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1. Introduction — Indian Climate

India has variety of climate: Tropical in the South, Temperate and Alpine in the Himalayan North. The Himalayas receive sustained winter snowfall. Indian climate is strongly influenced by the Himalayas and the Thar Desert. The Himalayas act as a barrier to cold winds flowing down from Central Asia — this keeps most of the Indian subcontinent warmer compared to similar latitudes. The coastal regions are warmer and the rains are more frequent. India is influenced by **two seasons of rains** accompanied by seasonal reversal of winds from January to July. During winters, dry and cold NWly winds blow from the north. In summer the Indian land mass becomes hot → draws moist winds from the Arabian Sea and Bay of Bengal → causes reversal of winds → called the **SW Monsoon** — the most important feature controlling the Indian climate. About **75%** of the annual rainfall is received during the short span of four months (**June to September**). There is large variation — W Rajasthan receives less than **13 cm**, Mawsynram in Meghalaya gets as much as **1187.3 cm (467.4 in)**; Cherrapunji gets **1177.7 cm (463.7 in)**. The word **Monsoon** is derived from Arabic "*Mausim*" — it is the **seasonal reversal of winds and the rainfall**.

2. Six Seasons (Ritu) & IMD Four Climatological Seasons

#	Ritu (Sanskrit)	Months	Characteristics
1	Vasant (Spring)	Chaitra & Vaisakh (Mar–Apr)	Temps around 20–30°C; Vernal Equinox in mid-season
2	Grishm (Summer)	Jyeshtha & Asadha (May–Jun)	Very hot; around 40–50°C; Summer Solstice
3	Varsha (Monsoon)	Shravana & Bhadrapad (Jul–Aug)	Very hot, humid, heavy monsoon rains
4	Sharad (Autumn)	Ashwina, Asauj, Kartika (Sep–Oct–mid Nov)	19–25°C; autumnal equinox in mid-season
5	Hemanta (Fall)	Margashirsha, Agahan, Pausha (late Nov–Dec)	Very pleasant 19–25°C; ends with winter solstice
6	Shishira (Winter)	Magha & Phalguna (Jan–Feb)	Cold, below 10°C; pleasant with occasional sunshine

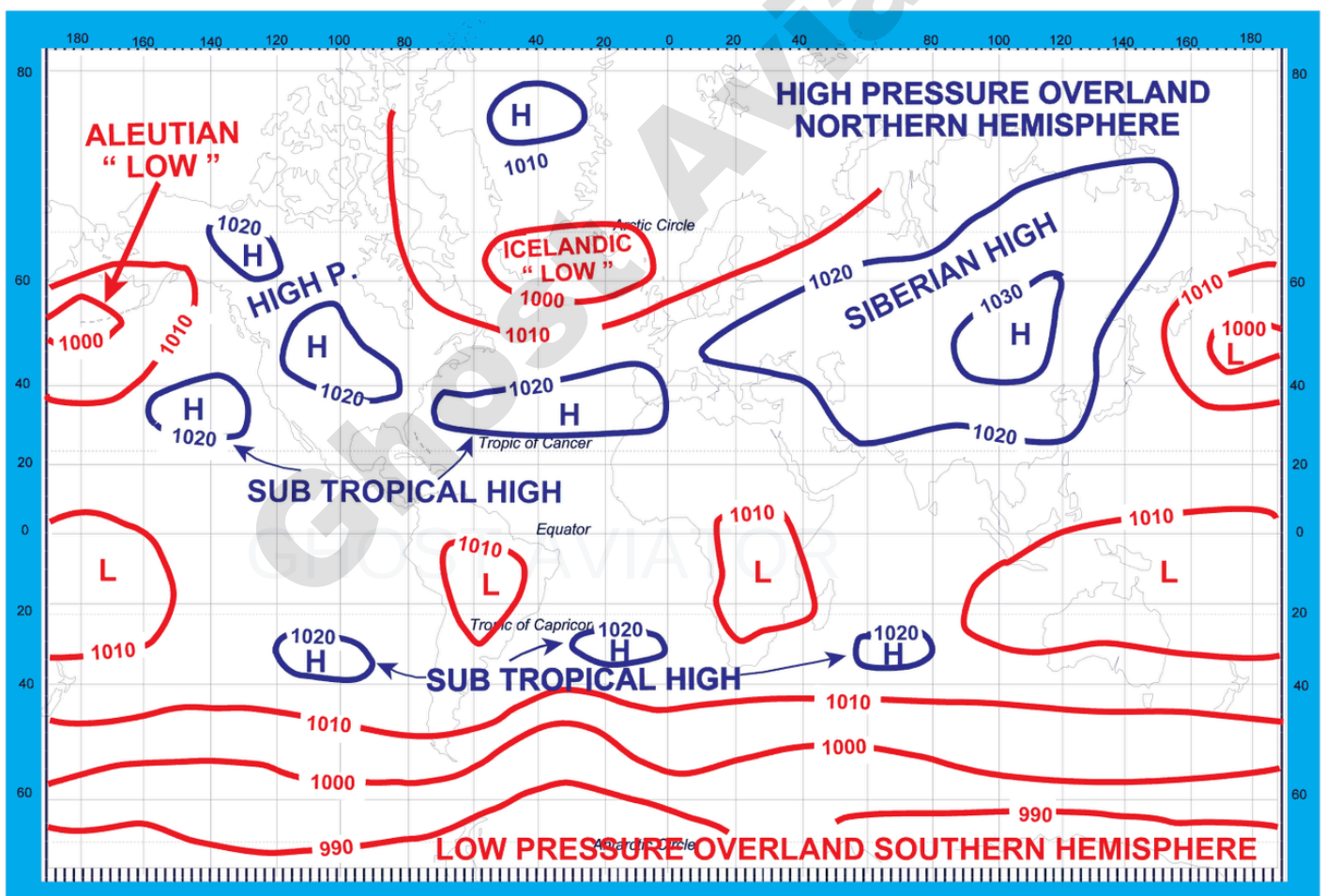
N India mostly conforms to the marked change of Ritus; Southern India (close to Equator) less so.

IMD Four Climatological Seasons

Season	Months
Winter Season / Cold Weather Season	January–February (Dec–Feb for NW India)
Summer / Pre-Monsoon Season	March to May
SW Monsoon (Rainy Season)	June to September
Post / NE Monsoon (Cool Season)	October–November

3. Winter Season / Cold Weather Season

Months: January–February (December–February for NW India)



Surface pressure in January

Pressure Distribution

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An extensive belt of high pressure from Sahara to Siberia. High is centered at **45° N and 105°E**. India is at the southern periphery of this high. High pressure over the Indian ocean (on surface isobaric chart, about **four isobars: 1012–1018 hPa**, at 2 hPa interval). The **1012 hPa** isobar extends from Arabian Sea islands to Kerala to Gujarat along the West Coast. The **1018 hPa** isobar over Pakistan and J&K. A shallow trough extends from Kerala to Gujarat along West Coast and a shallow ridge over adjoining Myanmar. NWly winds prevail over N India; NEly winds over S India. Under this pressure distribution, NWly winds prevail over N India and NEly over S India.

Surface Temperatures

December and January are coldest months. Mean daily minimum temperatures range from **22°C** in extreme south to **10°C** in northern plains to **6°C** in Punjab. Diurnal range of temperature is about **13°C**; about **10°C** over coastal areas; **5°C** over coastal Tamil Nadu.

Surface & Upper Winds

Surface: Light, mainly NEly south of **25°N**; NWly over N India; Ely over Assam. **Upper Winds:** Up to **10,000 ft** NWly over N and Central India; NEly over S India. Thereafter Wly winds prevail aloft, strengthening with height (spreading S to tip of Peninsula). Sub Tropical Jet Stream (STJ) prevails over N India at height of about **12 km** and **27° N**, with strong Westerly winds of **80–100 kt**, maximum being **200 kt**.

Synoptic Systems

N India is affected by STJ and **5–7 WDs per month**. A few CS and Easterly waves affect S India.

Weather

In N India: clear skies, poor visibility, dry weather, low humidity and low temperatures are normal features. Dry spells are broken by passage of WDs (mostly Occluded Fronts of extra tropical origin) → they initially cause Warm Front type weather. Weather sequence: backing of winds from NWly to SWly/SEly → rise in temperature, fall in pressure, appearance of CI clouds → thickening and lowering of clouds to AS, NS, ST and DZ. RA may occur → followed by Cold Front type weather (appearance of CU and CB, rise in pressure and occurrence of TS). As WD passes off, skies become clear and cold dry continental N–NWly winds set in. Widespread Radiation Fog and **Cold Waves** (temperature **≥4.0°C below minimum normal**) follow. Cold wave conditions may last for **2–3 days**. When maximum temperature is **≤16°C** in plains, it is declared a **Cold Day**.

Cold Wave: Temperature $\geq 4.0^{\circ}\text{C}$ below minimum normal . Common in Jan–Feb in W India N of 20°N , J&K, Rajasthan, W MP, Gujarat are most affected. Punjab receives comparatively lesser number of severe cold waves.

Aviation Hazards — Winter:

- **Poor visibility** is the main aviation weather hazard during winter, specially over N India. Fog, mist and haze are all common all over the country in morning and evening.
- Smoke from industries and automobiles reduces visibility. Low level inversion favours reduction in visibility. Conditions most favourable for **Radiation Fog after passage of a WD** — over NW India, UP, Bihar, Central India, N Bengal and Assam (particularly S banks of Brahmaputra river). Sometimes fog prolongs, disrupting air traffic adversely, especially over polluted airfields like Palam (Delhi). On such occasions, there may be little improvement in visibility to **1000–2000 m** during noon, but may again deteriorate in evening and night. Such conditions may last for a few days.
- **Advection Fog** occurs over coastal areas and where large water bodies are present. Generally lifts by **1000–1100 hr IST** .
- **CAT** is experienced over NE India and in the vicinity of STJ. Mountain waves are also common over high terrain over N and E India.
- **Icing** — freezing level lowers in winter. Hence ice accretion may be experienced at lower levels.

4. Pre-Monsoon / Hot Weather / TS Season (Mar–Apr–May)

Pressure Distribution

Transition season — winter pattern changes over to monsoon pattern. Continuous rise in temperature and fall in pressure over the country. Weak pressure gradient — only two isobars (1006 and 1008 hPa) cover entire country. These run parallel almost along Indian coast line — trough along Peninsula with axis along **78°E** longitude. In May the trough shifts to **79°E** along Chennai coast. A weak low over NW Pakistan (upper Sindh) and a weak trough over E UP and Bihar. A low lies over Myanmar and a closed high over E Central Bay, W of Bay Islands.

Surface Temperatures

Due to N wards march of sun, land progressively gets heated after January. Temperatures are of the order of **30–35°C** over central peninsula. Day temps highest in May in Andamans; in Rajasthan and Kashmir in June and July. Maximum temp highest in April in Saurashtra and in Rajasthan and Kashmir in July. Maximum diurnal range of wave conditions (**≥4°C above normal maximum**) → **Heat Wave declared**. Along coasts about **6°C** . Sometimes heat wave maximum temperature is **5°C** or more — heat wave conditions.

Surface Winds

In March N–NWly up to E India; April they are N–NWly, they shift to E of India. In May SWly prevail over Rajasthan and Ely from E UP to NE India. Over Orissa, WB, Bihar, Jharkhand and Chhattisgarh, they are Sly. In rest of country NWly to SWly winds prevail. In June winds are Sly and are W–SWly **10–15 kt** over rest of country. On certain occasions winds become gusty and dust laden over Gangetic plains. **Dust Raising Winds (DRW)** mostly start at about **0900 hr** and continue up to **1700 hr** . Thereafter they weaken. Visibility on such occasions reduces considerably over a large area.

Upper Winds (Mar–May)

April: Wly strengthen with height over N India and Peninsula. At **300 hPa** max speeds are **40 kt** and at **200 hPa** , **60 kt** N of **22°N** . Wind weakens slowly. In May Wly belt shifts to **30°N** ; Ely 15–20 kt aloft S of 25°N. In June winds are Wly up to **700 hPa** and Ely aloft S of **25°N** , which strengthen with height to **50 kt** at **100 hPa** .

Synoptic Systems & Weather

Characterised by widespread dust haze and extremely high temperatures over N India. Dust storms over N India and Kalbaisakhi (Norwesters) over E and NE India. Triggered by WDs. A few tropical cyclones strike Bengal coast and move NW. STJ weakens and moves northwards. This is the most hazardous season for flying.

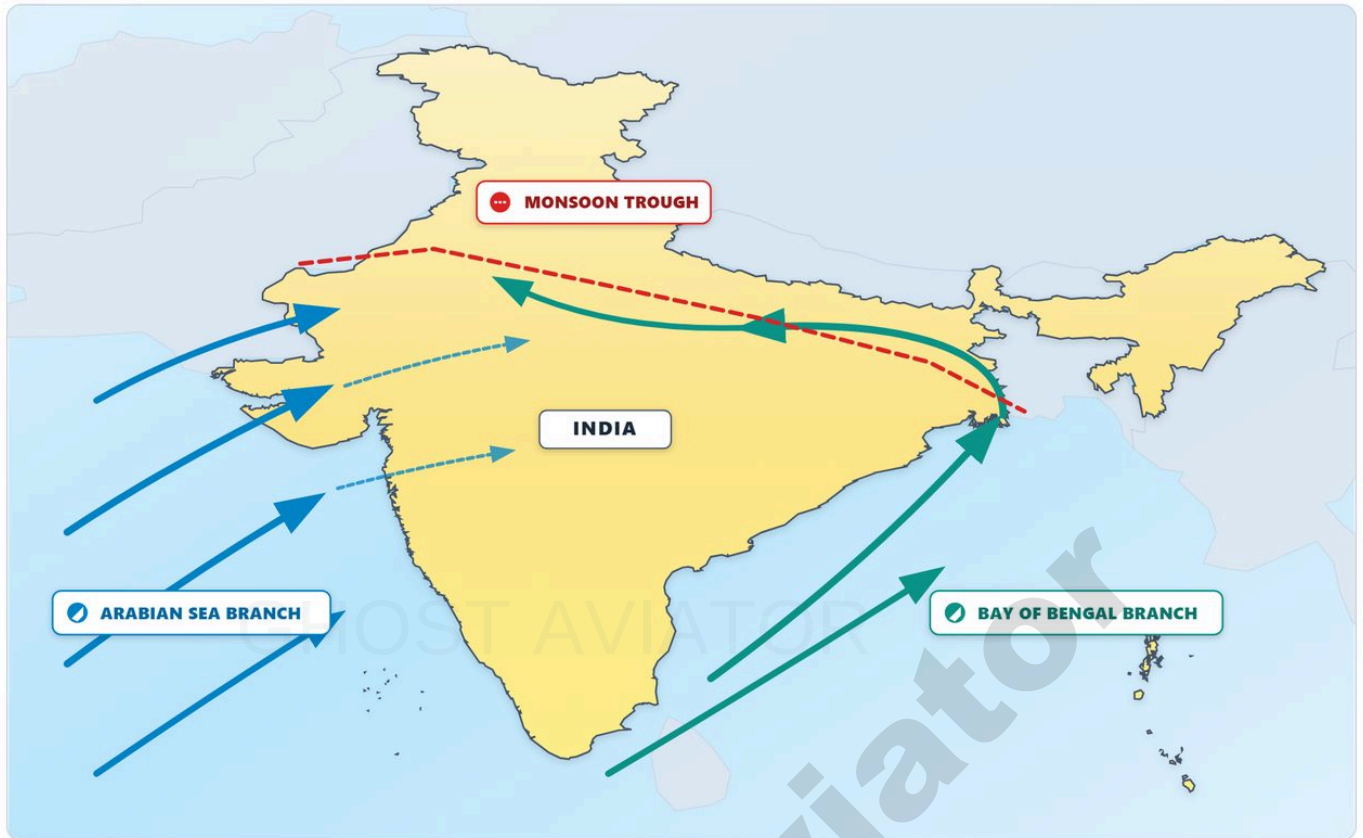
Aviation Weather Hazards — Pre-Monsoon (Most Hazardous Season for Flying):

1. **TS and DS Activity:** Violent TS are common over Rajasthan and NW India with all attendant hazards. Line squall type of development is most common over Rajasthan and NW India. **Norwesters** affect Eastern parts — line squall type of development is also reported by the aircrew. Poor visibility due to widespread dust haze is experienced over entire N India. Dust haze may extend to **7–8 km aloft**.
2. **Dust Raising Winds:** Strong surface winds of **30–50 kt** between **0900 and 1700 hr**. Visibility may reduce to a few hundred metres.

5. SW Monsoon / Rainy Season (June–September)

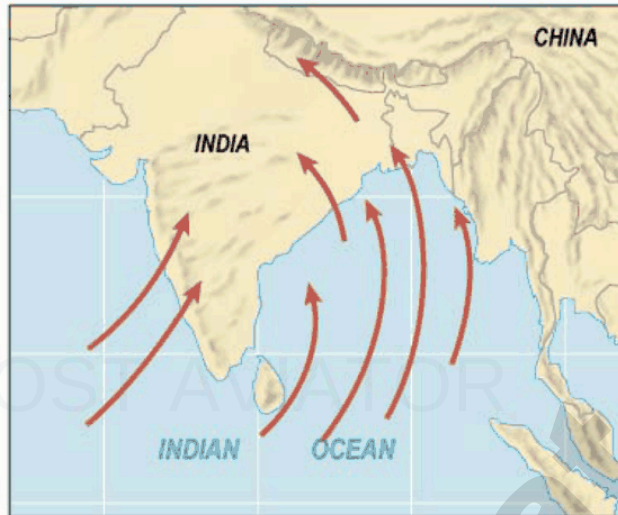
The most important feature of Indian climate. Spread over four months (**June to September**). Actual period varies from less than 75 days over SW Rajasthan regions to more than 120 days over the SW regions. **Onset of SW Monsoon:**

- South Andaman Sea: **20 May**
- Kerala: **01 June**
- Mumbai: **15 June**
- New Delhi: **01 July**
- Covers whole country by: **08 July**



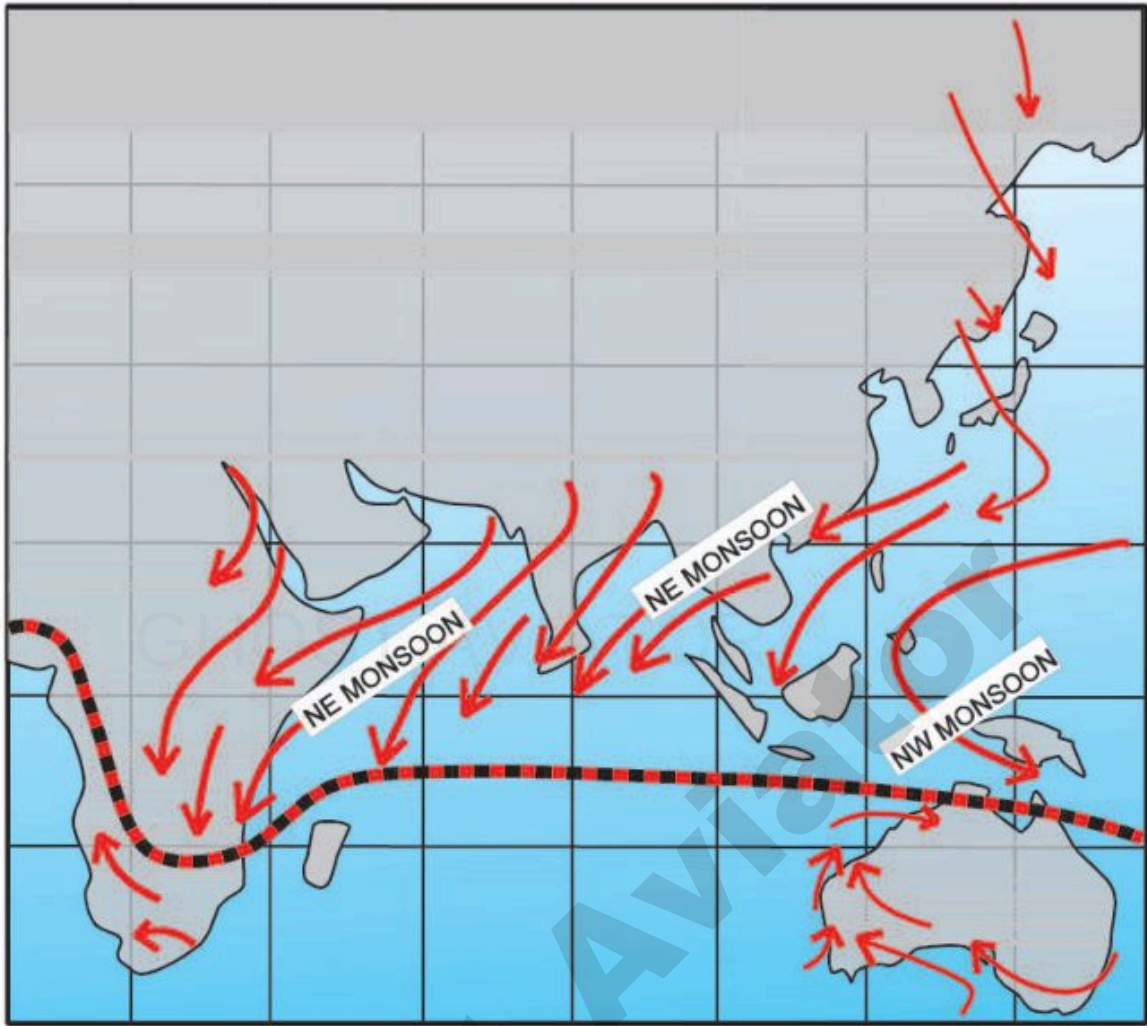
The two branches of the south-west monsoon

The South Easterly Trade Winds cross the Equator and become South Westerly with a long maritime track

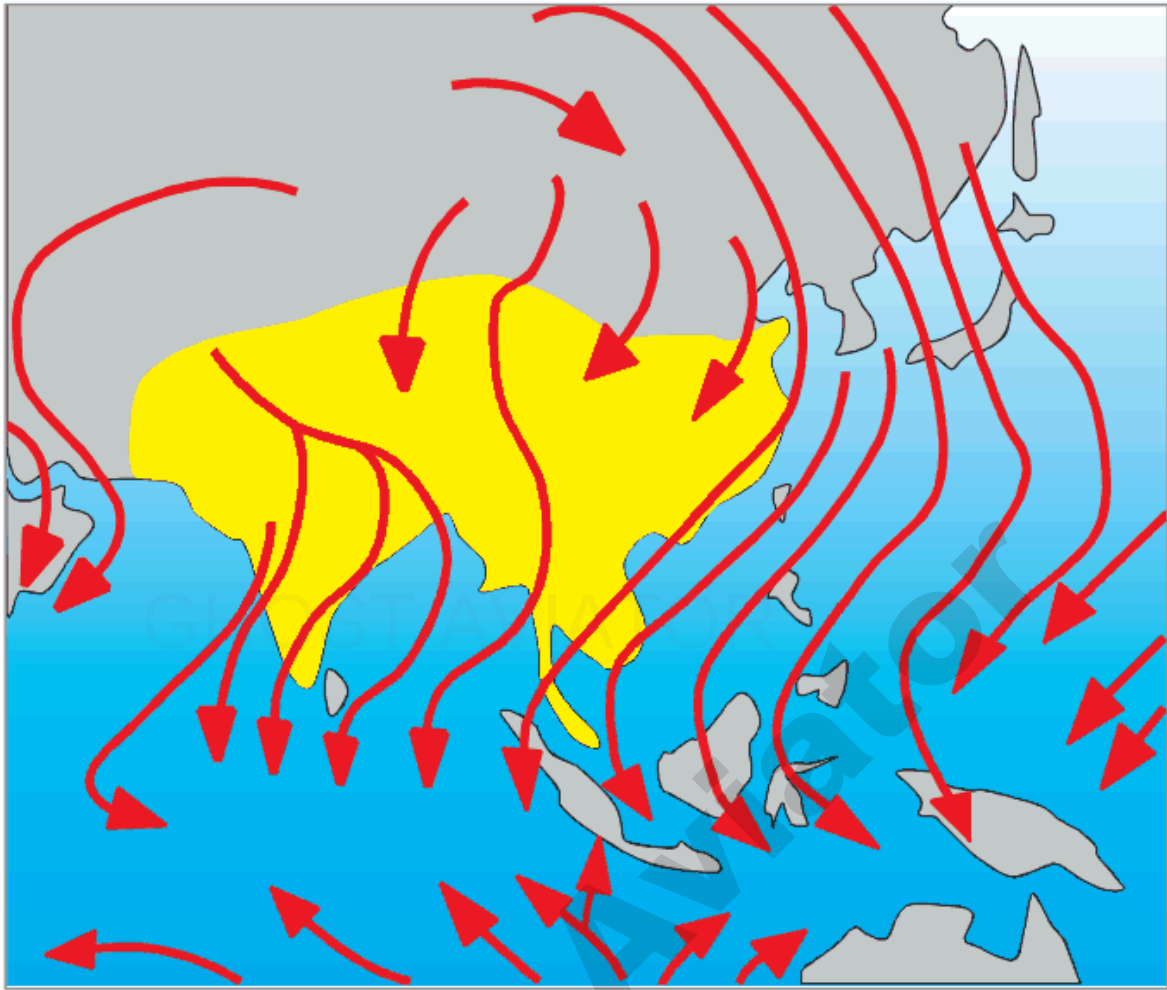


Summer

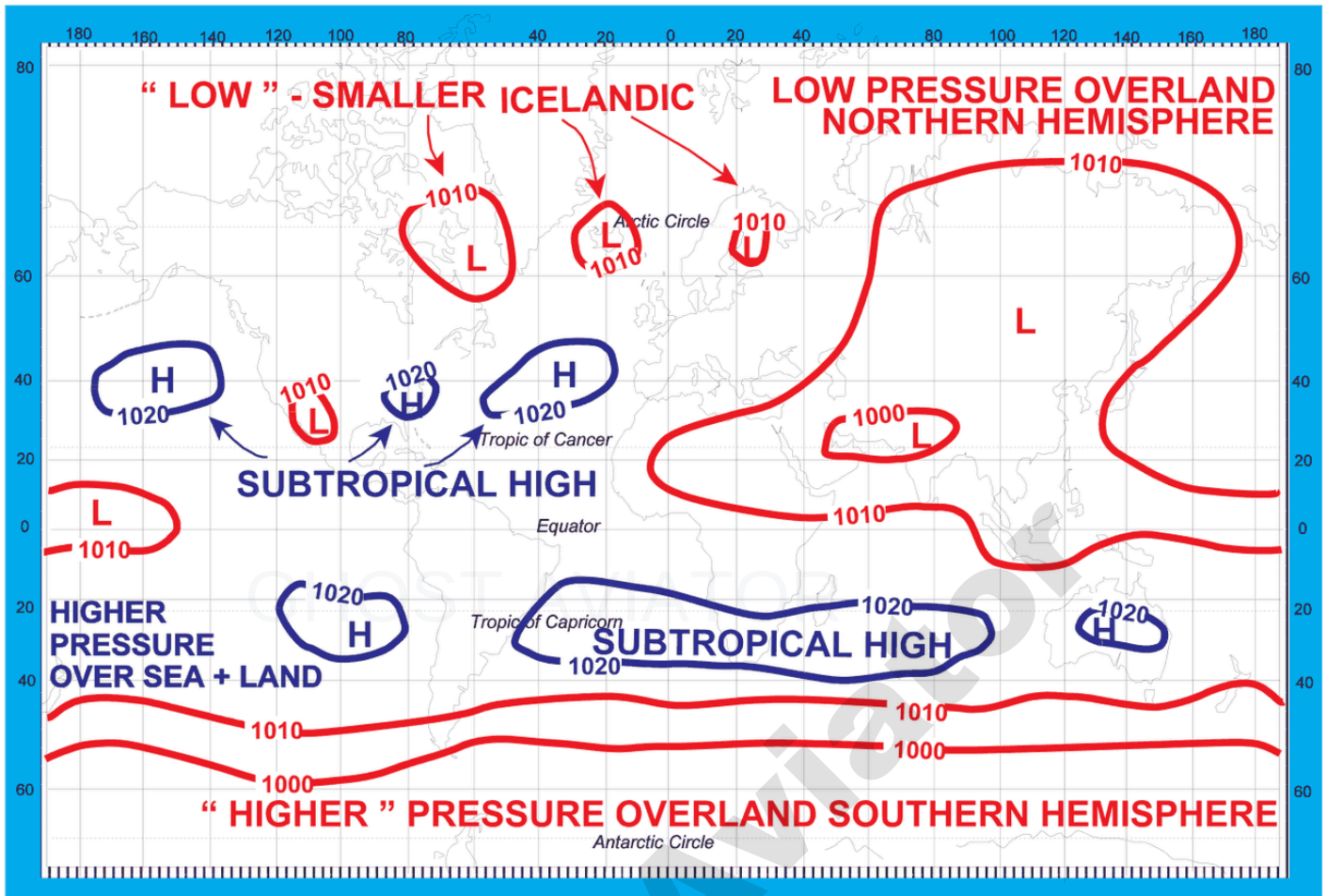
Summer monsoon winds



The monsoon winds in January and July



North-east monsoon



Surface pressure in July

Normal date of Withdrawal: SW monsoon generally starts withdrawing from Rajasthan by **01 Sept** and from NW parts of India by **15 Sept**. It withdraws from almost all parts by **15 Oct** and is replaced by a northerly continental airflow called **North-East Monsoon**.

Pressure Pattern — SW Monsoon

Low pressure area lies over Baluchistan (**994 hPa**). A trough — **Monsoon Trough (MT)** — lies over the Gangetic plains with its axis extending from Sriganaganagar to the Head Bay, through Allahabad. A high pressure is over S Hemisphere. Seven isobars at 2 hPa interval (**994 hPa** over Baluchistan and **1008 hPa** over Tenasserim Coast and S Hemisphere). Pressure gradient steep along west coast.

Surface Temperature — SW Monsoon

Temperatures over S parts are about **26°C** and over Rajasthan **31°C**. Spatial range is **9°C**. Temperatures rise during break monsoon. Diurnal range is about **4 to 9°C**.

Surface Winds — SW Monsoon

Ely to SEly prevail to the N of the MT and SW to Wly elsewhere. NWly winds prevail over Malabar coast. Wind speed is about **5–10 kt** over land and over seas **15 kt**. Strength of monsoon depends on strength of these winds.

Advance of Monsoon — Two Branches

The SW monsoon current advances in **two distinct branches**:

1. **Arabian Sea branch** — moves to Kerala
2. **Bay of Bengal branch** — moves to Bangla Desh and Bengal

Upper Winds — SW Monsoon

Up to about **10,000 ft** winds are W–SWly to the S of MT and to the N. At **200 hPa** upwards Ely winds prevail over almost entire India. At **200 hPa** and aloft an anticyclone lies over Tibet and another over Baluchistan. The winds are SWly From 500 hPa upwards and Ely jet stream (**Tropical Jet Stream**) prevails at **15–16 km** with max speed of **70–100 kt** (max. **150 kt**) roughly along **13°N**.

Monsoon Trough (MT)

Normal position on sea level chart passes through Ganganagar–Allahabad–Kolkata to Head Bay. The trough fluctuates N–S of its normal position and accordingly governs the rainfall. To the N of this trough lies the Bay branch. And to the S, the Arabian Sea branch. This trough more or less coincides with ITCZ. At **10,000 ft (700 hPa)**, it is almost parallel to 22°N; from Gujarat to Orissa and at **500 hPa** it can be seen around 10–15°N across S Peninsula. Above that it is not traceable.

Break Monsoon

Monsoon Trough shifts northwards, running close to foot hills of Himalayas → drastic reduction in rainfall over the country outside the foot hills. During this period pressure rises over the country. Heavy rains occur over foot hills of Himalayas, particularly over Sub Himalayan West Bengal, Nepal and Bhutan → resulting in floods over NE India and Bihar. Also experienced over East UP, Bihar and adjoining states. During this phase the weather is of Pre-Monsoon type with widespread dust haze of moderate intensity.

Subtropical (Mid-Tropospheric) Cyclone

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Sometimes during SW monsoon a cyclonic circulation establishes at Lat/Long **60–80°E and 18–28°N**, between levels **500 and 700 hPa**, and a trough at the surface. Heavy rainfall in W India and NE Arabian Sea are mostly attributed to this system. Particularly MP, Maharashtra, especially Mumbai received very heavy, unprecedented rainfall in year 2005. The heavy rainfall is due to thick stratiform clouds in which CB clouds are embedded. Such heavy build-up and rainfall occurs mainly to W and SW of the subtropical cyclone centre.

Weather — SW Monsoon

Rainfall oscillates between active spells of widespread rains and breaks. Heavy rainfall in mountains; uncomfortable weather due to high humidity and temperatures — the feature associated with the Breaks. Monsoon Depressions form in northern part of the Bay at frequency of about **2–3 per month** moving Nly/Wly direction bringing well-distributed rainfall over central and northern parts.

Strength of Monsoon (Table 19.1)

Strength	Wind Speed Over Sea	Rainfall Over Land
Weak Monsoon	Up to 12 kt	<1½ times the normal
Moderate Monsoon	13–22 kt	1½ to 2 times the normal
Strong Monsoon	23–32 kt	1½ to 4 times the normal
Vigorous Monsoon	>32 kt	>4 times the normal

El Niño and ENSO

El Niño = unusual warming of surface waters in eastern tropical Pacific Ocean = "warm phase" of El Niño-Southern Oscillation (ENSO). **La Niña** = "cool phase" = cold Sea Surface Temperature (SST) = High in W Pacific and L in E Pacific. El Niño occurs irregularly at **two to seven year intervals**. ENSO cycle affects global climate. During El Niño: SE Trades become weak → weak SW Monsoon. During La Niña: SE trades are strong → active monsoon. Now evident that severe droughts occur in India in El Niño years, though opposite is not true. Trade winds push warm water to western Pacific; cooler waters rise up (upwelling) toward surface on coasts of Ecuador, Peru, Chile.

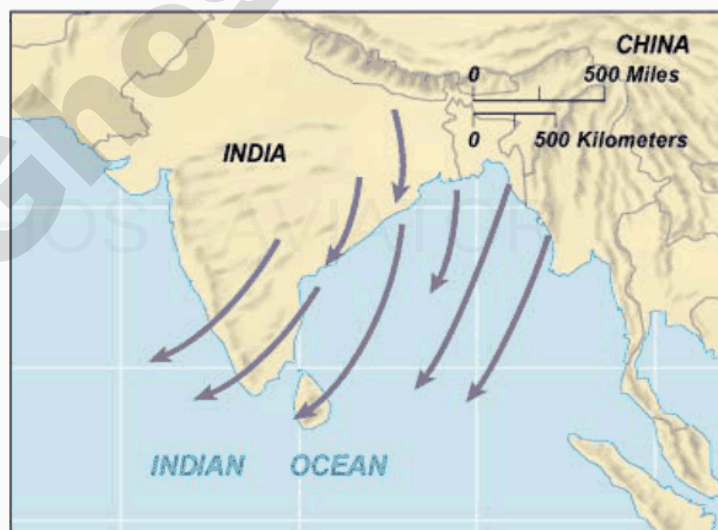
Aviation Hazards — SW Monsoon:

1. **Low Clouds:** Very low clouds (150–200 m agl) and strong surface winds are common during strong monsoon conditions and passage of Monsoon Depressions.
2. **Poor Visibility:** Generally good, but may deteriorate during precipitation. Dust haze in north; monsoon haze along west coast reduces visibility to a certain extent.
3. **CAT:** CAT is likely in the vicinity of TJ.
4. **TS Activity:** At onset of monsoon TS activity of longer duration is a common feature. During Break and then during revival of monsoon also TS are experienced.

6. Post Monsoon / NE Monsoon Season (Oct–Nov)

Also called **Retreating SW Monsoon Season**. Transition season — establishment of NEly wind regime over Indian subcontinent. **This is the major period of rainfall activity over coastal AP, Rayalaseema and TN-Pondicherry.** For TN this is the main rainy season, accounting to about **49% of annual rainfall**. Rainfall mostly occurs between **2100 and 0300 hr** in spells of 3 to 4 days duration.

The Siberian High is the dominant feature with North Westerly winds flowing over China



Winter

Pressure Pattern

Summer pressure and wind patterns undergo slow but steady modification to finally change to winter pattern. One isobar (**1010 hPa**) surrounds the entire country including Bay Islands, Pakistan and parts of Myanmar. Monsoon trough shifts to Bay of Bengal with its axis along **13°N** . Pressure field is flat over the country. A weak low (**1008 hPa**) lies off Chennai coast and another over Baluchistan.

Surface Temperature & Winds

Temperatures are nearly uniform, **18°C** , over the country. Diurnal range is **6–7°C** . Start falling sharply all over country. Mean temps over NW India show decline from about **38°C** in Oct to **28°C** in Nov. With withdrawal of monsoon from N and Central India and N Peninsula by first half of Oct, the lower level wind rapidly changes from SWly to NE to SW and get diagonally NE to SW, cross diagonally Bay of Bengal before reaching Cape Comorin and rest of TN. Due to this TN and some parts of Kerala get significant rainfall. Parts of West Bengal, Orissa, Andhra Pradesh, Karnataka and Mumbai also receive minor precipitation. Due to flat pressure distribution, surface winds are light and variable. Sea breeze pronounced along coasts up to 160 km inland.

Upper Winds

Gradually Wly winds start establishing at all levels and pattern changes to that of winters. STJ reappears over J&K. Above 500 hPa level Ely remain confined to extreme S of country, which weaken to **20 kt** .

Weather

A few (1–2 per month) WDs affect N parts. They cause clouding and precipitation over J&K and Punjab. **This is the best period for flying except over southern India.** Good visibility and clear skies are the main features. A few tropical storms form over Arabian sea and Arabian Sea and cause weather over coastal areas. Retreating monsoon winds cause occasional showers along the east coast of TN. In Tamil Nadu this is the main rainy season — accounts for nearly **60%** of annual rainfall in coastal districts.

Maximum Cyclonic Storms

Maximum Cyclonic Storms occur in Oct over Bay of Bengal and in Nov over the Arabian sea. SCS are more in Nov than Oct. They usually form near Andaman Seas and move towards TN, AP and Orissa. Some move N and strike W Bengal or Bangla Desh. A few after crossing over peninsula, revive, recurve and strike Maharashtra or Gujarat coasts.

Aviation Hazards — Post Monsoon:

1. **Poor Visibility:** Generally good. May deteriorate near industrial areas during dawn and dusk. After passage of WD the S poor visibility is during precipitation. In S, CS over S India.
2. **Low Clouds:** Low clouds, very strong winds, heavy rain and TS activity is experienced during passage of a CS over S India.
3. **CAT:** CAT may be experienced due to STJ in the north.

Note: January and July Upper Wind Maps are in later pages.

7. Route Winds

The general pattern of winds over various routes in India is summarised below:

October to May (8 months)

Level	Wind
Above 3 km	Winds all over India are Wly. They become stronger with height. STJ (Wly/80–150 kt) over DLH–CAL Route at 12 km.
Below 3 km	NW–Wly over N India and NEly over S India

June to September (4 months)

Level	Wind
Above 6 km	Ely becoming stronger with height. TJ (Ely/60–100 kt) over MDS (Chennai) lat at 15 km.
Below 6 km	W–SWly over S India and SEly over N India

8. Present System of Forecasting SW Monsoon

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Since 2007, forecast for SW Monsoon (Jun–Sep) rainfall over India is issued in two stages:

- First stage forecast is issued in **April**
- Second stage (update forecast) is issued in **June**
- Along with update, forecast for seasonal rainfall over four broad geographical regions (NW India, Central India, South Peninsula, NE India) and July rainfall over the country as a whole are also issued.

8 Predictors for Forecasting (Table 19.2)

S. No	Predictor (Period)	Used for F/C in
1	N Atlantic Sea Surface Temp (SST)(Dec+Jan)	April and June
2	Equatorial SE Indian Ocean SST (Feb+Mar)	April and June
3	East Asia MSL Pressure (Feb+Mar)	April and June
4	NW Europe Land Surface Air Temp. (Jan)	April
5	Equatorial Pacific warm Water Volume (Feb+Mar)	April
6	Central Pacific (Nino 3.4) SST Tendency (Mar Apr May–Dec Jan Feb)	June
7	N Atlantic MSLP (May)	June
8	North Central Pacific Wind at 1.5 Km ASL (May)	June

Model error of April forecast system is **5%** and of June forecast system is **4%**. **For forecasting July rainfall over the country**, a statistical model is used with 6 predictors (error of the model is 5%): (a) N Atlantic SST, (b) NNO 3.4 SST (May+Jun), (c) N Pacific MSL pressure (Mar), (d) E Asia MSL pressure (Feb+Mar), (e) N Atlantic MSL pressure (May), (f) Equatorial Indian Ocean MSL pressure (Nov of previous year). For forecasting seasonal rainfall over four broad geographical regions, multiple regression (MR) models based on separate set of predictors. All four multiple linear regression models have model errors of **8%**. Since 2005, National Climate Centre also prepares an extended range forecast of onset of SW Monsoon over Kerala. Forecast is issued based on a statistical model with **6 predictors** (accuracy is a few days, plus minus). IMD also prepares operational long range forecasts for Winter Precipitation (Jan–Mar over NW India) and NE Monsoon rainfall (Oct to Dec) over S Peninsula. Separate statistical models have been developed.

9. Quick Revision Summary

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Quick Revision — Chapter 19: Climatology of India

- 75% annual rainfall in just 4 months: **June–September**
- Wettest place: Mawsynram **1187.3 cm** ; Cherrapunji **1177.7 cm**
- Driest: W Rajasthan < **13 cm**
- "Monsoon" from Arabic "Mausim" = seasonal reversal of winds + rainfall
- STJ in winter: **12 km, 27°N, 80–100 kt (max 200 kt)**
- WDs in winter: **5–7 per month** affect N India
- Cold Day: max temp **≤16°C** in plains; Cold Wave: **≥4°C below min normal**
- SW Monsoon onset: Andaman **20 May** → Kerala **01 Jun** → Mumbai **15 Jun** → Delhi **01 Jul** → Full India **08 Jul**
- SW Monsoon withdrawal: Rajasthan **01 Sep** , NW India **15 Sep** , all India **15 Oct**
- Two branches: Arabian Sea (→ Kerala) and Bay of Bengal (→ Bengal/Bangladesh)
- MT (Monsoon Trough): Ganganagar–Allahabad–Kolkata–Head Bay
- TJ (Tropical Jet): **15–16 km, ~13°N, 70–100 kt (max 150 kt)**
- Subtropical cyclone: **60–80°E, 18–28°N, 500–700 hPa**
- Monsoon Dep frequency: **2–3 per month** in Bay
- Post monsoon: best flying except S India; TN gets **49%** annual rainfall
- Most hazardous season: **Pre-Monsoon (Mar–May)**
- El Niño = weak SW Monsoon; La Niña = active SW Monsoon
- SW Monsoon forecast: April (1st stage) + June (2nd stage update); model errors **5%** and **4%**

10. Practice Q&A

Q1. During winters the activity of radiation fog increases after the passage of a WD over N India. Which of the following is correct?

- (a) Advection fog occurs over northern & central parts of India
- (b) Radiation fog occurs over southern parts of India
- (c) Activity of Radiation fog increases after the passage of a WD over N India

✓ Correct Answer: (c) Radiation fog increases after the passage of a WD over N India

✗ Distractors: (a) Advection fog is coastal/water body area phenomena. (b) Radiation fog is predominantly N India phenomenon, not S India.

💡 WD passes → sky clears → radiational cooling → Radiation Fog. This sequence is a classic DGCA question.

Q2. Low Temperatures and low humidity is the characteristic of:

- (a) Pre Monsoon
- (b) Summer
- (c) Monsoon
- (d) Winter

✓ Correct Answer: (d) Winter — low temps and low humidity are winter characteristics in N India

✗ Distractors: (a) Pre-monsoon has high temps and low humidity. (b) Summer same as pre-monsoon. (c) Monsoon has high humidity and moderate temps.

💡 Winter = Cold + Dry (low humidity). Monsoon = Warm + Wet (high humidity). Pre-monsoon = Hot + Dry (dust haze).

Q3. The Summer Season period is:

- (a) Jan–Feb
- (b) Mar–May
- (c) Jul–Sept
- (d) Oct–Dec

✓ Correct Answer: (b) Mar–May — Pre-Monsoon/Hot Weather/TS Season

✗ Distractors: (a) Jan–Feb = Winter. (c) Jul–Sep = SW Monsoon. (d) Oct–Dec = Post Monsoon + onset of winter.

💡 IMD Seasons: Jan–Feb (Winter), Mar–May (Summer/Pre-Monsoon), Jun–Sep (SW Monsoon), Oct–Nov (Post Monsoon).

Q4. During Summer season, the WDs cause TS activity over Punjab & Rajasthan and track of WD is: (a) No WD (b) NE Part (c) Northern most part of country (d) Southern most part of country

✓ Answer: (c) Northern most part of country — In summer the Western Disturbances are fewer and their track shifts to the northern-most part of the country, but they can still trigger thunderstorms and dust storms over Punjab and Rajasthan.

✗ (a) The question itself says the WDs cause thunderstorms, so they are present. (d) In summer the track moves north, not south.

💡 Summer WD track: northern most.

**Q5. The monsoon current over the West Coast of India is:
(a) SWly (b) SEly (c) NEly (d) NWly**

✓ Correct Answer: (a) SWly — the SW Monsoon current comes from SW direction and is called SW Monsoon

✗ Distractors: NWly winds prevail over Malabar coast at lower levels, but the monsoon current itself is SWly.

💡 "SW Monsoon" = winds from SW direction. The name tells you the direction!

Q6. Monsoon period is:

(a) Jan to Feb (b) March to May (c) Jun to Sep (d) Oct to Dec

✓ Correct Answer: (c) June to September

✗ All other options are other seasons. Monsoon = Jun–Sep = 4 months delivering 75% of India's annual rainfall.

💡 "JJAS" = June July August September = SW Monsoon. Easy to remember as 4 consecutive months.

Q7. The monsoon advances with: (a) Bay of Bengal current only (b) Arabian Sea current only (c) Bay of Bengal and Arabian Sea currents

✓ Answer: (c) Bay of Bengal and Arabian Sea currents — The south-west monsoon advances in two branches: the Arabian Sea branch up the west coast and the Bay of Bengal branch towards Bengal and the north-east.

✗ (a) and (b) each name only one branch.

💡 Two branches: Arabian Sea and Bay of Bengal.

Q8. The rainfall over India during monsoon depends on:

(a) Low over Pakistan (b) Depression over Bay of Bengal (c) The position of the axis of Monsoon Trough

✓ Correct Answer: (c) Position of the axis of Monsoon Trough — the MT position controls rainfall distribution

✗ Distractors: (a) Low over Pakistan affects N India but doesn't control all India rainfall. (b) Depressions enhance rainfall but the MT position is the overarching control.

💡 MT normal position = Ganganagar–Allahabad–Kolkata–Head Bay. MT moves N = Break Monsoon.
MT normal = Active Monsoon.

Q9. Rainfall occurs all over the country during monsoon when the axis of MT is along the:
(a) Axis of MT is in its normal position along Gangetic plains (b) Foot hills of Himalayas (c) Depression formed over Bay of Bengal

✅ Correct Answer: (a) MT in normal position along Gangetic plains = widespread rainfall all over India

❌ Distractors: (b) MT at foot hills = Break Monsoon = heavy rain only in foothills; dry elsewhere. (c) Depression enhances but doesn't replace MT effect.

💡 MT position = rainfall switch: Normal position → active monsoon everywhere. Northward shift → Break Monsoon (only foothills get rain).

Q10. Break in monsoon occurs when the axis of the monsoon trough is along the:
(a) Gangetic plains (b) Foot hills of Himalayas (c) Bay of Bengal

✅ Correct Answer: (b) Foot hills of Himalayas — MT shifts northward → Break Monsoon

❌ Distractors: (a) MT along Gangetic plains = active/normal monsoon. (c) Bay of Bengal position is also active for Bay area.

💡 "Break = MT goes to the Hills." The trough retreats northward to the Himalayan foothills during a Break.

11. Master Reference Tables

IMD Four Seasons

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Season	Months	Key Feature
Winter / Cold Weather	Jan–Feb (Dec–Feb NW India)	STJ, WDs, fog, cold waves
Pre-Monsoon / Hot Weather	Mar–May	Dust haze, Norwesters, TS — most hazardous flying
SW Monsoon / Rainy	Jun–Sep	75% rainfall; two branches; MT governs distribution
Post Monsoon / NE Monsoon	Oct–Nov	Best flying (except S India); TN main rainy season

SW Monsoon Onset Dates

Location	Normal Onset Date
South Andaman Sea	20 May
Kerala	01 June
Mumbai	15 June
New Delhi	01 July
Entire India	08 July

SW Monsoon Withdrawal Dates

Region	Normal Withdrawal Date
Rajasthan	01 September
NW India	15 September
Almost all India	15 October

All Key Numerical Values

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Parameter	Value
Annual rainfall % in Jun–Sep	75%
Min annual rainfall (W Rajasthan)	<13 cm
Max rainfall (Mawsynram)	1187.3 cm (467.4 in)
Max rainfall (Cherrapunji)	1177.7 cm (463.7 in)
STJ height & latitude	~12 km, 27°N
STJ speed	80–100 kt (max 200 kt)
WDs per month in winter	5–7
Cold Day threshold	Max temp $\leq 16^{\circ}\text{C}$ in plains
Cold Wave threshold	Temp $\geq 4.0^{\circ}\text{C}$ below minimum normal
Cold Wave duration	2–3 days
TJ height & latitude	15–16 km, ~13°N
TJ speed	70–100 kt (max 150 kt)
Monsoon Trough — 700 hPa	Parallel to 22°N, Gujarat to Orissa
Monsoon Trough — 500 hPa	Around 10–15°N across S Peninsula
Subtropical cyclone location	60–80°E, 18–28°N, 500–700 hPa
Monsoon Dep frequency	2–3 per month
TN rainfall (post monsoon)	~49% annual rainfall; 60% coastal TN
Advection fog lifts by	1000–1100 hr IST
SW Monsoon forecast — April model error	5%
SW Monsoon forecast — June model error	4%
Regional model error	8%
DRW active hours	0900–1700 hr
Fog improvement timing (noon)	1000–2000 m visibility during noon

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Strength of Monsoon (Table 19.1)

Strength	Wind Speed Over Sea	Rainfall Over Land
Weak Monsoon	Up to 12 kt	<1½ times normal
Moderate Monsoon	13–22 kt	1½ to 2 times normal
Strong Monsoon	23–32 kt	1½ to 4 times normal
Vigorous Monsoon	>32 kt	>4 times normal