

Aviation Hazards: Thunderstorms and Deep Convection

TREND

Effects of Thunderstorms on Aircraft



Australian Government

Bureau of Meteorology

Contents

- **Aviation weather hazards associated with convection / thunderstorms:**
 1. Turbulence
 2. Wind shear
 3. Icing
 4. Reduced visibility
 5. Lightning
 6. Damaging hail
 7. Tornado / Water Spout
 8. Heavy precipitation
 9. Water ingestion
 10. Altimeter Interference

- **Hazards at take-off / landing, in flight, on the ground**



Turbulence

- **Vertical displacements, velocities and accelerations**
- **Gust front from horizontal outflow from down draft spreading out from storm base / wind shears**

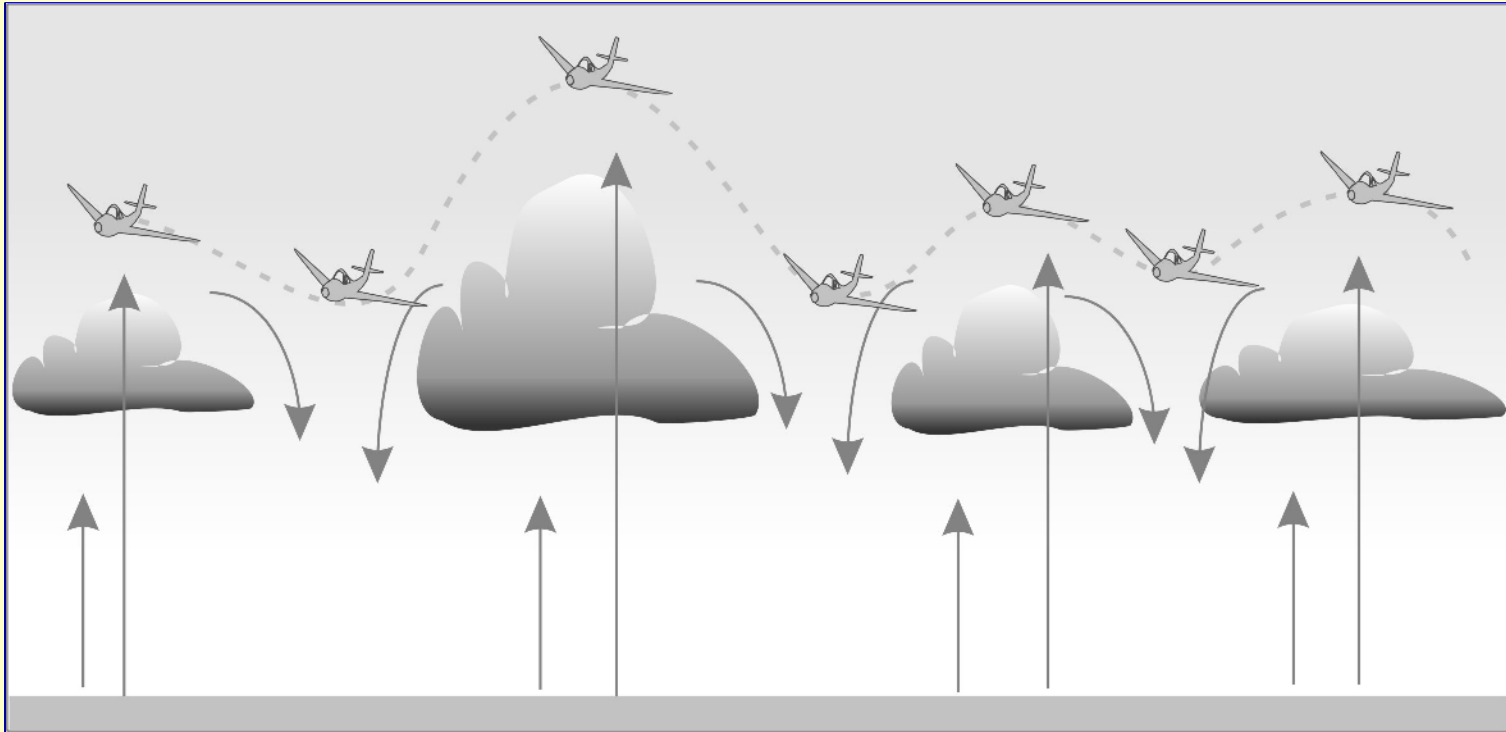


Turbulence Hazards

- **Up / down draft boundaries within the cloud**
- **Leading edge and upper surface of the gust front:**
 - **Strong vertical and horizontal wind shears**
- **Funnel clouds (e.g., tornadoes)**
- **Upper extent of updraft within cloud**



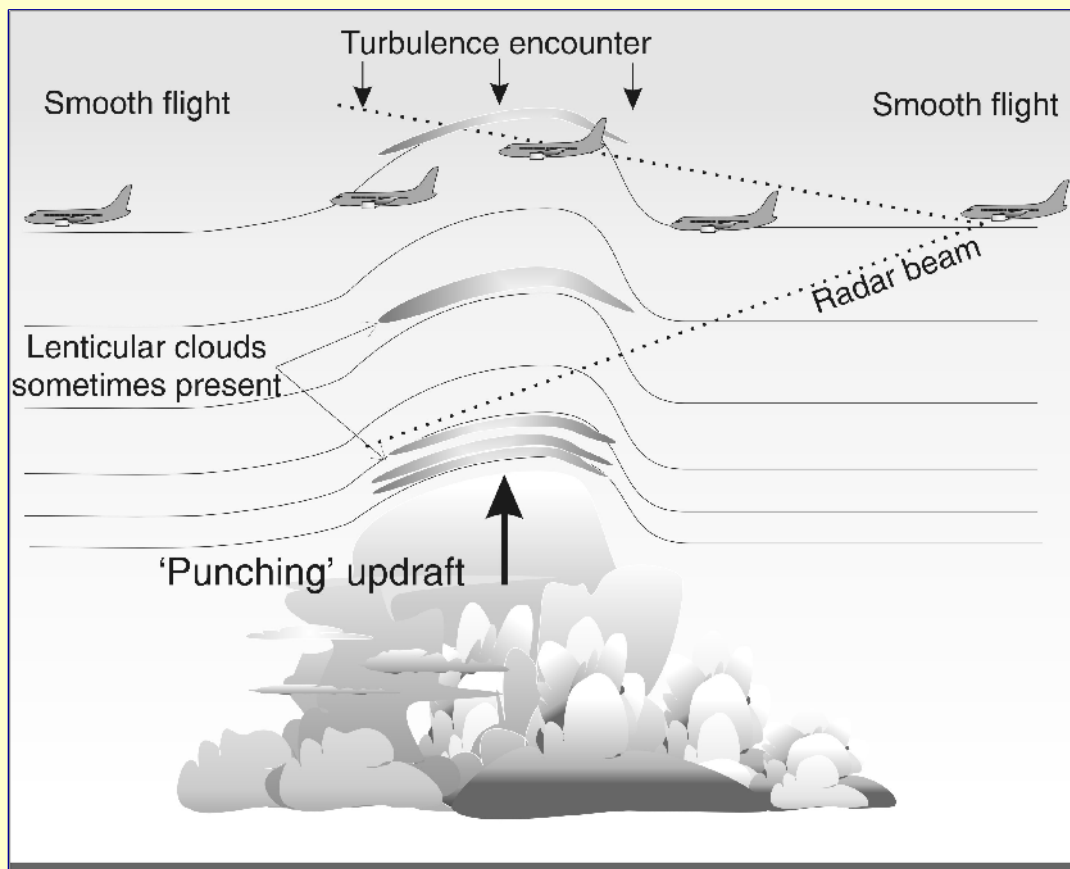
Vertical Motion Close to Convective Clouds



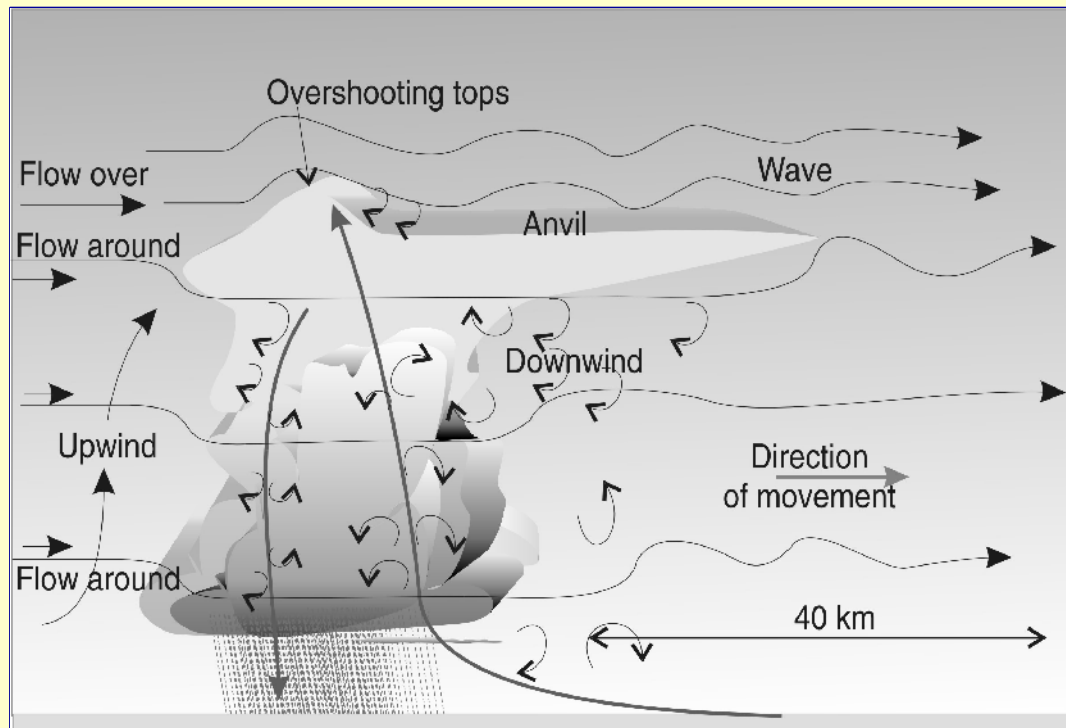
Aircraft deviations due to convective up and down motion



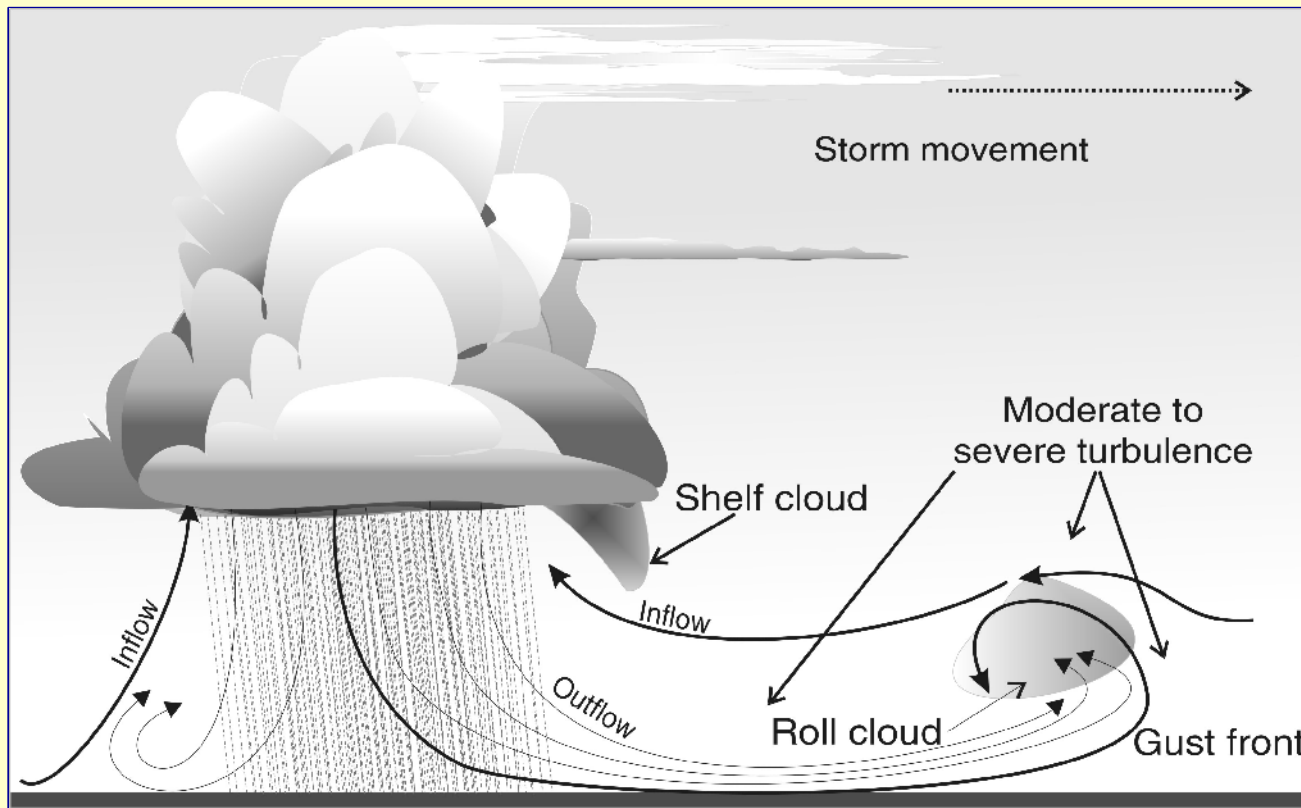
Cruising Above Cumulonimbus Tops



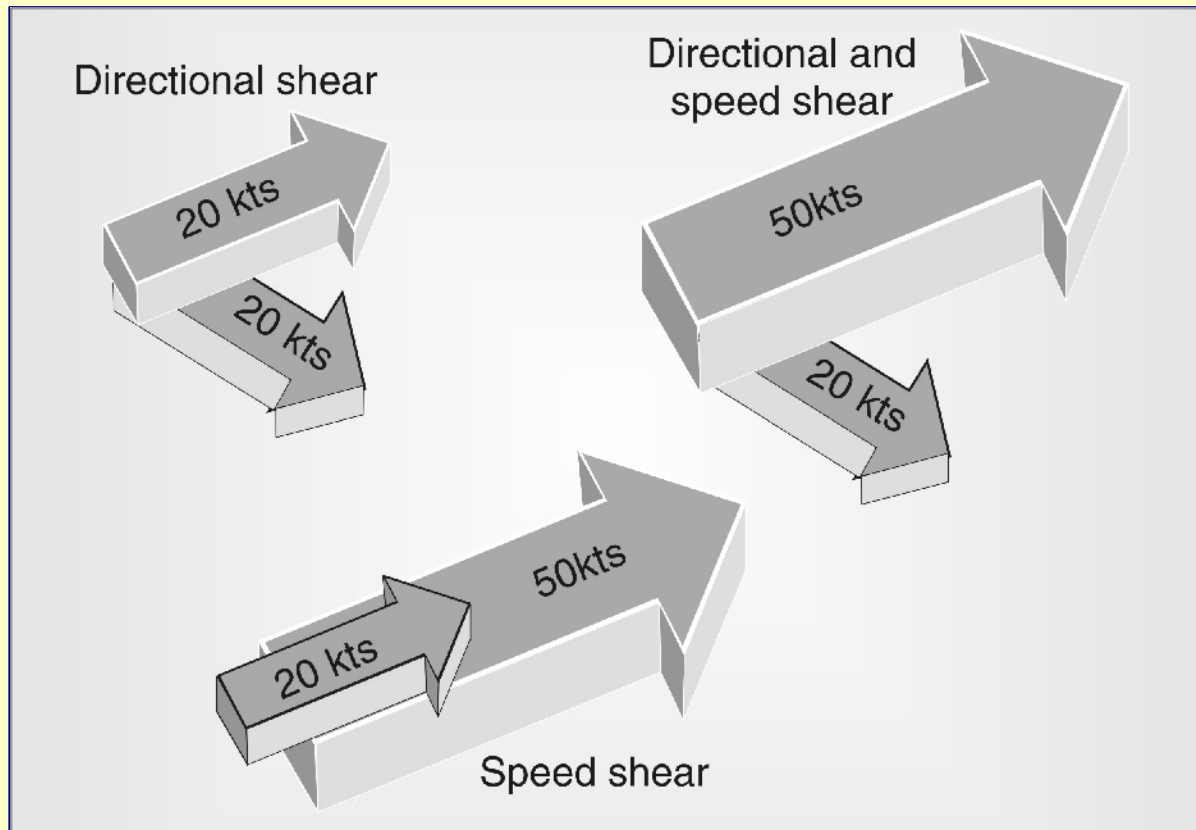
Turbulence Associated with a Large Cumulus Cloud



Turbulence Associated with a Downdraft



Wind Shear: Shears in Horizontal Winds

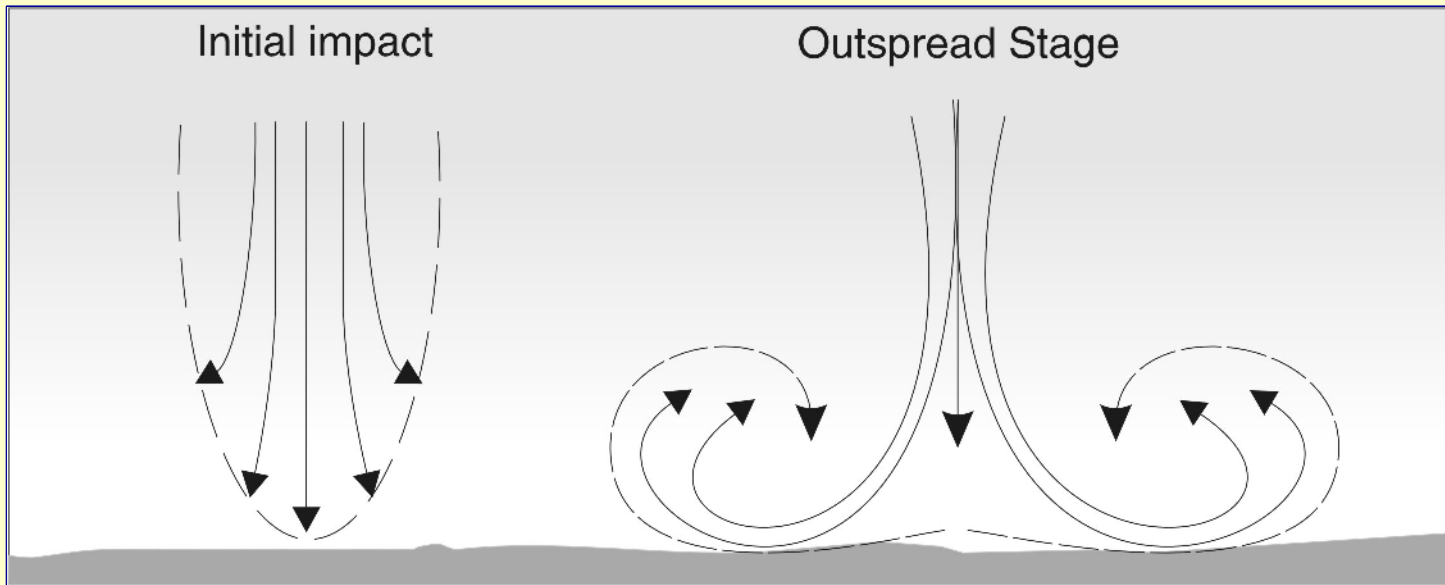


Low-level Wind Shear Hazard

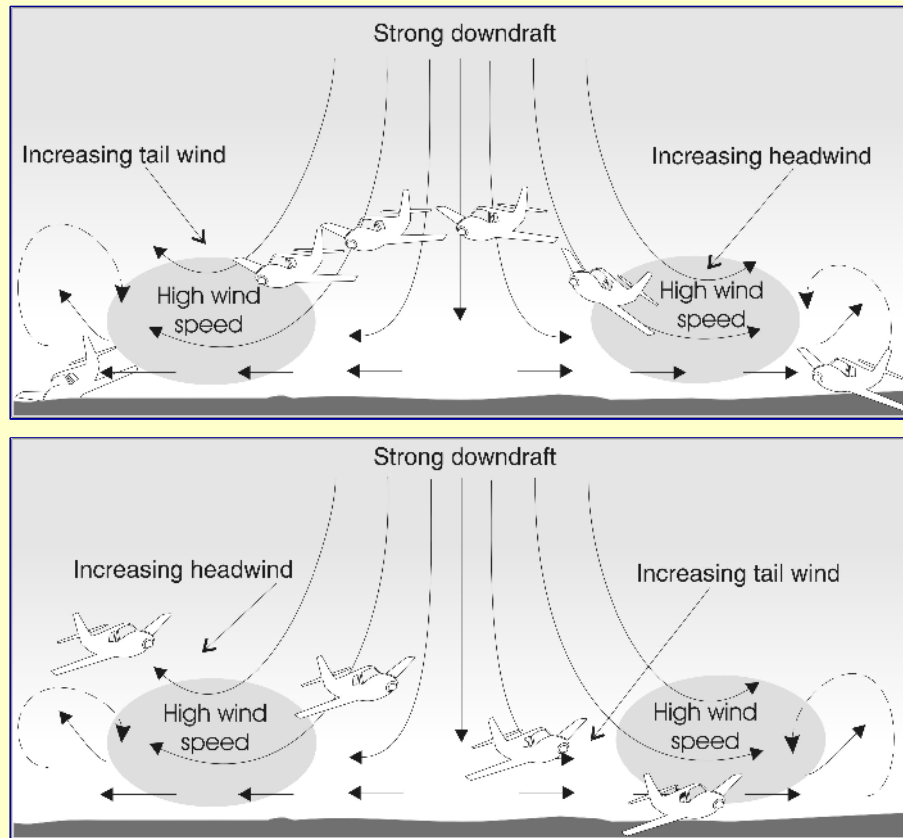
- **Thunderstorm out-flow:**
 - **Associated with low-level wind shear**
 - **Capable of upsetting the flight of an aircraft, sometime disastrously**



Downburst Schematic



Downburst Wind Shears: Effects on Landing and Taking Off



Icing in Thunderstorms

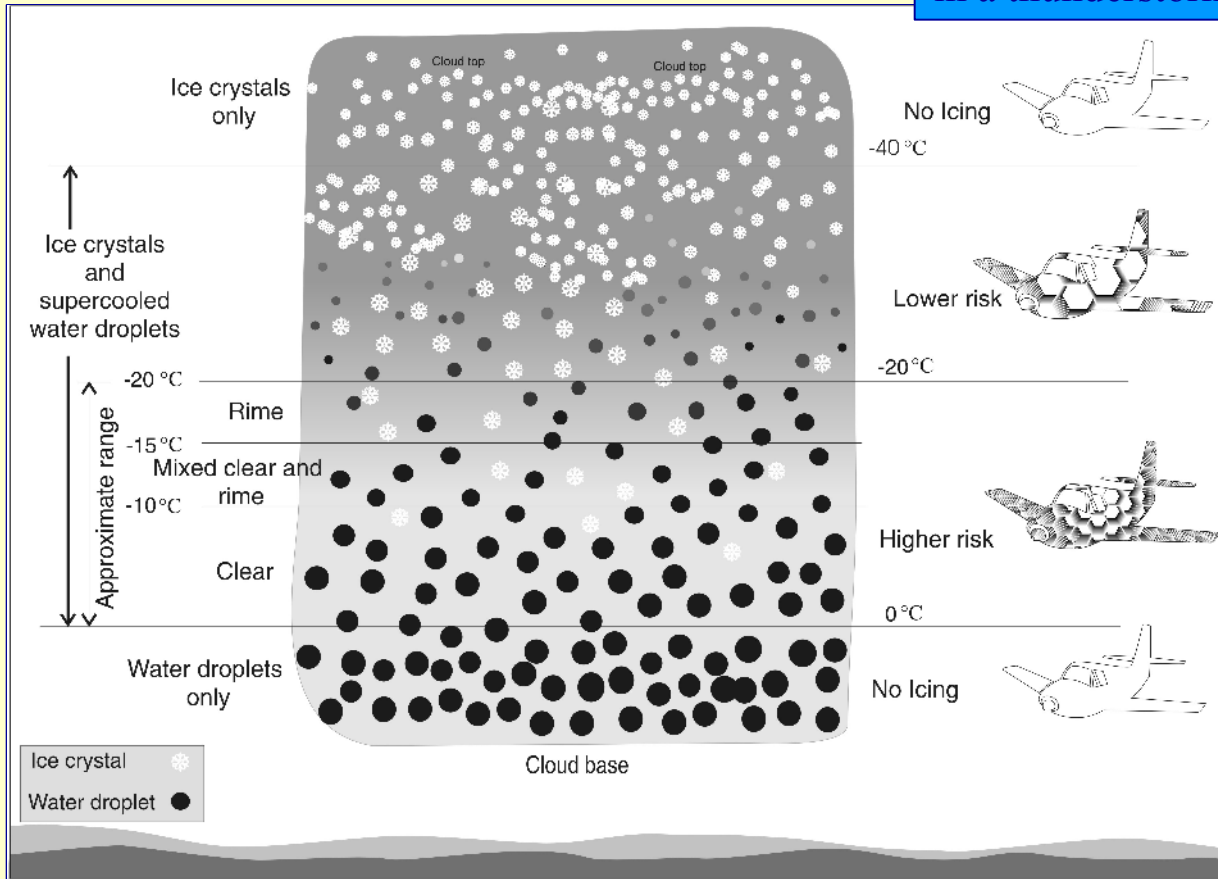
➤ Mechanism:

- Thunderstorm updrafts support large drops of super-cooled liquid water
- Super-cooled water may freeze upon impact with an aircraft



General Icing Regimes

An abundance of large supercooled water droplets in a thunderstorm cloud between 0° C and -20° C



Hazardous Effects of Aircraft Icing

- **Accumulated icing may lower aircraft performance:**
 - Increase stalling speed
 - Destroy optimal aerodynamic flow over the aircraft
 - Increase drag
 - Decrease lift
 - Cause engine failures
 - Cause propeller vibration
 - In jet engines, damage compressor blades
 - Interfere with:
 - Control surfaces and landing gear
 - Instrument readings (e.g. air speed, altitude and vertical speed)
 - Communication systems
 - Reduce visibility



Icing Intensity

- **Trace**
 - Ice is perceptible – not hazardous unless exposure is for an extended period
- **Light**
 - Accumulation rate may cause problems if flight is prolonged
- **Moderate**
 - Short periods of exposure become hazardous
- **Severe**
 - Short term exposures are hazardous and an immediate diversion is necessary



Reduced Visibility

- **Mechanism:**
 - **Horizontal visibility**
 - **Due to precipitation**
 - **Showers of rain, snow and hail**
 - **Vertical visibility**
 - **Due to obscuring cloud**
 - **Cumulonimbus, Stratus, etc.**



Lightning

- **A high-current electrical discharge caused by a thunderstorm ...**
 - **Cloud-to-cloud**
 - **Within-cloud (~ 50 % of all strikes)**
 - **Cloud-to-ground – prime hazards to people (risk of electrocution) or property on the ground**
 - **Generally, the higher the frequency of strikes**
 - **The more severe the thunderstorm**
 - **In precise location and timing, lightning strikes are difficult to predict**



Lightning



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 instruments



The Effects of Lightning on Aircraft

- **Flight Safety Australia Magazine article:**
 - **“Bolt from the Blue”**
 - <http://www.casa.gov.au/fsa/2005/aug/48-50.pdf>



Damaging Hail

- Hail can inflict severe damage to an aircraft in flight or on the ground
- Hail is mostly a mid-latitude phenomenon
- An intense thunderstorm allows:
- Storm updrafts are strong
 - Large hail is suspended and circulated up and down within the cloud until it falls from the storm cloud
 - Hail stones accumulate mass by sweeping through super-cooled water droplets and ice particles



Funnel Clouds: Tornado / Water Spout

- **Tornadoes / water spouts are usually identified by a funnel cloud**
 - **Tornadic winds are extremely destructive – the most violent weather phenomenon**
 - **Can cause structural damage to an aircraft**
 - **Tornado formation depends on the wind shear environment of the severe storm**



Heavy Precipitation

- **Thunderstorms are capable of extreme rainfall intensities**
- **Heavy precipitation can:**
 - **Reduce visibility in flight and on the ground**
 - **“St. Elmo's Fire”**
 - **Precipitation, especially in vicinity of a thunderstorm can build up static electric on the aircraft**
 - **Interferes with radio transmission**
 - **Noisy disturbance at low radio frequencies**
 - **Wet runways – reduce stopping ability upon landing and decrease steering control on the ground**
 - **Flooding of airfield, boggy environs**



Water Ingestion

- **If thunderstorm updraft suspends sufficient water droplets ...**
 - **Jet engine may ingest more water than design specifications**
 - **Can lead to engine flame-out**
 - **There is no known successful operational recovery procedure**



Altimeter Interference

- **Air pressure changes often respond to a thunderstorm's downdraft ...**
 - **Usually, the pressure changes are very rapid**
 - **As the storm approaches, often the pressure falls steadily**
 - **Air pressure then rises rapidly**
 - **With the onset of gust front and arrival of the cold down draft (with heavy precipitation)**
 - **Air pressure falls back to ambient pressure when the storm moves away**
 - **Total cycle time = 10 to 15 minutes only**
 - **Whence, the altimeter could be of the order of 100 feet in error**



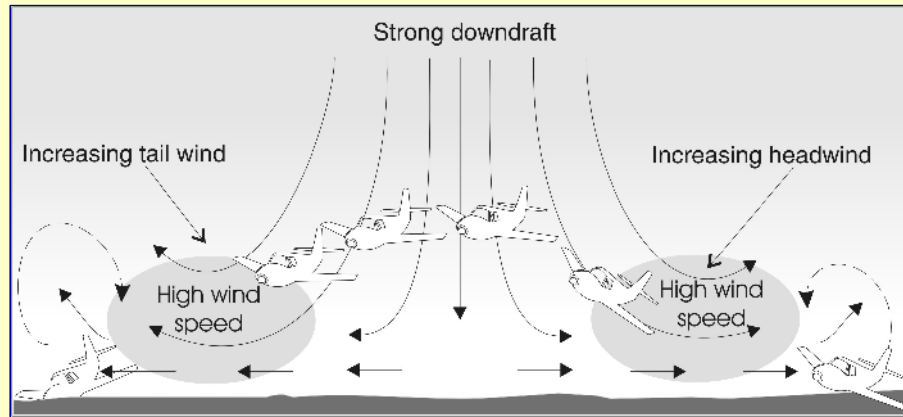
Take-off / Landing Thunderstorm Hazards

- **Statistically, the most hazardous phase of flight is take-off and /or landing**
 - **Turbulence**
 - **Wind shear**
 - **Reduced Visibility:**
 - **Vertical visibility, due to Cloud (Cb, St, etc)**
 - **Horizontal visibility, due to Precipitation (SHRA, SHGR, SHSN)**
 - **Lightning**
 - **Damaging hail**
 - **Tornado / Water Spout**
 - **Heavy precipitation**
 - **Water ingestion**

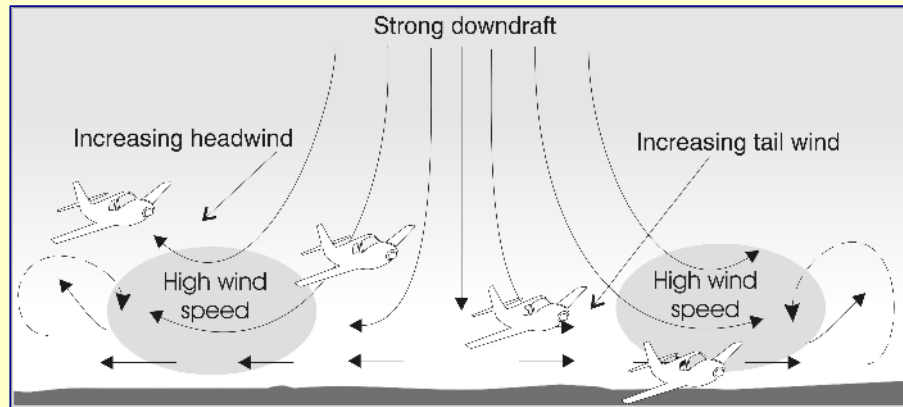


Downdrafts Interfering with Landing and Taking Off

Taking off, right to left



Landing, left to right



In-flight Thunderstorm Hazards

- **Turbulence**
- **Wind shear**
- **Icing**
- **Reduced Visibility:**
 - **Vertical visibility, due to Cloud (Cb, St, etc)**
 - **Horizontal visibility, due to Precipitation (SHRA, SHGR, SHSN)**
- **Lightning**
- **Damaging hail**
- **Tornado / Water Spout**
- **Water ingestion**



On-the-ground Thunderstorm Hazards

- **Turbulence / Gusts / Strong Winds**
- **Lightning**
- **Damaging hail**
- **Tornado / Water Spout**
- **Heavy precipitation**



Strong Gusts Blew these Aircraft into Each Other on the Ground



Summary

- **Thunderstorms are extremely hazardous to flight**
- **Pilots should avoid thunderstorms because of the number and severity of associated hazards**
- **Forecasting thunderstorm activity in a timely and accurate way has great utility to the aviation Industry**



Forward to

Satellite and radar observations of thunderstorms

