Aviation Hazards: Thunderstorms and Deep Convection

TREND

Effects of Thunderstorms on Aircraft
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

- Smooth flight
- Turbulence encounter
- Smooth flight
- Lenticular clouds sometimes present
- 'Punching' updraft
- Radar beam
Turbulence Associated with a Large Cumulus Cloud
Turbulence Associated with a Downdraft
Wind Shear: Shears in Horizontal Winds

- Directional shear
  - 20 kts
  - 20 kts

- Directional and speed shear
  - 50 kts
  - 20 kts

- Speed shear
  - 20 kts
  - 50 kts
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

Initial impact

Outspread Stage
Downburst Wind Shears: Effects on Landing and Taking Off

![Diagram showing the effects of downburst wind shears 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 0º C and -20º 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: 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”
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