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Join live classes for guided practice and doubt clearing.

1. Definition & Basic Facts

Thunderstorm (TS): A weather system produced by strong convection currents in CB clouds. Characterised by lightning flashes, rumbling thunder, blackening of sky, sharp showers, squally winds, and at times hail, snow, sleet, or warm winds. Some TS cause floods, forest fires, tornadoes, waterspouts, and microbursts.

For Aviation: TS is also known as Electrical storm, Lightning storm, or Thundershower. It is reported when thunder is heard. Under suitable conditions, TS may line up = **squall line** or **rain band**.

⚠ **TS is one of the most hazardous meteorological phenomena for aviation.**

- Diameter of individual CB cells: **1 to 10 km**
- In a cluster of CB cells: no narrow cloud-filled lanes between neighbouring cells
- **Severe TS:** accompanied by locally damaging winds, frequent lightning, or large hail

2. Types of Thunderstorms

Type	Characteristics
Heat (Air Mass) TS	Intense heating and convergence due to low pressure. Also occur when cold air passes over a warmer sea. Pop up randomly in warm humid air. Relatively weak, mostly develop in afternoons on plains; nights in valleys and hills.
Frontal TS	Occur at Cold Front (occasionally warm front). Triggered by vigorous uplift of moist air along/ahead of front. More violent than air mass TS. May develop as Squall Line along/ahead of cold front → causes severe weather.
Steady State TS	Associated with Fronts, Converging Winds, and Troughs aloft. Intensified by afternoon heating. Precipitation falls outside updraughts → become stronger in mature stage. Last several hours.
Mesoscale Convective Complex (MCC)	Nearly circular cluster of many interacting TS over a large area (~area of an Air Mass TS). No TS develop continually within an MCC. Life: 6 to 24 hr . Produce severe weather, Tornadoes, Flash Floods (sudden rise in rivers/streams). Form near fronts and in tropics in ITCZ.

🧠 **Meso-Scale Weather examples:** TS, DS, Land and Sea breeze, Katabatic wind, etc. = local scale phenomena.

3. Classification by Cell Structure

Type	Structure	Key Features
Single Cell	One main updraught	Rarely severe. Local instability/heating in summers (Heat/Air mass TS). Also in cold front in winters.
Multi Cell Cluster	Cluster of storms due to convective updraughts in/near mountain ranges and strong cold fronts or troughs	Each cell lasts 20 min ; the cluster may last hours.
Multi Cell Lines (Squall Lines)	Hundreds of km long; move swiftly along/ahead of cold fronts	Heavy rain, hail, lightning, strong winds, even isolated tornadoes. Unusually powerful = derecho . Also near tropical cyclone outer rain band.
Super Cell	Large and severe; separate up/down draughts; rotating updrafts = mesocyclone ; NO wind direction changing with height (WS)	Reach lower stratosphere. Destructive tornadoes, hailstones up to 10 cm dia. , winds > 130 km/h . Up to 24 km wide.

4. Favourable Conditions & Triggering Mechanisms

Three essential conditions for TS formation:

1. **Steep Lapse Rate:** Steeper than SALR throughout a layer at least **5–6 km** in depth, permitting development of clouds above **0°C** level.
2. **High Humidity:** Adequate supply of moisture from below; high humidity aloft. If humidity aloft is low → growth of cloud is arrested due to evaporation of rising parcel.
3. **Trigger Action:** A lifting mechanism which can produce saturation in the region of the steep lapse rate.

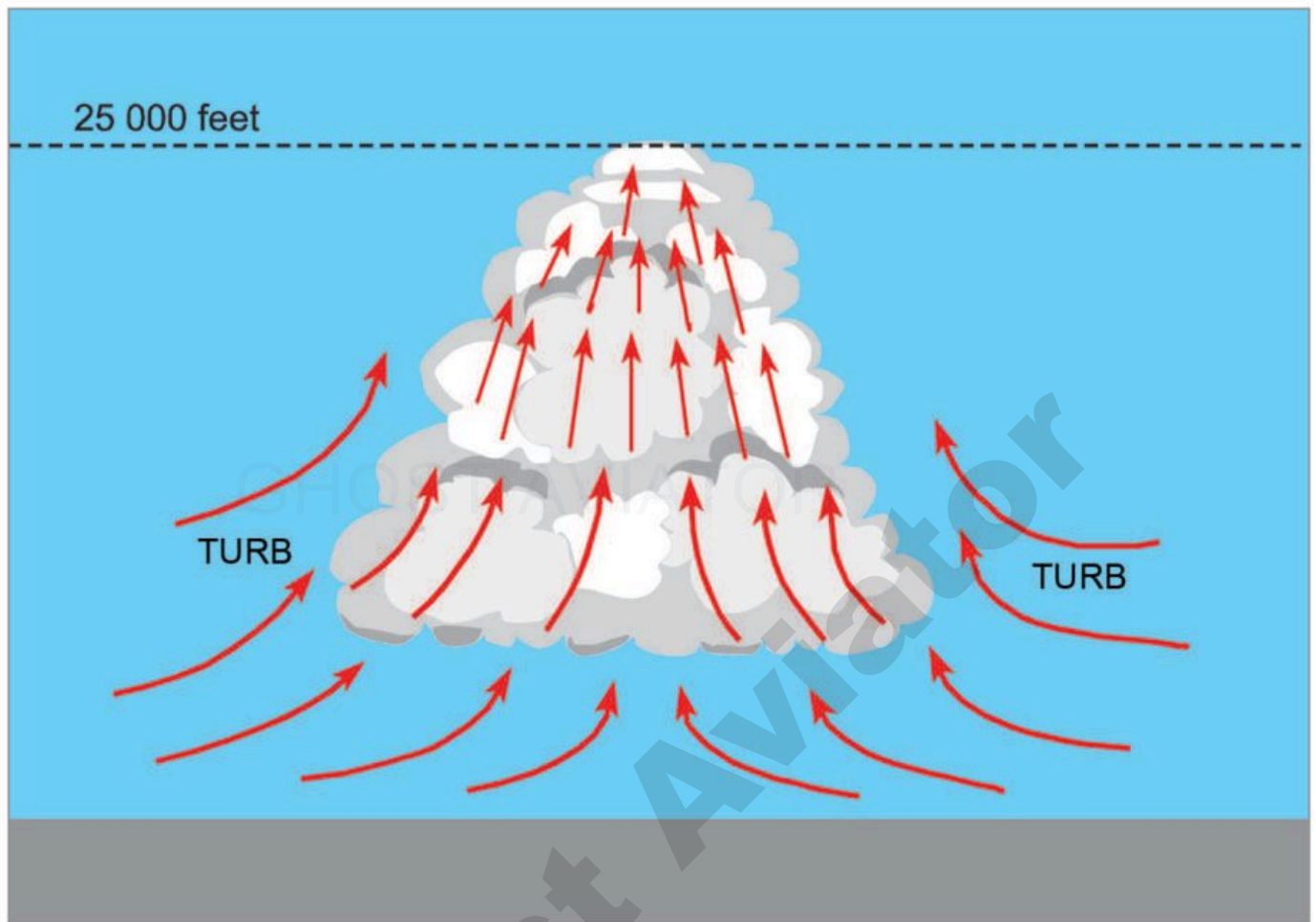
Triggering Mechanisms:

- (a) Insolation / Local Convection
- (b) Frontal Lifting
- (c) Convergence
- (d) Orographic Lifting
- (e) Radiational or Katabatic Cooling

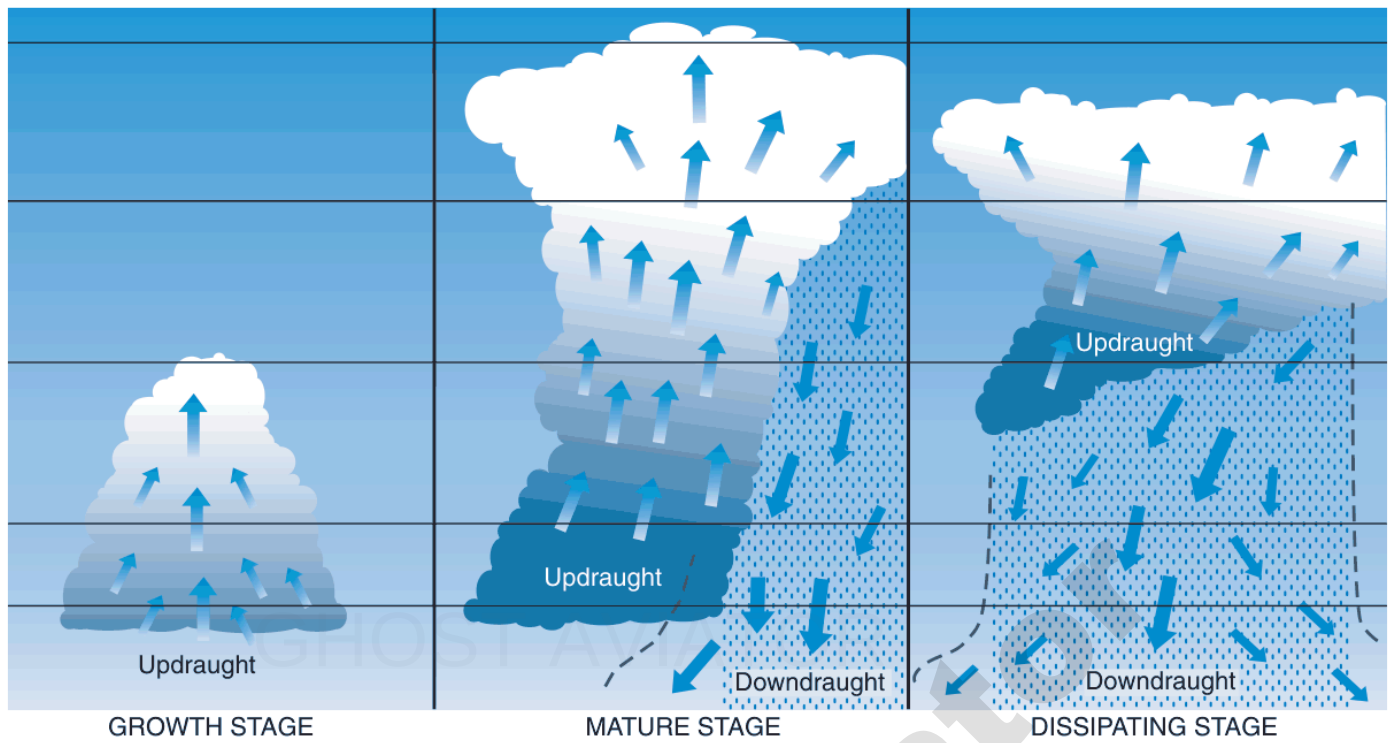
flowchart TD

```
A[Steep Lapse Rate\n≥ SALR over 5-6 km depth] --> D{All 3 conditions met?}
B[High Humidity\nMoisture from below + aloft] --> D
C[Trigger Action\nLifting mechanism] --> D
D -->|Yes| E[THUNDERSTORM DEVELOPS]
D -->|No| F[No TS]
C1[Insolation] --> C
C2[Frontal Lifting] --> C
C3[Convergence] --> C
C4[Orographic] --> C
C5[Katabatic Cooling] --> C
```

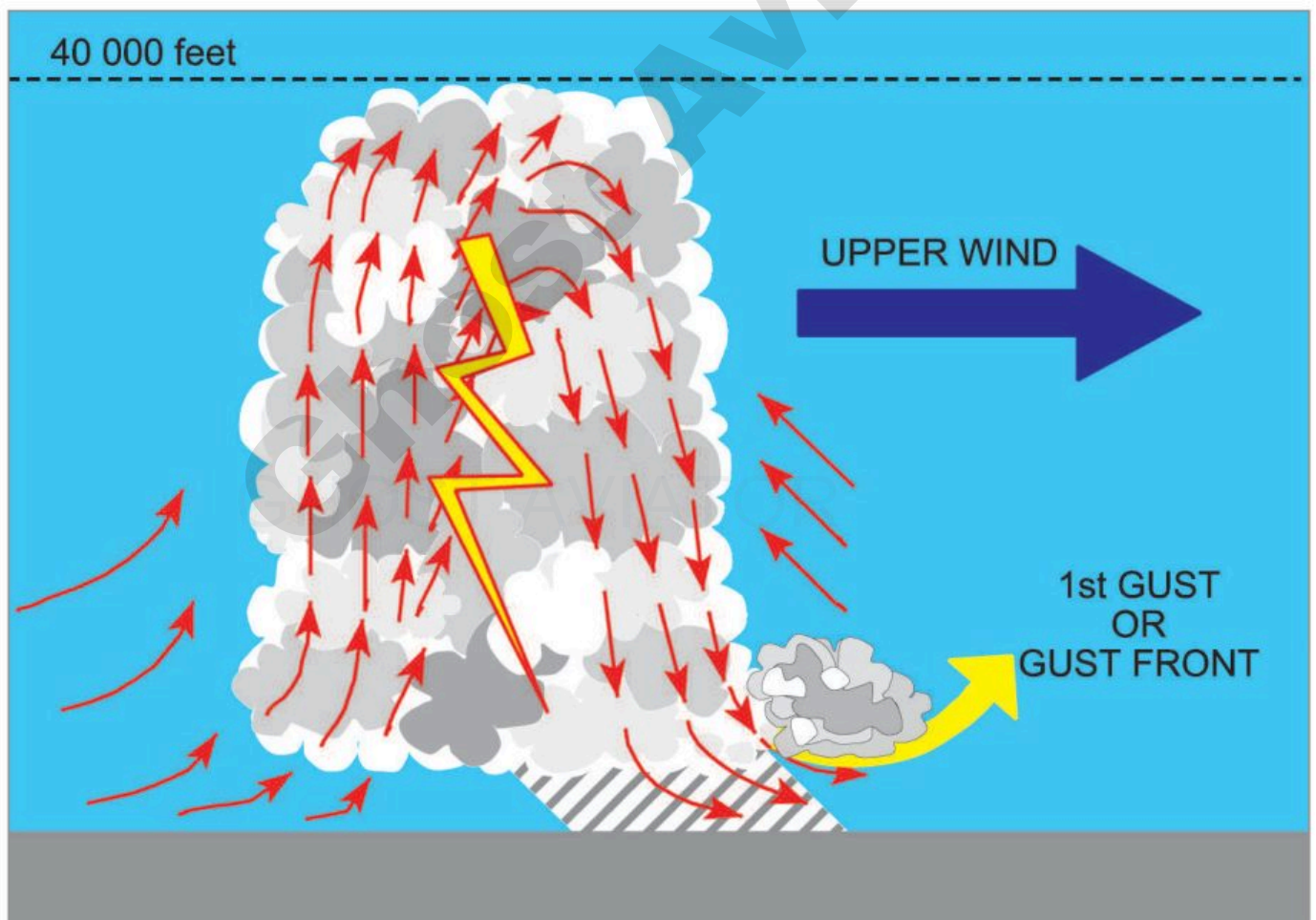
5. Life Cycle of a TS



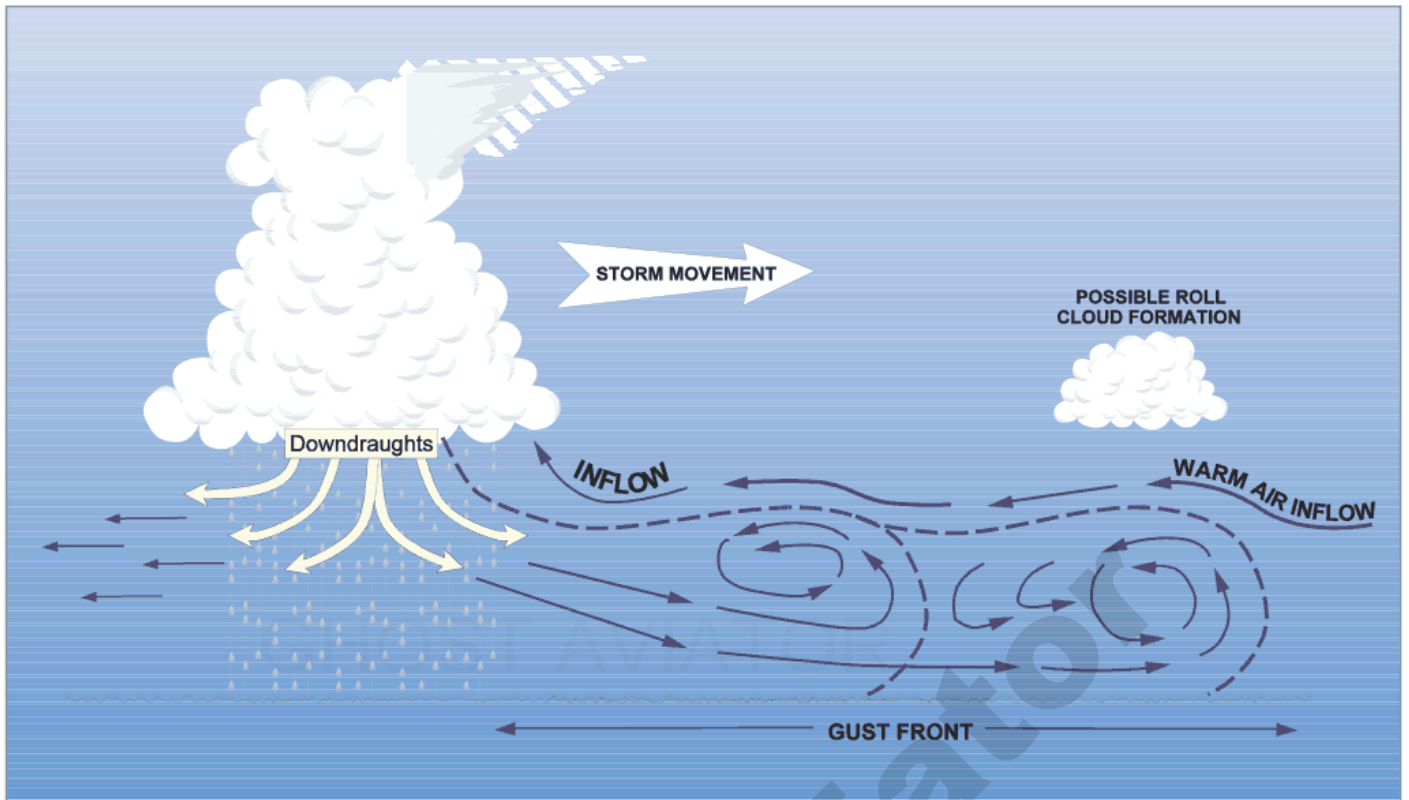
Cumulus (building) stage



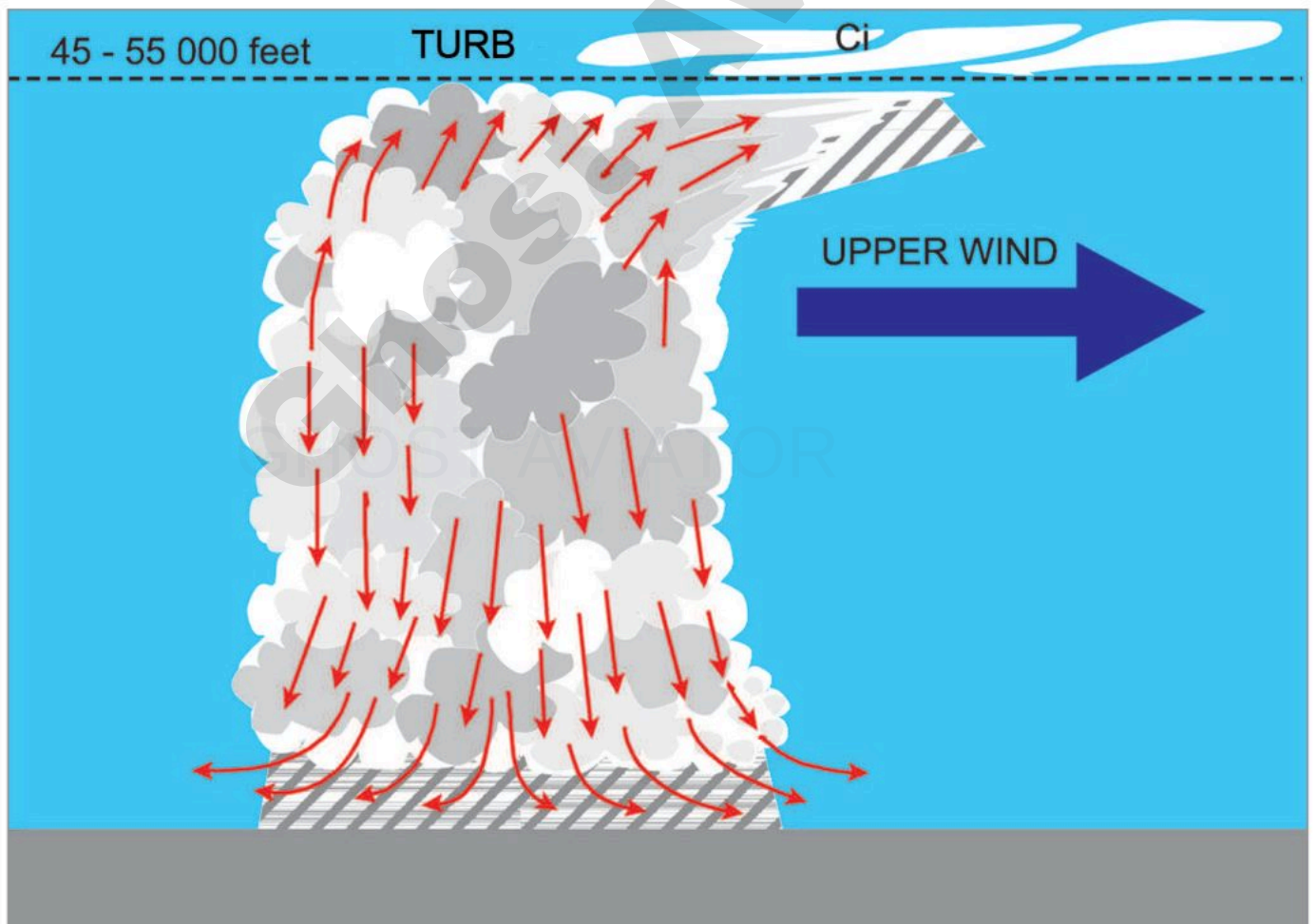
The three stages of a thunderstorm



Mature stage



Gust front and roll cloud



Dissipating stage

Stage 1: Cumulus Stage

Trigger lifts air → expands and cools → condensation → latent heat released → air warmer than surroundings → low pressure develops → **inflow (entrainment)** takes place through sides at all levels and base of cloud.

Entrainment: The mixing of environmental air into a cloud. Parcel rises higher and higher as long as it is warmer than surroundings → CU building up into a CB cloud.

Updraught speeds of **30 m/sec** or **60 kt** are not uncommon.

Rain/snow/hail particles grow inside cloud → fall as precipitation when too large/heavy to be sustained by updraughts.

Aviation hazards from this stage: turbulence and icing.

Stage 2: Mature Stage

Warmed air continues to rise up to tropopause (which is the cap) → forced to spread out as cirrus clouds giving the anvil shape = **False Cirrus** (also called False Cirrus).

Water droplets coalesce into larger → ice particles. Falling precipitation drags adjacent air → **downdraught**. Entrained drier air cools downdraught further and accelerates it. **Both up and downdraughts coexist.**

At ground level: sudden rush of **very strong cold winds** = **squall**.

Downdraught close to ground spreads horizontally → leading edge = **First Gust / Gust Front** (arc-shaped surface).

May be followed by heavy rain/showers. Gust front undercuts warm air at surfaces → generates new TS cells.

Duration: **20–40 min**. Lightning and considerable **turbulence** within and around cloud.

Mature stage = production of precipitation + coexistence of up and downdraughts side by side.

⚠ Mature stage presents serious aviation weather hazards. This is the most violent stage of a TS.

Stage 3: Dissipating Stage

Updraught ceases → storm dominated by downdraughts. Precipitation may still occur but decreases as moisture is depleted. Downdraughts spread across the lower portion of CB → cloud gradually dissipates.

If little vertical WS: storm rapidly enters dissipating stage.

If sufficient vertical WS: storm may become a super cell — mature stage can sustain itself for several hours; tornadoes may develop.

flowchart LR

```
A[CUMULUS STAGE\nOnly Updraughts\nTurbulence + Icing] --> B[MATURE STAGE\nUp + Downdraughts\nLightning + Squall\nAll hazards present\n20-40 min]\nB --> C[DISSIPATING STAGE\nOnly Downdraughts\nPrecipitation decreases\nCloud dissipates]\nB -->|Strong vertical WS| D[SUPER CELL\nSelf-sustaining\nHours of duration\nTornadoes possible]
```

6. Associated Clouds & Features

Feature	Description
Anvil / False Cirrus	Cirrus cloud at tropopause level; air forced to spread out horizontally. Indicates mature/dissipating stage.
Roll Cloud	Elongated cylindrical dark cloud appearing to rotate slowly about horizontal axis. Occurs <i>behind</i> the First Gust, <i>detached</i> from CB. Seldom associated with severe weather.
Shelf Cloud	Wedge-shaped elongated cloud with flat base. At edge of Gust Front, <i>attached</i> to CB. Due to uplift of warm air along Gust Front. Associated with Severe weather .
Gust Front / First Gust	Arc-shaped leading edge of cold downdraught spreading along the ground. Causes sudden pressure rise. Undercuts warm air → new TS cells generated.

 **Roll vs Shelf Cloud:** Roll = Detached + Behind gust = less severe. Shelf = Attached to CB + At gust front edge = SEVERE weather. Remember: "Shelf = Serious."

Structure of Severe TS

Severe TS are **tilted** due to vertical WS. Because of tilt, precipitation and downdraughts fall *away* from the updrafts → updrafts cannot be cut off → cell grows to great heights and lasts longer. The **700–500 hPa** level winds influence movement of TS. Upper level Jet Stream produces wind shear, tilts updrafts → favours great vertical development.

7. Intensity, Diurnal & Seasonal Variation

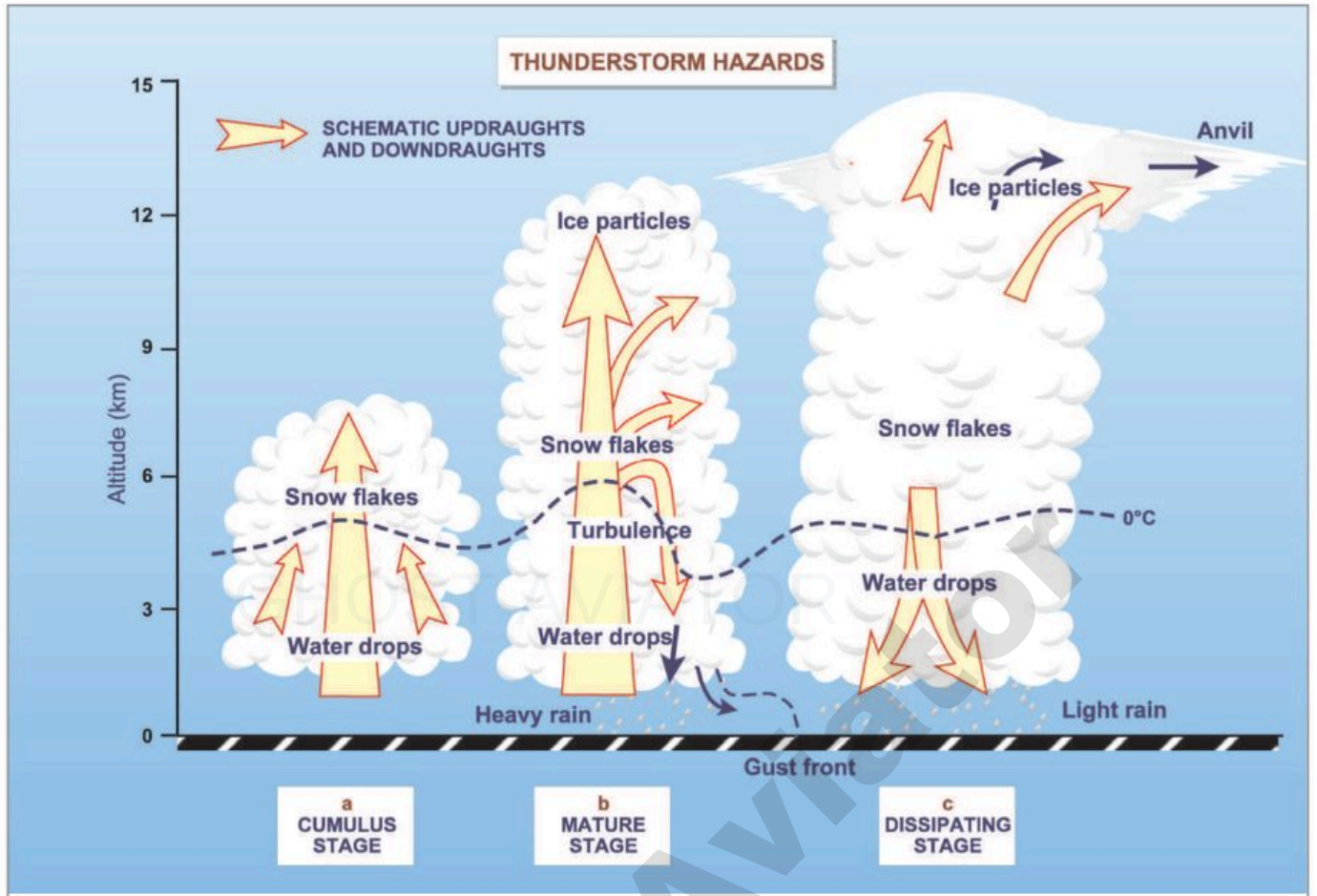
Intensity	Thunder & Lightning	Precipitation	Max Wind
Light	Faint peals at long intervals	Light showers	–
Moderate	Loud peals, frequent flashes	Moderate or heavy showers, light hail	15–40 kt
Severe	Almost continuous	Heavy rain/shower, may be hail	>40 kt

Diurnal Variation:

- Over plains: mostly **afternoon**, die out in evening
- Valley and foot hills: generally **night and early morning**
- Over sea: more frequent at **night**
- Middle latitudes: over land most frequent in **summers**; frontal TS more frequent in **winters** (frequent Cold Fronts)

8. Aviation Hazards

 **TS pose a variety of hazards to aircraft on ground and in flight:**



Thunderstorm hazards



Lightning

(a) Turbulence

Most serious hazard of a TS. Sources: gusts, eddies, up and downdraughts inside CB; large amount of air entrained from outside → strong upcurrents in clear air around CB.

- Moderate to severe turbulence: **inside CB** (at boundary between up and downdraughts)
- Clear air turbulence: **10–20 km** around CB in clear air
- Downwind: **25–30 km** downwind
- Above CB: **thousands of feet above CB top** (especially when winds are very strong)
- Below cloud base: down to surface — makes landing/takeoff dangerous

Turbulence increases gust load which may exceed stress limit of aircraft. Attempts to regain control → structural failure may occur.

Turbulence Level	Effect Inside Aircraft
Light	Feel slight strain on seat belt; unsecured objects displaced; walking is difficult
Moderate	Feel definite strain on seat belt; unsecured objects dislodged; walking very difficult
Severe	Forced violently against seat belt; objects tossed around; walking and food serving are impossible

(b) Wind Shear (WS)

Strong WS often associated with TS. Outflow of TS can cause extreme changes in wind speed and direction near surface during critical phases of flight.

- Cold strong downdraught from CB strikes the surface → rises up to **2000 ft**
- WS zone forms between outflow and warm air above (blowing opposite direction toward CB)
- Aircraft initially encounters head wind → then strong horizontal spreading → then tail wind
- Landing angle may become dangerously steep; accidents during take-off, landing, climb/descent, final approach
- WS hazardous during all critical phases; **strong vertical WS is necessary for severe TS**

(c) Squall

Initial downdraught from cloud spreads all around horizontally on the ground as squall. Speed normally up to **40 kt** but can be as high as **100 kt**. The strongest speeds are ahead of the direction of movement.

(d) Draughts

Strong up and downdraughts within cloud; greater vertical extent.

- Can suck gliders in; updraughts impose sudden **negative g force**
- Stronger from middle of cloud to the surface; can force even powerful jet aircraft to ground if below cloud base
- Horizontal extent: can be more than **1 km** in a TS
- 3– **5,000 ft** horizontal spreading

(e) Gusts

Near boundary between up and downdraughts, vigorous eddies form. Severe turbulence = combined effect of gusts and draughts. Impose severe load factor. Structural failure may occur if pilot attempts to correct attitude changes too quickly or harshly.

(f) Icing

Always possible in temperature range **0° to -30°C**. Affects aerodynamics, jams controls, blocks pitot tube, engine, and carburetor.

- **Glazed clear ice** is worst within first **10,000 ft** from the freezing level (large supercooled drops present)
- Towards top: more ice crystals → rime ice
- In piston engine aircraft: carburetor icing may cause loss of power
- Along frontal line: icing may become a serious problem
- Use of **de-icing devices and carburetor heat is essential**

(g) Hail

Hailstone starts as an ice crystal → grows by collision with supercooled water drops while being tossed up and down in cloud.

- Onion-like structure: alternate layers of rime and clear ice
- Clear ice forms nearer the freezing level; rime ice above
- Worst hail: from freezing level to **25,000 ft**
- Hail encounters are rare but if encountered, only in small region of cloud
- Small hail: superficial damage | Large hail: serious damage
- Damaging hail may occur up to **45,000 ft** in CB and under the Anvil

(h) Heavy Showers

May reduce visibility to very low value. Creates thick film of water on runway → hydroplaning and skidding of aircraft. Ingestion of heavy showers in engine → reduces power. Noise disturbs aircrew. Fractostratus clouds below **1000 ft** generally accompany heavy showers. Avoid landing and take-off during heavy rain/showers.

(i) Lightning

Potential difference for lightning flash: ~ **3×10^6 V/m** in clear air; ~ **1×10^6 V/m** in cloud.

- Strike on aircraft is relatively harmless; bonding prevents electrical discharge penetrating to interior
- Lightning can burn or puncture small holes in the skin
- Magnetic compass shows erroneous readings
- Electronic equipment may be damaged; radio noise
- Temporary blinding of crew and passengers in dimly lit environment
- Lightning strikes most likely in temperature range **+10°C to -10°C**
- Extreme heat due to lightning expands the surrounding air → shock wave = thunder

(j-m) Other Hazards

- **(k) Noise:** Hail striking aircraft and windscreen can be very frightening; more so in turbulence
- **(l) Darkness & Disorientation:** Absolute darkness in thick CB → constant eye on Artificial Horizon is essential
- **(m) Instrumental Error:** Below base of growing/mature CB, reduction in pressure → altimeter tends to **over-read** (indicates more height than actual); adequate ground clearance essential. Pitot tube may be blocked by heavy water ingestion → **ASI reading would be misleading**

9. Radar Detection of Thunderstorms

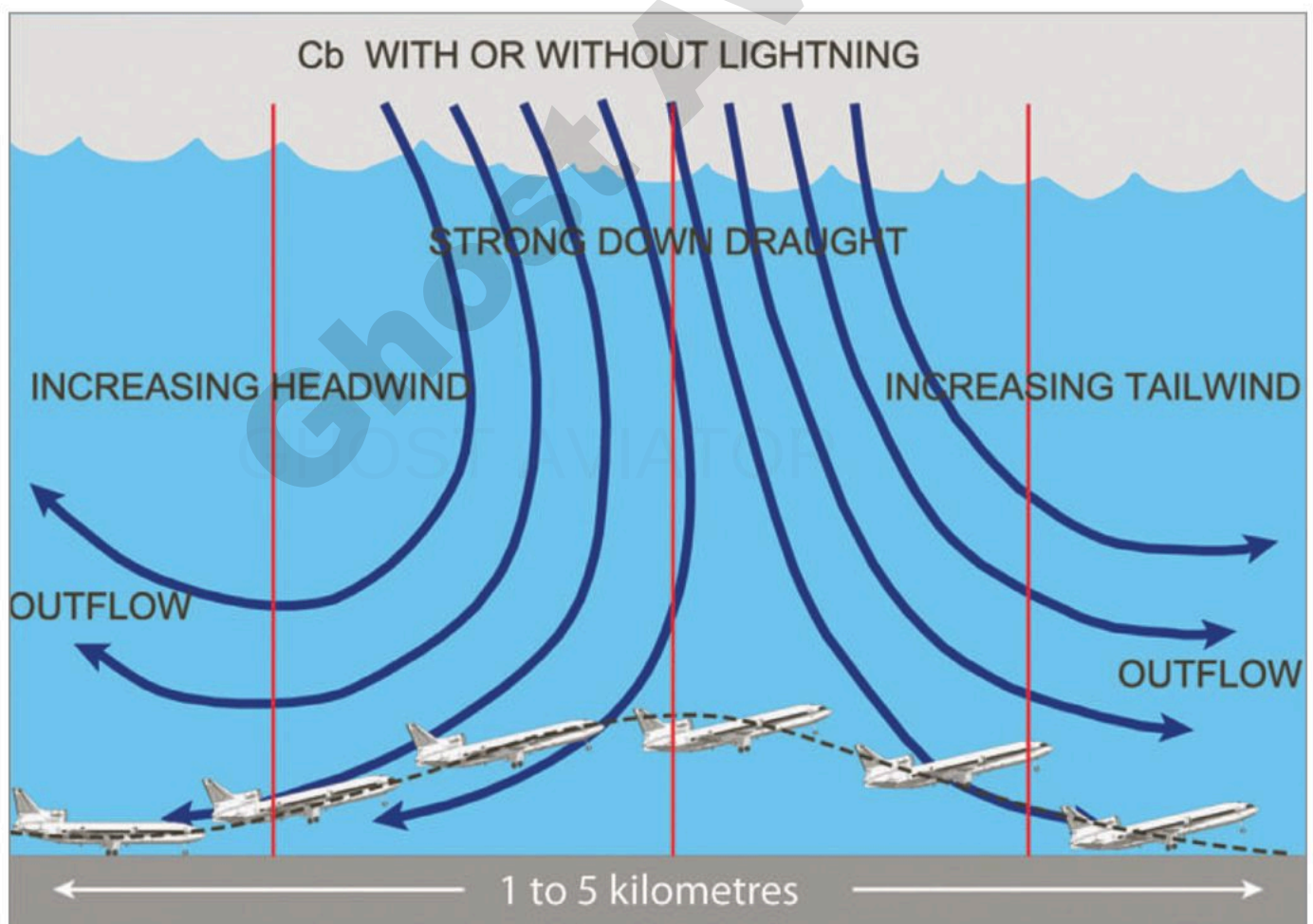
Storm Detection Radars: wavelength **3 to 20 cm**. For detecting precipitation: **3 to 20 cm** wavelength. Wavelength of **10 cm** is widely used. Can be ground-based or airborne.

Band	Wavelength (cm)	Common Use
K Band	0.86	–
X Band	3.0	Airborne weather radar
C Band	4.0	Ground-based weather radar
S Band	10.0	TS detection (widely used)
L Band	20.0	Long-range detection

🧠 **Mnemonic for radar bands:** "Kings eXplore Clear Skies Loudly" → K(0.86), X(3.0), C(4.0), S(10.0), L(20.0).

Airborne radars: wavelength **20 mm (2 cm)** generally used. For TS detection: **S Band (10 cm)** most widely used.

10. Air Pocket, Downburst & Microburst



Microburst

Join live classes for guided practice and doubt clearing.

Air Pocket

An updraught or downdraught caused by localized regions of warm or cool air and High or Low pressure areas. A pocket of warm air rises (less dense); a low pressure region creates updraft; a high pressure region creates downdraught. Extreme cases = **downburst** and **microburst**.

Downburst

A local intense severe downdraught exceeding **>4 km horizontally** with damaging winds from a TS.

Microburst vs Macroburst

Parameter	Microburst	Macroburst
Diameter	less than 4 km	4 km or more
Life	1–5 min (may prolong 15–20 min)	Longer
Max Wind Speed	May exceed 75 km/h close to ground	Similar or higher
Avg Horiz Wind	90 km/h (may exceed 200 km/h)	–

Cause of Microburst: Dryness of atmosphere → falling rain evaporates rapidly (Virga) → evaporation reduces temperature of the air column → column colder than environment → descends and accelerates towards ground as microburst.

Systems which produce Microburst:

1. CB cloud: **about 5%** of all TS produce microburst
2. Heavy rain: high probability of microburst
3. Virga: medium probability of microburst

Aviation Hazards from Microburst

Microburst affects aircraft in three stages:

1. **Contact Stage:** Cold downdraught accelerates towards the ground
2. **Outburst Stage:** Downdraught curls upwards after hitting the ground
3. **Cushion Stage:** Wind above curls and accelerates, posing danger to aircraft

An aircraft on approach encounters: first a **head wind** → then strong **horizontal spreading** → then a **tail wind**. The head and tail wind components are due to horizontal spreading of the microburst.

⚠ Time for recognition and avoidance: as little as 5–15 seconds.

Best avoided by NOT flying below a CB cloud, through a TS/DS, in heavy rain, and below Virga.

No take-off and landing is advisable during TS/DS.

Effects on aircraft:

- **Head Wind / Tail Wind Response:** Increasing head wind → lifts aircraft above AoA for landing → may overshoot. Increasing tail wind → undershoot.
- **Vertical WS Response:** Alternating up/downdraughts → momentary stick shaking or airframe shuddering; additional strain on pilot.
- **Cross Wind Shear:** Roll or yaw.
- **Turbulence:** Intense; may mask changing airspeed; delay recognition of severe downburst.
- **Rain Effect:** Heavy rain → reduce visibility; increase cockpit noise → avoid.

11. Dust Storms (DS) / Sand Storms (SS)

In the Pre-Monsoon season, surface temperatures very high (**35°C** or more) over NW India. Atmosphere highly unstable over desert/semi-arid areas. Small moisture incursion → CB cloud formation possible. Convective clouds do not build up high (low humidity aloft) — but if tops extend above freezing level → Duststorms/Sandstorms. Raise dust/sand from ground up to over **10,000 ft**. Reduce visibility to **50 m** or less. In N India: called **Andhi** (blinding storms).

Category	Wind Speed	Visibility
Light DS	Up to 21 kt	500 to <1000 m
Moderate DS	22 to 40 kt	200 to <500 m
Severe DS	>40 kt	<200 m

🧠 Aviation hazards of DS/SS are almost same as TS. After DS passes, visibility remains poor for a long time. Moderate to severe vertical WS may be experienced during take-off/landing as DS/SS approaches. Radar echoes of DS are **less intense** than TS echoes.

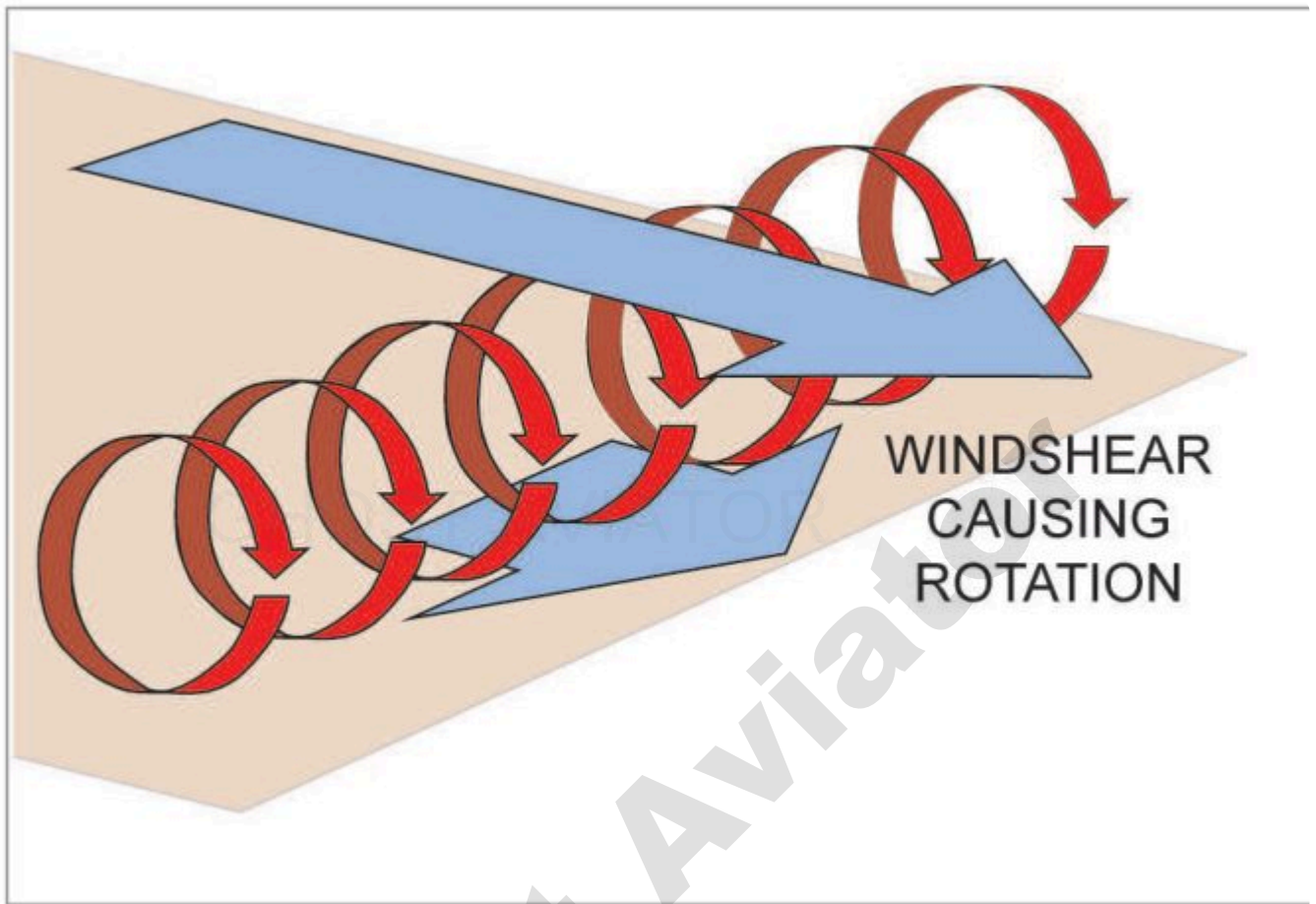
12. Norwesters

During Pre-Monsoon period (**March to May**): West Bengal, Chhatisgarh, Bihar, Jharkhand (Chotanagpur), North-East states, and Bangladesh are affected by violent TS called **Norwesters** because they approach from the **North-West**.

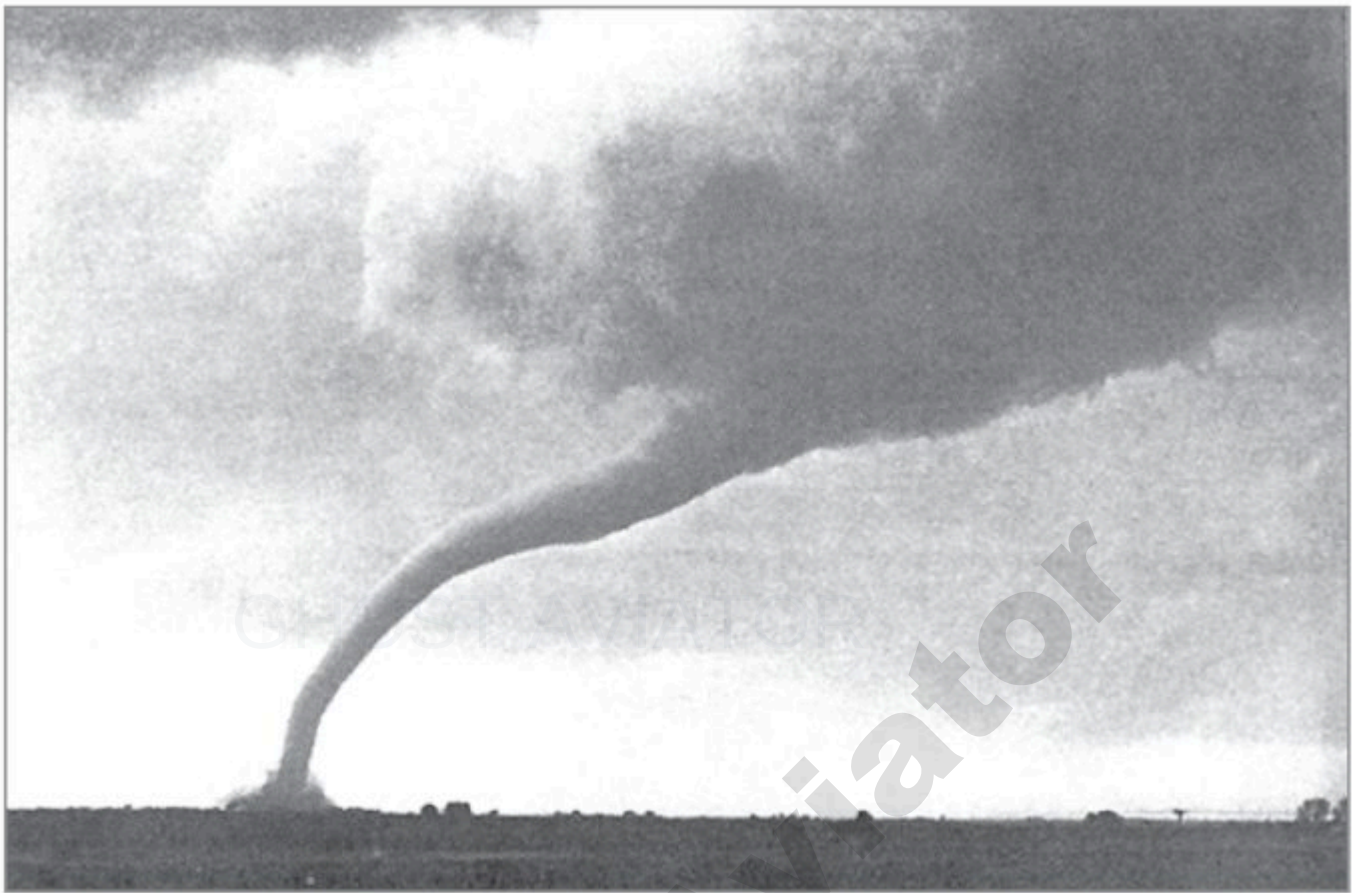
Begin March, increase in frequency till monsoon establishes over NE India. Also known as **Kalbaisakhi** (demon-like destructive character). Often accompanied by strong squalls; sometimes hail; on rare occasions a tornado may accompany them.

Flying through Norwesters can be extremely dangerous. They may regenerate TS in a line (**Line Squalls**). Circumnavigating or penetrating these may be disastrous.

13. Tornado, Water Spout & Dust Devil



Wind shear and rotation



A tornado

Tornado

A rotating funnel in which air is sucked up from below the base of a CB. TDO = Tornado.

- Strong rotational wind produced when existing circulation below CB is drawn into its base through convergence; also by low level WS below CB
- Speed of rotating winds: **in excess of 150 kt**
- Pressure in core may drop **hundreds of hPa**
- Fall in temperature makes tornado visible (condensation)
- Diameter: few metres to **200 m**
- Life: few minutes to more than **an hour**
- Tornadoes uproot trees, explode buildings, cause devastation in narrow path
- Gives **hook-shaped radar echo**
- Rare in India; In April 1978: tornado struck New Delhi → severe damage
- Fujita Damage Scale for Tornadoic Winds → at Appendix B

Water Spout

Tornado over the sea = Water Spout (WTSPT). Funnel sucks up sea water; sometimes rain of fish is observed over the adjoining coastal area.

Dust Devil

Hot summer months, local surface winds converge towards a hot spot. Start rotating about a vertical axis; a whirl of dust raising wind rises from the ground. Vertically may reach **2 km**. Diameter: **about 10 m**. Short-lived phenomenon. Capable of lifting light loose articles like paper.

14. Quick Revision Summary

⚡ AMBER Quick Revision — Thunderstorm

- **TS = CB cloud + lightning + thunder + squally winds**
- **CB cell diameter:** 1–10 km | Severe TS = damaging winds, frequent lightning, large hail
- **Types:** Heat, Frontal, Steady State, MCC (life 6–24 hr)
- **Cells:** Single → Multi Cluster → Multi Line (squall/derecho) → Super Cell (mesocyclone, 24 km wide, >130 km/h)
- **3 conditions:** Steep LR (5–6 km depth), High humidity, Trigger action
- **Triggers:** Insolation, Frontal, Convergence, Orographic, Katabatic
- **Cumulus:** Only updrafts; 30 m/s or 60 kt | **Mature:** Up + Down, 20–40 min, Squall, Gust Front | **Dissipating:** Only downdraughts
- **False Cirrus** = Anvil | **Shelf Cloud** = attached to CB, severe | **Roll Cloud** = detached, less severe
- **TS movement:** 700–500 hPa winds; Jet Stream favours severe TS development
- **Lightning:** 3×10^6 V/m clear air; 1×10^6 V/m in cloud; most likely +10°C to –10°C
- **Radar:** S Band (10 cm) widely used; X Band (3 cm) airborne
- **Microburst:** dia <4 km; life 1–5 min; wind >75 km/h; 5–15 sec reaction time
- **DS wind:** Light ≤21 kt, Moderate 22–40 kt, Severe >40 kt
- **Norwesters:** March–May; NE India; Kalbaisakhi; from NW direction
- **Tornado:** >150 kt; dia <200 m; hook radar echo; rare in India
- **Hail:** worst between freezing level and 25,000 ft; can reach 45,000 ft; max dia 5.5 in
- **Altimeter:** over-reads below CB base (low pressure); ASI unreliable if pitot blocked

15. Practice Q&A

Q1. The condition necessary for the formation of a thunderstorm are:

- (a) Steep lapse rate, strong winds (b) Shallow lapse rate, adequate supply of moisture (c) Steep lapse rate, adequate supply of moisture and trigger action

✓ **Answer: (c)** — Three conditions: steep lapse rate (steeper than SALR over 5–6 km depth), adequate supply of moisture (humidity from below and aloft), and a trigger action (lifting mechanism).

✗ (a) Strong winds alone not sufficient — direction/shear matters, not speed. ✗ (b) Shallow lapse rate is stable — suppresses convection.

💡 Classic DGCA question. Memorise: "SLR + Humidity + Trigger = TS."

Q2. Hail is most likely to fall from a cloud:

- (a) Having layers of ice crystals (b) Composed of ice crystals (c) Having strong vertical development

✓ **Answer: (c)** — Strong vertical development (CB) provides the repeated up/down cycling needed for hailstone growth by collision with supercooled water drops.

✗ (a)(b) Ice crystal clouds (Ci, Cs) do not sustain hail growth — no liquid water present.

💡 Hail = CB with strong updrafts. Updraft speed must be high enough to sustain the growing hailstone.

Q3. Norwesters are:

- (a) The western disturbances which affect NW India (b) Severe thunderstorms which occur over NE India during hot weather period (c) Severe thunderstorms which occur over Peninsula during hot weather period

✓ **Answer: (b)** — Norwesters are violent TS affecting West Bengal, Bihar, NE states during Pre-Monsoon (March–May), approaching from the NW direction.

- ✗ (a) Western disturbances = extra-tropical cyclones affecting NW India in winter — completely different. ✗
(c) Norwesters affect NE India, not the Peninsula.

💡 "Norwester" = from NW direction, over NE India. Also called Kalbaisakhi.

Q4. Duststorm occurs over NW India during:

- (a) Post-monsoon (b) Winter (c) Pre-Monsoon

✓ **Answer: (c) Pre-Monsoon** — Very high surface temperatures ($35^{\circ}\text{C}+$) over NW India create intense instability; small moisture incursion $\rightarrow$ CB $\rightarrow$ Duststorms.

✗ (a)(b) Post-monsoon/Winter: lower temperatures, less instability over NW India.

💡 DS = Pre-Monsoon = NW India = Andhi (blinding storms in N India).

Q5. A 'mature' thunderstorm has strong:

- (a) updraft only (b) downdraft only (c) updrafts and downdraughts

✓ **Answer: (c)** — The defining characteristic of the mature stage is the COEXISTENCE of both updrafts and downdraughts side by side.

✗ (a) Updraft only = Cumulus stage. ✗ (b) Downdraft only = Dissipating stage.

💡 Mature = Most dangerous = Both up AND downdraughts coexist.

Q6. Aircraft icing is most favoured in the cloud at temperatures ranging between:

- (a) -20°C and -40°C (b) 0°C and -20°C (c) below -40°C

✓ **Answer: (b) 0°C and -20°C** — Maximum supercooled liquid water content exists in this range, particularly in CB and TCu clouds where severe icing is most likely.

✗ (a) -20°C to -40°C : droplets increasingly freeze $\rightarrow$ icing reduces. ✗ (c) Below -40°C : virtually all ice crystals, negligible icing.

💡 **0°C to -20°C** is the prime icing zone. Above this range → more ice crystals, less supercooled water.

Q7. A short duration, showery precipitation is associated with:

(a) ST (b) AS (c) CB

✅ **Answer: (c) CB** — CB clouds produce intense, short-duration convective showers and thunderstorms due to strong updrafts and rapid precipitation development.

❌ (a) St — stratus gives drizzle, continuous light rain. ❌ (b) As — continuous moderate rain/snow from layer clouds.

💡 "Showery" = convective = CB. "Continuous" = stratiform = As/Ns/St.

Q8. Hail is:

(a) Solid precipitation commonly occurring over the mountainous regions in winters (b) Frozen or partly frozen rain falling from sheet type of clouds (c) Solid precipitation falling from a deep convective cloud

✅ **Answer: (c)** — Hail is solid precipitation falling from a deep convective cloud (CB) where strong updrafts support the growth of hailstones by repeated cycling through supercooled water drop regions.

❌ (a) Describes ice pellets more than hail. ❌ (b) Frozen rain from sheet clouds = ice pellets or sleet, not hail.

💡 Hail = deep convective (CB) cloud. Always.

Q9. The most hazardous cloud for aviation is:

(a) CB (b) CU (c) NS

✅ **Answer: (a) CB** — Cumulonimbus combines ALL aviation hazards: turbulence, icing, hail, lightning, wind shear, microburst, and instrument errors.

❌ (b) CU — less developed, fewer hazards. ❌ (c) Ns — gives continuous rain but lacks the violent convection

of CB.

💡 CB = The most dangerous cloud in aviation. Period.

Q10. The life of a Cb cell is usually:

(a) 7 to 8 hrs (b) 3 to 4 hrs (c) 2–3 hr

✅ **Answer: (c) 2–3 hr** — An individual CB cell has a life cycle of about 2–3 hours (some sources say the mature stage alone is 20–40 min; total cell life ~1–3 hr). MCC life is 6–24 hr.

❌ (a) 7–8 hr — too long for a single cell (this applies to MCC or Steady State TS). ❌ (b) 3–4 hr — possible for multi-cell systems.

💡 Single CB cell ≈ 2–3 hr total. MCC = 6–24 hr. Multi-cell cluster: each cell = 20 min but cluster lasts hours.

Q11. Generally the mature activity of a heat type, TS is for:

(a) 2 hrs (b) 30 to 45 min (c) 3 to 4 hr

✅ **Answer: (b) 30 to 45 min** — The mature stage of a heat (air-mass) thunderstorm lasts about 30 to 45 minutes. It is the most violent stage, with updraughts and downdraughts side by side.

❌ (a) 2 hr and (c) 3–4 hr are far too long for a single cell.

💡 Single-cell TS: life about 1–1.5 hours, mature stage 30–45 min.

Q12. Norwesters occur during:

(a) Jan–Feb (b) Mar–May (c) Jun–Sep

✅ **Answer: (b) Mar–May** — Norwesters are a Pre-Monsoon phenomenon, beginning in March and increasing in frequency till the monsoon establishes over NE India.

❌ (a) Jan–Feb: winter, too cold for this convective activity in NE India. ❌ (c) Jun–Sep: monsoon season — different weather pattern.

💡 Norwesters = March to May = Pre-Monsoon = NE India = Kalbaisakhi.

Q13. Norwesters occur during:

(a) Winter (b) Hot weather (c) Monsoon

✅ **Answer: (b) Hot weather** — Pre-Monsoon = Hot weather season in India (March–May). Intense surface heating drives convective instability.

❌ (a) Winter: western disturbances dominate, not Norwesters. ❌ (c) Monsoon: monsoon TS are different from Norwesters.

💡 "Hot weather" = Indian Met term for Pre-Monsoon (March–May).

Q14. Norwesters affect:

(a) N India (b) Bengal, Bihar, Orissa and Assam (c) Central India

✅ **Answer: (b) Bengal, Bihar, Orissa and Assam** — Norwesters primarily affect West Bengal, Bihar, Jharkhand, Chhatisgarh, NE states, and Bangladesh.

❌ (a) N India: Western disturbances, not Norwesters. ❌ (c) Central India: not the primary area for Norwesters.

💡 Norwesters = Eastern/NE India + Bangladesh = Kalbaisakhi zone.

Q15. The trigger action may take place due to:

(a) Clear night sky, no wind (b) Orographic lifting (c) high pressure

✅ **Answer: (b) Orographic lifting** — Orographic lifting forces moist air upward along mountain slopes → trigger action for TS. Other triggers: insolation, frontal lifting, convergence, katabatic cooling.

❌ (a) Clear night sky → radiational cooling → stable surface layer → suppresses convection. ❌ (c) High pressure → subsidence → suppresses convection.

💡 Trigger = any lifting mechanism. Orographic, frontal, convergence, insolation, katabatic.

Q16. Norwesters normally occur during:

(a) Mornings (b) Afternoons (c) Nights

✅ Answer: (b) Afternoons — Norwesters are heat-driven thunderstorms of the pre-monsoon hot weather and are most frequent in the afternoon and evening, when surface heating is at its peak.

❌ (a) Mornings and (c) Nights: the surface is cool then and convection is weak.

💡 Norwester = hot weather, afternoon/evening.

Q17. Norwesters originates over:

(a) Chota-Nagpur hills (b) Deccan Plato (c) Khasi hills

✅ Answer: (a) Chota-Nagpur hills — Norwesters originate over the Chota Nagpur plateau and move south-eastwards across Bengal and Bangladesh.

❌ (b) The Deccan plateau and (c) the Khasi hills are not the usual starting region.

💡 Chota Nagpur → West Bengal, Bihar, Orissa, Assam (Kalbaisakhi).

Q18. Andhi (blinding storms) occur generally over:

(a) S India (b) N India (c) NE India

✅ Answer: (b) N India — Andhi (Duststorms) are a North India phenomenon, occurring in the Pre-Monsoon season over the semi-arid/desert regions of NW India (Rajasthan, Punjab, Haryana, UP).

❌ (a) S India — different climate; less dust. ❌ (c) NE India — Norwesters, not Andhi.

💡 Andhi = N India (NW India especially). Kalbaisakhi = NE India. Don't mix up!

Q19. Wind speed in Light DS is:

(a) 25 kt (b) 30 kt (c) up to 21 kt

✅ **Answer: (c) up to 21 kt** — Light DS: wind up to 21 kt, visibility 500 to <1000 m.

❌ (a) 25 kt — falls in Moderate DS range. ❌ (b) 30 kt — also Moderate DS.

💡 DS classification: Light ≤ 21 kt | Moderate 22–40 kt | Severe > 40 kt.

Q20. The diameter of Microburst is:

(a) less than 4 km (b) less than 2 km (c) less than 6 km

✅ **Answer: (a) less than 4 km** — Microburst dia < 4 km; Macroburst dia ≥ 4 km.

❌ (b)(c) — not the correct threshold values.

💡 Micro = less than 4 km. Macro = 4 km or more. Life of microburst: 1–5 min (may prolong 15–20 min).

Q21. The diameter of and Macroburst:

(a) < 4 km (b) 4 km or more (c) > 8 km

✅ **Answer: (b) 4 km or more** — Macroburst diameter is 4 km or more (contrast with Microburst < 4 km).

❌ (a) < 4 km = Microburst. ❌ (c) > 8 km — not the threshold used.

💡 Paired question with Q20 — must know both thresholds.

Q22. For detecting precipitation a Radar wavelength in the range is suitable:

(a) 30 to 200 mm (b) 400–500 mm (c) 600–700 mm

✅ Answer: (a) 30 to 200 mm — Weather radars used for precipitation work in the 3–20 cm band (30–200 mm), which is the range of X, C and S band radars. Longer wavelengths (400 mm and more) are not used for rain detection.

❌ (b) and (c) are far too long to be reflected by raindrops.

💡 Rain detection radars: roughly 3–10 cm wavelength.

Q24. The wavelength of TS detection X band radar is:

(a) 10 mm (b) 20 mm (c) 30 mm

✅ Answer: (c) 30 mm — An X-band radar works at a wavelength of about 3 cm (30 mm) and is used for storm detection.

❌ (a) 10 mm and (b) 20 mm are shorter wavelengths (K band).

💡 $X = 3 \text{ cm}$, $C = 5 \text{ cm}$, $S = 10 \text{ cm}$.

Q25. The wavelength of storm detection S band radar is:

(a) 50 mm (b) 100 mm (c) 200 mm

✅ Answer: (b) 100 mm (10 cm) — S Band = 10.0 cm = 100 mm. The widely used wavelength for TS detection.

❌ (a) 50 mm = 5 cm (between C and S). ❌ (c) 200 mm = 20 cm = L Band.

💡 S Band = 10 cm = 100 mm = widely used for storm detection. Easy to remember: S = Standard storm radar.

Q26. Over plains TS mostly occur during the:

(a) afternoon (b) night (c) early morning

✅ Answer: (a) afternoon — Over plains, maximum surface heating occurs in afternoon → convective instability → TS form in afternoon, die out in evening.

✗ (b) Night: sea TS. ✗ (c) Early morning: valley/foot hills TS and sea TS.

💡 Plains = afternoon. Sea = night. Valley/hills = night and early morning.

Q27. Over valley and foot hills TS generally occur during:

(a) afternoon (b) night & early morning (c) early morning

✅ **Answer: (b) night & early morning** — In valleys and foot hills, katabatic winds and radiational cooling at night + orographic lifting create TS conditions during night and early morning.

✗ (a) Afternoon: plains TS. ✗ (c) Early morning only: too restrictive.

💡 Valley TS timing: night AND early morning (both). Over sea also night.

Q28. Over the sea TS are more frequent:

(a) afternoon (b) night (c) early morning

✅ **Answer: (b) night** — Over the sea, low-level convergence and moisture availability are greatest at night → TS more frequent at night.

✗ (a) Afternoon: land TS. ✗ (c) Early morning: can occur but not the most frequent time for sea TS.

💡 Sea TS = night. Land TS = afternoon. Classic DGCA question.

Q29. The life of Mesoscale Convective Complex is:

(a) 2-3 hr (b) 3-4 hr (c) 6 to 24 hr

✅ **Answer: (c) 6 to 24 hr** — MCC life span is 6 to 24 hours, much longer than individual CB cells.

✗ (a) 2-3 hr: individual CB cell life. ✗ (b) 3-4 hr: not the stated value for MCC.

💡 MCC = **6-24 hr** life. No TS develop continually within an MCC.

Q30. Loud peals of thunder, frequent flashes of lightning, moderate or heavy showers accompanied by light hail, and a wind speed of 15–40 kt are characteristic of a TS of intensity:
(a) Light TS (b) Moderate TS (c) Severe TS

✅ **Answer: (b) Moderate TS** — Moderate TS: loud peals and frequent lightning, moderate or heavy showers, light hail, and maximum wind speed of 15–40 kt.

❌ (a) A light TS has distant thunder and light showers. (c) A severe TS has almost continuous thunder and lightning, large hail and winds above 40 kt.

💡 15–40 kt = Moderate. Above 40 kt = Severe.

Q31. For a severe TS one of the requirements is strong Wind Shear:
(a) Horizontal (b) Vertical (c) Slant

✅ **Answer: (b) Vertical** — Strong vertical wind shear tilts the TS cell → precipitation falls away from updrafts → updrafts not cut off → storm grows to great heights and persists → severe TS.

❌ (a) Horizontal WS: affects aircraft at different altitudes but not the storm structure in the same way. ❌ (c) Slant: not a standard classification for this purpose.

💡 Severe TS requires strong *vertical* WS. Jet Stream provides this shear → super cells.

Q32. Severe TS cells are tilted:
(a) in a vertical (b) to the South (c) to the North

✅ **Answer: (a) in vertical** — Severe TS cells are tilted in the vertical: vertical wind shear carries the top of the cloud away from its base, so the updraught leans downwind. The direction of the lean depends on the shear, not on a fixed compass direction.

❌ (b) South and (c) North give a fixed direction, which the shear does not guarantee.

💡 Severe TS = leaning, tilted updraught, long-lived.

Q33. When flying through an active TS, lightning strikes are most likely:

(a) Above 5000 ft and under the anvil (b) In the clear air below the cloud in rain (c) In the temperature band between +10° and –10°C

✅ Answer: (c) In the temperature band between +10° and –10°C — Lightning is most likely within about 5000 ft of the freezing level, in the temperature band from +10 °C to –10 °C, where the electric charges separate most strongly.

❌ (a) and (b) are not the most likely zone for a strike on an aircraft.

💡 Lightning risk: +10 to –10 °C, around the freezing level.

Q34. Hazards of TS to aircraft of a TS Cell include turbulence, lightning, and:

(a) Microburst, wind shear and anvil (b) Icing, microburst and WS (c) —

✅ Answer: (b) Icing, microburst and WS — The mature thunderstorm cell contains supercooled water that gives icing, and its downdraughts produce microbursts and wind shear, along with turbulence and lightning.

❌ (a) The anvil is a cloud feature, not a separate hazard in this list.

💡 CB hazards: turbulence, lightning, icing, hail, microburst, wind shear.

Q35. Hail grows as it freezes as it:

(a) freezes as it falls (b) up and down forces in CU cloud (c) collision with ice crystals (d) collision with supercooled water drops

✅ Answer: (d) collision with supercooled water drops — Hailstone grows by collision with supercooled water drops while being tossed up and down by strong updrafts in CB clouds.

❌ (a) Freezing while falling — no updraft cycling. ❌ (b) CU: not deep enough. ❌ (c) Collision with ice crystals — doesn't grow hailstones.

💡 Hail growth = supercooled water drop collision + strong updraft cycling. Onion structure = alternating rime

(cold levels) + clear ice (warmer levels near 0°C).

GHOST AVIATOR

Ghost Aviator

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16. Master Reference Tables

All Numerical Values — Chapter 13

Parameter	Value
CB cell diameter	1–10 km
Super Cell width	up to 24 km
Super Cell winds	> 130 km/h
Super Cell hailstone diameter	10 cm
MCC life	6–24 hr
TS condition: steep LR depth	5–6 km
Updraft speed in Cumulus stage	30 m/sec or 60 kt
Mature stage duration	20–40 min
WS zone height (cold downdraught)	up to 2000 ft
Squall max speed	40 kt (can reach 100 kt)
Moderate TS max wind	15–40 kt
Severe TS max wind	> 40 kt
CAT around CB (clear air)	10–20 km
CAT downwind of CB	25–30 km
Icing temperature range in TS	0° to –30°C
Glaze ice worst: below freezing level	first 10,000 ft
Hail worst zone	Freezing level to 25,000 ft
Hail can reach up to	45,000 ft
Hail max diameter	5.5 in

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Largest hail weight (China)	4.5 kg
Largest hail weight (India)	3.4 kg
Lightning potential (clear air)	3×10^6 V/m
Lightning potential (in cloud)	1×10^6 V/m
Lightning most likely temp range	+10°C to -10°C
Fractostratus below heavy showers	below 1000 ft
Radar wavelength for precipitation	3–20 cm
S Band radar wavelength	10.0 cm (widely used)
X Band radar wavelength	3.0 cm
Microburst diameter	<4 km
Macroburst diameter	≥4 km
Microburst life	1–5 min (may reach 15–20 min)
Microburst wind speed (close to ground)	>75 km/h
Microburst avg horizontal wind	90 km/h (may exceed 200 km/h)
CB producing microburst	5% of all TS
Microburst reaction time	5–15 sec
DS surface temp trigger (NW India)	35°C or more
DS raises dust to	over 10,000 ft
DS reduces visibility to	50 m or less
Light DS wind / visibility	≤21 kt / 500–1000 m
Moderate DS wind / visibility	22–40 kt / 200–500 m
Severe DS wind / visibility	>40 kt / <200 m
Norwesters season	March–May
Tornado wind speed	>150 kt

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Tornado diameter	few m to 200 m
Dust Devil height	up to 2 km
Dust Devil diameter	about 10 m
Multi Cell Cluster: each cell life	20 min

Mnemonics

- **TS conditions:** "SHT" = Steep lapse rate, High humidity, Trigger
- **TS types:** "HFSM" = Heat, Frontal, Steady State, MCC
- **Life cycle:** "CuMaDi" = Cumulus → Mature → Dissipating
- **Mature stage:** Both UP and DOWN draughts = MOST dangerous
- **Radar bands (K→L):** "Kings eXplore Clear Skies Loudly" = 0.86, 3.0, 4.0, 10.0, 20.0 cm
- **Microburst reaction time:** 5–15 sec — "FIFTEEN seconds to react"
- **DS classification:** Light ($\leq 21/1000\text{m}$), Moderate (22–40/500m), Severe ($> 40/200\text{m}$)
- **Norwesters = Kalbaisakhi = NE India = March–May = from NW**
- **Shelf Cloud = Serious (Severe) | Roll Cloud = Relatively harmless (detached)**
- **Altimeter below CB base:** Over-reads (actual height is LESS than indicated)
- **WS below CB = 3 winds:** Head wind → Horizontal spreading → Tail wind