MET 451: Aviation Meteorology
(3 Credit Hours)

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https://github.com/jeffjay88/Aviation-Meteorology

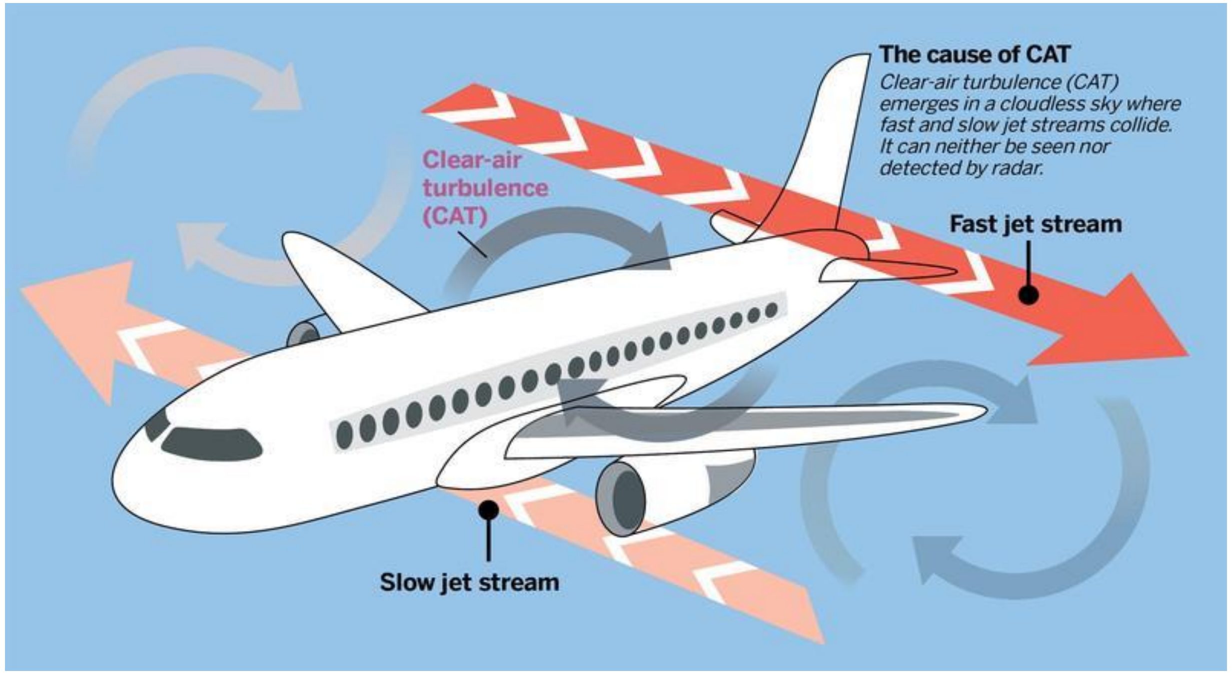
Google Classroom Code: 63zl2i

LECTURE 5

Recommended Links and Media

- https://www.youtube.com/watch?v=NPsas4Uswv8
- https://www.youtube.com/watch?v=yZNliKTGrdc
- https://www.youtube.com/watch?v=S5tN9nVLgcM

CLEAR AIR TURBULENCE (CAT)



- CAT is the term used to describe medium- or high-level turbulence produced in regions of marked wind shear. As its name suggests, this often - though not necessarily- occurs in the absence of cloud, making it difficult to detect visually.

Effects on Aircraft

As with all turbulence types, the degree of turbulence is categorised by the ICAO definitions. Although the aircraft is at height on most occasions, severe turbulence must never be trivialised. In extremes, structural damage may occur.

For civil aviation, passengers may be made uncomfortable, or suffer injuries when not wearing their seat belts.

CLEAR AIR TURBULENCE (CAT)

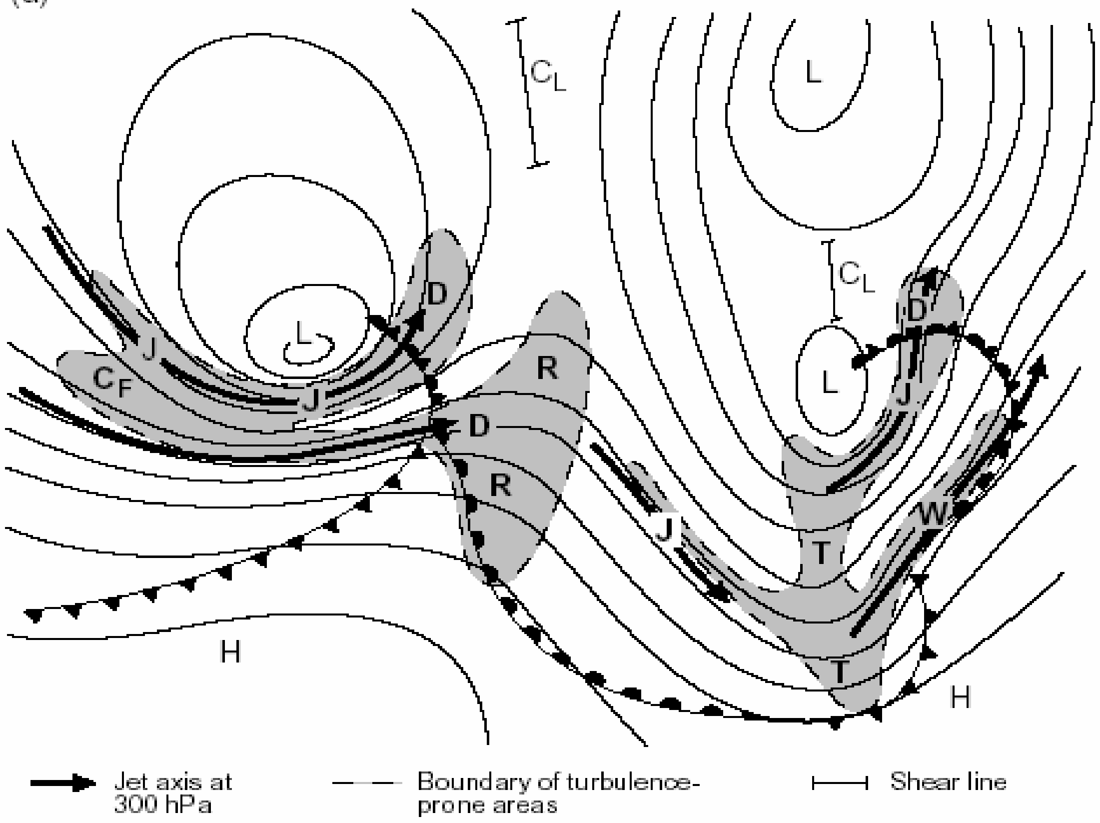
A characteristic pattern of cirrus clouds, known as 'billows', is a signal of a region of CAT. The billows are an indication of breakdown into turbulent flow in the form of Kelvin-Helmoltz instability.

Empirical Forecasting Techniques

CAT is often reported;

- on the cold side, near and below the core
- on the warm side, above the core
- near exits with marked curvature and diffluence
- at the confluence or diffluence of two jet streams
- near sharp upper troughs
- around sharp ridges on the warm side of jets
- where one jet undercuts another
- where the tropopause height fluctuates

(a)



Some more characteristics:

- If the core speed exceeds 100 kt and vertical windshear 4 kt/1000 ft, forecast moderate CAT within 150 nautical miles.

- CAT may occur, or be intensified, over a region of convection, especially embedded frontal convection.

CAT occurs more often over land, especially over mountainous land, than over the sea. 60% of CAT reports are near jet-streams. The severity of CAT may be estimated if the horizontal and vertical windshear values are known

Subjective guide relating CAT to horizontal and vertical wind shear.

	Moderate	**Severe**
Horizontal wind shear	20 kt per degree of latitude	30 kt per degree of latitude
Vertical wind shear	6 kt per 1000 ft	9 kt per 1000 ft

i. Turbulence within the favourable areas is most likely to occur near the tropopause or other stable layers.

ii. In jet streams, turbulence is generally found in the **baroclinic zones** above and below the core. There is some tendency for turbulence to be concentrated in the lower zone of cyclonically curved jets and in the upper zone of anticyclonically curved jets.

iii. In terms of temperature, the criterion for moderate or severe turbulence is 5°C or more per 2 deg latitude.

iv. There is some qualitative evidence that turbulence is more likely to be severe within turbulence-prone areas if rapid change or development in the upper air pattern is occurring locally than if the pattern is relatively static.

v. The incidence of CAT is more frequent over land, particularly over mountains, than over the sea. It is not possible to give precise quantitative values to this difference but it is suggested that a factor of 3 or more over most land areas, increasing perhaps to 10 over very mountainous areas, is reasonable.

vi. CAT appears to affect a relatively small area and occur temporarily although the factors leading to CAT are present all the time. Hence only in a small percentage of CAT forecast will there in fact be turbulence reports by aircraft.

Associated NWP products

For high level jet-streams, appropriate geopotential height (gph) fields, combined with isotach and streamline analysis can help diagnose areas of likely CAT. Consider how ridges and troughs are developing in the model, and apply the empirical techniques above to the model fields.

CUMULONIMBUS AND THUNDERSTORMS

Cumulonimbus (CB) clouds are a severe hazard to aviation, due to the likelihood of:

- severe turbulence,
- severe icing,
- micro-bursts giving severe low-level turbulence;
- lightning,
- high liquid water content,
- hail

- Because Cumulonimbus clouds can generate many different types of hazards at the same time and location, they must never be underestimated. Aircraft should avoid flying into areas of known CB activity, especially when such activity may be hidden by obscuring cloud layers.

- Whilst individual Cumulonimbus clouds may have a lifetime of 1½ hours, the most intense Cumulonimbus development and thunderstorm/lightning activity is associated with Multi-Cell Convective systems which may develop further into Super-cells. Such systems are long lived due to the spawning of daughter cells and may last for many hours.

Class Discussion

- *In what way does lightning impact on the aviation industry?*

Thunderstorms and Lightning

Lightning can occur in and near Cumulonimbus clouds including the anvil layers and the sub-anvil atmosphere.

Effects on aircraft

Lighting strikes on modern composite materials will cause de-lamination of the material. If such strikes are upon structurally important areas of the aircraft, its integrity may be compromised. For this reason, lightning strikes on composite helicopter blades are particularly hazardous.

Following a lightning strike,

- electrical/electronic systems may fail, with circuit breakers tripping. Magnetic compasses will become untrustworthy.

- Radio communications and navigation equipment may be adversely affected.

- The Automatic Direction Finder (ADF) will often point into the storm's centre.

Lightning: Aircraft Damage

Direct Damage:

- Puncturing the fuselage
- Burning, melting or distorting aircraft parts

Indirect damage:

- Temporary or permanent damage to avionics
- Fire in the fuel system
- Temporary blinding of the pilot
- Visual or instrument

Diagnosis of Hazard Using Appropriate Imagery

- Satellite imagery, especially loops, can help identify developing convective cloud.

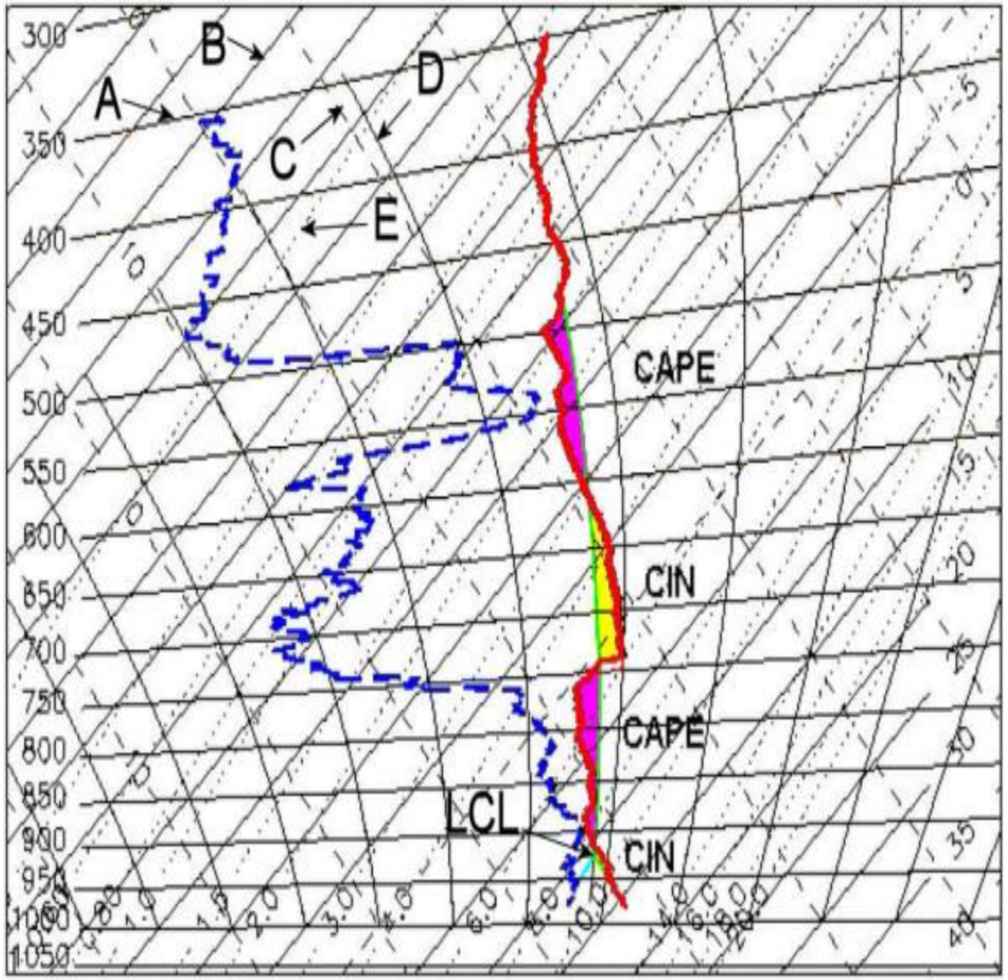
- Infra red imagery can give estimates of cooling tops, and an approximate value for the cloud top temperature.

- Water vapour imagery can help identify areas of high Positive Vorticity Advection which may favour Cumulonimbus, and thunderstorm/lightning, development.

- The monitoring with a weather radar is an essential tool in monitoring the development of convective cells. The colour code representing rainfall rates can be used as an assessment of the likelihood of lightning.

Empirical Forecasting Techniques

Elements that assist the forecaster in assessing the likelihood, or not, of thunderstorm and lightning activity include, but are not limited to:



- ➢Tephigram constructions, both on actual and forecast profiles.
- ➢Examine depth of convection and check thunderstorm occurrence according to local criteria.
- ➢Convection ascending to and through the minus 20° C isotherm.
- ➢Monitoring for regions of decreasing θw with height to diagnose areas of Potential Instability.
- ➢'Shallow moist' zones associated with split cold fronts are always worth studying.

➢Consider the effects of nil, uni-directional, or directional wind shear through the cloud depth.

➢Consideration of instability indices such as CAPE and Equivalent Potential Temperature values.

CAPE (Jkg-1)	Atmospheric State
0	stable
0-1000	marginally unstable
1000 – 2500	moderately unstable
2500 – 3500	very unstable
≥ 3500	extremely unstable

Heavy rain

There is no agreed international definition regarding rainfall intensity. Some use the following criteria:

Heavy rain is defined as rates in excess of 4 mm per hour.

Heavy showers are defined as rates in excess of 10 mm per hour. For aviation purposes rain rates are essentially a measure of rain water content.

Effects on Aircraft

Heavy or very heavy rates of rainfall will clearly have a detrimental impact on general visibility. However, in addition to any true meteorological reduction of visibility, raindrops impacting the windscreen/canopy will additionally reduce visibility. Windscreen wipers (if fitted) may not be able to fully cope with the rainfall rate.

- Light, non pressurised aircraft may allow water ingestion into the cabin/cockpit/engine compartments with subsequent risks to electronic equipment during heaviest rain rates

- Civil airliner engines are tested and certified to ensure that engines will normally not ‘flame out’ under conditions of intense rainfall and water ingestion

- Runway flooding, or areas of deep standing water will affect braking action, and may result in asymmetric braking and possible sliding off runways.

- Low cloud (stratus pannus) may form in periods of moderate or heavy rain, when it had not previously been expected

Diagnosis of Hazard Using Appropriate Imagery

Rainfall radar is invaluable for diagnosing areas of rainfall and the intensity of that rainfall.

Satellite imagery can assist in showing areas of cooling (and therefore ascending and developing) cloud tops. Combining the various wavelengths sensed by a meteorological satellite (RGB products) may prove increasingly useful in determining areas of precipitation, and general development.

When analyzing such data, the forecaster should be mindful of the development of daughter cells, and the triggering of quite separate cells elsewhere, i.e. storms may not appear to move with the general wind flow or ‘steering level’.

Empirical Forecasting Techniques

Look out for and consider those occasions where high values of Positive Vorticity Advection and Warm Advection coincide as being the most likely areas to generate heavy rainfall – both from stratiform and convective cloud.
Remember that orography will enhance rainfall on the windward side of hills and mountains.

Associated NWP Products

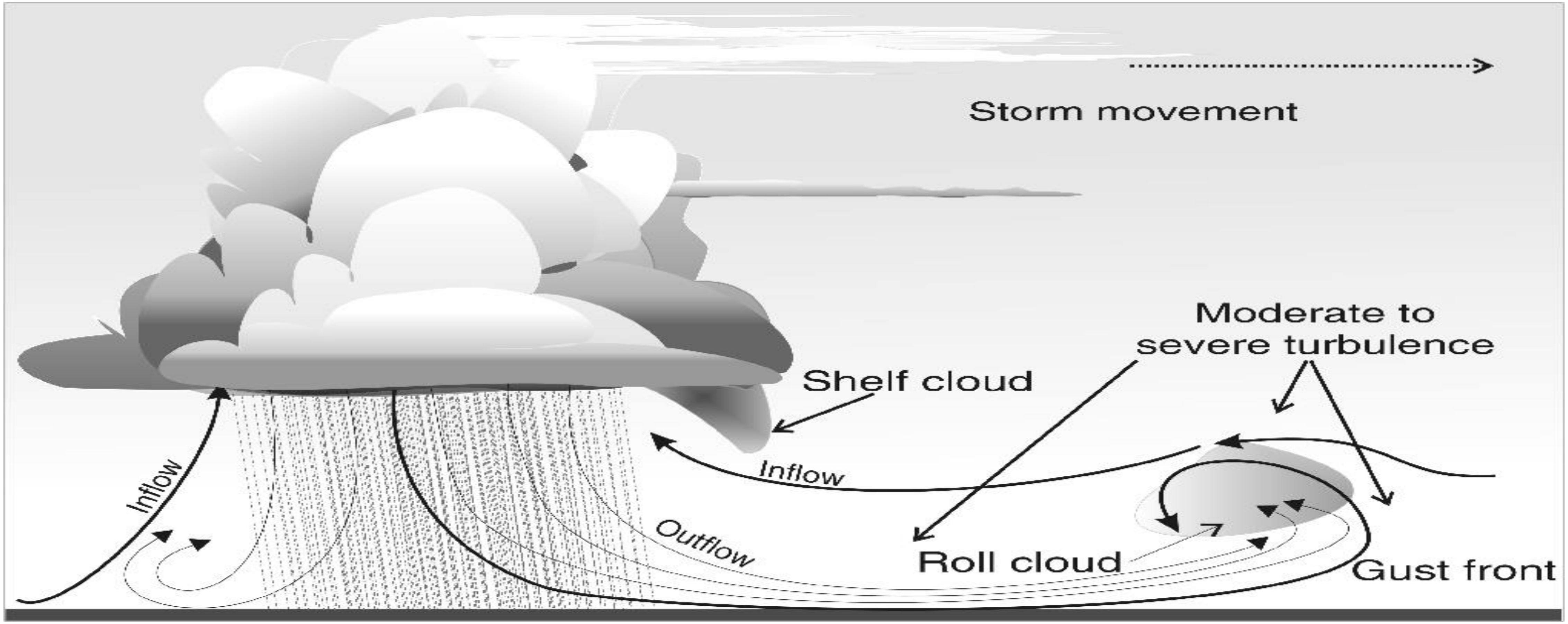
Basic model output data will provide values for expected dynamic rainfall/convective rainfall rates at specified times, and for accumulated totals over specified periods.
Always be aware of the limitations of model data and that such rates will be averaged over a gridbox. Consider the effects of enhanced rainfall on windward slopes.

Turbulence associated with clouds types

St – slight
Ci, Cs, Cc, Ac, As – nil or slight except when Ac occurs or when merging into Cb
Sc – moderate
Ns – moderate but may be severe near base
Cu, TCu, Cb – Generally severe but may be catastrophic and include the downbursts described below and the internal up/downdraughts.

Surface winds of thunderstorms may be both high velocity and extremely turbulent, originating from the downdraughts of cold, dense air. When thunderstorms are about light aircraft should not be airborne.

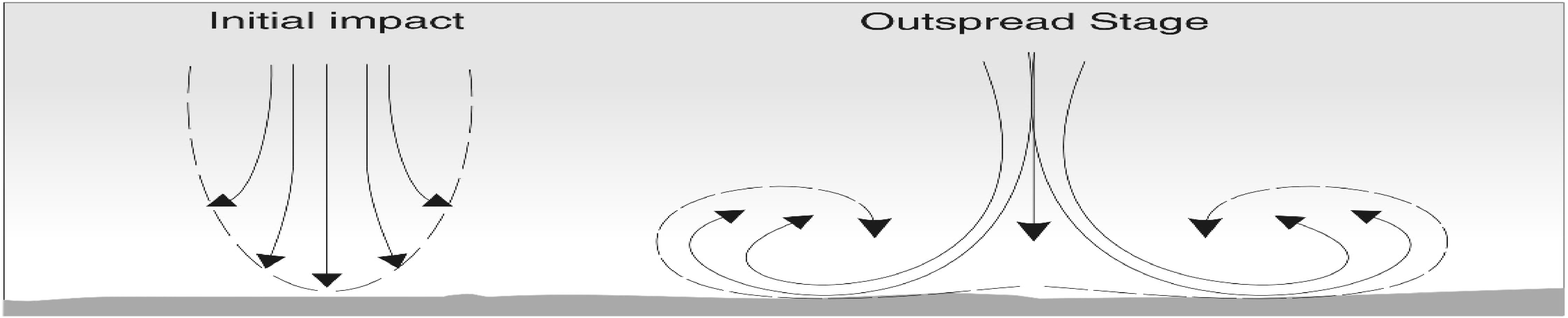
Turbulence Associated with a Downdraft



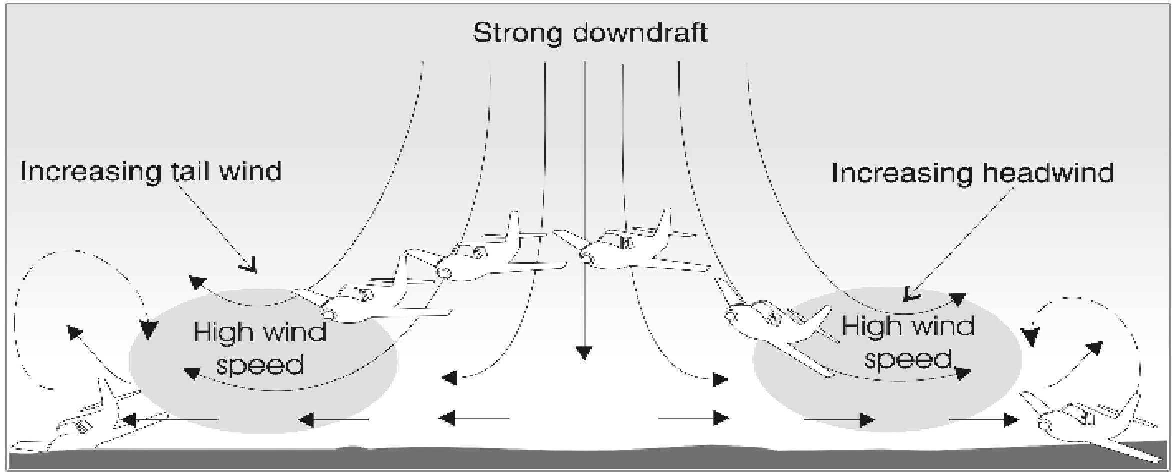
Thunderstorm out - flow :

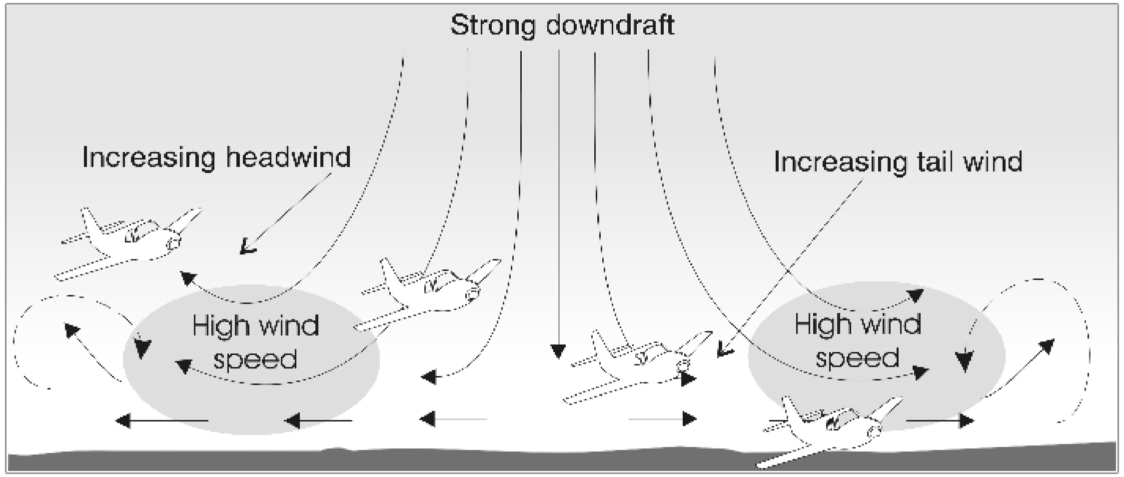
- ➢Associated with low - level windshear
- ➢Capable of upsetting the flight of an aircraft , sometime disastrously

Down burst Schematic diagram



Effects on Landing and Taking Off





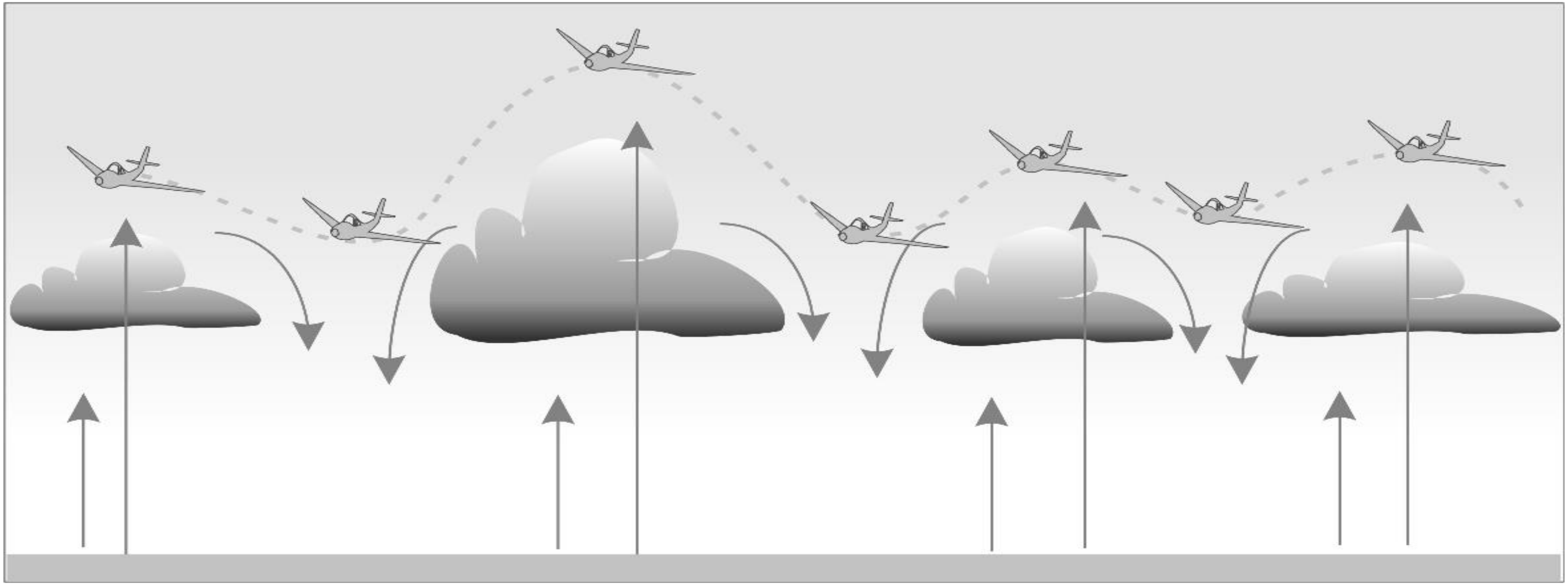
Vertical wind shear is usually detrimental to early development of Cb cells, however if there is:

- strong vertical wind shear, backing and strengthening with height,
- associated with a deep surface layer of warm moist air below a mid-level layer of dry air,
- with an inversion separating the layers,
- and a rapid decrease in temperature with height above the inversion,

then the ideal conditions are created for a severe multicell storm. Or a supercell storm if the surface wind is greater than 20 knots and the vertical wind shear exceeds about five knots for each 3000 feet.

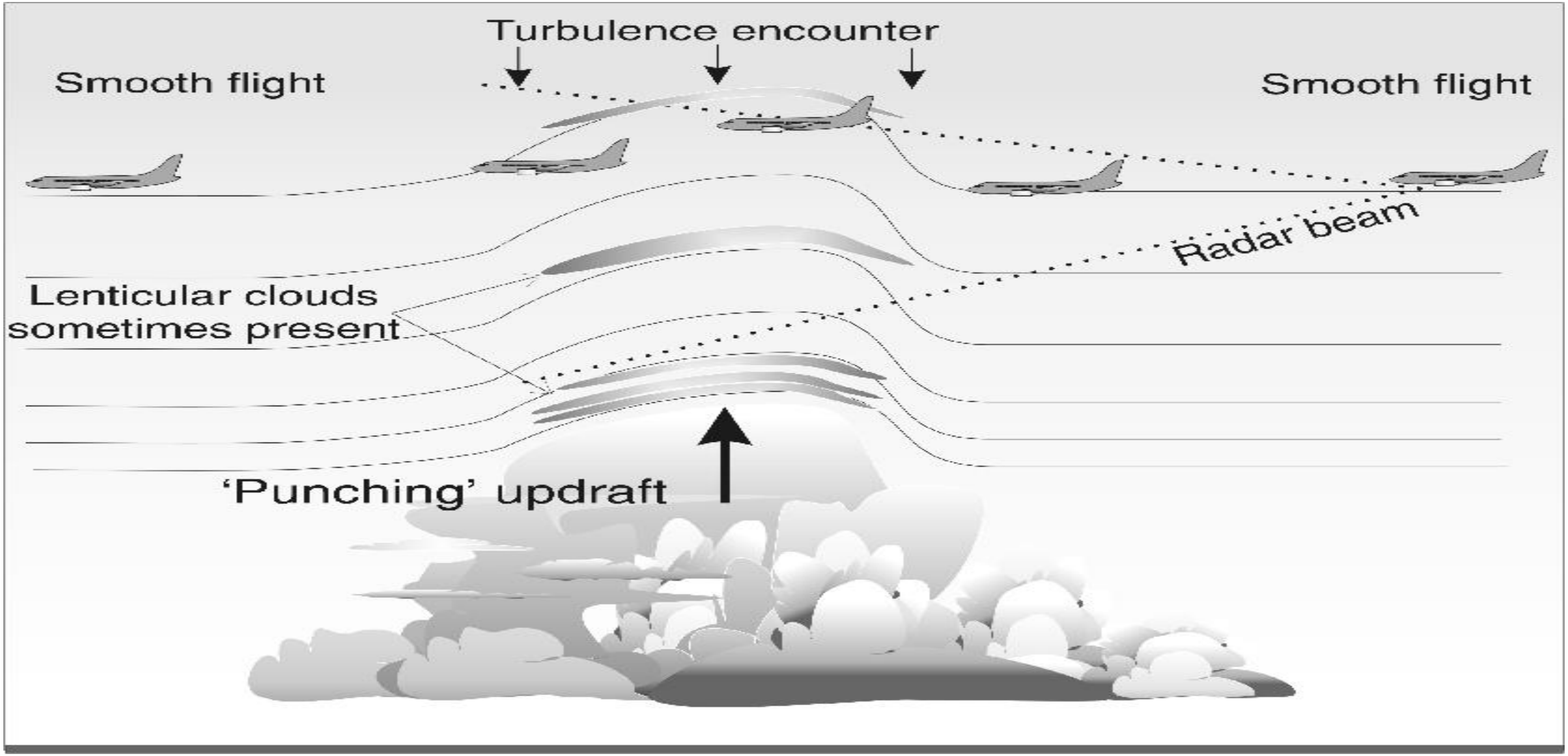
The **capping inversion** keeps the lid on development until the lifting force builds up sufficiently to burst through the inversion and great buoyancy develops in the colder upper layer. Upper level divergence and a jet stream will also enhance the vertical motion.

Vertical Motion Close to Convective Clouds



Air craft deviations due to convective up and down motion

Cruising Above Cumulonimbus Tops




Questions?

RECAP OF LECTURE

1. Clear Air Turbulence
2. Cumulonimbus Clouds and Thunderstorms
3. Lightning
4. Heavy Rains