Climate of India [UPSC Geography Notes]

Climate of India

The Climate of India is “monsoon” type which is found mainly in South-Asia and South-East Asia. The word “monsoon” is derived from the Arabic word “mausim” which means seasons. Originally, the word “monsoon” was used by Arab navigators several centuries ago, to describe a system of seasonal reversals of winds along the shores of the Indian Oceans, especially over the Arabian Sea, in which the winds blow from south-west to north-east during the summer season and from north-east to south-west during the winter season. In other words, monsoons are periodic (seasonal) winds in which there is a complete reversal of the wind direction after every six months.

Weather and Climate

- Weather refers to the state of the atmosphere over an area at any point in time while Climate refers to the sum total of weather conditions and variations over a large area for a long period of time (more than 30 years).
- Weather is the momentary state of the atmosphere and it changes quickly (within a day or week) but climate changes imperceptively and may be noted after 50 years or even more.
- The elements of weather and climate are the same i.e, atmospheric pressure, temperature, humidity, wind and precipitation.
- On the basis of the generalised monthly atmospheric conditions, the year is divided into seasons e.g, winter, summer or rainy.
- Though the climate of India is monsoon type, there are regional variations in climatic conditions within the country. These regional variations may be described as sub-types of monsoon climate.
    - **Regional variations in Temperature** – Churu (Rajasthan) may record a temperature of 50℃ or more on a June day while the mercury hardly touches 19℃ in Tawang (Arunachal Pradesh) on the same day. The temperature may drop down to -45℃ in Drass (Ladakh) while Thiruvananthapuram or Chennai may record 20℃ or 22℃ on the same day.
    - **Regional variations in Precipitation and its Amount** – It snows in the Himalayan regions while the rest of the country gets rains. Cherrapunji and Mawsynram in the Khasi Hills (Meghalaya) receive rainfall over 1080 cm in a year while Jaisalmer (Rajasthan) rarely gets more than 9 cm of rainfall during the same period.
- Despite these differences and variations, the climate of India is monsoonal in rhythm and character.

Factors determining the Climate of India

The factors which determine the climate of a place can be broadly classified into two:

1. Factors related to location and relief
2. Factors related to air pressure and winds

Factors related to location and relief

1. **Latitude** – The Tropic of Cancer passes through the middle of the country from the Rann of Kachchh in the west to Mizoram in the east. Almost half of the country lying south of the Tropic of Cancer lies in the Tropical zone and the northern part of India lies in the sub-tropical and temperate zone. The tropical zone is nearer to the equator and therefore experiences high temperatures throughout the year with a small daily and annual range. The area north of the tropic of cancer being away from the equator experiences an extreme climate with a high daily and annual range of temperature.
2. **The Himalayan Mountains** – The lofty Himalayan mountains in the north act as an effective climate divide. These mountains provide a shield against the cold northern winds which originate near the Arctic Circle and blow across central and eastern Asia. It is because of these mountains that this subcontinent experiences comparatively milder winters as compared to Central Asia. These mountains also trap the monsoon winds forcing them to shed their moisture within the subcontinent.
3. **Distribution of land and water** – India is surrounded by water bodies on three sides in the south and is girdled by a high and continuous mountain wall in the north. Water heats up and cools down quickly as compared to land. This differential heating creates different air pressure zones in different seasons in and around the subcontinent. This difference in air pressure causes a reversal in the direction of monsoon winds.
4. **Distance from the sea** – The sea exerts a moderate influence on climate. As the distance from the sea increases, its moderating influence decreases and such regions have extreme weather conditions. This condition is known as continentality i.e, very hot summers and very cold winters.
5. **Altitude –** The places in the mountains are cooler than the places on the plains because with the increase in height temperature decreases. Though Agra and Darjeeling are located at the same latitude, the temperature in January in Agra is 16℃ whereas it is only 4℃ in Darjeeling.
6. **Relief –** The physiography or relief of India also affects the temperature, air pressure, direction and speed of the wind and, the amount and distribution of rainfall. The windward sides of Western Ghats and Assam receive high rainfall during June and September whereas the southern plateau remains dry due to its leeward situation along the Western Ghats.

Factors related to air pressure and wind

The climate and associated weather conditions in India are governed by the following atmospheric conditions:

1. Distribution of air pressure and winds on the surface of the earth.
2. Upper air circulation caused by factors controlling global weather and the inflow of different air masses and jet streams.
3. The inflow of western cyclones generally known as disturbances during the winter season and tropical depression during the southwest monsoon period into India, creating weather conditions favourable to rainfall.

Mechanism of weather in the winter season –

1. **Surface pressure and winds**
    a. In winter, the weather conditions over India are greatly influenced by the distribution of pressure in Central and Western Asia.

   b. During winter, a high-pressure centre develops in the region lying to the north of the Himalayas. This high-pressure area gives rise to the flow of air at the low level from the north towards the Indian subcontinent (south of the Himalayan mountain range).
   c. These high-pressure surface winds blow over Central Asia and reach India in the form of a dry continental air mass. These continental winds come in contact with trade winds over north-western India.
   d. Occasionally, the contact zone may shift its position as far east as the middle Ganga valley.
   e. Thus, the entire region of northwestern and northern India up to the middle Ganga valley comes under the influence of dry northwestern winds.

2. **Jet stream and upper air circulation**
   a. The upper air circulation is dominated by a westerly flow.
   b. Western and Central Asia remain under the influence of westerly winds along the altitude 9-13 km (Troposphere) from west to east.
   c. These winds blow across the Asian continent at latitudes north of the Himalayas roughly parallel to the Tibetan Highlands.
   d. These are known as Jet streams and are located approximately over 27°-30° North latitude, therefore also known as subtropical westerly jet streams.
   e. In the winter season, the upper air westerly jet streams are bifurcated into two branches due to physical obstruction of the Himalayas and the Tibetan Plateau.
   f. One branch blows to the north of the Tibetan highlands while the southern branch blows in an eastward direction, south of the Himalayas. This southern branch of the jet stream exercises a great influence on the winter weather in India. (Jet Stream – narrow belts of high altitude westerly winds in the troposphere. Their speed varies from about 110 km/hr in summer to about 184 km/hr in winter).
3. **Western cyclonic disturbance and tropical cyclones**
   a. The western cyclonic disturbances are weather phenomena of the winter months brought in by the westerly flow from the Mediterranean region.
   b. They usually influence the weather of the north and north-western regions.
   c. Tropical cyclones originate over the Bay of Bengal and the Indian Ocean.
   d. These disturbances are part of the easterly flow and hit the coastal regions of the country (Tamil Nadu, Andhra Pradesh and Odisha coast).
   e. Most of these cyclones are very destructive due to high wind velocity and torrential rains accompanying them.

Mechanism of weather in summer season

1. **Surface pressure and winds**
   a. During the summer season, the sun shifts northwards and the wind circulation over the subcontinent undergoes a complete reversal at the lower as well as upper levels.
   b. The Inter-Tropical Convergence Zone (ITCZ), which is the low-pressure belt near the surface, shifts to the north (roughly parallel to the Himalayas between 20°N and 25°N) by the middle of July.
   c. The westerly jet streams also withdraw from the Indian region at about the same time.
   d. Meteorologists have found an inter-relationship between the northward shift of the equatorial trough (ITCZ) and the withdrawal of the westerly jet stream from over the North Indian plain.

   e. It is believed that there is a cause and effect relationship between the two. The ITCZ being a zone of low pressure, attracts an inflow of winds from different directions.
   f. The maritime Tropical air mass (mT) from the southern hemisphere, after crossing the equator, reaches the low-pressure area in the general south-westerly direction. It is this moist air current that is popularly known as the southwest monsoon.
2. **Jet streams and upper air circulation**
   a. An easterly jet stream flows over the southern part of the peninsula in June and has a maximum speed of 90 km/hr. In August it is confined to 15°N latitude and in September up to 22°N. These easterly jet streams do not extend to the north of 30°N latitude in the upper atmosphere.
3. **Easterly jet streams and tropical cyclones**
   a. The Easterly jet streams steer the tropical depressions into India.
   b. These depressions play a significant role in the distribution of monsoon rainfall over the Indian subcontinent.
   c. The tracks of these depressions are the areas with the highest rainfall in India.
   d. The frequency at which these depressions visit India, their direction and their intensity determine the rainfall pattern during the southwest monsoon period.

The Inter-Tropical Convergence Zone (ITCZ) is a broad trough of low pressure in equatorial latitudes. Here the north-east and south-east trade winds converge and air tends to ascend. This convergence zone lies almost parallel to the equator but moves north or south with the apparent movement of the sun. In July, ITCZ is located around 20°N – 25° N latitude, over the Gangetic plain and is also called the monsoon trough. This monsoon trough enhances the development of thermal low over north and north-west India. Due to this shift of ITCZ, the trade winds of the Southern Hemisphere cross the equator between 40°E and 60°E longitude and start blowing from south-west to north-east due to the Coriolis force and give rise to the south-west monsoon. The ITCZ moves to the Southern Hemisphere in winter which causes reversal of winds from north-east to south and south-west. These are called north-east monsoons.

Indian Monsoon

The monsoons are experienced in the tropical area roughly between 20°N and 20°S. The following facts help in understanding the **mechanism of the monsoons in India –**

1. The differential heating and cooling of land and water (land heats up and cools down faster than water) creates a pressure difference. The movement is from high pressure to low pressure.
2. The ITCZ positions itself over the Ganga plain in summer (normally 5°N of the equator) and is called the monsoon trough.
3. There is a high-pressure area, east of Madagascar, approximately at 20°S over the Indian Ocean. The position and intensity of this high-pressure area affect the Indian monsoon.
4. During summer, the Tibetan plateau heats up intensely, develops low pressure over it at about 9 km above sea level and results in strong vertical air currents.
5. The movement of westerly jet streams and tropical easterly jet streams also influence the monsoon of India.
6. **Southern Oscillations and El-Nino**
   1. The change in the pressure conditions over the southern oceans also affect the monsoon.

2. Normally when the tropical eastern south Pacific Ocean experiences high pressure, the tropical eastern Indian Ocean has low pressure over it.
3. But in certain years, there is a reversal in the pressure conditions and the eastern Indian Ocean has high pressure in comparison to the eastern Pacific ocean.
4. This periodic change in pressure conditions is called Southern Oscillations (SO).
5. The pressure difference over Tahiti (Pacific Ocean, 18°S/149°W) and Darwin in northern Australia (Indian Ocean, 12°30´S/131°E) predict the intensity of monsoons.
6. If the pressure difference is negative, it indicates below average and late monsoons.
7. South Oscillations is the precursor to the occurrence of an El-Nino phenomenon which is the development of a warm ocean current along the coast of Peru (in the eastern Pacific) as a temporary replacement of the cold Peruvian current.
8. El-Nino is a Spanish word meaning “the child” and refers to the baby Christ as this current starts flowing during Christmas. This El Nino phenomenon leads to an increase in sea surface temperature and therefore, weakened trade winds in the region.
9. El-Nino is used in India for forecasting long-range monsoon rainfall. In 1990-91, there was a wild El-Nino event and the onset of southwest monsoon was delayed over most parts of the country ranging from 5-12 days.

Also read: El-Nino, La-Nina & ENSO

Monsoons [Onset and Withdrawal]

- The differential heating of land and sea during the summer months is responsible for the monsoon winds to drift towards the subcontinent.
    - The sun shines vertically over the Tropic of Cancer during April and May and the large landmass in the north of the Indian ocean gets intensely heated which results in the formation of intense low pressure in the north-western part of the subcontinent.
    - As the pressure in the Indian ocean in the south of the landmass is high (water gets heated slowly), the low-pressure region attracts the south-east trade winds across the equator.
    - These factors help in the northward shift in the position of ITCZ. The south-west monsoon is thus the continuation of the south-east trades deflected towards the Indian subcontinent after crossing the equator.
    - These winds cross the equator between 40°E and 60°E longitude.
    - The shift in the position of ITCZ is also related to the phenomenon of the withdrawal of the westerly jet stream from its position over the north Indian plain, south of the Himalayas.
    - The easterly jet stream sets in along 15°N latitude once the western jet stream has withdrawn itself from the region.
    - This easterly jet stream is considered to be responsible for the burst of monsoon in India.
- The south-west monsoon sets in over the Kerala coast by 1st June and subsequently it proceeds into two – the Arabian branch and the Bay of Bengal branch.
    - The Arabian branch reaches Mumbai about ten days later (approximately 10th June).
    - The Bay of Bengal branch also advances rapidly and arrives in Assam in the first week of June.

- The lofty mountains cause the monsoon winds to deflect towards the west over the Ganga plains. By mid-June, the Arabian Sea branch of the monsoon arrives over Saurashtra-Kachchh and the central part of the country.
- Both branches of the monsoon merge over the north western part of the Ganga plains.
- Delhi generally receives the monsoon showers from the Bay of Bengal branch by the end of June (approx. 29th June).
- By the first week of July, western Uttar Pradesh, Haryana, Punjab and eastern Rajasthan experience the monsoons. By mid-July, the monsoon reaches Himachal Pradesh and the rest of the country.

Image source: NCERT

- Breaks in the monsoon – During the monsoon when it rains for a few days and then, if the rains fail to occur for one or more weeks, it is known as a break in the monsoon. These dry spells in different regions are due to different reasons:
    - In northern India, rains are likely to fail if the rain-bearing winds are not very frequent along the monsoon trough (ITCZ).

- Over the west coast, the dry spell is associated with days when winds blow parallel to the coast.

- Retreating Monsoon – By early September, monsoon begins to withdraw from the north-western states of India. From the northern half of India, it withdraws completely by mid-october.
  The withdrawal from the southern half of the peninsula is fairly rapid. By early December, the monsoon withdraws from the rest of the country.

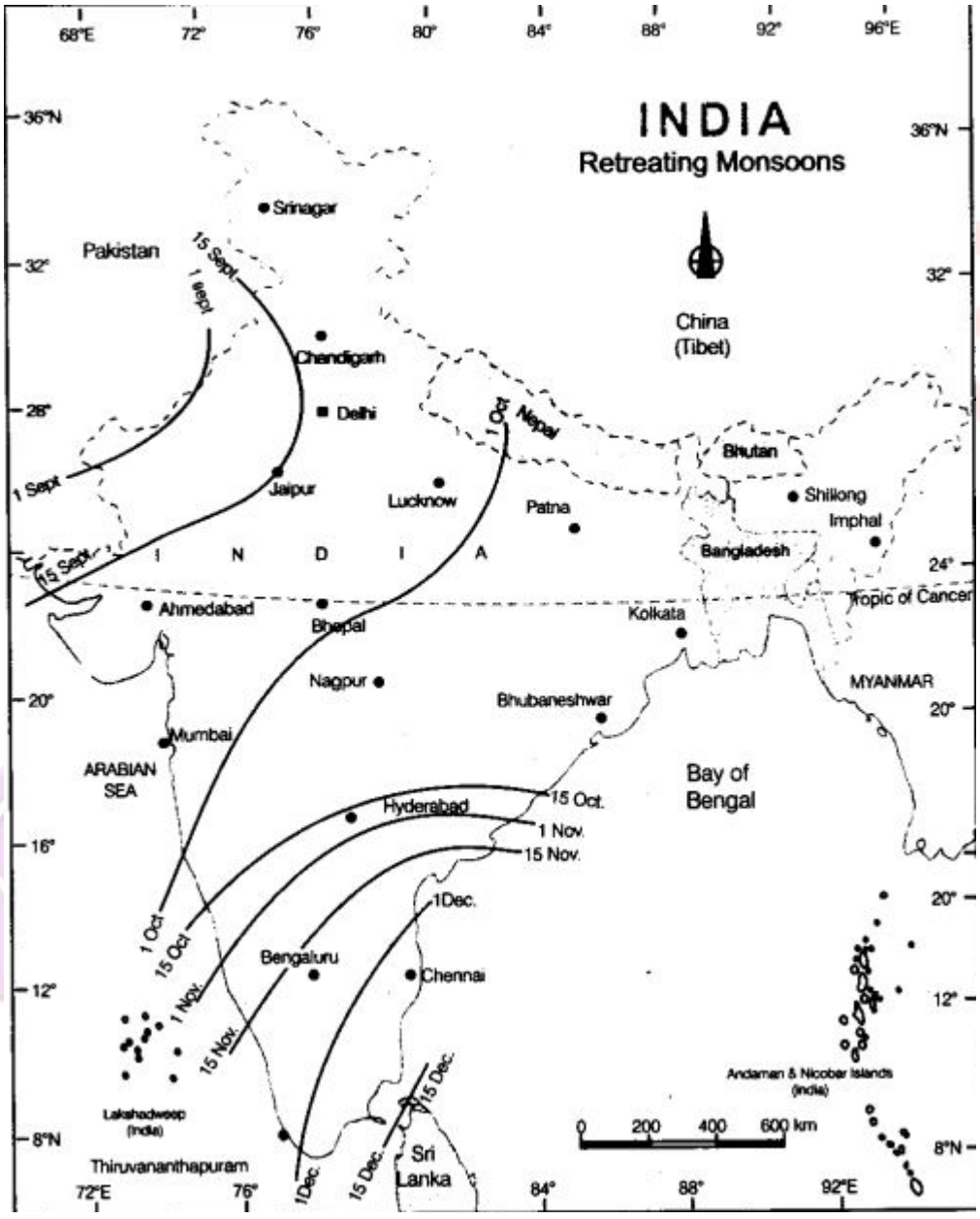

Image source: NCERT

Seasons in India

The subcontinent of India has great latitudinal dimensions. There are different seasons from Kashmir to Kanyakumari. The meteorologists, however, recognise, the following four seasons –

1. The cold weather season, Winter season
2. The hot weather season, Summer season
3. The south-west monsoon season/Rainy season
4. The retreating monsoon season

The Cold Weather Season (Winter)

- The cold weather season begins from mid-November in northern India and stays till February. December and January are the coldest months in the northern part of India. During the winter season, there is a general decrease in temperature from south to north. Days are warm and nights are cold. Frost is common in the north and the higher slopes of the Himalayas experience snowfall.
- Due to the moderating influence of the sea and proximity to the equator, the peninsular region of India does not have any well defined cold weather season. There is hardly any seasonal change in the distribution pattern of the temperature in coastal areas.
- During the winter season, north-east trade winds prevail over the country. As they blow from land to sea, therefore for most parts of the country, it is a dry season. However, rainfall occurs on the Tamil Nadu coast from these winds, as they blow from sea to land.
- By the end of December (22nd December), the sun shines vertically over the Tropic of Capricorn in the Southern Hemisphere. In the northern part of the country, a feeble high-pressure region develops, with light winds moving outwards from this area. Influenced by the relief, these winds blow through the Ganga valley from the west and the north-west. The weather is normally marked by clear skies, low temperatures, low humidity and feeble, variable winds.
- A characteristic feature of the cold weather season over the northern plains is the inflow of cyclonic disturbances from the west and the northwest. These disturbances originate from over the east Mediterranean sea and travel eastwards across West Asia, Iran, Afghanistan and Pakistan before they reach north-western parts of India. They cause much-needed rains over the plains and snowfall in the mountains. Although the amount of rainfall is small, they are of immense importance for the cultivation of Rabi crops.

The Hot Weather Season

- The apparent northward movement of the sun towards the Tropic of Cancer in March results in the rise of temperature in north India. April, May and June are the summer months in north India. In March, the highest temperature is about 38°C, recorded on the Deccan plateau. In April, temperatures in Gujarat and Madhya Pradesh are around 42°C. In May, a temperature of 45°C is common in the north-western part of the country.
- In Peninsular India, the moderating influence of the oceans keeps the temperatures lower than that prevailing in north India and remain between 20°C and 32°C. Due to altitude, the temperature in the hills of Western Ghats remains below 25°C.

- The Inter Tropical Convergence Zone (ITCZ) moves northwards due to increased temperature. This elongated low-pressure monsoon trough extends over the Thar desert in the north-west to Patna and Chotanagpur plateau in the east and south-east. The ITCZ attracts a surface circulation of the winds which are southwesterly on the west coast as well as along the coast of West Bengal and Bangladesh. They are easterly or south-easterly over north Bengal and Bihar. These currents of south-westerly monsoon are actually displaced equatorial westerlies. The influx of these winds by mid-June brings about a change in the weather towards the rainy season.
- A striking feature of the hot weather season is the “loo”. These are strong, gusty, hot, dry winds blowing during the day over the north and north-west India and sometimes they even continue until late in the evening. Dust storms in the evening are very common during May in Punjab, Haryana, eastern Rajasthan and Uttar Pradesh. These temporary storms bring some respite from the oppressing heat since they bring along light rains and a pleasant cool breeze. This is also the season for localised thunderstorms, associated with violent winds, torrential downpours, often accompanied by hail. In West Bengal, these storms are known as the “Kaal Baisakhi”. These showers are helpful for tea, jute and rice cultivation. In Assam, these storms are called “Bardoli Chheerha”.
- Towards the end of summer, there are pre-monsoon showers which are common phenomena in Kerala and coastal areas of Karnataka. They are known as “Mango showers” as they help in the ripening of mangoes.

South-West Monsoon Season/Rainy Season

- The low-pressure conditions over the north-western plains get intensified due to increasing temperature. By early June, the low pressure attracts the trade winds of the Southern Hemisphere coming from the Indian ocean. The south-east trade winds cross the equator and follow a south-westerly direction (that is why they are known as south-west monsoons). These winds enter the Bay of Bengal and the Arabian sea and while passing over the equatorial warm currents they pick up moisture in abundance.
- The sudden onset of moisture-laden winds together with violent thunder and lightning is often termed as the “break” or “burst” of monsoons. In the coastal area of Kerala, Karnataka, Goa and Maharashtra the monsoon burst occurs in the first week of June while in the interior regions of the country it may be delayed to the first week of July.
- The monsoon approaches the landmass in two branches – the Arabian sea branch and the Bay of Bengal branch.
- The Arabian sea branch – The Arabian sea branch splits into three parts:
    - One branch of the Arabian sea strikes the Western Ghats and these winds climb the slopes of Western Ghats from 900 – 1200m. Soon, these winds become cool and the windward side of the Sahyadris and western coastal plain experiences very heavy rainfall (between 250 cm and 400 cm). After crossing the Western Ghats, these winds descend and heat up which reduces the humidity in the winds. This leads to scanty rainfall east of the Western Ghats and this region is called the rain shadow area.
    - A second branch of the Arabian sea strikes the coast north of Mumbai. Moving along the Narmada and Tapi river valleys, these winds cause rainfall in central India. The Chotanagpur plateau gets about 15 cm of rainfall from this branch. Thereafter, they enter the Ganga plains and merge with the Bay of Bengal branch.

    - A third branch strikes the Saurashtra Peninsula and the Kachchh. It then crosses over west Rajasthan and along the Aravallis, causing only a little rainfall. In Punjab and Haryana, it mingles with the Bay of Bengal branch. These two branches together bring rains in the western Himalayas.
- The Bay of Bengal branch –
    - The Bay of Bengal branch hits the coast of Myanmar and parts of southeast Bangladesh. The Arakan hills along the coast of Myanmar deflect a large part of this branch towards the Indian subcontinent. The monsoon thus enters West Bengal and Bangladesh from south and south-east and not from a south-westerly direction.
    - This branch of monsoon splits into two – one branch moves in a west direction along the Ganga plains reaching as far as the Punjab plains. The second branch moves up the Brahmaputra valley in the north and north-east, causing heavy rains. The maximum rainfall is received in the north-eastern part of the country. Mawsynram in the southern ranges of the Khasi Hills receives the highest average rainfall in the world. Rainfall in the Ganga plains decreases from east to west.
    - The Tamil Nadu coast remains dry during this season because it is situated parallel to the Bay of Bengal branch of the south-west monsoon. Also, it lies in the rain shadow area of the Arabian sea branch of the south-west monsoon.
- Breaks in the monsoon – The monsoon rains take place only for a few days at a time and are interrupted with rainless intervals. These breaks are related to the movement of the monsoon trough. When the axis of the monsoon trough lies over the plains, rainfall is good in these parts and when the axis shifts closer to the Himalayas, there are large dry spells in the plains and heavy rainfall in the mountainous catchment areas of the Himalayan rivers. The frequency and intensity of tropical depressions too, determine the amount and duration of monsoon rains. These depressions are formed at the head of the Bay of Bengal and cross over to the mainland. The depression follows the axis of the monsoon trough of low pressure.
- Monsoons play an important role in the agrarian economy of India because over three-fourths of the total rain in the country is received during the south-west monsoon season.

Retreating Monsoon Season

- During the months of October and November, with the apparent movement of the sun towards the south, the monsoon trough or the low-pressure trough over the northern plains become weakened.
- This gets gradually replaced by the high-pressure system. The south-west monsoon winds weaken and start withdrawing gradually.
- The monsoon withdraws from the northern plains by the beginning of October. October and November months form a period of transition from hot rainy season to dry winter season.
- The withdrawal of the monsoon is marked by clear skies and increasing temperatures. However, the land is still moist.
- Due to high temperature and humidity, the weather becomes rather oppressive during the day. This is commonly known as “October heat”.
- In the second half of October, the mercury begins to fall rapidly in north India. The low-pressure trough over north-western India gets transferred to the Bay of Bengal by early November.

- This shift is associated with the occurrence of cyclonic depressions, which originate over the Andaman sea.
- These cyclones generally cross the eastern coasts of India and bring heavy and widespread rainfall. These tropical cyclones are highly destructive.
- The densely populated deltas of the Godavari, Krishna and Kaveri are often hit by cyclones which cause great damage to life and property.
- These cyclones may also reach the coasts of Bangladesh, West Bengal and Odisha. The bulk of the rainfall of the Coromandel coast is derived from depressions and cyclones. Such cyclonic storms are less frequent in the Arabian sea.

Climatic Regions of India

India is often referred to as a country with a Tropical monsoon type of climate. The large size of India, its latitudinal extent, the Himalayas in the north and the Indian Ocean, Arabian Sea and Bay of Bengal in the south have resulted in great variations in the distribution of temperature and precipitation in the subcontinent of India. A number of attempts have been made by climatologists, geographers and agricultural experts to divide India into climatic regions. Temperature and precipitation are two important factors that are considered to be decisive in all the schemes of climatic classification. The classification of climate, however, is a complex exercise. There are different schemes of classification of Climate.

Koppen's classification of the Indian climate

- Koppen's classification is empirical in nature based on climatic data. He based his classification on the mean monthly temperature, the mean monthly rainfall and the mean annual rainfall. He identified five major climatic types;

1. Tropical climates (A), where the mean monthly temperature throughout the year is over 18°C.
2. Dry climates (B), where rainfall/precipitation is very low as compared to temperature, hence dry. If the dryness is less, the climate is semi-arid designated as "S" and if it is more, the climate is arid designated as "W".
3. Warm temperate climates (C), where the mean temperature of the coldest month is between 18°C and minus 3°C.
4. Cool temperate climates (D), where the mean temperature of the warmest month is over 10°C and the mean temperature of the coldest month is under minus 3°C.
5. Ice climates (E), where the mean temperature of the warmest month is under 10°C.

- Each climatic type is subdivided into subtypes on the basis of seasonal variations in the distribution pattern of precipitation and temperature. The Climatic types are designated in capital letters and subtypes in small letters. The following small letters are used to define subtypes; f – sufficient precipitation, w – winter dry season, h – hot and dry, g – Gangetic plain, c – less than four months with mean temperature over 10°C.

Read more on Koeppen's Climate Classification in the link.

- Based on Koppen's climatic scheme, India can be divided into eight climatic regions.

Code	Climate type	Regions of India
Aw	Tropical Savanna	Most of the peninsular plateaus, south of the Tropic of Cancer.
Amw	Tropical monsoon with short dry season	West coast of India, south of Goa.
As	Tropical moist	Coromandel coast of Tamil Nadu
BShw	Semi Arid steppe	North-western Gujarat, parts of Rajasthan and Punjab.
Bwhw	Hot desert	Extreme western Rajasthan
Cwg	Monsoon with dry winters	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 & Kashmir, Himachal Pradesh and Uttarakhand.