Geography Optional - 2025

CLIMATE OF INDIA

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The monsoon regime emphasizes the unity of India with the rest of Southeast Asian region. The climate of Kerala and Tamil Nadu in the south are so different from that of Uttar Pradesh and Bihar in the north, and yet all of these have a monsoon type of climate. The climate of India has many regional variations expressed in the pattern of winds, temperature and rainfall, rhythm of seasons and the degree of wetness or dryness. While in the summer the mercury occasionally touches 55°C in the western Rajasthan, it drops down to as low as minus 45°C in winter around Leh. Churu in Rajasthan may record a temperature of 50°C or more on a June day while the mercury hardly touches 19°C in Tawang (Arunachal Pradesh) on the same day. On a December night, temperature in Drass (Jammu and Kashmir) may drop down to minus 45°C while Thiruvananthapuram or Chennai on the same night records 20°C or 22°C. These examples confirm that there are seasonal variations in temperature from place to place and from region to region in India. While snowfall occurs in the Himalayas, it only rains over the rest of the country. Similarly, variations are noticeable not only in the type of precipitation but also in its amount.

While Cherrapunji and Mawsynram in the Khasi Hills of Meghalaya receive rainfall over 1,080 cm in a year, Jaisalmer in Rajasthan rarely gets more than 9 cm of rainfall during the same period. Tura situated in the Garo Hills of Meghalaya may receive an amount of rainfall in a single day which is equal to 10 years of rainfall at Jaisalmer. While the annual precipitation is less than 10 cm in the north-west Himalayas and the western deserts, it exceeds 400 cm in Meghalaya. The Ganga delta and the coastal plains of Orissa are hit by strong rain-bearing storms almost every third or fifth day in July and August while the Coromandal coast, a thousand km to the south, goes generally dry during these months.

Most parts of the country get rainfall during June-September, but on the coastal areas of Tamil Nadu, it rains in the beginning of the winter season. In spite of these differences and variations, the climate of India is monsoonal in rhythm and character.

Factors determining the climate of India

India's climate is controlled by a number of factors which can be broadly divided into two groups — factors related to location and relief, and factors related to air pressure and winds.

Latitude: Northern part of the India lies in sub-tropical and temperate zone and the part lying south of the Tropic of Cancer falls in the tropical zone. The tropical zone, being nearer to the equator, experiences high temperatures throughout the year with small daily and annual range of temperature. The area north of the Tropic of Cancer which is away from the equator, experiences extreme climate with high daily and annual range of temperature.

The Himalayan Mountains: The lofty Himalayas in the north along with its extensions act as an effective climatic divide. The towering mountain chain provides an invincible shield to protect the subcontinent from the cold northern winds. These cold and chilly winds originate near the Arctic circle and blow across central and eastern Asia. The Himalayas also trap the monsoon winds, forcing them to shed their moisture within the subcontinent.

Distribution of Land and Water: India is flanked by the Indian Ocean on three sides in the south and girdled by a high and continuous mountain-wall in the north. As compared to the landmass, water heats up or cools down slowly creating different air pressure zones in different seasons in and around the Indian subcontinent. Difference in air pressure causes reversal in the direction of monsoon winds.

Distance from the Sea: With a long coastline, large coastal areas have an equable climate. Areas in the interior of India are far away from the moderating influence of the sea. The seasonal contrasts in weather at places in the interior of the country such as Delhi, Kanpur and Amritsar affect the entire sphere of life.

Altitude : Temperature decreases with height. Due to thin air, places in the mountains are cooler than places on the plains. For example, Agra and Darjeeling are located on the same latitude, but temperature of January in Agra is 16°C whereas it is only 4°C in Darjeeling.

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. The windward sides of Western Ghats and Assam receive high rainfall during June-September whereas the southern plateau remains dry due to its leeward situation along the Western Ghats.

To understand the differences in local climates of India, we need to understand the mechanism of the following three factors:

(i) Distribution of air pressure and winds on the surface of the earth.

(ii) Upper air circulation caused by factors controlling global weather and the inflow of different air masses and jet streams.

(iii) Inflow of western cyclones generally known as disturbances during the winter season and tropical depressions during the south-west monsoon period into India, creating weather conditions favourable to rainfall.

The mechanism of these three factors can be understood with reference to winter and summer seasons of the year separately.

Mechanism of Weather in the Winter Season In winter months, the weather conditions over India are generally influenced by the distribution of pressure in Central and Western Asia. A high pressure centre in the region lying to the north of the Himalayas develops during winter giving rise to the flow of air at the low level from the north towards the Indian subcontinent, south of the mountain range. The surface winds blowing out of the high pressure centre over Central Asia reach India in the form of a dry continental air mass and come in contact with trade winds over northwestern India. The position of this contact zone is not, however, stable but occasionally shift its position as far east as the middle Ganga valley with the result that the whole of the northwestern and northern India up to the middle Ganga valley comes under the influence of dry northwestern winds.

Jet Stream and Upper Air Circulation: The variations in the atmospheric pressure closer to the surface of the earth have no role to play in the making of upper air circulation. All of Western and Central Asia remains under the influence of westerly winds along the altitude of 9-13 km from west to east that blow across the Asian continent at latitudes north of the Himalayas

roughly parallel to the Tibetan highlands. These are known as jet streams. Tibetan highlands act as a barrier in the path of these jet streams resulting in bifurcation of jet streams. One of its branches blows to the north of the Tibetan highlands, while the southern branch blows in an eastward direction, south of the Himalayas.

Western Cyclonic Disturbance and Tropical Cyclone: The western cyclonic disturbances which enter the Indian subcontinent from the west and the northwest during the winter months, originate over the Mediterranean Sea and are brought into India by the westerly jet stream. An increase in the prevailing night temperature generally indicates an advance in the arrival of these cyclones disturbances. Tropical cyclones originate over the Bay of Bengal and the Indian ocean and with a high wind velocity and heavy rainfall, hit the Tamil Nadu, Andhra Pradesh and Orissa coast. Most of these cyclones are very destructive due to high wind velocity and torrential rain that accompanies it.

Mechanism of Weather in the Summer Season As the summer sets in and the sun shifts northwards, the wind circulation over the subcontinent undergoes a complete reversal at both, the lower as well as the upper levels. By the middle of July, the low pressure belt nearer the surface [termed as Inter Tropical Convergence Zone (ITCZ)] shifts northwards, roughly parallel to the Himalayas between 20° N and 25° N. By this time, the westerly jet stream withdraws from the Indian region. The ITCZ being a zone of low pressure, attracts inflow of winds from different directions. The maritime tropical air mass (mT) from the southern hemisphere, after crossing the equator, rushes to the low pressure area in the general southwesterly direction. It is this moist air current which is popularly known as the southwest monsoon.

Jet Streams and Upper Air Circulation: An easterly jet stream flows over the southern part of the Peninsula in June, and has a maximum speed of 90 km per hour. In August, it is confined to 15oN latitude, and in September up to 22o N latitudes. The easterlies normally do not extend to the north of 30o N latitude in the upper atmosphere.

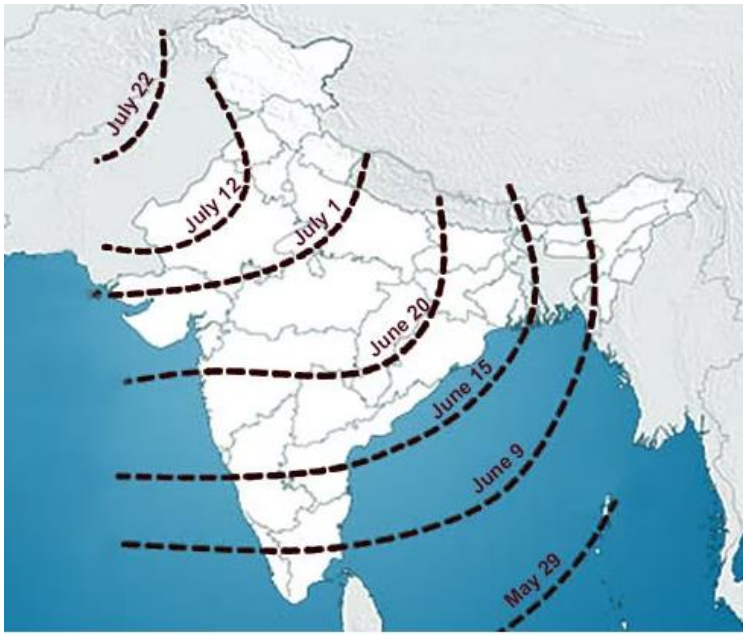
Easterly Jet Stream and Tropical Cyclones: The easterly jet stream steers the tropical depressions into India that play a significant role in the distribution of monsoon rainfall over the Indian subcontinent. The tracks of these depressions are the areas of highest rainfall in India and

the frequency at which these depressions visit India, their direction and intensity, all go a long way in determining the rainfall pattern during the southwest monsoon period.

Indian monsoon

Monsoon is a familiar though a little known climatic phenomenon. Many attempts have been made to discover the exact nature and causation of monsoon, but so far, no single theory has been able to explain the monsoon fully. Systematic studies of the causes of rainfall in the South Asian region help to understand the causes and salient features of the monsoon, particularly some of its important aspects, such as: The onset of the monsoon, Rain-bearing systems (e.g. tropical cyclones) and the relationship between their frequency and distribution of monsoon rainfall. and Break in the monsoon.

Onset of the Monsoon During April and May when the sun shines vertically over the Tropic of Cancer, the large landmass in the north of Indian Ocean gets intensely heated. This causes the formation of an intense low pressure in the northwestern part of the subcontinent. Since the pressure in the Indian Ocean in the south of the landmass is high as water gets heated slowly, the low pressure cell attracts the southeast trades across the Equator. These conditions help in the northward shift in the position of the ITCZ. The shift in the position of the 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 only after the western jet stream has withdrawn itself from the region. This easterly jet stream is held responsible for the burst of the monsoon in India.



Entry of Monsoon into India: The southwest monsoon sets in over the Kerala coast by 1st June and moves swiftly to reach Mumbai and Kolkata between 10th and 13th June. By mid-July, southwest monsoon engulfs the entire subcontinent.

Rain-bearing Systems and Rainfall Distribution There seem to be two rain-bearing systems in India. The first one originates in the Bay of Bengal causing rainfall over the plains of north India and the second is the Arabian Sea current of the south-west monsoon which brings rain to the west coast of India. Much of the rainfall along the Western Ghats is orographic as the moist air is obstructed and forced to rise along the Ghats. The intensity of rainfall over the west coast of India is, however, related to two factors:

(i) The offshore meteorological conditions.
(ii) The position of the equatorial jet stream along the eastern coast of Africa.

The frequency of the tropical depressions originating from the Bay of Bengal varies from year to year. Their paths over India are mainly determined by the position of ITCZ which is generally termed as the monsoon trough. As the axis of the monsoon trough oscillates, there are fluctuations in the track and direction of these depressions, and the intensity and the amount of rainfall vary from year to year. The rain which comes in spells, displays a declining trend from west to east over the west coast, and from the southeast towards the northwest over the North Indian Plain and the northern part of the Peninsula.

Break in the Monsoon

During the south-west monsoon period after having rains for a few days, if rain fails to occur for one or more weeks, it is known as break in the monsoon. These dry spells are quite common during the rainy season. These breaks in the different regions are due to different reasons:

(i) In northern India rains are likely to fail if the rain-bearing storms are not very frequent along the monsoon trough or the ITCZ over this region.
(ii) Over the west coast the dry spells are associated with days when winds blow parallel to the coast.

Season Cycle

The climatic conditions of India can best be described in terms of an annual cycle of seasons. The meteorologists recognize the following four seasons:

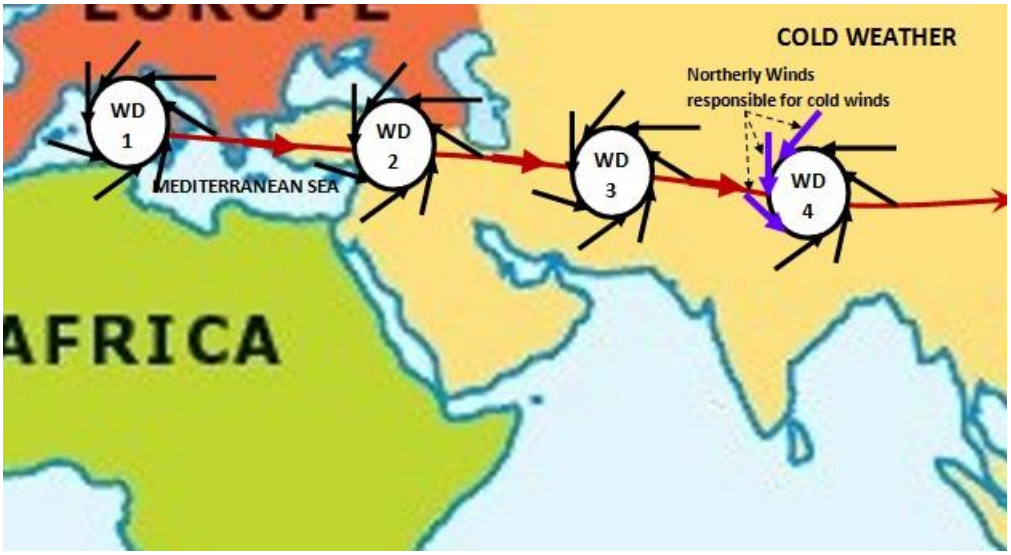
- The cold weather season
- The hot weather season
- The southwest monsoon season
- The retreating monsoon season.

The Cold Weather Season *Usually*, the cold weather season sets in by mid-November in northern India. December and January are the coldest months in the northern plain. The mean daily temperature remains below 21°C over most parts of northern India. The night temperature may be quite low, sometimes going below freezing point in Punjab and Rajasthan. There are three main reasons for the excessive cold in north India during this season :

(i) States like Punjab, Haryana and Rajasthan being far away from the moderating influence of sea experience continental climate.
(ii) The snowfall in the nearby Himalayan ranges creates cold wave situation; and
(iii) Around February, the cold winds coming from the Caspian Sea and Turkmenistan bring cold wave along with frost and fog over the northwestern parts of India.

The Peninsular region of India, however, 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 because of moderating influence of the sea and the proximity to equator. By the end of December (22nd December), the sun shines vertically over the Tropic of Capricorn in the southern hemisphere. The weather in this season is characterized by feeble high pressure conditions over the northern plain. In south India, the air pressure is slightly lower. As a result, winds start blowing from northwestern high pressure zone to the low air pressure zone over the Indian Ocean in the south. Due to low pressure gradient, the light winds with a low velocity of about 3-5 km per hour begin to blow outwards. By and large, the topography of the region influences the wind direction. They are westerly or northwesterly down the Ganga Valley. They

become northerly in the Ganga-Brahmaputra delta. During the winters, the weather in India is pleasant but gets disturbed by shallow cyclonic depressions originating over the east Mediterranean Sea and travelling eastwards across West Asia, Iran, Afghanistan and Pakistan before they reach the northwestern parts of India. On their way, the moisture content gets augmented from the Caspian Sea in the north and the Persian Gulf in the south. Winter monsoons do not cause rainfall as they move from land to the sea.



It is because firstly, they have little humidity; and secondly, due to anti cyclonic circulation on land, the possibility of rainfall from them reduces. So, most parts of India do not have rainfall in the winter season. However, there are some exceptions to it:

- In northwestern India, some weak temperate cyclones from the Mediterranean sea cause rainfall in Punjab, Haryana, Delhi and western Uttar Pradesh. The precipitation is in the form of snowfall in the lower Himalayas. It is this snow that sustains the flow of water in the Himalayan rivers during the summer months. The precipitation goes on decreasing from west to east in the plains and from north to south in the mountains. The average winter rainfall in Delhi is around 53 mm. In Punjab and Bihar, rainfall remains between 25 mm and 18 mm respectively.

- Central parts of India and northern parts of southern Peninsula also get winter rainfall occasionally.

- Arunachal Pradesh and Assam in the northeastern parts of India also have rains between 25 mm and 50 mm during these winter months.

- During October and November, northeast monsoon while crossing over the Bay of Bengal, picks up moisture and causes torrential rainfall over the Tamil Nadu coast, southern Andhra Pradesh, southeast Karnataka and southeast Kerala.

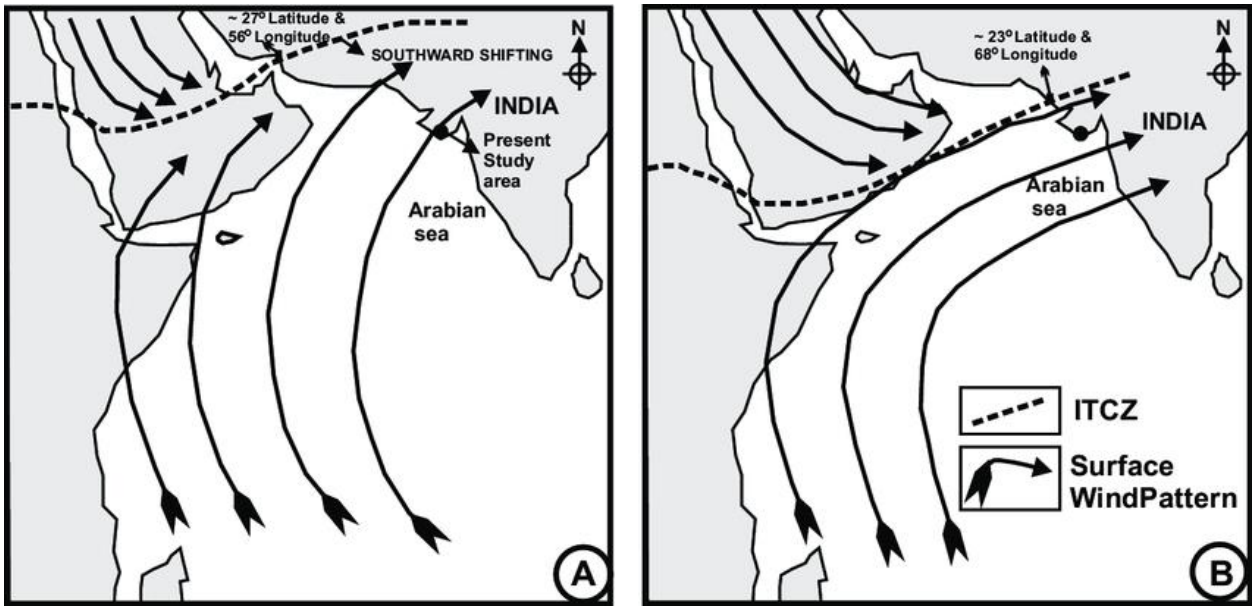
The Hot Weather Season

With the apparent northward movement of the sun towards the Tropic of Cancer in March, temperatures start rising in north India. In most parts of India, temperatures recorded are between 30°-32°C. In March, the highest day temperature of about 38°C occurs in the Deccan Plateau while in April, temperature ranging between 38°C and 43°C are found in Gujarat and Madhya Pradesh. In May, the heat belt moves further north, and in the north-western part of India, temperatures around 48°C are not uncommon. The hot weather season in south India is mild and not so intense as found in north India. The Peninsular situation of south India with moderating effect of the oceans keeps the temperatures lower than that prevailing in north India. So, temperatures remain between 26°C and 32°C. Due to altitude, the temperatures in the hills of Western Ghats remain below 25°C. In the coastal regions, the north-south extent of isotherms parallel to the coast confirms that temperature does not decrease from north to south rather it increases from the coast to the interior. The mean daily minimum temperature during the summer months also remains quite high and rarely goes below 26°C. The summer months are a period of excessive heat and falling air pressure in the northern half of the country. Because of the heating of the subcontinent, the ITCZ moves northwards occupying a position centered at 25°N in July. The location of 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. In the heart of the ITCZ in the northwest, the dry and hot winds known as *'Loo'*, blow in the afternoon, and very often, they continue to well into midnight. Dust storms in the evening are very common during May in Punjab, Haryana, Eastern Rajasthan and Uttar Pradesh. These temporary storms bring a welcome respite from the oppressing heat since they bring with them light rains and a pleasant cool

breeze. Occasionally, the moisture-laden winds are attracted towards the periphery of the trough. A sudden contact between dry and moist air masses gives rise to local storms of great intensity. These local storms are associated with violent winds, torrential rains and even hailstorms.

The Advancing Monsoon

By early June, they are powerful enough to attract the trade winds of Southern Hemisphere coming from the Indian Ocean. These southeast trade winds cross the equator and enter the Bay of Bengal and the Arabian Sea, only to be caught up in the air circulation over India. Passing over the equatorial warm currents, they bring with them moisture in abundance. After crossing the equator, they follow a southwesterly direction. That is why they are known as southwest monsoons. The rain in the southwest monsoon season begins rather abruptly. One result of the first rain is that it brings down the temperature substantially. This sudden onset of the moisture-laden winds associated with violent thunder and lightning, is often termed as the "break" or "burst" of the monsoons. The monsoon may burst in the first week of June in the coastal areas of Kerala, Karnataka, Goa and Maharashtra while in the interior parts of the country, it may be delayed to the first week of July. The day temperature registers a decline of 5°C to 8°C between mid-June and mid-July. As these winds approach the land, their southwesterly direction is modified by the relief and thermal low pressure over the northwest India.



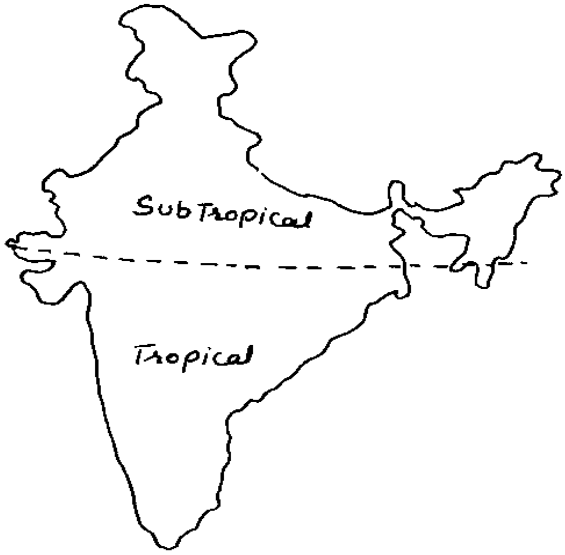
The monsoon approaches the landmass in two branches:

(a) The Arabian Sea branch

(b) The Bay of Bengal branch.

Monsoon Winds of the Arabian Sea

The monsoon winds originating over the Arabian Sea further split into three branches: Its one branch is obstructed by the Western Ghats. These winds climb the slopes of the Western Ghats from 900-1200 m and soon becomes cool, and as a result, the windward side of the Sahyadris and Western Coastal Plain receive very heavy rainfall ranging between 250 cm and 400 cm. After crossing the Western Ghats, these winds descend and get heated up reducing humidity in the winds. As a result, these winds cause little rainfall east of the Western Ghats. This region of low rainfall is known as the rain-shadow area. Another branch of the Arabian sea monsoon strikes the coast north of Mumbai. Moving along the Narmada and Tapi river valleys, these winds cause rainfall in extensive areas of central India. The Chotanagpur plateau gets 15 cm rainfall from this part of the branch. Thereafter, they enter the Ganga plains and mingle with the Bay of Bengal branch. A third branch of this monsoon wind strikes the Saurashtra Peninsula and the Kachchh passing over west Rajasthan and along the Aravallis, causing only a scanty rainfall. In Punjab and Haryana, it too joins the Bay of Bengal branch. These two branches, reinforced by each other, cause rains in the western Himalayas.



Monsoon Winds of the Bay of Bengal

The Bay of Bengal branch strikes the coast of Myanmar and part of southeast Bangladesh. But the Arakan Hills along the coast of Myanmar deflect a big portion of this branch towards the Indian subcontinent and the monsoon, therefore, enters West Bengal and Bangladesh from south and southeast instead of from the south-westerly direction.

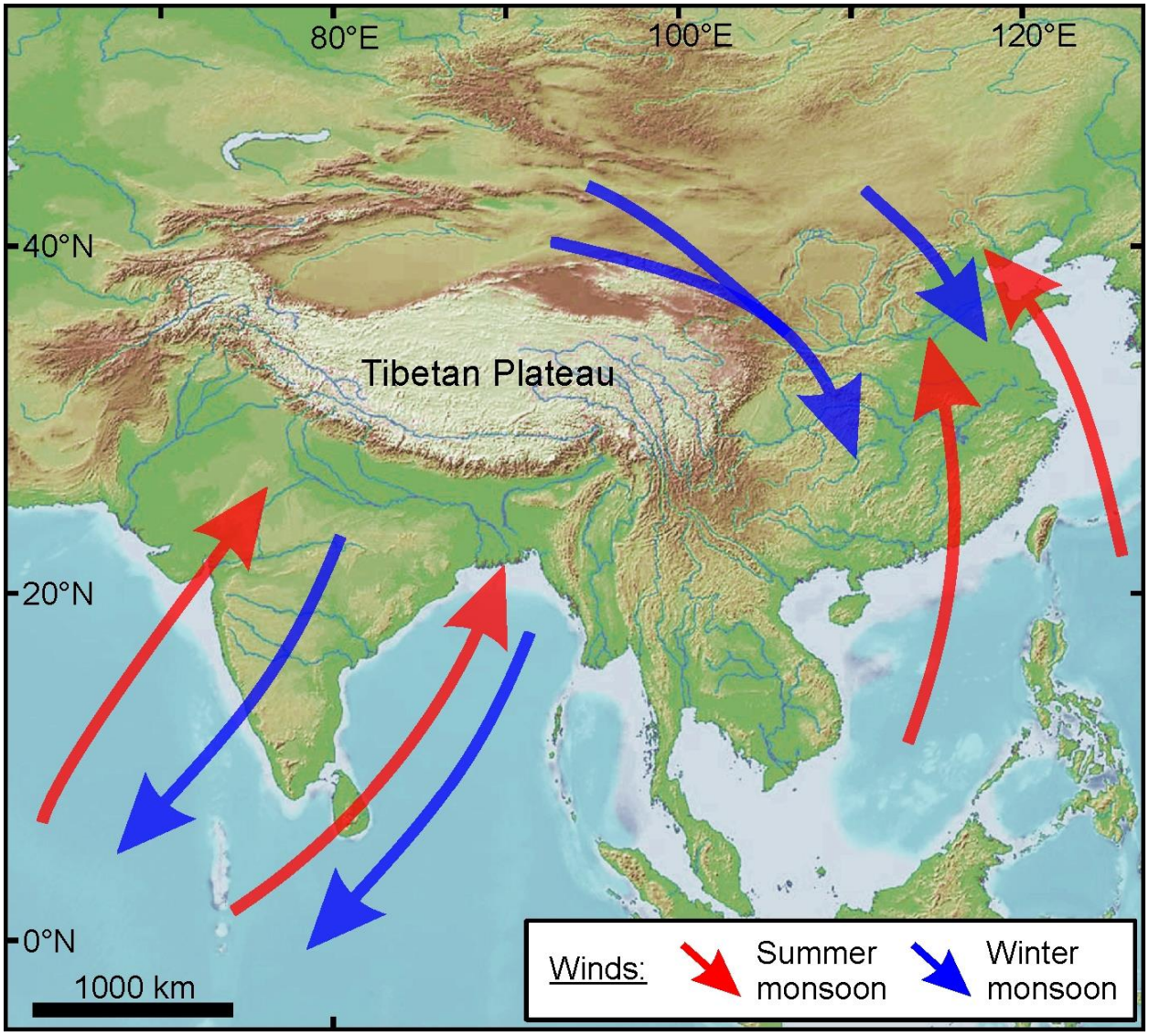
From here, this branch splits into two under the influence of the Himalayas and the thermal low is northwest India. It's one branch moves westward along the Ganga plains reaching as far as the Punjab plains. The other branch moves up the Brahmaputra valley in the north and the northeast, causing widespread rains. Its sub-branch strikes the Garo and Khasi hills of Meghalaya. Mawsynram, located on the crest of Khasi hills, receives the highest average annual rainfall in the world. The Tamil Nadu coast remains dry during this season because of the two factors:

(i) The Tamil Nadu coast is situated parallel to the Bay of Bengal branch of southwest monsoon.

(ii) It lies in the rain shadow area of the Arabian Sea branch of the south-west monsoon.

Characteristics of Monsoonal Rainfall

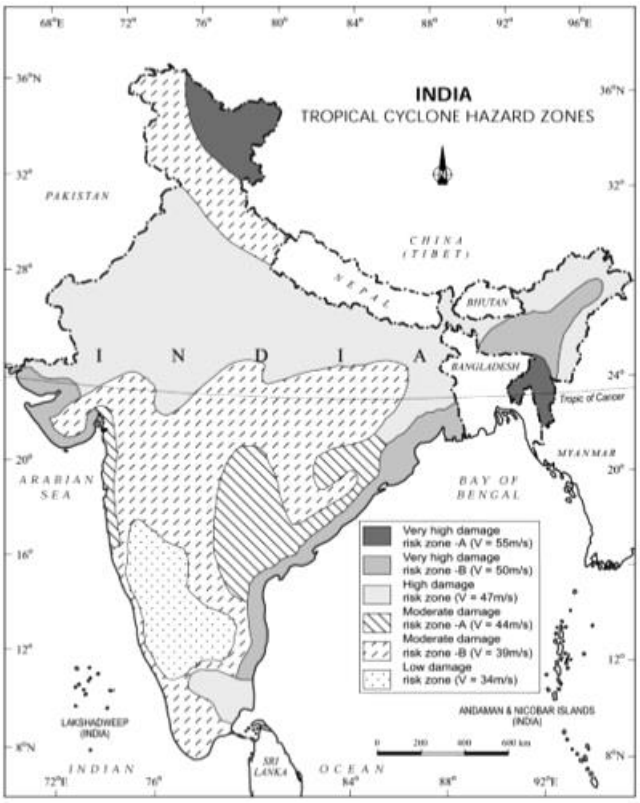
Rainfall received from the southwest monsoons is seasonal in character, which occurs between June and September. Monsoonal rainfall is largely governed by relief or topography. For instance the windward side of the Western Ghats register a rainfall of over 250 cm. Again, the heavy rainfall in the northeastern states can be attributed to their hill ranges and the Eastern Himalayas. The monsoon rainfall has a declining trend with increasing distance from the sea. Kolkata receives 119 cm during the southwest monsoon period, Patna 105 cm, Allahabad 76 cm and Delhi 56 cm. The monsoon rains occur in wet spells of few days duration at a time that are interspersed with rainless interval known as 'breaks'. These breaks in rainfall are related to the cyclonic depressions mainly formed at the head of the Bay of Bengal, and their crossing into the mainland. Besides the frequency and intensity of these depressions, the passage followed by them determines the spatial distribution of rainfall. The summer rainfall comes in a heavy downpour leading to considerable run off and soil erosion. Monsoons play a pivotal 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. Its spatial distribution is also uneven which ranges from 12 cm to more than 250 cm. The beginning of the rains sometimes is considerably delayed over the whole or a part of the country. The rains sometimes end considerably earlier than usual, causing great damage to standing crops and making the sowing of winter crops difficult.



Season of Retreating Monsoon

The months of October and November are known for retreating monsoons. By the end of September, the southwest monsoon becomes weak as the low pressure trough of the Ganga plain starts moving southward in response to the southward march of the sun. The monsoon retreats from the western Rajasthan by the first week of September. By the beginning of October, the low pressure covers northern parts of the Bay of Bengal and by early November, it moves over Karnataka and Tamil Nadu. By the middle of December, the centre of low pressure is completely removed from the Peninsula. The retreating southwest monsoon season is marked by clear skies

and rise in temperature. Owing to the conditions of high temperature and humidity, the weather becomes rather oppressive. This is commonly known as the 'October heat' .In the second half of October; the mercury begins to fall rapidly, particularly in northern India. The weather in the retreating monsoon is dry in north India but it is associated with rain in the eastern part of the Peninsula. Here, October and November are the rainiest months of the year. The widespread rain in this season is associated with the passage of cyclonic depressions which originate over the Andaman Sea and manage to cross the eastern coast of the southern Peninsula. These tropical cyclones are very destructive.



The thickly populated deltas of the Godavari, Krishna and Kaveri are their preferred targets. Every year cyclones bring disaster here. A few cyclonic storms also strike the coast of West Bengal, Bangladesh and Myanmar. A bulk of the rainfall of the Coromondel coast is derived from these depressions and cyclones. Such cyclonic storms are less frequent in the Arabian Sea.

Distribution of Rainfall

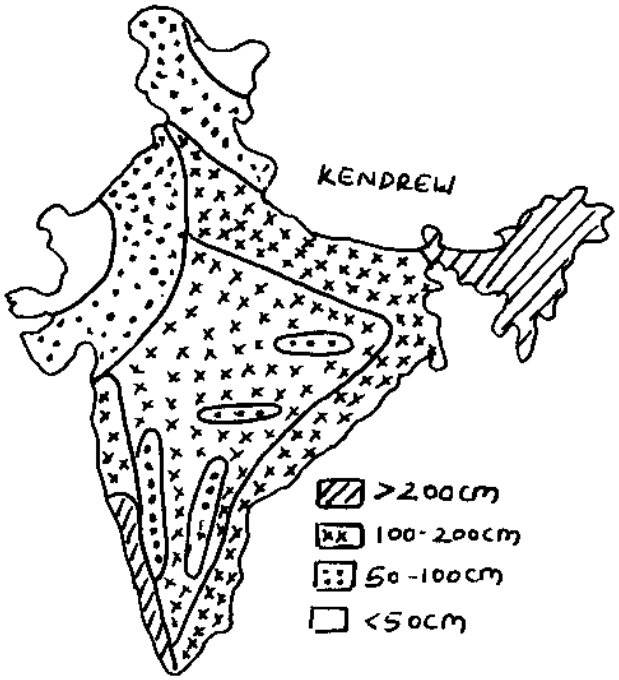
The average annual rainfall in India is about 125 cm, but it has great spatial variations.

***Areas of High Rainfall* :** The highest rainfall occurs along the west coast, on the Western Ghats, as well as in the sub-Himalayan areas is the northeast and the hills of Meghalaya. Here the rainfall exceeds 200 cm. In some parts of Khasi and Jaintia hills, the rainfall exceeds 1,000 cm. In the Brahmaputra valley and the adjoining hills, the rainfall is less then 200 cm.

Areas of Medium Rainfall **:** Rainfall between 100-200 cm is received in the southern parts of Gujarat, east Tamil Nadu, northeastern Peninsula covering Orissa, Jharkhand, Bihar, eastern Madhya Pradesh, northern Ganga plain along the sub-Himalayas and the Cachar Valley and Manipur.

Areas of Low Rainfall**:** Western Uttar Pradesh, Delhi, Haryana, Punjab, Jammu and Kashmir, eastern Rajasthan, Gujarat and Deccan Plateau receive rainfall between 50-100 cm.

Areas of Inadequate Rainfall**:** Parts of the Peninsula, especially in Andhra Pradesh, Karnataka and Maharashtra, Ladakh and most of western Rajasthan receive rainfall below 50 cm.



Like Kendrew, R.L. Singh based this classification on the amount of rainfall. He divided India into 10 climatic types: (i) Per-humid north east, (ii) humid Sahyadri and west coast, (iii) humid south east, (iv) sub-humid transition, (v) sub-humid littoral, (vi) sub-humid continental, (vii) semi-arid sub-tropical, (viii) semi-arid tropical, (ix) arid, and (x) west Himalaya.

Variability of Rainfall

A characteristic feature of rainfall in India is its variability. The variability of rainfall is computed with the help of the following formula:

$$C.V. = \frac{\text{Standard Deviation}}{\text{Mean}} \times 100$$

where C.V. is the coefficient of variation.

The values of coefficient of variation show the change from the mean values of rainfall. The actual rainfall in some places deviates from 20-50 per cent. The values of coefficient of variation

show variability of rainfall in India. A variability of less than 25 per cent exists on the western coasts, Western Ghats, northeastern Peninsula, eastern plains of the Ganga, northeastern India, Uttaranchal and Himachal Pradesh and south-western part of Jammu and Kashmir. These areas have an annual rainfall of over 100 cm. A variability of over 50 per cent exists in the western part of Rajasthan, northern part of Jammu and Kashmir and interior parts of the Deccan plateau. These areas have an annual rainfall of less than 50 cm. Rest of India have a variability of 25-50 per cent and these areas receive an annual rainfall between 50 -100 cm.

CLIMATIC REGIONS OF INDIA

Tropical rainy climate: This regions belonging to this group experience persistent high temperatures which normally do not go below 18°C even in the coolest month. There are two climatic types which fall under this group.

Tropical monsoon rain forest:

This type of climate is found in the west coastal plain and sahyadris and in parts of Assam. The temperature is high, not falling below 18.2ºC even during winter and rising to 29ºC in April and May, the hottest months. Mangalore records 29.3ºc in April, because of heavy rainfall and squally winds, the period of southwest monsoon is quite cool. The average annual rainfall exceeds 200 cm: Mangalore receives 250 cm. the south west monsoon breaks out here earlier and lasts longer than in most other parts of the country. December to March is the dry months with very little rainfall. The heavy rain is responsible for the tropical wet forests in these regions, which consists of a large number of species of animals. Evergreen forests are the typical feature of the region. Dense, forests and plantation agriculture with crops like tea, coffee and spices are the characteristics vegetation in the area.

Tropical wet and dry or savanna climate:

Most of the peninsula, except the semi arid zone in the leeside of the Sahyadris experiences this type of climate. Winter and early summer are long dry periods with temperature above 18°C. Summer is very hot and the temperatures in the interior low level areas can go above 45°C during May. The rainy season is from June to September and the annual rainfall is between 75 and 150 cm. Only central eastern Tamil falls under this tract and receives rainfall during the winter months of late November to January. The natural vegetation all over the area is savanna. A variety of crops with or without irrigation are raised in the area. Nagpur has a mean temperature of 35.4

degree C for May which is the hottest month and 20.7 degree C for December the coldest month in the year. The natural vegetation all over the area is savanna.

Dry climate group:

This group consists of regions where the rate of evaporation of water is higher than the rate of moisture received through precipitation. It is subdivided into three climate types.

Tropical semi-arid steppe climate:

The rain-shadow belt, running southward from central Maharashtra to Tamil Nadu, in the leeside of the Sahyadris and Cardamom Hills come under this type of climate of low and uncertain rainfall.

A long stretch of land situated to the south of Tropic of Cancer and east of the western ghats and the Cardamom Hills experiences this climate. It includes Karnataka, interior and western Tamil Nadu, western Andhra Pradesh and central Maharashtra. This area receives minimal rainfall due to being situated in the rain shadow area. This region is a famine prone zone with very unreliable rainfall which varies between 40 to 75 cm annually.

Towards the north of Krishna River the summer monsoon is responsible for most of the rainfall, while to the south of the river rainfall also occurs in the months of October and November. The coldest month is December but even in this month the temperature remains between 20°C and 24°C. The months of March to May are hot and dry with mean monthly temperatures of around 32°C. The vegetation mostly comprises grasses with a few scattered trees due to the rainfall. Hence this area is not very well suited for permanent agriculture. The climate is suitable only for dry farming and livestock rearing.

Tropical and sub-tropical desert:

Most of western Rajasthan falls under this climate type characterized by scanty rainfall. Cloud bursts are largely responsible for all the rainfall seen in this region which is less than 30 cm. These happen when the monsoon winds penetrate this region in the months of July, August and September. The rainfall is very erratic and a few regions might not see rainfall for a couple of years. The summer months of May and June are very hot with mean monthly temperatures in the region of 35°C and highs which can sometimes reach 50°C.

During winters the temperatures can drop below freezing in some areas due to cold wave. There is a large diurnal range of about 14°C during summer which becomes higher by a few more degrees during winter. This extreme climate makes this a sparsely populated region of India. This type of climate occurs over a broad crescent from Punjab to Kachchh between the Thar Desert to its west

and the more humid climates of the Ganga Plain and the Peninsula to its east and south respectively. The climate, therefore, is transitional between these two areas. The annual rainfall is not only low but it is also highly erratic.

Tropical and sub-tropical steppe:

The region towards the east of the tropical desert running from Punjab and Haryana toKathiawar experiences this climate type. This climate is a transitional climate falling between tropical desert and humid sub-tropical, with temperatures which are less extreme than the desert climate. The annual rainfall is between 30 to 65 cm but is very unreliable and happens mostly during the summer monsoon season. Maximum temperatures during summer can rise to 40°C. The vegetation mostly comprises short coarse grass. Some crops like jowar and bajra are also cultivated. The western part of Barmer, Jaisalmer and Bikaner districts of Rajasthan and most of the part of Kachchh form the sandy wastes of the Thar which experiences a typical desert climate. Ganganagar has recorded a maximum temperature of 50 degree C, the highest record.

Humid sub-tropical climate group:

The temperature during the coldest months in regions experiencing this climate falls between 18 and 0°C. It has one climatic subdivision in India.

Humid sub-tropical with dry winters:

This climate experience in the foothills of the Himalayas, Punjab-Haryana plain adjacent to the Himalayas, Rajasthan east of the Aravalli range, Uttar Pradesh, Bihar and northern part of West Bengal and Assam. The rainfall is received mostly in the summer and is about 65 cm in the west and increases to 250 cm annually to the east and near the Himalayas. The winters are mainly dry due to the land derived winter winds which blow down the lowlands of north India towards the Bay of Bengal. The summers are hot and temperatures can reach 46°C in the lowlands. May and June are the hottest months. Winter months are mostly dry with feeble winds. Frost occurs for a few weeks in winter. The difference in rainfall between the east and the west gives rise to a wide difference in the natural vegetation and crops.

Mountain climate:

In the Himalayan mountains the temperature falls by 0.6°C for every 100 m rise in altitude and this gives rise to a variety of climates from nearly tropical in the foothills to tundra type above the snow line. One can also observe sharp contrast between temperatures of the sunny and shady slopes, high diurnal range of temperature, inversion of temperature, and variability of rainfall based on altitude.

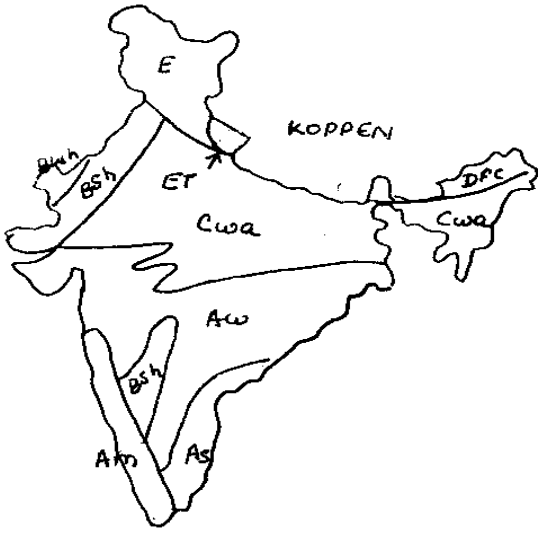
The northern side of the western Himalayas also known as the trans-Himalayan belt is arid, cold and generally windswept. The vegetation is sparse and stunted as rainfall is scanty and the winters are severely cold. Most of the snowfall is in the form of snow during late winter and spring months. The area to the south of the Himalayan range is protected from cold winds coming from interior of Asia during winter. The leeward side of the mountains receives less rain while the well exposed slopes get heavy rainfall. The places situated between 1070 and 2290 m altitudes receive the heaviest rainfall and the rainfall decreases rapidly above 2290 m. The great Himalayan range witnesses' heavy snowfall during winter months of December to February at altitudes above 1500 m. The diurnal range of temperature is also high. The states of Jammu and Kashmir, Himachal Pradesh, Uttarakhand, Arunachal Pradesh, and Sikkim experience this kind of weather.

Climatic Classification Schemes

Several scholars including Blanford (1889), Koppen (1918, 1931, 1936), Williamson and Clarke (1931), Thornthwaite (1931, 1933, 1948), Chatterjee (1953), Kendrew and Stamp (1953), Trewartha (1954), Subrahmanyam (1956), Shanbag (1956), Johnson (1969), K.N. Rao (1971) etc. have attempted to divide India into climatic regions. Many of these classifications pertain to the world, while some are exclusively for India.

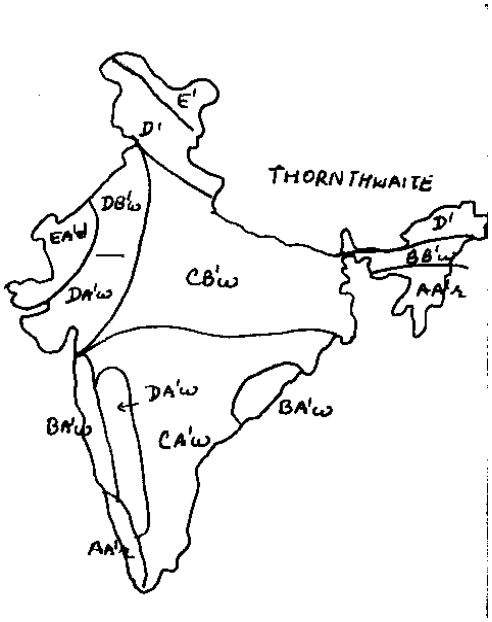
Koppen's Classification

Blanford (1988) was the first to attempt a climatic classification of India. He observed world-wide climatic variations within the boundaries of India. Later, Koppen (1918) divided into three broad climatic zones:



- **Aw (Tropical Savanna type)** – It is associated with tropical savanna grasslands and deciduous (monsoon) forests. Major parts of Peninsular India, South Bengal and Jharkhand experience this type of climate. Here, May is the hottest month and the coldest month has a temperature of over 18° C. The climate is characterized by seasonal rainfall, dry winter and a high range of temperature.

- **Amw (Tropical Monsoon type)** – It is characterized by a short dry winter season, and a heavy summer rainfall that favours the growth of luxuriant evergreen rainforests. Konkan, Malabar Coast, Western Ghats, Tripura and Mizoram have this type of climate.
- **As (Tropical Moist type)** – It is characterized by dry summer season. Nearly 75% of the rainfall occurs between September and December. It occupies a narrow zone along the Coromandel Coast.
- **BShw (Semi-arid Steppe type)** – It is characterized by summer rainfall and mean annual temperature above 18° C. It occupies rain shadow area of Karnataka and Tamil Nadu, eastern Rajasthan, and some parts of western Haryana.
- **BWhw (Hot-Desert type)** – It is characterized by high temperature, high range of temperature and scanty rainfall. This type of climate prevails over western parts of Rajasthan (Thar Desert).
- **Cwa (Mesothermal type)** – It is characterized by dry winter and less than 18° C average temperature for the coldest month and over 10° C for the warmest month. This climate prevails over the Gangetic Plains.
- **Dfc (Cold Humid winter type)** – It is characterized by short summer and cold and humid winter. Average temperature of the warmest month is more than 30° C and for the coldest month is above 10° C. It includes Sikkim and Arunachal Pradesh.
- **E (Polar or Mountain type)** – The warmest month has a temperature less than 10° C. This climate extends over Jammu and Kashmir and Himachal Pradesh.
- **ET (Tundra type)** – The average temperature of the warmest month is below 10° C. It prevails over the hilly areas of Uttarakhand.



Thornthwaite's Classification

Thornthwaite (1931, 1933, 1948) presented a classification of world's climate on the basis of precipitation effectiveness (P/E Ratio), thermal efficiency (T/E Ratio), and seasonal concentration

of rainfall. He divided India into eleven climatic zones.

- **AA'r** – It represents Per Humid Climate with rainfall throughout the year. It is characterised by PE/TE more than 128, high temperature, heavy rainfall, and tropical rainforests. It covers a narrow patch along the Western Ghats, Tripura and Mizoram.
- **BA'w** – This climate is tropical wet with scarcity of moisture during winter, PE over 128 and TE between 64-127. It includes parts of Western Ghats and eastern parts of West Bengal.
- **BB'w** – It is warm wet climate, with deficiency in moisture during winter, PE/TE ratio between 64-127. It prevails over Meghalaya, Assam, Nagaland and Manipur.
- **CA'w** – It is tropical sub-humid climate with dry winter, PE between 32-63, TE above 128. It stretches over major parts of Peninsular India and southern parts of Ganga plains.
- **CB'w** – It is sub-tropical and sub-humid climate with scarcity of rains during winter, PE 32-63 and TE 64-127. It covers major parts of the Ganga-Brahmaputra plains.
- **DA'w** – It is tropical semi-arid climate with dry winter season, PE 16-31, and TE above 128. It lies over Kachchh, and south-eastern Rajasthan.
- **DB'w** – It is temperature sub-arid climate with PE 16-31, TE 64-127 and dry winter. It includes north western Rajasthan, Punjab and south-western Haryana.
- **DB'd** – It is temperate semi-arid climate with deficient moisture through the year, PE 16-31, TE 64-127. It occupies rain shadow area of the Sahyadris.
- **D'** – It is Taiga type climate with TE 16-31. It stretches over the lower slopes of the Himalayas from Himachal Pradesh to Arunachal Pradesh.
- **EA'd** – It is tropical desert climate, with TE above 128, PE less than 16, rainfall deficient in all seasons. It occupies the western parts of Rajasthan (Thar Desert).
- **E** – It is tundra type climate, with TE less than 16. It includes northern parts of Kashmir.

Trewartha's Classification

Trewartha (1954) modified Koeppen's classification and put more emphasis on the genetic characteristics of climates. He based this classification on temperature and precipitation characteristics. He divided India into four major climatic regions and seven sub-types.

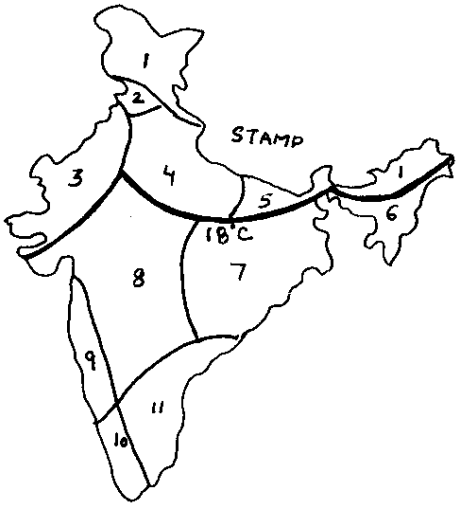
- **Tropical Rainy Climate (Am)** – It is characterized by average annual temperature of 27 C and annual rainfall exceeding 250 cm. It prevails over Western Ghats, Tripura and southern Assam.
- **Tropical Savanna Climate (Aw)** – It is characterized by average annual temperature of 27° C and annual rainfall of 100 cm with a marked dry season. It occupies major parts of Peninsular India.
- **Tropical Steppe Climate (Bs)** – It has average annual temperature over 27° C and annual rainfall below 100 cm. It includes the rain-shadow areas of the Western Ghats occupying central Maharashtra, Karnataka, interior Tamil Nadu and western Andhra Pradesh.
- **Sub-Tropical Steppe Climate (Bsh)** – It has over 27° C average annual temperature and 50-100 cm annual rainfall. It covers parts of Gujarat, eastern and central Rajasthan, and southern Haryana.
- **Tropical Arid Climate (Bwh)** – It has high summer temperature reaching up to 48° C, and dropping to 12° C during winter revealing high seasonal and diurnal range of temperature. Rainfall is scanty (less than 12.5 per annum) and unreliable. This climate prevails over western Rajasthan and Kachchh (Gujarat).
- **Humid Sub-Tropical Climate (Cwa)** – It resembles the Cwa type of Koeppen's classification. During the winter average temperature is less than 18° C soaring to 48° C during summer. The average annual rainfall is 62.5 cm which increases to 250 cm in the east. The regions include northern plains and Assam.
- **Mountain Climate (H)** – It has an average temperature between 15°-17° C in June that falls below 8° C during winter. Rainfall decreases from east to west. In high altitudes snow fall occurs. Western parts receive winter rainfall from temperate, cyclones. The regions include the entire Himalayan belt from Kashmir to Arunachal Pradesh.

Stamp's Classification

Kendrew and Stamp (1954), on the basis of 18° C isotherm following the Tropic of Cancer, divided India into two major climatic regions – subtropical and tropical. The former was further divided into five, and the latter into six (total eleven) climatic regions on the basis of variations in rainfall.

(a) Sub-Tropical India

- **Himalayan region** – The climate of this region is affected by the altitude from the sea level. Upto an elevation of 2450 m, the average temperature in winter ranges between 4°-7° C and in summer, between 13°-18° C. The amount of rainfall decreases westward (above 200 cm in the east, 150 cm in the central part and 125 cm in the west). Western parts receive rainfall in winter and the higher reaches receive snowfall.
- **North Western Plateau** – This area lies north west of the Sutlej river. The average temperature of winter is 16° C which at times falls below freezing point creating frost conditions. The average temperature of the warmest month reaches 34° C. The average annual rainfall is 40 cm. The region receives rainfall in winter from temperate cyclones.
- **North Western Dry Plains** – This region includes parts of Rajasthan, Kachchh, and south western Haryana. The average temperature in winter ranges between 13°-24° C and shoots upto 46° C during summer season. The average annual rainfall is less than 50 cm.



- **The Region of Medium Rainfall** – It includes Punjab, Haryana, western Uttar Pradesh, Delhi, eastern Rajasthan and northern parts of Madhya Pradesh. The average winter temperature ranges between 15°-17° C and that of summer 35° C, thus giving high annual range of temperature. The amount of annual rainfall ranges between 40-80 cm with a summer maxima and slight winter rainfall.
- **Transitional Plains** – It includes the middle Ganga Plain in eastern Uttar Pradesh and northern Bihar. The average winter temperature ranges between 16°-18° C and that of summer is 35° C. The amount of annual rainfall ranges between 100-150 cm, 90% occurring during summer.

(b) Tropical India

- **Region of very heavy rainfall** – It extends over Assam, Meghalaya, Nagaland, Manipur, Tripura and Mizoram having an annual rainfall over 250 cm mostly occurring in summer and average temperature of 27° C.
- **Region of heavy rainfall** – It extends over West Bengal, Orissa, Jharkhand, Chhattisgarh and eastern Andhra Pradesh and receives 100-200 cm annual rainfall decreasing westwards and southwards. Average winter temperature ranges between 18°-24° C and that of summer between 29°-35° C.
- **Region of medium rainfall** – This region lies east of the Western Ghats including south-eastern Gujarat, south western Madhya Pradesh, Maharashtra, Karnataka and Andhra Pradesh. This rain-shadow area receives an average rainfall below 75 cm. The average temperature of summer is 32° C while that of winter ranges between 18°-24° C.
- **Konkan Coast** – The region stretches from the mouth of the Narmada to Goa. The region experiences marine influence, average temperature of January being 24° C and 3° C annual range of temperature. The region receives more than 200 cm annual rainfall.
- **Malabar Coast** – The region extends between Goa and Kanyakumari. Annual rainfall is 500 cm, average annual temperature is 27° C and the annual range of temperature is 3° C.
- **Tamil Nadu Coast** – It includes the Coromandel coast with an annual rainfall ranging between 100-150 cm, caused by the retreating monsoon during November and December. The average temperature of winter is 24° C and annual range is very low (3° C).

Johnson's Classification

B.L.C. Johnson (1969) divided India into six climatic types –

I. Kerala-Assam type,
II. Coromandel coast type,
III. Central India – Konkan type,
IV. Punjab type,
V. Thar Desert type and
VI. Himalayan type.

K.N. Rao, C.J. George and K.S. Ramasastri's Classification

Rao, George and Ramasastri (1971) attempted to classify India's climates according to the technique suggested by Thornthwaite (1955), using potential evapo-transpiration values estimated according to Penman's formula, and available water capacity of soil on the basis of soil type and crop variety. Based on this method, India is divided into five moisture regimes – (i) Per-humid, (ii) humid, (iii) sub-humid, (iv) semi-arid and (v) arid.

In terms of thermal regime, most of the country belongs to mega thermal type. Meso thermal regime is confined to western Himalaya, north east Assam, Meghalaya and small pockets in the south.

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