CPL Theory
Meteorology (CMET)

CMET 6 – Meteorological Hazards

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Related Documents	Document Identification

CMET 6 – Meteorological Hazards

Amendments made to this document since the previous version are listed below. All amendments to this document have been made in accordance with CAE OAAM's document management procedure.

Slide	Changes
36	Change to AIP page reference

THUNDERSTORMS

Thunderstorms – What are the necessary conditions?

- The necessary conditions include:

1. **Moisture throughout a deep layer of the atmosphere (high humidity)**
2. **Atmospheric instability**
3. **A trigger mechanism to commence lifting of air**

- The trigger mechanism determines the thunderstorm classification:

  - Heat/Convective Thunderstorm
  - Frontal Thunderstorm
  - Cold Stream Thunderstorm
  - Orographic Thunderstorm
  - Convergence Thunderstorm
  - Shear Thunderstorm
  - Night Equatorial Thunderstorm

Thunderstorms – Stages of Development

- There are 3 main stages in the life cycle of a thunderstorm:

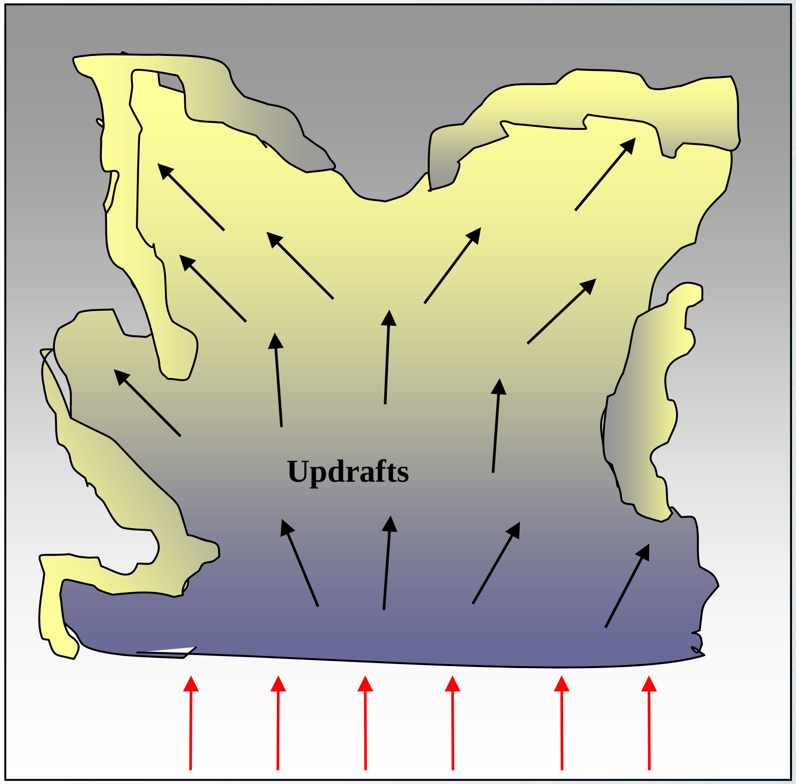
1. Cumulus/Growing Stage

2. Mature Stage

3. Dissipating Stage

Thunderstorms – Stage 1: Growing Stage

- Air is lifted by a trigger mechanism
- The air and any water droplets it carries continues to rise due to atmospheric instability

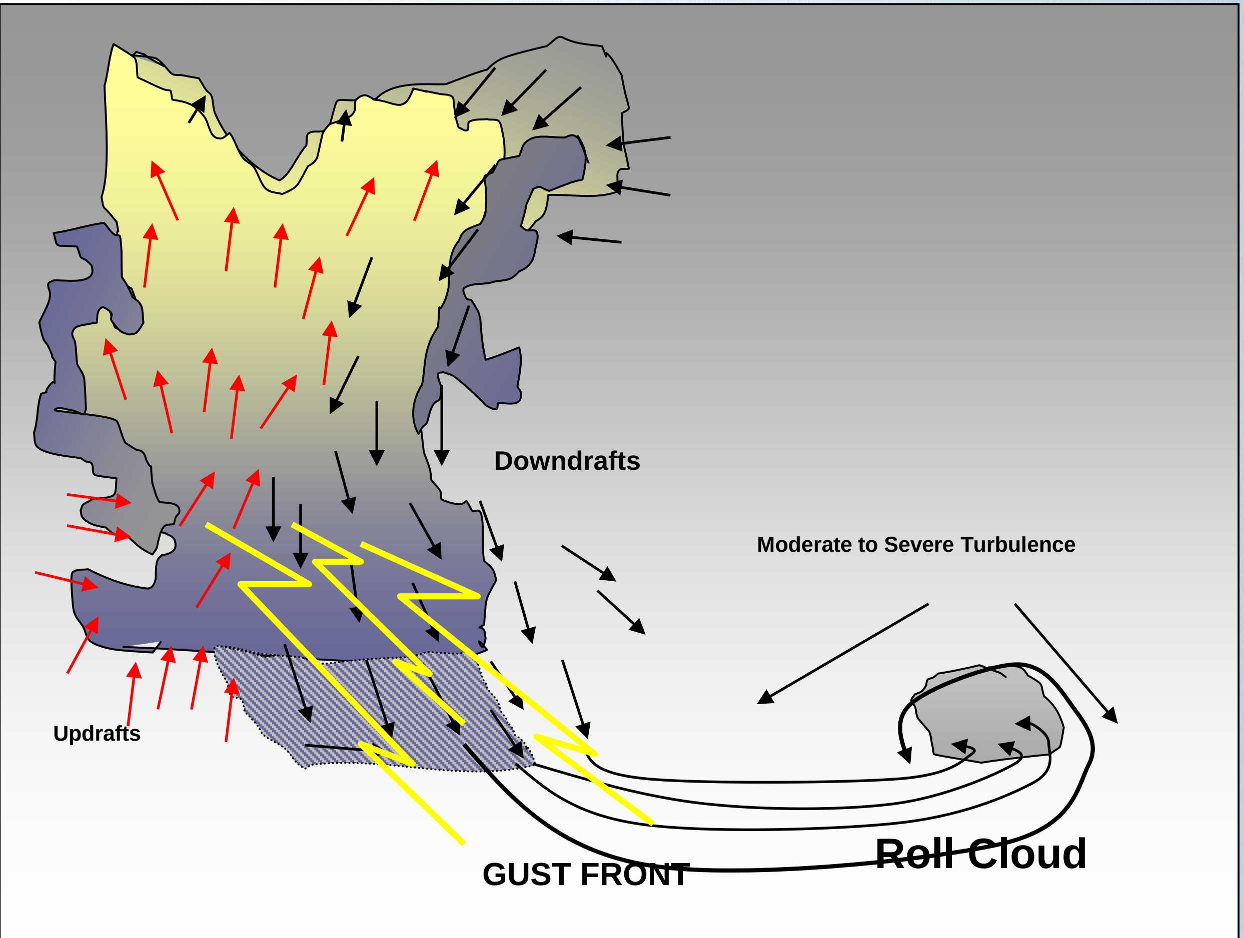


Characteristics:

- **Updrafts only (as much as 5000fpm)**
- **Moderate to severe airframe icing**
- **No significant weather at this stage**
- **Collision of water droplets causes them to become larger and heavier**

Thunderstorms – Stage 2: Mature Stage

- Eventually, the droplets become too heavy to be supported by the updrafts
- They begin to fall which leads to the commencement of **downdrafts**

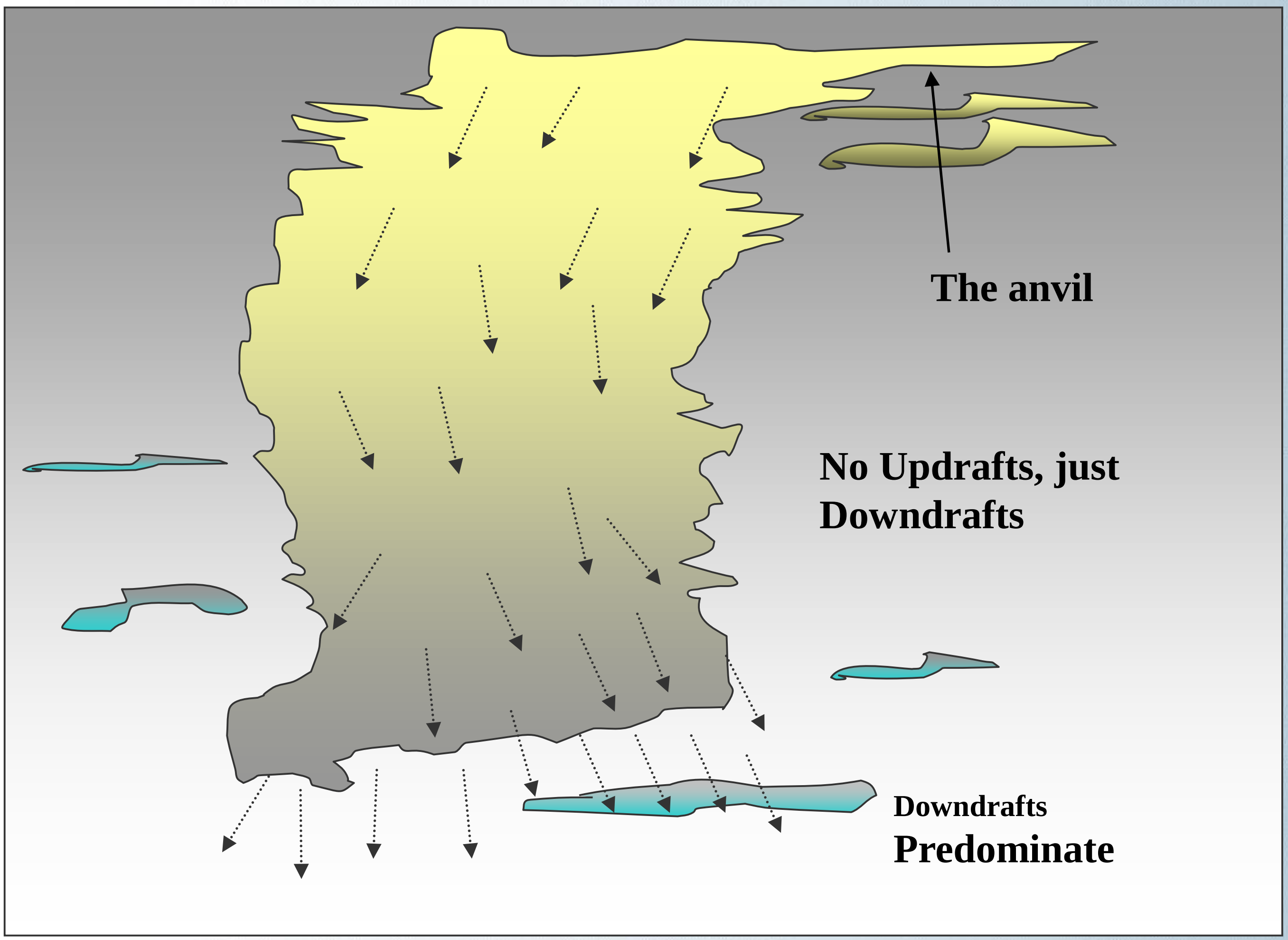


Characteristics:

- **Combination of updrafts & downdrafts causes severe turbulence (particularly in middle of cloud)**
- **Low level wind shear caused by downdrafts escaping bottom of storm**
- **Most severe weather occurs here – lightning, thunder, hail, heavy rain, severe icing etc.**

Thunderstorms – Stage 3: Dissipating Stage

- Updrafts will eventually cease (air has cooled and will now sink)



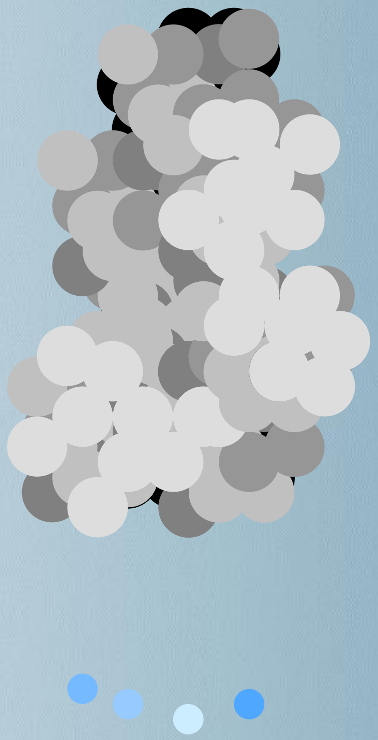
Characteristics:

- **Downdrafts only**
- **Cloud will eventually fragment and evaporate**

Thunderstorms – Convective Thunderstorms

Heat or convective thunderstorms

- Formed when the initial lifting is caused by solar heating of the surface.
- Typically begin forming in the mid afternoon during the summer months.



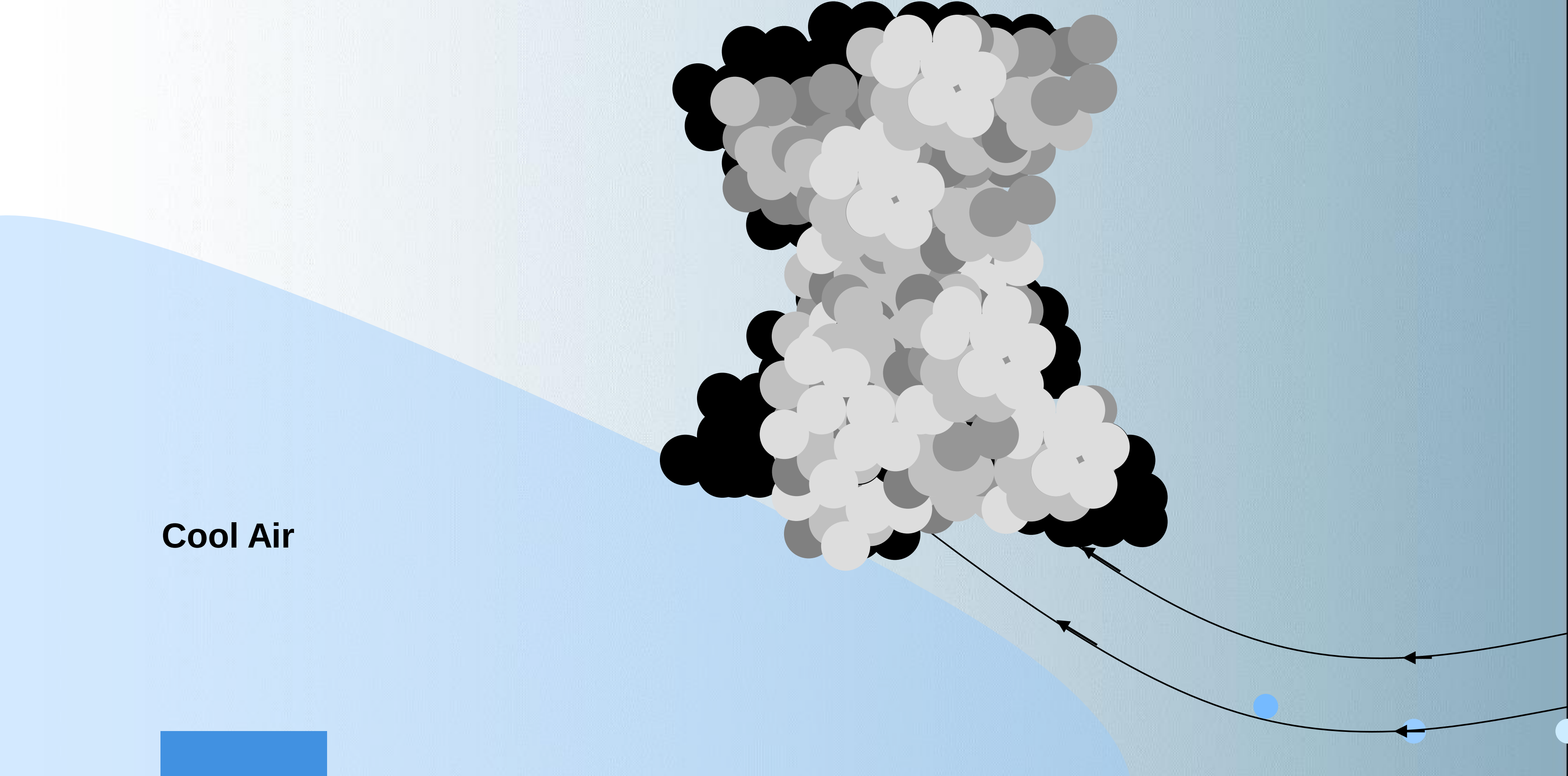
Thunderstorms – Frontal/squall line thunderstorms

Frontal (Shear) and squall line thunderstorms

- Formed along the boundary of two air masses or lines of significant weather such as a cold front and are most dangerous because a line of **closely spaced cells** may develop along the boundary of the air mass or frontal line.

- These squall line thunderstorms are often **fast moving** and have **lower cloud basses** than air mass thunderstorms and **stronger downdraughts** near the ground making passage around or through the storm difficult.

Thunderstorms – Frontal/squall line thunderstorms



Thunderstorms – Frontal/squall line thunderstorms

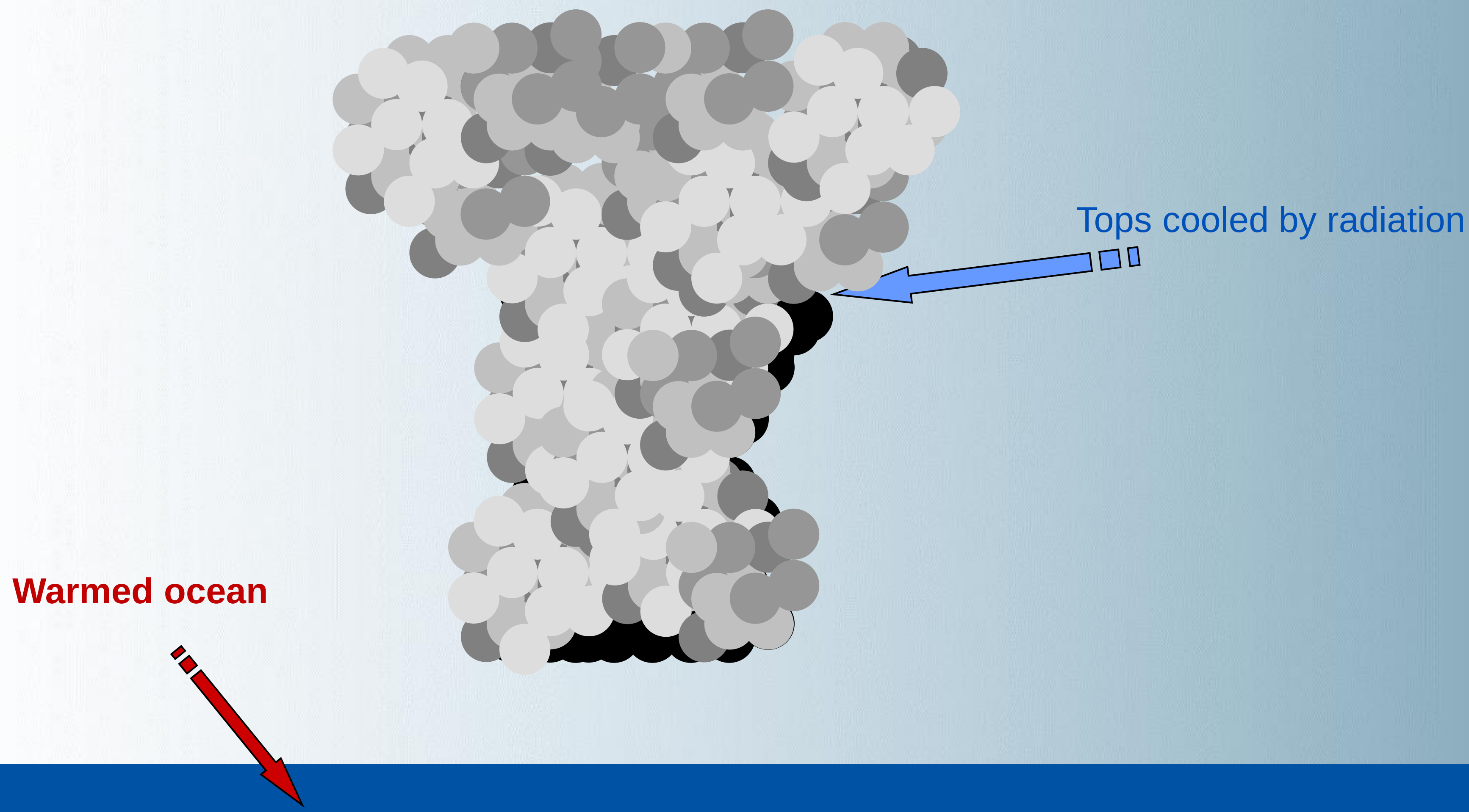
Thunderstorms – Nocturnal Thunderstorms

Nocturnal Equatorial Thunderstorms

- Develop near the equator over the ocean.

- The ocean temperatures remain warmer at night (around 28ºC) but the tops of cumulus clouds are cooled due to radiation. This leads to instability and thunderstorms can develop around sunrise.

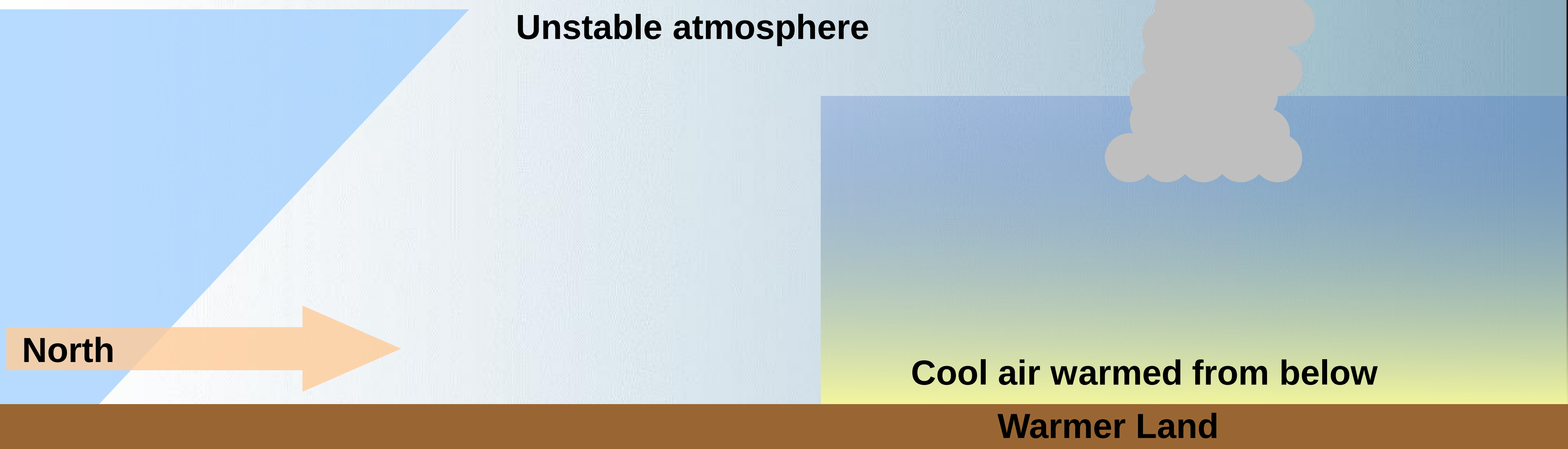
Thunderstorms – Nocturnal Thunderstorms



Thunderstorms – Cold stream thunderstorms

Cold stream thunderstorms

- Form in cold airstream which moves rapidly into warmer latitudes, form south to north in the southern hemisphere.
- The latitudinal heating of the surface layers does not depend on [illegible] solar heating, so it continues day and night. The lightning from these [illegible] can sometimes be seen over the ocean throughout the night.



Thunderstorms – Orographic thunderstorms

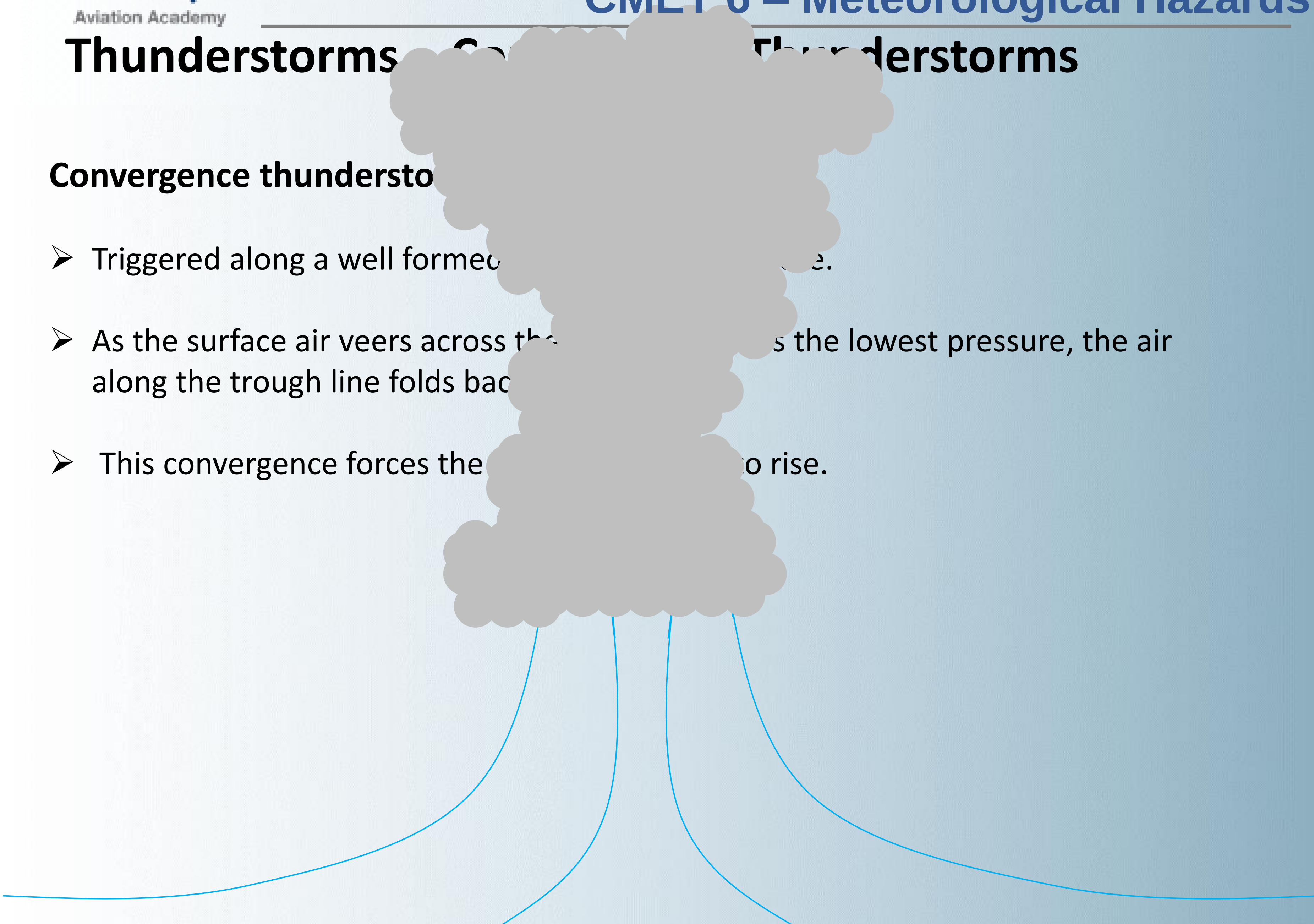
…ifted by its passage over a mountain range.

- T… …mbined with convection, causing storms which have formed in th… …come more frequent and persist longer in the vicinity of m…

Thunderstorms – Co[illegible]Thunderstorms

Convergence thundersto[illegible]

- Triggered along a well formed[illegible]e.
- As the surface air veers across th[illegible]s the lowest pressure, the air along the trough line folds bac[illegible]
- This convergence forces the [illegible]o rise.



Thunderstorms – Summary of Hazards

- **Severe Turbulence – greatest hazard to pilots!**

- Airframe Icing
- Lightning
- Hail
- Low Level Hazards:

1. **Squalls & Gusts**
2. **Wind Shear**
3. **Microbursts**

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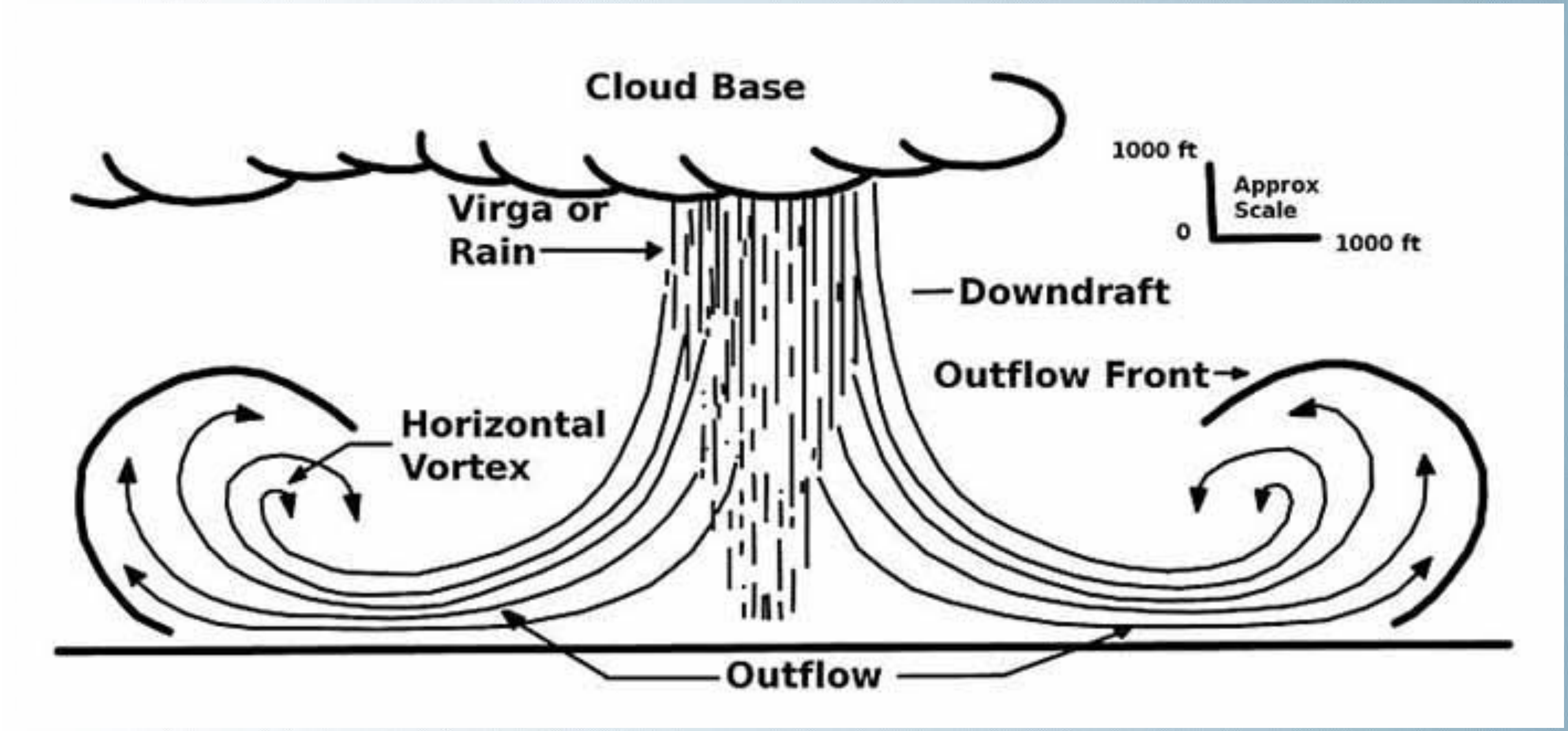
Thunderstorms – Microbursts

- Microburst: localised area of intense downdraft



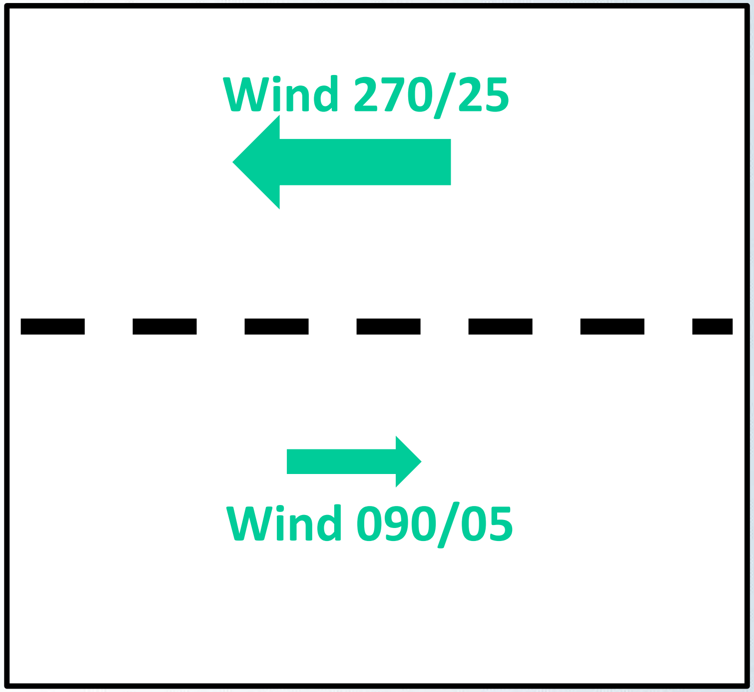
But before talking about microbursts in detail, we will first define windshear

WIND SHEAR

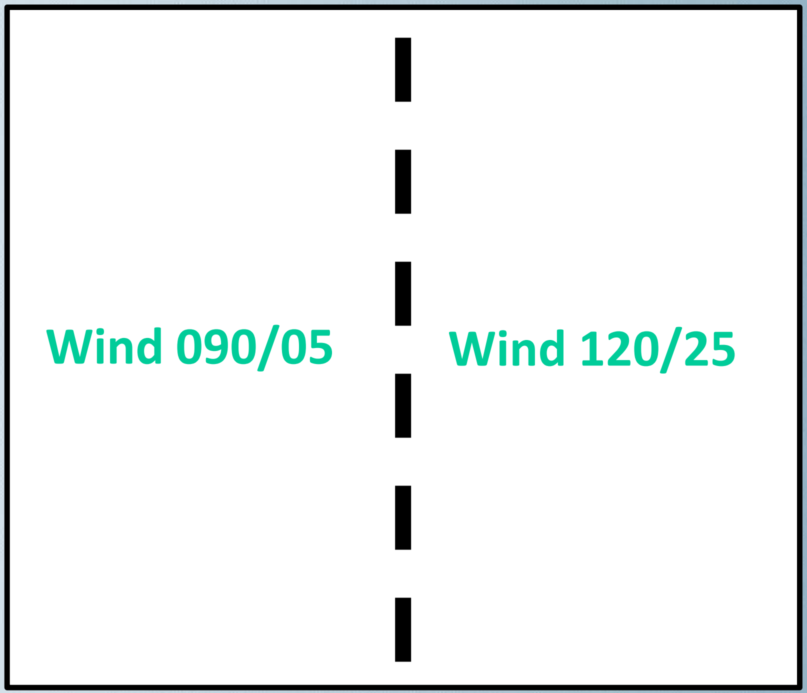
Wind Shear

- A sudden change in **wind speed and direction**

Refer AIP GEN 3.5 -21/22 for windshear strength classification and reporting



Vertical Wind Shear



Horizontal Wind Shear

Wind Shear

Overshoot windshear: A sudden increase in headwind or loss of tail wind
Undershoot windshear: A sudden loss of headwind or increase in tailwind

Wind shear may be encountered in the following places:

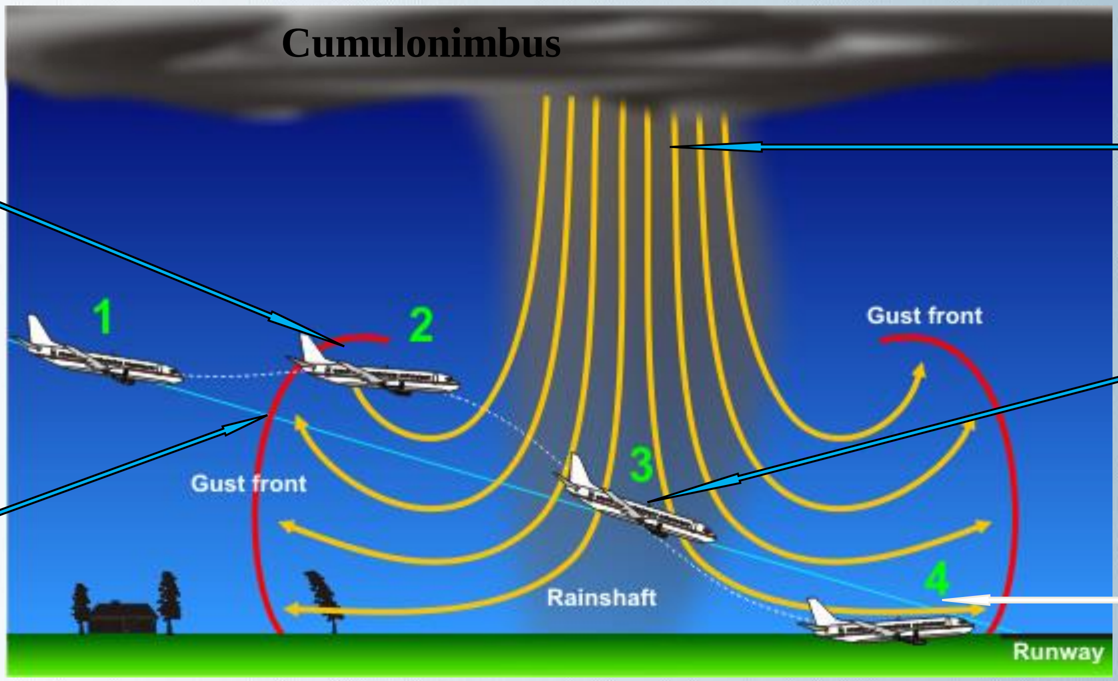
- Boundaries between air masses
- Beneath/near storms (see microburst)
- When exiting/entering an inversion layer
- Passing through a lower level Jetstream
- When descending/climbing between layers of differing wind speeds (e.g. Local sea breeze blows opposite to prevailing wind)

Wind Shear – Microburst

Aircraft first enters a headwind, followed by decreasing headwind and strong downdraft, eventually turning into a tailwind

2. Increase in HW Resulting in an Increase in Lift

1. Intended Approach path



Virga

3. Sudden loss of HW resulting in reduced lift

4. Dramatic increase in TW resulting in the AC undershooting the runway

Wind Shear – Microburst

Virga is sometimes a symptom of a microburst:

- Precipitation falls from the cloud base
- Water droplets get evaporated back into the air
- Air supplies the droplets with the necessary latent heat, thus the air cools
- The cool air now descends rapidly

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Delta 191

https://www.youtube.com/watch?v=HY7pH3fzsvY

TURBULENCE

Turbulence

- There are several types of turbulence:

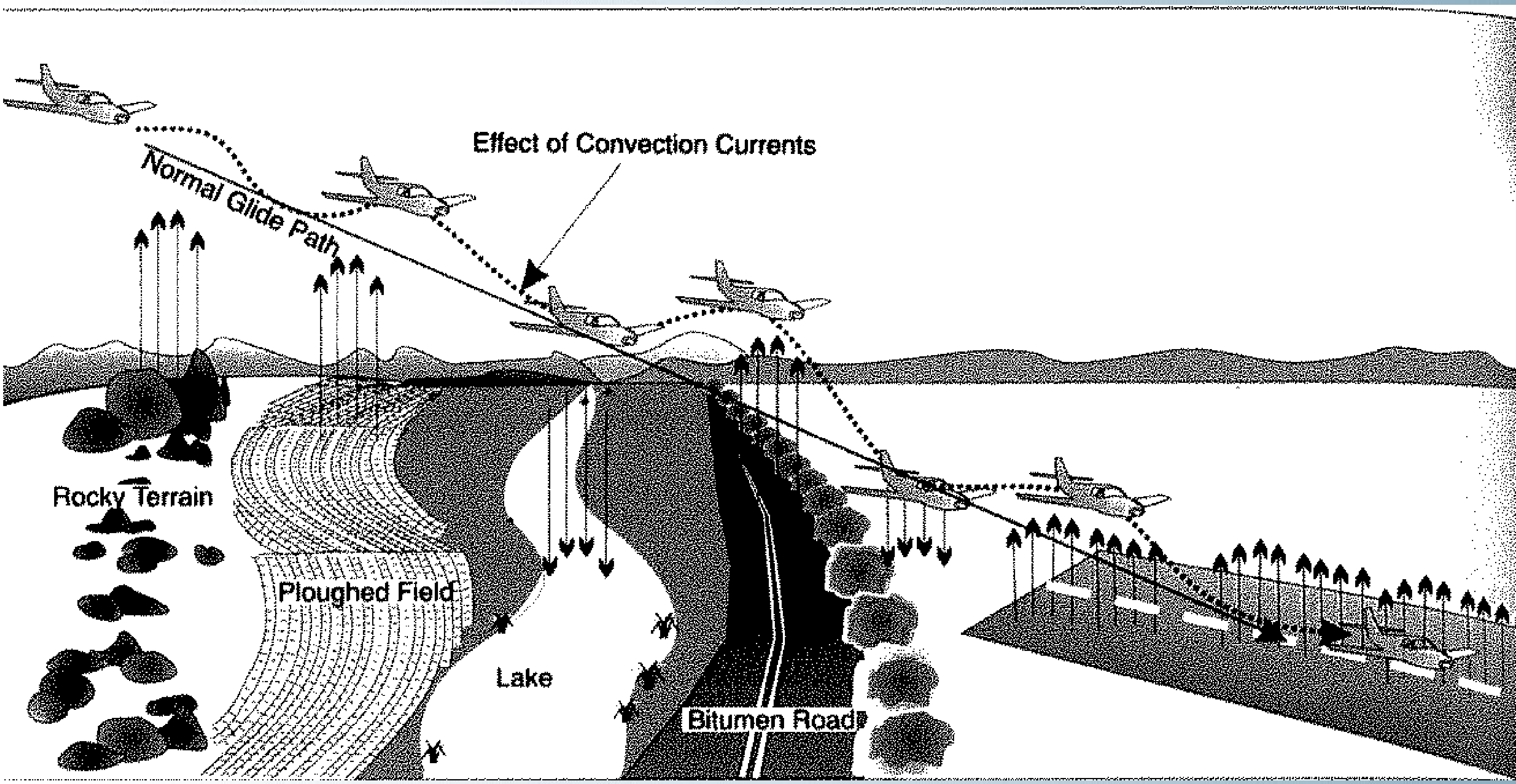
1. **Convective**
2. **Mechanical**
3. **Frontal**
4. **Kelvin-Helmholtz Waves**
5. **Wake Turbulence (aircraft-induced)**

Turbulence – Convective (Thermal)

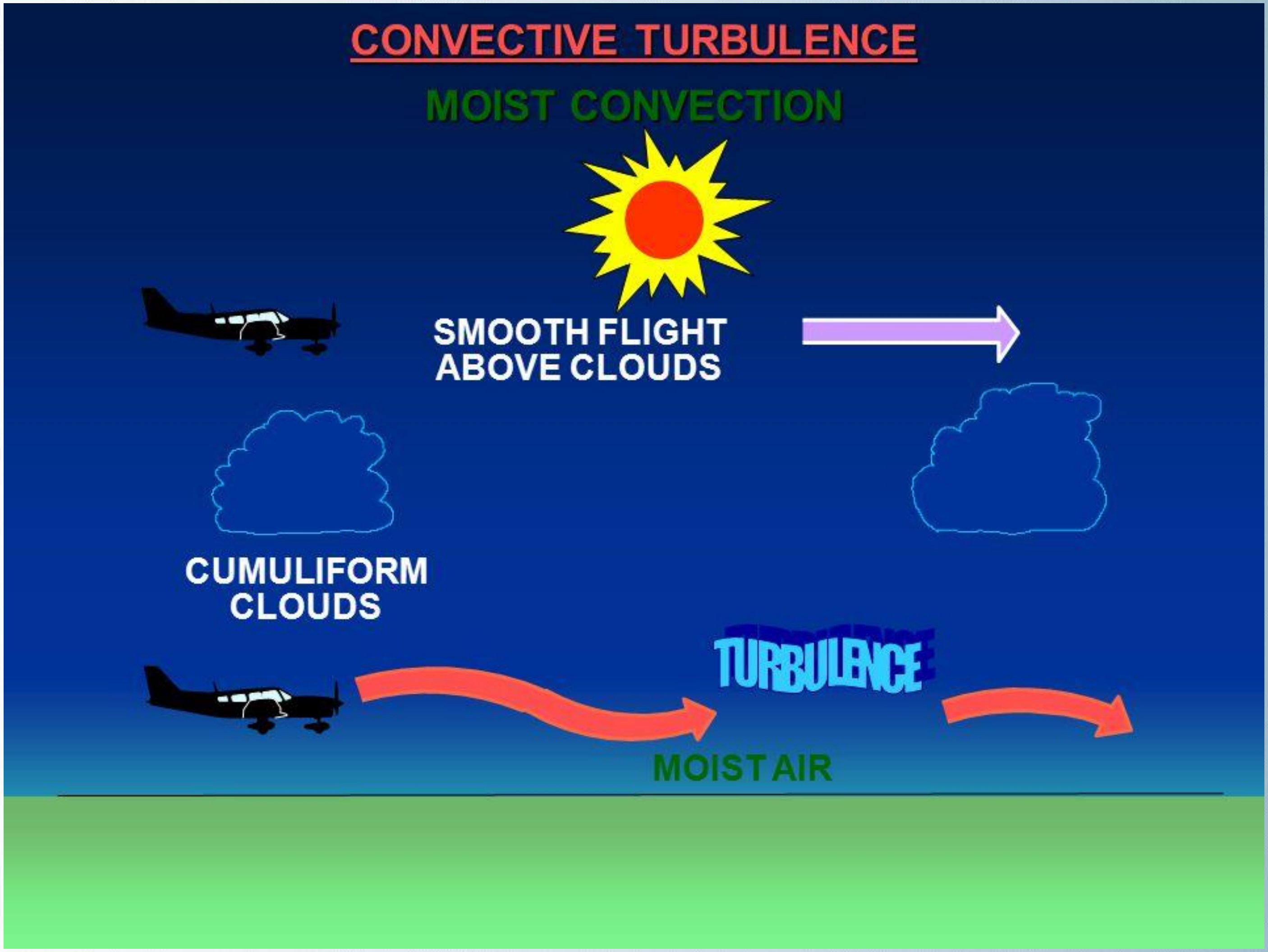
- As air is heated, it becomes less dense
- As the density decreases, the air begins to rise. This process is known as **convection**
- Rising currents of air are known as **thermals**
- Different surfaces e.g. water vs land will heat at different rates, creating uneven currents of rising air

Turbulence – Convective (Thermal)

- The effect of this is particularly apparent when on approach

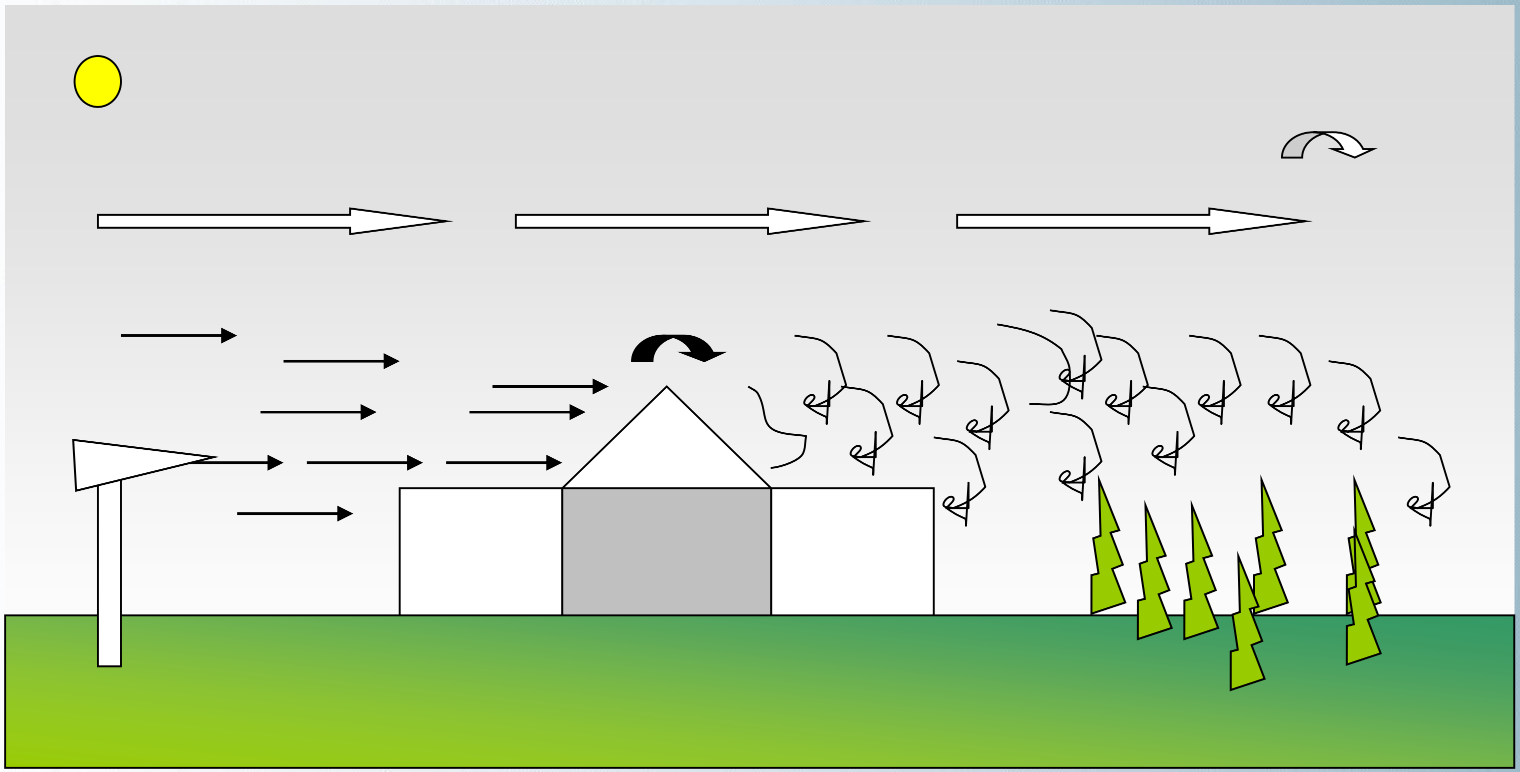


Turbulence – Convective (Thermal)



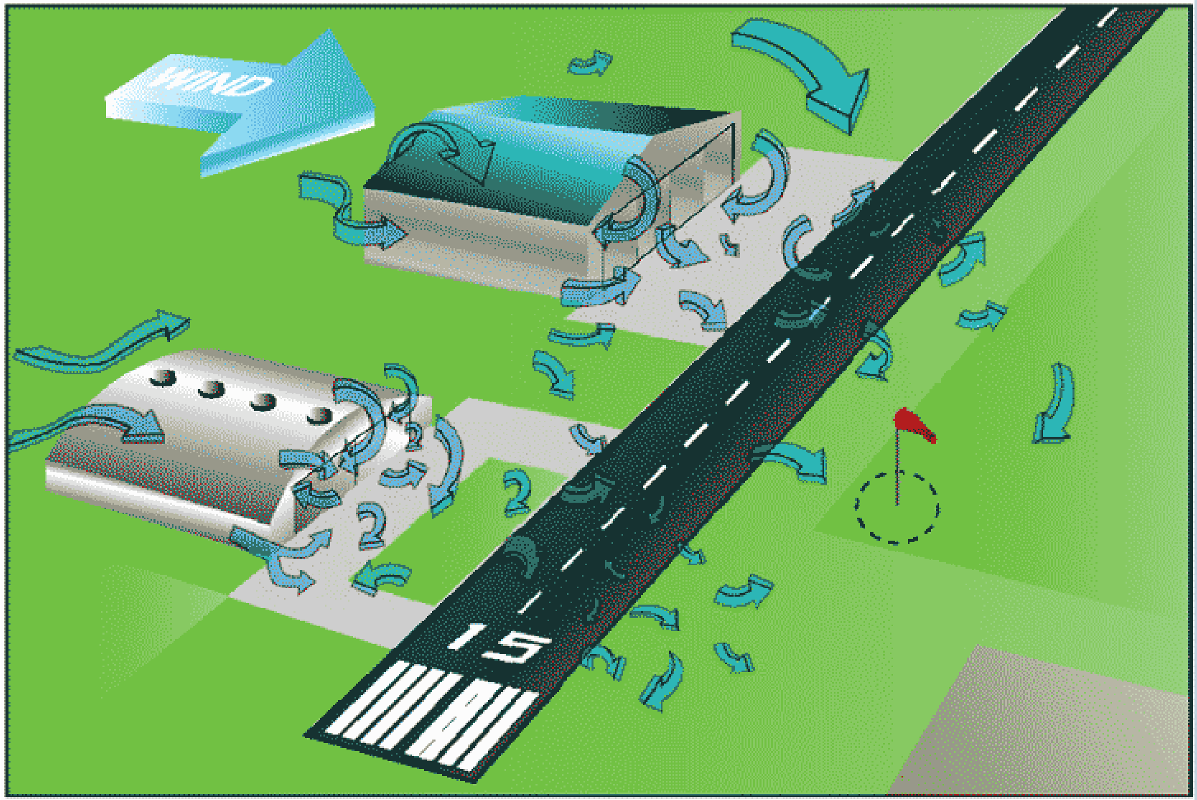
Turbulence – Mechanical

- At low level, turbulent eddies are formed when wind flow encounters obstacles



- The severity of the turbulence depends on the size of the obstacle and wind strength

Turbulence – Mechanical



- Turbulence can reach as high as 20 times obstacle height
- Turbulence can be felt downwind as far as 200 times obstacle height

Clear Air Turbulence (CAT)

- ➢ CAT is turbulence which occurs in clear air, generally with few visible warning signs

- ➢ Definition: Turbulence which occurs outside convective cloud

- ➢ CAT can generally be found in the following locations:
- Areas of horizontal and vertical wind shear
- Temperature lapse rate changes (e.g. Inversions)
- Converging winds
- Low and high level jet streams

Turbulence – Classification

Refer: AIP GEN 3.4 – 106, note item 11

Light: noticeable bumps but of little concern or impact to the flight

Moderate:

- Moderate changes in aircraft attitude and/or altitude, but remains under positive control at all times.
- Small variations in speed, changes in G-load of 0.5G to 1.0G
- Difficulty walking, occupants feel strain against seat belts, loose items move about

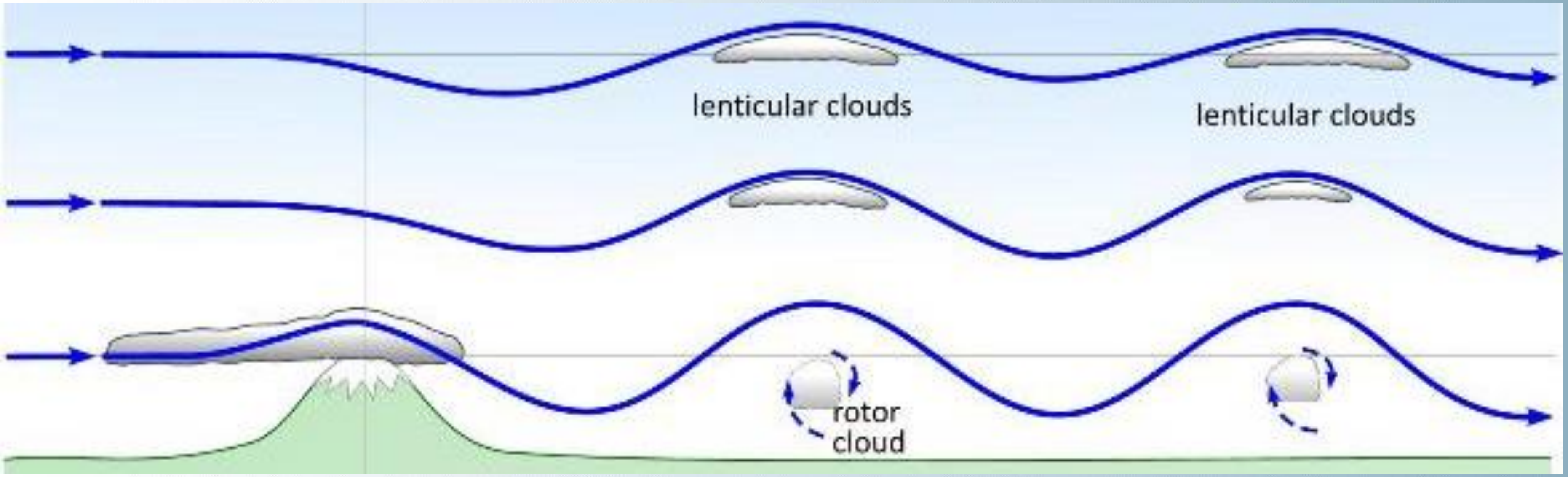
Severe:

- Abrupt changes in aircraft attitude and/or altitude, may be out of control for brief periods
- Large variations in airspeed, changes in G-load are greater than 1G
- Occupants are forced violently against seat belts, loose objects tossed about

MOUNTAIN WAVES

Mountain Waves – What are they?

- Known as Mountain or Standing Waves, these are “wave” like airflows located on the lee side of a mountain range under certain circumstances



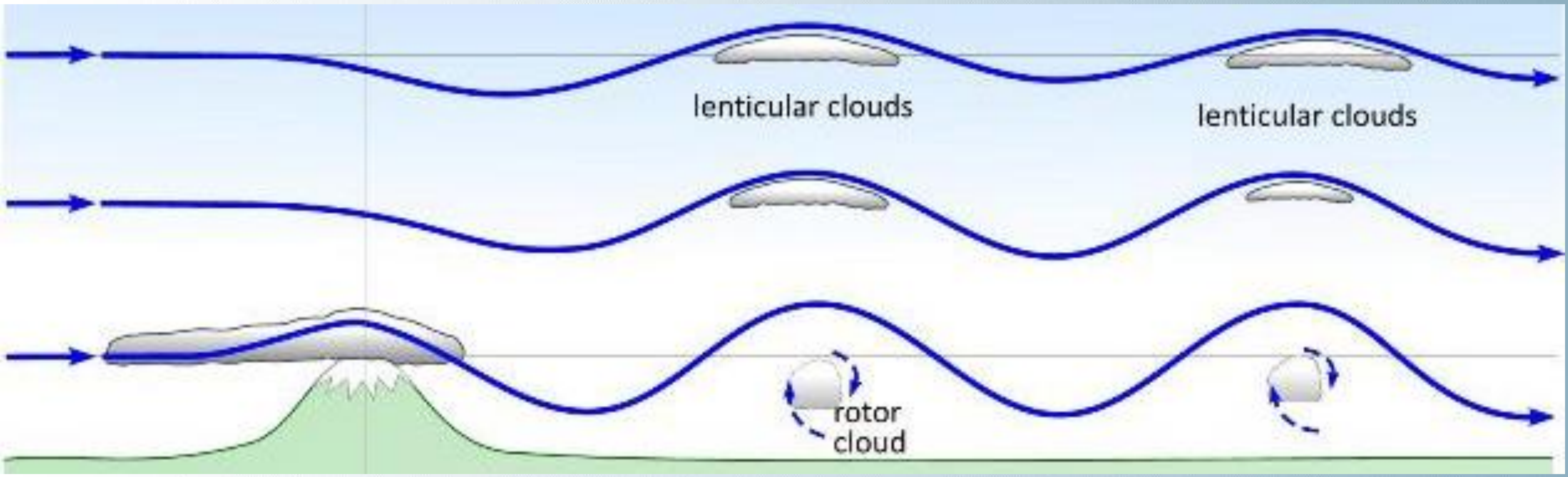
- The conditions necessary for the presence of mountain waves are:

1. Wind direction perpendicular to mountain range

2. Wind speed of at least 25 knots at mountain tops, increasing with height

3. Stable layer at mountain tops with unstable layers above and below

Mountain Waves – What are the hazards?



- The dangers associated with mountain waves include:

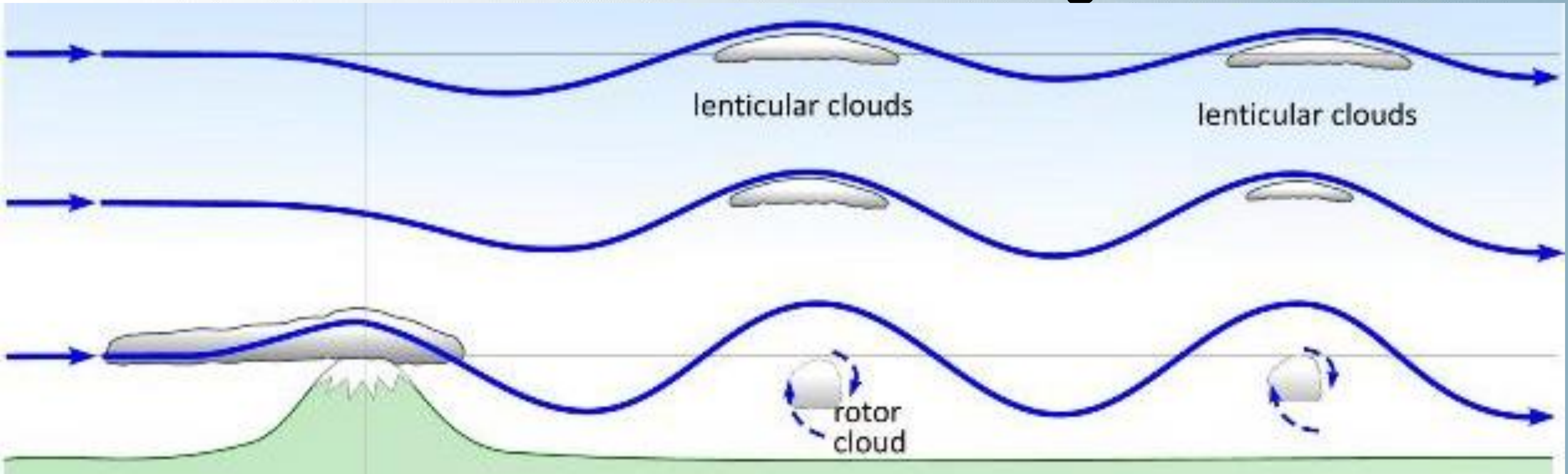
  1. Updrafts on the windward-side of the mountain

  2. Turbulence in updraft and downdrafts

  3. Turbulence in the rotor zones beneath each wave crest

  4. Downdrafts on the lee-side of the mountain (can exceed MRoC of aircraft)

Mountain Waves – How can we manage this threat?



- The easiest option is to just avoid the mountain waves altogether:

  1. **Where possible, avoid flying over mountain ranges when the necessary conditions are present**

  2. **Mountain Waves may be visible through the presence of altocumulus lenticularis clouds (lens/almond shaped) & rotor cloud (ragged shaped)**

Mountain Waves – How can we manage this threat?

Mountain Waves – How can we manage this threat?

Mountain Waves – How can we manage this threat?

- If we must fly across the mountain range, then it is a good idea to:

  1. Allow as much altitude as possible above the mountain tops (at least 1000ft)

  2. Cross the mountain range at an oblique angle

- Crossing the range at an oblique angle will require less turning to escape the turbulence/downdrafts than a 180° escape manoeuvre

TORNADOS

Tornados

- Tornados are large rapidly rotating columns of air **extending from the base of a Large Cu or Cb cloud down to the ground**

- They are capable of very destructive winds and pose a significant threat to aircraft, severe turbulence is present

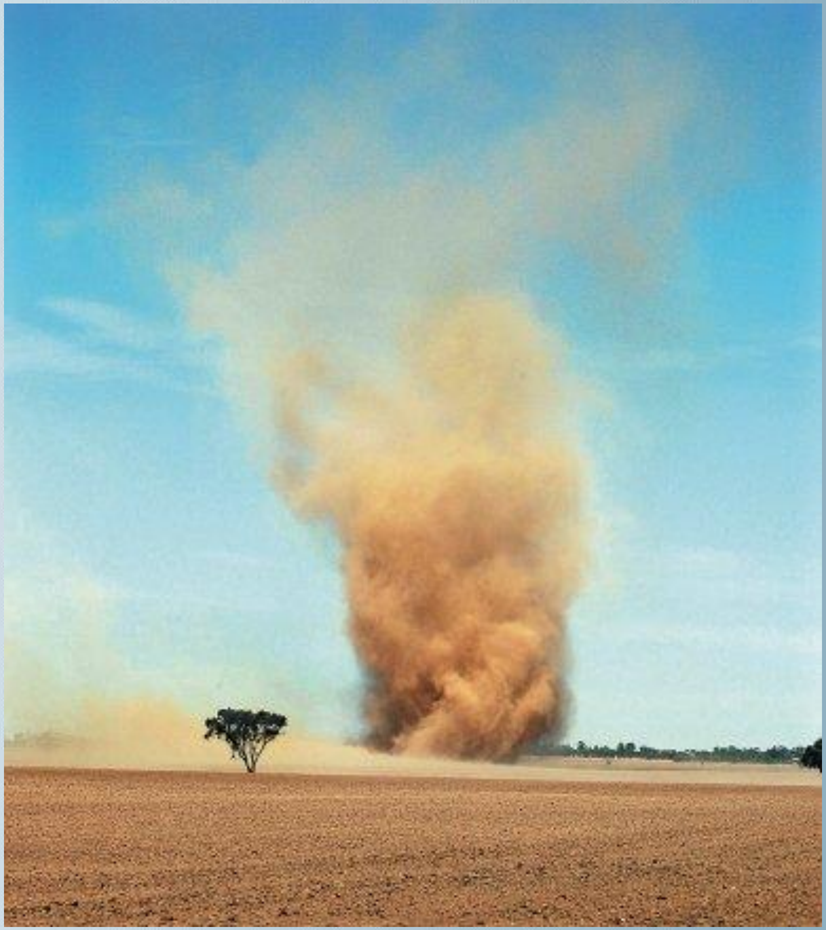
- A rotating column which does *not* reach the ground is known as a funnel cloud

- The strongest tornados develop in supercell thunderstorms, but they may also develop from non-supercell storms or from squall line storms

DUST DEVILS

Dust Devils

- Dust devils are small (~30m diameter or less) rotating columns of air with warm updrafts in the centre, typically reaching up to several hundred feet (in extreme cases over the desert in summer, they can extend several thousand feet).
- Typically found over hot surfaces with light winds
- Wind speeds are commonly 30kts (up to 50kts recorded)



DUST STORMS

Dust Storms

- Dust storms are masses of air where dust has been picked up from the ground and suspended in the air.

- To be classified as a dust storm the prevailing visibility must be less than 1000m.

- **Conditions needed for the formation of a dust storm**:
  - Dry, dusty environment (to provide the dust)
  - Strong winds (to kick up the dust)
  - Unstable atmosphere (to keep the dust aloft)

Dust Storms

Severe dust storms may reduce visibility below 200m and reach up to 10,000ft

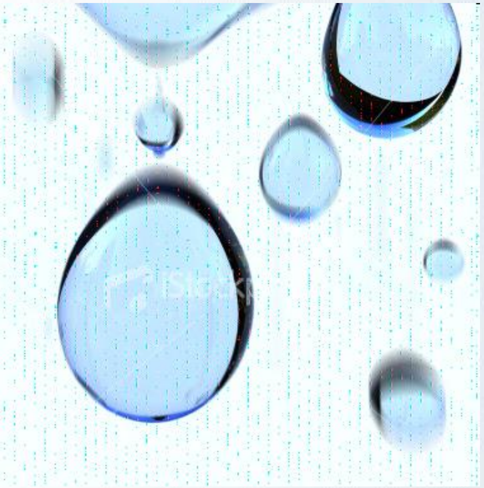
ICING

Super cooled Water Droplets

- When you make ice cubes in your refrigerator, the liquid water freezes when its temperature drops to or below 0°C.

- To allow water to freeze, latent heat must be released from the water to the environment.

- When water exists as tiny droplets suspended in the atmosphere, the exchange of latent heat is much less efficient and freezing does not occur until temperatures well below zero are achieved.



Super cooled Water Droplets

- Depending on their size, water droplets suspended in a cloud can remain liquid at temperatures as low as -40°C.

- The roughly spherical shape of the supercooled water droplets in a cloud has a lot to do with their resistance to freezing.

- Any disturbance or shock that changes their shape will cause them to lose their latent heat and freeze.

- An aircraft flying above the freezing level in cloud provides the necessary disturbance and since the airframe is also below zero, the supercooled droplets freeze on impact and a layer of ice builds up on the leading edges

Formation of airframe ice

- There are **three conditions** which must be satisfied for the formation of ICE:

1) There must be **visible moisture**

2) The temperature must be at or below **freezing** (0°C).

3) The **airframe** temperature must be less than (0°C).

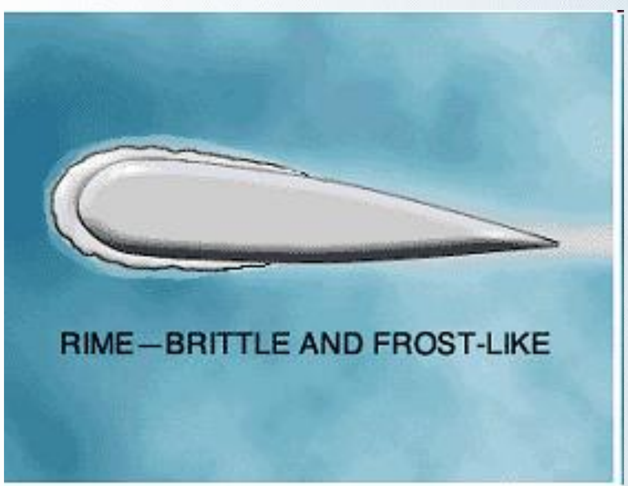
- Worst continuous icing conditions are usually found near the freezing level in heavy stratified clouds or in freezing rain.

Formation of airframe ice

- In cumuliform clouds with strong updrafts, however, large water droplets may be carried to high altitudes making structural icing a possibility up to very high altitudes.
- The freezing level in this cloud is distorted often by many thousands of feet, due to the updrafts and downdrafts that are produced. This leads to severe icing occur almost at any level.
- Structural damage is most likely to occur in conditions of freezing rain.

Rime ice

- When very cold supercooled droplets collide with the leading edges, they freeze so quickly that they don't have time to splash or spread across the skin.
- They maintain their spherical shape after freezing, producing a granular layer of ice with a lot of air trapped between the grains.
- Ice formed in this manner is white and fairly brittle.



Sideview of wing with rime.

Rime ice

- A disruption to the oncoming airflow reduces lift and increases drag, requiring a greater angle of attack to compensate.
- Rime ice degrades aircraft performance and can also deprive the pilot of airspeed indication if Pitot tube is blocked.
- There is no great weight to rime ice.
- Rime builds forward into the airstream ahead onto leading edges, air intakes, pitot probes and itself. Being very brittle, rime is easily removed by conventional de icing methods – often breaking off in irregular lumps.
- The temperature range for the formation of rime ice can be between 0°C and -40°C, but is most commonly encountered in the range from -10°C to -20°C.

Rime ice

Cloud Types:

- Rime Ice is formed by small droplets, found in:
- **Thin altostratus** or **altocumulus** or near the tops of **large cumulus**.
- In very cold climates it is possible in **stratocumulus, stratus or small cumulus**, but only above the freezing level.
- Note: Serious icing is not generally considered to be a major problem when air temperature is colder than -25°C.

Clear ice

- Clear ice is the most dangerous form of structural icing.
- It is most likely to form when you are flying through freezing rain, which consists of raindrops that spread out and freeze on contact with the cold airframe.
- Because the larger droplets are not so cold and have more latent heat to lose, they take longer to freeze.
- A layer of clear ice builds up on the leading edges.
- Clear ice has very little air trapped within it, therefore making it much heavier and stronger than rime ice.

Clear, hard and glossy

Clear ice

- Clear Ice clings tenaciously to the surfaces, making removal difficult.

- Ice formation on propeller blades can cause serious engine vibration and in extreme cases, may make it necessary to shut down a perfectly good engine.

- The temperature range for the formation of clear ice can be between 5°C and -15°C, but is most commonly encountered in the range from 0°C to -10°C.

- **Cloud Types:**

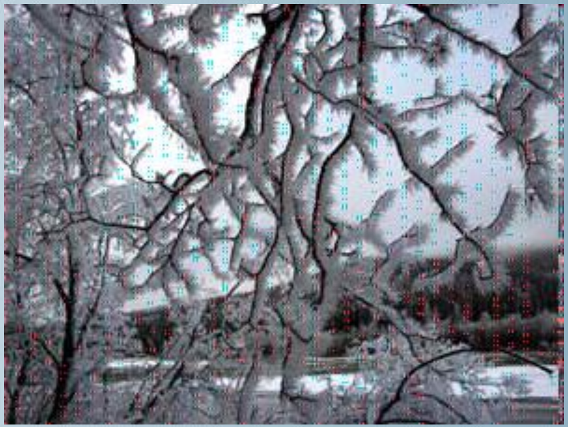
- Clear ice is generally developed from large water droplets, found in **thick altostratus** and **altocumulus** or just above the freezing level in **large cumulus, cumulonimbus** and **nimbostratus**.

Hoar Frost

- Aircraft is cold soaked.
- If a cold-soaked aircraft on descent from its cruising level enters a layer of warmer humid air, the water vapour in the air can skip the liquid state and turn directly into ice on its cold surfaces.
- This type of process is called deposition.
- This type of ice forms from cloud-free air that contains no supercooled liquid droplets.
- The resulting coating of ice is called hoar frost; it is a white crystallite deposit which often forms on windscreens as well.

Hoar Frost

- A white crystalline deposit of ice of a light feathery nature, usually needle-shaped.
- Occurs in conditions of high RH.
- Frost disturbs otherwise smooth airflow over lifting surfaces – surface friction drag and thus TOTAL DRAG is increased; stall AoA is decreased; stall speed is increased.
- Frost can seriously limit movement of primary control and trimming surfaces.
- Hoar frost can also form on aircraft parked overnight in a dry atmosphere when the dew point temperature is below zero.



- PRE-CONDITIONS (for formation on a parked aircraft)

Calm (surface wind-speed < 2kts), clear, cloud free nights
Anticyclonic influence; long autumn/winter nights
ie. "radiation nights".

Other forms of ice

Mixed Ice

- A mixture of clear ice and rime
- Nearly all experience of airframe icing will be like this, especially when flying inside cloud.

Pack Snow

- Is formed when ice crystals and super cooled water droplets coexist in cloud. The droplets freeze on impact trapping the ice crystals (snowflakes)

Freezing Rain

- It is not always necessary for an aircraft to be in cloud for airframe ice to form.

One of the most rapid build-ups of ice occurs when supercooled rain drops fall from a cloud Base onto an aircraft cruising below the cloud but above the freezing level.

Frost

- Frost is simply frozen dew. It forms on the top surfaces of aircraft left overnight.

Factors affecting icing

- Subzero temperatures: Ice melts when its temperature is above 0°C. Therefore airframe icing is impossible unless the skin of the aircraft is at subzero temperatures.

- Supercooled droplets: Subzero temperatures alone cannot produce ice, liquid water must also be present. If the water in the atmosphere is already frozen (ice crystals), it will not stick to the skin of the aircraft.

- Droplet size: If the supercooled droplets are very small (<u>drizzle size or smaller</u>) rime ice is likely. <u>Larger</u> supercooled droplets produce clear ice.

- The larger supercooled droplets are common between 0°C and about -15°C. From -10°C to -40°C the smaller supercooled droplets predominate. However the type of ice is much more strongly influenced by droplet size than by the actual temperature.

Classifications of Ice

Light (FBL)

- No change of track or altitude is necessary and no loss of airspeed occurs.

Moderate (MOD)

- Change of heading and / or altitude is considered **desirable**. Ice accretion continues to increase but not at a rate sufficiently serious to affect safe flight unless it continues for an extended period of time; airspeed may be lost.

Severe (SEV)

- Change of heading and / or altitude is considered **essential**. Ice accretion continues to build up and begins to seriously affect the performance and manoeuvrability of the aircraft.

Icing in cloud types

Within which clouds can we expect to get icing?

Thin As	(L Rime)
Thick As	(M Rime, L Clear, Mixed?)
Ac Lenticularis	(L Rime)
Ac Castellanus	(L Rime)
Large Cu	(Clear)
CB	(Severe Clear)
SC	(M Rime)

Within which clouds can we expect more than light turbulence?

Ac Lenticularis, Ac Castellanus, Cu, Cb, Sc, Mountain wave rotor cloud

Comair 3272

https://www.youtube.com/watch?v=sA4vYENBb5w

American Eagle 4184

https://www.youtube.com/watch?v=0UdE8_PP_ik

VOLCANIC ASH

Volcanic Ash (VA)

Volcanic eruptions can pose a serious threat to aircraft safety:

- Volcanic ash is fine and abrasive, it can damage aircraft skin, engines and interfere with instruments
- At high temperatures, such as inside combustion engines, it can melt and form a sticky glassy coating
- Molten ash can block and interfere with normal engine operation, causing engine failure in severe cases

Volcanic Ash

On 24th July 1982 British Airway B747-236 G-BDXH was flying from Kuala Lumpur to Perth at FL370 when it flew into the Volcanic Ash from Mount Gallanggung.
All four Engines failed over about a minute. The aircraft subsequently performed an emergency landing at Jakata on three engines.
Significant Damage to the Aircraft occurred.

Stator Blades