MODULE 1

Monsoon

Generally, across the world, the monsoons are experienced in the tropical area roughly between 20° N and 20° S.

The climate of India is described as the **'monsoon'** type. In Asia, this type of climate is found mainly in the south and the southeast.

Out of a total of 4 seasonal divisions of India, monsoon occupy 2 divisions, namely.

- **The southwest monsoon season -** Rainfall received from the southwest monsoons is seasonal in character, which occurs between June and September.
- **The retreating monsoon season -** The months of October and November are known for retreating monsoons.

Factors Influencing South-West Monsoon Formation

- **The differential heating and cooling of land and water** creates a low pressure on the landmass of India while the seas around experience comparatively high pressure.
- **The shift of the position of Inter Tropical Convergence Zone (ITCZ)** in summer, over the Ganga plain (this is the equatorial trough normally positioned about 5°N of the equator. It is also known as the monsoon-trough during the monsoon season).

Inter Tropical Convergence Zone

The Inter Tropical Convergence Zone (ITCZ,) is a broad trough of low pressure in equatorial latitudes. This is where the northeast and the southeast trade winds converge. This convergence zone lies more or less parallel to the equator but moves north or south with the apparent movement of the sun.

- **The presence of the high-pressure area,** east of Madagascar, approximately at 20°S over the Indian Ocean. The intensity and position of this high-pressure area affect the Indian Monsoon.
- **The Tibetan plateau** gets intensely heated during summer, which results in strong vertical air currents and the formation of low pressure over the plateau at about 9 km above sea level.
- **The movement of the westerly jet stream** to the north of the Himalayas and the presence of the tropical easterly jet stream over the Indian peninsula during summer.
- **Tropical Easterly Jet (African Easterly Jet).**
- **Southern Oscillation (SO):** Normally when the tropical eastern south Pacific Ocean experiences high pressure, the tropical eastern Indian Ocean experiences low pressure. But in certain years, there is a reversal in the pressure conditions and the eastern Pacific has lower pressure in comparison to the eastern Indian Ocean. This periodic change in pressure conditions is known as the SO.

El Nino

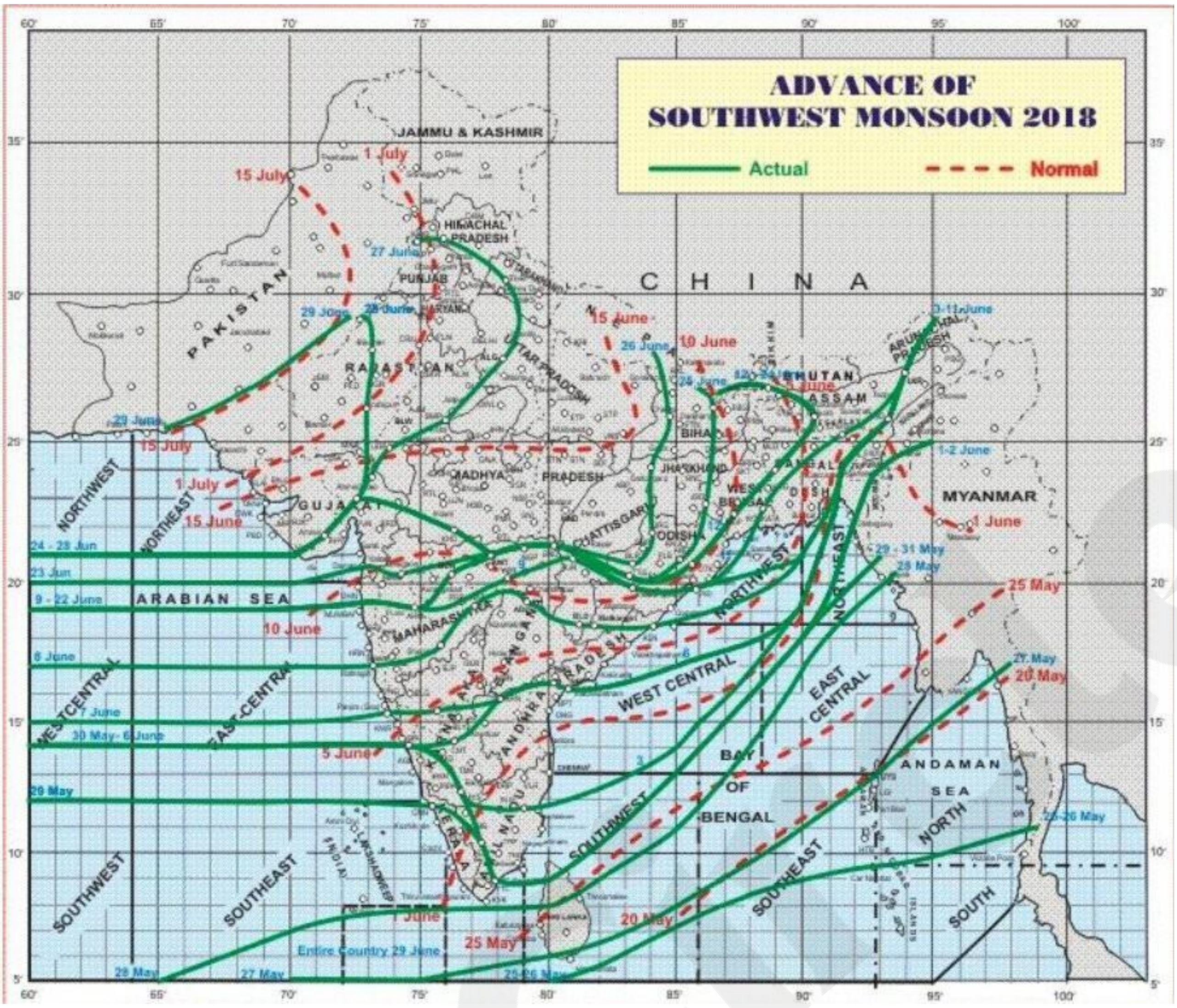
This is a name given to the periodic development of a warm ocean current along the coast of Peru as a temporary replacement of the cold Peruvian current. 'El Nino' is a Spanish word meaning 'the child', and refers to the baby Christ, as this current starts flowing during Christmas. The presence of the El Nino leads to an increase in sea-surface temperatures and weakening of the trade winds in the region.

Mechanism

Onset of the South-West Monsoon

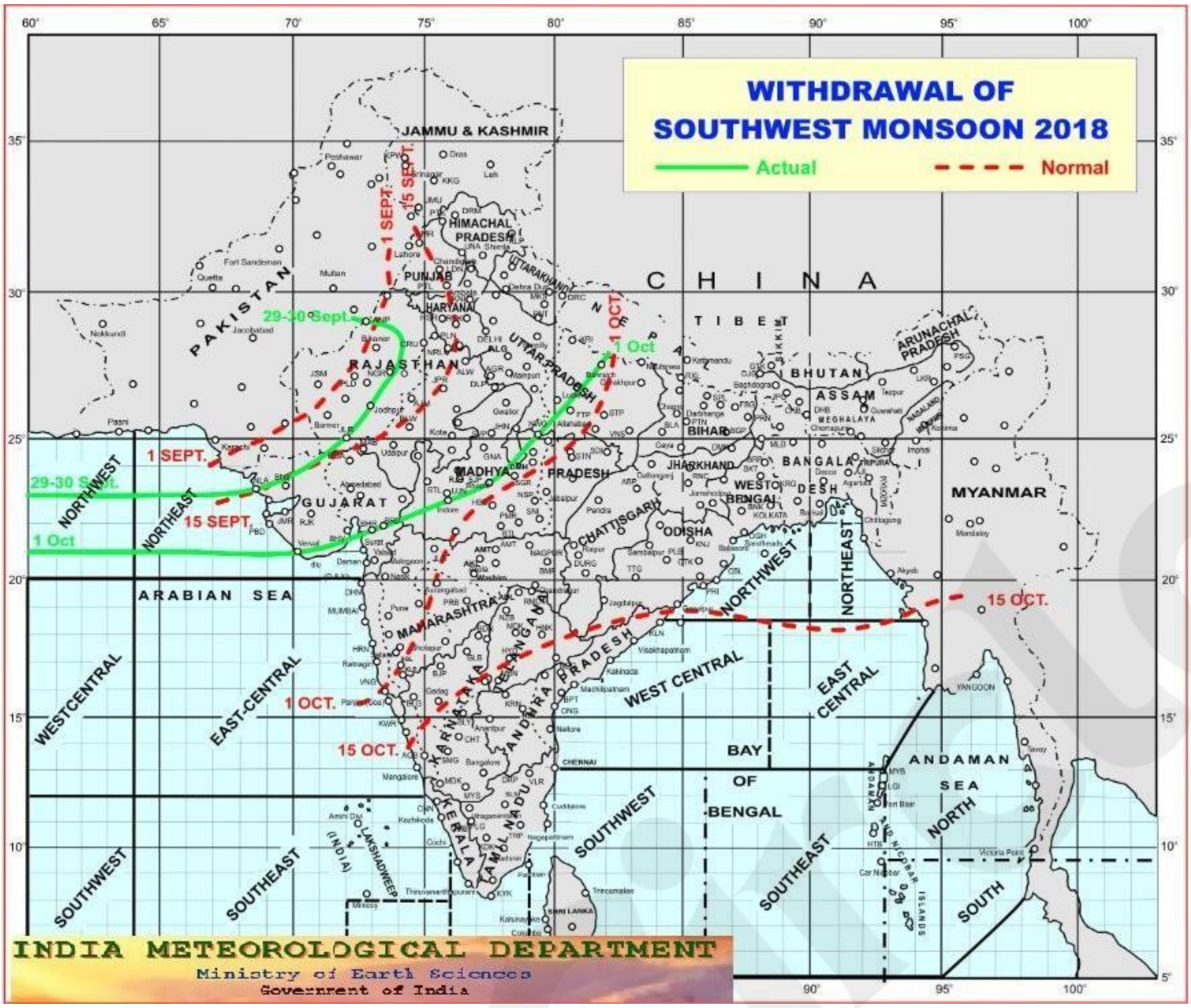
- The location of **ITCZ shifts north and south of the equator** with the apparent movement of the Sun.
- During the month of June, the **sun shines vertically over the Tropic of Cancer** and the **ITCZ shifts northwards**.
- The southeast trade winds of the southern hemisphere cross the equator and start blowing in southwest to northeast direction under the influence of **Coriolis force**.
- These winds collect moisture as they travel over the warm Indian Ocean.
- In the month of July, the **ITCZ shifts to 20°-25° N latitude and is located in the Indo-Gangetic Plain** and the south-west monsoons blow from the Arabian Sea and the Bay of Bengal. The ITCZ in this position is often called the **Monsoon Trough**.
- 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 (Somali Jet) 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.
- As these winds approach the land, their southwesterly direction is modified by the relief and thermal low pressure over northwest India. The monsoon approaches the Indian landmass in two branches:
    - **The Arabian Sea branch -** The monsoon winds originating over the Arabian Sea.
    - **The Bay of Bengal branch -** The Arakan Hills along the coast of Myanmar deflect a big portion of this branch towards the Indian subcontinent. The monsoon, therefore, enters West Bengal and Bangladesh from south and southeast instead of from the south-westerly direction.
- Another phenomenon associated with the monsoon is its tendency to have **'breaks'** in rainfall. The monsoon rains take place only for a few days at a time. They are interspersed with rainless intervals. **These breaks in monsoon are related to the movement of the monsoon trough.**

Despite an overall unity in the general pattern, there are perceptible regional variations in climatic conditions within the country.



Retreating Monsoon Season

- The retreating southwest monsoon season is **marked by clear skies and rise in temperature**. The land is still moist. 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.**
- A bulk of the rainfall of the Coromandel Coast is derived from these depressions and cyclones. Unlike the rest of the country, which receives rain in the southwest monsoon season between June and September, the **northeast monsoon is crucial for farming** and **water security in the south**.



Impact of Monsoons on Life in India

Positive

- [About 64% of people in India depend on agriculture for their livelihood]() and agriculture itself is based on monsoon.
- Agricultural prosperity of India depends very much on timely and adequately distributed rainfall. If it fails, agriculture is adversely affected particularly in those regions where means of irrigation are not developed.
- Regional variations in monsoon climate help in growing various types of crops.
- Regional monsoon variation in India is reflected in the vast variety of food, clothes and house types.
- Monsoon rain **helps recharge dams and reservoirs,** which is further used for the **generation of hydro-electric power**.
- Winter rainfall by temperate cyclones in north India is highly beneficial for Rabi crops.

Negative

- Variability of rainfall brings **droughts or floods** every year in some parts of the country.
- Sudden monsoon burst creates a problem of **soil erosion** over large areas in India.
- In hilly areas sudden rainfall brings **landslide** which **damages natural and physical infrastructure** subsequently **disrupting human life economically** as well as **socially**.

Monsoon Prediction In India

- More than a century ago, when there were no computers, IMD's forecasts depended only on snow cover. Lesser cover meant a better monsoon.
- British physicist Gilbert Walker, who headed the IMD, designed a **statistical weather model** – an empirical way of predicting the weather – based on the relationship between two weather phenomena.
- In 2014, the IMD started to use **numerical models** to supplement statistical models for long- range forecasting as well.
- Now, although the numerical models used by the IMD are state-of-the-art – developed by the **US National Centres for Environmental Prediction** – their forecast capacity is still weak because a longer period of forecast creates more uncertainty in prediction.
- At the moment, the IMD provides district-wise weather data but it's not sufficient; because when IMD says there will be scattered rainfall over a particular district, it means that 26-50% that district (by area) will receive rainfall.
- The **IMD collects weather data like temperature, humidity, wind and precipitation** through 679 automatic weather stations, 550 surface observatories, 43 radiosonde or weather balloons, 24 radars and three satellites.
- Currently, highly advanced dynamical models need supercomputers. Prediction models will not run until proper data about current weather conditions is available.

Factors Responsible for Inaccurate Monsoon Forecast

- The **lack of data** due to insufficient monitoring stations.
- Automatic weather stations are of substandard quality. They need to be calibrated and cleaned regularly, which does not happen often. That affects data.
- Then, there are major data gaps, like those involving dust, aerosols, soil moisture and maritime conditions are not monitored.
- The models that we have brought from the west have been developed by western scientists to forecast in their region, little progress has been made is the **fine-tuning of weather models to suit Indian conditions**.
- **Lack of competent software professionals** and scientists working with the IMD.

Recent Indian Initiatives

It is crucial for farmers (sowing, harvesting, etc.) and policymakers (payment of compensation, minimum support price, etc.) to know when and for how long the monsoon will remain active over India. For that, better predictions and timely advisories are needed.

To achieve this following initiatives have been taken:

1. **Monsoon Mission of India**
   This initiative of **Ministry of Earth Sciences, launched in 2012,** has utilized new approaches (high resolution, super parameterizations, data assimilation etc.) so that forecast skill gets quantitatively improved further for forecasting services of India Meteorological Department (IMD). For the first time, India Meteorological Department used the Monsoon Mission dynamical model to prepare operational seasonal forecast of 2017 monsoon rainfall over India.

   Objectives
   1. To improve Seasonal and Intra-seasonal Monsoon Forecast
   2. To improve Medium Range Forecast.
2. IMD in collaboration with Indian Council of Agricultural Research (ICAR) provides **district-level agro-meteorological advisories** to farmers through 130 agro-met field units in vernacular languages.

These advisories are used for critical farm operations such as: ◦ Management of sowing (delayed onset of rains);
◦ Changing crop variety (delay in rainfall);
◦ Spraying Pesticides for disease control (occurrence of rainfall); ◦ Managing Irrigation (Heavy rainfall Forecast).

3. India Meteorological Department (IMD) provides **meteorological support to the Central Water Commission (CWC)** for issuing flood warnings.

4. **Indo-US expedition**

In 2018, The Indian Ocean Research Vessel, 'Sagar Nidhi', set out from Chennai, as part of an Indo- US expedition seeking to find answers to the vagaries of the Bay of Bengal-fed southwest monsoon by collecting various data to improve prediction models.

5. National Supercomputing Mission will fill the necessary gaps in the computing superpower required to predict timely and accurate monsoon forecasts.

Global Warming and Monsoon

- A drastic change in the monsoon rainfall intensity, duration, frequency and spatial distribution can be attributed to the climate change. However, it is too soon to arrive at a conclusion.
    - If all this is in response to global warming then it can be permanent and might accelerate. If not then the monsoon system will revert to a more normal state.
- More data and reanalysis is needed to get a clear picture on the complete separation of the global warming impact from natural climate variability (such as El Niño).

Way Forward

- The **population of India is increasing** and to provide **food security** to the population, a large part of the monsoon water which is currently unutilized should be held at suitable locations for irrigation and power generation purposes.
- **India needs to invest more resources** in better prediction of Monsoon forecast in order to achieve reliability and sustainability.
- With a warming climate, more moisture will be held in the atmosphere, leading to heavier rainfall, consequently, inter-annual variability of the monsoon will increase in future. The country needs to prepare for this change.
- Thus, to secure and bring sustainability to the climate pattern of India we need to take effective and timely steps not just at the domestic front (National Action Plan on Climate Change) but also at international front (UN Framework Convention on Climate Change), as we live in a shared world with a shared future.

MONSOON IN INDIA

*The **Monsoon in India** is a defining climatic phenomenon that profoundly impacts the subcontinent's weather patterns, agriculture, and daily life. Originating from various atmospheric and geographical factors, the monsoon in India brings essential rainfall that sustains the region's agriculture and replenishes water resources. This article aims to study in detail the characteristics, types, and impacts of the Indian monsoon, exploring its intricate mechanisms and regional variations that shape the country's weather patterns and influence multiple sectors.*

What is Monsoon?

- The word **"monsoon"** is derived from the Arabic word **"mausim**,**"** meaning **"**season.**"**
- The term **"monsoon"** refers to a seasonal wind pattern characterised by significant changes in wind direction and associated precipitation.

About Monsoon in India

- The Indian Monsoon is a critical climatic phenomenon characterised by seasonal wind shifts that bring heavy rains to the Indian subcontinent.
- The Southwest Monsoon typically begins in June, bringing moisture-laden winds from the Indian Ocean, and continues until September.
- The Northeast Monsoon, occurring from October to December, affects southeastern India.

Features of Monsoon in India

Some key features of the Monsoon in India are:

- **Seasonal Rainfall** - The Monsoon in India is characterised by heavy rainfall, primarily between June and September.
- **Two Main Phases** - It consists of the Southwest Monsoon (June to September) and the Northeast Monsoon (October to December).
- **Geographical Influence** - The monsoon in India is influenced by the Himalayas, the Thar Desert, and the Indian Ocean, which affect wind patterns and rainfall distribution.
- **Diversity in Rainfall** - Different regions receive varying amounts of rainfall, with coastal areas and the Western Ghats experiencing heavy precipitation, while some interior regions may receive less.
- **Monsoon Winds** - The monsoon winds are characterised by a shift in wind direction, bringing moisture-laden winds from the southwest.

Types of Monsoon in India

There are mainly two types of Monsoon in India:

- South-West Monsoon
- North-East Monsoon

Each of them has been discussed in detail in the following section.

South-West Monsoon in India

- The southwest monsoon in India extends from June to mid-September. During the hot summers, the Thar desert and adjoining areas of the northern and central Indian subcontinent heat up considerably.
- This causes low pressure over the north and central Indian subcontinent.
- The sudden onset of monsoons is an important feature of southwest monsoons.
- With the onset of monsoons, the temperature falls drastically, and the humidity level rises.
    - It is a rainy season for most parts of India. Hence, this season is also known as the Hot-Wet Season.

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North-East Monsoon in India

- During October and November, the sun's movement towards the south shifts monsoon troughs or low-pressure systems towards the south.
- It results in the weakening of the trough over the Northern Plains.

- Also, the withdrawal of southwest monsoon winds results in the development of a high-pressure system over that area, i.e., cold winds that swipe down from the Himalayas and Indo-Gangetic Plains towards the vast Indian Ocean.
- By the beginning of October, monsoons had withdrawn from the Northern Plains.

Factors Affecting Monsoon in India

The monsoon climate arises from the shifting patterns of pressure and wind belts. Indian monsoon has its origin, and its mechanisms are related to the following factors:

- ITCZ (Inter-Tropical Convergence Zone)
- Tibetan Plateau
- Jet Streams
- Somali Jet

Each of them has been discussed in detail in the following section.

Inter-Tropical Convergence Zone (ITCZ)

- The Inter-Tropical Convergence Zone (ITCZ), also called the Equatorial convergence zone, is a low-pressure belt of converging trade winds and rising air that encircles the Earth near the Equator.
- The ITCZ shifts north and south seasonally with the Sun. Over the Indian Ocean, it undergoes especially large seasonal shifts of 40˚-45˚ of latitude.
- In June, the ITCZ moves polewards towards the Tropic of Cancer. However, it extends North over India (as far as 30˚ N) northwards of the Himalayan Mountains.
  - This is due to the intense heating of the land mass that takes place over India.
  - This intense heating and the movement of the ITCZ create low pressure over northern India.
- Meanwhile, the Indian Ocean heats up slowly, creating a zone of relatively high pressure (a subtropical anticyclone) off India's southern coastline.
- Also, the winds blow from High to Low pressure. Air moves south-westerly from the sea to India in the north and northeast.
  - Here, it is deflected towards the right by the Coriolis force as the Earth spins.
- This low pressure draws in warm, unstable air from the Indian Ocean, laden with water vapour, bringing heavy rain to India.
  - The uplift of this air over the foothills of the Himalayas and intense convection of the landmass further increase rainfall.
- In January, the ITCZ and the subtropical jet stream move southwards over the Equator and towards the Tropic of Capricorn.
  - At the same time, the continental landmass at the centre of Asia around Mongolia and the Himalayas experiences intense cooling as the Northern Hemisphere points away from the Sun.
- The intense cooling creates an area of high pressure in northern India, and the low pressure of the ITCZ is found to the south of India.
  - The winds blow from the Northeast, away from the high-pressure cell over northern India, bringing dry conditions to most of the Indian subcontinent as they travel over land.

Tibetan Plateau

- The Tibetan Plateau affects the monsoon in two ways:
  - As a mechanical barrier, and
  - As a high-level heat source.
- The Tibetan Plateau, along with the Himalayas, is an enormous block of highland that acts as a formidable barrier and a heat source.
  - In summer, Tibet's air is 2˚C to 3˚C warmer than the air over the adjoining regions, hence the heat source.
- As a mechanical barrier, it causes the advancement of the Subtropical westerly jet stream to the south of the Himalayas, bifurcating it into two parts—one branch in the north of the Himalayas and the other in the south of it by November.
  - As a high-level heat source, the Tibet Plateau gives birth to a temporary jet called the Tropical Easterly Jet, which originates from the Tibet Plateau and travels over the Indian subcontinent and Indian Ocean.

Jet Stream

- Jet streams are narrow, strong wind bands that generally blow from west to east across the globe.
    - They are found at heights ranging from 11 to 13 km above the surface of the Earth.
- In the Northern Hemisphere, the mean position of the jet stream ranges from 20˚N to 50˚N latitude, while the polar jet stream is found between 30˚ and 70˚N latitude.
    - These streams are driven by substantial temperature differences between adjacent air masses.
- There are four major jet streams, which, despite being discontinuous at times, circulate the globe at middle and polar latitudes in both hemispheres.
    - Rather than moving in a straight path, the jet stream exhibits a wavelike flow.

Somali Jet

- Apart from polar and subtropical jet streams, which are permanent jet streams, there are some temporary jet streams.
- Temporary jet streams are narrow winds with speeds of more than 94 kph in the upper, middle, and sometimes lower troposphere.
- Two important ones are the Somali Jet and the African Easterly Jet or Tropical Easterly Jet, which play an essential role in the formation and progression of Indian Monsoons.
- The Somalian current changes its flow direction due to upwelling and downwelling on the eastern coast of Africa.
- In winter, the Somali Jet flows from north to south, travelling from the coast of Arabia to the East African coastline.
    - However, with the onset of the summer monsoon, this current reverses direction, moving from south to north.
- The progression of the southwest monsoon toward India is significantly facilitated by the Somali Jet, which crosses Kenya, Somalia, and the Sahel.
    - This jet reinforces the high-pressure system near Madagascar and enhances the intensity and pace of the southwest monsoons reaching India.

Regional Variations of Monsoon in India

Various regional variations in the monsoon across different parts of India include:

Western Ghats and Coastal Areas

- This region experiences heavy monsoon rainfall due to orographic lift, where moist winds from the Arabian Sea are forced to rise over the Western Ghats, causing intense rain on the windward side.

Northern Plains

- The Northern Plains receive moderate to heavy rainfall, with the monsoon arriving from the southwest. The region is influenced by the Indian monsoon's northward progression and the Himalayan foothills.

Northeast India

- The Northeast, including states like Assam and Meghalaya, receives very high rainfall due to its proximity to the Bay of Bengal and the influence of the Himalayan foothills.

Deccan Plateau

- The Deccan Plateau receives less rainfall compared to the Western Ghats and coastal areas. The monsoon winds weaken as they cross the plateau, resulting in lower precipitation.

Arid and Semi-Arid Regions

- Regions like Rajasthan and parts of Gujarat receive minimal rainfall, with the monsoon rains being sporadic and insufficient to replenish water sources fully.

Impact of Monsoon in India

The Monsoon in India has significant impact on various sectors:

- **Agriculture** - The Monsoon in India is vital for crop production in India. It provides the necessary water for planting and growing crops such as rice, wheat, and pulses.
    - A good monsoon in India ensures abundant harvests, while a poor monsoon can lead to drought and crop failures.
- **Water Resources** - Monsoon rains replenish rivers, lakes, and reservoirs, crucial for drinking water, irrigation, and hydroelectric power generation.
    - Adequate rainfall helps in maintaining the balance of water resources across the country.
- **Economy** - The performance of the monsoon season influences the overall economy, particularly in rural areas.
    - It affects food prices, agricultural incomes, and rural employment. Good monsoon conditions can boost economic growth, while adverse conditions can strain economic resources.

- **Health** - The monsoon season can impact public health, with increased risks of waterborne diseases, such as cholera and dengue fever, due to stagnant water and poor sanitation.
    - Proper management of water and sanitation is essential to mitigate health risks.
- **Infrastructure** - Heavy rains can lead to flooding, which impacts infrastructure such as roads, bridges, and buildings.
    - Effective drainage systems and infrastructure maintenance are crucial to minimise damage and disruptions caused by monsoon rains.
- **Environment** - The monsoon season maintains ecological balance by supporting diverse ecosystems, replenishing soil moisture, and sustaining plant and animal life.
    - However, extreme weather events can also cause environmental degradation and habitat loss.

Monsoon Prediction and Management

- **Weather Forecasting** - Advances in meteorology enable accurate monsoon onset, intensity, and duration predictions, which are crucial for planning and preparedness.
- **Technology and Methods** - Utilizing satellite imagery, radar systems, and climate models enhances the accuracy of weather forecasts and monitoring of monsoon patterns.
- **Government Initiatives** - Various government programs and agencies work to improve monsoon forecasting, flood management, and disaster response to mitigate the impact of adverse weather conditions.
- **Policies and Schemes** - Implementing policies and schemes to improve water management, agricultural practices, and infrastructure development helps address the challenges of monsoon variability.
- **Adaptation Strategies** - Developing and implementing adaptation strategies, such as rainwater harvesting and resilient agricultural practices, assists communities in coping with the effects of the monsoon.
- **Agricultural and Urban Planning** - Effective planning for agriculture and urban development, including improved drainage systems and crop management, is essential to mitigate the impact of monsoon-related disruptions.

Conclusion

The Monsoon in India is a crucial climatic system influencing the subcontinent's weather, agriculture, and economy. Its distinct phases, regional variations, and effects on various sectors underscore its importance and complexity. As climate change and environmental challenges impact monsoon patterns, effective prediction, management, and adaptation strategies become increasingly vital. Sustainable practices and advancements in weather forecasting will be essential to mitigate the adverse effects and ensure that the monsoon continues to support India's ecological balance and economic stability.

THE ONSET AND WITHDRAWAL OF THE MONSOON

- THE ONSET AND WITHDRAWAL OF THE MONSOON
  THE TRADE WINDS ARE STEADY BUT THE MONSOON WINDS ARE PULSATING IN NATURE. THEY ARE AFFECTED BY DIFFERENT ATMOSPHERIC CONDITIONS, ESPECIALLY AS THEY FLOW OVER WARM TROPICAL AREAS. STARTING FROM EARLY JUNE, IN THE SOUTHERN PART OF THE INDIAN PENINSULA, THE MONSOON LASTS BETWEEN 100 AND 120 DAYS, WITHDRAWING BY MID-SEPTEMBER.
- RAINFALL INCREASES SUDDENLY AND CONTINUES FOR SEVERAL DAYS AT THE TIME OF ARRIVAL OF MONSOON. THIS PHENOMENON IS CALLED THE “BURST” OF THE MONSOON. IT IS DIFFERENT FROM PRE-MONSOON SHOWERS. IN ITS DURATION THE MONSOON RAINS ALTERNATE BETWEEN WET AND DRY SPELLS.
- ONSET OF MONSOON
  THE MONSOON GENERALLY REACHES THE SOUTHERN TIP OF THE PENINSULA DURING THE FIRST WEEK OF JUNE. AFTER STRIKING THE SOUTHERN TIP, IT BRANCHES INTO TWO PARTS: THE ARABIAN SEA BRANCH AND THE BAY OF BENGAL BRANCH; BOTH BRANCHES MOVE RAPIDLY.
- THE ARABIAN SEA BRANCH ADVANCES NORTH ALONG THE WESTERN GHATS, REACHING MUMBAI BY ABOUT 10TH OF JUNE AND SOON COVERS THE SAURASHTRA-KUCHCHH AND CENTRAL MOST PART OF THE DECCAN PLATEAU.
- THE BAY OF BENGAL BRANCH REACHES ASSAM IN THE FIRST WEEK OF JUNE AND GETS DEFLECTED TOWARDS THE WEST BY THE MOUNTAIN RANGES, THUS GIVING RAINFALL TO THE GANGA PLAINS.
- BOTH THE BRANCHES AGAIN MERGE OVER THE NORTH-WESTERN PART OF THE GANGA PLAINS. USUALLY, DELHI RECEIVES RAINFALL BY THE END OF JUNE, FROM THE BAY OF BENGAL BRANCH. BY THE FIRST-WEEK OF JULY, THE MONSOON COVERS WESTERN UTTAR PRADESH, PUNJAB, HARYANA AND EASTERN RAJASTHAN.
- WITHDRAWAL OF MONSOON
  THE WITHDRAWAL OR RETREAT OF THE MONSOON IS A MORE GRADUAL PROCESS. IT BEGINS BY EARLY SEPTEMBER IN THE NORTH-WESTERN STATES. BY MID- OCTOBER, IT WITHDRAWS COMPLETELY FROM THE NORTHERN HALF OF THE PENINSULA. THE WITHDRAWAL FROM THE SOUTHERN HALF OF THE PENINSULA IS FAIRLY RAPID. BY EARLY DECEMBER THE MONSOON HAS WITHDRAWN FROM THE REST OF THE COUNTRY.

IMPORTANT FEATURES OF MONSOON

- THE MONSOON IS KNOWN FOR ITS VARIABILITY AND UNCERTAINTY.
- THERE IS AN ALTERNATION OF DRY AND WET SPELLS, WHICH VARY IN INTENSITY, FREQUENCY AND DURATION.
- WHILE IT CAUSES HEAVY FLOODS IN ONE PART, IT MAY BE RESPONSIBLE FOR DROUGHT IN OTHER PARTS.
- ITS IRREGULAR ARRIVAL AND RETREAT (SOMETIMES DUE TO THE EFFECT OF EL NINO), CAUSES DISRUPTION TO FARMING SCHEDULES, FLOODS IN SOME AREAS AND DROUGHTS IN OTHER AREAS OF THE COUNTRY.

THE SEASONS IN INDIA

- **THE SEASONS**
  THE DISTINCT, SEASONAL PATTERN IS AN IMPORTANT CHARACTERISTIC OF THE MONSOON TYPE OF CLIMATE. THE WEATHER CONDITIONS IN INDIA GREATLY CHANGE FROM ONE SEASON TO ANOTHER. THESE CHANGES ARE PARTICULARLY NOTICEABLE IN THE INTERIOR PARTS OF THE COUNTRY. THE COASTAL AREAS DO NOT EXPERIENCE MUCH VARIATION IN TEMPERATURE THOUGH THERE IS VARIATION IN RAINFALL PATTERN.
- **THERE ARE BASICALLY FOUR SEASONS IDENTIFIED IN INDIA**: THE COLD WEATHER SEASON (WINTER), THE HOT WEATHER SEASON (SUMMER), THE ADVANCING MONSOONS (THE RAINY SEASON), AND THE RETREATING/POST MONSOONS (THE TRANSITION SEASON).

THE FOUR SEASONS IN INDIA

1. THE COLD WEATHER SEASON (WINTER)

THE COLD WEATHER SEASON BEGINS FROM MID-NOVEMBER AND STAYS TILL FEBRUARY IN NORTHERN PARTS OF INDIA, WITH DECEMBER AND JANUARY BEING THE COLDEST MONTHS. THE TEMPERATURE DECREASES FROM SOUTH TO NORTH.

- **THE FEATURES OF THE COLD WEATHER SEASON** ARE:: CLEAR SKY, LOW TEMPERATURE AND HUMIDITY, AND FEEBLE, VARIABLE WINDS ARE THE CHARACTERISTICS OF THE WEATHER DURING THE PERIOD.

2. THE HOT WEATHER SEASON(SUMMER)

THE HOT WEATHER SEASON STARTS WITH THE APPARENT MOVEMENT OF THE SUN TOWARDS THE NORTH, WHICH SETS OFF THE NORTHWARD MOVEMENT OF THE GLOBAL HEAT BELT. THE HOT WEATHER SEASON STARTS IN MARCH AND LASTS UP TO THE END OF MAY.

- **FEATURES OF HOT WEATHER SEASON ARE:** RISE IN TEMPERATURE, FALLING AIR PRESSURE, DUST STORMS, HOT, GUSTY, DRY WINDS, LOCALIZED THUNDERSTORMS.
- TEMPERATURE VARIATION DURING HOT WEATHER

  THE INFLUENCE OF THE SHIFTING OF THE HEAT BELT CAN BE SEEN FROM TEMPERATURE RECORDINGS TAKEN DURING MARCH TO MAY AT DIFFERENT LATITUDES. IN MARCH, THE HIGHEST TEMPERATURE IS ABOUT 38°C, RECORDED IN THE DECCAN PLATEAU AND IN GUJARAT AND MADHYA PRADESH IT IS AROUND 42°C IN THE MONTH OF APRIL. IN MAY, THE NORTH-WESTERN PARTS OF THE COUNTRY EXPERIENCE TEMPERATURES AROUND 45°C. DUE TO THE MODERATING INFLUENCE OF THE OCEANS, THE TEMPERATURES REMAIN LOW IN PENINSULAR INDIA.

THE FOUR SEASONS IN INDIA (2)

3. **ADVANCING MONSOON (THE RAINY SEASON)**

THE LOW-PRESSURE AREA OVER THE NORTHERN PLAINS INTENSIFIES BY MID-JUNE AND ATTRACTS THE TRADE WINDS. THESE TRADE WINDS ORIGINATE OVER THE WARM TROPICAL OCEAN IN THE SOUTHERN HEMISPHERE. AFTER CROSSING THE EQUATOR, THESE BLOW IN THE SOUTH-WEST DIRECTION, ENTERING THE PENINSULA AS THE SOUTH-WEST MONSOON. IN JUST OVER A MONTH, THE MONSOON SYSTEM COVERS THE ENTIRE SUB-CONTINENT, EXCEPT THE EXTREME NORTH-WEST. .

- **RAINFALL IN THE WESTERN GHATS AND DECCAN PLATEAU**

  A TOTAL CHANGE IN WEATHER IS BROUGHT ABOUT BY THE INFLOW OF THE SOUTH-WEST MONSOON IN INDIA. THE WINDWARD SIDE OF THE WESTERN GHATS RECEIVES VERY HEAVY RAINFALL; MORE THAN 250 CM IN THE EARLY SEASON. DESPITE LYING IN A RAIN- SHADOW AREA, THE DECCAN PLATEAU AND PARTS OF MADHYA PRADESH ALSO RECEIVE SOME AMOUNT OF RAINFALL.

- **AREAS OF MAXIMUM AND LEAST RAINFALL**

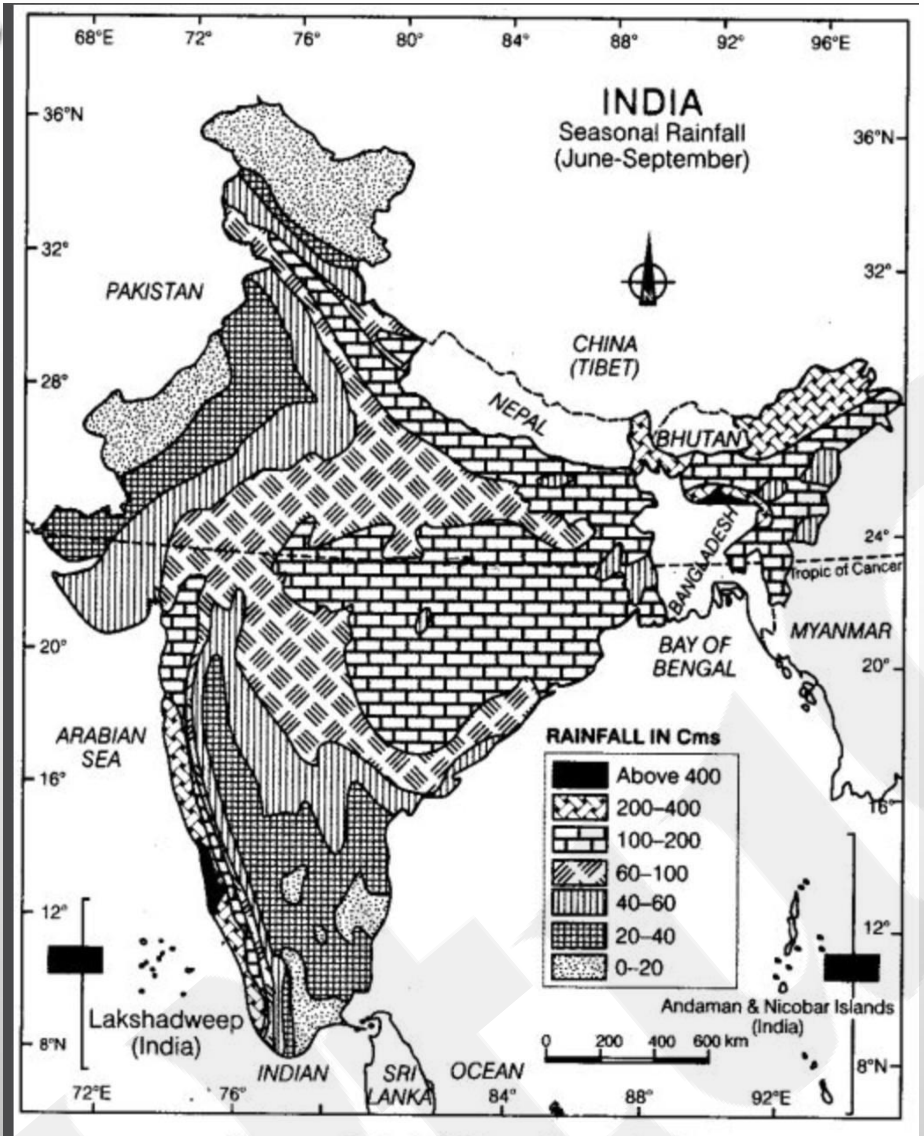
  THE MAXIMUM RAINFALL OF THIS SEASON IS RECEIVED BY THE NORTH-EASTERN PART OF THE COUNTRY. THE HIGHEST AVERAGE RAINFALL IN THE WORLD FALLS AT MAWSYNRAM IN THE SOUTHERN RANGES OF THE KHASI HILLS IN MEGHALAYA.

  IN THE NORTHERN PLAINS PRECIPITATION DECREASES FROM EAST TO WEST, WITH THE WESTERN PARTS OF RAJASTHAN AND THE NORTHERN PARTS OF GUJARAT GETTING THE LEAST RAINFALL.

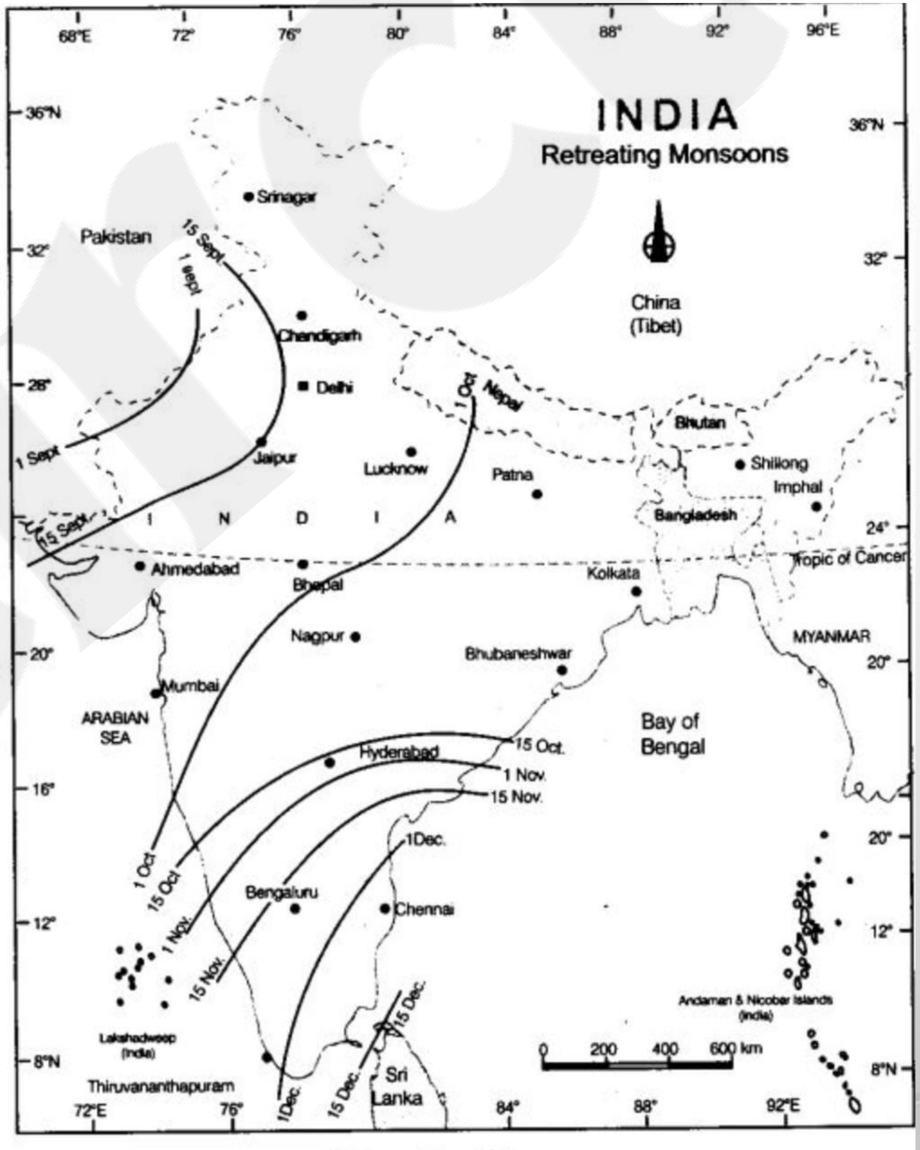
- **FEATURES OF ADVANCING MONSOON:**

  WET AND DRY SPELLS, THE MONSOON TROUGH, AND TROPICAL DEPRESSIONS.

THE MONSOON



Seasonal Rainfall (June-September)



Retreating Monsoon

HANDOUT FOR CLIMATE MODULE 2
(P1/2)

- MONSOONS ARE PULSATING IN NATURE AND ARE AFFECTED BY DIFFERENT ATMOSPHERIC CONDITIONS. THEY ARE ABOUT 100-120 DAYS IN DURATION, AND OCCUR JUNE-SEPT.
- THE ARABIAN SEA BRANCH AND BAY OF BENGAL BRANCH ARE ***THE TWO BRANCHES OF SOUTH-WEST MONSOON*** IN INDIA.
- THE ***ARABIAN SEA BRANCH*** OF THE MONSOON CAUSES RAINFALL IN THE WESTERN GHAT, MUMBAI, GUJARAT AND CENTRAL INDIA.
- THE ***BAY OF BENGAL BRANCH*** OF THE MONSOON CAUSES RAINFALL IN NORTH-EAST INDIA AND THE GANGA PLAIN.
- AROUND THE TIME OF THE ARRIVAL OF THE MONSOON, A SUDDEN AND CONSTANT RAINFALL, ALONG WITH VIOLENT THUNDER AND LIGHTNING IS CALLED THE ***BURST*** *OF THE MONSOON*.
- THE ***FOUR-MAIN SEASONS IN INDIA*** ARE: THE COLD WEATHER SEASON (WINTER), THE HOT WEATHER SEASON (SUMMER), THE ADVANCING MONSOONS (THE RAINY SEASON), AND THE RETREATING/POST MONSOONS (THE TRANSITION SEASON).
- THE **COLD WEATHER SEASON** ***IS MARKED BY*** A CLEAR SKY, LOW TEMPERATURES, LOW HUMIDITY AND A FEEBLE, VARIABLE WIND.
- DUE TO THE MODERATING INFLUENCE OF THE SEA, **THE PENINSULAR REGION** DOES NOT HAVE A WELL-DEFINED COLD SEASON, NOR ANY NOTICEABLE CHANGE IN TEMPERATURE.
- THE SMALL AMOUNT OF WINTER RAINFALL, DUE TO AN INFLOW OF CYCLONIC DISTURBANCES FROM THE WEST AND THE NORTH-WEST, IS LOCALLY KNOWN AS '***MAHAWAT***,' AND IS USEFUL IN THE CULTIVATION OF THE RABI OR WINTER CROPS.
- THE ***MAIN FEATURES OF THE*** **HOT WEATHER SEASON** ARE: SUBSTANTIALLY HIGH TEMPERATURES IN THE NORTH, A LOWERING OF ATMOSPHERIC PRESSURE, DUST STORMS, AND HOT, GUSTY, DRY WINDS; LOCALIZED THUNDERSTORMS ALSO OCCUR.
- ***DUST STORMS*** IN NORTH INDIA OCCUR IN THE MONTH OF MAY AND CAN BRING TEMPORARY RELIEF FROM THE HEAT BY *LOWERING THE TEMPERATURE* AS THEY CAN BRING LIGHT RAIN AND A COLD BREEZE.

HANDOUT FOR CLIMATE MODULE 2
(P2/2)

- THE "***LOO***" IS HOT, DRY, AND STRONG WIND THAT CAN CAUSE DEATH IN CASES OF PROLONGED EXPOSURE. IT BLOWS DURING THE DAY OVER NORTH AND NORTH-WESTERN INDIA IN THE SUMMER OR HOT WEATHER SEASON.
- ***KAAL BAISAKHI*** IS A LOCALIZED THUNDER STORM IN WEST BENGAL. IT OCCURS IN THE HOT SUMMER SEASON BUT IS ASSOCIATED WITH VIOLENT WINDS, TORRENTIAL DOWNPOURS AND QUITE OFTEN, HAIL.
- THE PRE-MONSOON SHOWER THAT OCCURS TOWARD THE END OF THE SUMMER SEASON IN THE COASTAL AREAS OF KARNATAKA AND KERALA ARE OFTEN CALLED, "***MANGO SHOWERSF*** BECAUSE THEY HELP IN THE EARLY RIPENING OF MANGOES.
- ***MAXIMUM RAINFALL*** DURING THE MONSOON OCCURS IN THE NORTHEAST, MAINLY MEGHALAYA AND ASSAM, AND THE WINDWARD SIDE OF THE WESTERN GHATS (THIRUVANANTHAPURAM TO MUMBAI).
- ***MINIMUM RAINFALL*** OCCURS IN THE WESTERN PARTS OF RAJASTHAN AND THE NORTHERN PARTS OF GUJARAT.
- FEATURES OF THE ***ADVANCING MONSOON*** *ARE*: MONSOON RAINS OCCUR IN WET AND DRY SPELLS; EFFECTS OF THE MONSOON TROUGH, AND TROPICAL DEPRESSIONS.
- THE RAINLESS INTERVALS INTERSPERSING THE MONSOON ARE CALLED "***BREAKSF*** *IN THE MONSOON.*'
- THE ***MONSOON TROUGH*** IS THE INTENSE AND ELONGATED LOW-PRESSURE AREA, WHICH DEVELOPS OVER NORTH-WESTERN INDIA. IT EXTENDS FROM THE THAR DESERT IN THE WEST TO THE CHOTA NAGPUR PLATEAU IN THE EAST. IT'S MOVEMENT DETERMINES THE SPATIAL DISTRIBUTION OF RAINFALL.
- ***TROPICAL DEPRESSIONS*** FOLLOW THE AXIS OF THE 'MONSOON TROUGH OF LOW PRESSURE' AND DETERMINE THE AMOUNT AND DURATION OF THE MONSOON RAINS BY THEIR FREQUENCY AND INTENSITY.

CLIMATE MODULE 2
WORKSHEET 2

1. EXPLAIN THE FOUR FEATURES OF THE MONSOON RAIN
2. WHAT ARE THE FOUR MAIN SEASONS OF INDIA?
3. DIFFERENTIATE BETWEEN THE COLD WEATHER SEASON AND THE HOT WEATHER SEASON OF INDIA BY EXPLAINING THREE DISTINCTIVE FEATURES OF EACH
4. WRITE IN BRIEF ABOUT THE MECHANISM OF THE MONSOON
5. WHY IS THE SOUTH WEST MONSOON LESS RAINY IN TAMIL NADU?
6. DEFINE & DESCRIBE THE FOLLOWING:

- A. BURST OF MONSOON B. MAHAWAT
- C. MANGO SHOWERS D. CONTINENTALITY

E. DUST STORMS F. LOO

RAINFALL – CHARACTERISTICS AND DISTRIBUTION

As we know there are some countries where it rains all time and this continuous rain helps in proper growth of grass and crops. In this unit we will discuss types of rainfall NCERT Notes for UPSC aspirants for Geography syllabus. Rain is not only essential for plant growth but it is equally important for better survival of life. Formation of rainfall occurs when saturated air is heated and rises either by a frontal action or by a mountain.

With the rising process saturated air or water vapour cools down and further they attach themselves to tiny particles of dust salt, seeds or smoke in the atmosphere. These attached particles are also known as condensed nuclei. When so many condensed nuclei join together then there occurs a process of condensation. This condensation process is necessary for formation of rain drop. Further raindrop leads to the formation of clouds.

Classification of Rainfall

On the basis of origin rainfall is classified into three types:

- Conventional rainfall
- Orographic rainfall or relief rainfall
- Cyclonic rainfall or frontal rainfall

Convectional Rainfall:

The formation of convectional rainfall occurs when air is on the surface of the earth or a few metre above the surface of the earth it is heated by the sun. Once the air is heated it becomes lighter and further this lighter air rises up and cools down and condenses on the condensation nuclei which are present in the atmosphere. This is because of the fact that only a small surface of area is covered by converging air. As soon as air converges it gets condense to form a thick cumulus cloud. as the cloud Rises up they become unstable and because of this instability cloud drops on the ground in the form of raindrops or rainfall.

Characteristic Features of Conventional Rainfall:

- Once the air gets heated they become light and rise in a convection current.
- With the rise of air they expand and the temperature drops down and by this condensation process takes place and forms clouds.
- Convectional rainfall is usually in the summer or the hotter part of the day.
- Sach rainfall is mainly associated with hail and graupel.
- The equatorial region and internal part of the continents mainly in the Northern hemisphere receive conventional rainfall.

Orographic or Relief Rainfall:

When wind forces moist air landwards towards the mountain's terrain then the mountain further lifts the moist air in an upward direction that is into the atmosphere. Once the air reaches the atmosphere it cools down and undergoes a precipitation process.

With rising in winter water vapour they started becoming unstable and heavy and because of this they develop around conventional nuclei and form thick clouds. Further, this cloud moves up and becomes an unstable water droplet. And after this, they fall on the ground as raindrops.

Characteristic Features of Orographic or Relief Rainfall:

- The principal characteristic behind this type of rainfall is that the windward slope gets heavy rainfall.
- The reason located on the leeward side opposite side is known to be rain-shadow area.
- This rainfall is seen in mountainous areas and along hills.

- Mountains act as an obstacle that force vapour to rise which leads to orographic rainfall.

Cyclonic or Frontal Rainfall:

It is the last type of rainfall and occurs when two air masses that have different characteristics combine together. For example when a warm Maritime air mass combines with a cold heavier air mass then in that case the warm air mass is undercut by cold air mass. And because of this warm air mass is forced to move up because of its lightweightness. And warm water vapour cools down as it rises up which leads to the condensation process and a cloud is formed and the condensation nuclei in the atmosphere. With rise in clouds they become unstable as more water droplets are accumulated in the cloud and they fall on the ground in the form of cyclonic rainfall.

Characteristic Features of Cyclonic or Frontal Rainfall:

- The Tropic and Temperate Zones receive such rainfall.
- The layer which separates two masses of air is known as the front.
- The type of rainfall is mainly for a few hours to a few days.

Effects of Rainfall

Water is considered as one of the most valuable resources on the earth and rainfall is the only way by which all the water reservoirs can be filled. This reservoir's supply of drinking water is done. Along with that water is also a Habitat for fish to leave, also nourishes the soil for proper vegetation as while doing agriculture practice water helps both people and animals for harvesting and for the consumption process also. Among all the sources of water, rainfall is considered as one of the major sources.
Sometimes rainfall also has a negative effect like it causes soil erosion when rain is having high pH. Along with that, it can also cause natural disasters which destroy properties and lives also.

Types of Rainfall

Rainfall has been classified into three main types based on the origin −
Convectional rainfall
Orographic or relief rainfall
Cyclonic or frontal rainfall

Convectional Rainfall − Major Characteristics

The air, on getting heated, becomes light and rises in convection currents.
As the air rises, it expands and drops the temperature and subsequently, condensation takes place and cumulus clouds are formed.
Heavy rainfall with lightning and thunder takes place which does not last long.
Such rain is usually in the summer or the hotter part of the day.
This type of rainfall generally takes place in the equatorial regions and internal parts of the continents, predominantly in the northern hemisphere.
This rainfall is usually associated with hail and graupel

Orographic Rainfall − Major Characteristics

When the saturated air mass comes across a mountain, it is forced to rise.
The rising air expands, and eventually, the temperature falls, and the moisture gets condensed.
The principal characteristic of this type of rain is that the windward slopes get more rainfall.
After giving rain on the windward side, when these winds reach the other slope, they drop away, and their temperature increases. Then their ability to take in moisture increases and hence, these leeward slopes remain dry and rainless.
The region situated on the leeward side is known as the rain-shadow area.

Cyclonic Rainfall - Major Characteristics

Cyclonic activity causes cyclonic rain and it occurs along the fronts of the cyclone.
When two masses of air of unlike density, temperature, and humidity meet then it is formed.
The layer that separates them is known as the front.
A warm front and the cold front are the two parts of the front.
At the warm front, the warm lighter wind increases slightly over the heavier cold air.
As the warm air rises, it cools, and the moisture present in it condenses to form clouds
This rain falls gradually for a few hours to a few days.

Types of Rainfall based on Intensity

The types of rainfall based on intensity can be classified as:

1. Light rain - Rate of rain varies between 0 to 2.5 millimetres
2. Moderate rain - Rate of rain varies between 2.6 millimetres to 7.6 millimetres
3. Heavy rain - Rate of rain is beyond 7.6 millimetres

Notes on Rainfall: Characteristics and Distribution

1. Characteristics of Rainfall

- **Definition:** Rainfall is the process by which water vapor in the atmosphere condenses into droplets that fall to the Earth's surface due to gravity. It is a key component of the Earth's hydrological cycle.
- **Measurement:** Rainfall is typically measured in millimeters (mm) or inches (in) using instruments such as rain gauges. The amount of rainfall is often recorded over a specific period (daily, monthly, or annually).
- **Intensity:**
  - **Light Rain:** Less than 2.5 mm per hour.
  - **Moderate Rain:** 2.5 mm to 7.5 mm per hour.
  - **Heavy Rain:** More than 7.5 mm per hour.
  - **Very Heavy Rain:** More than 50 mm per hour.
- **Duration:** Rainfall can vary in duration, ranging from brief showers (minutes) to prolonged periods of rain (days or weeks).
- **Type of Rainfall:**
  - **Convectional Rainfall:** Caused by the heating of the Earth's surface, leading to rising warm air, which cools and condenses into rain. Common in tropical regions.
  - **Orographic Rainfall:** Occurs when moist air is forced to ascend over mountain ranges, cooling and condensing to form rain on the windward side of the mountains.
  - **Frontal Rainfall:** Results from the meeting of two air masses with different temperatures (warm and cold), causing the warm air to rise, cool, and condense into rain.
- **Rainfall Distribution Patterns:** Rainfall patterns can vary significantly based on geographical location, season, and climatic factors.

2. Distribution of Rainfall

- **Tropical Regions:**
  - High rainfall throughout the year.
  - Rain is typically heavy and frequent, with distinct wet and dry seasons in some areas.
  - Equatorial regions, such as the Amazon and Congo basins, receive abundant rainfall due to convectional processes.
- **Desert Regions:**

- Very low rainfall, often less than 250 mm annually.
- Deserts like the Sahara and Arabian Desert receive minimal rainfall due to high-pressure systems and descending air currents.

- **Temperate Regions:**
  - Moderate rainfall throughout the year.
  - Characterized by frontal rainfall, with distinct wet and dry seasons, as seen in regions like western Europe and the eastern United States.
- **Mountainous Areas:**
  - Orographic rainfall leads to high precipitation on the windward side of mountains and much drier conditions on the leeward side (rain shadow effect).
  - Example: The western slopes of the Andes or the Sierra Nevada mountains.
- **Monsoon Regions:**
  - Monsoon winds bring seasonal heavy rainfall during specific periods, such as the South Asian monsoon.
  - Rainfall is concentrated in certain months, often resulting in a wet season followed by a dry season.
- **Polar Regions:**
  - Very low rainfall, often in the form of snow.
  - Polar deserts, such as Antarctica, receive very little precipitation due to extremely cold temperatures and limited moisture in the air.

3. Factors Influencing Rainfall Distribution

- **Latitude:** Regions near the equator (tropical) experience more consistent rainfall, while polar regions receive minimal rainfall.
- **Altitude:** Higher altitudes can lead to increased rainfall due to orographic effects, where moist air is lifted and cooled.
- **Proximity to Water Bodies:** Coastal regions tend to receive more rainfall due to the availability of moisture from oceans or large lakes.
- **Wind Patterns:** Winds such as the trade winds, westerlies, and monsoon winds influence the amount of rainfall in different regions.
- **Topography:** Mountain ranges can create significant variations in rainfall patterns. Windward sides tend to receive more rain, while the leeward sides are drier.
- **Seasonal Variations:** The Earth's tilt and orbit around the sun lead to changes in seasonal rainfall patterns, such as in regions affected by monsoons or temperate climates with distinct wet and dry seasons.

4. Rainfall and Climate Zones

- **Tropical Rainforest (Af):** High rainfall throughout the year (over 2000 mm annually), found in regions near the equator.
- **Desert (BW):** Extremely low rainfall, less than 250 mm annually.
- **Temperate (C):** Moderate rainfall with distinct seasonal variation, typically ranging from 600 mm to 1500 mm annually.
- **Mediterranean (Csa, Csb):** Seasonal rainfall, with wet winters and dry summers.
- **Continental (D):** Rainfall varies greatly, with more precipitation in summer than winter.
- **Polar (E):** Low rainfall, often in the form of snow, and extreme cold conditions.

Conclusion

Rainfall is a critical component of the Earth's climate system, with distinct characteristics influenced by location, altitude, and seasonal changes. The distribution of rainfall is uneven across the globe, and understanding these patterns helps in areas such as agriculture, water resources, and climate studies.

Rainfall: Characteristics, Distribution, Onset, and Withdrawal of Effective Rains

1. Characteristics of Rainfall:

Rainfall is a key component of the hydrological cycle, and its characteristics can vary significantly depending on several factors like geography, season, and climatic conditions. Some key characteristics include:

- **Amount**: This refers to the total volume of rain received in a specific area over a period of time. It is typically measured in millimeters (mm) or inches.
- **Intensity**: This is the rate at which rainfall occurs, usually measured in millimeters per hour (mm/h). Intensity can vary from light showers to heavy downpours.
- **Duration**: Refers to how long the rain lasts. It can range from short, intense bursts to long-lasting drizzles.
- **Frequency**: This refers to how often rainfall occurs in a given period, which can influence the local climate (e.g., frequent rainfall in tropical areas vs. sporadic rainfall in arid zones).
- **Seasonality**: Some regions experience rainfall only during certain seasons (monsoon seasons, wet vs. dry periods).
- **Type**: Rainfall can also be classified into different types:
  - **Convectional**: Often occurring in tropical areas, due to rising warm air cooling and condensing.
  - **Frontal**: Occurs when a warm air mass meets a cold air mass, typically in temperate zones.
  - **Orographic**: When air is forced to rise over mountains, leading to cooling and precipitation.
  - **Cyclonic**: Associated with low-pressure systems, particularly in tropical and subtropical regions.

2. Distribution of Rainfall:

Rainfall distribution is highly variable across the globe due to differences in climate zones, geographical features, and atmospheric circulation patterns. It can generally be divided into the following:

- **Tropical Regions**: The equator, particularly areas near the Intertropical Convergence Zone (ITCZ), experiences heavy, frequent rainfall, often throughout the year due to high temperatures and convection. Rainfall is often intense but of short duration.
- **Desert Regions**: These areas, typically found around 30° latitude (both north and south), receive very little rainfall, often less than 250 mm annually.
- **Temperate Regions**: These regions have moderate rainfall, with distinct wet and dry seasons. Much of the rainfall in these regions is frontal in nature, where warm air meets cold air.
- **Mountainous Regions**: Orographic rainfall results in high rainfall on the windward side of mountains, while the leeward side (rain shadow) often remains dry.
- **Polar Regions**: Rainfall is very low in these areas, and precipitation often falls as snow.

Rainfall is also influenced by other climatic factors such as:

- **Monsoons**: Seasonal wind patterns that bring heavy rainfall during certain months, typically affecting parts of Asia, Africa, and Australia.
- **El Niño and La Niña**: These phenomena can cause irregular rainfall patterns globally, often bringing droughts to some regions and excessive rainfall to others.

3. Onset of Effective Rains:

The onset of effective rains marks the beginning of the rainy season, which is critical for agricultural and ecological cycles in many regions. The onset is influenced by the following:

- **Monsoon Onset**: In South Asia, for example, the southwest monsoon usually arrives between late May and June, bringing the onset of the rainy season. The arrival of effective rains is associated with the shift in atmospheric pressure systems, where low-pressure areas in the Bay of Bengal or Arabian Sea lead to moisture-laden winds reaching the subcontinent.
- **Climate Shifts**: The shift in oceanic and atmospheric conditions, such as the movement of the ITCZ or the retreat of a dry air mass, signals the onset of effective rains. The arrival of tropical storms or cyclones can also trigger the start of effective rains in coastal areas.

Factors affecting the onset:

- **Sea Surface Temperatures (SST)**: Warm ocean waters can intensify atmospheric convection and lead to earlier or stronger monsoon rains.
- **Wind Patterns**: Shifting wind directions (e.g., the monsoon winds in India) are critical for the onset.
- **Pressure Systems**: Low-pressure systems generally signal the beginning of heavy rainfall.
- **Geographical Location**: Coastal regions and areas near water bodies tend to experience an earlier onset compared to inland areas.

4. Withdrawal of Effective Rains:

The withdrawal of effective rains marks the end of the rainy season, when rainfall starts to decrease and the dry season sets in. This process is influenced by various atmospheric and geographical factors:

- **Monsoon Withdrawal**: In monsoon-driven climates, the retreat of the monsoon winds marks the withdrawal of effective rains. For example, in South Asia, after the southwest monsoon peaks in August, it gradually withdraws from the north and west, leaving drier conditions.
- **Shifting of the ITCZ**: The ITCZ moves with the seasons. Its shift towards the equator during the dry season causes the retreat of rainfall from higher latitudes.
- **Temperature and Humidity**: As temperatures decrease or atmospheric moisture levels drop, the conditions become less favorable for sustained rainfall. This often happens after the peak of the rainy season.
- **Wind Changes**: The prevailing winds often shift as the seasons change, leading to the withdrawal of moisture-laden air and the arrival of dry, cooler winds that signal the end of rainfall.

The timing of rainfall withdrawal can vary significantly based on regional conditions:

- **Tropical and Subtropical Regions**: Withdrawal tends to happen gradually, often influenced by cyclonic activities or the retreat of the monsoon trough.
- **Temperate Regions**: Effective rains often start to taper off in autumn as the atmospheric pressure systems stabilize and temperatures cool.
- **Desert and Semi-Arid Regions**: In these regions, any rainfall tends to be sporadic, and the withdrawal may be marked by long periods without rain.

Summary of Key Concepts:

- **Rainfall Characteristics**: Amount, intensity, duration, frequency, seasonality, and type (convectional, frontal, orographic, cyclonic).
- **Rainfall Distribution**: Varies globally due to factors like latitude, geographical features, atmospheric circulation, and seasonal shifts (e.g., tropical rainforests vs. deserts).
- **Onset of Effective Rains**: Initiated by changes in atmospheric pressure, wind systems, and moisture availability (e.g., monsoon onset).
- **Withdrawal of Effective Rains**: Linked to shifts in atmospheric pressure, wind patterns, and seasonal temperature changes (e.g., monsoon retreat).

Understanding these factors is crucial for predicting rainfall patterns, managing water resources, and planning agricultural activities.

Dry Spell, Wet Spell, and Critical Dry Spell

These terms are typically used in meteorology, agriculture, and hydrology to describe certain periods in weather patterns and their impact on ecosystems, crop production, and water resources. Here's a breakdown:

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1. Dry Spell

A **dry spell** refers to a period of below-average precipitation or drought-like conditions over a specific duration. It's characterized by the absence or significant reduction of rainfall for a period, but it may not meet the threshold for what would officially be called a "drought."

- **Duration**: Can vary from a few days to several weeks, depending on the region.
- **Characteristics**:
  - Low rainfall or no precipitation.
  - Potential impact on agriculture, especially in areas reliant on rainfall for irrigation.
  - Soil moisture levels decrease, leading to possible crop stress.
  - Water supplies may begin to feel the effects, though it may not yet be critical.
- **Implications**:
  - Short-term water stress for crops, pastures, and other natural vegetation.
  - Possible fire risks due to dry conditions.
  - Lower river or stream flow, particularly in areas with shallow groundwater tables.

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2. Wet Spell

A **wet spell** is essentially the opposite of a dry spell — a period of above-average rainfall or excessive precipitation. These spells can lead to flooding, waterlogging, or other water-related issues.

- **Duration**: Can last from a few days to several weeks, sometimes extending into months depending on the season.
- **Characteristics**:
  - Increased rainfall or precipitation that significantly exceeds the average for a specific region or season.
  - Higher-than-normal moisture levels in the soil and groundwater.
  - Potential for rivers, streams, and lakes to rise above their normal levels.
- **Implications**:
  - Risk of flooding, especially in areas that are already prone to heavy rain events.
  - Disruption to agricultural activities (e.g., planting, harvesting) due to wet soil or crop damage.
  - Possible delays in transportation, infrastructure damage, and erosion.

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3. Critical Dry Spell

A **critical dry spell** refers to a period of drought-like conditions that lasts long enough to have significant adverse effects on water resources, agriculture, and ecosystems. A "critical" dry spell typically has more severe and lasting consequences than a regular dry spell.

- **Duration**: A critical dry spell lasts longer than a normal dry spell and can extend for several weeks or even months. The impact becomes more pronounced the longer it persists.
- **Characteristics**:
  - Extremely low rainfall, often for weeks or months.
  - Significant reduction in water levels in rivers, lakes, and groundwater tables.
  - Increased evaporation rates due to higher temperatures, further exacerbating the water shortage.
  - Severe soil moisture depletion, leading to drought conditions in agriculture.
- **Implications**:
  - **Agricultural Stress**: Crops may fail, and livestock may suffer from water shortages and lack of feed.
  - **Water Scarcity**: Critical dry spells often lead to water rationing in affected regions, with restrictions on usage for irrigation, industry, and sometimes even for domestic consumption.
  - **Ecosystem Disruption**: Forests, wetlands, and other natural ecosystems may suffer from prolonged dry conditions, which can lead to biodiversity loss.
  - **Wildfires**: The risk of wildfires is heightened due to the dry conditions, particularly in regions with flammable vegetation.

- **Economic Impact**: Critical dry spells can result in significant economic losses, particularly in agriculture-dependent economies, as crop yields fall and water shortages impact industry.

Key Differences Between Dry Spell, Wet Spell, and Critical Dry Spell:

Criteria	Dry Spell	Wet Spell	Critical Dry Spell
Duration	Short to moderate (days to weeks)	Short to moderate (days to weeks)	Longer (weeks to months)
Precipitation	Below-average precipitation or none	Above-average precipitation	Severe lack of rainfall, leading to drought-like conditions
Impact on Agriculture	Minor to moderate stress	Can delay or hinder agricultural work	Severe crop damage, crop failures, and livestock stress
Water Resources	Minor impact on local water resources	Possible flooding, increased water levels	Significant water scarcity, potential for water rationing
Environmental Impact	Soil moisture decreases, risk of fires	Waterlogging, erosion	Soil degradation, ecosystem disruption, heightened fire risk

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Summary:

- **Dry Spell**: Period of reduced rainfall, potentially stressing agriculture and ecosystems, but not yet critical.
- **Wet Spell**: Period of excessive rainfall, possibly causing flooding and waterlogging.
- **Critical Dry Spell**: An extended dry period with severe consequences for water resources, agriculture, and ecosystems, akin to a drought, requiring intervention.

Soil Moisture Measuring Techniques and Factors Affecting the Moisture Dynamics: A Comprehensive Review

Water Loss from Soil: Overview, Measurements, and Factors

Water loss from soil refers to the process by which water in the soil is depleted due to evaporation, transpiration by plants, and drainage below the root zone. This is a critical process for managing irrigation, agriculture, and understanding soil-water dynamics in ecosystems.

Key Processes Contributing to Water Loss

1. **Evaporation**:
   The process by which water is lost directly from the soil surface to the atmosphere due to heat energy. This is largely driven by solar radiation, wind, and air temperature.
2. **Transpiration**:
   Water is absorbed by plant roots from the soil and then lost through small pores (stomata) on the leaves into the atmosphere. This is often combined with evaporation and is referred to as "evapotranspiration" (ET).
3. **Drainage/Percolation**:
   Water can percolate or drain downward through the soil, typically below the root zone, due to gravitational forces. This movement may be temporary (e.g., during rainfall) or continuous in some soils.
4. **Runoff**:
   Water that is not absorbed into the soil due to saturation or high rainfall intensity may flow across the soil surface into nearby water bodies.

Measuring Water Loss from Soil

1. Evapotranspiration (ET) Measurement

- **Methods**:
  - **Gravimetric Method**: Weigh soil samples before and after evaporation to estimate the amount of water lost.
  - **Pan Evaporation**: A standardized approach where the evaporation rate from a water-filled pan is used as an indicator of ET.
  - **Lysimeter**: A device that directly measures water loss by monitoring the changes in water content in a soil column. There are two types:
    - **Weighing lysimeter**: Measures the mass of water lost over time.
    - **Non-weighing lysimeter**: Measures the volume of water lost from the soil.
  - **Eddy Covariance**: A sophisticated method for measuring actual ET at a larger scale, using instruments that measure changes in air properties near the soil or plant canopy.
  - **Soil Moisture Sensors**: Can be used to monitor changes in soil moisture, which is indicative of water loss over time. Sensors such as TDR (Time Domain Reflectometry) or capacitance probes are commonly used.
- **Evapotranspiration Models**:
  - **Penman-Monteith Equation**: A widely used model that estimates ET based on weather data (temperature, humidity, solar radiation, wind speed) and crop characteristics.
  - **FAO-56**: A method provided by the FAO (Food and Agriculture Organization) for calculating reference evapotranspiration, used for irrigation scheduling.

2. Soil Water Content Measurement

- **Soil Moisture Tensiometer**: Measures the tension in the soil (how hard roots must work to extract water), giving an indirect measure of water availability.
- **Gravimetric Method**: Soil samples are weighed before and after drying in an oven to determine the moisture content.
- **Neutron Probe**: Measures soil moisture by detecting hydrogen atoms in water using neutron scattering.

3. Soil Water Potential

- Measured with psychrometers or tensiometers to assess the potential energy of water in the soil, providing insights into the availability of water to plants.

Factors Affecting Water Loss from Soil

1. **Soil Properties**:

- **Texture**:
  - Clay soils have a high water-holding capacity but low infiltration rates.
  - Sandy soils allow water to drain quickly but hold less water.
- **Structure**: Soil structure influences water movement; well-aggregated soils allow better infiltration.
- **Organic Matter**: Soils with high organic content hold more water and have better water retention.

2. **Climate and Weather Conditions**:
   - **Temperature**: Higher temperatures increase evaporation rates.
   - **Humidity**: Low humidity accelerates evaporation since there is a greater gradient between soil water and atmospheric moisture.
   - **Wind Speed**: Wind increases evaporation by removing the saturated air above the soil, thus enhancing the rate of water loss.
   - **Solar Radiation**: More solar energy leads to higher evaporation rates, especially when combined with higher temperatures.
3. **Soil Moisture Levels**:
   - When the soil moisture content is high, the rate of evaporation and transpiration tends to be higher. As the soil dries, these processes slow down, particularly transpiration, as plants close their stomata to conserve water.
4. **Vegetation Cover**:
   - **Crop Type**: Different plants have different transpiration rates. For instance, leafy crops like corn transpire more water compared to root crops like potatoes.
   - **Canopy Cover**: Dense vegetation can reduce evaporation from the soil surface by providing shade.
   - **Plant Growth Stage**: During certain growth phases (e.g., flowering, fruiting), plants may have higher transpiration rates.
5. **Soil Cover and Surface Conditions**:
   - **Mulching**: Organic or synthetic mulches can reduce evaporation from the soil surface.
   - **Surface Crust Formation**: A hard surface layer can impede evaporation, although this layer can also limit water infiltration.
   - **Soil Surface Roughness**: Rough surfaces may increase water retention and slow down evaporation rates due to decreased wind speed at the soil surface.
6. **Water Availability and Irrigation Practices**:
   - **Irrigation**: The amount and timing of irrigation directly affect water loss. Over-irrigation can lead to excessive drainage, while under-irrigation can reduce plant transpiration.
   - **Rainfall**: Periods of rainfall reduce the need for irrigation, influencing water loss dynamics.
7. **Soil Depth and Root Zone**:
   - A deeper soil profile holds more water, potentially reducing water loss due to evaporation and transpiration, especially during dry periods.
   - Shallow root zones in plants can lead to faster depletion of water resources, increasing water loss.

Managing Water Loss from Soil

- **Irrigation Scheduling**: Optimizing irrigation timing to coincide with periods of high evaporation or high plant water demand.
- **Soil Conservation Techniques**: Methods like mulching, contour farming, and no-till practices can help reduce evaporation and improve water retention.
- **Water Stress Management**: For crops, managing periods of water stress can help control unnecessary water loss, promoting efficient water use.
- **Rainwater Harvesting**: Collecting and storing rainwater for later use during dry periods helps reduce reliance on irrigation systems.

Conclusion

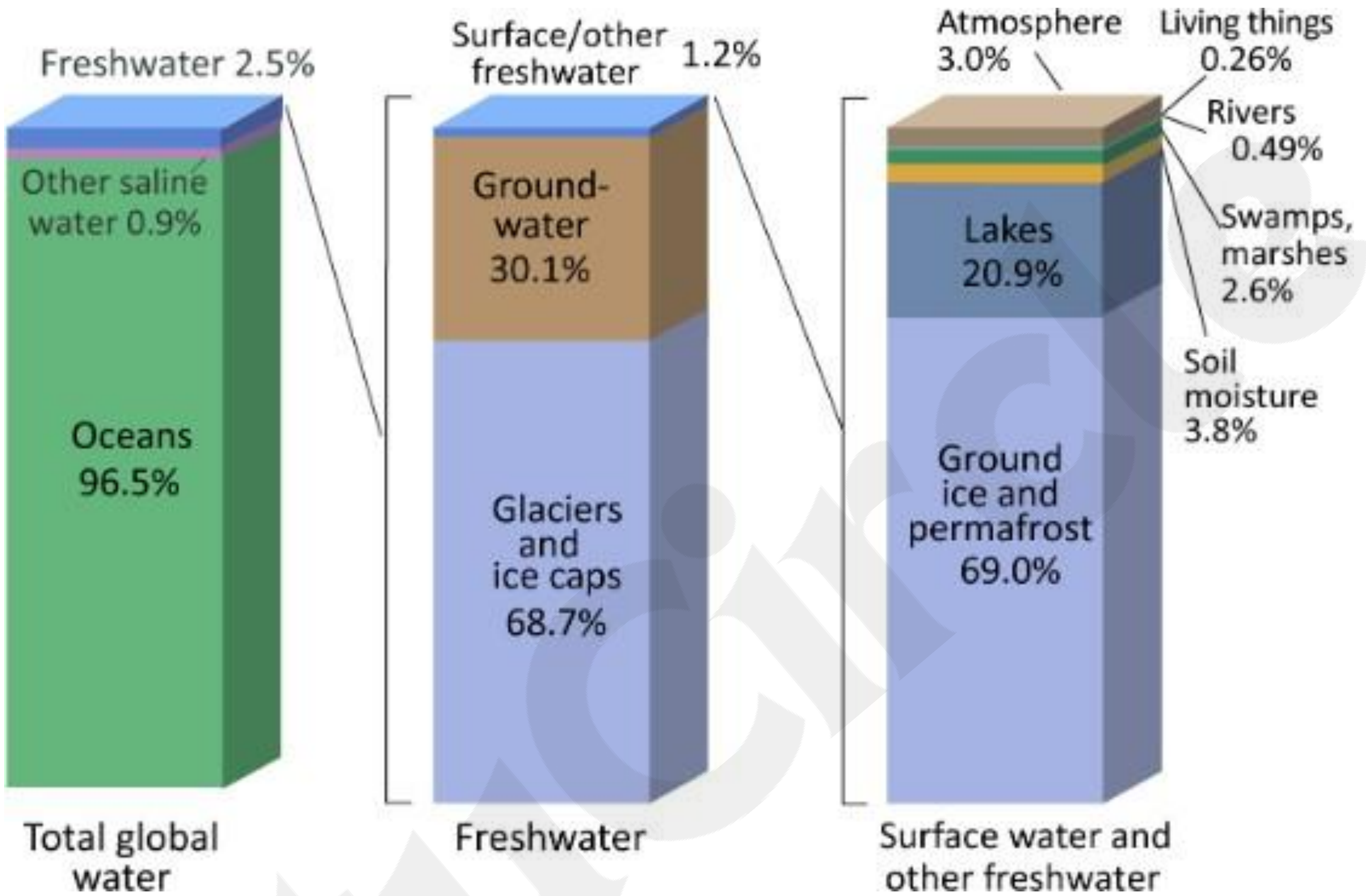
Water loss from soil is a complex process that is influenced by soil properties, plant factors, climatic conditions, and management practices. Effective measurement and management of soil water loss are crucial for sustainable agriculture, particularly in regions facing water scarcity or erratic rainfall patterns. Understanding the dynamics of water loss can help optimize irrigation strategies and improve crop productivity while minimizing water waste.

The hydrological cycle involves the continuous circulation of water in the Earth-Atmosphere system. At its core, the water cycle is the motion of the water from the ground to the atmosphere and back again. This article aims to provide a comprehensive overview of the Hydrological Cycle: Definition and its Component.

What is Water?

- Water, a substance consists of the chemical elements **oxygen** and **hydrogen** and exists in **solid, liquid** and **gaseous** states.
- It is **abundant** and **crucial** in nature. A **odourless** and **tasteless liquid** at room temperature, it has the important ability to dissolve many other substances.

Distribution of the Water on the Earth



Source: US Geological Survey

What is Hydrological Cycle?

- The hydrological cycle encompasses the ongoing movement of water within the **Earth-Atmosphere system**.
- Essentially, the hydrological cycle involves the transfer of water from the ground to the atmosphere and its subsequent return.

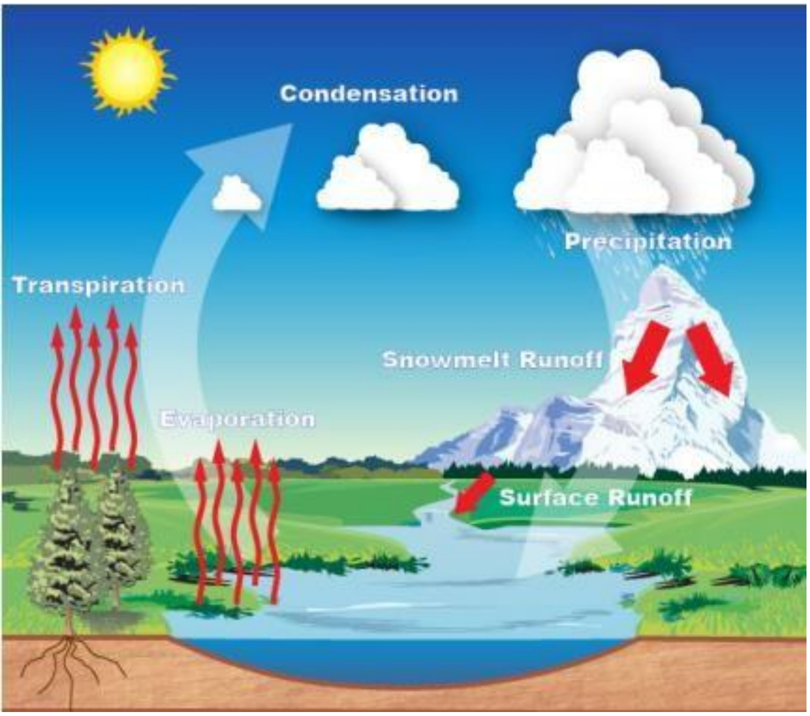


Fig: Diagram of Hydrological Cycle

Component of Hydrological Cycle

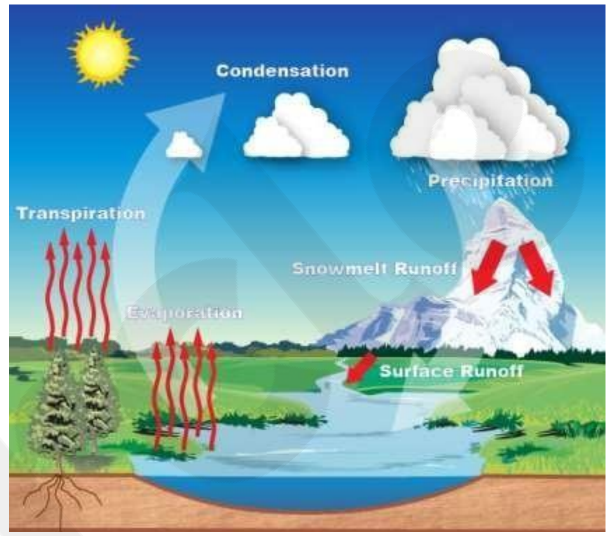
- The component of the **hydrological cycle**, the following are of utmost significance:

Evaporation	- It is the process by which a **substance undergoes a change of state from liquid to gas**. Water is the primary substance of interest in relation to evaporation. - For **Evaporation**, energy is required thus the source of energy comes from the **Sun,** the **Earth**, the **Atmosphere**, and the objects of the Earth such as **humans**. - For instance, it is a phenomenon that we encounter in our daily lives. It occurs when our bodies get warmer either because of the **surrounding air temperature or physical activity**, leading to sweating and the release of water onto our skin. 1. The purpose of this process is to utilize the body's **heat to evaporate the liquid**, effectively dissipating heat and cooling down the body.
Transpiration	- It refers to the **process of water evaporation** from plants through small openings called **stomata**. - These stomata are located on the underside of leaves and are connected to the plant's vascular tissues. - In most plants, transpiration occurs passively and is mainly influenced by the **humidity of the surrounding air** and the **moisture level** in the soil. - Only a small portion, around 1%, of the water transpired by a plant is utilized for its growth, while the remaining **99%** is released into the atmosphere.
Condensation	- It is the process by which **water vapour transforms into a liquid state.** - In the atmosphere, condensation can manifest as **clouds or dew.** 1. For instance, it is also the process responsible for the **formation of water droplets** on the surface of a cold drink can or bottle that lacks insulation. - It is not solely dependent on a specific temperature, but rather on the **temperature difference between two variables:** 1. Air temperature and 2. Dew point temperature - The **dew point** temperature is the point at which air becomes saturated and unable to hold any more water vapour, resulting in the formation of dew. Thus, cooling causes the water vapour to condense. When the air temperature and dew point temperature are equal, it often leads to foggy conditions. - **Condensation** is the opposite of **evaporation**. **a.** When condensation occurs, the higher energy level of water vapour compared to liquid water is released in the form of heat energy.

	b. This release of heat contributes to the **development of hurricanes**.
Precipitation	- It occurs when small particles of condensation **collide and merge,** becoming too large for the ascending air to sustain, and subsequently descending to the Earth's surface. **a.** This precipitation can manifest as **rain, hail, snow, or sleet.** - The process of precipitation serves as the main mechanism through which **Earth obtains freshwater**. - In total, the planet receives an average annual precipitation of approximately **38½ inches (980 mm)** across both its oceans and land masses.
Runoff	- Runoff occurs when there is **extreme precipitation** and the ground is saturated i.e., cannot absorb water any more. - **Rivers** and **lakes** are the result of runoff. Some of the runoff water evaporates into the atmosphere, but most water in lakes and rivers returns to the oceans. - If runoff water flows into a lake only with **no outlet** for water to flow out, then evaporation is the only means for water to return to the atmosphere. - As water evaporates, impurities or salts are left behind. **a**. As a result, the lake becomes salty like **Great Salt Lake** in Utah or **Dead Sea** in Israel. - Evaporation of this runoff into the atmosphere begins the **hydrological cycle** over again. - Some of the water percolates into the **soil** and into the ground water only to be drawn into plants again for transpiration to take place.

The Hydrologic Cycle

The hydrologic cycle involves the continuous circulation of water in the Earth-Atmosphere system. At its core, the water cycle is the motion of the water from the ground to the atmosphere and back again. Of the many processes involved in the hydrologic cycle, the most important are:



- evaporation
- transpiration
- condensation
- precipitation
- runoff

Evaporation

Evaporation is the change of state in a substance from a liquid to a gas.

In meteorology, the substance we are concerned about the most is water.

For evaporation to take place, energy is required. The energy can come from any source: the sun, the atmosphere, the Earth, or objects on the Earth such as humans.

Everyone has experienced evaporation personally. When the body heats up due to the air temperature or through exercise, the body sweats, secreting water onto the skin. The purpose is to cause the body to use its own heat to evaporate the liquid, thereby removing heat and cooling the body. The same effect can be seen when you step out of a shower or swimming pool. The coolness you feel is the removal of body heat through evaporation of the water on your skin.

Transpiration

Transpiration is the evaporation of water from plants through stomata. Stomata are small openings found on the underside of leaves that are connected to vascular plant tissues. In most plants, transpiration is a passive process largely controlled by the humidity of the atmosphere and the moisture content of the soil. Of the transpired water passing through a plant only 1% is used in the growth process of the plant. The remaining 99% is passed into the atmosphere.

Learning Lesson: Leaf it to Me

Condensation

Condensation is the process whereby water vapor is changed into a liquid state. In the atmosphere, condensation may appear as clouds or dew. This is also the process whereby water appears on the side of an uninsulated cold drink can or bottle.

Condensation is not a matter of one particular temperature but of a difference between two temperatures: the air temperature and the dewpoint temperature. The dew point is the temperature at which dew can form - it is the point at which air becomes saturated and can not hold any more water vapor. Any additional cooling causes water vapor to condense. Foggy conditions often occur when air temperature and dew point are equal.

Condensation is the opposite of evaporation. Since water vapor has a higher energy level than that of liquid water, when condensation occurs, the excess energy in the form of heat energy is released. This release of heat aids in the formation of hurricanes.

Learning Lesson: Sweatin' to the Coldies

Precipitation

Precipitation results when tiny condensation particles, through collision and coalescence, grow too large for the rising air to support, and thus fall to the Earth. Precipitation can be in the form of rain, hail, snow, or sleet.

Precipitation is the primary way we receive fresh water on Earth. On average, the world receives about 38½" (980 mm) each year over both th oceans and land masses.

Learning Lesson: The Rain Man

Runoff

Runoff occurs when there is excessive precipitation and the ground is saturated (cannot absorb any more water). Rivers and lakes are results of runoff. Some runoff evaporates into the atmosphere, but most water in rivers and lakes returns to the oceans.

If runoff water flows into a lake only with no outlet for water to flow out, then evaporation is the only means for water to return to the atmosphere. As water evaporates, impurities or salts are left behind. As a result, the lake becomes salty, as in the case of the Great Salt Lake in Utah or Dead Sea in Israel.

Evaporation of this runoff into the atmosphere begins the hydrologic cycle over again. Some of the water percolates into the soil and into the ground water only to be drawn into plants again for transpiration to take place.

Water Resources in Karnataka

Water resources of Karnataka primarily constitute surface and groundwater. Rainfall is the basic source of water in the state.

A. ***Surface water***

It is available in Karnataka in the form of rivers, lakes, waterfalls, reservoirs, etc. Karnataka has surface water potential of around 102 km. Being the seventh largest state in India (area-wise), Karnataka possesses about six percent of the country's total surface water resources of about 17 lakh million cubic metres (Mcum). Karnataka is blessed with seven river basins. There are 36,753 tanks in the state and they have a capacity of about 684518 hectares. The rivers, along with their tributaries, account for much of Karnataka's surface water resources. About 60 percent of the state's surface water is provided by the west flowing rivers while the east flowing rivers account for the remaining portion. The annual average yield in the seven river basins of the state is estimated to be around 3,475 TMC. The yield in the six basins, excluding the west flowing rivers is estimated to be 1,440 TMC.

B. ***Groundwater resources***

Karnataka has groundwater resources estimated to be around 485 TMC. Ground water resources have not been exploited evenly across the state. In areas where adequate surface water is available, exploitation of ground water resources is minimum. Exploitation of ground water in the dry taluks of North and South interior Karnataka is higher as compared to Coastal, Malnad and irrigation command areas of the state. In about 43 taluks there is over exploitation of ground water resources. Further, groundwater exploitation has exceeded 50% of the available ground water resources in 29 taluks of the State. These 72 taluks are critical taluks from the point of view of the ground water exploitation. In the 72 critical taluks about 4 lakh wells irrigate an area of 7.5 lakh ha.

Due to over exploitation of ground water resources, more than 3 lakh dug-wells have dried. Shallow bore wells have failed and yield in deep bore wells are declining. Area irrigated by ground water extraction structures is decreasing. Consequently, more than Rs. 2000 crores of investment made by the individual farmers on the construction of wells, pumping equipment, pipelines, development etc., have become infructuous.

Central Ground Water Board, South Western Region, Bangalore, is monitoring water levels in the State of Karnataka from the established network of 1538 monitoring stations, as a part of 'Ground Water Monitoring' programme. The monitoring is carried out four times in a water year during May, August, November and January for water level. Water samples from these stations are collected once in a year, during the month of May to assess the ground water quality.

C. *Rainfall in Karnataka*

Karnataka primarily enjoys a tropical climate that is largely dependent on its physio-graphic and geographic location with respect to the Arabian Sea and the monsoons. The state receives the benefit of two monsoons: the North-East monsoon and the South-West monsoon. Karnataka receives mean annual rainfall of around 1,355 millimeters. More than 73 percent of this rainfall is received due to the South-West monsoon. The state can be earmarked into three meteorological zones, namely, North Interior Karnataka, South Interior Karnataka and Coastal Karnataka. The occurrence and distribution of rainfall in the state is not uniform. The region that receives the maximum rainfall is Coastal Karnataka. It gets an average annual rainfall of 3,456 mm. South Interior Karnataka receives only 1286 mm average rainfall while North Interior Karnataka receives the least rainfall with 731 mm average figure annually.

D. *River Systems*

There are seven river systems in Karnataka which with their tributaries drain the state. The names of these river systems and area drained by them are given below as shown in Table 1 and in Fig. 1.

Godavari River. The river Godavari rises in the Nasik district of Maharastra about 80km from the shore of Arabian sea, at an elevation of 1067m, after flowing for about 1465km in a general south-easterly direction, through Maharastra and Andhra Pradesh, Godavari falls into the Bay of Bengal above Rajamun dry.

S.No.	River System	Drainage System	
		1000 Sq Km	Percentage
1	Godavari	4.41	2.31
2	Krishana	113.29	59.48
3	Kaveri	34.27	17.99
4	North Pennur	6.94	3.64
5	South Pennur	4.37	2.29
6	Palar	2.97	1.56
7	West flowing rivers	24.25	12.73
	Total	190.50	100

The Godavari has a drainage area of about 3,12,813 sq.kms. The principal tributaries of Godavari are the Pravara, the Purna, the Manjra, the Pranahita, the Indravathy and the Sabari.

Krishna River. The river Krishna is an Inter-State river in Southern India. It is the second largest river in Peninsular India, rises in the Western Ghats at an altitude of 1337 m. near Mahabaleshwar in Maharashtra State. It flows across the whole width of the peninsula, from west to east, for a length of about 1400 km, through Maharashtra, Karnataka and Andhra Pradesh.

The entire catchment area of Krishna basin is 2,58,948 sq km. including the other basin states, and their catchment. The principal tributaries of Krishna in Karnataka are Ghataprabha, Malaprabha, Bhima and Tungabhadra. All these rivers except the Malaprabha River having their catchment area both in Karnataka and Maharastra.

Cauvery River. The river Cauvery is an Inter-State river in Southern India. It is one of the major rivers of the Peninsular flowing east and running into the Bay of Bengal. The Cauvery rises at Talakaveri on the Brahmagiri Range of Hill in the Western Ghats, presently in the Coorg district of the State of Karnataka, at an elevation of

1.341m (4,400 ft.) above mean sea level.

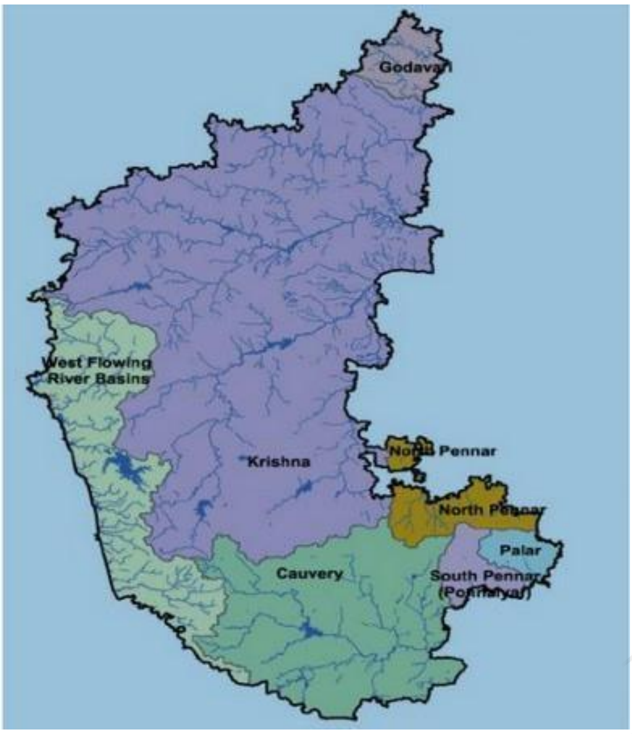
North Pennar. The north Pennar raises Nandi hills of Kolar Karnataka State at an elevation of about 597 Mts. It drains catchment area of 6337Sq kms in Karnataka and Andhra Pradesh.
South Pennar. The south Pennar raises Talagavara village in Kolar, 900 meters in Karnataka State. It drains catchment area of 4370Sq kms in Karnataka and Tamil Nadu.
Palar River. The south Pennar raises Nandi hills of Kolar Karnataka State. It drains catchment area of 2813 Sq kms in Karnataka, Andra Pradesh and Tamil Nadu.

West Flowing Rivers. The Western Ghats provides a principal geographical barrier in the path of the Arabian Sea branch of the Southwest monsoon, and is principally responsible for the heavy rainfall over the western coastal belt. The Southwest monsoon season (June to September) is the principal rainy season, over 90 % of annual rainfall is realized in this period.

The rivers in the Western Ghats region generally originate at an elevation ranging from 400 meters to 1,600 meters above the mean sea level, close to the Western Ghats ridge. The rivers generally flow westward and meet the Arabian Sea after a short run varying from 50 kms to 300 kms. the rivers are very steep in the upper reaches and fairly steep in the middle reaches. It is only near the sea that they have relatively flat gradients and some sort of flood plain.

Stressful situation of water resources in Karnataka The state of Karnataka enjoys a substantial amount of rainfall and has a significant quantity of water resources but it is not enough to meet the ever increasing water requirement of the state.
1. Karnataka suffers repetitive droughts. In spite of the availability of water from the river systems and tanks, Karnataka faces the serious issue of 67 percent of its land marked for irrigation falling under dry tracts.
2. Increasing population and living standards. With a rapidly increasing population and improved living standards, the pressure on the water resources is constantly on the rise.
The per capita availability of water resources is reducing day by day.
3. Rainfall and water deputes. The erratic behaviour of rainfall and the Inter-State River Water disputes aggravate the problem. The impact of climate change on the water resources also cannot be ignored.
4. Misuse and poor management. Siltation of water bodies, misuse of resources, poor management of catchment area all add to the stressful water resource situation in the state.
5. Fast decline of ground water resources. The groundwater is the major source of drinking water in Karnataka.

Over 90 percent of the drinking water supply schemes in the rural areas of the state are based on ground water. This over exploitation is causing the fast decline of ground water resources in the state. The result is the scarcity of safe drinking water across many parts of Karnataka. In order to cater to the water requirement of the expanding population, the existing water resources must be conserved and prevented from further degradation and depletion. As a conclusion the judicious and economic use of water resources for agricultural, industrial and domestic purposes can help in solving the problem to a large extent.



I. WATER DEMAND AND SUPPLY DEMAND GAP

Karnataka's water resources are fast dwindling due to population explosion and increased utilization of water for the rapidly growing economic activities. Water demand on the one hand for consumptive (drinking, health and sanitation needs) and productive uses (agriculture, industrial production, power generation, mining operations and navigation, and recreational activities) has increased tremendously, and on the other hand, water supply has declined with depletion and degradation of water resources causing water distress or scarcity in the state. Depletion of quantity and degradation of quality of water has restricted the availability of water for consumptive and productive uses and has consequently caused "negative externality" which imposes economic and social cost on society.

The Considering domestic and non-domestic water requirement including wastage totaling 140 liters per capita per day, the recommendation made at the conference of Secretaries, Chief Engineers responsible for Urban Water Supply and Sanitation at Mysore during 1989 (Million liters per day) the water demand projections have been made. For Krishna basin, it is estimated that the population for Karnataka for 2050 will be 59.90 million for rural areas and 21.08 million for urban areas. Considering the per capita requirement of 150 liters per day for rural and 220 liters per day for urban, the drinking water needs are 115.62 TMC for rural and 59.78 TMC for urban population. The total requirement for water is 150.31 TMC for rural and 77.71 TMC for urban including the T and D losses of 30 percent. The total demand for the State including all areas can be conveniently taken as twice that of the demand for Krishna basin. Accordingly the total requirement for domestic water needs for urban and rural population in Karnataka in 2050 is 456.04 TMC. The estimated demand and supply is subject to limitation of methodology used and the source of data used. The positive gap shown is due to lack of infrastructure to store the rain / river water. Groundwater utilization according to volume exceeds 70 percent of supply or availability.

There are obvious differences between the sources of data as well as between volumetric measurement and the area measurement regarding supply and demand for water As a thumb rule, usually 1 TMC of water can irrigate 4000 ha of semi dry crops or 1000 ha of paddy or 1600 ha of sugarcane.

II. FINDINGS AND SUGGESTIONS

The state of Karnataka enjoys a substantial amount of rainfall and has a significant quantity of water resources but it is not enough to meet the ever increasing water requirement of the state.

1. **Karnataka suffers repetitive droughts.** In spite of the availability of water from the river systems and tanks, Karnataka faces the serious issue of 67 percent of its land marked for irrigation falling under dry tracts.
2. **Increasing population and living standards.** With a rapidly increasing population and improved living

standards, the pressure on the water resources is constantly on the rise. The per capita availability of water resources is reducing day by day.

3. **Rainfall and water deputes.** The erratic behaviour of rainfall and the Inter-State River Water disputes aggravate the problem. The impact of climate change on the water resources also cannot be ignored.

4. **Misuse and poor management.** Siltation of water bodies, misuse of resources, poor management of catchment area all add to the stressful water resource situation in the state.

5. **Fast decline of ground water resources.** The groundwater is the major source of drinking water in Karnataka. Over 90 percent of the drinking water supply schemes in the rural areas of the state are based on ground water. This over exploitation is causing the fast decline of ground water resources in the state. The result is the scarcity of safe drinking water across many parts of Karnataka.

Water Status in Karnataka: Importance and Issues

Karnataka, a state located in the southern part of India, has a diverse and complex water scenario. Its water resources are influenced by geography, climate, and population pressures. Below is a detailed look at the importance and issues related to water status in Karnataka, focusing on sources, geographical distribution, and quality.

1. Water Sources in Karnataka

The primary water sources in Karnataka are:

- **Rivers**: Karnataka is blessed with several rivers, both perennial and seasonal. Major rivers include the **Kaveri**, **Krishna**, **Godavari**, **Tungabhadra**, **Ganga**, and **Yamuna**. The Kaveri River is especially crucial, serving as a major source of irrigation and drinking water for large parts of the state.
- **Lakes**: The state also has a significant number of lakes, including those around Bangalore. These lakes act as critical sources for domestic and irrigation purposes.
- **Groundwater**: Groundwater plays a crucial role in supplying water for agricultural, domestic, and industrial uses. However, over-exploitation of groundwater is a growing concern, particularly in urban and industrial areas.
- **Reservoirs**: Karnataka has several major reservoirs, including the **Krishna Raja Sagara** and **Tungabhadra Reservoir**, which store water for both drinking and irrigation purposes.

2. Geographical Distribution of Water in Karnataka

Water distribution across Karnataka is highly uneven, with some regions being water-rich, while others face severe scarcity.

- **South and Western Parts**: The southern and western parts of Karnataka, including districts like Kodagu, Chikkamagalur, and Hassan, receive a good amount of rainfall due to the Western Ghats, which catch the monsoon winds. These regions are the primary catchment areas for several rivers.
- **Northern and Eastern Parts**: Areas like Raichur, Bellary, and Bidar are more arid and face water scarcity. These regions often depend on water from the Krishna and Kaveri river basins, but the available resources are limited.
- **Urban Areas**: Cities like Bengaluru have a high demand for water, leading to pressure on surrounding resources and groundwater.

3. Water Quality Issues in Karnataka

The quality of water in Karnataka varies widely, and several issues affect both surface and groundwater:

- **Pollution from Industrial and Domestic Waste**: Rivers, lakes, and groundwater in urban areas like Bengaluru and industrial zones face contamination due to untreated industrial effluents, sewage, and household waste. The **Yamuna** and **Krishna** rivers, which flow through the state, have been subject to pollution from agricultural runoff and industrial discharge.

- **Groundwater Contamination**: Over-extraction of groundwater, combined with contamination from chemicals, fertilizers, and waste disposal, has led to the degradation of water quality in many areas. Some regions also face salinity intrusion due to over-pumping of groundwater.

- **Pesticide and Fertilizer Runoff**: In agricultural regions, the use of pesticides and chemical fertilizers leads to runoff, which pollutes water bodies, affecting both the quality of water and aquatic life.

- **Fluoride Contamination**: Some districts, such as Raichur and Gulbarga, face issues with high fluoride concentrations in groundwater, leading to health issues like fluorosis.

4. Water Scarcity and Management Challenges

Water scarcity is a growing issue, particularly in the arid and semi-arid regions of the state. The following factors exacerbate water stress:

- **Decreasing Rainfall**: The state is experiencing irregular rainfall patterns due to climate change. This affects the availability of water for both agriculture and consumption, especially in rainfed regions.
- **Over-exploitation of Resources**: Excessive use of groundwater for agriculture, urban supply, and industrial purposes has led to a depletion of water tables. This is particularly severe in cities and rural areas that depend on wells for their water supply.
- **Inter-State Water Disputes**: Karnataka shares rivers with neighboring states, leading to disputes over

water sharing. The most notable example is the **Kaveri water dispute** with Tamil Nadu, which has been ongoing for decades and affects water availability in southern Karnataka.

- **Lack of Proper Water Management**: There is insufficient infrastructure for water conservation and efficient distribution, especially in rural areas. The state also faces challenges in the proper maintenance of reservoirs, canals, and pipelines, leading to water loss.

5. Government Initiatives and Solutions

The government of Karnataka has taken several steps to address water issues:

- **Rainwater Harvesting**: Various programs to promote rainwater harvesting have been implemented, especially in urban areas like Bengaluru, to conserve rainwater and recharge groundwater.
- **Desalination Plants**: The state is exploring desalination technologies for coastal regions to meet increasing water demands.
- **Irrigation Projects**: Major irrigation projects, including the **Kaveri Basin Irrigation** and **Tungabhadra Irrigation Project**, aim to improve water use efficiency in agriculture.
- **Water Quality Monitoring**: Efforts are being made to monitor and control pollution in rivers, lakes, and other water bodies, with the establishment of water quality testing and treatment facilities.
- **Water Conservation Awareness**: Programs to encourage water conservation among citizens and promote sustainable agricultural practices have been launched to tackle the growing water scarcity.

Conclusion

Water is a vital resource for the people of Karnataka, and its management is crucial to the state's agricultural, industrial, and domestic needs. While the state has abundant water resources, distribution and quality issues pose significant challenges. Addressing these issues requires integrated water management strategies, improved infrastructure, sustainable agricultural practices, and solutions for inter-state water disputes. With proper conservation measures, Karnataka can better ensure water security for its growing population.

HUMAN INTERFERENCE OF WATER CYCLE

> Water is the basis for all human life. That's why it's essential to remember how we use water. Unfortunately, humans significantly negatively impact the water cycle, resulting in adverse effects on the earth and life.

To prevent the problem from worsening, it's essential to understand the water cycle and how humans affect it. How do humans impact the water cycle? Read on to learn this and more so that you can understand the problem and the possible solutions.

What Is the Water Cycle?

The **water cycle** is how water moves continuously between the earth and the atmosphere. You may remember the circular model of the water cycle illustrated in grade school, consisting of precipitation, condensation, and evaporation. Here's how it works:

> Liquid water evaporates into the air as water vapor.
> It cools, condenses, and forms clouds.
> It falls back to earth as rain and snow.

While this captures the basic principle of the cycle, in reality, it's more complex than that, as we must also consider liquid water flowing across the land and into the ground and how it moves into plants.

Within the cycle, there are several ways that humans intervene and disrupt the natural flow of water. Let's take a look at how humans impact the water cycle.

How Do Humans Impact the Water Cycle?

Humans impact the water cycle in several different ways – directly and indirectly.

To start, humans directly change the dynamics of the water cycle through direct manipulation. This includes building dams for water storage and withdrawing water from lakes and rivers for industrial, agricultural, or domestic purposes.

Of course, humans indirectly impact the water cycle through actions that contribute to global warming.

Let's take a closer look at how humans impact the water cycle.

Hydroelectricity

Hydroelectricity involves changing the stored gravitational energy of water behind a dam into electrical power for everyday use.

Hydroelectricity was initially considered an excellent solution for renewable energy as it is non-polluting; however, it does affect the water cycle.

The mere act of damming rivers impacts how the water flow functions, including impeding fish from flowing naturally through the waters, affecting the aquatic ecosystem.

This has a trickling impact on the lakes that typically connect to these rivers, which can put the upstream and downstream water flow out of balance.

This can lead to a build-up of silt and affect the amount of water that the plants and animals that rely on this water source get.

Deforestation

Trees play a significant role in the water cycle. Deforestation is an essential issue in the natural world today. Deforestation is the removal of trees from their natural habitat for human use

Trees release water into the atmosphere when they transpire, which produces humidity. This vapor evaporates into the atmosphere before being turned into precipitation and re-released

trees, the land and the air will become drier, affecting surrounding life that previously relied on a certain humidity level. It may also create more run-off and leaching, increasing droughts and floods in certain areas.

Irrigation

Irrigation is the artificial watering of the land. As the human population has grown, so has our need for agriculture and, consequently, water to cultivate this agriculture.

The problem with using irrigation for soil moisture is that it displaces water from its natural source, which then causes leaving or run-off where it used to be. It also introduces more salt into our water systems.

Climate change

Finally, climate change has one of the most significant impacts on the earth's water cycle.

Human activity such as buring fossil fuel contributes to the Earths raising temperature. An increase in temperature means an increase in evaporation and rapid melting of ice sheets, such as glaciers, which causes sea level to rise and impacts other critical processes of the water cycle.

HOW TO MINIMIZE OUR IMPACT ON THE WATER CYCLE

As you can see, the water cycle plays a crucial role in the earth's sustainability. However, human intervention is hurting the water cycle and impeding its ability to function.

Luckily, we can do a few things to **minimize our impact on the water cycle**. Some of these actions include:

Conserving water in your home
Making use of public transit and biking rather than driving
While these actions may seem small, they add up when done consistently

That said, a more significant impact calls for more extensive changes, often at the corporate level. While individuals have little control over the actions of corporations, disseminating information can make a huge difference.

While humans have been able to manipulate water to promote human life, it has come at the expense of the water cycle. Earth's water cycle is in danger due to constant human intervention.

If you want to be part of an effective change, you can start with what you do at home. Practice water conservation in your home, be mindful of how you commute, and pay attention to what products you use. Putting pressure on corporations to change their practices may also have an impactful change on the world.

How do humans affect the water cycle?

Hint: Water cycle depicts the evaporation of water, condensation of water vapours into rain and snow in clouds and finally their precipitation. Water cycle is now interrupted due to human interference like cutting trees, polluting water bodies etc.

Humans interrupt water cycle in multiple ways:

1)Deforestation: The removal of trees has a major impact on the water cycle and the local or global climate. Trees release water vapours when they transpire, and it further creates a humid environment. This water vapour evaporates into the atmosphere where it accumulates before precipitating back to the Earth as rain, sleet or snow. If trees are cut down, there is less water to be evaporated into the atmosphere and subsequently less rain.

2)GreenHouse Effect: Human activity such as the burning of fossil fuels leads to the overall increase of the Earth's temperature. Raising the Earth's temperature results in an increase of evaporation, melting of ice or other processes of the water cycle that adversely affect the climate on Earth

3)Irrigation: With increasing human population our demands have increased. We need more food and to produce more food we need more water. Irrigation is the artificial watering of land and is used for watering land that does not get enough rain. Irrigation removes water from its natural sources and often causes leaching and run-off in the land where it is used. This removal of nutrients from the land results in more use of fertilizers by the farmers to keep their lands more productive. As a result waterways become more polluted.

4)Discharges: Before rainwater merges into the river it mostly picks up a whole range of pollutants. In rural areas the pollutants mostly include pesticides, herbicides, fertilizers, wastes from faulty septic systems and improperly handled manure. Such rain water flowing through contaminated streams, may affect plant and animal population in the water bodies. In urban areas the pollutants include gas, oil, pet waste, fertilizers, pesticides, salt and treated human waste from sewage treatment plants. Such waste when dumped into the water bodies contaminates the water bodies and in turn affects the water cycle.

Note: Deforestation, Irrigation, Burning of fossil fuels and Industrial discharges deteriorates water bodies, which leads to less evaporation of water and in turn less rainfall. This also leads to an increase of the environmental temperature Which in turn leads to global warming.

SURFACE WATER RESOURCES

Surface water resources are obtained from rivers, streams, creeks, lakes etc.,

Watershed organizations Trust (WOTR) in India monitor the streamflow and surface water quality regularly. They currently work in more than 3,939 villages from across 7 states of India. Flooding and drought conditions are predicted by monitoring streamflow.

Mainly, the water utilization in India is provided by the surface water resources. Hence, the water quality is critical. There are various biological, chemical, anc physical tests that determine the quality of the water. Electrical conductivity, pH,

Temperature, phosphorous levels, dissolved oxygen levels, nitrogen levels and bacteria levels are examined as indicators of water quality standards.

Turbidity

Turbidity is a water quality indicator that measures the amount of suspended material a stream. The worse the water quality, the more turbid the water.

Concerns About Color/Odour

Water takes a brownish yellow colour due to rotting leaves or algae. Natural dissolved organics or gases can give a bad taste and smell, Iron, manganese, copper, zinc and chloride are some of the chemical contaminants linked to Indias aesthetic quality of water resources. Water tainted with dissolved metals has a harsh taste and can stain clothing and plumbing fittings. Chlorides in excess provide an unpleasant salty taste in the water.

Hardness

Hardness is another criterion for water quality standards. This word refers to dissolved minerals (mostly calcium and magnesium). Minerals induce scale build-up in hot water pipes and obstruct soap lather. Humans are unaffected by hard water.

Protection of Surface Water Sources

Even while most communal drinking water (particularly from surface water sources) is treated before entering the home, the cost of this treatment and the hazards to public health can be lowered by preventing contamination of source water. We all live in a watershed, defined as an area that drains into a shared waterway such as a stream, lake, wetlands, or the ocean. The Environmental Protection Agency (EPA) and many other agencies engage with communities to maintain surface water resources.

Applications of Surface Water Resources

The most common surface water applications are drinking water and other public use, irrigation, and by the thermoelectric power generating industry.

Surface-water resources provided most of the water needed for thermoelectric generation, public supply, agriculture, mining, and industry.

Surface-water resources provide nearly all of the water consumed in the United States. The remaining 30% was made up of water derived from underground sources.

In 2021, surface-water resources provided around 71% of the freshwater utilized in the United States.

Groundwater accounted for the remaining 29%. Surface water is a valuable natural resource used for various purposes, including irrigation and public drinking water (supplying people with drinking water and everyday use).

Conclusion

Due to considerable population shift and growing demand, groundwater supplies, which are unevenly dispersed in space and time, are under stress. Access to reliable data on water availability, quality, quantity, and variability is essential for effective water resource management. To develop and safeguard our man-made surface water resources in India efficiently and sustainably, all components of the hydrological cycle and human activities' influence must be understood and quantified.

Surface water availability is becoming increasingly uncertain, and water pollution and diversions are increasing, posing a threat to social and economic growth and ecosystem health. Drinking water is derived from groundwater resources. Sustainable management of non-renewable groundwater should receive more emphasis.

Water (Hydrological) Cycle

The **hydrological cycle** refers to the continuous movement of water within the Earth's atmosphere, surface, and subsurface regions. This cycle is driven by solar energy and includes several key processes:

1. **Evaporation**: Water is heated by the sun and converted from liquid to vapor from bodies of water such as oceans, rivers, and lakes.
2. **Transpiration**: Plants release water vapor into the air through small openings in their leaves, contributing to the moisture in the atmosphere.
3. **Condensation**: Water vapor cools and condenses into droplets, forming clouds.
4. **Precipitation**: The condensed water falls back to Earth in the form of rain, snow, sleet, or hail.
5. **Infiltration**: Some of the water that reaches the ground infiltrates into the soil, replenishing groundwater supplies.
6. **Runoff**: Water that does not infiltrate the soil flows over the surface, eventually reaching rivers, lakes, and oceans. These processes ensure the continual movement and renewal of water across the planet.

Influence of Human Activity on the Water Cycle

Human activities significantly impact the natural water cycle in various ways:

1. **Deforestation**: Removing trees and vegetation reduces transpiration, which is a key process in the water cycle. This can lead to reduced atmospheric moisture and, consequently, less precipitation.
2. **Urbanization**: The development of cities increases impervious surfaces such as roads and buildings. This limits infiltration and increases runoff, which can lead to flooding and reduced groundwater recharge. Additionally, urban heat islands can affect local evaporation and precipitation patterns.
3. **Agriculture**: Large-scale irrigation, particularly in arid regions, can alter local water availability by drawing large quantities of water from rivers and aquifers. Overuse of water resources for irrigation can also lead to groundwater depletion and salinization of soil.
4. **Water Pollution**: Industrial, agricultural, and domestic pollutants can contaminate water sources, affecting both surface and groundwater. Pollutants can impact evaporation and precipitation processes by altering water quality and ecosystem health.
5. **Climate Change**: Human-induced climate change is altering precipitation patterns, increasing the frequency of extreme weather events such as floods and droughts, and changing the distribution of freshwater resources. Global warming can also accelerate the rate of evaporation and melting of glaciers, influencing the water cycle on a larger scale.

Surface Water Resources

Surface water refers to water that is found in bodies of water such as rivers, lakes, reservoirs, and wetlands. These resources are critical for human consumption, agriculture, industry, and ecosystem health. Key characteristics of surface water resources include:

1. **Rivers and Streams**: These provide a continuous flow of water from higher elevations to lower elevations, often feeding into larger bodies of water. They are essential sources of freshwater for irrigation, drinking, and hydroelectric power generation.
2. **Lakes and Reservoirs**: These are stationary bodies of water that store large volumes of water, often used for irrigation, drinking water supply, recreation, and flood control.
3. **Wetlands**: Wetlands such as swamps and marshes store water and act as natural filters, improving water quality by trapping pollutants. They also provide habitat for biodiversity and contribute to groundwater recharge.
4. **Water Management**: Human activities such as dam construction, water diversion, and reservoir management are used to control and store surface water. These activities help manage water availability for consumption and mitigate flood risks but can also disrupt natural ecosystems and reduce water quality.

In conclusion, the hydrological cycle is essential for maintaining Earth's water balance, and human activities have significant impacts on both the water cycle and surface water resources. Proper management and sustainable practices are crucial to ensure the continued availability of water resources for both human use and environmental hea