## CLIMATE OF INDIA

**Climate :**

- refers to the average of the weather conditions over a longer period of time. ( more than thirty years)

**Weather :**

- refers to the state of atmosphere over an area at any point of time.
- Weather is the momentary state of the atmosphere

**Climate of Any Place Affected by** ( Six Major Control Parameters )

- Latitude
- Altitude
- Distance from the sea
- Distribution of Land and Water
- Relief Factors
- pressure and winds
- Ocean Currents

**[UPSC 1997] Match List-I with List-II and select the correct answer:**

| List-I (Climatic conditions) | List-II (Reasons) |
|---|---|
| A. Madras is warmer than Calcutta | 1. North-east monsoon |
| B. Snowfall in Himalayas | 2. Altitude |
| C. Rainfall decreases from West Bengal to Punjab | 3. Western depressions |
| D. Sutlej-Ganga plain gets some rain in winter | 4. Distance from the sea |
| | 5. Latitude |

**Codes:**

a) A – 1; B – 2; C – 4; D – 5
b) A – 4; B – 5; C – 1; D – 3
c) A – 5; B – 2; C – 4; D – 3
d) A – 5; B – 1; C – 3; D – 4

[UPSC 2012] Consider the following statements:
1. The duration of the monsoon decreases from southern India to northern India.
2. The amount of annual rainfall in the northern plains of India decreases from east to west.
Which of the statements given above is/are correct?
a) 1 only
b) 2 only
c) Both 1 and 2
d) Neither 1 nor 2

**Discuss The Factors Which Determining The Climate Of India**
India's climate is controlled by a number of factors which can be divided into two groups:
**Factors Related to Location and Relief:**
**Latitude :**

- Air temperature generally decreases from the equator towards the poles.

- The Tropic of Cancer divides India, placing the northern part in the sub-tropical and temperate zones, and the southern part in the tropical zone
- The tropical zone being nearer to the equator, experiences high temperatures throughout the year with small daily and annual range. Area north of the Tropic of Cancer being away from the equator, experiences extreme climate with high daily and annual range of temperature.

Revise Notes

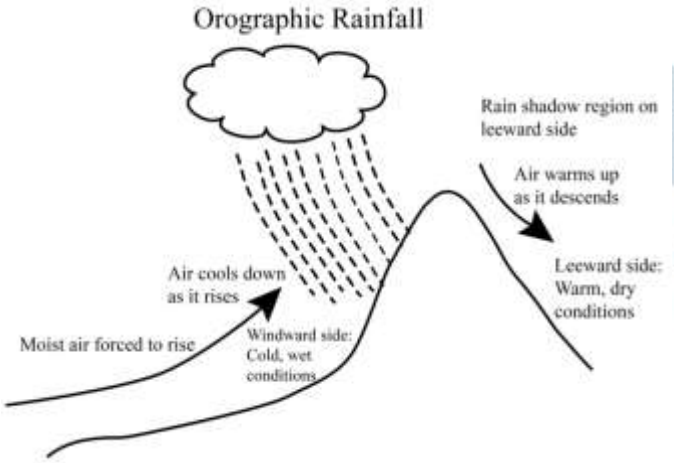
- Thermal Anamoly -Difference of observed temperature of place and mean temperature of latitude passing through that place.
- Annual Range of Temperature : refers to difference between average temperature of hot month and cold month of year is minimum near equator and increase towards poles but seasonal contrasts minimum at Equator and maximum at poles.

**Altitudes :**

- Elevated regions are cooler due to the decline in temperature with height.
- For example, Agra and Darjiling are located on the same latitude, but temperature of January in Agra is 16°°C whereas it is only 4°°C in Darjiling.
- The Himalayas prevent the cold winds from Central Asia to Indian subcontinent . therefore subcontinent experiences mild winters as compared to Central Asia. They also help trap the monsoon winds.

**Relief:**

- The physiography or relief of India also affects the temperature, air pressure, direction and speed of wind and the amount and distribution of rainfall
- . Eg. The windward side of the Western Ghats and Assam receives high rainfall during June-September whereas the southern plateau remains dry due to its leeward situation along the Western Ghats.






**Distribution of Land and Water:**

- Differential heating of land and sea (water heats up or cools down slowly) creates different air pressure zones in different seasons in the Indian subcontinent that cause reversal in the direction of monsoon winds.

**Distance from the Sea:**

- Sea exerts a moderating influence on climate.
- As the distance from the sea increases, its moderating influence decreases .
- continentality - very hot during summers and very cold during winters
- The coastal areas have a balanced climate and distant locations from the sea, experience more pronounced seasonal contrasts.

[UPSC 2005] Which one of the following is the correct sequence of Indian cities in the decreasing order, of their normal annual rainfall?
a) Kochi–Kolkata–Delhi–Patna
b) Kolkata–Kochi–Patna–Delhi
c) Kochi–Kolkata–Patna–Delhi
d) Kolkata–Kochi–Delhi–Patna
Ans b

**Factors Related to Air Pressure and Wind**

- Pressure and wind system of any area depend on the latitude and altitude of the place .This influence the temperature and rainfall pattern.
- India lies in the region of north easterly winds ( North east trade winds-origin: subtropical highpressure belt of the northern hemisphere; bring little or no rain.
- movement of Jet stream and upper air circulation and movement of different airmass
- Sub tropical Jet Stream in Winter Months of India
- Tropical Easterly jet Stream in Summer Months of India
- Western cyclonic disturbances (Rainfall caused by the westerly disturbances in winter) and Tropical cyclones (tropical depressions in south-west monsoon season.)
- The mechanism of these three factors can be understood with reference to winter and summer seasons of the year separately

**Describe the regional variations in the climatic conditions of India with the help of suitable examples.**

Despite India's uniform Monsoon climate, the regional variations in the country varies from place to place and season to season due to variations in temperature and precipitation.

Example :

- In some places of India, there is wide difference between day and night temperature .
- Ex- Thar Desert ( day temp upto 50degree C and nearly 15 degree C the same night)
- Less difference between day and night temperature in coastal regions (Kerala and ANI)
- Coastal areas experiences less contrasts in temperature conditions.
- Seasonal contrast are more the interior of the country
- On winter night, temperature at Drass in JK is very cold and Thiruvanthapuram may have 22 degree c.
- annual precipitation varies from over 400cm in Meghalaya to less than 10cm in Ladakh and Western Rajasthan
- Coromandal coast receive more rain during october to November
- there is decrease in rainfall from east to west in Northern Plains and Himalayas side .
- All these variations have given rise to variety in lives of people in terms of Food they eat, the clothes they wear and kind of houses they live in

Ex:

- Rajasthan Houses have thick wall ( do not allow heat to get in to houses)
- Rajasthan have Flat roofs ( to retain little water that comes as rain in desert)
- Sloping roofs in Terai region, Goa and Mangalore( receive heavy rainfall during monsoon)
- Houses in Assam are built on stilts because the state receives plentiful rainfall due to which there are chances of floods. so in order to avoid flooding of houses, houses are built on stilts and above the ground level.

So Inspite of these differences and variations the climate of India is monsoonal in rhythm and character

**SEASONS IN INDIA**

TRADITIONAL INDIAN SEASONS

- In the Indian tradition, a year is divided into six two-monthly seasons.
- However, this system does not match with the seasons of south India where there is little variation in the seasons.

| *Seasons* | *Months (According to the Indian Calendar)* | *Months (According to the Gregorian Calendar)* |
|---|---|---|
| Vasanta | Chaitra-Vaisakha | March-April |
| Grishma | Jyaistha-Asadha | May-June |
| Varsha | Sravana-Bhadra | July-August |
| Sharada | Asvina-Kartika | September-October |
| Hemanta | Margashirsa-Pausa | November-December |
| Shishira | Magha-Phalguna | January-February |

**The Climatic conditions of India can explain through annual cycle of seasons, which are four seasons**

- Cold weather season (Mid November to February)

- Hot weather season (March to May)
- Advancing Southwest monsoon season (June to September)
- Retreating monsoon season(October-November)

**WINTER**

- **Duration:** December to March.
- **Characteristics:** Winter varies across regions, with temperatures dropping significantly in northern and central India. December and January are the coldest months in North India (above Tropic of Cancer) . Temperature decrease from south to north. Northern and central India experiences cool to cold temperatures, while southern and coastal areas remain milder. Some northern states and mountainous regions experience snowfall.

- Sun apparent path is south of the equator ( SITCZ)
- January is the coldest month during this season.
- Dras Valley in Kashmir is the coldest region in India
- Days are warm and night are cold
- Diurnal range of temperature in interior parts is high
- Dry season for most part of the Country ;
- HP regions develops and light winds moving outwards from this area
- Anticyclonic conditions are formed in winter season when atmospheric pressure is high and air temperatures are low
- Winds start blowing from the northwestern high pressure zone to the low air pressure zone over the Indian Ocean in the south.
- Blow From Land to Sea
- North East Trade Winds Prevail in the Country (North-Westerly winds.)
- weather marked by clear skies, pleasant weather , low temperature, low humidity

**Jet Stream and Upper Air Circulation-**

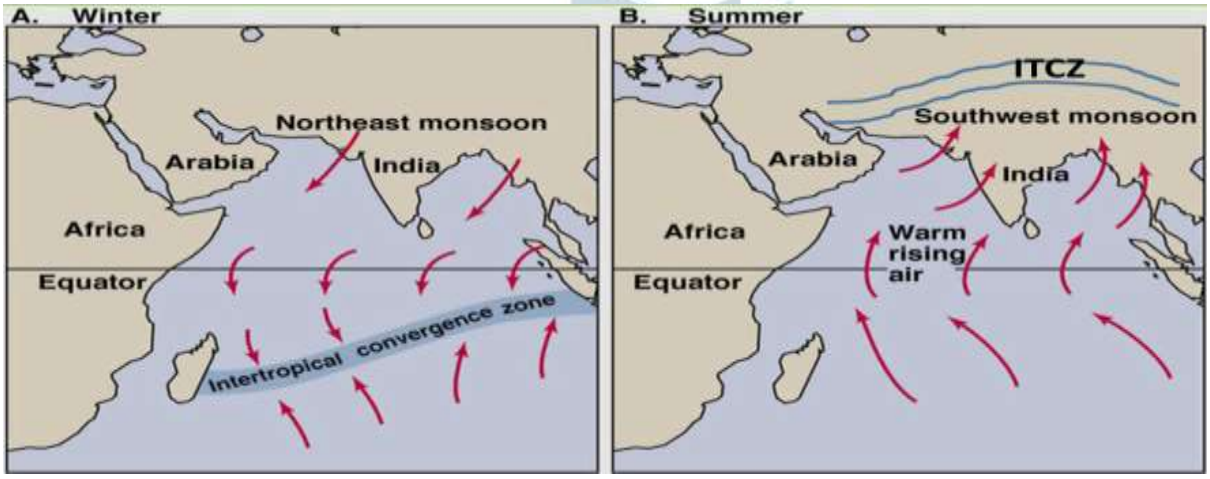
- During winters the SubTropical Westerly Jet Streams flowing across the Asian continent gets bifurcated at the Tibetan Himalayas.
- Branches: Northern branch blows north of the Tibetan highlands and southern branch blows in an eastward direction, south of the Himalayas.
- Southern branch has a significant influence on the winter weather


**Key Features of winter rainfall in India** :

- In Northern Plains Winter rainfall in the West and North West Region of India due to Western Cyclonic disturbances ( refers to Low Pressure systems originate over the Mediterranean Sea and Western Asia and move to India as westerly jetstream flow)

- They pick up the moisture from the Caspian Sea in the north and the Persian Gulf in the south and cause winter rainfall in North west India
- Total amount of winter rainfall called " mahawat" is small, but good for rabi crops
- rainfall region - northwestern India, Punjab, Haryana, Delhi and western Uttar Pradesh. It is in the form of snowfall in the lower Himalayas.
- Precipitation decreases from west to east in the plains and from north to south in the mountains
- The amount of rainfall gradually decreases from the north and north-west to the east
- Peninsular Region of India does not have a well defined cold season.( due to moderating influence of the sea and its equatorial proximity)
- Tamil Nadu coast experiences rain during winter . Rainfall occurs in Coromondal Coast bringing Bay of Bengal moisture towards it
- Northeast monsoon during October and November crosses over Bay of Bengal, picks up moisture and causes rainfall over the Tamil Nadu coast, southern Andhra Pradesh, southeast Karnataka and southeast Kerala.

**Inter-Tropical Convergence Zone (ITCZ)** is a **low-pressure** zone located at the equator where trade winds converge & tends to ascend. **In July**, the ITCZ is located around **20°N-25°N latitudes** (over the Gangetic plain), sometimes called the **monsoon trough** leading to development of thermal low over north and northwest India. Due to the shift of ITCZ, the trade winds of the southern hemisphere cross the equator and start blowing from **southwest to northeast** due to the Coriolis force. ITCZ moves southward in winter, and so the reversal of winds from northeast to south and southwest, takes place. They are called **northeast monsoons**.



| Feature | ITCZ in a Relatively Northern Position (e.g., July) | ITCZ in a Relatively Southern Position (e.g., January) |
|---|---|---|
| General Location | Generally located north of the equator. Maximum northward shift over land (e.g., over South Asia). | Generally located south of the equator. Maximum southward shift over land (e.g., over Southern Africa, Australia, South America). |
| Influence on Northern Hemisphere Tropics and Subtropics | Brings the wet season (summer monsoon in South Asia, wet season in parts of Central America and Africa north of the equator). Characterized by increased rainfall, cloudiness, and thunderstorms. | These regions experience the dry season as the ITCZ moves away to the south. |
| Influence on Southern Hemisphere Tropics and Subtropics | These regions generally experience the dry season as the ITCZ is located further north. | Brings the wet season (summer monsoon in parts of Australia, wet season in parts of Southern Africa and South America). Characterized by increased rainfall, cloudiness, and thunderstorms. |
| Driving Force | Follows the apparent northward movement of the sun, leading to maximum solar heating in the Northern Hemisphere. | Follows the apparent southward movement of the sun, leading to maximum solar heating in the Southern Hemisphere. |
| Trade Wind Convergence | Convergence of Northeast Trade Winds and Southeast Trade Winds occurs north of the equator. The Southeast Trade Winds may cross the equator and are deflected to the southwest due to the Coriolis force. | Convergence of Northeast Trade Winds and Southeast Trade Winds occurs south of the equator. The Northeast Trade Winds may cross the equator and are deflected to the northwest due to the Coriolis force. |
| Strength & Activity over Land | Often more pronounced and leads to more intense rainfall over large landmasses in the Northern Hemisphere due to greater land-sea temperature contrasts. | Can be pronounced over landmasses in the Southern Hemisphere during their summer, but the overall influence might differ due to the distribution of land and ocean. |
| Relationship to Monsoons | Directly linked to the development and intensity of Northern Hemisphere summer monsoons (e.g., Indian, West African). The northward shift of the ITCZ establishes the monsoon trough. | Associated with the development of Southern Hemisphere summer monsoons (e.g., Australian). The southward shift of the ITCZ brings rainfall to these regions. |

**SUMMER - HOT WEATHER SEASON**

- Duration: April to June.
- Characteristics: Hot and dry weather dominates most parts of India during summer. Temperatures can soar, especially in the northern and central regions, exceeding 40°C). Southern coastal areas are relatively milder.
- **Temperature**: During summer, temperatures can vary widely across India. In the northern plains, temperatures often exceed 40°C , while coastal areas are relatively cooler due to the moderating effect of sea.

- **Pressure**: The atmospheric pressure is relatively high during summer, especially in the northern and central parts of India.
- **Wind Patterns**: The summer season is characterized by the pre-monsoon winds, known as the 'Loo' in the northern plains. These hot, dry winds contribute to the elevated temperatures.
- **Mango Showers**: These are pre-monsoon showers that occur in some parts of southern and eastern India during late April to early June. These early rains are often associated with the ripening of mango trees and the onset of the monsoon season.
- There are also **Blossom Showers in Kerala** and Karnataka which are beneficial for coffee flowers.
- **Nor westers (Kalbaisakhi):** They are common in the northeastern states( Bardoli Cheerha in Assam) and West Bengal(Kalbaisakhi).
- Nor westers are pre-monsoon thunderstorms. They bring relief from the heat but can also cause damage due to strong winds and heavy rainfall.

The seasonal reversal of winds is the typical characteristic of
a) Equatorial climate b) Mediterranean climate
c) Monsoon climate
d) All of the above climates

**MONSOON CLIMATE OF INDIA**

- **Word Derived -** Arabic Word " Mausim" ( means season)
- **Define :** refers to the seasonal reversal shift in the prevailing wind direction during a year.
- **In Asia Monsoon climate mainly found in :** South Asia and South east Asia
- The Monsoon are experienced in the tropical area generally between 20 degree N and S.

**Mechanism of Monsoon :**

- **The Differential Heating and Cooling of Land and Water creates low pressure on the land mass of India while the seas around experience comparatively high pressure. ( Thermal concept of Sir Edmund Halley, in 1686. Large scale land and sea breezes )**
- **( Dynamic concept - Flohn - atmospheric circulation pattern ( planetary wind and pressure belts -contribute to monsoon behaviour)**
- **The Shift of the position of Inter Tropical Convergence Zone in Summer over the Ganga Plain - it is called as " Monsoon Trough " during the Monsoon Season . ( Air Mass theory )**
- **The Presence of HP area east of Madagascar ,approx 20 Degree South Over the Indian Ocean . The Intensity and position of this HP area affects the Indian Monsoon**
- **The Tibetan Plateau gets intensely heated during summer, which results in vertical air currents and the formation of LP over the plateau at about 9 km above sea level. (MONEX - Monsoon Experiment India and Russia)**
- **The movement of Westerly Jet Stream to the north of the Himalayas and the presence of tropical easterly jet stream over the Indian Peninsula during summer**
- **Change in Pressure conditions over the Southern Oceans also affects the Monsoons**

[UPSC 1996] High temperature and low pressure over the Indian subcontinent during the summer season draws air from the Indian Ocean leading to the in-blowing of the:
a) South-east monsoon
b) South-west monsoon
c) Trade winds
d) Westerlies

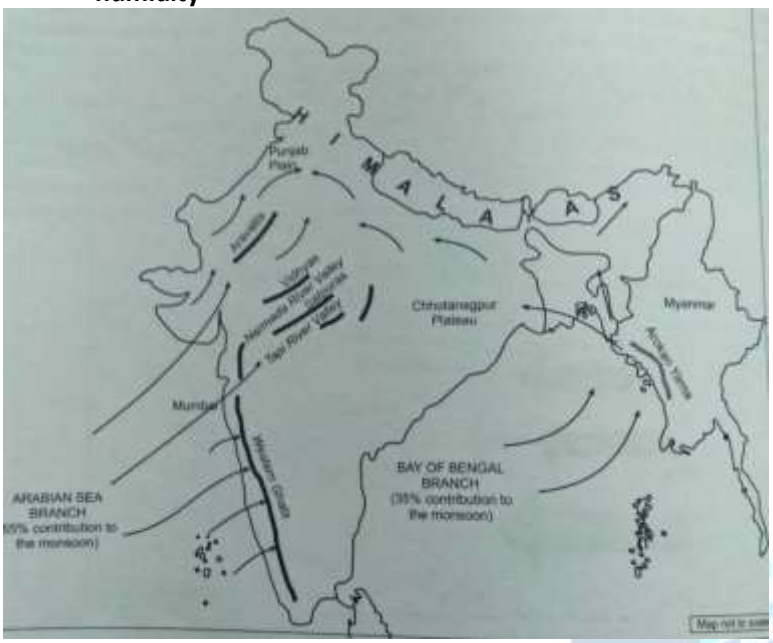
**SOUTH-WEST MONSOON SEASON**

- **called as " Advancing Monsoon " or The Rainy Season**
- Landmass in the north of Indian ocean gets intensely heated during April and May when the sun shines vertically over the Tropic of Cancer leading to formation of an intense low pressure in the northwestern part of the subcontinent.
- These conditions help in the northward shift in the position of the ITCZ.
- Shifting of the ITCZ is related to withdrawal of the westerly jet stream from its position (south of the Himalayas) over the north Indian plain.
- Low pressure cell attracts the Southeast trades across the Equator. These winds cross the Equator between 40°E and 60°E longitudes.

- The Easterly jet stream sets in along 15°N latitude only after the western jet stream has withdrawn. It is held responsible for the Monsoon's sudden burst
- Entry of the Monsoon into India: Coastal areas like Kerala, Karnataka, Goa, and Maharashtra typically experience this burst in the first week of June, while interior regions might witness it by the first week of July.

Two Branches : The monsoon approaches the landmass in two branches:

**The Arabian Sea branch is stronger than the Bay of Bengal branch. 65% of the humidity brought by the monsoon comes from the Arabian Sea whereas the monsoon coming from the Bay of Bengal contributes only 35% to the humidity**




**Arabian Sea Branch**

- The monsoon winds from the Arabian Sea ascend the Western Ghats' slopes, cooling down in the process and causing Orographic rainfall.
- After crossing the windward side, wind descends, warms up and loses moisture thus resulting in minimal rainfall on the leeward side of Ghats
- Another branch moves through the Narmada and Tapi river valleys, bringing rainfall to vast areas of central India. Eventually, these winds reach the Ganga plains and merge with the monsoon winds of the Bay of Bengal.
- The Chotanagpur plateau receives some rainfall from this branch
- The third branch hits the Saurashtra Peninsula and Kachchh, moving parallel to Aravallis producing limited rainfall.
- In Punjab and Haryana, it converges with the Bay of Bengal monsoon branch, producing rain in the western Himalayas

**Bay of Bengal Branch**

- Initially hits the Myanmar coast and parts of southeast Bangladesh.
- Arakan Hills along Myanmar's coast, redirects a significant portion of this branch towards the Indian subcontinent. Monsoon enters West Bengal and Bangladesh from the south and southeast.
- Influenced by the Himalayas and the thermal low in northwest India, this monsoon branch divides into two major streams:
- One stream moves westward along the Ganga plains, extending to the Punjab plains; The other heads north, traveling up the Brahmaputra valley, its sub-branch targets the Garo and Khasi hills in Meghalaya.
- Mawsynram (Khasi Hills) receives the highest average annual rainfall.
- The Tamil Nadu coast is situated parallel to and in the rainshadow area of the Bay of Bengal branch and Arabian sea branch respectively. It receives rain from the North East branch of retreating monsoon winds

The Monsoon is known for Uncertainties. Alternation of Wet and dry spells vary in intensity, frequency and duration.

**'Breaks' in Monsoon**

- If rain fails to occur for one or more weeks during the south-west monsoon period, it is known as a break in the monsoon

**Reasons :**

- due to movement of monsoon trough or ITCZ northwards or southwards determines the spatial distribution of rainfall.
- when axis of monsoon trough lies over the Plains, rainfall is good in these parts.
- When axis of monsoon trough shifts closer to Himalayas, there is dry spells in the plains and wetspells in near Himalayas
- And other factor When winds blow parallel to the west coast.

**Why The Tamil Nadu Coast Remains Dry During This Season.**

Reasons:

- The Tamil Nadu coast is situated parallel to the Bay of Bengal branch of southwest monsoon
- It lies in the rain-shadow area of the Arabian Sea branch of the south-west monsoon.

**ROLE OF TIBETAN PLATEAU AND FORMATION OF EASTERLY JET STREAM:**

- Tibet plateau plays a crucial role in initiating the monsoon circulation and the formation of the Tropical Easterly Jet (TEJ).
- Heating of Tibet Plateau develops Tropical Easterly Jet stream (flows from the Tibetan Plateau to Mascarene High in the Indian Ocean)
- the strengthening of Easterly Jet Stream (TEJ) increases rainfall pattern across India
- If there is snow cover in the plateau during winter , it leads in weaker monsoon due to reducing heating in subsequent summers.

**SOMALI JET STREAM**

- it is atmospheric phenomenon that occurs in Indian Ocean during summer months formed due to differential heating of land and ocean surfaces, which creates pressure differences .
- The heating of land areas, particularly over East Africa and the Arabian Peninsula, creates significant temperature differences between land and ocean surfaces. This difference generates pressure gradients that drive wind patterns.
- As the southwesterly monsoon winds cross the equator and move towards East Africa, they encounter the high mountain ranges of East Africa-Ethiopian Highlands).
- These mountains act as a barrier, blocking the low-level airflow. his blockage causes the air to be deflected and channeled northward along the eastern coast of Africa.(channelling effect)
- The presence of the Somali jet stream is crucial for the onset of the southwest monsoon in India
- The Somali Jet aids in driving southwest monsoons towards India by enhancing wind speeds and moisture availability.
- The Somali jet can also influence cyclonic activity in the Arabian Sea, leading to tropical cyclones that can impact coastal regions of India.

| Feature | Somali Jet Stream (Findlater Jet) | Tropical Easterly Jet (TEJ) |
|---|---|---|
| Altitude | Low-level jet stream, typically 1-1.5 km above sea level (lower troposphere) | Upper-level jet stream, around 6-9 km (upper troposphere, near 150 hPa) |
| Direction | Southwesterly over the Arabian Sea | Easterly (west to east) over peninsular India and northern Africa |
| Location | Originates near Madagascar, flows across East Africa and the Arabian Sea towards the west coast of India | Develops over southern Asia and northern Africa, centered around 15°N latitude |
| Timing | Strongest during the summer monsoon (June-September) | Present during the summer monsoon (June to early October) |
| Formation | Driven by strong pressure gradient between the Mascarene High and the monsoon low over northern India, channeled and accelerated by East African topography, influenced by Coriolis force after crossing the equator | Develops due to intense solar heating of the Tibetan Plateau, creating a temperature gradient between the plateau and the air over the Indian Ocean |
| Role in Monsoon | Transports moisture from the Arabian Sea to India, helps maintain the monsoon low, influences the onset and distribution of rainfall | Influences the upper-level circulation, helps in the development of low-pressure systems (monsoon depressions), its strength is linked to the intensity and distribution of monsoon rainfall |
| Hemisphere of Origin | Southern Hemisphere | Primarily Northern Hemisphere |

**JETSTREAMS**



**General Concepts:**

- **Upper Troposphere:** Location of jet streams.
- **Strong Winds:** High velocity air currents.
- **Zonal Flow:** Primarily west-to-east movement.
- **Meridional Flow:** North-south undulations (Rossby Waves).
- **Temperature Gradient:** Primary driving force.
- **Pressure Gradient:** Resultant force accelerating wind.
- **Coriolis Effect:** Deflects wind, crucial for westerly direction

**Specific Jet Streams:**

- **Subtropical Jet Stream (STJ):**
  - **Mid-latitudes (30-35°):** Typical location.
  - **Ferrel Cell Boundary:** Associated with this atmospheric cell.
  - **Westerly:** Direction of flow.
  - **Seasonal Shift:** Northward in summer, southward in winter.
  - **Monsoon Onset/Withdrawal:** Key influence over India.
  - **Western Disturbances:** Steering mechanism for winter rain/snow in India.

**Polar Jet Stream (PJS):**

- **High Latitudes (around 60°):** Typical location.

- **Polar Front:** Associated with strong temperature contrast.
- **Westerly:** Direction of flow.
- **Mid-latitude Cyclones:** Steering mechanism for temperate storms.
- **Rossby Waves:** Pronounced meandering pattern.

**Tropical Easterly Jet (TEJ):**

- **Tropical/Subtropical (around 15°N in summer):** Location over India/Africa.
- **Easterly:** Direction of flow.
- **Tibetan Plateau Heating:** Formation mechanism.
- **Summer Monsoon (India):** Crucial influence on intensity and distribution.
- **Monsoon Depressions:** Interaction with these low-pressure systems.
- **Vertical Wind Shear:** Potential impact on tropical cyclones.

Vertical wind shear refers to the change in wind speed and/or direction with altitude in the atmosphere

**Monsoon Connection (India Specific):**

- **STJ Retreat:** Northward shift allows monsoon onset.
- **TEJ Establishment:** Coincides with monsoon arrival.
- **TEJ Strength:** Correlates with monsoon rainfall intensity.
- **Jet Stream Interaction:** Overall influence on monsoon dynamics.

SUBTROPICAL JET STREAM (STJ) AND TROPICAL EASTERLY JET (TEJ) INFLUENCE ON INDIAN MONSOON

| Feature | Subtropical Jet Stream (STJ) | Tropical Easterly Jet (TEJ) |
|---|---|---|
| Altitude | Upper troposphere (around 9-16 km) | Upper troposphere (around 6-9 km) |
| Direction | Westerly (west to east) | Easterly (east to west) |
| Location (Summer) | Shifts north of the Himalayas | Over peninsular India, around 15°N latitude |
| Location (Winter) | South of the Himalayas, influences Western Disturbances | Generally absent over India |
| Formation | Temperature gradient between mid-latitudes and subtropics | Intense heating of the Tibetan Plateau creates upper-level high pressure |
| Influence on Monsoon Onset | Northward shift weakens its influence over India, allowing monsoon winds to establish. Considered a key indicator of monsoon onset. | Its establishment over India coincides with the onset of the monsoon. |

| | | |
|---|---|---|
| Influence on Monsoon Intensity & Rainfall | Its position and strength can influence the movement of monsoon depressions. | Its strength and position are linked to the intensity and distribution of monsoon rainfall. Weak TEJ can lead to deficient rainfall. |
| Influence on Weather Systems | Steers Western Disturbances during winter, bringing winter precipitation. | Influences the development and movement of monsoon depressions and potentially suppresses intense tropical cyclones in the Bay of Bengal due to vertical wind shear. |
| Seasonal Variation | Stronger and located further south in winter; weaker and shifts north in summer. | Develops and is strongest during the summer monsoon; weakens and disappears in winter. |

RETREATING (POST MONSOON ) MONSOON - Transition Period

- **Duration**: October to December.
- The retreating monsoon, also known as post-monsoon season, refers to the reversal of the wind pattern and the withdrawal of the southwest monsoon winds from the Indian subcontinent.
- **Onset**: The retreating monsoon season begins as the southwest monsoon winds, which brought widespread rainfall during the summer months, start to weaken and retreat.
- **Characteristics**: After the monsoon, the weather becomes more moderate, with decreasing rainfall. The temperatures start to drop, and humidity levels reduce.
- **Temperature**: Post-monsoon witnesses a gradual drop in temperatures across the country, marking the transition from the monsoon season to winter.
- **Pressure**: As the monsoon retreats, a high-pressure system begins to establish over northern India and the low pressure is removed.
- **Wind Patterns:** The retreating monsoon winds, known as the northeast monsoon, bring some rainfall to the southeastern coast. These northeast winds are commonly known as the northeasterly winds. However, overall wind patterns become calmer during this transition.
- **Rainfall:** The retreating monsoon primarily impacts the southern and eastern parts of India. Coastal areas along the Bay of Bengal, such as Tamil Nadu, Andhra Pradesh, and parts of Karnataka, experience rainfall during this period. These rains are crucial for the Rabi (winter) crop season.
- **Cyclonic Activity:** The withdrawal of the monsoon is often accompanied by the development of cyclonic systems in the Bay of Bengal. These cyclones can bring heavy rainfall to the eastern coastal areas.
- **October Heat**: The retreating monsoon season is characterized by clear skies, an increase in temperature and humidity, resulting in uncomfortable weather. This phenomenon is commonly referred to as the 'October heat.'
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| South-West Monsoon | North-East Monsoon |
|---|---|
| This season is from June to September. | This season starts from December and ends in February. |
| It does not rain continuously. There are rainless intervals in this season. | It does not possess any rainless intervals. |
| It blows in India as the Arabian Sea branch and Bay of Bengal branch. | It does not have any branches. |
| Major portion of annual rainfall in India is due to this type of monsoon. | Minor portion of the annual rainfall in India is due to this type of monsoon. |

**RAINFALL DISTRIBUTION OF INDIA**

- Rainfall decreases with increasing distance from the sea
- The average annual rainfall in India is about 125 cm with great spatial variations.

- High Rainfall Zones with rainfall over 200 cm: west coast, Western Ghats, and the sub-Himalayan areas in the northeast; Rainfall > 1000 cm in some parts of the Khasi and Jaintia hills; Brahmaputra valley and adjoining hills get slightly less, under 200 cm.
- Medium Rainfall Zones with rainfall between 100-200 cm: southern Gujarat, east Tamil Nadu, northeastern Peninsula covering Odisha, Jharkhand, Bihar, eastern Madhya Pradesh, northern Ganga plain along the sub-Himalayas and the Cachar Valley and Manipur
- Low Rainfall Zones with rainfall between 50-100 cm; western Uttar Pradesh, Delhi, Haryana, Punjab, Jammu and Kashmir, eastern Rajasthan, Gujarat, and the Deccan Plateau
- Inadequate Rainfall Zones with rainfall less than 50cm; Parts of the Peninsula, especially in Andhra Pradesh, Karnataka, Maharashtra, Ladakh, and most of western Rajasthan
- Snowfall: This phenomenon is limited to the Himalayan region.

**MONSOONS AND THE ECONOMIC LIFE IN INDIA**

- about 64 per cent people of India depend on agriculture for their livelihood and agriculture itself is based on southwest monsoon.
- Regional variations in monsoon climate help in growing various types of crops.
- Variability of rainfall brings droughts or floods every year in some parts of the country.
- Sudden monsoon burst creates problem of soil erosion over large areas in India.
- Winter rainfall by temperate cyclones in north India is highly beneficial for rabi crops
- Regional climatic variation in India is reflected in the vast variety of food, clothes and house types.

**BENEFITS OF MONSOON :**

- Direct Impact on India's economy
- Boost farm production and income and boost rural economy
- Stimulates demands for goods and services
- Increase agricultural output
- food security
- ground water recharge ( ground water conservation)
- hydropower generation
- Economic growth; GDP Increase ; Inflation control
- Mitigation of Droughts

ISSUES :

- Intense rainfall
- severe flooding in Urban areas
- Landslides
- crop damage , failures and food insecurity
- Drought conditions - in monsoon fails or arrives late
- Prolonged dry spells
- Intense storms

| MAJOR PHENOMENA INFLUENCING MONSOON RAINFALL | |
|---|---|
| Good Monsoon ( Normal Year ) | Bad Monsoon ( Abnormal Year) |
| La nina | El nino |
| Walker cell | Reverse walker cell |
| LNSO | ENSO |
| SOI + | SOI- |
| IOD+ | IOD- |

**Normal Conditions:**

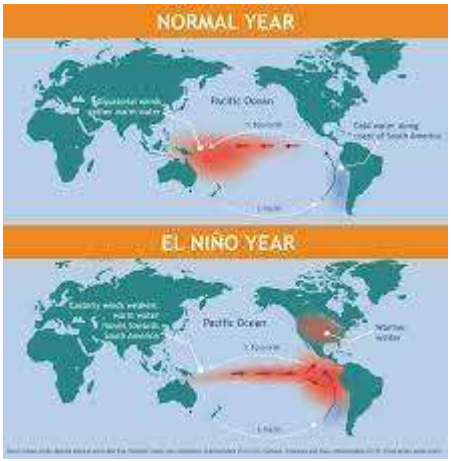
- warming and cooling of Pacific Ocean is key concern for India's Monsoon .

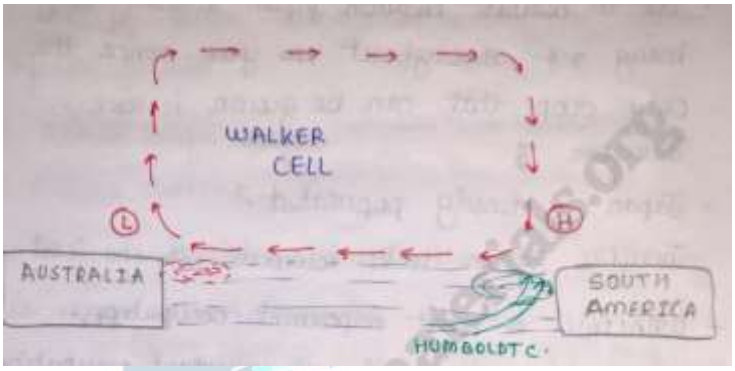
A Normal Year conditions :

- a sea surface LP area develops in the region of North Australia & Indonesia and HP system develops over the coast of Peru.
- As a result, the Trade winds over the pacific ocean moves strongly from east to west .
- The easterly flow of trade winds carries warm surface water westward, bringing convective storms ( thunderstorms) to Indonesia and coastal Australia.
- Along the Peru coast , cold bottom nutrient rich water wells up to the surface to replace warm water that is pulled to the west .

Normal Conditions :

- Warm water accumulation in Western Pacific and cold water upwelling in Eastern Pacific ocean bring thunderstorms in Western Pacific and Calm conditions in Eastern Pacific
- benefits to India for good monsoon due to warming of Western Pacific ocean and cooling of Eastern Pacific ocean



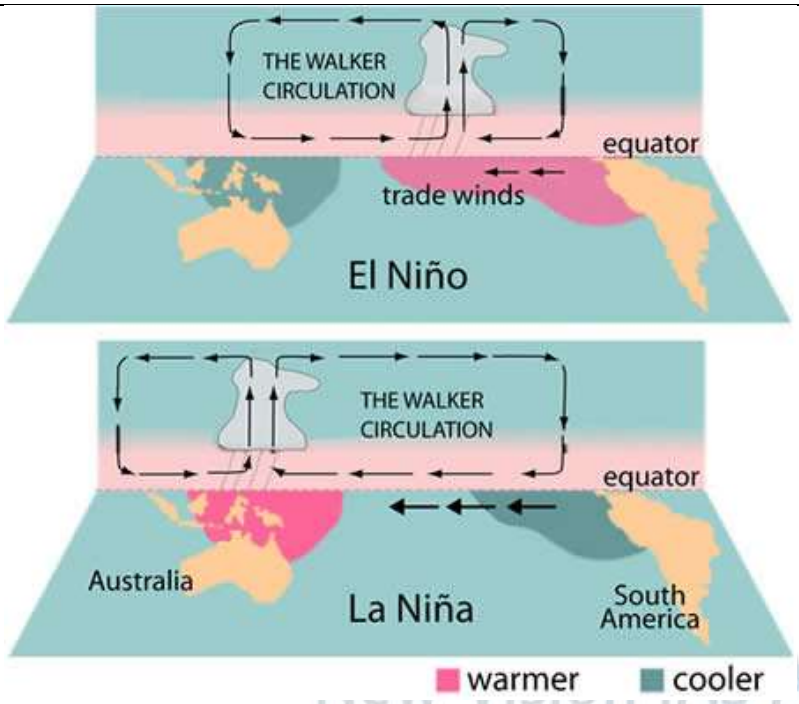

- Normal Year : Walker Cell or Circulation
- Abnormal Year : El Nino or Reverse Walker Circulation

**CONCEPT OF WALKER CIRCULATION ( WALKER CELL)**

- Atmospheric circulation pattern affecting tropical weather.
- it is atmospheric phenomenon describes the east west flow of air in the Tropics, particularly over the equatorial Pacific Ocean
- Walker Cell: A pressure gradient from east to west creates an air circulation from the Eastern Pacific i.e. along the coast of Peru-Chile to western Pacific (Australia-New Guinea).
- The pattern of low and high pressures gives rise to vertical circulation along the equator with its rising limb over low pressure area and descending limb over high pressure area. This is known as Walker Circulation
- Driving Force behind this circulation are primarily temperature and pressure gradient created by uneven heating of ocean waters.
- **caused by pressure gradient force that result from HP system over the eastern PO and LP system over Indonesia**
  good for India Monsoon ( like La Nina)

[UPSC 2002] For short-term climatic predictions, which one of the following events, detected in the last decade, is associated with occasional weak monsoon rains in the Indian subcontinent?
a) La Nina
b) Movement of Jet Stream
c) El Nino and Southern Oscillations
d) Greenhouse effect at global level

**Ans c** El Niño-related changes in wind patterns can weaken the Indian monsoon, leading to reduced rainfall over the subcontinent.




Only El Nino == [Warm water in Eastern Pacific + Cold water in Western Pacific].

**Concept of El Nino**

- complex weather system that appears once every three to seven years, bringing droughts, floods and other weather extremes to different parts of the World .
- The system involves oceanic and atmospheric phenomenon with the appearance of warm ocean current off the coast of Peru in the Eastern Pacific and affects weather in many places including India .
- Here Peruvian or Humboldt cold current temporarily replaced by warm current due to weak trade winds and altered atmospheric pressure systems
- This increases in sea surface temperature of water on Peruvian- Chile coast and brings rainfall in region and affects fish diversity ( warm water temp creates downwelling of nutrients )
- Weakening the trade winds in the Region

- Spanish word - Child Christ- because this current appears around Christmas in December.
- December is summer month in Peru ( Southern Hemisphere)
- Warming of central and eastern pacific Region is known as El nino

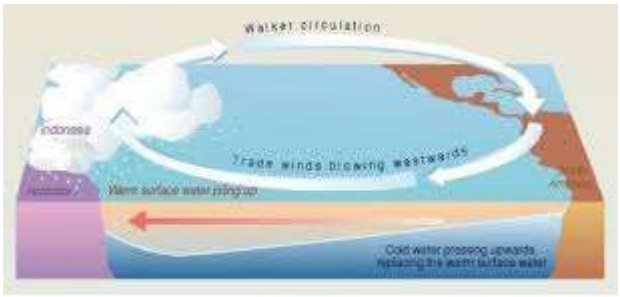
**EFFECTS OF - EL NINO**

- **heavy rainfall in drought region of Peru Chile coast and Atacama Desert**
- **Good for agriculture in Peru Chile Region but impacts fish Industry**
- **India , Australia , Indonesia - weak Monsoon and causes drought and forest fires**
- **Large scale bleaching of coral reefs in Australia**
- **Hp conditions in Indian ocean and western pacific ocean ( anticyclone conditions )**

- related with reverse walker cell

**Concept of - La Nina**

- Cold event - in Spanish called as " little girl"
- abnormal cooling of the ocean temperatures in eastern and central pacific region
- Cold Ocean Current in Eastern Pacific Ocean
- Heavy Rainfall in Australia, Indonesia and India
- LP in Indian Ocean
- abnormally heavy monsoons in India and Southeast Asia
- chances of cyclones in Indian Ocean
- Anticyclones in Pacific ocean
- cold winter in western Canada and North western USA
- winter drought in the southern USA
- called as Normal walker cell




(Southwest Climate Change Network, 2013)

| | El Nino Event | La Nina |
|---|---|---|
| Define | warming phase of the waters in the eastern Pacific, | cooling phase |
| Ocean Temp changes | Sea surface temperature increases in central and eastern pacific Ocean | Sea surface temperature decreases in central and eastern pacific Ocean |
| Trade Winds | Trade winds weak | Trade winds strengthen and pushing warmer waters further west |
| Weather conditions | Wetter conditions in eastern pacific region and dry in western pacific region | Wetter conditions in south east Asia and Australia and dry in eastern pacfic region |
| Historical context | Fisherman noticed warming ocean temperature called " boy child " | |
| | | Good for monsoons and cyclogenesis in the Bay of Bengal Suppressed cyclogenesis in the Arabian Sea |

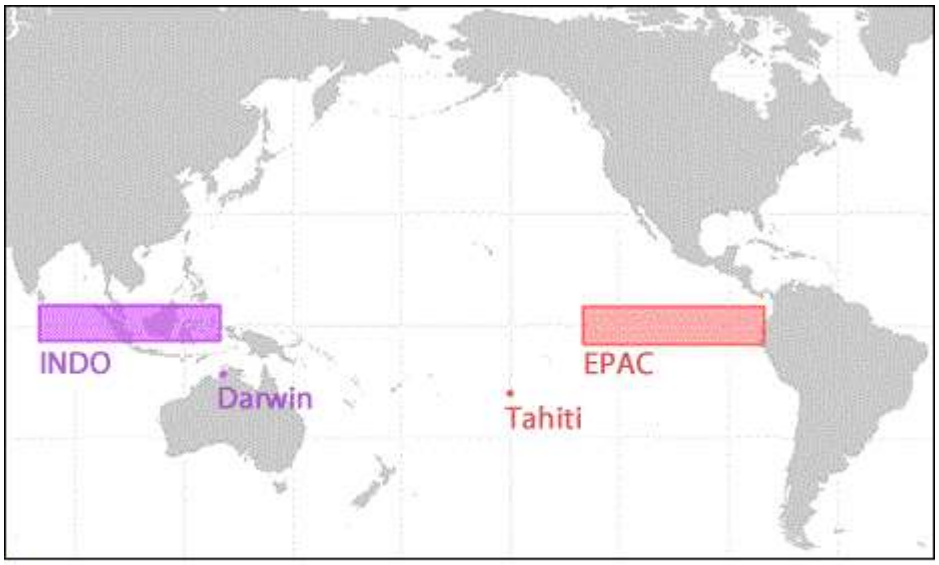
- Southern Oscillation: Periodic fluctuation of air pressure differences across tropical Pacific.
- Southern Oscillation Index: Measurement tool for assessing ENSO-related air pressure changes
- Indian Ocean Dipole: Variations in sea surface temperatures influencing regional climates.

**SOUTHERN OSCILLATION**:

- refers to atmospheric climatic phenomenon
- Periodic change in pressure conditions called as SO
- Sea Saw Effect of Walker Cell called Southern Oscillations
- (oscillation of low-pressure and high-pressure cells) between the eastern and western tropical Pacific Ocean
- Only SO == [Low Pressure over Eastern Pacific + High Pressure over Western Pacific
- refers specifically to the atmospheric component of the ENSO.

**SOUTHERN OSCILLATION INDEX - SOI :**

- term used to describe changes in air pressure, temperature, and sea surface temperatures between the Pacific and Indian Oceans
- Rainfall in India can be predicted by analyzing the positive and negative values of the SOI
- Southern Oscillation Index used to measure pressure difference between two location Tahiti in French Polynesia, Pacific Ocean 18 degree South and Darwin in North Australia about 12 degree South




**Source: http://www.climate.gov/news-features/understanding-climate/climate-variability-southern-oscillation-index**



- if the pressure difference were negative between two places - mean below average and late monsoons
- Positive SOI is good for Indian Monsoon
- When Walker circulation enters La Nina Phase - the SOI is positive
- When walker circulation enters it elnio phase, SOI is strongly negative
- A positive SOI value (> +7) indicates La Niña conditions.
- A negative SOI value (< -7) suggests El Niño conditions.
- La Nina Southern Oscillation: LNSO: Good For India/ Walker Cell: LP in Indian Ocean HP in Pacific Ocean
- El Nino Southern Oscillation : ENSO : Bad for India / Reverse Walker cell, HP in Indian Ocean and LP in Pacific Ocean

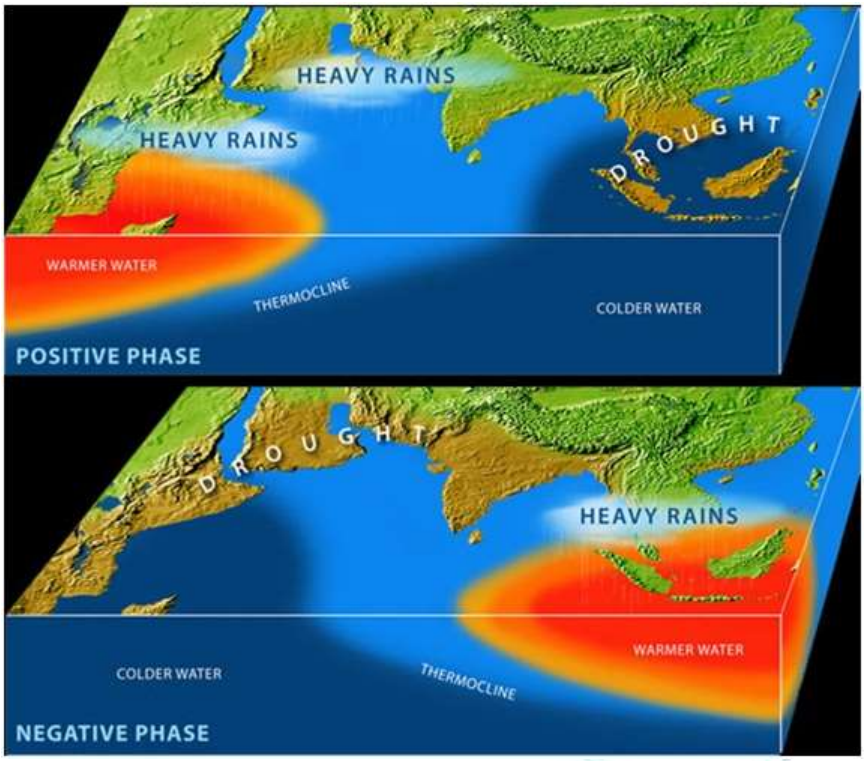
**El Niño–Southern Oscillation**

- Southern Oscillation coinciding with El Nino is called ENSO.
- refers to the large-scale ocean-atmosphere climate across Pacific Ocean
- ENSO encompasses both the oceanic and atmospheric interaction components of El Nino
- ENSO = [Warm water in Eastern Pacific + Low Pressure over Eastern Pacific] + [Cold water in Western Pacific + High Pressure over Western Pacific]

**Indian Ocean Dipole (IOD)**

- However, it was later discovered that just like ENSO was an event in the Pacific Ocean, a similar seesaw ocean-atmosphere system in the Indian Ocean was also at play
- it is climatic phenomenon ( discovered in 1999)
- is an atmosphere-ocean coupled phenomenon in the tropical Indian Ocean
- it has two poles: western pole in the Arabian sea ( western Indian Ocean ) and an eastern pole ( eastern Indian Ocean ) south of Indonesia
- involves fluctuations (difference ) in sea surface temperatures (SST) across the Western Indian Ocean near the Arabian Sea and the eastern counterpart near Indonesia in the Indian Ocean.
- Positive IOD is good for monsoon despite of an El Nino year

- Positive IOD: When the western part of the Indian Ocean experiences higher SSTs compared to that over the eastern Indian Ocean, it signifies a positive IOD, which tends to be conducive for the stronger than normal Indian monsoon.
- Conversely, a negative IOD phase results in weaker than normal Indian monsoon.




With reference to Indian Ocean Dipole . sometimes mentioned in the news while forecasting the Indian Monsoon, which of the following statements is/ are correct ? ( upsc 2017)
1. IOD phenomenon is characterised by a difference in sea surface temperature between Tropical Western Indian Ocean and tropical Eastern Pacific Ocean.

2. An IOD phenomenon can influence an El nino impact on the monsoon.

Select the correct answer :
1 only
2 only
both
none
Answer : B

In summary:
- Southern Oscillation: Periodic fluctuation of air pressure differences across tropical Pacific.
- Walker Cell: Atmospheric circulation pattern affecting tropical weather.
- Indian Ocean Dipole: Variations in sea surface temperatures influencing regional climates.
- Southern Oscillation Index: Measurement tool for assessing ENSO-related air pressure changes

[UPSC 2015] How far do you agree that the behaviour of the Indian monsoon has been changing due to humanizing landscapes? Discuss.
[UPSC 2017] What characteristics can be assigned to monsoon climate that succeeds in feeding more than 50 percent of the world population residing in Monsoon Asia?

## CLIMATIC REGIONS OF INDIA

**KOEPPEN'S CLASSIFICATION**:

- classification- On the basis of Latitude, Altitude and Natural Vegetation ,
- Although developed in 1918 and modified over a period of time, Koeppen's scheme is still popular and in use
- Used various letter symbols to denote climatic types on the basis distributional pattern of temperature and rainfall
- The capital letters : A,C, D and E delineate humid climates and B dry climates.
- The B- Dry Climates are subdivided using the capital letters S for steppe or semi-arid and W for deserts

Ex

Major Types:

| Capital Letter | Climate Types | Average Temperature |
|---|---|---|
| A | Tropical Climate | above 18°C throughout the year. |
| B | Dry Climate | S- Semi Arid and W - arid |
| C | Warm Temperate | Between 18°C and -3°C |
| D | Cool Temperate | Between 10°C and below -3°C |
| E | Ice Climates | Below 10°C |

The climatic groups are subdivided into types, designated by small letters, based on seasonality of precipitation and temperature characteristics.

The seasons of dryness are indicated by the small letters : f, m, w and s,

Small Letters : Sub types

- f -sufficient precipitation / corresponds to no dry season,
- m- monsoon climate
- w- winter dry season
- s- summer dry season
- h- dry and hot
- c- cool summer
- g - gangetic plain
- The small letters a, b, c and d refer to the degree of severity of temperature



| Main Climates | Precipitation | Temperature |
|---|---|---|
| A: equitorial | W:desert | h: hot arid |
| B: arid | S: steppe | k: cold arid |
| C: warm temperate | f: fully humid | a: hot summer |
| D: continental | s: summer dry | b: warm summer |
| E: polar | w: winter dry | c: cool summer |
| | m: monoonal | d: extremely continental |
| | | F: polar |
| | | T: polar |

**As per Koeppen's scheme, India comprises EIGHT distinct climatic regions.**


**Fig:** India: Climatic Region According to Koppen's Scheme

**Table:** Climatic Regions of India According to Koeppen's Scheme

**Table 4.1 : Climatic Regions of India According to Koeppen's Scheme**

| *Type of Climate* | *Areas* |
|---|---|
| Amw Monsoon with short dry season | West coast of India south of Goa |
| As – Monsoon with dry summer | Coromandel coast of Tamil Nadu |
| Aw – Tripical savannah | Most of the Peninsular plateaus, south of the Tropic of Cancer |
| BShw – Semi-arid steppe climate | North-western Gujarat, some parts of western Rajasthan and Punjab |
| BWhw – Hot desert | Extreme western Rajasthan |
| Cwg – Monsoon with dry winter | Ganga plain, eastern Rajasthan, northern Madhya Pradesh, most of North-east India |
| Dfc – Cold humid winter with short summer | Arunachal Pradesh |
| E – Polar type | Jammu and Kashmir, Himachal Pradesh and Uttarakhand |

**Table 12.2 : Climatic Types According to Koeppen**

| *Group* | *Type* | *Letter Code* | *Characteristics* |
|---|---|---|---|
| A-Tropical Humid Climate | Tropical wet | Af | No dry season |
| | Tropical monsoon | Am | Monsoonal, short dry season |
| | Tropical wet and dry | Aw | Winter dry season |
| B-Dry Climate | Subtropical steppe | BSh | Low-latitude semi arid or dry |
| | Subtropical desert | BWh | Low-latitude arid or dry |
| | Mid-latitude steppe | BSk | Mid-latitude semi arid or dry |
| | Mid-latitude desert | BWk | Mid-latitude arid or dry |
| C-Warm temperate (Mid-latitude) Climates | Humid subtropical | Cfa | No dry season, warm summer |
| | Mediterranean | Cs | Dry hot summer |
| | Marine west coast | Cfb | No dry season, warm and cool summer |
| D-Cold Snow-forest Climates | Humid continental | Df | No dry season, severe winter |
| | Subarctic | Dw | Winter dry and very severe |
| E-Cold Climates | Tundra | ET | No true summer |
| | Polar ice cap | EF | Perennial ice |
| H-Highland | Highland | H | Highland with snow cover |

Que : On what basis did Koeppen classified the climates of different regions of the world?

1. Latitude
2. Altitude
3. Vegetation

Select the correct code from the options given below:

**a) 1 and 3**
**b) 1 and 2**
**c) 3 only**
**d) 1,2 and 3**

**Que 2**

Which region of Rajasthan experience Aw type of climate as per Koeppen's climatic classification?

1. Southern most region
2. North Eastern region
3. Western region
4. Northern most region

**Q 3 :** Match the List

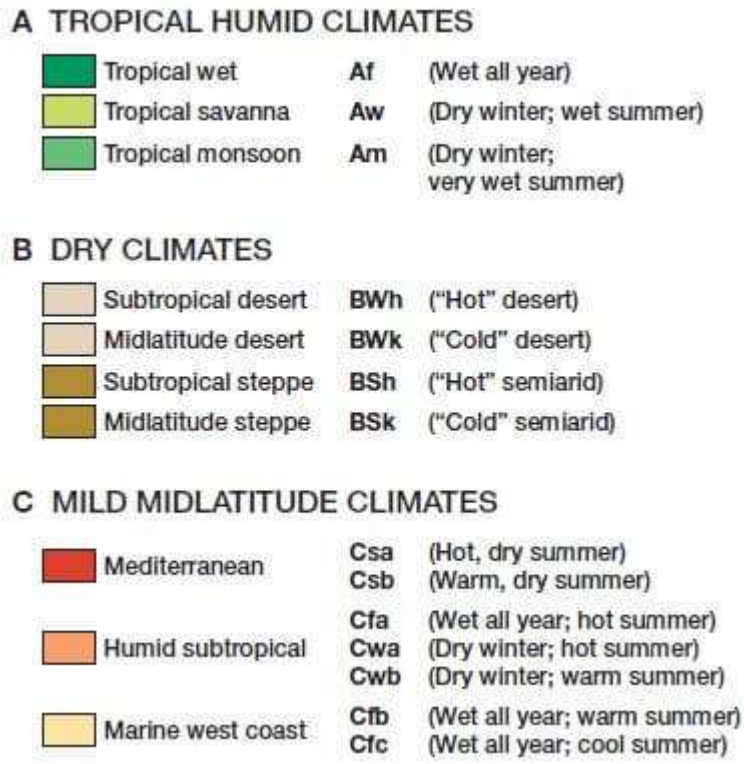
| Koeppen's Climate Region | Located In |
|---|---|
| As | Coromondal Coast |
| Bwhw | North West Gujarat |
| Dfc | Arunachal Pradesh |
| Amw | West Coast of India, SOuth of Goa |

**Q 4** According to Koeppen Climate the term " Aw" denoted as

a) Konkan Coast
**b) Peninsular Plateau**
c) Western Himalaya
d) Narmada Valley

**Q5** According to Koeppen Climate Classification, the climate of North Bihar or Great Northern Plains of India may be explained as

**a) Cwg**
b) Aw
c) Amw
d) As




**Q** The winter rains caused by Western Disturbances in North Western Plains of India gradually decrease from

a) East to West
**b) West to East**
c) North to SOuth
d) South to North

**Q** In Which of the following region, the rainfall variability is highest as compared to other three?

**a) Interior regions of Deccan Plateau**
b) Western Ghats
c) North Eastern Peninsular region
d) Uttarkhand and Himachal Pradesh

Q During the April June Months, the Peninsular region do not experience intense summer as compared to Northern region because of which of the following reason

a) There are many hill stations in the Peninsular region.
b) The Peninsular region is older than the Northern Plains o India
c) The Peninsula region is made up of Basaltic rocks
d) The Peninsula is surrounded by water from three sides

Q Where does the western cyclonic disturbances originate?

a) Arabian Sea
b) Bay of Bengal
c) Mediterranean sea
d) Black Sea

Q Which of the following region is not affected much by the Arabian Sea Branch of monsoon
a) Western Ghats
b) Deccan Plateau
c) Madhya Pradesh Basin
d) Chhatisgarh Plains

Q Which of the following Jet Stream mainly influences the mechanism of rainfall in the South West Monsoon season in India

a) Westerly Jet Stream
b) Polar Jet Stream
c) Tropical Easterly Jet Stream
d) None of the above

Q Which of the following wind system after crossing the equator , deflects to form the South West Monsoon Winds ?
a) North Eastern Trade Winds
b) South Eastern Trade Winds
c) Westerly Winds
d) Tropical Easterly Winds

Q What causes wind to deflect toward left in the Southern Hemisphere
a) Temperature
b) Magnetic Field
c) Rotation of the Earth
d) Pressure

Q Consider the Statements

1. Western disturbances are **storms that originate in the Caspian or Mediterranean Sea**, and **bring non-monsoonal rainfall to northwest India**
**2.** The disturbance **travels from the "western" to the eastern direction.**
**3.** These travel eastwards on high-altitude **westerly jet streams**

Select the correct code :
a) 1 and 2
b) 2 only
c) 1, 2 and 3
d) None