimeter determination of drift (D-value)
III. Single heading of flight

1.6 ICAO & ISA

ICAO and its role in International Aviation

- **ICAO**: International Civil Aviation Organization
- It is created to:-

1. Set up the principle and techniques of international air navigation.
2. To look after the planning and development of international air transport, to ensure safe and orderly growth

- The ICAO council adopts standards and recommended practices concerning:-

  -Air navigation

  - Prevention of un-law-full interference

  -Facilitation of boarder-crossing procedures for international civil aviation

The International Standard Atmosphere (ISA)

- The ISA is a hypothetical model of the vertical distribution of atmospheric temp, pressure and density by international agreement.

- It is taken to be the representative of the atmosphere for purpose of pressure altimeter and air speed calibration, aircraft performance and design.

- The ISA is used for aircraft altimetry and as a reference for aircraft performance standards (as we have seen above).

Cont…

- The model atmosphere (ISA) is based on the following assumptions:-

  - *Dry air is assumed through out the atmosphere*
  - *Mean Sea Level Pressure (MSLP)= 1013.25 hpa*
  - *MSL Temp is 15^{o}C (288^{o}k)*
  - *A fixed lapse rate for temperature of 2°C per 1000ft up to 36,000 feet (the theoretical tropopause height of the ISA), where the temperature is assumed to be -56.5°*

End Of Chapter One