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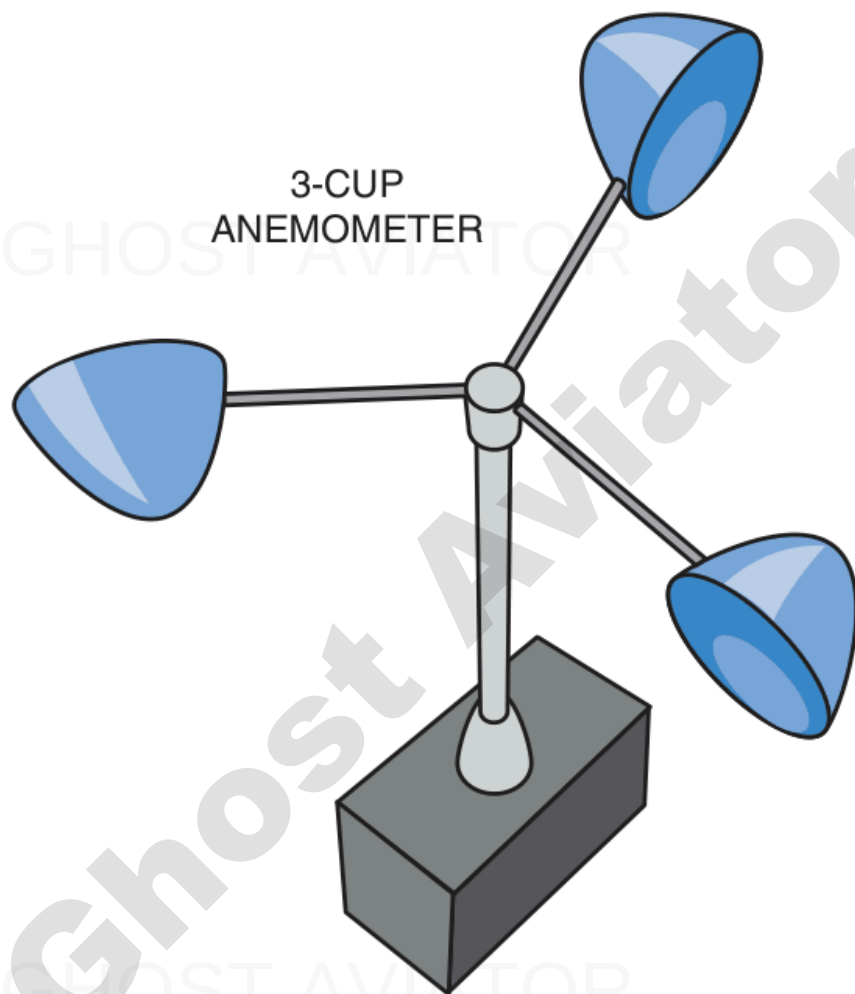
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Practice Q&A (45 Questions)

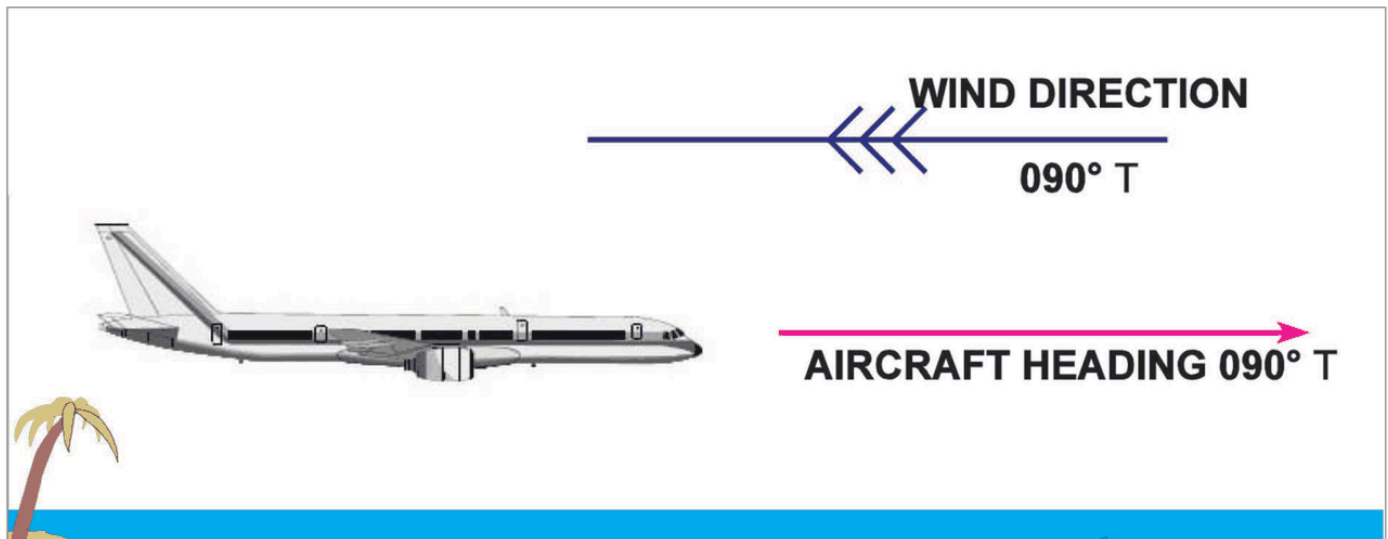
Master Reference Tables

1. Wind Measurement & Cross Wind

Definition: Wind is the horizontal movement of air from high pressure to low pressure. It is described by its direction (from which it blows) and speed.



Three-cup anemometer



Wind direction and aircraft heading

Cross Wind

Runways are oriented along the most prevailing wind directions of a locality based on climatological records. Sometimes — especially during adverse weather and transition seasons — the winds deviate from these directions. A wind **90°** to the runway in use is called the **Cross Wind Component**. Critical cross wind components for each type of aircraft are specified. Cross winds tend to swing the aircraft during take-off and landing, especially lighter aircraft.

⚠ **Critical Cross Wind Component:** Great caution is exercised whenever this value is exceeded. Cross winds tend to swing the aircraft during take-off and landing, especially lighter aircraft.

Instruments for Measuring Wind

- **Surface wind speed:** Measured by **Anemometer**
- **Wind direction:** Measured by **Wind Vane**
- **Upper winds:** Measured by RAWIN and Pilot Balloon equipment
- **Hydrogen-filled balloons:** Tracked by RADAR and Optical Theodolite

Exposure of Wind Instruments

- Anemometer and Wind Vane installed at height of **10 m** in area free of obstructions
- Averaged over **10 minutes** for all weather observations
- For **take-off and landing** purposes: wind is averaged for **2 minutes**

💡 **Exam Tip:** "10m, 10 minutes for all obs — 2 minutes for T/O and landing." Remember: **2 for T/O/Landing, 10 for general.**

2. Gust, Lull, Squall & Gale

Gust: An irregular and rapid positive fluctuation in wind. Caused by ground friction and uneven heating of the ground (especially on hot afternoons).

Lull: A negative fluctuation in wind (below mean).

Squall

Definition: Sudden increase in wind speed by **32 km/h (16 kt, 08 mps)**, should last for at least **1 minute** and speed should increase to **44 km/h (22 kt, 11 mps)** or more.

- Associated with CB clouds and violent convective activity
- Extends some km horizontally and several **thousands of feet** vertically
- Both speed and direction in squall may differ widely from prevailing winds
- Violent squalls experienced in Norwesters, Thunderstorms (TS) and Duststorms (DS) from **March to June**
- Line squalls occur ahead of Cold Fronts and sometimes with Norwesters

⚠ **Squall vs. Gust — Key Difference:** The main difference is **DURATION**. A gust lasts a few seconds; a squall lasts for at least one minute and may be accompanied by marked drop in temperature and precipitation.

⚠ **Strong squalls are more dangerous than strong mean winds.** A parked aircraft may sustain a gale (persistent mean 34 kt or more) but may NOT sustain a squall or sudden gust of say 60 kt, even though the mean wind may not reach gale force.

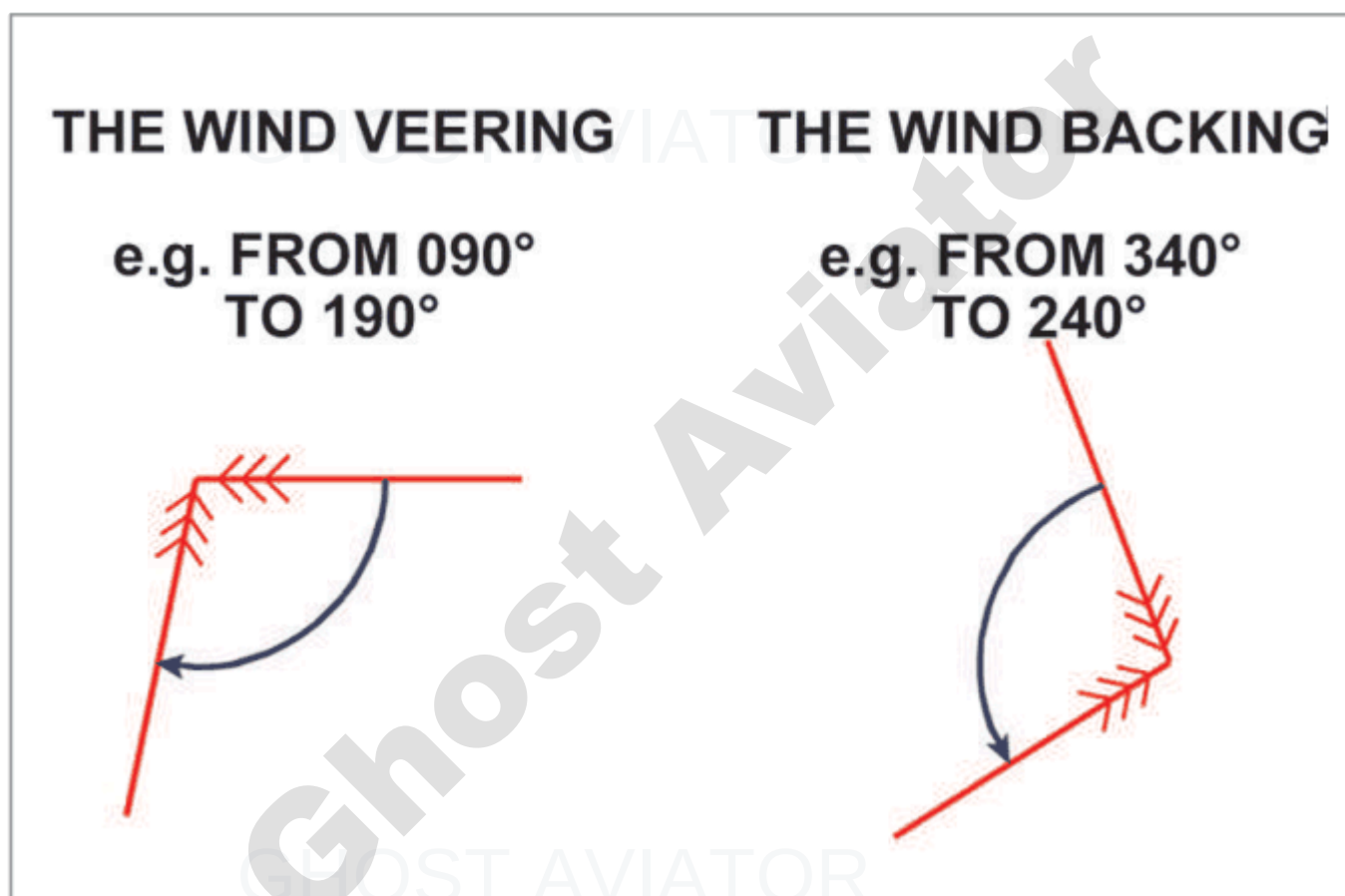
Gale

Definition: Persistent mean wind speed of **34 kt or more**. Associated with depressions and cyclonic storms.

flowchart LR

```
A["Wind Fluctuation"] --> B{Duration?}
B -->|"Few seconds"| C["GUST\n(Positive fluctuation)"]
B -->|"Negative fluctuation"| D["LULL"]
B -->|"≥1 min, ↑32kmh→44kmh"| E["SQUALL\n(CB associated)"]
A --> F{Speed ≥34kt persistent?}
F -->|Yes| G["GALE\n(Depressions/Cyclones)"]
```

3. Backing & Veering — Buys Ballot's Law



Veering and backing

Backing and Veering

Term	Definition	Example
Backing	Change of wind direction anti-clockwise	090° → 060° or 270° → 160°
Veering	Change of wind direction clockwise	060° → 090°

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In a low pressure area: Wind blows in anti-clockwise direction (**Backs**) in N hemisphere.

In a high pressure area: Wind blows clockwise (**Veers**) in N hemisphere.

Buy's Ballot's Law (Pressure and Wind)

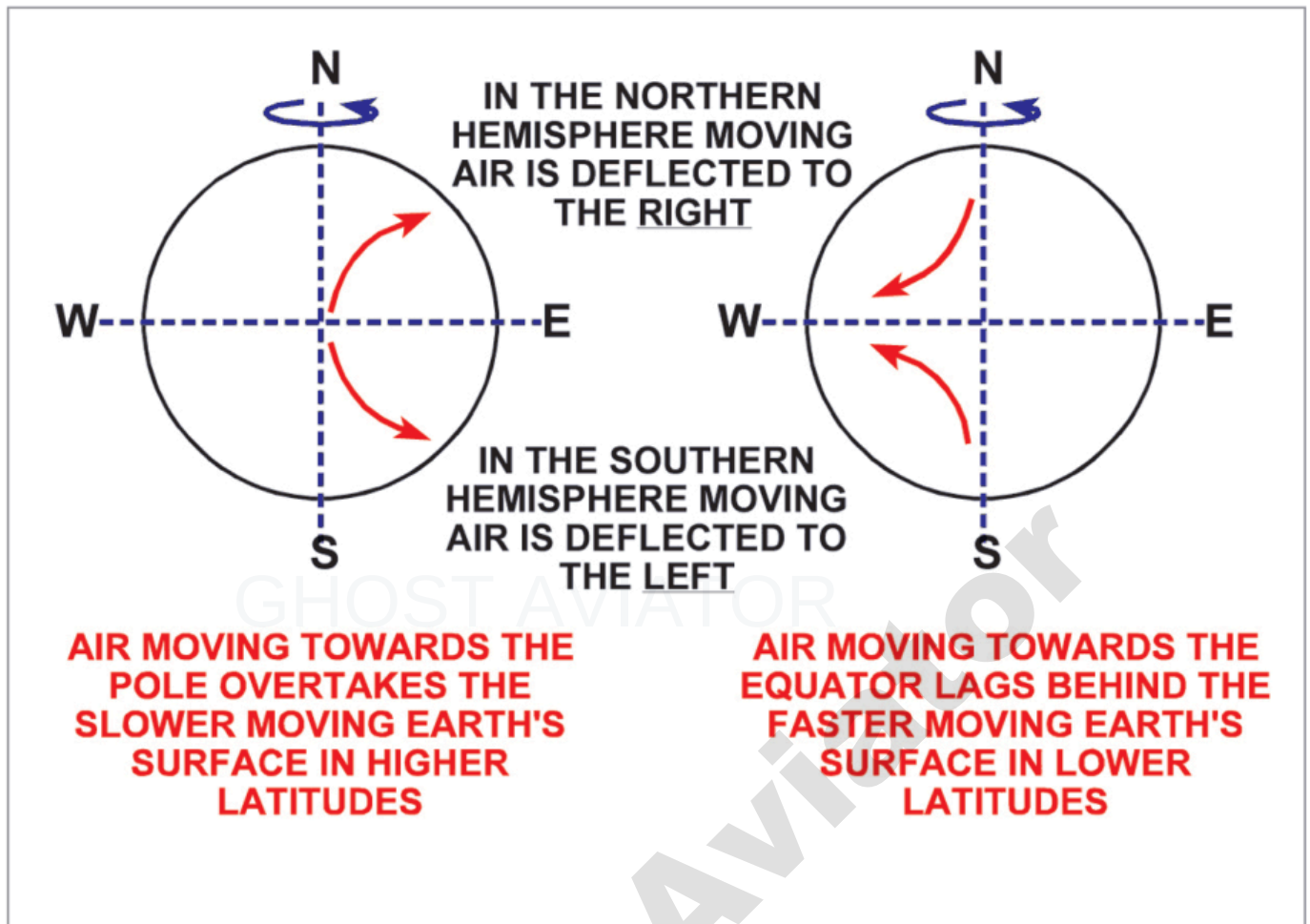
In the N hemisphere: If an observer stands with his back to the wind — Low pressure is to his **LEFT** and High pressure is to his **RIGHT**. (Converse in S hemisphere.)

- N hemisphere: wind blows **anti-clockwise** around a cyclone (Low) and **clockwise** around an anti-cyclone (High)
- S hemisphere: opposite sense

💡 **Mnemonic (N hemisphere):** "Back to wind — Low on Left, High on Right" = **BLL-HHR**. "N hemi Low = Anti-Clockwise = L for L"

4. Forces Acting on Wind — Coriolis Force

The **pressure gradient force** acts across isobars, from higher to lower pressure. In geostrophic balance, Coriolis balances this force and the wind flows along straight isobars. Due to Earth's rotation (W→E), wind is constantly deflected to its right (N hemisphere) until it attains uniform speed along isobars.



Coriolis deflection

Coriolis Force (f)

$$\text{Coriolis Force (f)} = 2 \Omega \rho V \sin \phi$$

Ω = angular velocity of Earth (unaffected by frictional forces)

ρ = density (unit volume of air, magnitude = $2\rho V \sin \phi$)

V = wind speed

ϕ = latitude

At poles: $\phi = 90^\circ$, $\sin \phi = 1 \rightarrow$ Coriolis force MAXIMUM

At equator: $\phi = 0^\circ$, $\sin \phi = 0 \rightarrow$ Coriolis force ZERO (minimum)

Coriolis force is directly proportional to wind speed and air density. Acts **perpendicular** to the wind direction.

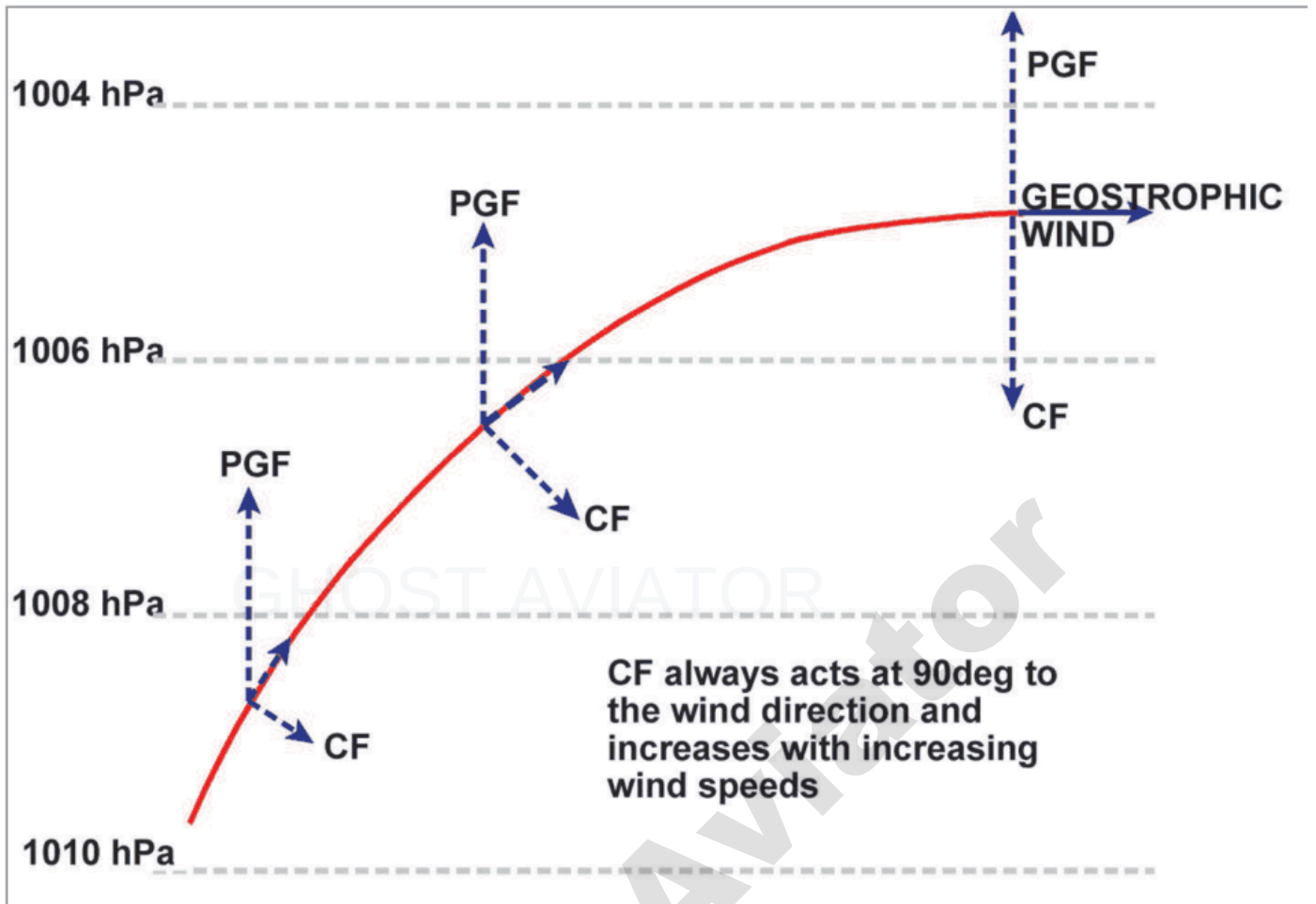
⚠ Key Properties of Coriolis Force:

- Acts perpendicular to the wind direction — does NO work on air
- Zero at equator — geostrophic formula breaks down
- Maximum at poles
- Deflects to the RIGHT in N hemisphere, LEFT in S hemisphere
- Also called the **Geostrophic Force** — it is an apparent force

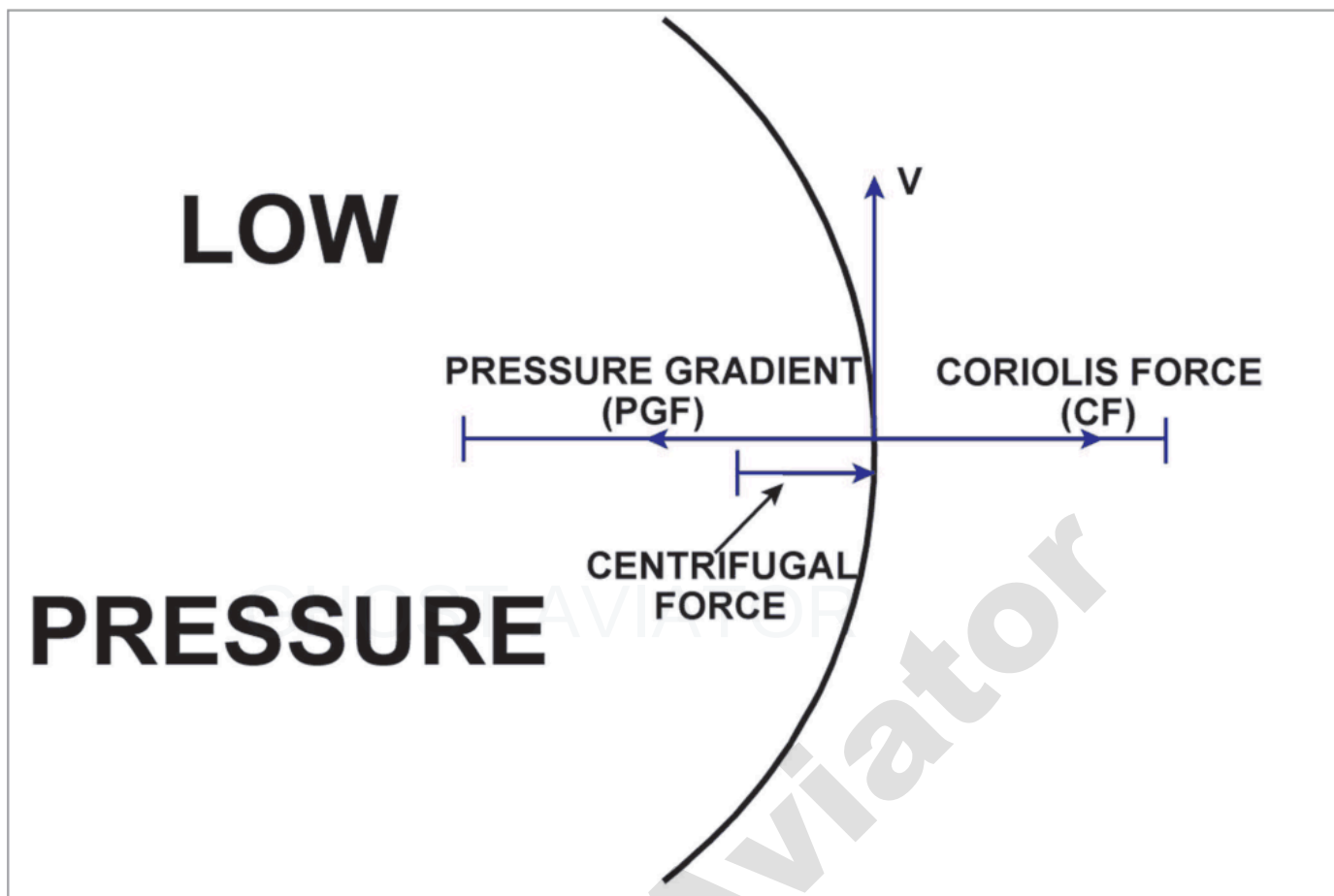
5. Types of Calculated/Balanced Winds

flowchart TD

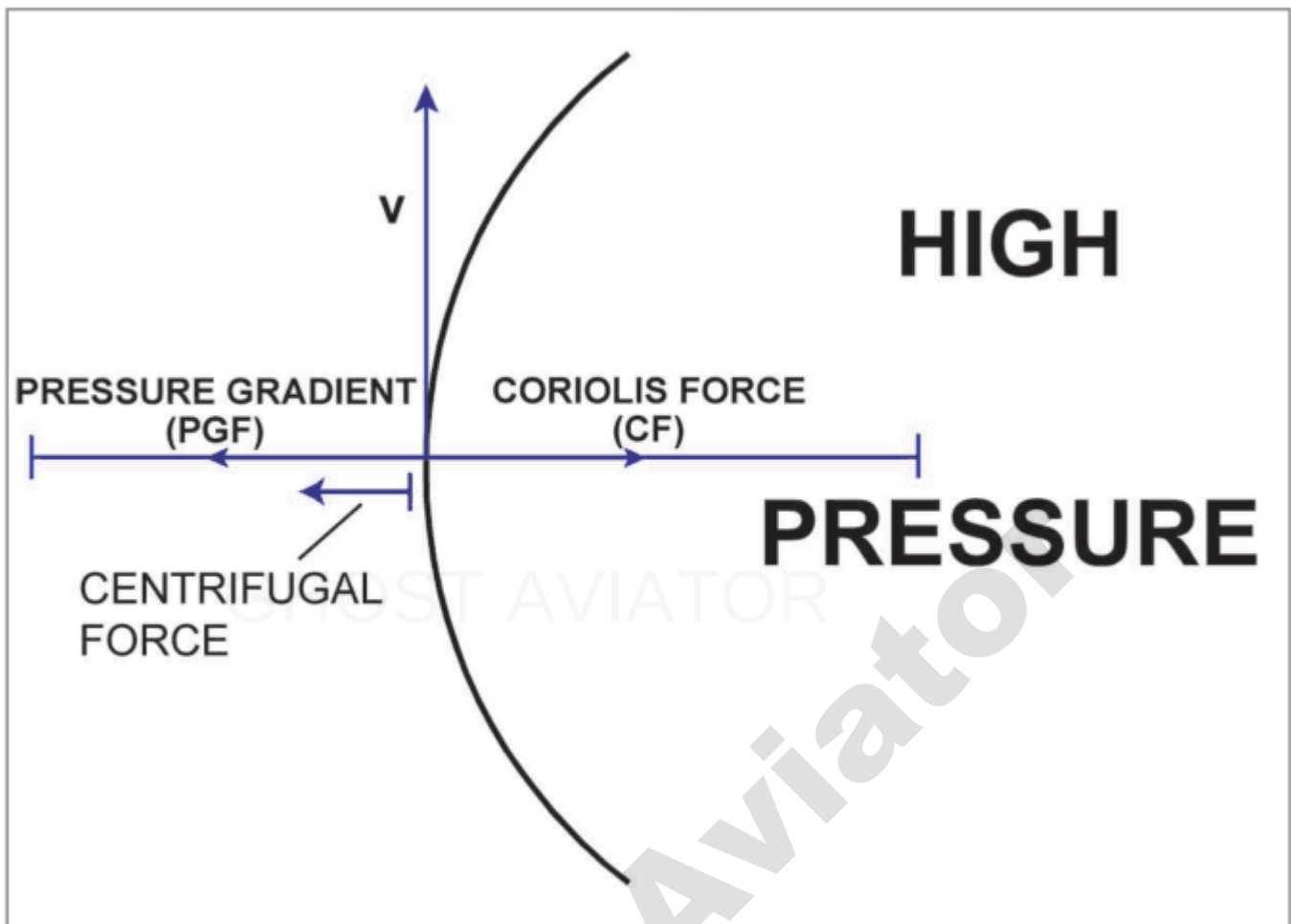
```
A["FORCES ON WIND"] --> B["Pressure Gradient (P)"]
A --> C["Coriolis (f)"]
A --> D["Centripetal (C)"]
A --> E["Friction (F)"]
A --> F["Isallobaric Force"]
B & C --> G["GEOSTROPHIC WIND\n(P = f)\nStraight isobars only"]
B & C & D --> H["GRADIENT WIND\n(P + f + C)\nCurved isobars"]
B & C & D & E --> I["ACTUAL SURFACE WIND\n(Friction layer)"]
C & D --> J["INERTIAL WIND\n(f + Centrifugal)\nVi = fR"]
```



Geostrophic wind



Gradient wind around a low



Gradient wind around a high

Geostrophic Wind (V_g)

The friction-less wind which blows **parallel to straight isobars** due to balance between Pressure Gradient Force and Coriolis force. It is a *calculated* wind.

$$P / \rho = 2 \Omega V \sin \phi$$

$$V_g = P / (2 \Omega \rho \sin \phi)$$

Where P/ρ = pressure gradient per unit mass

Closer isobars → stronger wind (inversely proportional to spacing)

⚠ Limitations of Geostrophic Rule:

- Valid only when PGF and Coriolis are in balance and isobars are straight & parallel
- The geostrophic approximation fails near the **Equator**, where Coriolis is weak. It also requires negligible friction, nearly steady conditions and straight, parallel isobars; it does not automatically fail at the poles.
- Winds like gusts, squalls, local winds, and sea breezes do NOT follow this rule
- Geostrophic wind differs in direction and speed from actual wind (especially middle latitudes)

Cyclostrophic Wind

Wind blowing along **curved isobars** where Coriolis is negligible compared to Pressure Gradient. Centripetal force acts. Balance: **P = Centripetal**

$$\rho V^2 / r = P \quad \therefore V = (Pr/\rho)^{1/2}$$

A useful approximation for some tightly curved flows, including tornadoes, where Coriolis is small relative to the pressure-gradient and curvature terms. The balance does not require anticyclonic rotation.

Cyclostrophic Wind = markedly curved wind that blows due to balance between **Pressure Gradient** and **Cyclostrophic force**. Frictional force is disregarded.

Gradient Wind

Blows parallel to curved isobars under balance of Pressure Gradient (P), Coriolis (f), and Centripetal (C) forces. Frictional force disregarded. Middle latitudes: closer approximation to actual wind than geostrophic.

System	Balance	Result
Cyclone (Low)	$P = f + C$, with C denoting centrifugal force	Sub-geostrophic ($V < V_g$)
Anticyclone (High)	$f = P + C$, with C denoting centrifugal force	Super-geostrophic ($V > V_g$)

Isallobaric Wind

When pressure changes rapidly, geostrophic and gradient rules do not apply. An additional force called **Isallobaric Force** comes into play, directed from higher isallobar to lower isallobar, deflecting wind towards falling pressure. The resulting wind is the **Isallobaric Wind**.

Inertial Wind

Frictionless flow under balance between **Centrifugal Force** and **Coriolis Force** only. No Pressure Gradient Force.

$$V_i = f \cdot R$$

f = Coriolis Force, R = radius of curvature (1/radius of path)

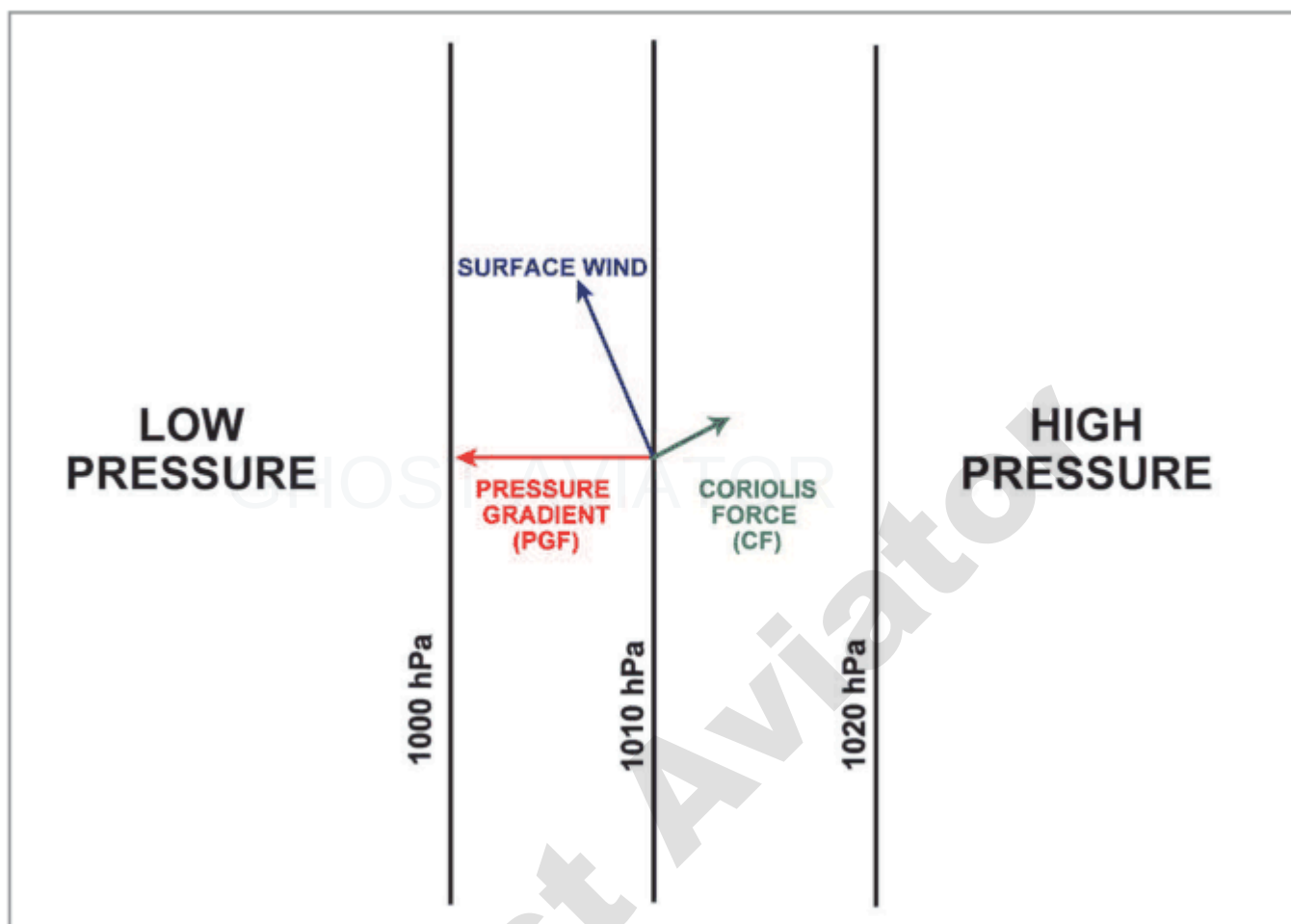
The constant Inertial wind speed is V_i .

The inertial flow is Anticyclonic in BOTH hemispheres.

💡 Quick Summary of Wind Types:

Geostrophic = $P \leftrightarrow f$ (straight isobars) | Cyclostrophic = $P \leftrightarrow \text{Centripetal}$ (near equator, curved) | Gradient = $P \leftrightarrow f \leftrightarrow C$ (curved, mid-lat) | Isallobaric = rapid pressure change | Inertial = $f \leftrightarrow \text{Centrifugal}$ (no PGF)

6. Effect of Surface Friction & Turbulence



Surface wind crosses the isobars

LOW

1002 hPa

1004 hPa

1006 hPa

220° / 15 kt

250° / 30 kt

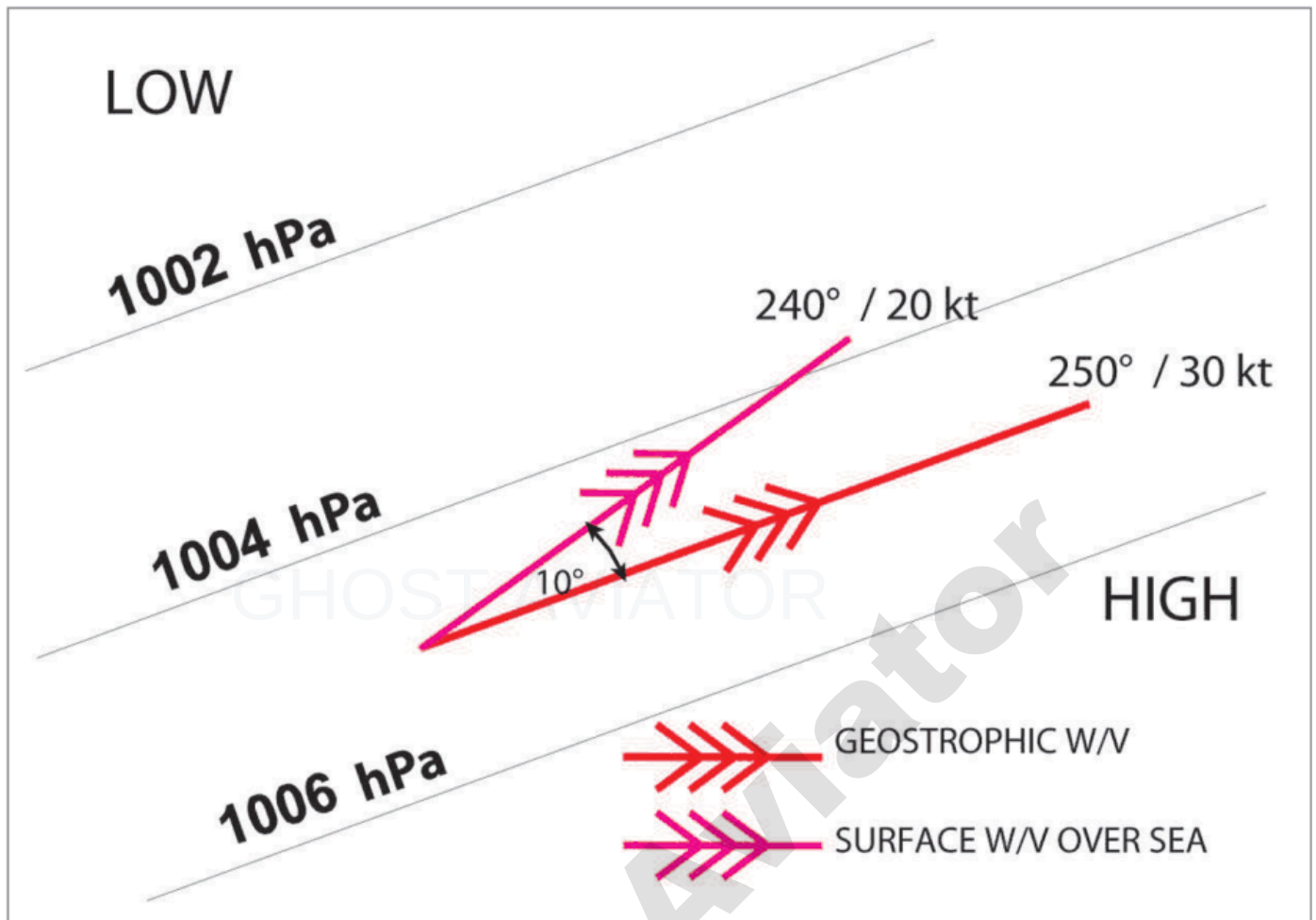
30°

HIGH

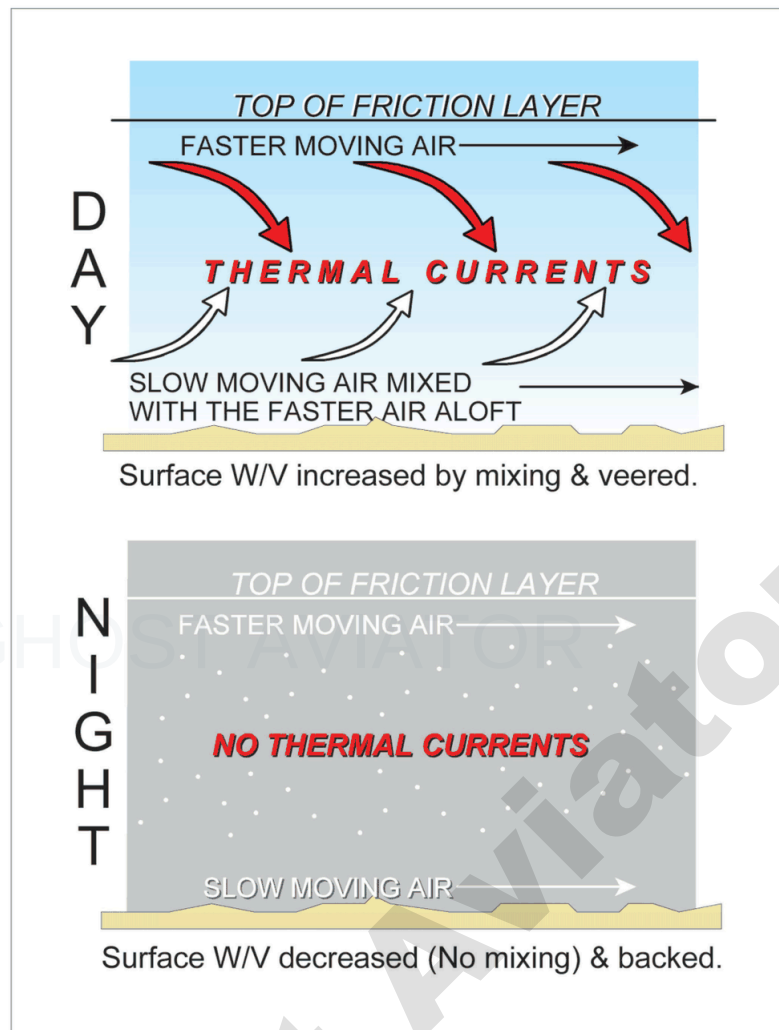
GEOSTROPHIC W/V

SURFACE W/V OVER LAND

Friction over land



Friction over sea



Surface wind by day and night

Friction Layer

- The rough earth causes friction, affecting the atmosphere up to about **1 km**
- This layer is called the **Friction Layer**; thickness is variable
- Within friction layer: wind slows down → Coriolis reduces → insufficient to balance PGF → wind is **deflected towards low pressure** → flow becomes **cross isobaric**

Surface	Inclination to Isobars	Speed (of V_g)
Over Sea	~ 15°	~ 2/3 V_g
Over Land	~ 30°	1/3 to 1/2 V_g

Turbulence and Gustiness

- Wind is seldom steady; peak fluctuations = **Gusts**, lowest = **Lulls**
- Width of fluctuations = **degree of gustiness**
- Air flow with such fluctuations = **turbulent**

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Types of Turbulence

Type	Cause	Characteristics
Frictional	When stream speed exceeds certain limit → flow unstable → eddies form	Both vertical and horizontal velocities; more over rough terrain/buildings/trees
Thermal	Convection currents due to surface heating; passage of cool air over warmer land/sea	Eddies of large dimensions; stronger gusts; extends to considerable heights when lapse rate is favourable

Factors Affecting Turbulence & Friction Layer

- Flow over buildings, trees, rugged country → vertical and horizontal eddies
- Develop more easily when lapse rate is steep
- Less on cool surfaces and stable atmosphere
- Over land: more by day (steep lapse rate), least on clear night (inversion)

Diurnal Variation of Surface Wind

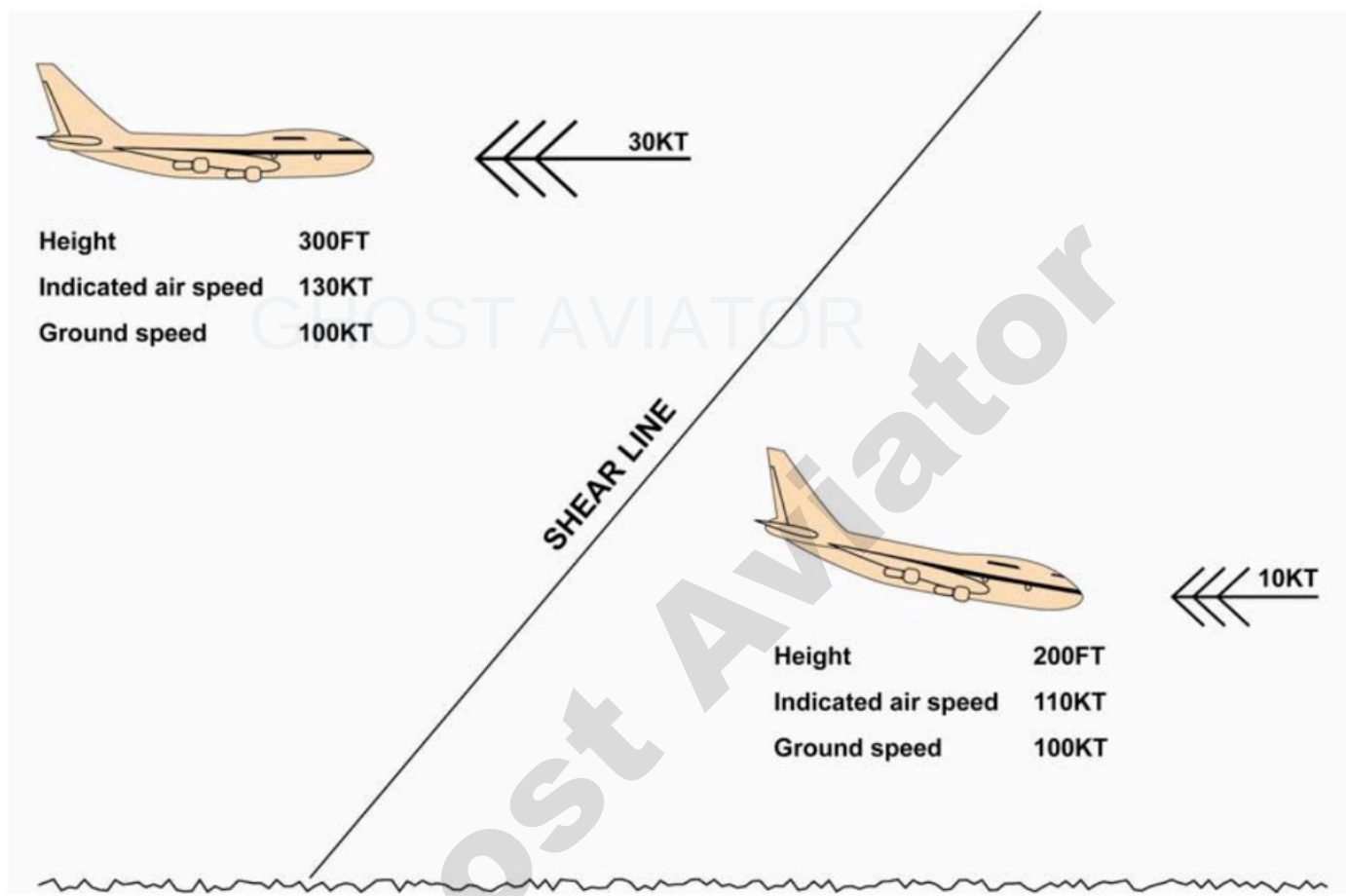
Time	Surface Wind	Upper Level Winds	Aviation Implication
Daytime	Strong, gusty; convection stretches friction layer upward; slackens frictional effect	Backs (due to friction aloft)	Gusty conditions, thermal turbulence
Night	Thermals die down; friction layer shrinks to surface; wind weak and backs ; friction prohibits upper winds from penetrating to surface	Becomes strong above friction layer	Wind shear ~500m — serious aviation hazard

⚠ **Night Wind Shear Hazard:** The surface wind is, therefore, weak and backs. There may be marked **wind shear around 500 m**, with strong winds above and weak winds below, which is serious as an aviation hazard.

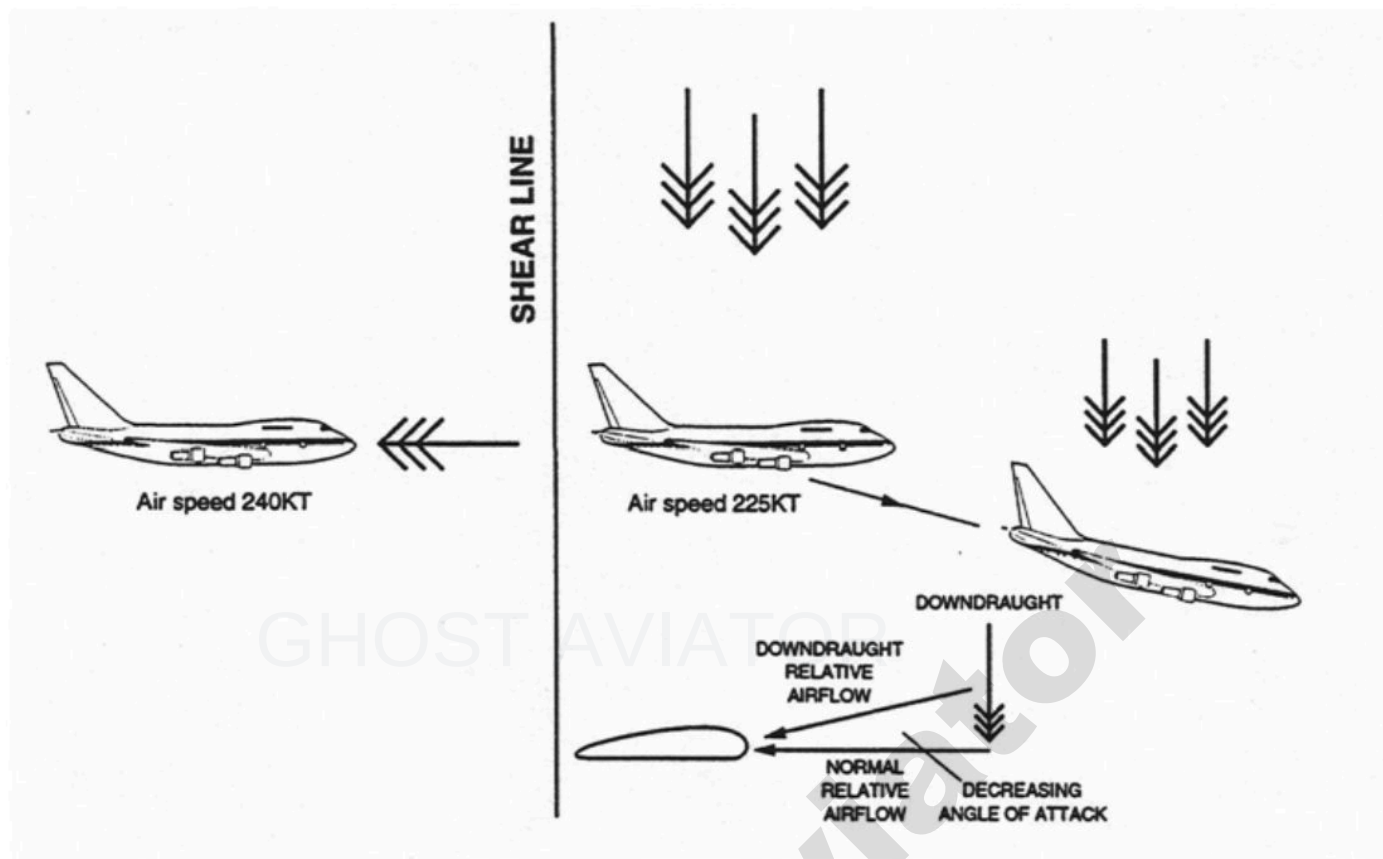
Diurnal variation over sea: Very little (about **1°C**); also over land under continuously overcast skies. Surface winds nearly the same 24 hr. Diurnal variation is most apparent in **fine weather, clear night and sunny days**.

7. Wind Shear (WS)

Definition: The variation in wind vector along the path of an aircraft, which can displace the aircraft from its intended path.



Windshear on the approach: loss of headwind



Downdraught and angle of attack

Type of WS	Definition
Low Level WS	WS along final approach, runway, take-off path, and initial climb out flight path
Vertical WS	The change in horizontal wind vector with height
Horizontal WS	The change in horizontal wind vector with distance
Up-Downdraughts	Change in vertical component of wind vector with distance

Causes of Wind Shear

1. Thunderstorm (TS)

(a) Gust Front (GF): The cold downdraught from TS spreads all around and creates GF as it meets the warm air near the ground. GF may extend as far as **30 km** in the direction of storm movement and extend to about **6000 ft** from ground. Great turbulence and WS are produced in the area, due to opposing winds and eddies.

(b) Microburst: Highly concentrated downdraught from TS, about **4 km** across, lasting for **1-5 minutes**. Most hazardous and powerful. Winds can be **90 kt** and their directions may also be opposite at the surface.

Microburst Type	Origin	Description
Wet Microburst	Heavy downpour under TS	Due to evaporation and cooling of cold downdraught
Dry Microburst	High based CB or Anvil (CI) in region of Virga	Virga = rain shaft evaporating before reaching ground

2. Low Level Inversion

Develops in clear nights; may extend to about **1 km**. In friction layer, winds are weak and winds aloft are strong → WS across inversion.

3. Gusty Surface Winds

Lead to strong gusts and lulls → WS.

4. Solar Heating

Intense solar heating causes WS and turbulence due to up and downdraughts.

5. Topography

Strong winds blowing across natural and man-made obstacles (mountain ranges, high rise buildings, flow along valleys, etc.) all lead to WS.

6. Fronts

Abrupt change of temperature and wind at a front. With passage of a front, strong WS may result; cross, head or tail wind. Very strong winds may also be encountered ahead of a Cold Front.

7. Jetstream

Strong vertical and horizontal WS are associated with jet streams in upper air.

Effects of WS on Aircraft

Sudden shear encountered	Initial effect
Decreasing headwind or increasing tailwind	Airspeed and performance decrease.
Increasing headwind or decreasing tailwind	Airspeed and performance increase.

Actual flight-path response depends on the aircraft, vertical wind and crew response. Follow approved aircraft windshear procedures.

⚠ **Critical: Effects of WS on Approach** — These effects are critical during landing and take-offs.

Decreasing headwind and increasing tailwind both initially reduce airspeed; the opposite changes initially increase it.

flowchart TD

WS["WIND SHEAR HAZARD"] --> A["Thunderstorm"]

WS --> B["Low Level Inversion\n(Night)"]

WS --> C["Fronts"]

WS --> D["Topography"]

WS --> E["Jetstream"]

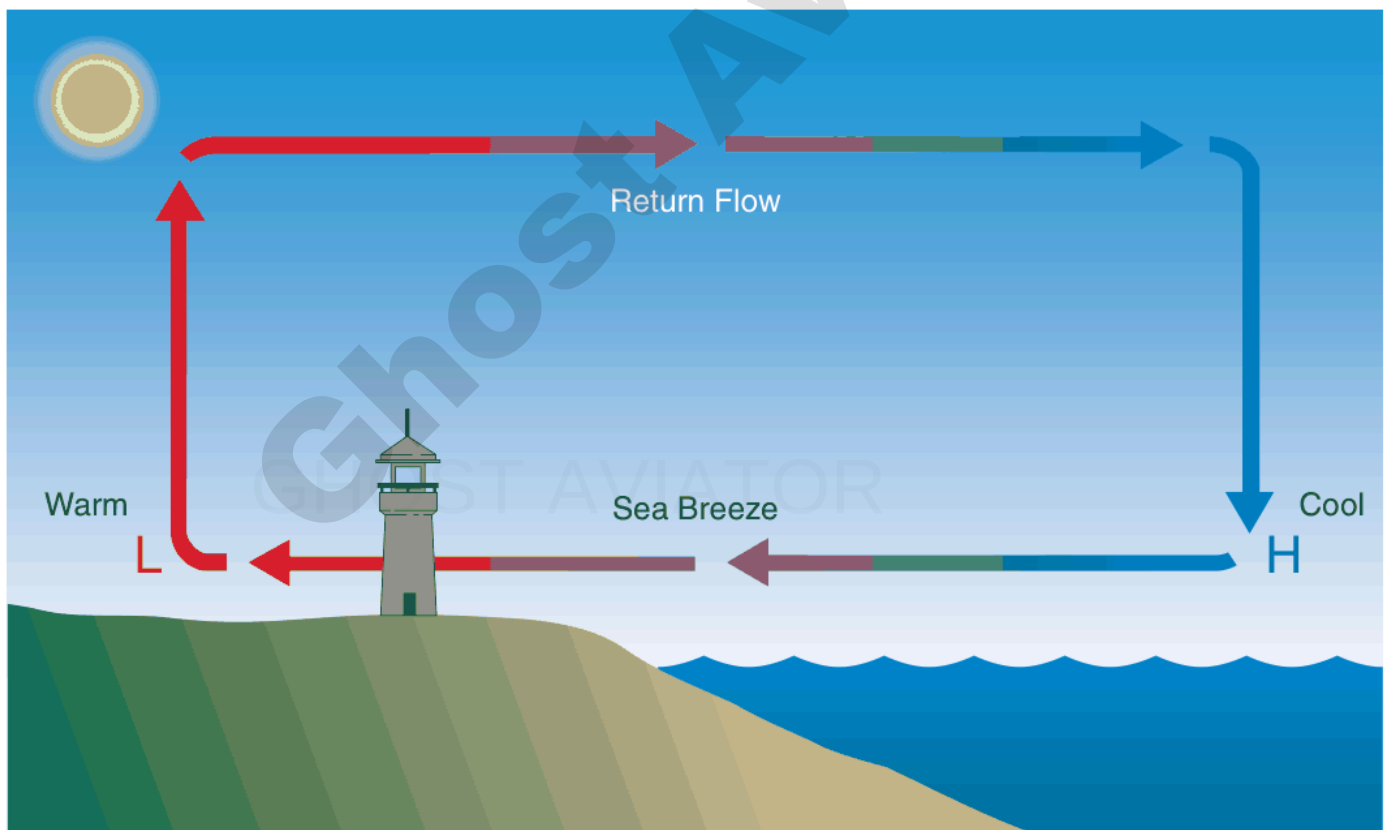
A --> A1["Gust Front\n(30km, 6000ft)"]

A --> A2["Microburst\n(4km, 1-5min, 90kt)"]

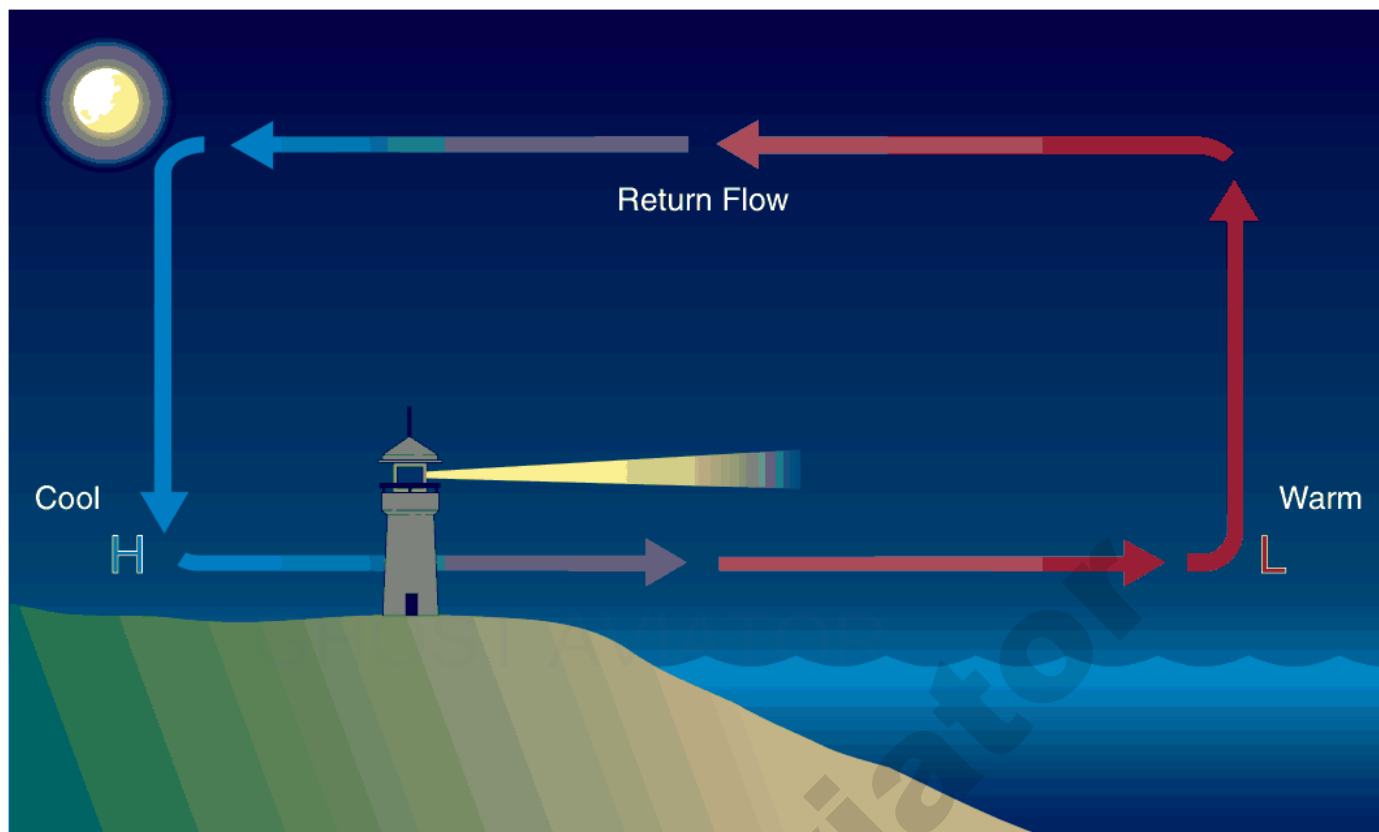
A2 --> A2a["Dry\n(Virga/Anvil)"]

A2 --> A2b["Wet\n(Heavy Rain)"]

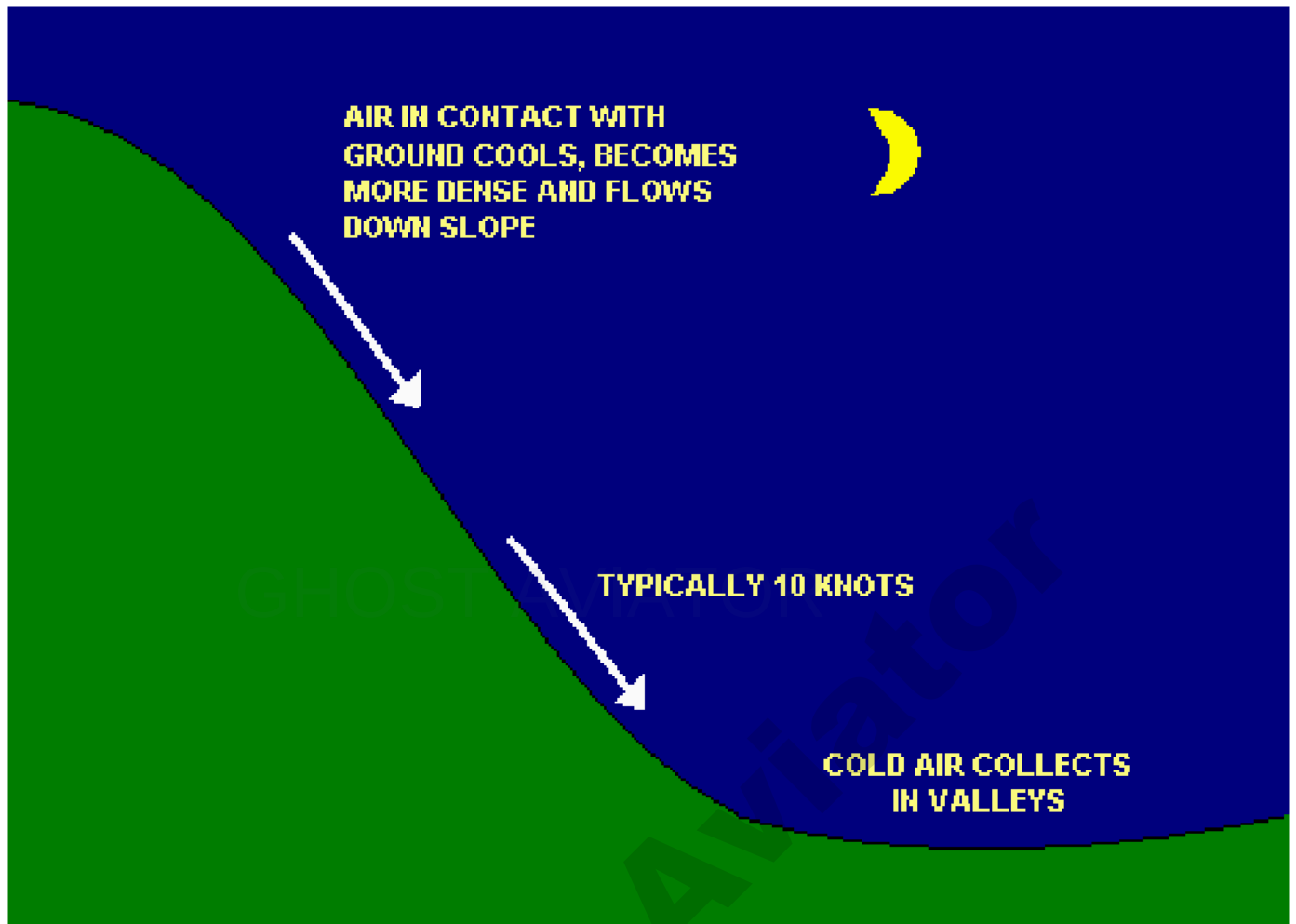
8. Local Winds Due to Topography



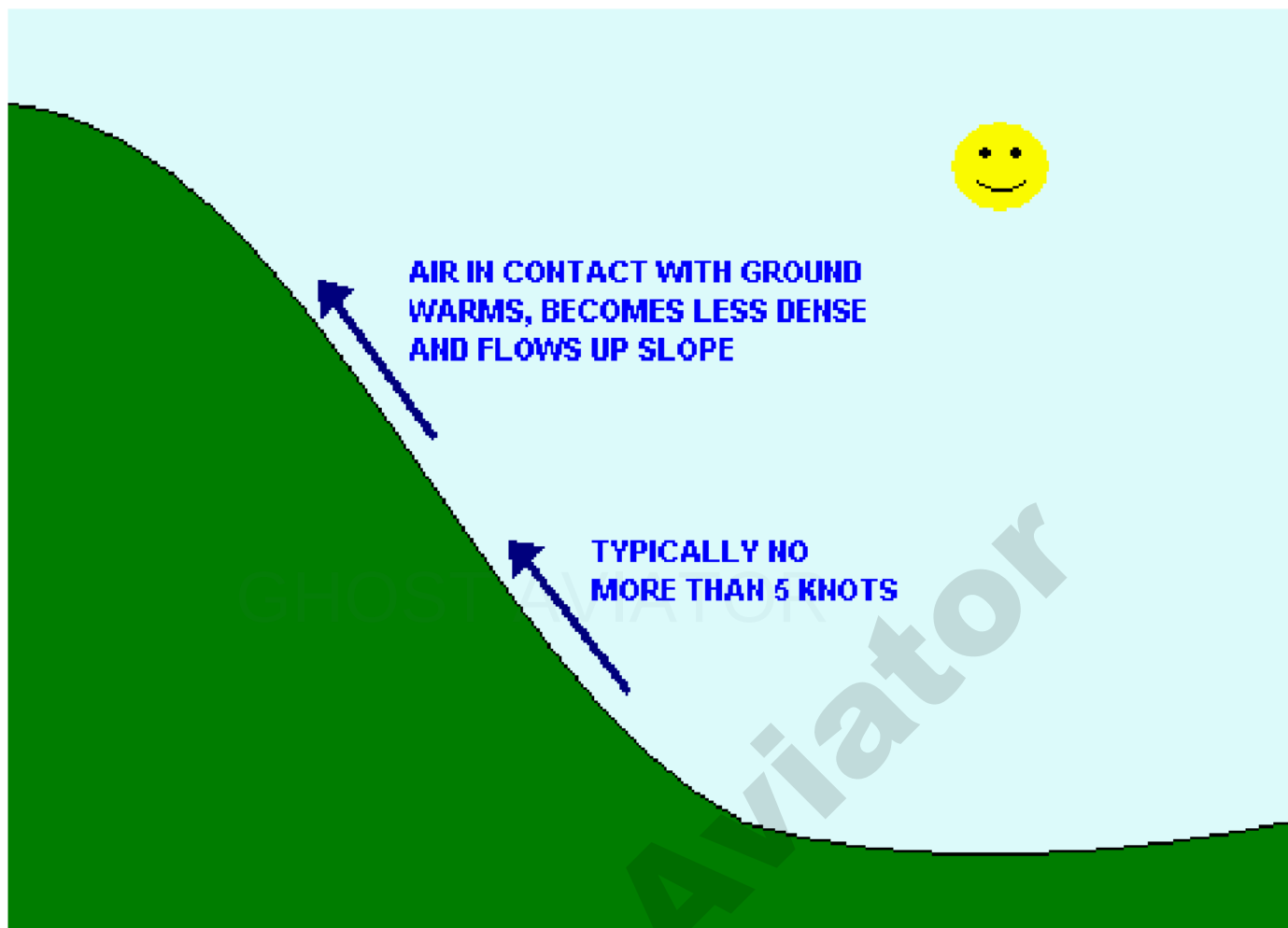
Sea breeze by day



Land breeze by night



Katabatic wind



Anabatic wind

Anabatic and Katabatic Winds

Feature	Anabatic (Valley) Wind	Katabatic Wind
Time	Daytime	Night (clear, quiet night)
Direction	Up-slope (mountain slope heated by sun)	Down-slope (mountain slope cools at night)
Character	Warm, lighter; ascends the slope; masked by irregular convection; intensified by sea breeze in funnel valley	Cold, down-slope wind; pools of cold on low-lying ground; causes local frost, mist and fog
Speed	Variable	No more than a few knots normally; Bora can exceed 100 kt
Aviation Hazard	Fog, TS in morning over NE India (when snow covered slopes)	Fog, frost; Bora (100+ kt) dangerous to shipping and low-flying aircraft

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⚠ **Bora:** An off-shore wind on northern shores of the Adriatic sea. It is a cold katabatic wind. Sets in suddenly and frequently reaches well over gale force with gusts of over **100 kt**. Extremely dangerous to shipping and low-flying aircraft. Similar winds occur on coast of Greenland and Black Sea shores. Over NE India — katabatic winds are common and cause fog and TS in the morning.

Fohn Wind

If air is forced over a mountain barrier, adiabatic cooling on windward side may lead to cloud and precipitation formation. Within cloud, rising air cools at SALR. Some condensed water falls as precipitation. Air descends on leeward side at the DALR (since cloud has disappeared). The local name in the Alps is the **Fohn**.

- In high mountains, Fohn wind may be **10°C or more** warmer than windward side
- The **Chinook** of the Rocky Mountains is an example
- Conditions for Fohn: (a) substantial mountain range, (b) wind blows within **30°** of range, (c) high moisture content

💡 **Distinction — Fohn vs. Katabatic:** Fohn is WARM and DRY on leeward. Katabatic is COLD. Both are down-slope winds off high ground.

Ravine Winds

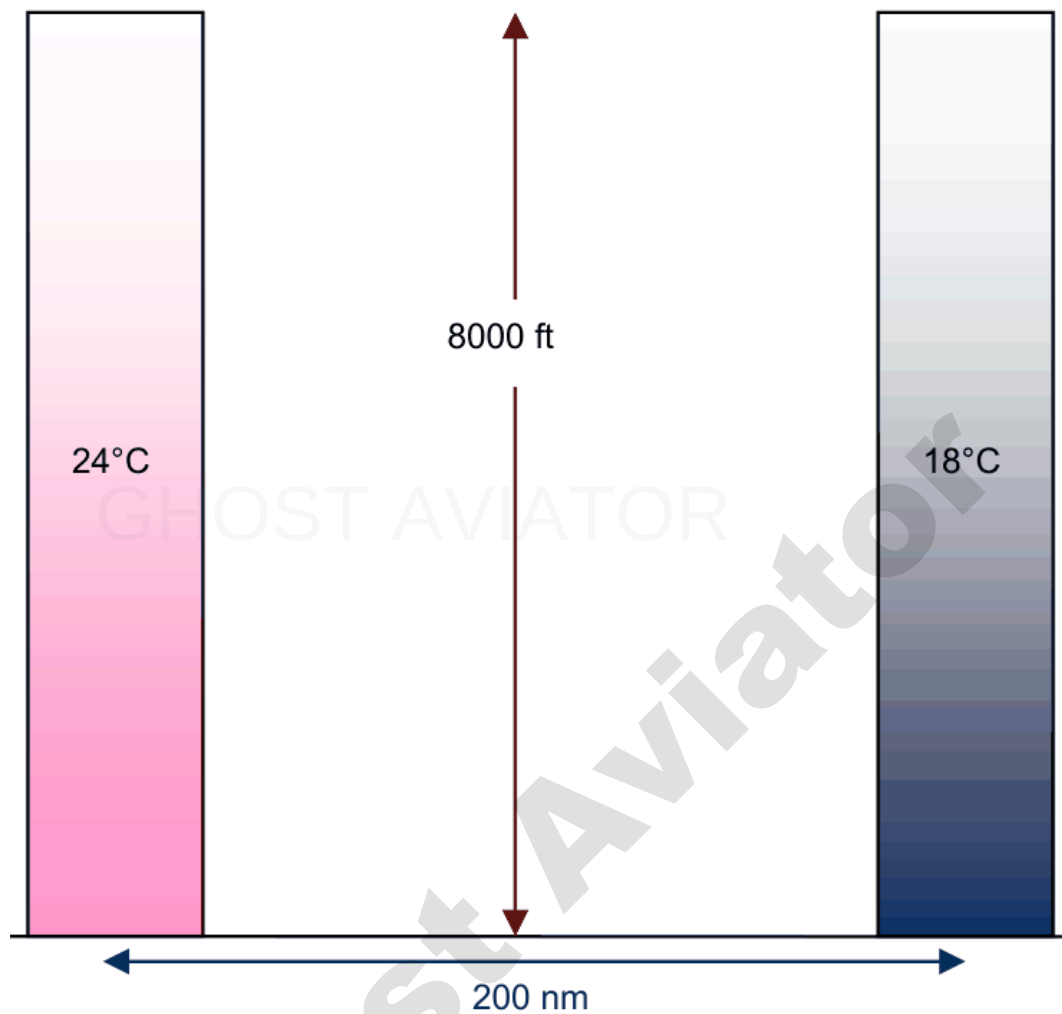
Occur in and near narrow valleys when there is a pressure difference between two sides of the hills. Air is impelled through the valley by the pressure gradient. Such winds may be very strong in the ravine and also after leaving its mouth.

Land Breeze and Sea Breeze

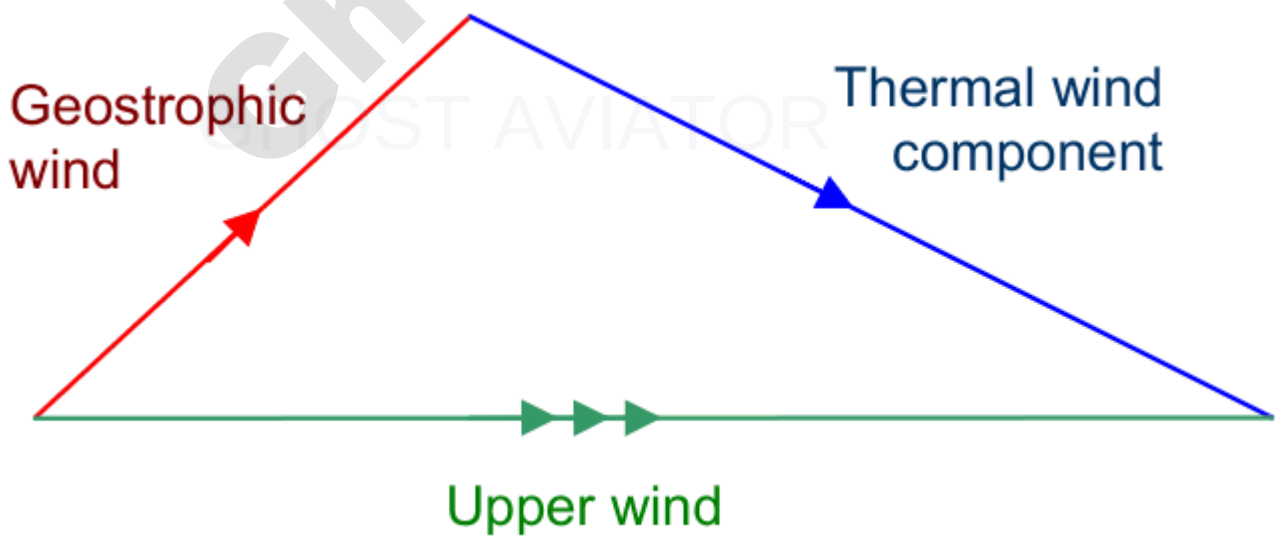
Feature	Sea Breeze	Land Breeze
Time	Day-time	Night
Direction	Sea → Land	Land → Sea
Cause	Land warmer → air rises → pressure aloft greater → upper air drifts to sea → sea level pressure over land drops → sea breeze	Radiative cooling of land → thermals die → friction layer shrinks → land breeze sets in
Extent	Generally 15-25 km on either side of coast; in Pune ~ 170 km from Mumbai	Shallower than sea breeze; few hundred feet only
Onset	Few hours after sunrise; delayed if off-shore wind	After sunset
Alignment	Initially perpendicular to coastline; then aligns with Coriolis (land on left in S hemisphere, right in N)	—
Other	In tropics and subtropics: routine and perpendicular to coast; may develop to 3000-5000 ft in tropics → line of small cumuliform clouds	Undetected by powered aircraft; useful to glider pilots

Sea Spray: Under favourable wind conditions, salt particles get sprayed from wave crests; water drops formed can reduce visibility considerably. In rare cases, a thin layer of salt may form on the wind screen of an aircraft flying at low level and render forward visibility to almost zero. Salt spray may also reduce visibility during monsoons and cyclones in coastal areas.

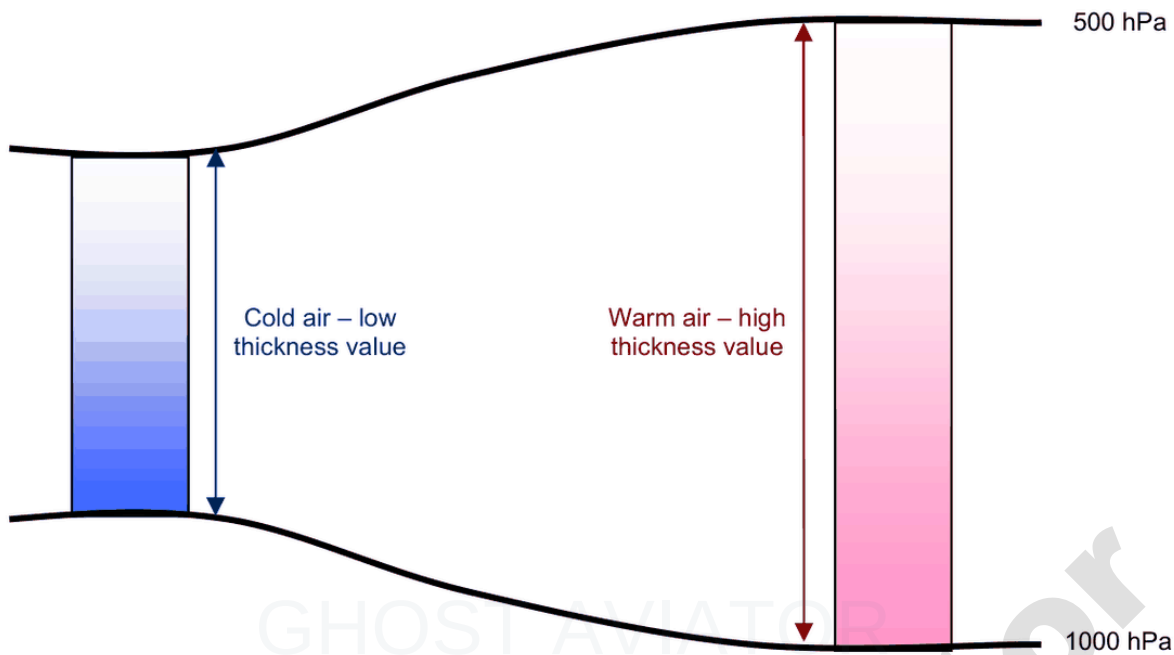
9. Thermal Wind & Contours



Thermal wind: a warm column and a cold column



The thermal wind component



Thickness: cold air gives low thickness, warm air high

Thermal Wind

Definition: The thermal wind in a layer is defined as that wind which must be added vectorially to the geostrophic wind at the lower level in order to obtain the geostrophic wind at the upper level. It is a fictitious wind.

$$\mathbf{V}_t = \mathbf{V}_1 - \mathbf{V}_0$$

$\mathbf{V}_t$ = thermal wind, $\mathbf{V}_1$ = upper level geostrophic wind, $\mathbf{V}_0$ = lower level geostrophic wind

Vector addition: Draw one vector; from head draw the other; join tail of first to head of second = sum.

Vector subtraction: direction of second vector is reversed.

Example: Calculation of Upper Level Wind

Lower Level Wind	Thermal Wind	Upper Level Wind
270/10kt	270/15kt	270/10kt + 270/15kt = 270/25kt
270/10kt	090/15kt	270/10kt + (-270/15kt) = 090/05kt

Join live classes for guided practice and doubt clearing.

- Thermal wind blows parallel to isotherms/thickness lines, keeping **low temperature to the left in N hemisphere**
- Speed is proportional to the temperature gradient
- If south is warm and north cold: temperature gradient acts S→N → thermal wind is **Westerly**
- If such temperature distribution continues, thermal wind will continue to be westerly from level to level → keeps increasing with height
- **Subtropical westerly Jet Stream** is an example of thermal wind

Wind and Contours

Lines joining equal heights on a constant pressure level are called **Contours**. Over warm atmosphere a contour will be at a higher height; over cold at a lower height. Contour lines depict centres of High and Low exactly as isobars do on surface maps. A contour line is horizontal — the pressure is the same at all points on the line. Contour of height say 5520 m = isobar in the horizontal surface at that height.

- Geostrophic wind blows along contours with **lower value on the left in N hemisphere**, right in S hemisphere
- Contour charts can determine cyclostrophic and gradient winds
- Limitations of geostrophic rule equally apply to contour charts

Variation of Wind with Height

- Temperatures in troposphere decrease from equator to poles → **thermal wind component throughout troposphere blows from Wly (W)**
- **In the upper troposphere the winds are, therefore, mainly Wly**
- Over India: easterlies prevail above **500 hPa** during monsoon months (**June, July, August, September**); strengthen with height, weaker over N India and stronger over S India; tropical easterly jetstream lies near **13N lat at about 15 km**
- Outside tropics: low level easterlies increase with height with little change in direction; on other hand easterlies weaken and become westerly
- Westerly thermal wind: northerly winds would back with height, southerly winds would veer
- In low stratosphere (winters): temperature lowest between **40° and 60° lat** → westerlies increase with height; equatorwards of temperature maximum → westerlies decrease above tropopause
- Summer hemisphere: temperatures highest in polar regions → easterly thermal wind in stratosphere

10. Vorticity

Vorticity is a measure of rotation or turning. Rotation can be cyclonic or anticyclonic. It plays an important role in formation and development of weather systems such as cyclones, depressions, anticyclones. Change in vorticity causes **divergence and convergence**.

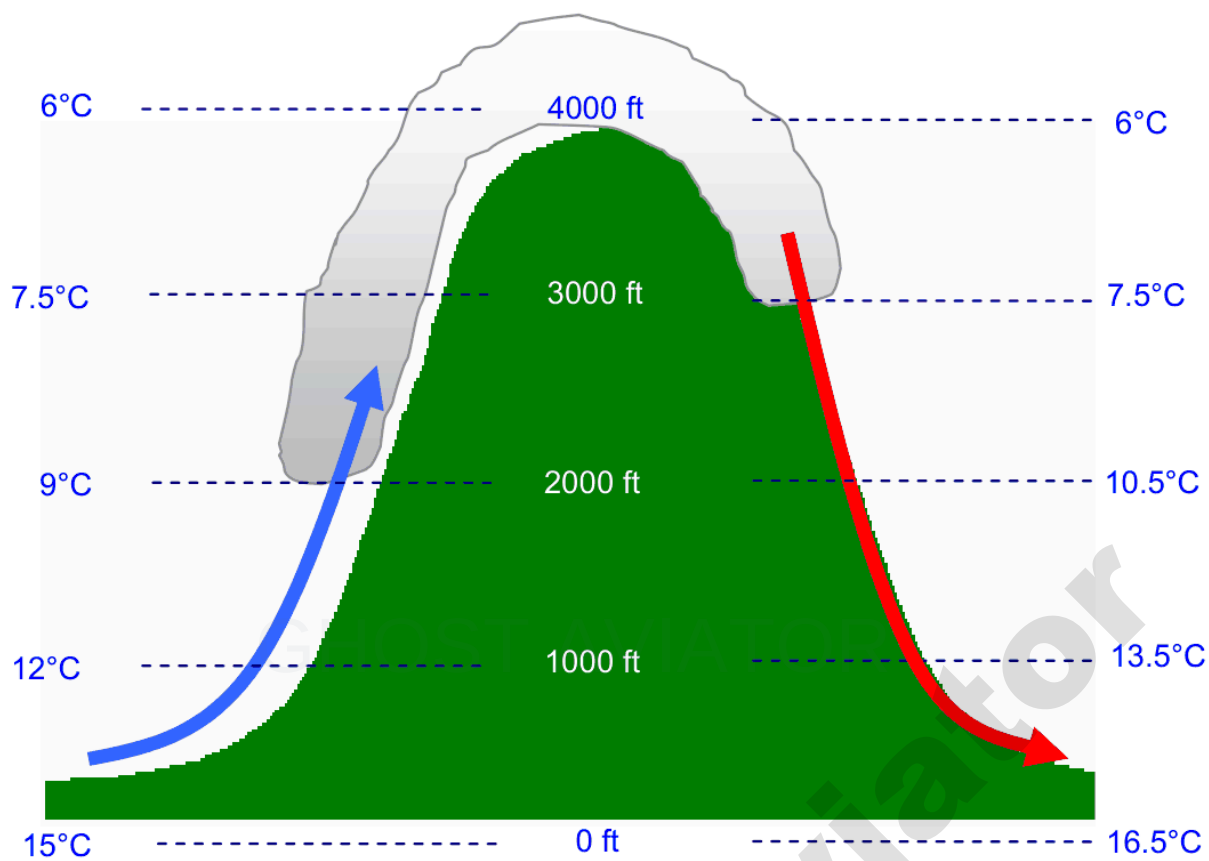
Causes of Vorticity

1. **Horizontal Wind Shear:** When a belt of strong winds lies alongside a belt of lighter winds, the faster flow rotates around the slower flow. May be cyclonic or anticyclonic depending on orientation.
2. **Curvature of the Flow:** Flow around a curve has cyclonic vorticity when air deflects to its left (in trough, N hemisphere) and anticyclonic when it deflects to the right (ridge).
3. **Rotation of the Earth:** Earth rotates from W to E (anti-clockwise = cyclonic for N hemisphere). Hence vorticity due to earth is cyclonic in both hemispheres.

Absolute Vorticity: Sum of all the above vorticities. Since vorticity due to earth is always cyclonic and it predominates, the **absolute vorticity is always cyclonic**.

11. Names of Winds of the World

Wind Name	Character	Location
Bora	Cold katabatic; originates in mountains of Yugoslavia and NE Italy	Coastal plains of the Adriatic sea
Burans (Russian Burans / Turkish Boran)	Strong NEly wind in Russia and Central Asia; often blows snow ('Purga')	Russia and Central Asia
Chinook	Warm dry Wly wind	Eastern side of Rocky Mountains
Doldrums	Calm winds near Equator; low atmospheric pressure; insignificant wind; cloudy and rainy; also called ITCZ	Between ~ 5°N and 5°S lat
Haboobs (Arabic: blowing furiously)	Any strong wind raising sand into a sand storm	Particularly in Sudan
Harmattan	Hot dusty NEly	Central Asia
Khamsin	Oppressive, hot, dry, often laden with sand; Sly wind	Egypt, April–June
Mistral	Cold katabatic — descends from snow-clad Alps down the Rhone River Valley	France and into Gulf of Lyons along the Mediterranean coast
Monsoon	Any markedly seasonal wind	Particularly E and SE Asia
Roaring Forties	Wly winds in both hemispheres between 35° and 60° lat; very stormy nature beyond 40° lat in S hemisphere. Called Roaring Forties, Furious Fifties, Crying Sixties	Mid-latitudes S hemisphere
Trades	Steady wind between 10° and 30° from NE in N hemisphere, SE in S hemisphere; 'wind that blows trade' by 18th century navigators	Subtropics both hemispheres



Föhn effect over a mountain

12. Beaufort Force Scale

BF Scale	Description	Speed at 10m (kt)
0	Calm	<1
1	Light air	1–3
2	Light breeze	4–6
3	Gentle breeze	7–10
4	Moderate breeze	11–16
5	Fresh breeze	17–21
6	Strong breeze	22–27
7	Near Gale	28–33
8	Gale	34–40
9	Strong Gale	41–47
10	Storm	48–55
11	Violent Storm	56–63
12	Hurricane	64 or more

💡 **Mnemonic for BF Scale:** "Calm Light Light Gentle Moderate Fresh Strong — Near Gale Gale Strong Storm Violent Hurricane" — Count from 0 to 12. **Gale starts at BF 8 = 34kt.** Hurricane = BF 12 = 64kt+.

Practice Q&A — Chapter 6: Winds

Q1. In S hemisphere if an observer faces wind, low will be to his

(a) Right (b) Left

✅ Answer: (b) Left — In S hemisphere, Buys Ballot's Law reversed. Face the wind → low is to your LEFT in S hemisphere.

❌ (a) Right: This applies to N hemisphere (back to wind → low on left; face wind → low on right in N hemisphere).

💡 Instructor's Note: In N hemisphere facing wind → Low on RIGHT. In S hemisphere → Low on LEFT. Just flip it!

Q2. In N hemisphere due to rotation of earth winds are deflected to

(a) Left (b) Right

✅ Answer: (b) Right — Coriolis effect deflects moving objects to the right in the N hemisphere.

❌ (a) Left: This is the S hemisphere effect.

💡 Instructor's Note: "N = Right, S = Left" — Never forget this. Coriolis = deflection due to Earth's rotation.

Q3. Local Winds follow Buys Ballot's Law

(a) False (b) True

✅ Answer: (a) False — Local winds such as sea breezes, land breezes, anabatic, katabatic winds do NOT follow Buys Ballot's Law or the geostrophic rule.

❌ (b) True: Local winds are driven by local temperature differences and topography, NOT by synoptic pressure gradient.

💡 Instructor's Note: Buys Ballot's Law applies to geostrophic/gradient winds on synoptic scale isobars. Local winds are exceptions.

Q4. Coriolis force acts perpendicular to the of wind direction in N hemisphere

(a) Left (b) Right

✓ Answer: (b) Right — Coriolis force acts perpendicular to the wind, to the right in N hemisphere.

✗ (a) Left: Left deflection is S hemisphere.

💡 Instructor's Note: Coriolis acts 90° to the right of motion in N hemisphere — this is why geostrophic wind ends up parallel to isobars.

Q5. Geostrophic wind is due to the balance between the forces

(a) Coriolis and Frictional

(b) Pressure gradient and Cyclostrophic

(c) Pressure gradient and Coriolis

✓ Answer: (c) Pressure gradient and Coriolis — $P = f$ is the geostrophic balance.

✗ (a) Coriolis + Frictional: When friction included → actual surface wind, not geostrophic.

✗ (b) PGF + Cyclostrophic: Cyclostrophic balance is $P = \text{Centripetal}$ (curved isobars near equator).

💡 Mnemonic: "Geo = PGF + Coriolis" — Gradient = PGF + Coriolis + Centripetal.

Q6. Coriolis force is strongest at

(a) Mid latitudes (b) Poles (c) Equator

✓ Answer: (b) Poles — $f = 2\Omega pV \sin \varphi$; at poles $\varphi = 90^\circ$, $\sin \varphi = 1$ (maximum).

✗ (a) Mid latitudes: $\sin 45^\circ = 0.707$, intermediate value.

✗ (c) Equator: $\sin 0^\circ = 0$, so Coriolis = zero at equator.

💡 "Poles = max Coriolis, Equator = zero Coriolis" — key formula: $\sin 90^\circ = 1$, $\sin 0^\circ = 0$.

Q7. Geostrophic rule breaks down at

(a) Mid latitudes (b) Poles (c) Equator

✓ Answer: (c) Equator — At equator $\sin \varphi = 0$, so Coriolis = 0, V_g formula gives infinity/undefined.

- ✗ (a) Mid latitudes: Geostrophic approximation works reasonably well.
- ✗ (b) Poles: Geostrophic rule gives a good approximation beyond 30°; also breaks at poles due to pressure changes with time but rule is NOT primarily said to break down here.

💡 The geostrophic formula has $\sin \phi$ in denominator — as $\phi \rightarrow 0$ (equator), $V_g \rightarrow \infty$, which is physically impossible, so rule breaks down.

Q8. Fohn winds are on the Leeward side of a mountain.

(a) Dry (b) Cold & Humid

✓ Answer: (a) Dry — Fohn wind is warm AND dry on the leeward side.

✗ (b) Cold & Humid: This is the windward side characteristic. The Katabatic wind is cold.

💡 "Fohn = Warm Dry Leeward" — moisture precipitates on windward, latent heat released, DALR on descent = warmer and drier than windward.

Q9. The wind sliding down a hill during night is called wind.

(a) Fohn (b) Anabatic (c) Katabatic

✓ Answer: (c) Katabatic — Night cooling → slope cools → air sinks → cold down-slope katabatic wind.

✗ (a) Fohn: Fohn is on leeward side of a mountain range, warm and dry — not driven by nocturnal cooling alone.

✗ (b) Anabatic: Anabatic is daytime up-slope wind.

💡 "Ana = Up = Afternoon; Kata = Down = Dark night." Both refer to mountain slope winds.

Q10. With the onset of sea breeze there is a in temperature and in RH.

(a) Fall/Rise (b) Rise/Fall (c) Fall/Fall

✓ Answer: (a) Fall/Rise — Sea breeze brings cooler, moister maritime air inland → temperature falls, RH rises.

✗ (b) Rise/Fall: Temperature doesn't rise with sea breeze onset.

✗ (c) Fall/Fall: RH rises as maritime air is more humid.

💡 Sea breeze = cool moist air from sea → cooling + moistening of coastal areas.

Q11. Sea breeze sets in by and dies off at

(a) Night/Day (b) Day/Night (c) Both Day and Night

✅ Answer: (b) Day/Night — Sea breeze begins during daytime (few hours after sunrise) and dies off after sunset.

❌ (a) Night/Day: That describes the Land Breeze pattern.

❌ (c) Both Day and Night: Sea breeze is specifically a daytime phenomenon.

💡 "Sea Breeze = Day; Land Breeze = Night" — simple and direct.

Q12. If an aircraft in N-hemisphere flies from H to L it will experience

(a) Starboard drift (b) Port drift

✅ Answer: (a) Starboard drift — Buys Ballot: with your back to the wind in the N hemisphere, low pressure is on your LEFT. Flying towards the low, the wind comes from your left and pushes you right → starboard drift.

❌ (b) Port drift: That is flying towards HIGH pressure in the N hemisphere (or towards low in the S hemisphere).

💡 N hemisphere: towards LOW = starboard drift; towards HIGH = port drift. S hemisphere: reverse.

Q13. In N-Hemisphere if you experience Port drift, altimeter will read

(a) Under (b) Over

✅ Answer: (a) Under — Port drift in the N hemisphere means you are flying towards HIGH pressure. Holding the same altimeter reading you follow a pressure level, and pressure levels are higher over a high, so you climb: true altitude is more than indicated → the altimeter under-reads.

💡 "High to Low, beware below": towards LOW (starboard drift in NH) the altimeter over-reads; towards HIGH (port drift in NH) it under-reads.

Q14. Lines of constant wind speed drawn on weather charts are called

(a) Isobars (b) Isotachs (c) Isogons

✓ Answer: (b) Isotachs — Lines of equal wind speed = Isotachs.

✗ (a) Isobars: Lines of equal pressure.

✗ (c) Isogons: Lines of equal wind direction.

💡 "Tach = speed (tachometer). Iso-tach = same speed. Iso-gon = same angle/direction."

Q15. Squall are distinguished from gusts by:

(a) Shorter duration (b) Longer duration (c) Lower wind speed

✓ Answer: (b) Longer duration — The main difference between squalls and gusts is DURATION. Squall lasts ≥ 1 minute; gust lasts only a few seconds.

✗ (a) Shorter duration: It is the gust that has shorter duration.

✗ (c) Lower wind speed: Squalls actually have higher wind speeds (must reach 44 km/h) and are more dangerous.

💡 "Squall = longer, stronger, sudden; Gust = short and sharp."

Q16. The thermal wind is:

(a) The wind that blows because of thermals

(b) The warm wind that blows down the hill on the leeward side

(c) The wind which must be added vectorially to the lower level geostrophic wind to obtain the upper level geostrophic wind

✓ Answer: (c) — Thermal wind = vector difference of upper and lower level geostrophic winds. It is a fictitious wind blowing parallel to thickness lines.

✗ (a) Blows because of thermals: That's convective updraft — not thermal wind.

✗ (b) Warm wind on leeward: That is the Fohn wind.

💡 "Thermal wind = $V_t = V_1 - V_0$ = vector subtraction. Blows parallel to thickness lines with low temp to LEFT in N hemisphere."

Q17. On a weather map if isobars are closely packed, the surface winds are likely to be

(a) Light and parallel to isobars

(b) Strong and parallel to isobars

(c) Strong and blowing across the isobars

✓ Answer: (b) Strong and parallel to isobars — Closely packed isobars mean a steep pressure gradient, so the wind is strong, and winds are normally read as flowing along the isobars. In detail, friction turns the surface wind across the isobars towards low pressure by about 30° over land and 10–15° over sea.

✗ (a) Light is wrong: a steep gradient gives a strong wind. (c) Across the isobars describes the friction turning in detail, but the standard description of a steep gradient is strong and parallel.

💡 Close isobars = strong wind. Above the friction layer the wind runs parallel to the isobars.

Q18. Anabatic wind occurs:

(a) At night (b) Any time of day and night (c) During day

✓ Answer: (c) During day — Anabatic wind is driven by daytime solar heating of mountain slopes.

✗ (a) At night: Katabatic winds occur at night.

✗ (b) Any time: Anabatic is specifically a daytime phenomenon.

💡 "Ana = Afternoon = Up-slope during day."

Q19. Anabatic wind is stronger than katabatic

(a) True (b) False

✓ Answer: (b) False — Katabatic wind can be much stronger. Katabatic (e.g., Bora) can exceed 100 kt. Anabatic winds are gentle and often masked by convection.

💡 Bora is a violent katabatic wind — completely disproves the notion that katabatic is weaker.

Q20. Katabatic wind is down slope cold wind due to nocturnal cooling

(a) True (b) False

✓ Answer: (a) True — Katabatic wind is indeed a cold, down-slope wind caused by nocturnal radiative cooling of the mountain slope.

💡 "Kata = down, cold, night." The reverse: "Ana = up, warm, day."

Q21. Katabatic wind occur due to sinking of cold air down the hill slope

(a) True (b) False

✅ Answer: (a) True — Nocturnal cooling → mountain surface becomes cold → adjacent air cools → sinks down slope = Katabatic.

Q22. Anabatic wind occur due to downward movement of air along valley

(a) True (b) False

✅ Answer: (b) False — Anabatic wind moves UPWARD along the valley/slope during daytime. Downward movement is katabatic.

Q23. Sea breeze is stronger than land breeze

(a) True (b) False

✅ Answer: (a) True — Sea breeze is stronger because daytime temperature differential (land vs sea) is greater than night differential. Land breeze is shallower and weaker.

Q24. The wind blows clockwise around a low in N-hemisphere

(a) True (b) False

✅ Answer: (b) False — In N hemisphere, wind blows ANTI-clockwise around a Low. Clockwise around a High.

💡 N hemi Low = Anti-clockwise. S hemi Low = Clockwise. Just reverse.

Q26. The wind blows anticlockwise around a low in N-hemisphere

(a) True (b) False

✅ Answer: (a) True — Confirmed: In N hemisphere, surface winds blow anti-clockwise (cyclonically) around a Low.

Q27. The wind blows anticlockwise around a low in S- hemisphere

(a) True (b) False

✓ Answer: (b) False — In S hemisphere, wind blows CLOCKWISE around a Low.

Q28. The resultant wind that blows under the influence of pressure gradient force, geostrophic force and cyclostrophic force is called

(a) Gradient wind (b) Geostrophic wind (c) Cyclostrophic wind

✓ Answer: (a) Gradient wind — Balance of PGF + Coriolis + Centripetal (cyclostrophic) = Gradient wind.

✗ (b) Geostrophic: Only PGF + Coriolis (no centripetal).

✗ (c) Cyclostrophic: Only PGF + Centripetal (Coriolis negligible).

💡 Gradient wind includes ALL three forces — closest approximation to actual upper-level wind in mid-latitudes.

Q29. Due to friction, from day to night for an isobaric pattern (in N hemisphere) the surface wind backs and weakens

(a) True (b) False

✓ Answer: (a) True — At night, friction layer shrinks, friction effect at surface increases; surface wind becomes weak and backs.

Q30. The winds which spirals inward counter-clockwise in the N Hemisphere are associated with

(a) Turbulence (b) High pressure area (c) Low pressure area

✓ Answer: (c) Low pressure area — Anti-clockwise inward spiraling in N hemisphere = cyclonic circulation = Low pressure system.

✗ (b) High pressure area: High pressure = clockwise outward spiral in N hemisphere.

Q31. Lower level wind 05010kt, upper level wind 23005kt, what is the thermal wind

(a) 05005kt (b) 23015kt (c) 05015kt

✓ Answer: (b) 23015kt — The thermal wind is the vector difference between the upper and lower winds (upper – lower). Lower 050/10 kt and upper 230/05 kt are in opposite directions, so subtract: 5 kt from 230 plus 10 kt from 230 gives 230/15 kt.

✗ (a) 050/05 and (c) 050/15 have the direction reversed: the thermal wind blows with the colder air on its left in the Northern Hemisphere.

💡 Draw it: thermal wind = upper minus lower. Opposite directions add their speeds.

Q32. A change in wind direction from 310° to 020° is

(a) Backing (b) Veering

✓ Answer: (b) Veering — 310° → 020° going clockwise (310→360→020) = clockwise change = VEERING.

✗ (a) Backing: Would be anti-clockwise change (e.g., 310→270→020 the long way around).

Q33. A change from 270° to 250° is

(a) Backing (b) Veering

✓ Answer: (a) Backing — 270° → 250° is an anti-clockwise change = Backing.

Q34. Sudden change in wind speed from 10 to 30kt and then to 15kt for 2-3 minutes

(a) Gust (b) Squall (c) Gale

✓ Answer: (a) Gust — A rise from 10 to 30 kt that quickly falls back to 15 kt is a gust: a short-lived increase of at least 10 kt above the mean speed, lasting under a minute.

✗ (b) A squall lasts a minute or more at the higher speed. (c) A gale needs a sustained speed above 33 kt.

💡 Gust = short, under a minute. Squall = a minute or more.

Q35. Sudden change in wind speed from 10kt to 30kt for 2 - 3 minutes

(a) Gust (b) Squall (c) Gale

✓ Answer: (b) Squall — Same reasoning as Q34.

Q36. A significant wind shear is generally associated with TS or line squall

(a) False (b) True

✅ Answer: (b) True — Thunderstorms produce gust fronts and microbursts — both are major sources of wind shear.

Q37. Cyclostrophic wind gives a close approximation of the 2000' wind in an intense tropical storm
(a) True (b) False

✅ Answer: (a) True — Near centre of a tropical revolving storm (cyclostrophic conditions), the cyclostrophic equation gives a close approximation to actual wind.

Q38. Rotor clouds have extremely turbulent flying conditions
(a) False (b) True

✅ Answer: (b) True — Rotor clouds form below mountain waves and contain extreme turbulence.

Q39. Friction cross isobar by over land and over sea
(a) 20°/10° (b) 30°/15° (c) 40°/30°

✅ Answer: (b) 30°/15° — Over land: ~30° to isobars; over sea: ~15° to isobars.

💡 "Land 30°, Sea 15°" — Land has more friction (buildings, trees, terrain) so greater angle.

Q40. If the S is warmer than the N level, from surface up to higher levels, then the wind will continue to increase with no change in direction in N hemisphere
(a) Ely (b) Wly (c) Sly (d) Nly

✅ Answer: (b) Wly — If south is warm and north is cold, temperature gradient acts S→N. Thermal wind blows westerly (along thickness lines, low temp to left in N hemi). If this distribution persists, thermal wind continues to be westerly from level to level, increasing with height.

💡 This is why the subtropical westerly jet stream exists — persistent equator-to-pole temperature gradient drives a persistent westerly thermal wind that increases with height.

Q42. Gale is:

- (a) Persistent strong winds with mean speed 44kt, associated with thunderstorms
- (b) Marked increase in wind speed lasting few minutes associated with CB or DS
- (c) Persistent strong winds exceeding 33kt, associated with depression

✅ Answer: (c) Persistent strong winds exceeding 33kt (≥ 34 kt), associated with depression — Definition of Gale: persistent mean wind ≥ 34 kt, associated with depressions and cyclonic storms.

❌ (a) 44kt with thunderstorms: 44 km/h is the squall speed criterion (not knots); thunderstorm association describes squall.

❌ (b) Lasts few minutes with CB: That is the description of squall.

💡 Gale = ≥ 34 kt MEAN PERSISTENT. Squall = sudden increase ≥ 32 kmh lasting ≥ 1 min, reaching 44 kmh. Don't confuse units (kmh vs kt)!

Q43. In N hemisphere thermal wind is parallel to with low value to left

(a) Isobars (b) Isotherms (c) Isallobars

✅ Answer: (b) Isotherms — Thermal wind blows parallel to isotherms (or thickness lines), keeping low temperature to the left in N hemisphere.

❌ (a) Isobars: Geostrophic wind is parallel to isobars.

❌ (c) Isallobars: Related to pressure change, relevant to Isallobaric wind.

Q44. The inertial flow is:

(a) cyclonic in both the Hemispheres

(b) anti cyclonic in both the Hemispheres

(c) anti cyclonic around an anticyclone

✅ Answer: (b) Anti cyclonic in both the Hemispheres — Inertial flow has no Pressure Gradient Force; balance of Centrifugal + Coriolis; the resulting flow is anticyclonic in both hemispheres.

💡 "Inertial flow = Anticyclonic EVERYWHERE." The textbook explicitly states this.

Q45. Upper level wind is 24025kt, lower level wind is 06015kt, the thermal wind is?

(a) 16010kt (b) 24040kt (c) 24010kt

✅ Answer: (b) 24040kt — Thermal wind = upper – lower. Upper 240/25 kt; lower 060/15 kt blows from the opposite direction. Subtracting a wind from 060 is the same as adding the same speed from 240: $25 + 15 = 40$ kt from 240.

❌ (a) 160/10 and (c) 240/10 do not follow from the vector subtraction.

💡 Opposite directions: speeds add when you subtract.

GHOST AVIATOR

Ghost Aviator

GHOST AVIATOR

Master Reference Tables — Chapter 6: Winds

Key Numerical Values

Parameter	Value
Anemometer height	10 m
Wind average for all observations	10 minutes
Wind average for T/O & landing	2 minutes
Squall: minimum wind increase	32 km/h (16 kt, 08 mps)
Squall: minimum speed reached	44 km/h (22 kt, 11 mps)
Squall: minimum duration	1 minute
Gale: minimum speed	34 kt
Friction layer height	~1 km
Surface wind angle over sea	15°
Surface wind speed over sea	2/3 V _g
Surface wind angle over land	30°
Surface wind speed over land	1/3 to 1/2 V _g
Night wind shear height	~500 m
Gust Front extent	30 km horizontally, 6000 ft height
Microburst diameter	~4 km
Microburst duration	1–5 minutes
Microburst wind speed	up to 90 kt
Sea breeze extent along coast	15–25 km either side
Sea breeze inland extent (Pune case)	~170 km from Mumbai

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Bora gusts	over 100 kt
Fohn warmth advantage over windward	10°C or more in high mountains
Tropical easterly jetstream latitude	13N, at ~15 km
Monsoon easterlies above	500 hPa (Jun-Sep)
Roaring Forties latitude range	35°–60°
Trade winds latitude range	10°–30°
Doldrums latitude	5°N–5°S
BF 8 (Gale)	34–40 kt
BF 12 (Hurricane)	≥64 kt

Formula Sheet

Formula	Explanation
$f = 2\Omega\rho V \sin\phi$	Coriolis Force; max at poles ($\phi=90^\circ$), zero at equator ($\phi=0^\circ$)
$V_g = P/(2\Omega\rho \sin\phi)$	Geostrophic wind; inversely proportional to $\sin \phi$ and isobar spacing
$\rho V^2/r = P \rightarrow V = (Pr/\rho)^{1/2}$	Cyclostrophic wind; pressure-gradient and curvature balance
$V_t = V_1 - V_0$	Thermal wind = upper level minus lower level geostrophic wind (vector)
$V_i = fR$	Inertial wind; f = Coriolis, R = radius of path; anticyclonic both hemispheres

Wind Type Comparison

Wind	Forces	Isobar Shape	Friction	Where
Geostrophic	$P + f$	Straight, parallel	No	Mid-latitudes, free atmosphere
Cyclostrophic	$P + \text{Centripetal}$	Curved	No	Near equator, tornadoes
Gradient	$P + f + C$	Curved	No	Mid-latitudes, upper air
Isallobaric	$P + f + \text{Isallobaric}$	Any	No	Rapid pressure change areas
Inertial	$f + \text{Centrifugal}$	No PGF	No	Any; anticyclonic both hemi
Surface wind	$P + f + F$	Any	Yes	Friction layer (surface–1km)

Quick Revision Summary

Chapter 6 — Winds: 60-Second Revision

Measurement: Anemometer (speed) + Wind Vane (direction) at 10m; 10-min average (2-min for T/O/Landing)

Squall: +32 kmh → 44 kmh, ≥ 1 min, CB associated. Gust = seconds. Gale = ≥ 34 kt mean persistent

Backing = ACW; Veering = CW. Buys Ballot: Back to wind → Low on Left (N hemi)

Coriolis: $f = 2\Omega \sin \phi$; max poles, zero equator; right in N hemi, left in S hemi

Winds: Geo = $P \leftrightarrow f$ (straight). Cyclo = $P \leftrightarrow C$ (curved, equatorial). Gradient = $P + f + C$. Inertial = $f + C$ (anticyclonic both hemi)

Friction: Layer ~1km. Sea: 15° , $2/3 V_g$. Land: 30° , $1/3 - 1/2 V_g$. Night WS at ~500m = aviation hazard

WS: TS Gust Front (30km, 6000ft); Microburst (4km, 1-5min, 90kt; dry = Virga; wet = downpour)

Local winds: Ana = up/day; Kata = down/night (Bora >100kt). Fohn = warm dry leeward. Sea Breeze = day; Land Breeze = night

Thermal Wind: $V_t = V_1 - V_0$; parallel to isotherms; low temp LEFT (N hemi); subtropical jet example

Beaufort: 8=Gale(34-40kt); 12=Hurricane(≥ 64 kt)