Meteorology and Hydrology Faculty

AVIATION METEOROLOGY

(chapter 2)

2nd Semester

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2020/2012

Aviation Meteorology **MHG 1902**

Chapter Two

Hazardous weather to aviation

2.1 Atmospheric Stability
2.2 Thunderstorm and lighting
2.3 Ice accretion (aircraft icing) and engine icing
2.4 Turbulences
2.5 Visibility in aviation
2 .6 Jet stream, CAT, contrails
2.7 Flying in stratosphere and troposphere

Chapter Two
Hazardous weather to aviation

Introduction

Cumulonimbus (CB) clouds are severe hazards to aviation due to the likelihood of:

- ✓ Severe turbulence
- ✓ Severe icing
- ✓ Lightning
- ✓ High liquid water content, eg. Rain water content
- ✓ Hail

- Whilst individual CB cloud may have a life time of one and half hours, the most intense CB development and thunderstorm/lightning activity is associated with multi-cell convective systems which may develop further into super-cell.

2.1 Atmospheric Stability

- Vertical motion of air is an important factor in the development of weather. The strength of vertical motion in the atmosphere is largely determined by the vertical stability of the atmosphere.

- A stable atmosphere will tend to resist vertical motion, while an unstable atmosphere will assist it.

- When the atmosphere neither resists nor assists vertical motion it is said to have neutral stability.

- Vertical motion and instability are responsible for atmospheric turbulence and cloud formation. Sometimes rising air is made visible by the development of clouds or by the rising dust in dust whirls. Violent vertical motion can be seen in tornadoes.

- At other times rising air may occur in the absence of any visual clue. Subsiding air is normally relatively gentle and associated with clear conditions.

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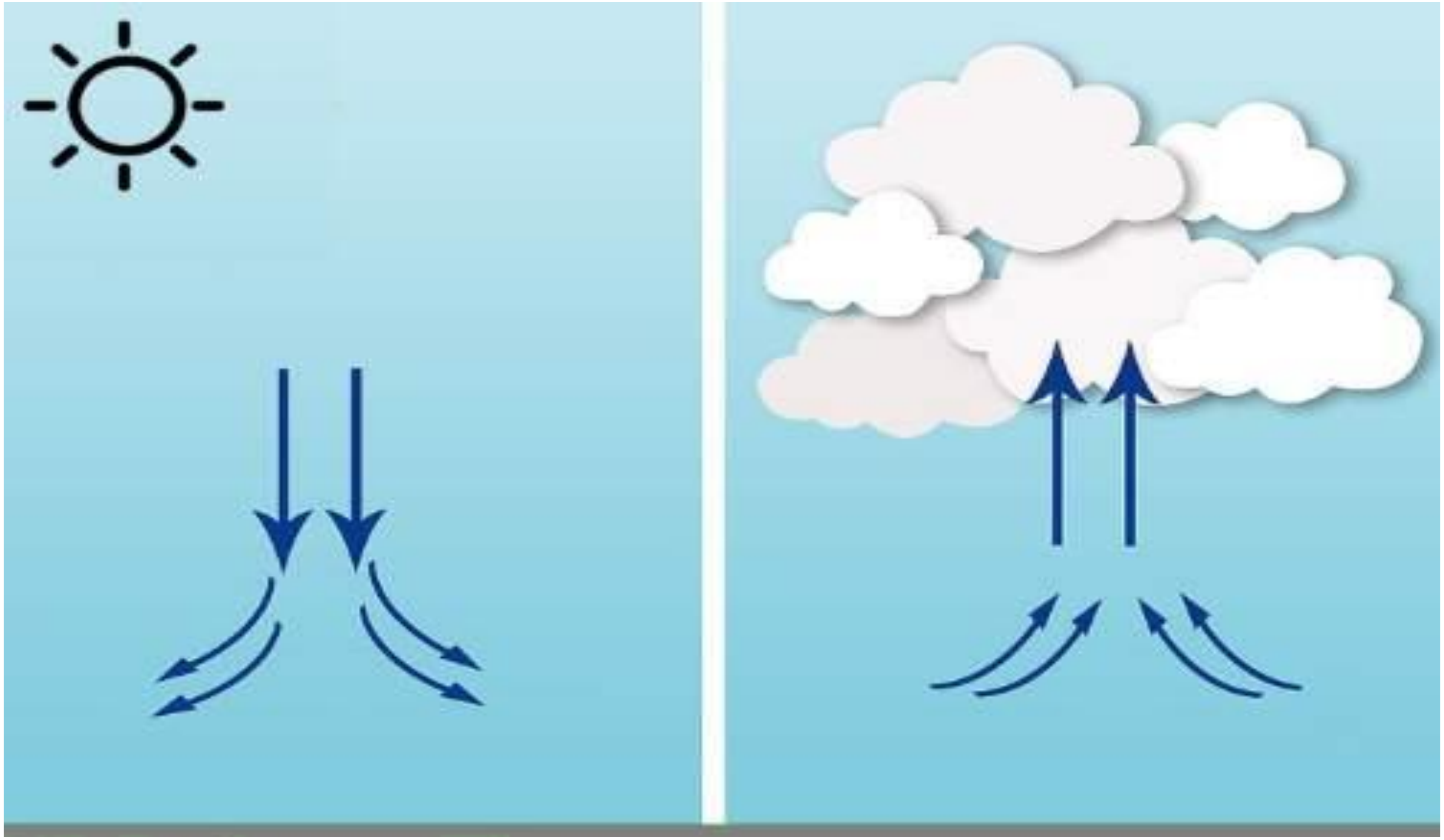

Figure: Vertical motion of the atmosphere

Adiabatic processes and lapse rates

- To explain the stability or instability of the atmosphere, we consider here what happens to an imaginary 'parcel' of air displaced vertically from one level to another.

- The parcel will expand when it moves to lower pressure (higher altitude) and contract when it moves to higher pressure (lower altitude).

- During displacement the parcel will undergo an adiabatic temperature change, i.e. no heat from the external environment is added or subtracted.

- Adiabatic heating is demonstrated when using a bicycle pump. Compression heats the air and thus the outer casing of the pump.

- The reverse occurs when air escapes from a tyre. It cools due to rapid expansion

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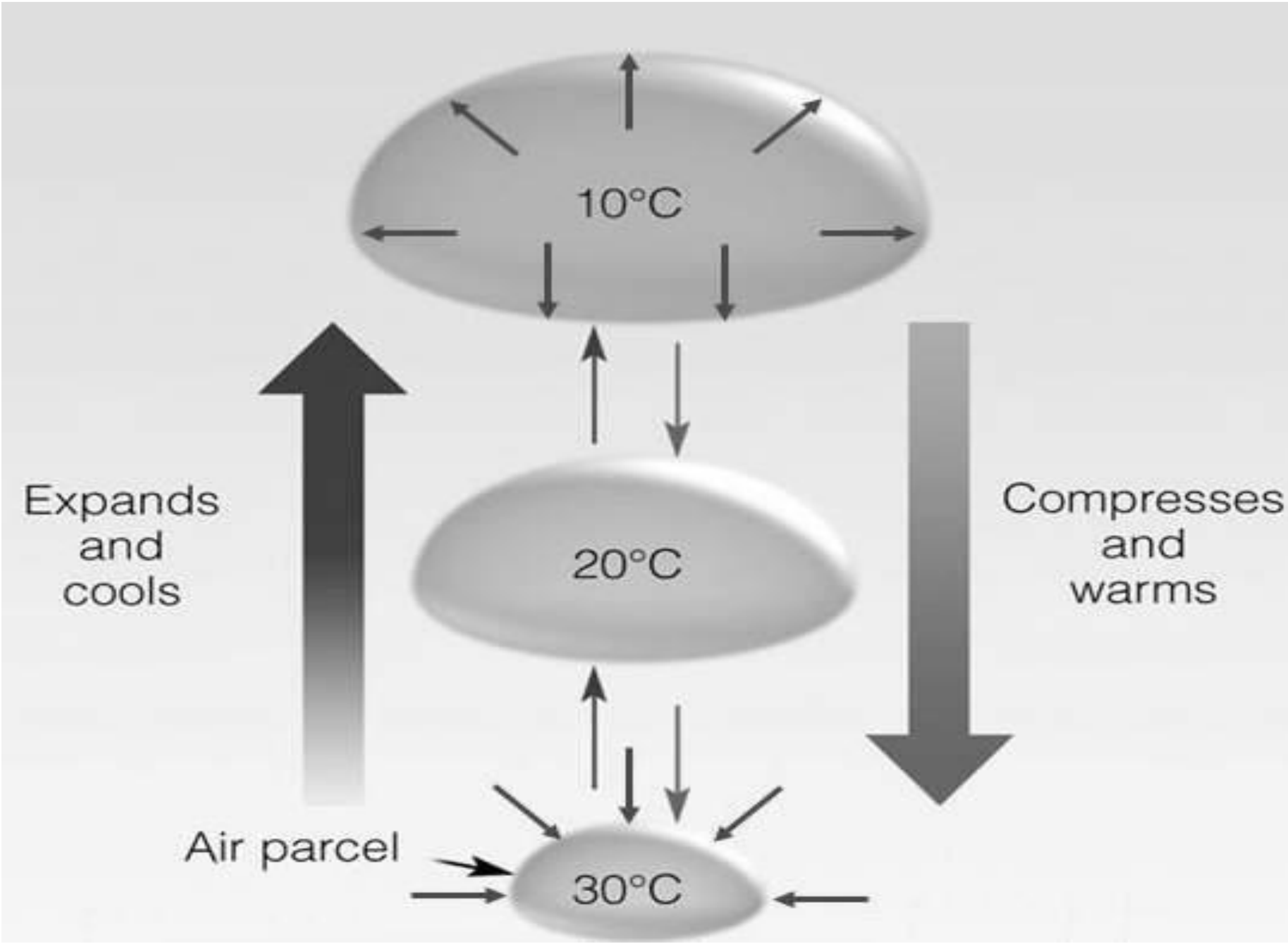

- **Figure**: Expanding and compressing of air parcel

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- The rate of change of temperature with height within a vertically displaced parcel of air is termed the adiabatic lapse rate.

Two different lapse rates apply:

- dry adiabatic lapse rate (DALR); and
- Saturated adiabatic lapse rate (SALR).

- **NB:-** Don't confuse these lapse rates with the Environmental Lapse Rate (ELR) - the rate of decrease of temperature with altitude in the stationary atmosphere at a given time and location.

- In other word the lapse rate of non-rising air. The ISA lapse rate of 2 degrees per thousand feet discussed earlier is an example of an ELR.

Cont…

Dry adiabatic lapse rate

- The DALR is the rate at which the temperature of an unsaturated parcel of air changes as it ascends or descends through the atmosphere.

➔The DALR is approximately 3°C/1000 feet

Saturated adiabatic lapse rate

- The SALR is the rate at which the temperature of a parcel of air saturated with water vapour changes as it ascends or descends

➔The SALR is often taken as 1.5°C/1000 feet

Why are the DALR and SALR different?

- The SALR is less than the DALR because as a parcel of saturated air ascends and cools the water vapour condenses into water droplets and releases latent heat into the parcel, thus slowing the cooling.

2.2 Thunderstorm and lightning

- A thunderstorm and the associated convective cloud can be collectively referred to as a cell. There are two basic types of thunderstorm cells, the ordinary and the supercell.

The ordinary thunderstorm cell

- Most thunderstorm cells are of this type and form in an environment of weak vertical wind shear.

- This type of cell is normally 5-10 km in horizontal extent and usually short-lived in its mature stage (15-30 minutes) due to its updraft becoming exhausted of moisture.

The supercell

- The supercell is a larger (10-40 km across), more organized convective cell that forms in a suitable environment of strong vertical wind shear, strong instability and large moisture supply.

- The supercell can last for several hours (up to seven hours has been observed) in its mature stage because of the way in which it interacts with the environmental vertical wind shear to maintain a strong, deep, persistent, rotating updraft of moist boundary layer air.

- The supercell is relatively rare and has the capacity to producing extremely severe weather.

Thunderstorm life cycle

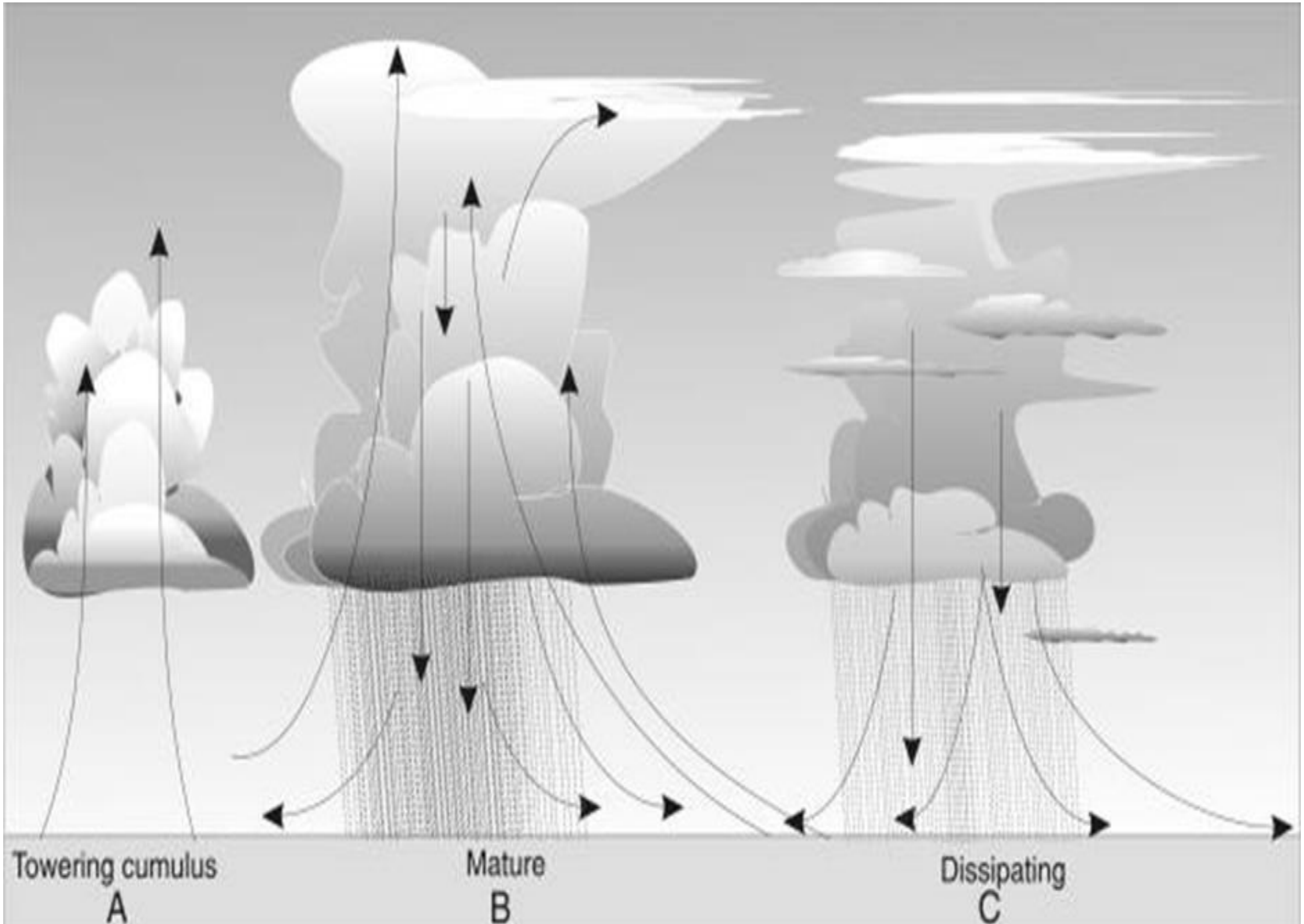
- **The towering cumulus stage (sometimes called the cumulus stage**)- characterized by an updraft throughout the cell; has updraft strength of 2,000 to 4,000 feet/minute, which is stronger than ordinary convection; a significant concentration of rain or ice (or both) suspended within the updraft at or slightly above the cloud freezing level.

- **The mature stage** - characterized by both updraft and downdraft, at least in the lower half of the cell; begins when precipitation starts falling from the cloud base; updrafts can reach a maximum intensity of 8,000 to 10,000 feet per minute; (this is the stage of maximum lightning activity).

- **The dissipating stage** - characterized by downdrafts throughout the cell. stage begins when the downdraft's low-level outflow spreads out and 'undercuts' the updraft, cutting off its source of warm, moist air.

The towering cumulus stage typically lasts 10-15 minutes, the mature stage 15-30 minutes, and the dissipating stage 30 minutes or so. During this time, the storm may travel many kilometers in the direction of the mid-level winds in which it is embedded.

Fig 2.1 life cycle of TS



Conditions necessary for thunderstorm development

There are three necessary conditions for thunderstorms to develop. They are:

- **Low-level moisture** - sufficient water vapour in the near-surface layers to allow significant buoyancy; once air from this level has reached the Level of Free Convection (LFC), where the temperature of the environment decreases faster than the moist adiabatic lapse rate of a saturated air parcel at the same level.

The LFC is the level at which a parcel of saturated air becomes warmer and therefore more buoyant than the surrounding air and begins to rise freely.

- **Instability** - a deep layer of conditionally unstable air above the LFC which allows the parcel of saturated air to continue to rise to a considerable height, i.e. to the -20°C level and beyond.

- **A lifting mechanism** - to lift a parcel air from near the surface to its LFC.

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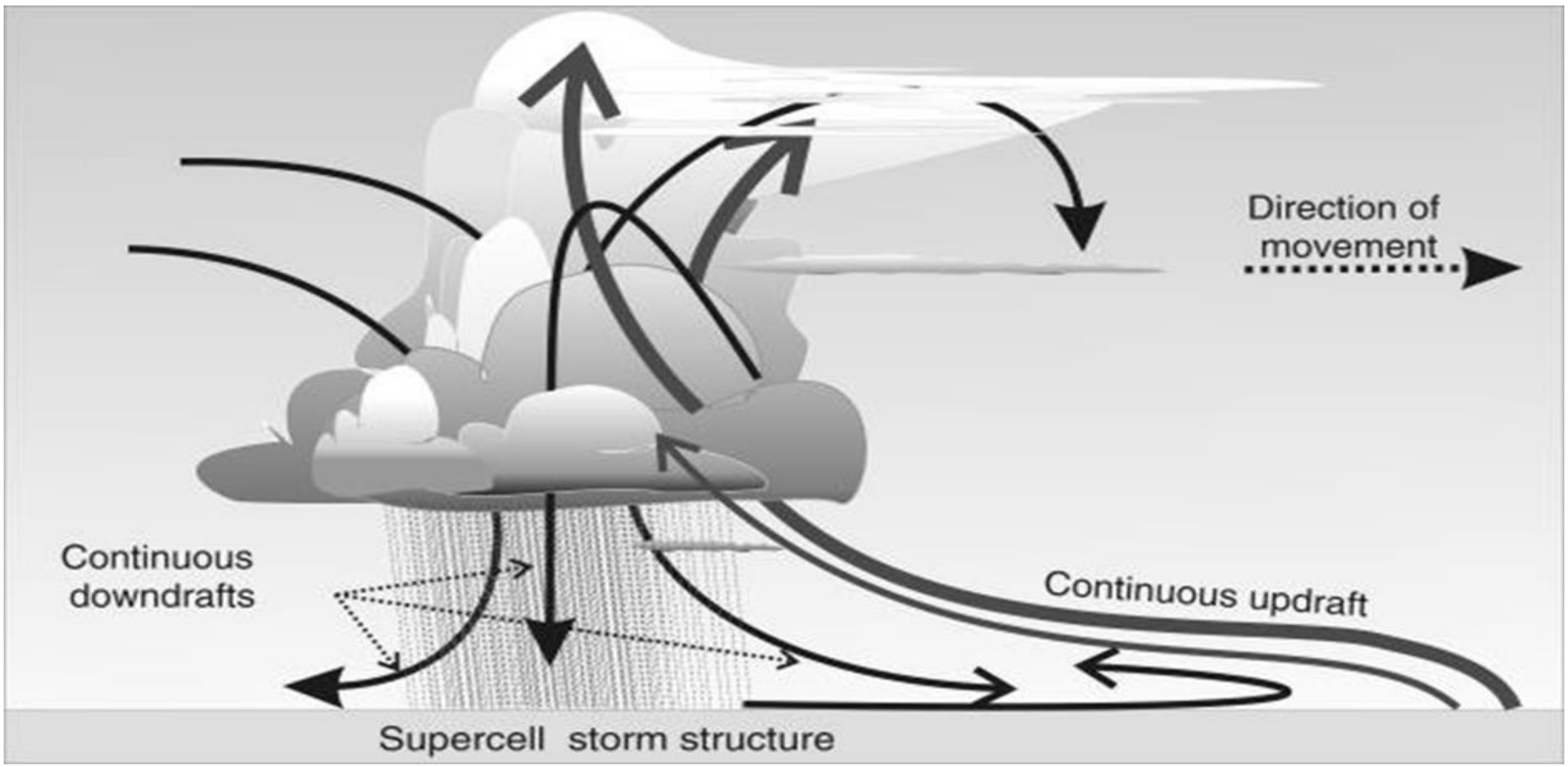
For supercell development, the vertical wind structure must be such that the updraft and downdraft remain separated for a long period. The diagram shows the organized structure of a supercell severe thunderstorm, with separate regions of continuous up and downdrafts.



Thunderstorm hazards

Hazardous weather conditions can be packed into very concentrated zones in and around thunderstorms. Hazards include:

- **Microbursts**:- is terms used to describe small scale but particularly concentrated downdrafts that are associated with severe wind shear, as distinct from the broader gust fronts.
- severe wind shear
- Turbulence
- large hail
- Icing
- Lightning
- Tornadoes
- heavy rain
- poor visibility

Lesser known hazards can include engine water ingestion and marked variations in altimeter readings.

Lightning

- Lightning can occur in and near CB clouds including the anvil layers and the sub-anvil atmosphere
- Lightning can be described as an electrical discharge of some 20 coulombs (unit of electrical charge) and a potential difference of some 108 or 109 volts.
- This electrical discharges may occur within the cloud, referred to as intra-cloud lightning and between the cloud and ground, referred to as cloud-to-ground lightning.
- Generally intra-cloud lightning is weaker than cloud-to-ground lightning, but still may reach the same strength.
- Thunder is the audible manifestation of the electrical discharge, caused by the violent heating and expansion of the atmosphere surrounding the path of the lightning strike.

The effects of lightning on an aircraft (its passengers and crew) are many:

- If lightning strikes a previously sound, metal bonded structure, the aircraft will remain structurally sound, and the passengers and crew will not be directly affected by the strikes voltage and current, due to the Faradays cage effect.

- A Faraday cage operates because an external electrical field causes the electric charges within the cage's conducting material to be distributed so that they cancel the field's effect in the cage's interior.

- They are also used to protect people and equipment against actual electric currents such as lightning strikes and electrostatic discharges, since the enclosing cage conducts current around the outside of the enclosed space and none passes through the interior.

- However, entrance and exit burn marks will be evident on the skin of the aircraft. This results from the temperature of 3000-32000 ^{o}k within the lightning channel.

Cont…

- The effect of lightning on both passengers and crew will be, induce shock and possibly fear. At night a lightning strike may cause the crew to suffer temporary blindness or degraded vision.

- Following a lightning strike electrical/electronic system may fail, with circuit breakers tripping. Magnetic compasses will be untrustworthy.

- Radio communication and navigation equipment may be adversely affected etc.

- Satellite imagery and water vapour imagery can help to identify areas of high positive vortices advection in which mass favor CB, thunderstorm and lightning development.

2. Aircraft Icing

- Aircraft flying through cloud in subfreezing temperatures are likely to experience some degree of icing.

- Ice may form on an aircraft by the freezing of supercooled water droplets or by the process of deposition, in which water vapour is converted into ice crystal without passing through the liquid state.

- During flight ice may occur in cloud, in freezing precipitation or in clear air. Parked aircraft are also susceptible to icing in cold conditions

The four main types of aircraft icing are:-

Hoar frost

Rime ice

Clear ice

Mixed ice

Cont…

Accumulation of ice can lower aircraft performance in many ways.

It can:

- increase drag and decrease lift;
- increase the stalling speed of the aircraft by changing the aerodynamics of the wing and tail as well as increasing weight

Stall speed is slowest speed a plane can fly to maintain level flight. Normally, when a plane slows down it makes less lift. ... This is known as a stall. Stall speed can be reached by increasing the angle of attack as close to stall as possible and slowing down until weight and lift balance out.

- jam the control surfaces and landing gear
- destroy the smooth flow of air over the aircraft;
- cause propeller vibrations and engine failures;
- damage compressor blades of jet engines;
- produce errors in instrument readings;
- interfere with communication systems;
- Reduce visibility.

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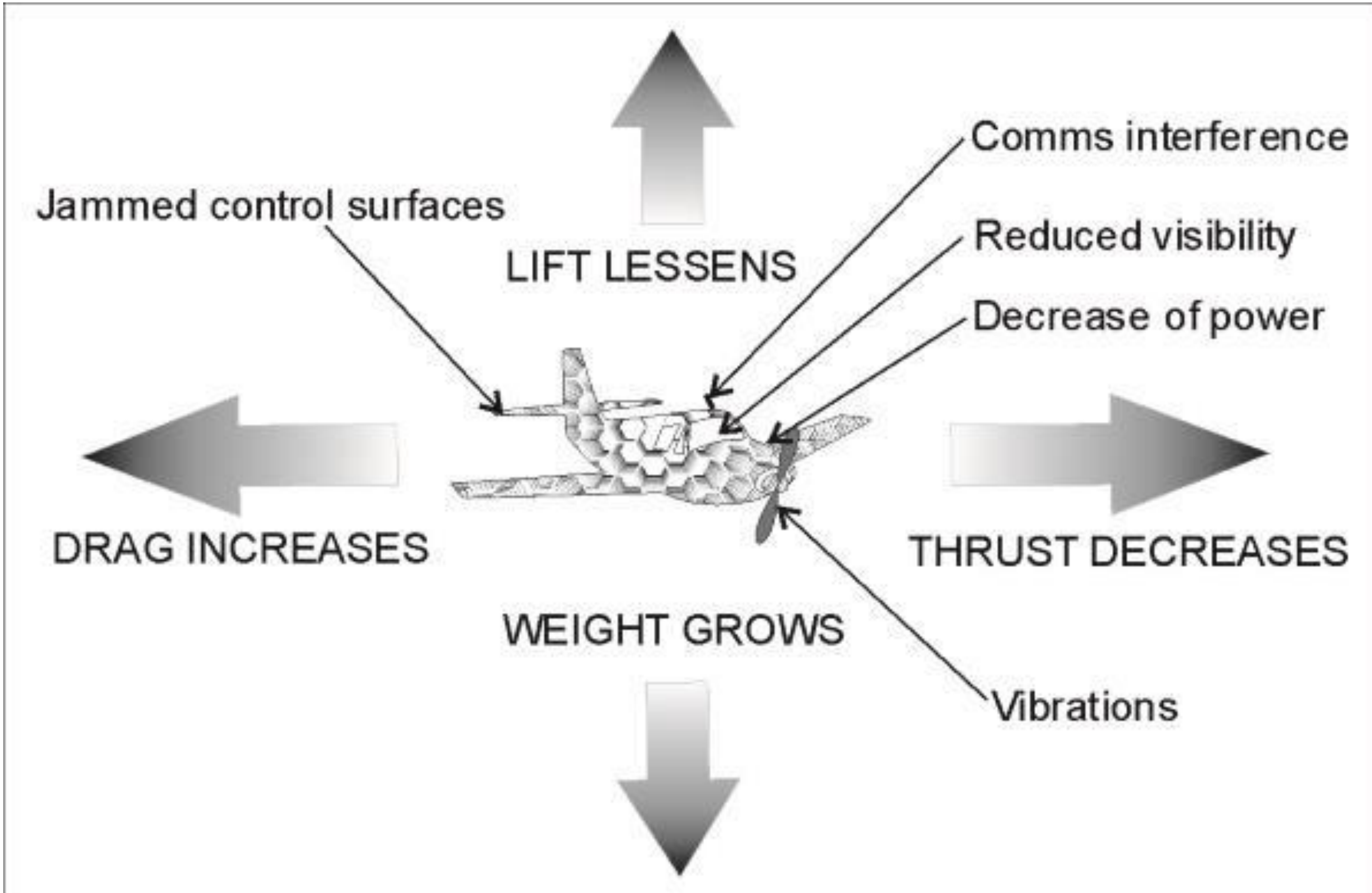

Comms interference
Jammed control surfaces
Reduced visibility
LIFT LESSENS
Decrease of power
DRAG INCREASES
THRUST DECREASES
WEIGHT GROWS
Vibrations

Cont…

- Aside from meteorological factors the rate of ice buildup on the airframe also depends on the characteristics of the aircraft. Faster aircraft with thin wing cross section are more susceptible to deteriorating aerodynamics and hence are more susceptible to ice accretion.

- Helicopters are particular susceptible to icing, since buildup of ice on the rotors can lead to imbalance or de-stabilizing of the aircraft

Anti-icing equipment

Airframe anti-icing or deicing equipment usually include the following types:-

a) **Therma**l: - hot air from the engine is led to the surface to protect against ice. The surface may also heat electrically.

b) **Chemical**:- alcohol sprays or other deicing fluids are applied to the surface . Non-freezing oil or greases are sometimes used.

c) **Mechanical**: - a pulsating rubber boot may be fixed to the leading edges and similar surfaces. Intermittent inflation and deflation is then used to break up the ice.

- In the case of artificial heating the aim is to lower the threshold icing temperature in water and mixed clouds. This technique is generally successful. However, in ice crystal clouds, heating may cause melting. It is therefore advisable to avoid airframe deicing heat in ice crystal clouds, unless icing is already occurred.

2.4 Turbulence

- Turbulence can be defined as small-scale, short-term, random and frequent changes to the velocity of air. In other words, when there are rapid changes to either the air's speed or its direction of movement or both, conditions are said to be turbulent.

- The aircraft response to this condition is "Bumpiness" in flight

- Turbulent eddies in the atmosphere occur on scales ranging from the planetary scale down to millimeters, but only eddies of approximately 100 m in size impact aviation.

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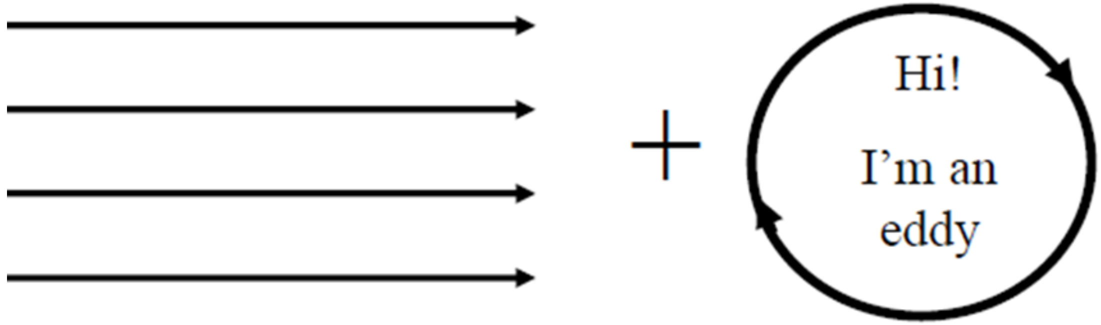
- Can be thought of as random eddies within linear flow:



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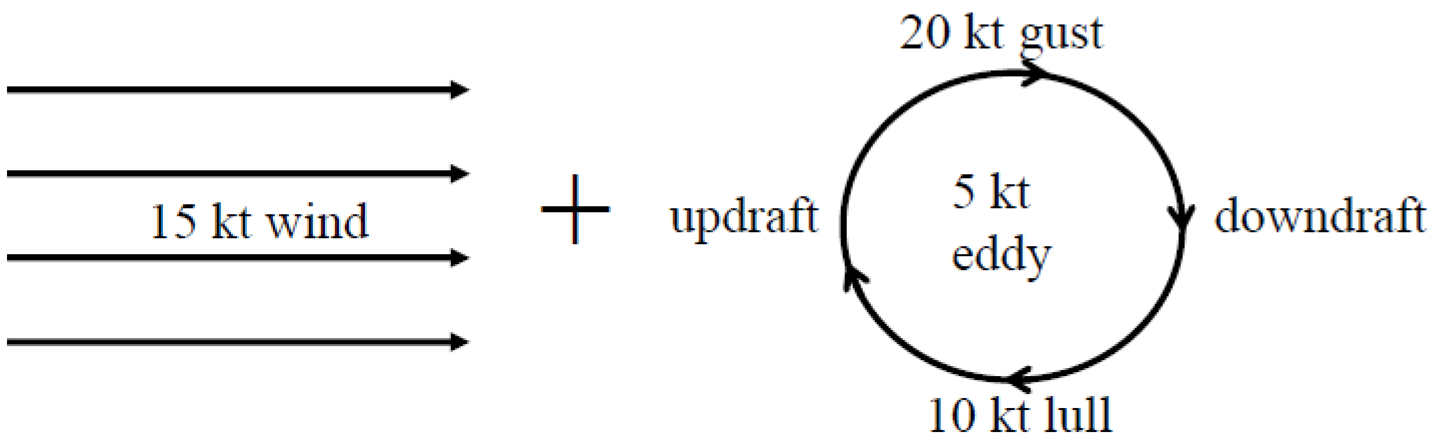
- Linear wind and eddy components add to gusts and lulls, up and down drafts that are felt as turbulence:



Turbulence intensity and effect

C. **Turbulence.** Table 3-3 below classifies each turbulence intensity according to its effects on aircraft control, structural integrity, and articles and occupants within the aircraft.

Intensity	Aircraft Reaction	Reaction Inside Aircraft
Light	Turbulence that momentarily causes slight, erratic changes in altitude and/or attitude (pitch, roll, yaw). Report as **light turbulence** or **clear air turbulence (CAT)**. or Turbulence that causes slight, rapid, and somewhat rhythmic bumpiness without appreciable changes in altitude or attitude. Report as **light chop**.	Occupants may feel a slight strain against belts or shoulder straps. Unsecured objects may be displaced slightly. Food service may be conducted and little or no difficulty is encountered in walking.
Moderate	Turbulence that causes changes in altitude and/or attitude occurs but the aircraft remains in positive control at all times. It usually causes variations in indicated airspeed. Report as **moderate turbulence** or **moderate CAT**. or Turbulence that is similar to light chop but of greater intensity. It causes rapid bumps or jolts without appreciable changes in aircraft or attitude. Report as **moderate chop**.	Occupants feel definite strains against seat belts or shoulder straps. Unsecured objects are dislodged. Food service and walking are difficult.
Severe	Turbulence that causes large, abrupt changes in altitude and/or attitude. It usually causes large variations in indicated airspeed. Aircraft may be momentarily out of control. Report as **severe turbulence** or **severe CAT**.	Occupants are forced violently against seat belts or shoulder straps. Unsecured objects are tossed about. Food service and walking are impossible.
Extreme	Turbulence in which the aircraft is violently tossed about and is practically impossible to control. It may cause structural damage. Report as **extreme turbulence** or **extreme CAT**.	

Types of Turbulence

- Four types:-

- ➢ Low-level turbulence (LLT)
- ➢ Turbulence near thunderstorms (TNT)
- ➢ Clear-air turbulence above 15,000 ft (CAT)
- ➢ Mountain wave turbulence (MWT)

Low-level turbulence (LLT)

- Turbulence that occurs primarily within the atmospheric boundary layer, where surface heating and friction are significant.

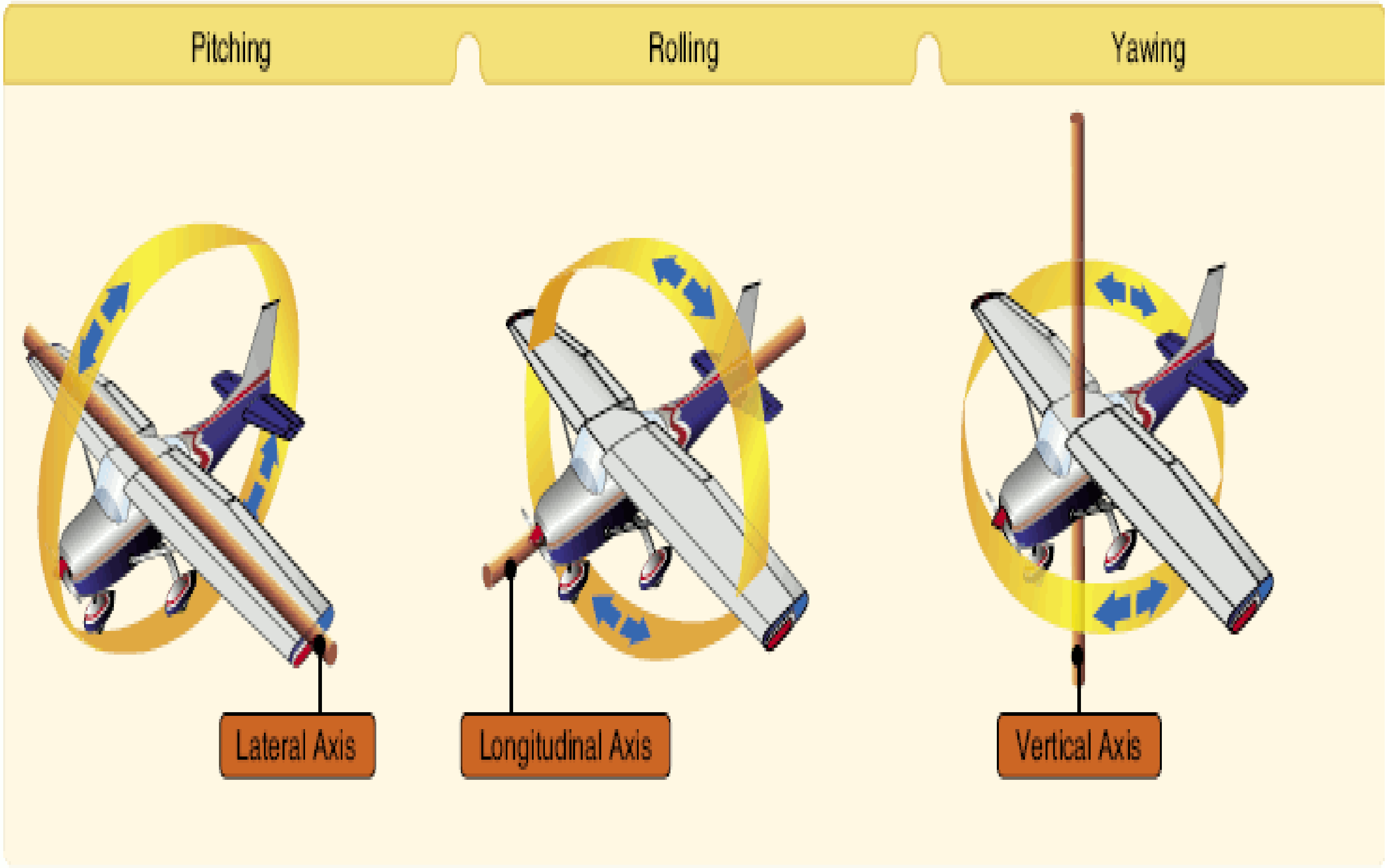
- Typically 3,000 ft deep, but varies a lot

- Friction is largest at surface, so wind increases with height in friction layer
- Vertical wind shear ➔ turbulence

- Important for landing and takeoffs

- Results in pitch, yaw and roll ➔ yaw, nose left or right about an axis running up and down; pitch, nose up or down about an axis running from wing to wing; and roll, rotation about an axis running from nose to tail.

Low-level turbulence (LLT)



Low-level turbulence (LLT)

Factors that make low-level turbulence (LLT) stronger

- **Unstable air** – encourages turbulence
  - –Air is unstable when the surface is heated
  - –Air is most unstable during the afternoon
  - –Cumulus clouds or gusty surface winds generally indicate an unstable atmosphere
- **Strong wind**
  - –More energy for turbulent eddies
- **Rough terrain**

  -When LLT is stronger than usual, the turbulent layer is deeper than usual

- For operational purposes, it is defined as turbulence below 15,000 ft MSL. LLT includes several subcategories of turbulence:-

Mechanical Turbulence, Thermal(convective) Turbulence, Turbulence in Fronts and Wake Turbulence

Mechanical Turbulence

- LLT that results when airflow is hindered by surface friction or an obstruction, like by mountains, and by buildings and trees .

- It occurs because friction slows the wind in the lowest layers causing the air to turn over in turbulent eddies which can cause fluctuations in winds and vertical velocities

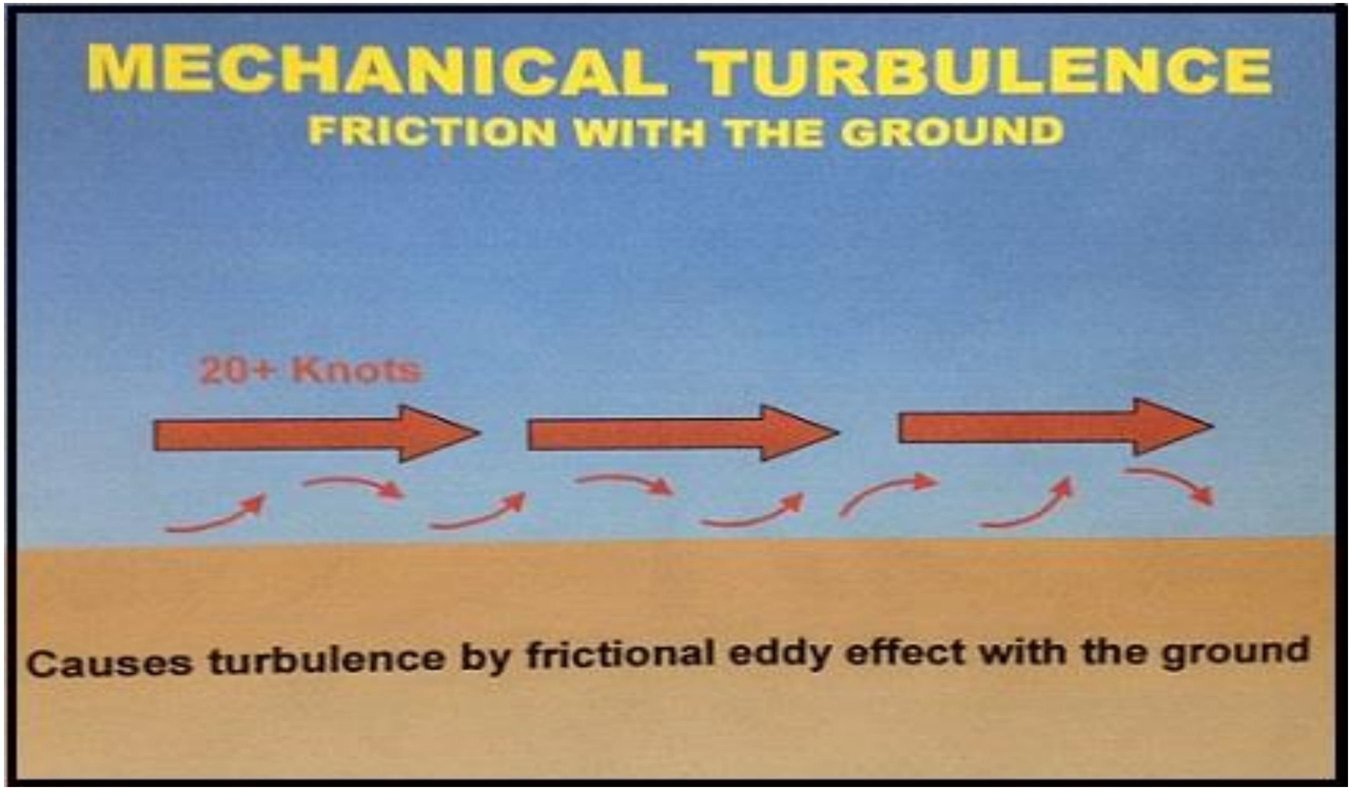
- Increases in both depth and intensity with increasing wind strength and decreasing stability. Worst in afternoon
  - Extends above 3000 ft for gusts more than 50 kt

- Strongest just downwind of obstacles

- Over flat terrain, mechanical turbulence intensity is usually strongest just above surface and decreases with height

Cont…

- The stronger the wind speed (generally, a surface wind of 20 knots or higher is required for significant turbulence), the rougher the terrain and the more unstable the air, the greater will be the turbulence. Of these factors that affect the formation of turbulence, stability is the most important.



Thermal (Convective) Turbulence.

- Occurs when air is heated from below, as on a summer afternoon, i.e Increases with surface heating

- Turbulence intensity typically increases with height from surface and is strongest 3-6,000 ft above the surface

- Generally light to moderate

- Usually occurs in light wind situations, but can combine with mechanical turbulence on windy days

- Often capped by inversion
  - Top of haze layer (may be Sc cloud)
  - ~3,000 ft, but up to 20,000 ft over desert in summer
  - Smoother flight above the inversion

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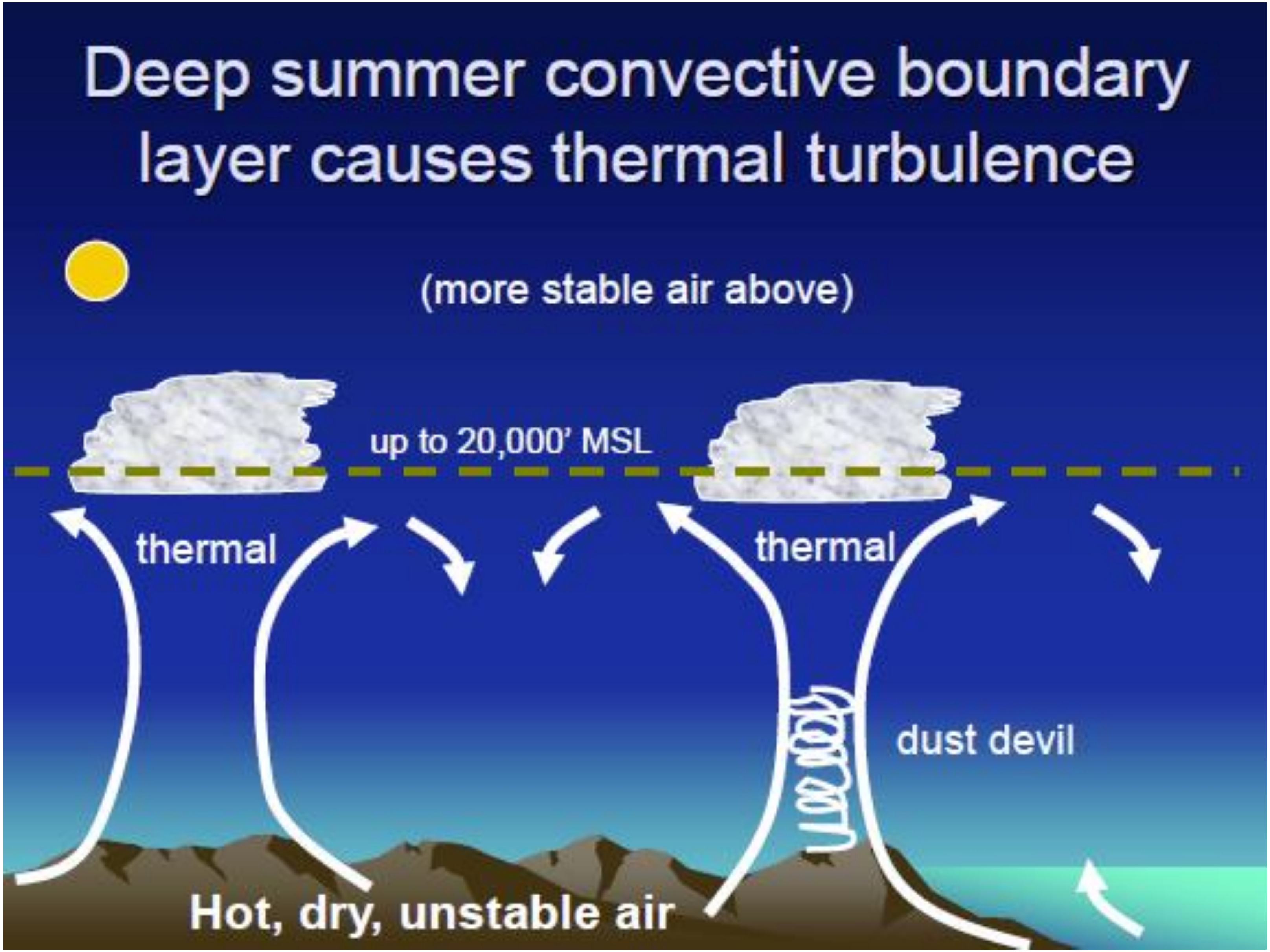

Deep summer convective boundary layer causes thermal turbulence
(more stable air above)
up to 20,000' MSL
thermal
thermal
dust devil
Hot, dry, unstable air

Cont…

- Thermal turbulence will have a pronounced-effect on the flight path of an airplane approaching a landing area.
- The airplane is subject to convective currents of varying intensity set in motion over the ground along the approach path.
- These thermals may displace the airplane from its normal glide path with the result that it will either overshoot or undershoot the runway.
- In weather conditions when thermal activity can be expected, many pilots prefer to fly in the early morning or in the evening when the thermal activity is not as severe.

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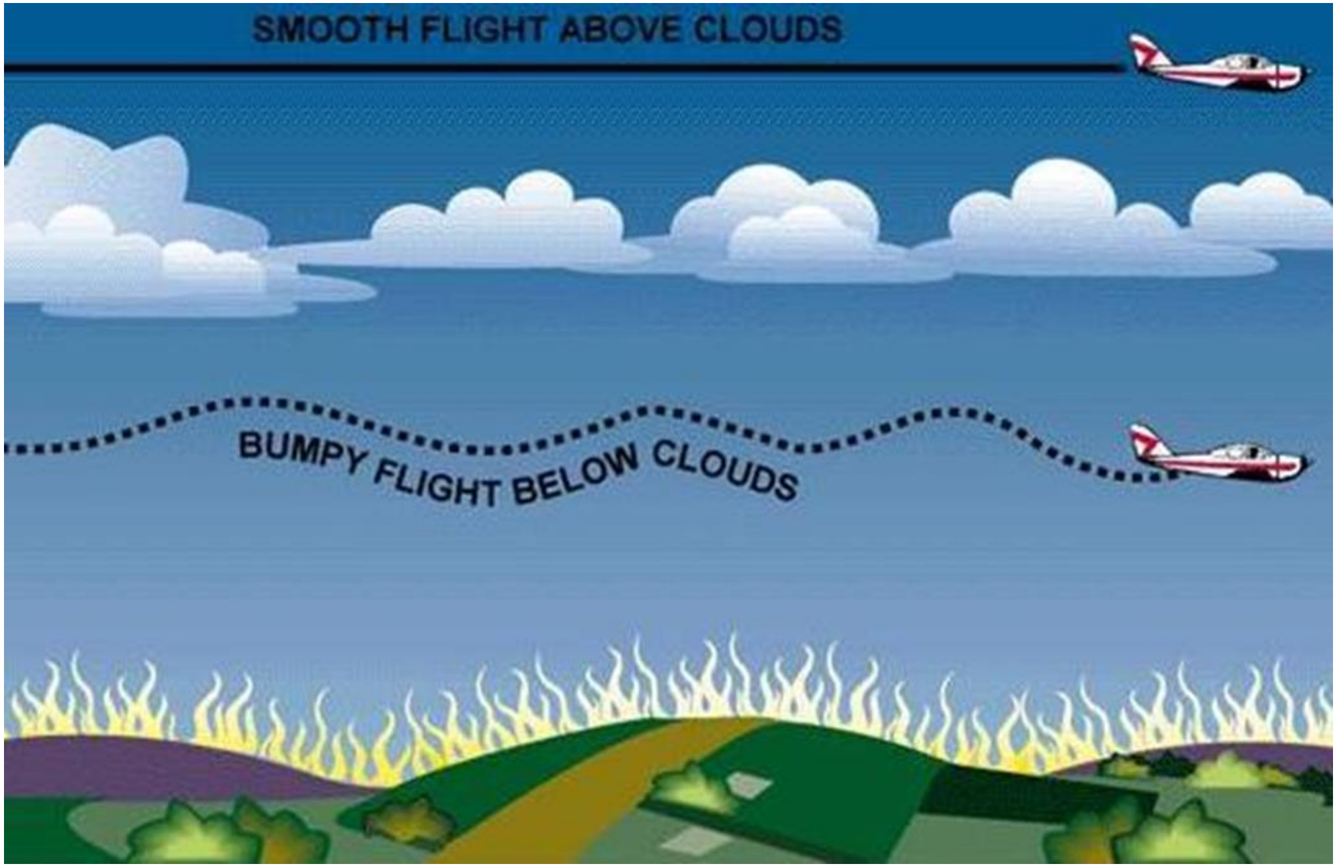
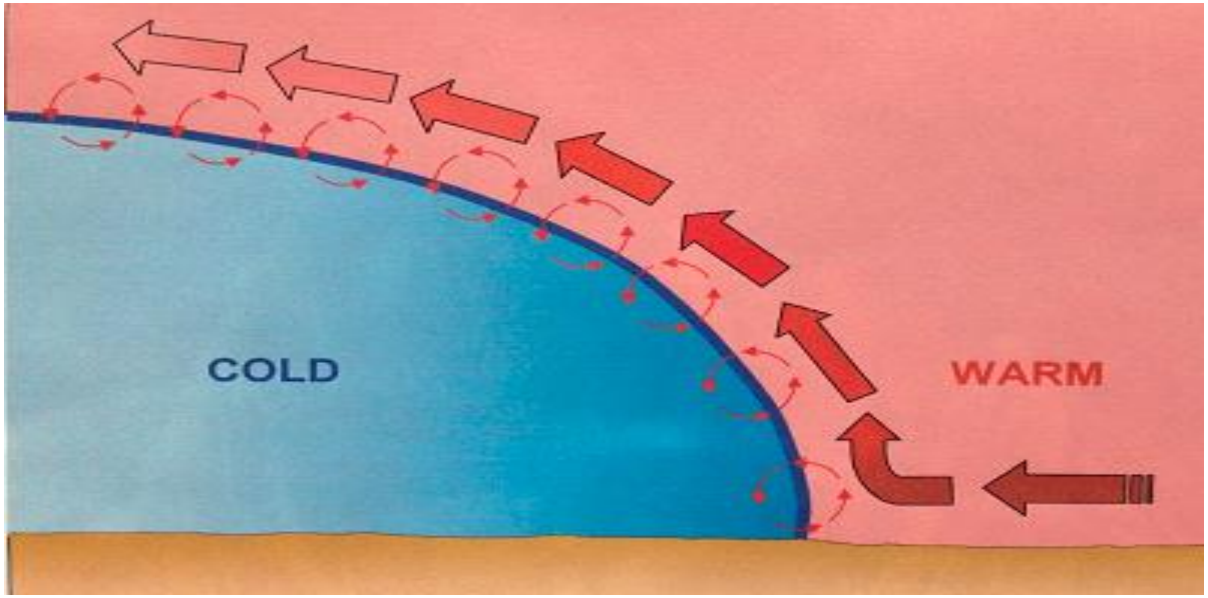


Frontal Turbulence

- The lifting of the warm air by the sloping frontal surface and friction between the two opposing air masses produce turbulence in the frontal zone.
- This turbulence is most marked when the warm air is moist and unstable and will be extremely severe if thunderstorms develop.
- Turbulence is more commonly associated with cold fronts but can be present, to a lesser degree, in a warm front as well.



Wake Turbulence

- Turbulence found to the rear of a solid body in motion relative to a fluid.
- In aviation, it is the turbulence caused by a moving aircraft.
- Wake turbulence is somewhat more predictable since all aircraft generate lift, a requirement for wake turbulence.

Turbulence in and near thunderstorms (TNT)

- Since multicell and supercell thunderstorms move slower than the winds at upper levels, part of the airflow is diverted around the storm, producing turbulent eddies.

- Turbulence, associated with thunderstorms, can be extremely hazardous, having the potential to cause overstressing of the aircraft or loss of control.

- Thunderstorm vertical currents may be strong enough to displace an aircraft up or down vertically as much as 2000 to 6000 feet.

- The greatest turbulence occurs in the vicinity of adjacent rising and descending drafts. Gust loads can be severe enough to stall an aircraft flying at rough air (maneuvering) speed or to cripple it at design cruising speed.

- Maximum turbulence usually occurs near the mid-level of the storm, between 12,000 and 20,000 feet and is most severe in clouds of the greatest vertical development.

Cont…

- Severe turbulence is present not just within the cloud. It can be expected up to 20 miles from severe thunderstorms and will be greater downwind than into wind.

- Severe turbulence and strong out-flowing winds may also be present beneath a thunderstorm. Microbursts can be especially hazardous because of the severe wind shear associated with them.

- Due to the combination of turbulent areas below thunderstorms along with wind shear, heavy precipitation, low ceilings and visibility, the area below a thunderstorm is very dangerous

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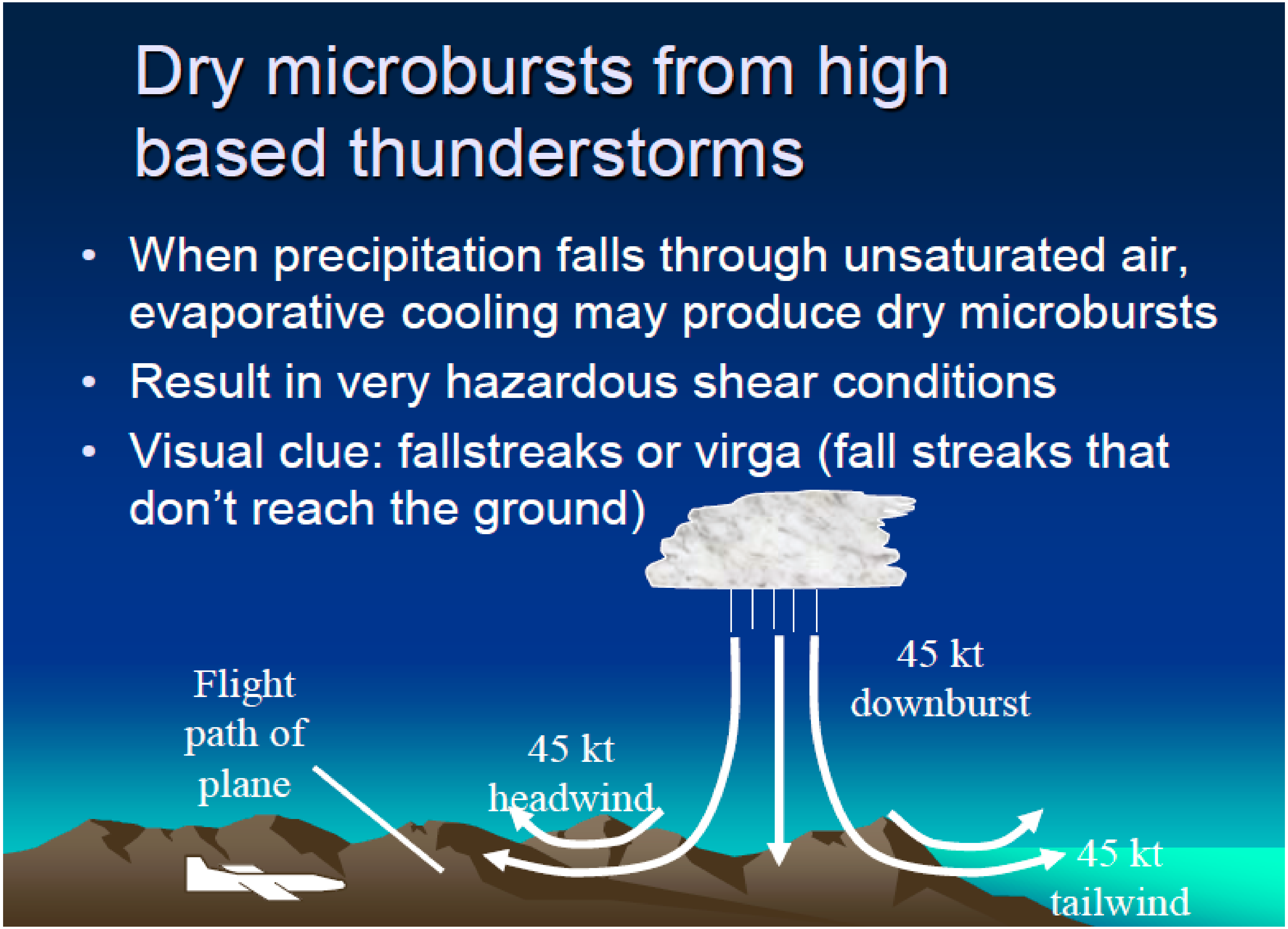
Dry microbursts from high based thunderstorms
• When precipitation falls through unsaturated air, evaporative cooling may produce dry microbursts
• Result in very hazardous shear conditions
• Visual clue: fallstreaks or virga (fall streaks that don’t reach the ground)
Flight path of plane
45 kt headwind
45 kt downburst
45 kt tailwind

Cont…

Clear air turbulence (CAT)

- CAT is turbulence which occurs in the free atmosphere away from any visible convective activity.

- CAT is defined as high-altitude aircraft bumpiness in regions devoid of significant cloudiness and away from thunderstorm activity.

- Far from mountains, CAT is generally accepted to result from shear instabilities. Wind shear is, therefore, a major source of CAT and is one of the best understood sources.

Cont…

General characteristics of clear air turbulence include:

- Occurs in patches
- Area is elongated with the wind
- Usually found above 15,000 feet
- In association with a marked change in speeds:
    - » with height (vertical shear)
    - » or in the horizontal (horizontal shear)
- 2,000 feet deep
- 20 miles wide
- 50 miles long
- transitory
- Most frequent during winter
- Least frequent during summer

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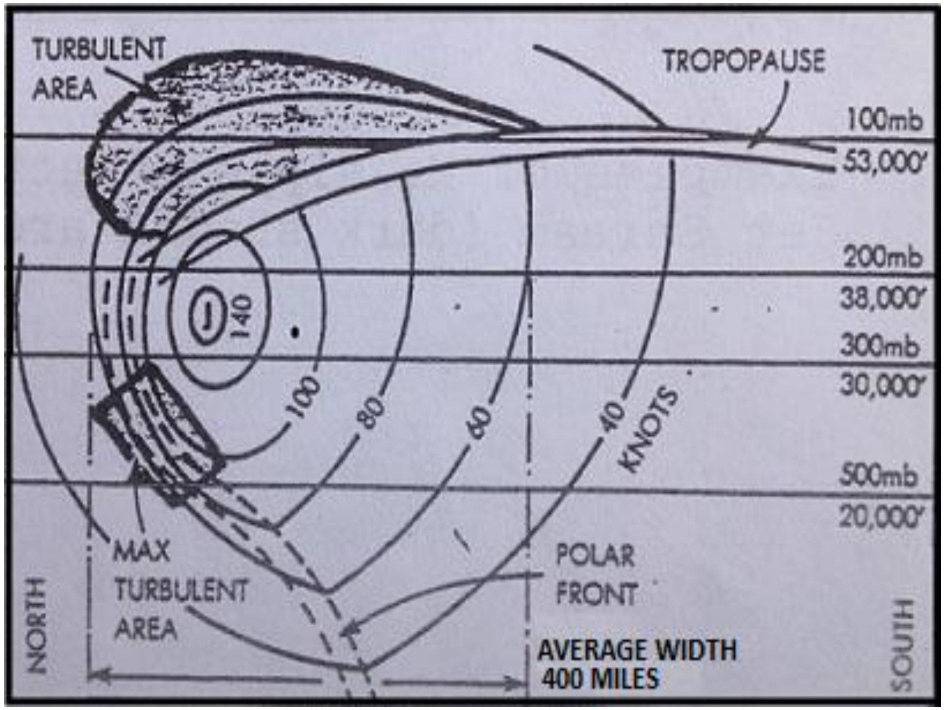
TURBULENT
AREA
TROPOPAUSE
100mb
53,000'
200mb
38,000'
300mb
30,000'
500mb
20,000'
J
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KNOTS
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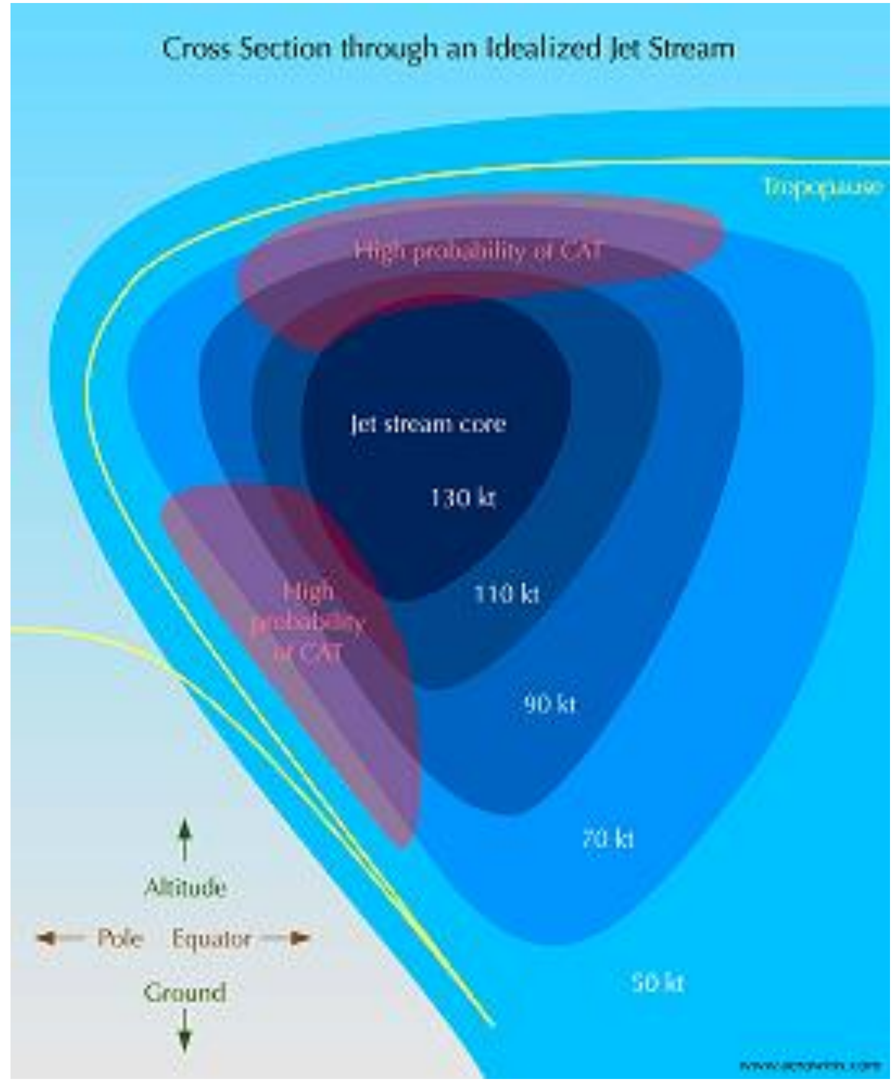
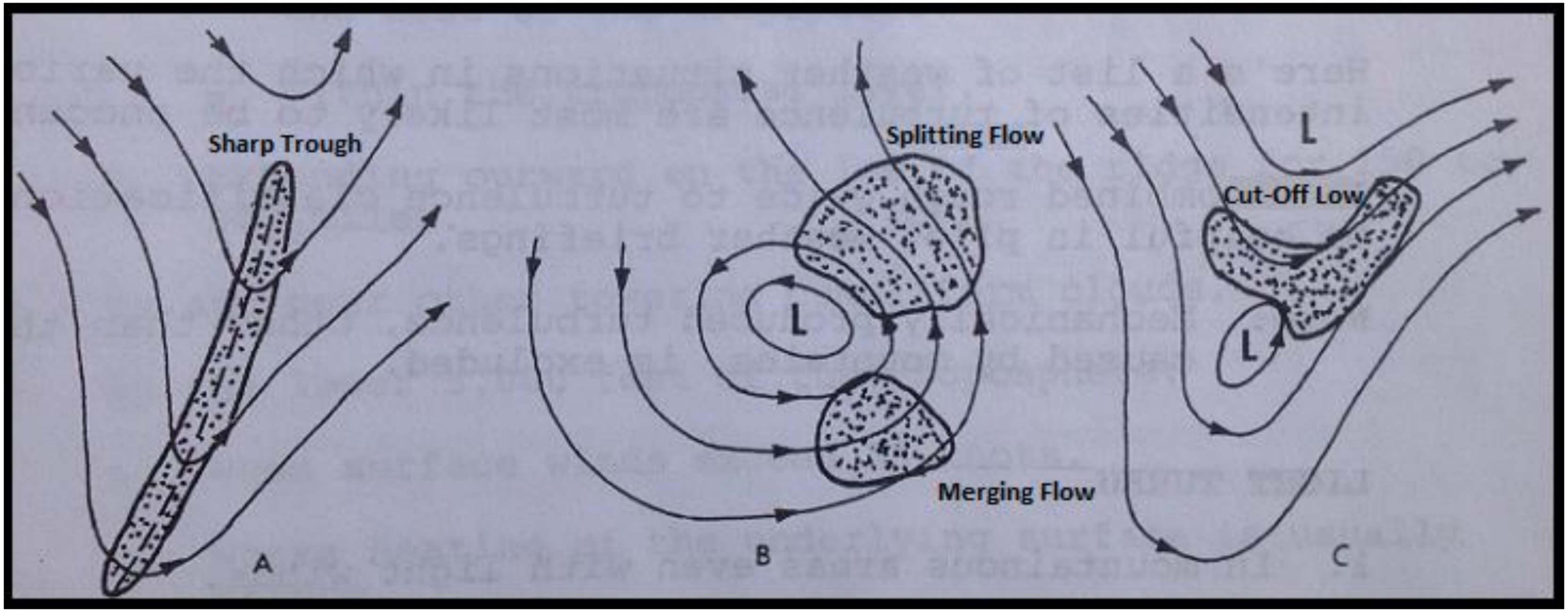
400 MILES
NORTH
SOUTH


Cross Section through an Idealized Jet Stream
Tropopause
High probability of CAT
Jet stream core
130 kt
110 kt
High
probability
of CAT
90 kt
70 kt
50 kt
Altitude
Pole
Equator
Ground

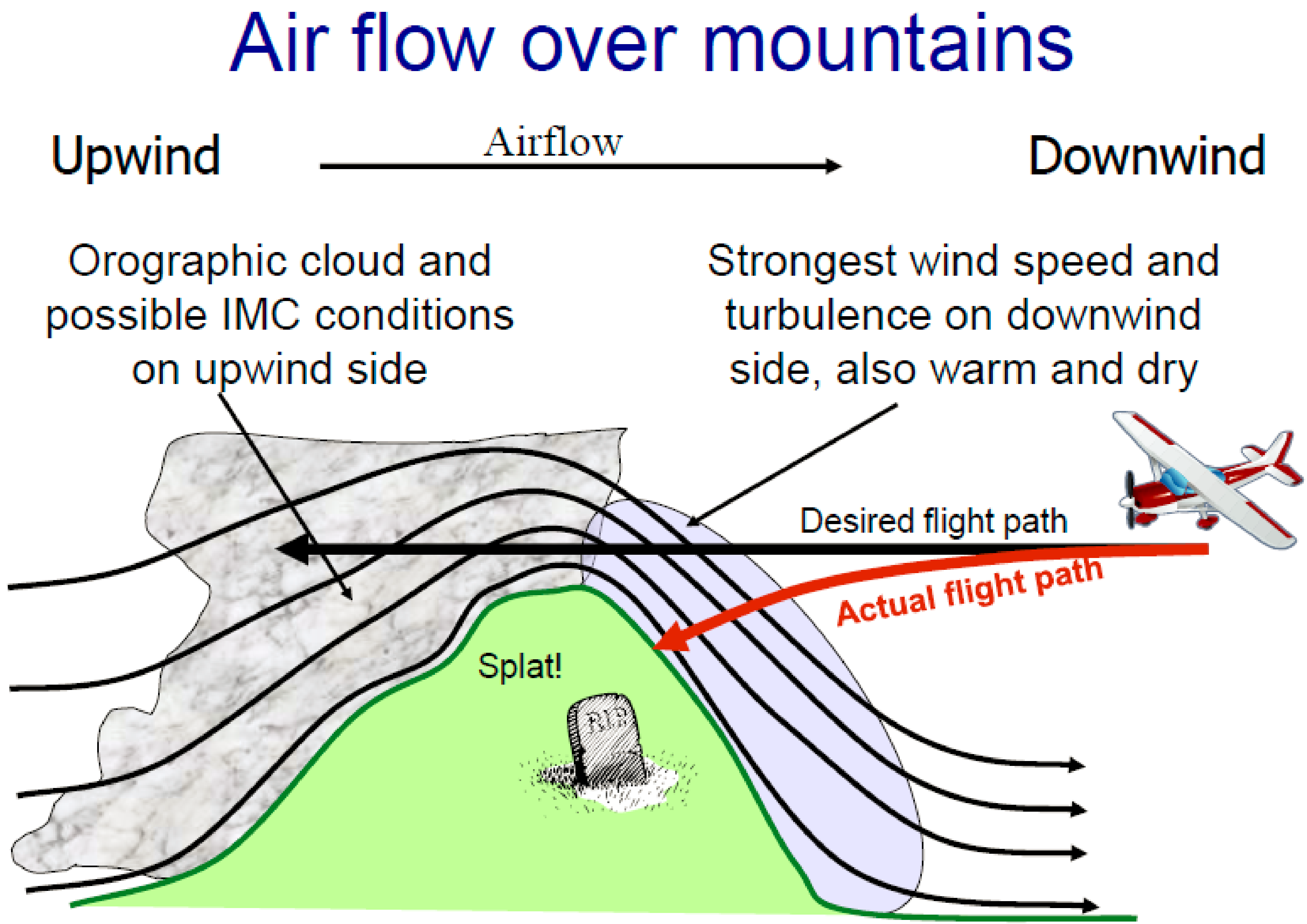
Cont…

The occurrence of CAT can extend to very high levels and can be associated with other wind flow patterns which produce shears:

- A sharp upper level trough, especially one moving at speeds greater than 10 knots. (See Figure A. below)
- A closed low aloft, particularly if the flow is merging or splitting (See Figure B. below)
- To the northeast of a cutoff low aloft as shown in Figure C. below



Mountain wave turbulence (MWT)



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- Produces the most violent turbulence (other than TS)
- Intensity of turbulence increases with wind speed and steepness of terrain
- Watch for strong downdrafts on lee side

  " Climb above well above highest peaks before crossing mountain or exiting valley "
- Occurs in two regions to the lee of mountains:

  1.Near the ground and

  2.Near the tropopause
- Turbulence at and below mountain top level is associated with rotors
- Turbulence near tropopause associated with breaking waves in the high shear regions just above and below troppouse

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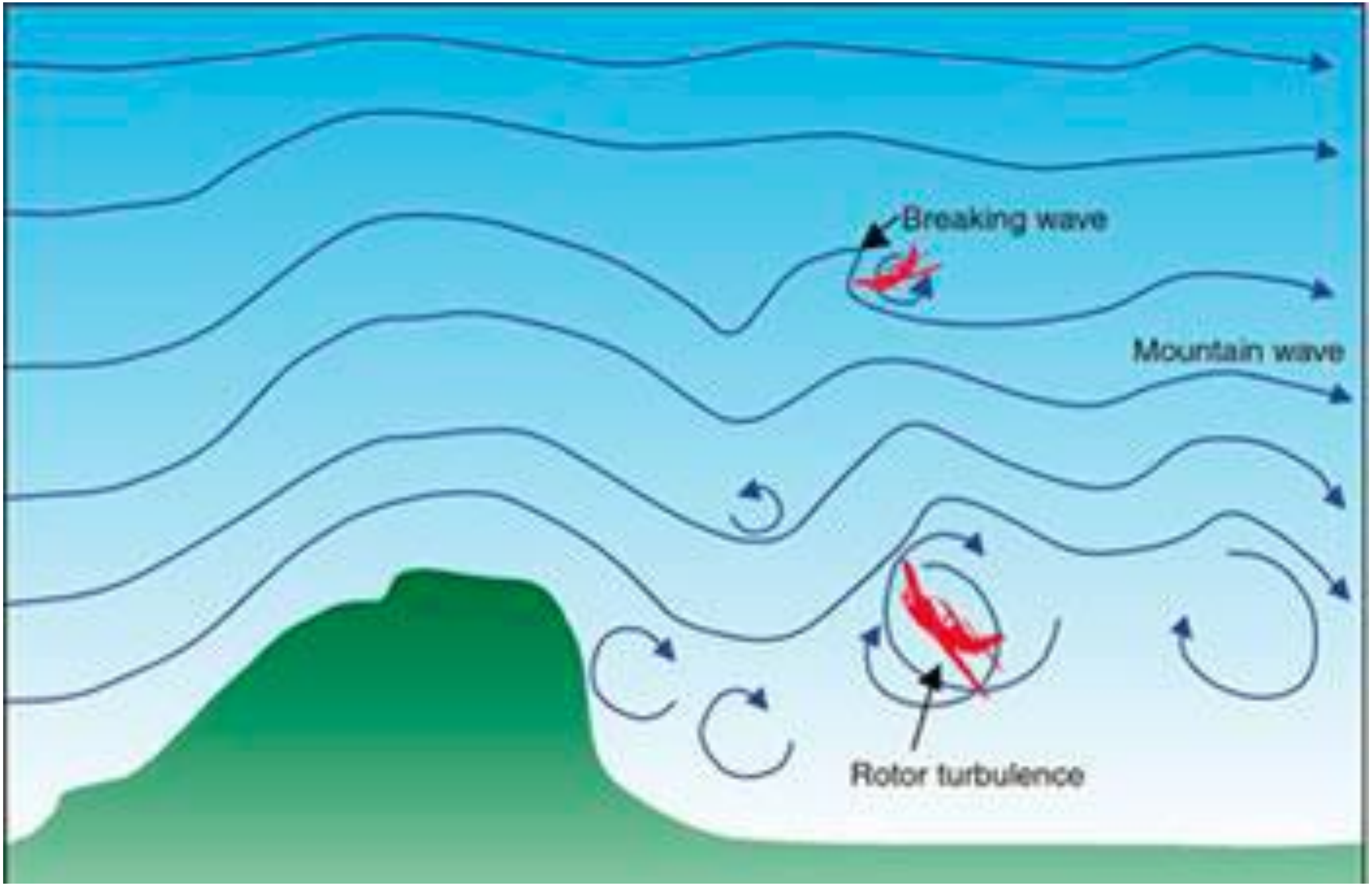

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- Severity increases with increasing wind speed at mountain crest
  - –For mountain top winds between 25 and 50 kt, expect moderate turbulence at all levels between the surface and 5,000 ft above the tropopouse
  - –For mountain top winds > 50 kt, expect severe turb 50-150 miles downstream of mountain at and below rotor level, and within 5,000 ft of the tropopause
  - –Severe turbulence in boundary layer. May be violent downslope winds
  - –Dust may indicate rotor cloud (picture)

Cont…

- Mountain waves become more pronounced as height increases and may extend into the stratosphere
  - Some pilots have reported mountain waves at 60,000 feet.
  - Vertical airflow component of a standing wave may exceed 8,000 feet per minute
- Vertical shear may cause mountain waves to break, creating stronger turbulence
  - Often happens below jet streak or near front

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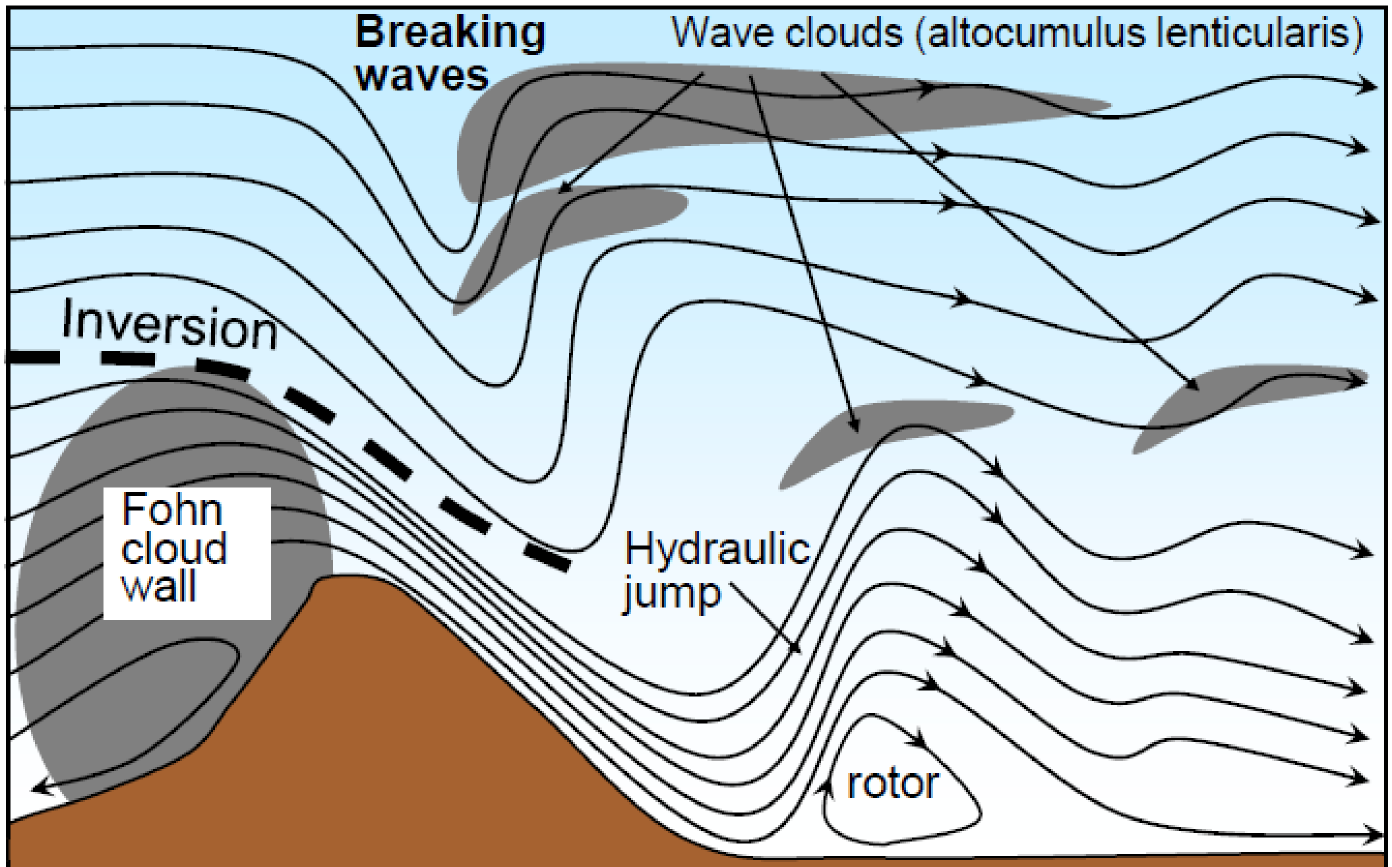
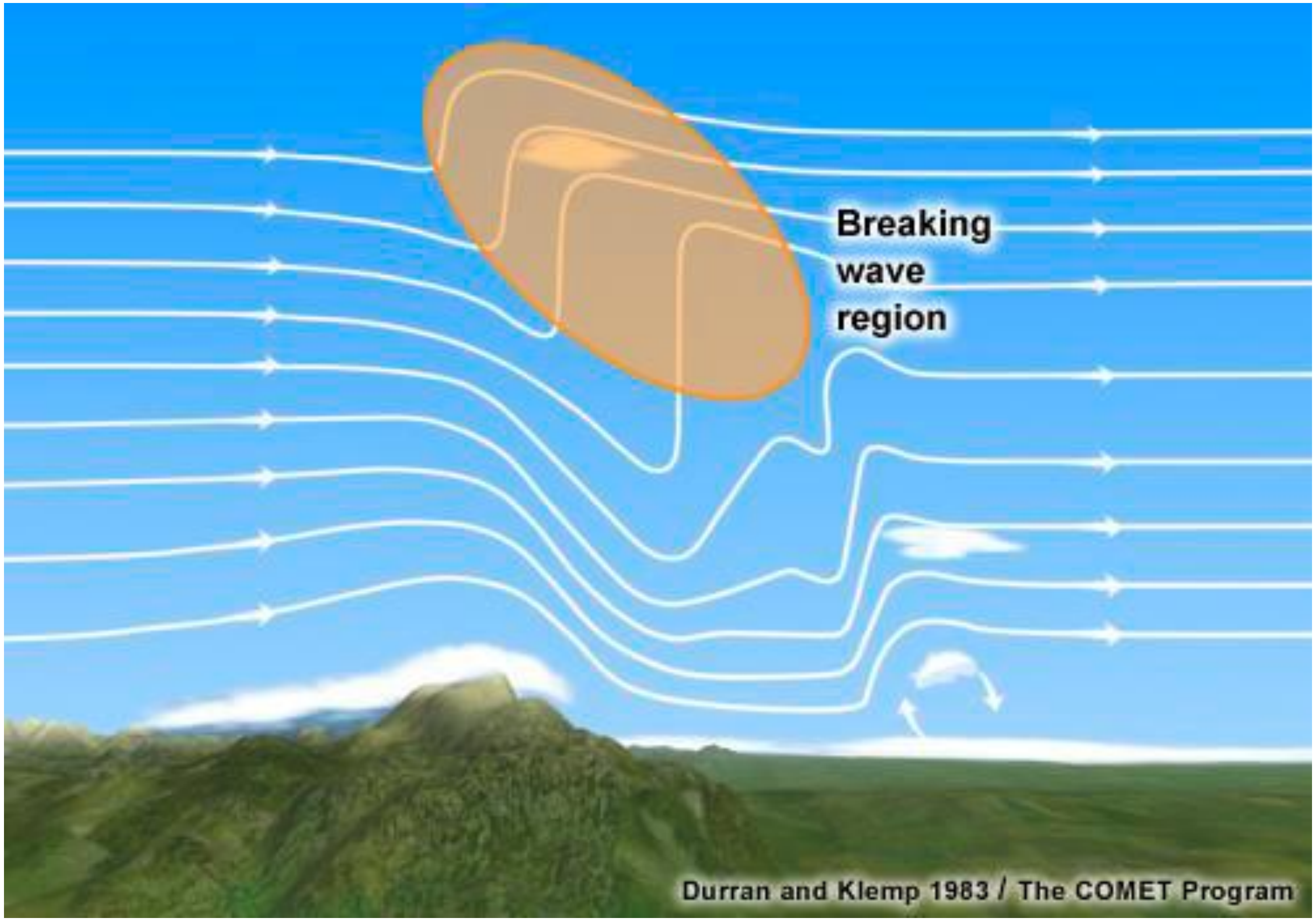
Mountain wave terminology



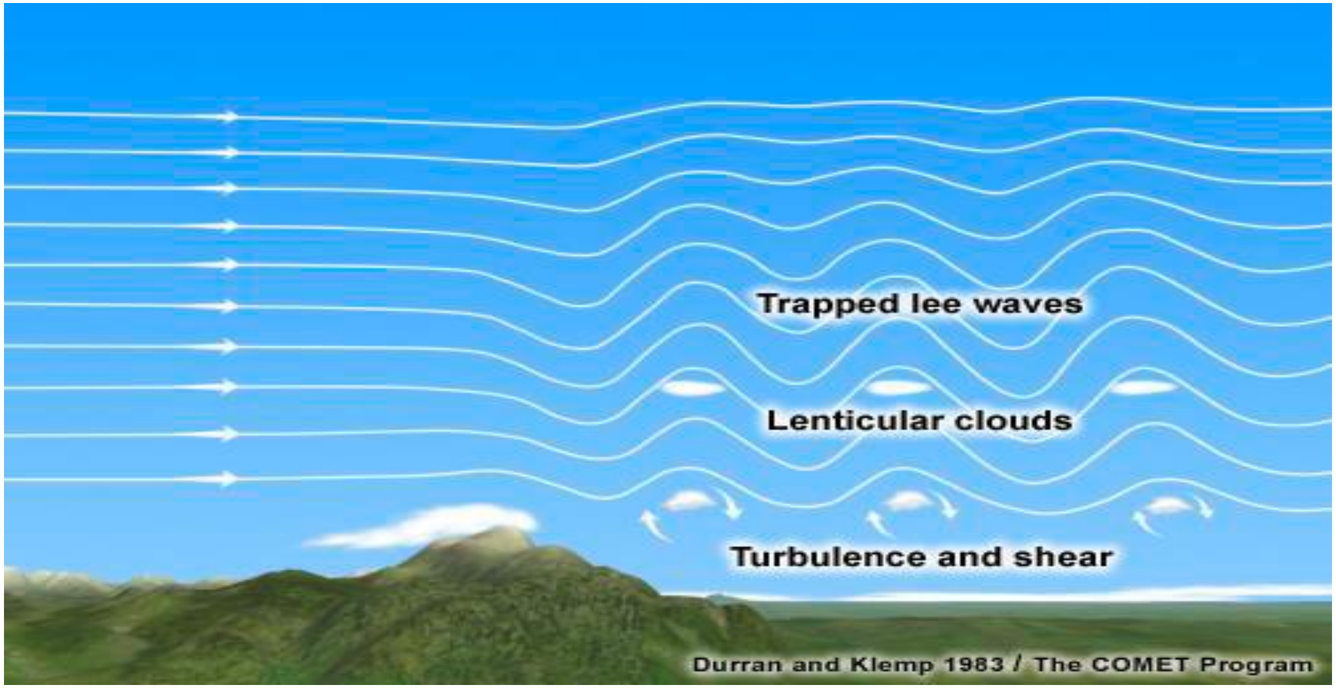
Breaking Wave Region

- Vertically-propagating waves with sufficient amplitude may break in the troposphere or lower stratosphere.



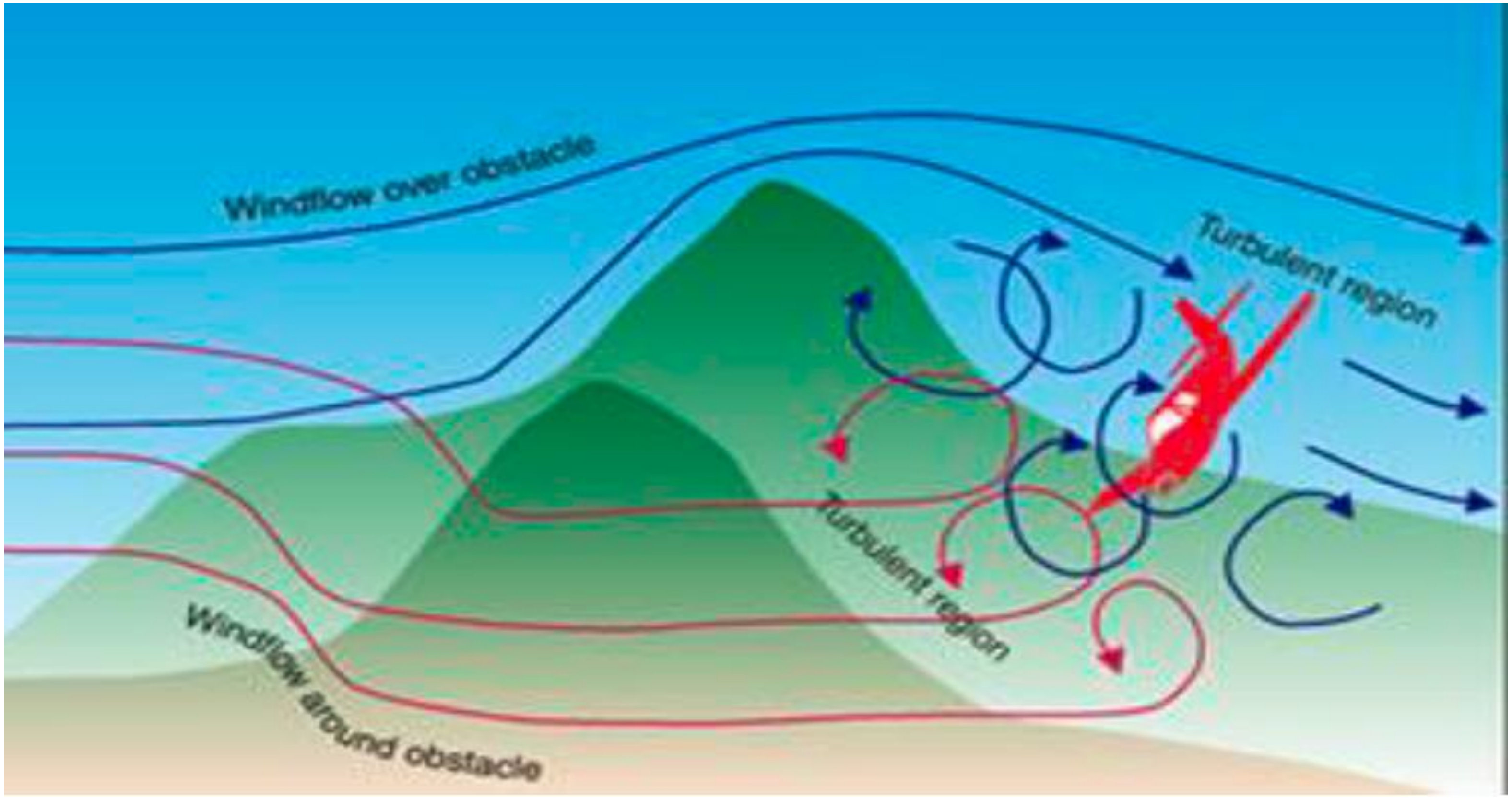
Lee Waves

- Lee waves propagate horizontally because of strong wind shear or low stability above. These waves are typically at an altitude within a few thousand feet of the mountain ridge crest.
- Lee waves are usually smooth, however, turbulence occurs in them near the tropopause
  - –Avoid lenticular cloud with ragged or convective edges
  - –Watch for smooth (but rapid) altitude changes



Flow over/around mountains

- Strongest flow near top and on downwind side
- For stable air and/or lighter winds, air will tend to go around rather than over mountain
- For less stable air and strong winds, air will go over mountain



Reduced Visibility

- Aircraft operations can be severely restricted by poor visibility. Flight visibility is the average range of visibility forward from the cockpit of an aircraft in flight

- Visual flight rules (VFR) are a set of regulations under which a pilot operates an aircraft in weather conditions generally clear enough to allow the pilot to see where the aircraft is going.

- For VFR rated pilots, it is the specified forecast and observed visibility and air to air and air to ground visibility that is critical to safe flight.

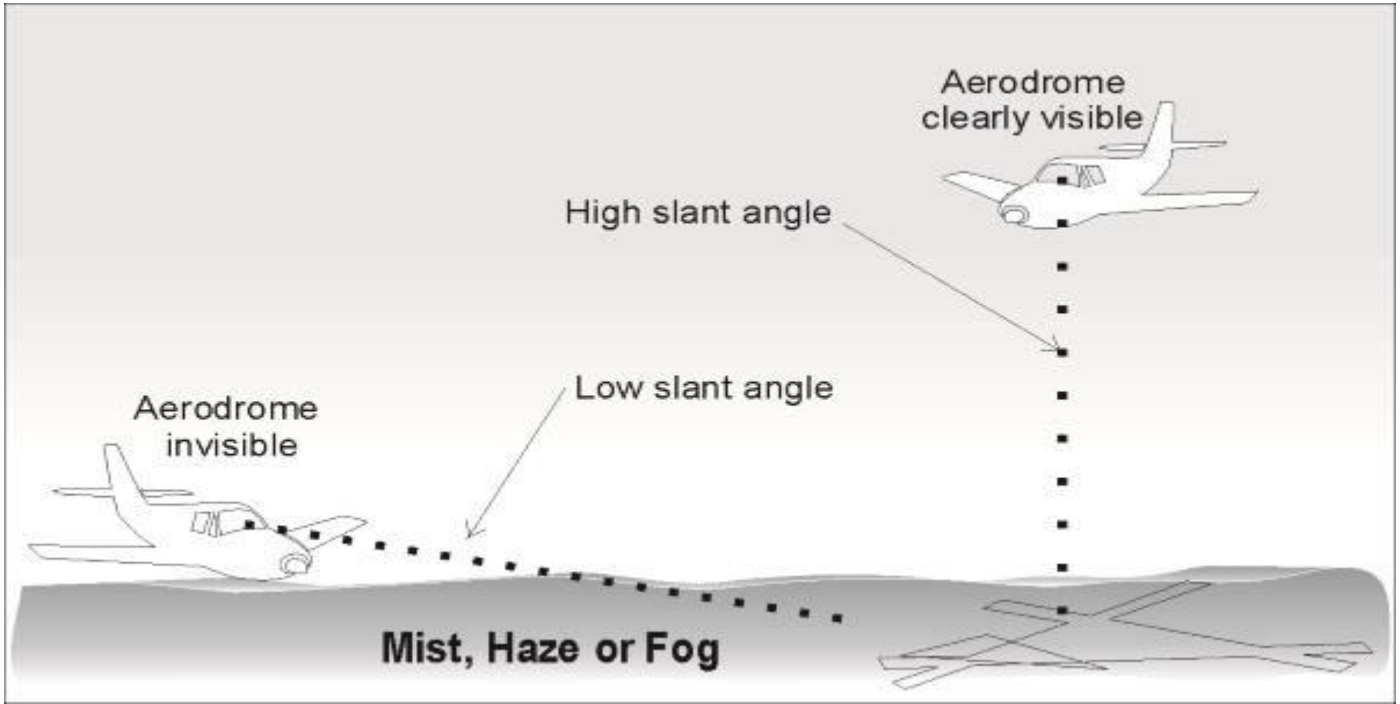
- There have been many accidents when VFR pilots have continued flight into weather below Visual Meteorological Conditions (VMC).

- Perceived visibility can vary greatly, depending on the point of view of the observer and the prevailing weather conditions.

In-flight visibility

- In-flight visibility changes as the angle of view changes. When over flying an aerodrome, the runway complex can be clearly visible through the fog – in fact, the fog might not be visible.

- As slant angle decreases, the runway will become obscured. On other occasions, a layer of cloud might reduce air to ground visibility while horizontal visibility is good.



Visibility in cloud

- Visibility within clouds might vary from less than 10m to over 1000m.
- In cirrus, visibility is generally greater than 1000m while in middle level cloud visibility can range from 20m to about 1000m.
- It can be below 10m in cumulonimbus and nimbostratus cloud.

Visibility in precipitation

- Visibility in rain will depend on the drop size and the rate of rainfall.
- Reductions in visibility will be greatest in very heavy rain (large droplets) and in drizzle (many small droplets very close to one another).
- Heavy rain is also often associated with low cloud below the main base, which reduces visibility even further.

Visibility in smoke

- Smoke haze can be a serious hindrance to visual navigation.

- It reaches its peak during periods of prolonged anticyclonic weather, when light winds and subsidence inversions allow pollution levels to build up and for visibility to be reduced.

Visibility in Dust storms

- Defined as blowing dust with prevailing visibility less than 1000 metres.
- Dust storms can cause major disruptions to flight in dry land areas.
- Very strong, gusty winds combined with instability will generate dust storms. A severe dust storm will reduce visibility below 200 metres.
- Such storms can be both widespread and deep. The depth depends on the height to which the atmosphere is markedly unstable, but is commonly well over 10 000 feet.
- Dust storms are usually a daytime phenomena because low-level thermal instability and gustiness decrease at night.

Fog

- Fog is defined as a concentrated suspension of very small water droplets reducing horizontal ground level visibility to below 1000 metres. Fog is actually a cloud occurring at ground level.

- Fog forms in the same basic ways as cloud. Either:

A) a moist air mass is cooled beyond its saturation point and condensation occurs; or

B) Extra moisture is added to make the air saturated at that temperature.

- Most fogs are initiated when moist air is cooled by contact with an underlying cold surface, whereas clouds form as a result of moist air being cooled by lifting.

Effect of fog on an aircraft

- Fog seriously degrades visibility to the extent that landing may be impossible except for most expensive aircraft. “auto land”

- Ice fog has similar visibility restriction, but in addition untreated taxiways and runways may be coated with thin layer of ice.

- Pilots may be given a false sense of security when over flying an airfield, since structures and runways may be quite clear to the pilot when looking down from directly above the airfield.

- However, when descending onto the approach and trying to view the airfield at a slant angle through the fog, the pilot may very quickly lose all visual cues and find themselves in a very serious difficulty.

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Volcanic Ash

- Volcanic ash is hazardous to aircraft; its effects range from a peculiar odour in the cabin to engine failure.
- The volcanic ash and corrosive gases from an erupting volcano can cover a wide area and remain in the atmosphere for days.
- Volcanic ash is composed of pulverised rock, predominantly silica (in the form of tiny glass shards) in most cases.
- It is usually electrically charged resulting in lightning, and is accompanied by corrosive gases such as hydrochloric acid and sulphur dioxide, which over time converts into droplets of sulphuric acid.
- The ash plume from a volcano may have the visible characteristics of Cumulus or Cumulonimbus cloud; downstream the plume may resemble fine, whispy cirroform cloud.

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- The most critical effect of volcanic ash on aeroplanes is engine damage.

- The heat of the engine can cause the silica in the ash to melt and fuse into a glass-like coating on components further back in the engine, causing loss of thrust and possible flameout.

- In addition volcanic ash can abrade engine parts and contaminate electrical systems, avionics equipment, hydraulic systems and fuel.

Chapter III

Meteorological service for aviation

3.1 met office for aviation and their services (WMO, ICAO)

3.2 information available at met office and supply

3.3 transmission of met information

Meteorological service for aviation

Introduction

- WMO became a specialized agency of the United Nations in 1951.

- ICAO and WMO soon established working arrangements that set out who does what when it comes to meteorological services to aviation.

- The relationship is conceptually simple: ICAO establishes the requirements for meteorological services to international aviation and WMO establishes how to meet these requirements and sets standards for service delivery.

- With the significant increase in air traffic over various regions in the past decade, demands for increasing consultations and new types of weather products by the airport management and air traffic management stakeholders are increasing.

3.1 Met Office for aviation and their services

- Meteorological information is supplied to the aviation personal for flight planning. This services are provided for informational air navigation in accordance with procedure specified by WMO and ICAO.

- The following terms are defined in accordance with WMO and ICAO specification for Meteorological services, for international air navigation.

- In regional or National context, it may sometimes be more appropriate to use other terminology.

A) Aeronautical Meteorological station : A station designated to make observations and meteorological reports for use in international air navigation.

B) Air Report : a report from aircraft inflight prepared in conformity with requirements for position or/and meteorological reportinhg

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c) Altitude: the vertical distance of a level, a point or an object considered as a point, measured from mean sea level.

D) Briefing (Meteorological Briefing): oral commentary on existing and or expected meteorological conditions.

E) Consultation: Discussion with meteorological or another qualified person of existing and/or expected meteorological conditions relating to flight operation, discussion includes answer to questions.

F) Forecast: A stetment of expected meteoological condditions for specified time or period and for a specified area or portion of airspace.

G) VOLMET broadcast: Routine broadcast of meteorological information for aircraft in flight.

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Meteorological information shall be supplied to operators and flight crew members for :

- ➔ pre-flight planning by operators
- ➔ use by flight crew members before departure
- ➔ Aircraft in flight

H) SIGMET information : Information issued by a meteorological Watch office concerning the occurrence or expected occurrence of specified en-route weather phenomenon which may affect the safety of aircraft operations

I) Prognostic charts: a forecast of a specified meteorological element(s) for a specific time or period and a specified surface or portion of airspace, depicted graphically on a chart.

Sources of Meteorological information for Aviation

Meteorological information required for flight planning is supplied by a variety of sources. Those providing meteorological services for international air navigation are as follows:

A) Area Forecast Centers : These centers issue and disseminate forecasts for the areas or routes for which they are responsible .

B) Meteorological office: An aerodrome meteorological office shall carry out all or some of the following function as necessary to meet the needs of flight operations at the aerodrome.

➔Prepare and/or obtain forecast and other relevant information for flight with which it is concerned. The extent of its responsibility to prepare forecasts shall be related to the local availability and use of en-route and aerodrome forecast material received from other offices

➔ Prepare and/or obtain forecasts of local meteorological conditiions

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- ➔ Maintain a continues survey of meteorological conditions over the aerodromes for which it is designated to prepare forecast
- ➔ Provide briefing, consultation and flight documentation to flight crew members and/or other flight operation personnel.
- ➔ Supply other meteorological information to aeronautical users
- ➔ Display the available meteorological information
- ➔ Exchange meteorological information with

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C) **Meteorological Watch office**

A meteorological watch office shall:

I) Maintain watch over meteorological conditions affecting flight operations within its area of responsibilities.

II) Prepare SIGMET information relating to its area of responsibilities

III) Supply SIGMET information and as required other meteorological information to associated air traffic services unit

IV) Disseminate SIGMET information

3.2 Information Available at Met office and supply

The type of meteorological information available for flight planning are as follows

a) Charts and diagrams

b) Routine information

- ➔ routine aerodrome observation
- ➔ aerodrome forecast

c) Non-routine information

- ➔ Special aerodrome observation
- ➔ Selected special reports
- ➔ Amendments to aerodrome forecasts

d) SIGMET information

e) Air reports

f) pressure values

g) Other information: ➔Area forecast ➔ Route forecast

➔ Forecast for take-off ➔ Forecast for landing

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Area Forecasts : specify the meteorological conditions expected to exist over a specific area during a specified period of time without reference to a particular flight or route.

Area forecasts are exchanged between meteorological offices , as required, in the ARFOR or ARMET codes.

Route Forecasts: Specifiy the meteorological conditions expected to exist along a route during a specified period of time, without reference to a specific flight.

Route forecasts are exchanged between meteorological offices as required, in the ROFOR code.

Forecast for Take-off : is supplied, when required. A landing forecast is prepared if it is needed in the in-flight stage (about one hour before the estimated time of arrival)

It is given as either as self-contained message on in the form of amendments to forecasts are included in meteorolgical information issued for flight planning

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Aerodrome Forecasts: specify the meteorological conditions expected at an aerodrome during a specified period of time.

Aerodrome forecasts and amendments to aerodrome forecasts which are exchanged between meteorological office shall be :

- ➔ In the TAF code format
- ➔ In abbreviated plain Language
- ➔ In teletype writer character and symbols

The significance of which has been agreed upon by the meteorological authorities concerned

3.3 Significance of Meteorological Information

- The significance of various elements included in the meteorological information provided for the flight planning is as follows.

A) Upper wind: the direction and speed of the wind at the selected flight level are used to determine the ground speed of the aircraft. In this way the time of flight and fuel consumption can be estimated .

upper wind information is required for various levels, depending on the type of aircraft operation. A suitable flight level can then be selected.

B) pper air Temperature : the air temperature at the flight level operation affects the engine performance of the aircraft. This need to be taken under consideration when determining fuel requirements for flight.

In general, aircraft engine operates more efficiently at low air temperature.

C) Cloud Characteristics : cloud information (type, amount, height of bases and tops) is needed to determine the likelihood of icing and turbulence . In some types of aircraft operation, a decission also has to be made on the possibility of flight under visual flight rule (FVL)

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D) Hazardous weather :

In general, hazardous weather is more significant during the take off and landing phase s than it is at cruising level. Nevertheless, it imposes restrictions on the flight level and course , if it is necessary to avoid such areas.

E) Aerodrome forecasts:

Aerodrome forecasts for selected aerodromes in conjunction with upper wind forecasts are needed to decide on the destination and alternate aerodromes to include in the flight planning . These forecasts are also required for fuel consumption estimates.

F) Surface wind and temperature:

This information is required for the take-off and landing phases of the flight. The performance of the aircraft, the length of the runway and maximum pay load can then be determined