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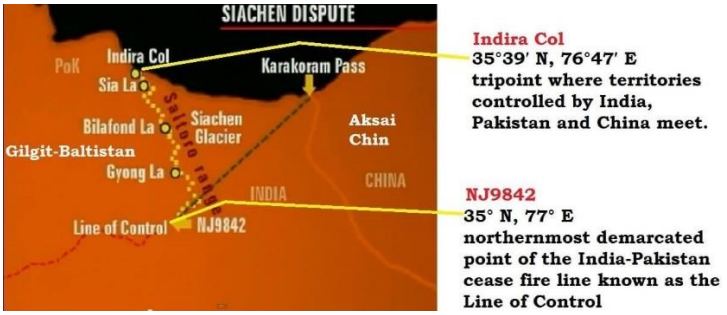
1. India as a Geographical Unit

Map of Jammu and Kashmir showing the occupied regions



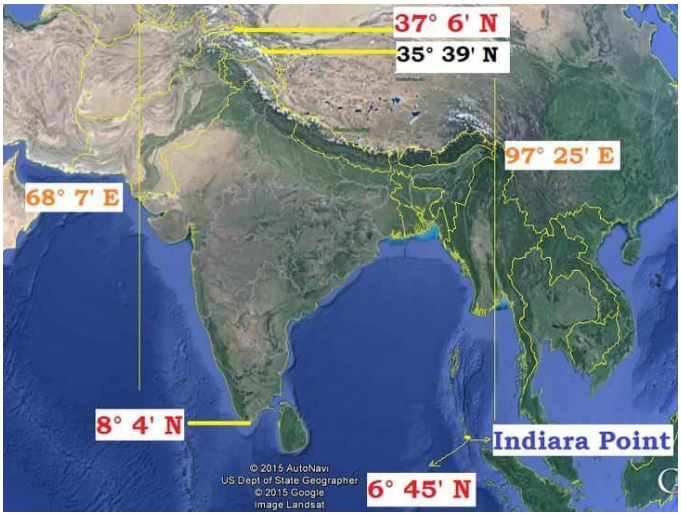
Location: Indira Col and NJ9842

- The southernmost point of the country is the **Pygmalion Point, or Indira Point** is located at **6° 45' N latitude**.
- North-south extent from **Indira Col** in Kashmir to Kanyakumari is **3,214 km**.
- East-west width from the Rann of Kutch to Arunachal Pradesh is **2,933 km**.

East-West Extent (~30°)	***68° 7' East to 97° 25' East longitude***
South-North Extent of mainland India (Including POK) (~29°)	***8° 4' North to 37° 6' North latitude***
South-North Extent of India (Including POK and the Andaman and Nicobar Islands) (~31°)	***6° 45' North to 37° 6' North latitude***

Top 10 Largest Countries in the World by Area

Rank	Country	Capital City	Continent	Area (km^2)
1	Russia	Moscow	Europe	1,70,98,242
2	Canada	Ottawa	North America	99,84,670
3	USA	Washington DC	North America	98,26,675
4	China	Beijing	Asia	95,96,961
5	Brazil	Brasilia	South America	85,14,877
6	Australia	Canberra	Oceania	77,41,220
7	**India**	**New Delhi**	**Asia**	**32,87,263**
8	Argentina	Buenos Aires	South America	27,80,400
9	Kazakhstan	Astana	Asia	27,24,900
10	Algeria	Algiers	Africa	23,81,741



Locational Extent of India

- With an area of **32,87,263 km^2**, India is the **seventh largest** country in the world.
- India accounts for about **2.4 per cent** of the total surface area of the world.
- The Tropic of Cancer passes through the middle of the country dividing it into two latitudinal halves.
- The area to the north of Tropic of Cancer is **near twice** the area which lies to the south of it.
- South of 22° north latitude, the country tapers off over 800 km into the Indian Ocean as a peninsula.
- East-West time difference is nearly **2 hrs**. (A difference of 1° longitude will make a difference of 4 minutes in time. ~30 x 4 = ~120 minutes or ~2 hours).

India, Tropical or Temperate Country?

- The temperate part (north of Tropic of Cancer) is twice the area of the tropical part.
- But India has always been treated as a tropical country for two different reasons – physical and cultural.

Physical Geographical (Climatic) Reasons

- The country is separated from the rest of Asia by the Himalayas.
- The tropical monsoons dominate its climate.
- Himalayas blocks the cold temperate air masses.
- Although winter night temperatures are low, yet clear skies and intense insolation raise the day temperatures to a tropical level.

Cultural Geographical Reasons

- Settlements, diseases, agricultural and primary economic activities are all tropical in nature.

It is primarily because of the Himalayas that India is a predominantly tropical country.

1.2 India's Frontiers

Data from the **Ministry of Home Affairs (Department of Border Management)**

- India has **15106.7 Km** of land border running through **17 States**.
- Indian has a coastline of **7516.6 Km (6100 km of mainland coastline + coastline of 1197 Indian islands)** touching 13 States and Union Territories (UTs).
- Barring Telangana, Madhya Pradesh, Chhattisgarh, Jharkhand, Delhi and Haryana, all other States in the country have one or more international borders or a coastline and can be regarded as **frontline States** from the point of view of border management.
- India's **longest border** is with **Bangladesh** while the shortest border is with Afghanistan.
- The length of India's land borders with neighbouring countries is given in the table below.

Neighbour	Length of the border (in Km)
1) Bangladesh	**4,096.7**
2) China	**3,488**
3) Pakistan	**3,323**
4) Nepal	1,751
5) Myanmar	1,643
6) Bhutan	699
7) Afghanistan	106
	15,106.7

Border with China

- This is the **second longest border of India**, next only to its border with Bangladesh.

- Five Indian states, namely Jammu and Kashmir, Himachal Pradesh, Uttarakhand, Sikkim and Arunachal Pradesh touch the Indian boundary with China.
- The Sino-Indian border is generally divided into three sectors namely: (i) the Western sector, (ii) the Middle sector, and (iii) the Eastern sector.

The Western Sector

- Separates Jammu and Kashmir state of India from the Xinjiang province of China.
- The western sector boundary is largely the outcome of the British policy towards the state of Jammu and Kashmir.
- China claims the **Aksai Chin, the Changmo valley, Pangong Tso and the Sponggar Tso area of north-east Ladakh**.
- China also claims a part of **Huza-Gilgit** area in **North Kashmir** (**ceded to it in 1963 by Pakistan**).

The Middle Sector

- Two Indian states of Himachal Pradesh and Uttarakhand touch this border.

The Eastern Sector

- The 1,140 km long boundary between India and China runs from the eastern limit of Bhutan to a point near **Diphu pass (Talu-Pass)** at the **tri-junction of India, Tibet and Myanmar**.

Diphu Pass *is a mountain pass around the area of the disputed tri-point borders of India, China, and Myanmar.*
It is ***Talu pass*** *on the Burmese side, and* ***Diphu pass*** *on the Indian (Tibetan) side.*

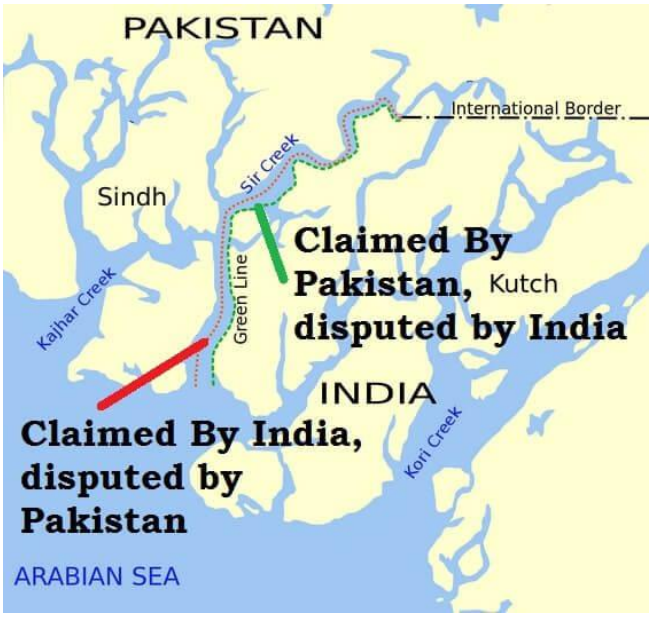
- This line is usually referred to as the **Mc Mahon Line** after Sir Henry Mc Mahon, then foreign secretary of British India, who negotiated the boundary agreement between Great Britain and Tibet at **Shimla accord in 1913-14**.

The India-Nepal Boundary

- Five states of India, namely Uttarakhand, Uttar Pradesh, Bihar, West Bengal and Sikkim touch the Nepalese border with India.
- The border is a **porous** one with an unrestricted movement of goods and people between Indian and Nepal.
- Major portion of Indo-Nepalese border runs in the east-west direction almost along the foothill of the **Shiwalik Range**.

The Indo-Pakistan Boundary

- The Indo-Pakistan boundary is the result of the partition of the country in 1947 under the **Radcliffe award** of which Sir Cyril Radcliffe was the chairman.
- Jammu and Kashmir, **Sir Creek** are the major disputed regions.



Creeks in the Kutch Region

The India-Bangladesh Border

- India's 4,096 km long border with Bangladesh is the **longest**.
- This boundary has been determined under the **Radcliffe Award** which divided the erstwhile province of Bengal into two parts.

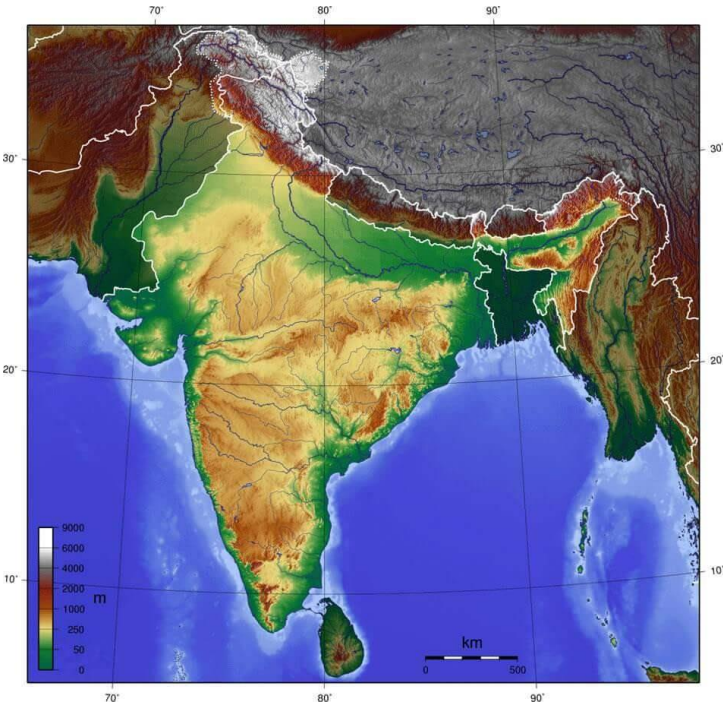
India-Myanmar Boundary

- This boundary runs roughly along the watershed between the Brahmaputra and Irrawaddy rivers.
- It passes through thickly forested regions, with Mizo Hills, Manipur and Nagaland on the Indian side and Chin Hills, Naga Hills and Kachin state on the Myanmar side.

India-Sri Lanka Boundary

- India and Sri Lanka are separated from each other by a narrow and shallow sea called **Palk Strait**.
- **Dhanushkodi** on the Tamil Nadu coast in India is only 32 km away from Talaimanar in Jaffna peninsula in Sri Lanka. These two points are joined by a group of islets forming **Rama Setu (Adam's Bridge)**.

1.3 Major Physical Divisions of India



Physical Map of India

1. **The Himalayas (young fold mountains),**
2. **Indo-Gangetic Plain (monotonous topography – featureless topography),**
3. **The Peninsular Plateau (one of the most stable landmasses; one of the oldest plateaus of the world),**
4. **Coastal Plains (sedimentation due to fluvial action).**
5. **The Indian Islands (Coral Islands ➔ coral reef built up on atolls. E.g. Lakshadweep Islands. Tectonic ➔ Andaman and Nicobar Islands – Interaction between the Indian Plate and Eurasian plate).**

Peninsular Plateau

- Includes entire south India, central India, Aravallis, Rajmahal hills, Meghalaya plateau, Kutch-Kathiawar region (Gujarat) etc.
- It is the **oldest** and the most **stable** landmass of India.

Himalayas

- Includes the **Himalayas, Purvanchal** and their extensions **Arakan Yoma (Myanmar)** and **Andaman and Nicobar Islands** (but we consider these as islands only).
- It is the youngest and **highly unstable** landmass of India. (Continent-Continent Convergence)
- Tectonic movements are widespread.

Indo-Gangetic Plain

- The **monotonous** region (featureless topography) between Peninsular and Himalayan region.
- **Most youthful** region prone to tectonic forces.

Coastal Plains

- Eastern Coastal Plains and Western Coastal Plains.
- It is formed due to the consolidation of sediments brought by rivers (fluvial deposits).
- Highly **stable** just like the peninsular plateau.

Indian Islands

- Two major groups – **Lakshadweep (coral islands)** and, Andaman and Nicobar Islands (tectonic islands).

- Lakshadweep (part of **Reunion Hotspot Volcanic chain**) are a group of atolls occupied by coral reefs.
- There has been no significant volcanism or tectonic activity in the recent past.
- The islands are highly vulnerable to sea-level rise.
- Andaman and Nicobar Islands is a continuation of Arakan Yoma.
- The islands have volcanoes (**Barren Island is the only active volcano**) and are tectonically active.

Type of Topography	Extent in %
Mountainous (more than 2135 m above sea level)	**10.7**
Hilly area (305 – 2135 m above sea level)	**18.6**
Plateau (305 – 915 m above sea level)	**27.7**
Plains	**43**

2. Rock System Based on Geological History of India

1) ***The Archaean Rock System.***
2) ***The Purana Rock System.***
3) ***The Dravidian Rock System.***
4) ***The Aryan Rock System.***

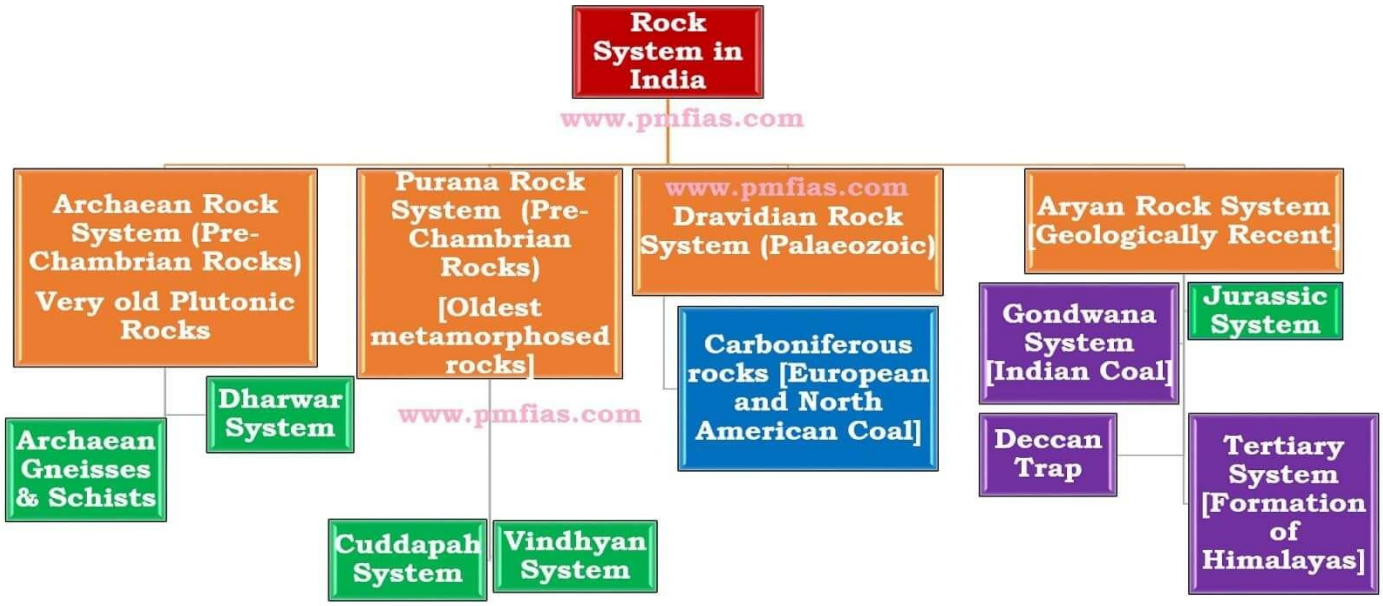
2.1 Archaean Rock System (Pre-Cambrian Rocks)

- Rocks formed prior to the Cambrian system.
- The Archaean rock system includes:

Archaean Gneisses and Schists (4 billion years old)

Gneiss ➔ Mineral composition varies from granite to gabbro.
Schists ➔ mostly crystalline, include mica, talc, hornblende, chlorite, etc.

- **Oldest rocks** (formed in the pre-Cambrian era – about 4 billion years ago).
- These rocks were formed due to solidification of molten magma – the earth's surface was very hot then.
- They are known as the **'Basement Complex'** (they are the oldest and forms the base for new layers).

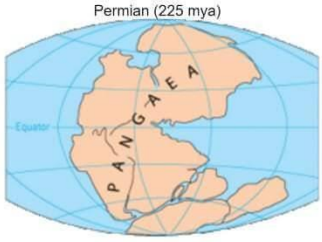


Rock System Based on Geological History of India

Geologic Time Scale
Tectonics (By Pmfias.com)

- Prechambrian Supereon (4.5 bya – 541 mya)
  - Hadean Eon (4.5 bya – 4.0 bya)
  - Archean Eon (4.0 bya – 2.5 bya)
  - Proterozoic Eon (2.5 bya – 541 mya)
- Unnamed Supereon (541 mya – present)
  - Phanerozoic Eon (541 mya – present)
    - Paleozoic Era (541 mya – 250 mya)
      - Cambrian Period (541 – 485 mya)
      - Ordovician Period (485 – 440 mya)
      - Silurian Period (440 – 415 mya)
      - Devonian Period (415 – 360 mya)
      - Carboniferous Period (360 – 300 mya)
      - Permian Period (300 – 250 mya)

Permian (225 mya)



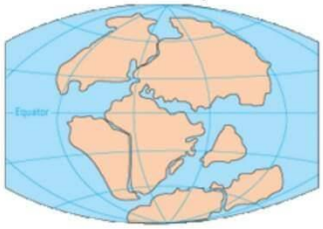
- Pangea Intact
- Pangea was covered by a mighty ocean called as Panthalassa

- Pangaea broke up into Laurentia (Laurasia) to the north and Gondwanaland to the south
- The Tethys sea seperated Laurentia and Gondwanaland
- Rifts formed splitting West Gondwana from east Gondwana.
- India separated from Antarctica.
- Laurasia split from South America and Africa.

Triassic 200 mya

    - Mesozoic Era (250 mya – 66 mya)
      - Triassic Period (250 – 200 mya)
        - Early Triassic Epoch (250 – 247 mya)
        - Middle Triassic Epoch (247 – 237 mya)
        - Late Triassic Epoch (237 – 200 mya)
      - Jurassic Period (200 – 145 mya)
        - Early Jurassic Epoch (200 – 175 mya)
        - Middle Jurassic Epoch (175 – 163 mya)
        - Late Jurassic Epoch (163 – 145 mya)
      - Cretaceous Period (145 – 66 mya)
        - Early Cretaceous Epoch (145 – 100 mya)
        - Late Cretaceous Epoch (100 – 65 mya)

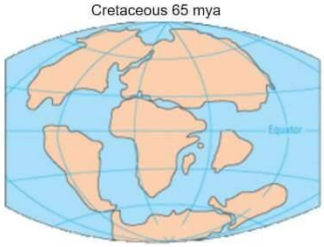
Jurassic 150 mya



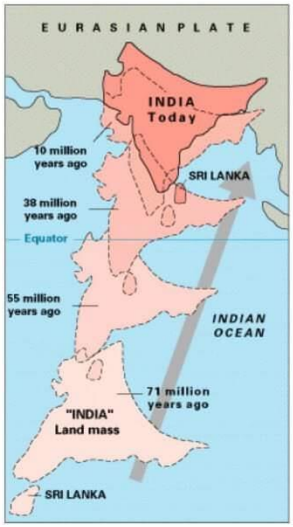
- Seafloor spreading further opened the central North Atlantic and Indian oceans.
- At the end of the period, a new rift split South America from Africa.

- Madagascar drifted away from Africa, which continued its move north.
- The northward drift of India continued, and Australia split from Antarctica.
- Zealandia, a microcontinent nearly half the size of Australia, broke away from the Gondwanan supercontinent about 83 million years ago.

Cretaceous 65 mya



    - Cenozoic Era (66 mya – present)
      - Paleogene Period (65 – 23 mya)
        - Paleocene Epoch (65 – 56 mya)
        - Eocene Epoch (56 – 33 mya)
        - Oligocene Epoch (33 mya – 23 mya)
      - Neogene Period (23 – 2.58 mya)
        - Miocene Epoch (23 mya – 5.3 mya)
        - Pliocene Epoch (5.3 mya – 2.58 mya)
      - Quaternary Period (2.58 mya – present)
        - Pleistocene Epoch (2.58 mya – 11,700 ya)
        - Halocene Epoch (11,700 ya – present)



Tertiary is the former term for the geologic period from 66 million to 2.58million years ago. The term is now obsolete.

Geologic Time Scale:
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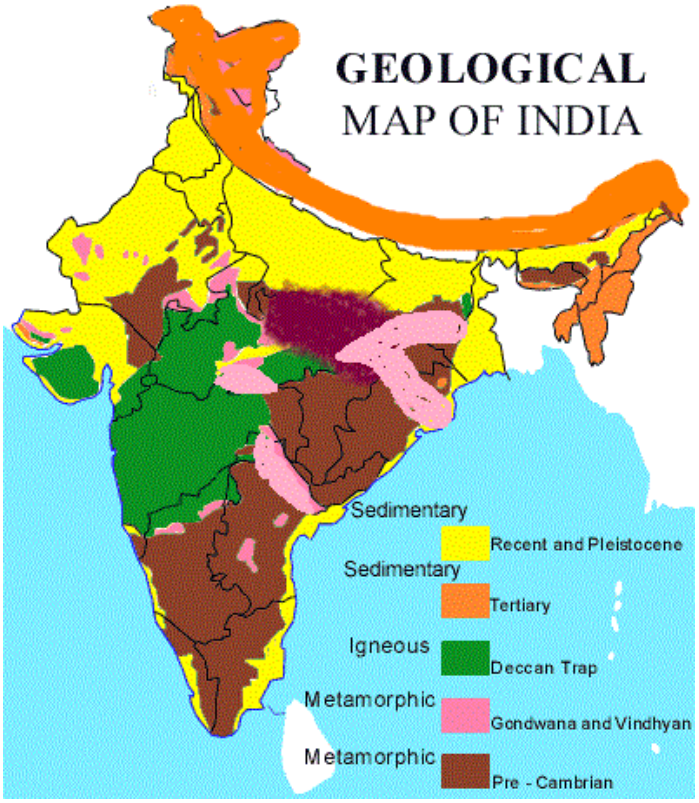
https://www.pmfias.com/wp-content/uploads/2019/03/Phanerozoic-Eon-Geological-Time-Scale.jpg



Rock System Based on Geological History of India

- They are **azoic or unfossiliferous plutonic intrusions (magma solidified below the surface)**.
- They are foliated (consisting of thin sheets).
- They are thoroughly crystalline (because they are volcanic in origin).

Dharwar System (1 to 4 billion years old)

- Formation period ranges from 4 billion years ago to – 1 billion years ago.
- They are highly **metamorphosed sedimentary** rock-system (formed due to the metamorphosis of sediments of Archaean gneisses and schists).
- They are the **oldest metamorphosed rocks**.
- They are found in abundance in the Dharwar district of Karnataka.
- They are **economically the most important rocks** because they possess valuable minerals like high-grade iron-ore, manganese, copper, lead, gold, etc.

Purana Rock System (600 to 1400 million years old)

- Includes two divisions: the **Cuddapah System** and the **Vindhyan System**.

Cuddapah System

- Unfossiliferous clay, slates, sandstones and limestones was deposited in **synclinal basins** (depression between two folds).
- Outcrops best observed in Cuddapah district of Andhra Pradesh.
- These rocks contain ores of iron, manganese, copper, cobalt, nickel, etc.
- They contain large deposits of cement grade limestones.

Vindhyan System

- This system derives its name from the great Vindhyan mountains.
- The system comprises of **ancient sedimentary rocks** (4000 m thick) superimposed on the Archaean base.
- They are mostly unfossiliferous.
- A large area of this belt is covered by the **Deccan Traps**.
- The Vindhyan system have **diamond bearing** regions from which **Panna** and **Golconda diamonds** have been mined.
- It is **devoid of metalliferous minerals** but provides large quantities of durable stones, ornamental stones, limestone, pure glassmaking sand etc.

2.2 Dravidian Rock System (Palaeozoic)

- Formed about **600 – 300 million years ago**.

- Found in the **extra-Peninsular region (the Himalayas and Ganga plain)** and are very rare in Peninsular India. (The name 'Dravidian' doesn't mean they are found in South India)
- They are **sedimentary rocks,** and **abundant fossils** can be found in them.
- The rocks of Cambrian, Ordovician, Silurian, Devonian and **Carboniferous periods** fall under the Dravidian system.

Carboniferous rocks (350 million years)

- The Carboniferous rocks (350 million years) comprise mainly of limestone, shale and quartzite.
- **Mount Everest** is composed of Upper Carboniferous limestones.
- **Coal formation** started in the Carboniferous age.
- Carboniferous in geology means **coal bearing**. (**most of the coal found in India is not of the Carboniferous period**; **High-quality coal of Great Lakes Region-USA, U.K and Ruhr** region is Carboniferous coal).

2.3 Aryan Rock System

- Upper **Carboniferous to the Recent**.

Gondwana System

- The **Gondwana System** (derives its name **Gonds**, tribes from Telangana and Andhra Pradesh)
- They are deposits laid down in **synclinal troughs** on ancient plateau surface.
- As the sediments accumulated, the loaded troughs subsided.
- Freshwater and sediments accumulated in these trough and terrestrial plants and animals thrived.
- This happened since the Permian period (250 million years ago).

Gondwana Coal

- Gondwana rocks contain nearly **98 per cent of India's coal reserves**.
- Gondwana coal is **much younger** than the Carboniferous coal, and hence its **carbon content is low**.
- They have rich deposits of iron ore, copper, uranium and antimony.
- Sandstones, slates and conglomerates are used as building materials.

Jurassic System

- The marine transgression in the latter part of the Jurassic gave rise to a thick series of **shallow water deposits** in Rajasthan and in Kutch.
- Coral limestone, sandstone, conglomerates and shales occur in Kutch.
- Another transgression on the east coast of the Peninsula is found between **Guntur and Rajahmundry.**

Deccan Trap

- The volcanic outburst over a vast area of Peninsular India from the end of the **Cretaceous** till the beginning of the **Eocene** gave rise to Deccan Traps.
- **Basaltic lava** flowed out of fissures covering a vast area of about **ten lakh km^2.**
- These volcanic deposits have a flat top and steep sides and therefore called **'trap'** meaning a 'stair' or 'step' in Swedish.
- The process of weathering and erosion (denudation) since millions of years has reduced the Deccan Trap to almost half of its original size.
- At present Deccan Traps covers about **5 lakh km^2** mainly in parts of Kutch, Saurashtra, Maharashtra, the Malwa plateau and northern Karnataka.
- The thickness of the Deccan Traps is 3,000 metres along the west which is reduced to 600-800 metres towards the south, 800 metres in Kutch and only 150 metres at the eastern limit.
- The weathering of these rocks for a long time has given birth to **black cotton soil** known as **regur**.

The Deccan Trap has been divided into three groups:

Group	Found in	Inter-trappean beds	Layers of volcanic ash
The Upper Trap	Maharashtra and Saurashtra	Present	Present
The Middle Trap	Central India and Malwa	Very rare to absent	Present
The Lower Trap	Madhya Pradesh	Present	Very rare to absent

- In basaltic volcanism (Deccan traps, Siberian shield, Laurentian shield), some sediments settle on the cooled and solidified basaltic layer.
- This sediment layer is covered further by basaltic volcanism and again some sediments settle over it.
- These successive layers of sediments separated by the basalt are called **inter-trappean beds**.

Tertiary System

- Formed between Eocene to Pliocene (60 to 7 million years ago).
- The tertiary is the most significant period in India's geological history because the **Himalayas** were born, and India's present form came into being in this period.

3. Himalayan Ranges

Division of the Himalayas

1. **The Shiwaliks or The Outer Himalayas**
2. **The Lesser Himalayas or The Middle Himalayas or The Himachal**
3. **The Greater Himalayas or The Himadri**
4. **The Trans-Himalayas – Tibetan Himalayas**
5. **The Eastern Hills – Purvanchal: A chain of hills in North-East India**

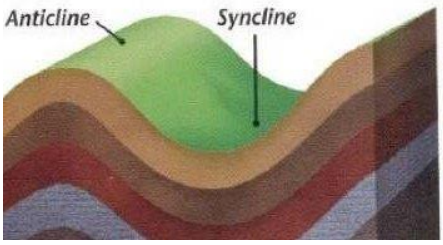
- Himalayan ranges are a series of several **parallel or converging ranges**.
- The ranges are separated by deep valleys creating a highly **dissected topography** (plateau or upland divided by a number of deep valleys).
- The **southern slopes have steep gradients,** and **northern slopes have comparatively gentler slopes**.

Scaling Mount Everest is less hectic from the northern side. But China places restrictions, so climbers take the steeper southern slopes from Nepal.

- Most of the Himalayan ranges fall in India, Nepal and Bhutan. The northern slopes are partly situated in Tibet (trans-Himalayas) while the western extremity lies in Pakistan, Afghanistan and Central Asia.
- The Himalayas between Tibet and Ganga Plain is a succession of three parallel ranges.

3.2 Shiwalik Range

- Also known as **The Outer Himalayas**.
- Located in between the Great Plains and **Lesser Himalayas**.
- The altitude varies from **600 to 1500 metres**.
- Runs for a distance of 2,400 km from the **Potwar Plateau (west)** to the **Brahmaputra valley (east)**.
- The southern slopes are steep while the northern slopes are gentle.
- **The width of the Shiwaliks varies from 50 km in Himachal Pradesh to less than 15 km in Arunachal Pradesh.**
- They are an almost unbroken chain of low hills except for a gap of 80-90 km which is occupied by the valley of the **Tista River** and **Raidak River**.
- Shiwalik range from North-East India up to Nepal are covered with thick forests, but the forest cover decreases towards west from Nepal (because of the **decrease in the quantum of rainfall from east to west**).
- The southern slopes of Shiwalik range in Punjab and Himachal Pradesh are almost devoid of forest cover.
- These slopes are highly dissected by seasonal streams called **Chos.**
- Valleys are part of synclines and hills are part of anticlines or antisynclines.



Syncline and Anticline (antisyncline)

Formation (Formation of Himalayas explained in C-C Convergence)

- Shiwaliks were formed **last** of all the ranges (**2-20 million years ago**).
- The Shiwaliks are consolidated sands, gravels and conglomerate deposits (alluvial fans – fluvial depositional landform) which were brought by the rivers flowing from the higher ranges.
- These deposits were **folded and hardened** due to compression offered by the northward movement of the Indian plate.

The Shiwaliks are known by different names in different areas

Name of Shiwaliks	Region
Jammu Region	Jammu Hills
Dafla, Miri, Abor and Mishmi Hills	Arunachal Pradesh
The Dhang Range, Dundwa Range	Uttarakhand
Churia Ghat Hills	Nepal

Explain the formation of Duns (Duras)

- Shiwalik Hills were formed by the accumulation of conglomerates (sand, stone, silt, gravel, debris etc.).
- These conglomerates, in the initial stages of deposition, obstructed the courses of the rivers draining from the higher reaches of the Himalayas and formed **temporary lakes.**
- With the passage of time, these temporary lakes accumulated more and more conglomerates. The conglomerates were well settled at the bottom of the lakes.
- When the rivers were able to cut their courses through the lakes filled with conglomerate deposits, the lakes were drained away leaving behind plains called **'duns' or 'doons'** in the west and **'duars'** in the east.
- **Dehra Dun in Uttarakhand** is the best example (75 km long and 15-20 km wide)
- **Kotah, Patli Kothri, Chumbi, Kyarda, Chaukhamba, Udhampur and Kotli** are other important duns.

3.3 The Lesser Himalayas or The Middle Himalayas or The Himachal

- In between the Shiwaliks in the south and the Greater Himalayas in the north.
- Runs almost parallel to both the ranges.
- They are also called the **Lower Himalaya**.
- **The Lower Himalayan** ranges are 60-80 km wide and about 2400 km in length.
- Elevations vary from **3,500 to 4,500 m** above sea level.
- Many peaks are more than 5,050 m above sea level and are snow-covered throughout the year.
- **The Lower Himalaya**s have **steep, bare southern slopes (steep slopes prevent soil formation)** and gentler, forest covered northern slopes.
- In Uttarakhand, the Middle Himalayas are marked by the **Mussoorie** and the **Nag Tibba** ranges.
- The **Mahabharat Lekh**, in southern Nepal, is a continuation of the **Mussoorie Range.**
- East of the **Kosi River, the Sapta Kosi, Sikkim, Bhutan, Miri, Abor** and **Mishmi hills** represent the lower Himalayas.
- The Middle Himalayan ranges are more friendly to human contact.

Majority of the Himalayan hill resorts like Shimla, Mussoorie, Ranikhet, Nainital, Almora and Darjeeling, etc. are located here.

Important Ranges in the Lesser Himalayas

Important ranges of Lesser Himalayas	Region

The Pir Panjal Range	**Jammu and Kashmir (The range is south of Kashmir Valley)**
The Dhaola Dhar Range	**Himachal Pradesh**
The Mussoorie Range and The Nag Tiba Range	**Uttarakhand**
Mahabharat Lekh	**Nepal**

The Pir Panjal range

- The **Pir Panjal range** in Kashmir is the longest and the most important range.
- It extends from the **Jhelum river** to the **upper Beas** river for over 300 km.
- It rises to 5,000 metres and contains mostly volcanic rocks.

Passes in Pir Panjal

- **Pir Panjal Pass (3,480 m), the Bidil (4,270 m), Golabghar Pass (3,812 m)** and **Banihal Pass (2,835 m)**.
- The **Banihal Pass** was used by the **Jammu-Srinagar highway** and **Jammu-Baramulla railway**.
- The **Kishanganga**, the **Jhelum** and the **Chenab** cut through the range.
- Southeast of the Ravi, the Pir Panjal continues as **Dhaola Dhar range**, passing through Dalhousie, Dharamshala, and Shimla.

Important Valleys

- **Between the Pir Panjal and the Zaskar Range** of the main Himalayas, lies the valley of Kashmir (average elevation is 1,585 m above mean sea level).
- The synclinal basin of the valley is floored with alluvial, lacustrine (lake deposits), fluvial (river action) and glacial deposits.
- Jehlum River meanders through these deposits and cuts a deep gorge in Pir Panjal through which it drains. (Kashmir is a basin with very few outlets. Hence the region is extremely vulnerable to flooding).
- In Himachal Pradesh, there is **Kangra Valley**. It is a **strike valley** and extends from the foot of the Dhaola Dhar Range to the south of Beas.
- On the other hand, the **Kulu Valley** in the upper course of the Ravi is a **transverse valley**.

Strike valley vs. Transverse valley

- A valley perpendicular to the slope or parallel to the ridge (also called as a longitudinal valley)
- In contrast, transverse streams cut valleys parallel to the slope (along the dip).

Strike valley vs. Transverse valley

3.4 The Greater Himalaya

- Also known as **Inner Himalaya, Central Himalaya or Himadri**.
- Average elevation of 6,100 m above sea level and an average width of about 25 km.
- It is mainly formed of the central crystallines (**granites and gneisses**) overlain by **metamorphosed sediments (limestone)**.
- The folds in this range are asymmetrical with steep south slope and gentle north slope giving hogback (a long, steep hill or mountain ridge) topography.
- This mountain arc convexes to the south just like the other two.
- The Himadri terminates abruptly at the **syntaxial bends**.
- One in the **Nanga Parbat** in the north-west and the other in the **Namcha Barwa** in the north-east.

Syntaxial Bends of the Himalayas

- The Himalayas extend in the east-west direction from the Indus gorge in the west to the Brahmaputra gorge in the east.
- Himalayan ranges take sharp southward bends at these gorges. These bends are called **syntaxial bends** of the Himalayas.
- The western syntaxial bend occurs near the **Nanga Parbat** (**western tip of The Zaskar Range**) where the Indus river has cut a deep gorge.
- The eastern syntaxial bend occurs near the **Namche Barwa**.

Nanga Parbat means Naked Mountain. It is called so due to its isolation from the Karakoram range that has many similar high peaks (eight-thousanders)

- This mountain range boasts of the tallest peaks of the world, most of which remain under perpetual snow.

Regional name of Mount Everest	Region
Sagarmatha (The Goddess of the Sky)	**Nepal**
Chomolungma (Mother of the World)	**China (Tibet)**

*Mount Everest was first located by **George Everest**, the then Surveyor General of India in 1841 and 1852 it was established as the highest peak of the world by the Great Trigonometrical Survey of India.*

Passes in the Greater Himalayas

- The passes are generally higher than 4,570 m above sea level and are snowbound for most of the year.

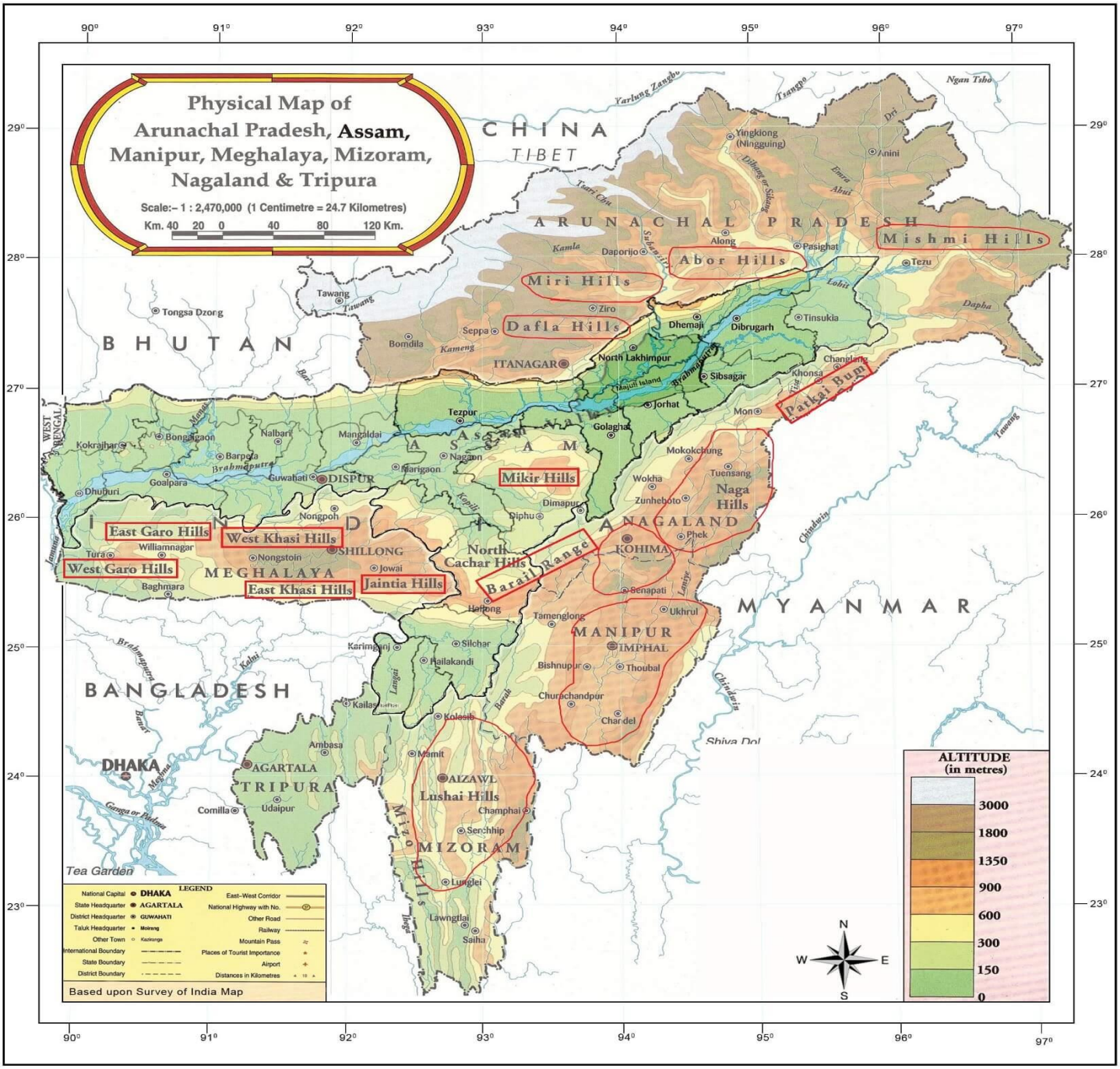
State	Passes of Greater Himalayas
Jammu and Kashmir	• Burzil Pass • Zoji La (La means pass)
Himachal Pradesh	• Bara Lacha La • **Shipki La (The Hindustan-Tibet Road through Shipki La connects Shimla with Gartok in Western Tibet)**
Uttarakhand	• Thaga La • Niti Pass • Lipu Lekh
Sikkim	• Nathu La • **Jelep La (important trade route connecting Kalimpong (near Darjeeling) with Lhasa in Tibet, passes through Jelep La (4,386 m))**

3.5 The Trans Himalayas

- The Trans Himalayas are the Himalayan ranges immediately north of the Great Himalayan range.
- Also called the **Tibetan Himalaya** because most of it lies in Tibet.
- The average elevation is 3000 m above mean sea level.
- The average width of this region is 40 km at the extremities and about 225 km in the central part.
- It stretches for a distance of about 1,000 km in the east-west direction (**occur only in the western part** of the Himalayas).

Ranges in The Trans Himalayas

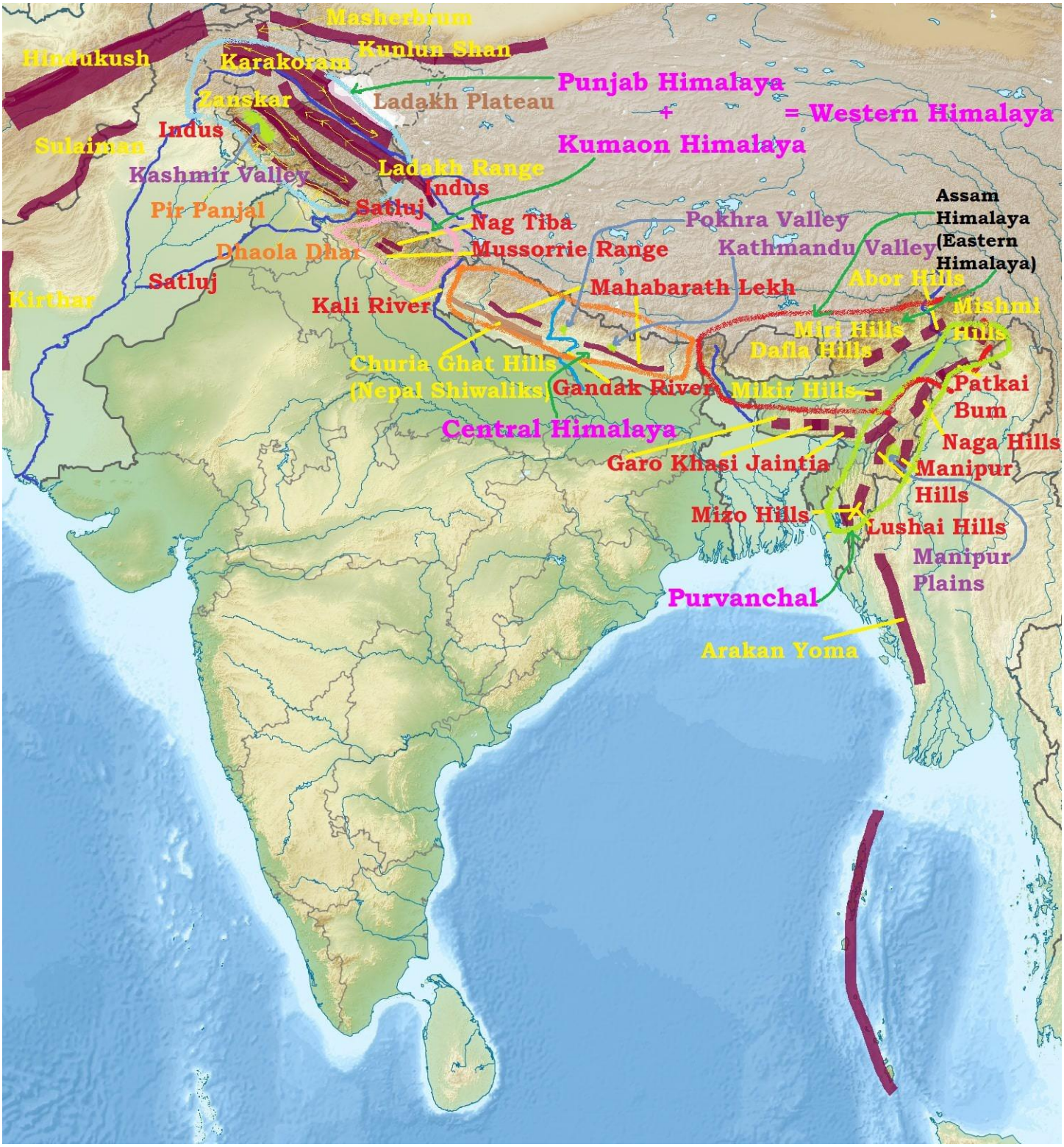
- The **Zanskar**, the **Ladakh**, the **Kailas** and the **Karakoram** are the main ranges.
- The **Nanga Parbat (8126 m) is in The Zaskar Range**.
- North of the Zaskar Range and running parallel to it is the Ladakh Range.
- Only a few peaks of this range attain heights of over 6000 metres.
- **The Kailas Range** (**Gangdise in Chinese**) in western Tibet is an **offshoot of the Ladakh Range**.
- The highest peak is **Mount Kailas (6714 m)**.
- **River Indus originates from the northern slopes of the Kailas range**.
- The northernmost range of the Trans-Himalayan Ranges in India is the **Karakoram Range** also known as the **Krishnagiri range**.



Purvanchal Hills

- **Karakoram Range** extends eastwards from the Pamir for about 800 km.
- It is a range with lofty peaks (elevation 5,500 m and above). It is the **abode of some of the greatest glaciers** of the world outside the polar regions.
- Some of the peaks are more than 8,000 meters above sea level. **K2 (8,611 m) (Godwin Austen or Qogir in Karakoram Range)** is the second highest peak in the world and the highest peak in the Indian Union.

3.6 Himalayas – Regional Divisions



Himalayan Ranges and Hills

- The Ladakh Plateau lies to the north-east of the Karakoram Range. It has been dissected into a number of plains and mountains (**Soda Plains, Aksai Chin, Lingzi Tang, Depsang Plains and Chang Chenmo**)

3.7 Purvanchal or Eastern Hills

- Eastern Hills or The Purvanchals are the southward extensions of the Himalayas running along the north-eastern edge of India.
- At the **Dihang gorge**, the Himalayas take a sudden southward bend and form a series of comparatively low hills which are collectively called as the Purvanchal.
- Purvanchal hills are convex to the west.
- They run along the India-Myanmar Border extending from Arunachal Pradesh in the north to Mizoram in the south.
- **Patkai Bum** hills are made up of strong sandstone; elevation varys from 2,000 m to 3,000 m; merges into **Naga Hills** where **Saramati (3,826 m)** is the highest peak.
- Patkai Bum and Naga Hills form the watershed between India and Myanmar.
- South of Naga Hills are the **Manipur hills** which are generally less than 2,500 metres in elevation.
- The **Barail range** separates Naga Hills from Manipur Hills.
- Further south the Barail Range swings to the west into **Jaintia, Khasi and Garo hills** which are an eastward continuation of the **Indian peninsular block**.
- They are separated from the main block by Ganga and Brahmaputra rivers.
- South of the Manipur Hills are the Mizo Hills (previously known as the **Lushai hills**) which have an elevation of less than 1,500 metres. The highest point is the **Blue Mountain (2,157 m)** in the south.

Punjab Himalayas

- The Himalayan region between the **Indus** and the **Satluj** rivers (560 km long).
- All the major rivers of the Indus river system flow through Punjab Himalayas.
- A large portion of Punjab Himalayas is in Jammu and Kashmir and Himachal Pradesh. Hence, they are also called the **Kashmir and Himachal Himalaya**.
- **Karakoram, Ladakh, Pir Panjal, Zaskar** and **Dhaola Dhar** are the major ranges in this section.
- The general elevation **falls westwards**.

Q. Match List-I with List-II and select the correct answer:

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

Codes:

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

- Madras is warmer than Calcutta because Madras is closer to the equator.
- Snowfall in the Himalayas is due to altitude.
- Rainfall decreases from east to west due to increasing distance from the sea.
- Sutlej-Ganga plain gets some rain in winter due to Western Disturbances (remnants of the temperate cyclone)

Answer: c) A – 5; B – 2; C – 4; D – 3

Western Himalayas

- Between the **Indus in the west and the Kali river in the east (880 km).**
- Spread across three states of Jammu and Kashmir, Himachal Pradesh and Uttarakhand.
- It encompasses three physiographic provinces namely **Kashmir Himalaya, Himachal Himalaya** and **Kumaon Himalaya (Uttarakhand Himalayas).**
- The Ladakh plateau and the Kashmir valley are two important areas of the Kashmir Himalayan region.

- In Himachal Himalayas, The Greater Himalaya is represented by the **Zaskar range**, lesser Himalaya by **Pir Panjal** and **Dhauladhar ranges** and the Outer Himalaya by the **Shiwalik range**.
- The southern slopes are rugged, steep and forested while the northern slopes are bare and gentle.
- The Kumaon Himalayas lie in Uttarakhand and extend from the **Satluj to the Kali river**.
- The Lesser Himalayas in Kumaon Himalaya is represented by the **Mussoorie and Nag Tiba ranges.**
- The Shiwalik in this region runs south of the Mussoorie range between the Ganga and the Yamuna rivers.
- The flat valleys **between the Lesser Himalaya and the Shiwalik range are called 'doons'** or 'Duns' of which Dehra Dun is the most famous.

Central Himalayas

- 800 km between river Kali in the west and river Tista in the east.
- The Great Himalaya range attains **maximum height in this portion**.
- Some of the world famous peaks **Mt. Everest, Kanchenjunga, Makalu, Annapurna, Gosainthan and Dhaulagiri,** are located here.
- The Lesser Himalaya is known as **Mahabharat Lekh** in this region.
- The range is crossed by rivers like Ghaghara, Gandak, Kosi, etc.
- In between the Great and the Lesser Himalayas, there are **Kathmandu and Pokhra** lacustrine **valleys** (previously, they were lakes).
- The Shiwalik range comes very close to the lesser Himalaya towards the east and is almost non-existent beyond Narayani (**Gandak**).

Eastern Himalayas

- Also known as the **Assam Himalayas**, this part of the Himalayas lies between the Tista river in the west and the Brahmaputra river in the east and stretches for a distance of about 720 km.
- Elevation here is much lesser than that of the Nepal Himalayas.
- The southern slopes are very steep, but the northern slopes are gentle.
- **The Lesser Himalayas are very narrow and are very close to the Greater Himalayas.**
- The Assam Himalayas show a marked dominance of fluvial erosion due to **heavy rainfall.**
- The Himalayas take a sudden southward turn after the **Dihang gorge** and the hill ranges running in a more or less north-south direction along India's border with Myanmar are collectively known as the **Purvanchal**.
- **Purvanchal hills are known by various local names such as Patkai Bum, Naga Hills, Kohima hills, Manipur hills, Mizo hills (previously known as the Lushai hills), Tripura hills and Barail range.**
- The extension of the Purvanchal Himalaya continues southwards up to Andaman and Nicobar Islands through the Myanmar range (Arakan Yoma) and even up to the Indonesian archipelago.

In the eastern section, the Himalayas rise abruptly from the plains of Bengal and Oudh and suddenly attain great elevations within a short distance. Thus, the peaks of Kanchenjunga and Everest are only a few kilometres from the plains.
In contrast, the western Himalayas rise gradually from the plains through a series of ranges. Their peaks of perpetual snow are 150 to 200 km away from the plain areas.

3.8 Important Valleys in the Himalayas

The most important valleys in the Himalayan region are

1) the **valley of Kashmir and the Karewas,**
2) **the Kangra and Kulu valley** in Himachal Pradesh;
3) the **Dun valley (Doon valley, Dehradun valley)**; the **Bhagirathi valley (near Gangotri)** and the **Mandakini valley (near Kedarnath)** in Uttarakhand and
4) the **Kathmandu valley** in Nepal.

Karewas

- Karewas are lacustrine deposits (deposits in the lake) in the Valley of Kashmir and Bhadarwah Valley of the Jammu Division.
- These are the flat-topped mounds that border the Kashmir Valley on all sides.
- They are characterised with fossils of mammals and at places by peat.

Formation

- During the Pleistocene Period (1 million years ago), the entire Valley of Kashmir was under water.
- Subsequently, due to endogenic forces, the Baramullah Gorge was created, and the lake was drained through this gorge.
- The deposits left in the process are known as **karewas.**
- The thickness of karewas is about 1400 m.
- The karewas have been elevated, dissected and removed by denudation as well as by the Jhelum river giving them the present position.

Economic Significance

- The karewas are mainly devoted to the cultivation of saffron, almond, walnut, apple and orchards.

3.9 Snow in the Himalayas – Snowline

- The snow line (the lowest level of perpetual snow) varies in different parts of the Himalayas depending upon **latitude, amount of precipitation and local topography**.
- In **Eastern Himalayas and Kumaon Himalayas, the snowline is around 3,500 m above sea level** whereas in the **western Himalayas snowline is about 2,500 m above sea level**.
- This difference in snowline is partly due to the **increase in latitude** from 28° N in Kanchenjunga to 36° N in the Karakoram.
- But the major factor is **precipitation**. Precipitation in the western Himalayas is comparatively low and occurs mostly as snowfall whereas in the eastern Himalayas the precipitation is greater and occurs mostly in the form of rain.
- In the Great Himalayan ranges, the **snow line is at a lower elevation on the southern slopes** than on the northern slopes because the **southern slopes receive more precipitation** as compared to the northern slopes.

3.10 Glaciers in the Himalayas

- There are about 15,000 glaciers in the Himalayas.
- The total area of Himalayas is about five lakh square kilometres (area of India is nearly 32 lakh square km). About 33,000 square km area is covered by snow.

Glaciers of the Karakoram Range

- Maximum development of glaciers occurs in the Karakoram range.
- Some of the largest glaciers outside the polar and sub-polar regions are found in this range.
- The southern side of this range has many gigantic glaciers.
- The **75 km long Siachen Glacier** in **Nubra valley** has the distinction of being the largest glacier outside the polar and the sub-polar regions.
- The second largest is the 74 km long **Fedchenko Glacier** (Pamirs).
- Third largest is the Hispar Glacier. It is 62 km long and occupies a tributary of the **Hunza River.**

Glaciers of the Pir Panjal Range

- The glaciers of the Pir Panjal Range are less numerous and smaller in size as compared to those of the Karakoram Range.
- The longest **Sonapani Glacier** in the **Chandra Valley** of **Lahul and Spiti region** is only 15 km long.

Others

- Glaciers of the Kumaon-Garhwal Region: In the Kumaon-Garhwal region of the Himalayas, the largest is the 30 km long **Gangotri Glacier** which is the source of the river Ganga.

Garhwal Region

- Lying in the Himalayas, it is bounded on the north by Tibet, on the east by Kumaon region, on the south by Uttar Pradesh state, and on the northwest by Himachal Pradesh state.
- It includes the districts of Chamoli, Dehradun, Haridwar, Pauri Garhwal, Rudraprayag, Tehri Garhwal, and Uttarkashi.

Garhwal Region

- Glaciers of Central Nepal: Zemu and the Kanchenjunga glaciers are the major ones.

3.11 The significance of the Himalayas

Influence on Indian Climate

- They **intercept the summer monsoons** coming from the Bay of Bengal and the Arabian Sea causing precipitation in the entire Ganga Plains, North-Eastern Hills.
- They direct the monsoon winds **towards northwestern India** (Punjab, Haryana etc. But these regions receive most of the rainfall due to **Western Disturbances** coming from the Mediterranean regions).
- They **protect** northern-plains from the cold continental air masses of central Asia.
- The Himalayas influence the path of Subtropical Jet stream flowing in the region. They split the jet stream, and this split jet stream plays an important role in bringing monsoons to India.
- Had there been no Himalayas, the whole of India would have been a desert and its winters would have been very severe.

Source of Rivers

- Rivers that feed nearly half a billion population of India originate in the Himalayas.
- All the rivers are **perennial** supplying water year round.

Fertile Soil

- The swift flowing rivers from the Himalayas bring an enormous amount of silt (alluvium) which continually enrich the Ganga and Brahmaputra plains.

Hydroelectricity

- Due to its natural topography and swift flowing perennial rivers, the Himalayan region offers several natural sites with great hydroelectric power generation potential.
- Many hydroelectric power plants have already been constructed.
- But all this comes at a tremendous environmental cost.

Forest Wealth

- The Himalayan host rich coniferous and evergreen forests.
- Lower levels have tropical evergreen forests, and higher levels have Alpine vegetation (Coniferous).
- The Himalayan forests provide fuelwood and a large variety of timber for industries.
- Himalayan forests host a wide variety of medicinal plants.

- Several patches are covered with grass offering rich pastures for grazing animals.

Agriculture

- Due to rugged and sloped terrain, the Himalayas are not potential agricultural sites.
- Some slopes are terraced for cultivation. Rice is the main crop on the terraced slopes.
- The other crops are wheat, maize, potatoes, etc.
- **Tea** is a unique crop which can be grown only on the **Shiwalik hill slopes** in the region.
- **Fruit cultivation** is a principal occupation. A wide variety of fruits such as apples, pears, grapes, mulberry, walnut, cherries, peaches, apricot, etc. are also grown in the Himalayan region.

Tourism

- Himalayan ranges have a large number of tourist spots.
- The hilly areas in the Himalayas are not affected by hot winds like the **loo**. Hence, they offer cool and comfortable climate.
- The increasing popularity of winter sports has increased the rush of tourists in winters.
- **Srinagar, Dalhousie, Dharamshala, Chamba, Shimla, Kulu, Manali, Mussoorie, Nainital, Ranikhet, Almora, Darjeeling, Mirik, Gangtok,** etc. are important tourist centres in the Himalayas.

Cultural Tourism

- Himalayas host many Hindu and Buddhist shrines.
- **Kailas, Amarnath, Badrinath, Kedarnath, Vaishnu Devi, Jwalaji, Uttarkashi, Gangotri, Yamunotri**, etc. are important places of pilgrimage.

Defense

- The Himalayas are a natural defense barrier.
- But the Chinese aggression on India in 1962 has reduced the defence significance of the Himalayas.

Mineral Resources in the Himalayas

- Geosynclinal (geosynclinical) deposits in tertiary rocks are regions of potential coal (peat) and oil reserves.
- Coal is found in Kashmir, Copper, lead, zinc, gold, silver, limestone, semi-precious and precious stones occur at some places in the Himalayas.
- But the exploitation of these resources requires advanced technologies which are not yet available.

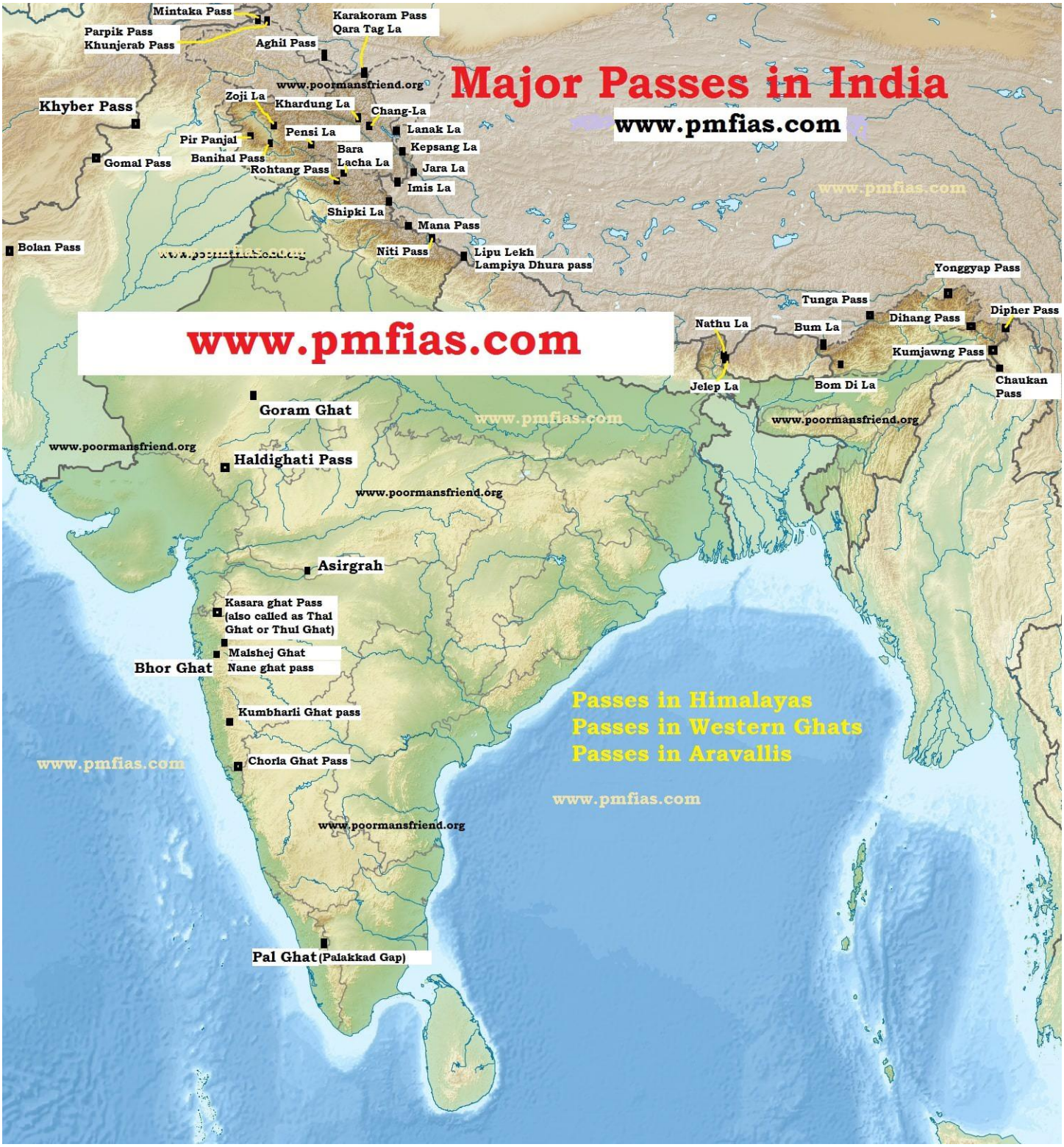
3.12 Major Passes in Himalayas and Indian Sub-continent

- **Sela Pass** is between Bum La and Bom Di La. **Tawang** is between Bum La and Sela Pass.
- Most of the Himalayan passes remain closed in winter (Nov – Apr) due to heavy snow fall.

Passes of the Western Himalayas		
Jammu and Kashmir		
Name	**Significance (connects)**	**Comments**
Mintaka Pass	**Kashmir and China**	**Trijunction of India-China and Afghanistan border**
Parpik Pass	Kashmir and China	• East of Mintaka pass on the Indo-China border
Khunjerab Pass	Kashmir and China	• Indo-China border
Aghil Pass	Ladakh with the Xinjiang Province (China)	• 5000 m above sea level. • north of K2 Peak (the highest peak in India)
Banihal Pass	**Jammu and Srinagar**	• 2832 m • across the **Pir-Panjal Range** • remains snow covered during the winter season
	• The road from Jammu to Srinagar transversed Banihal Pass until 1956 when Jawahar Tunnel was constructed under the pass.	

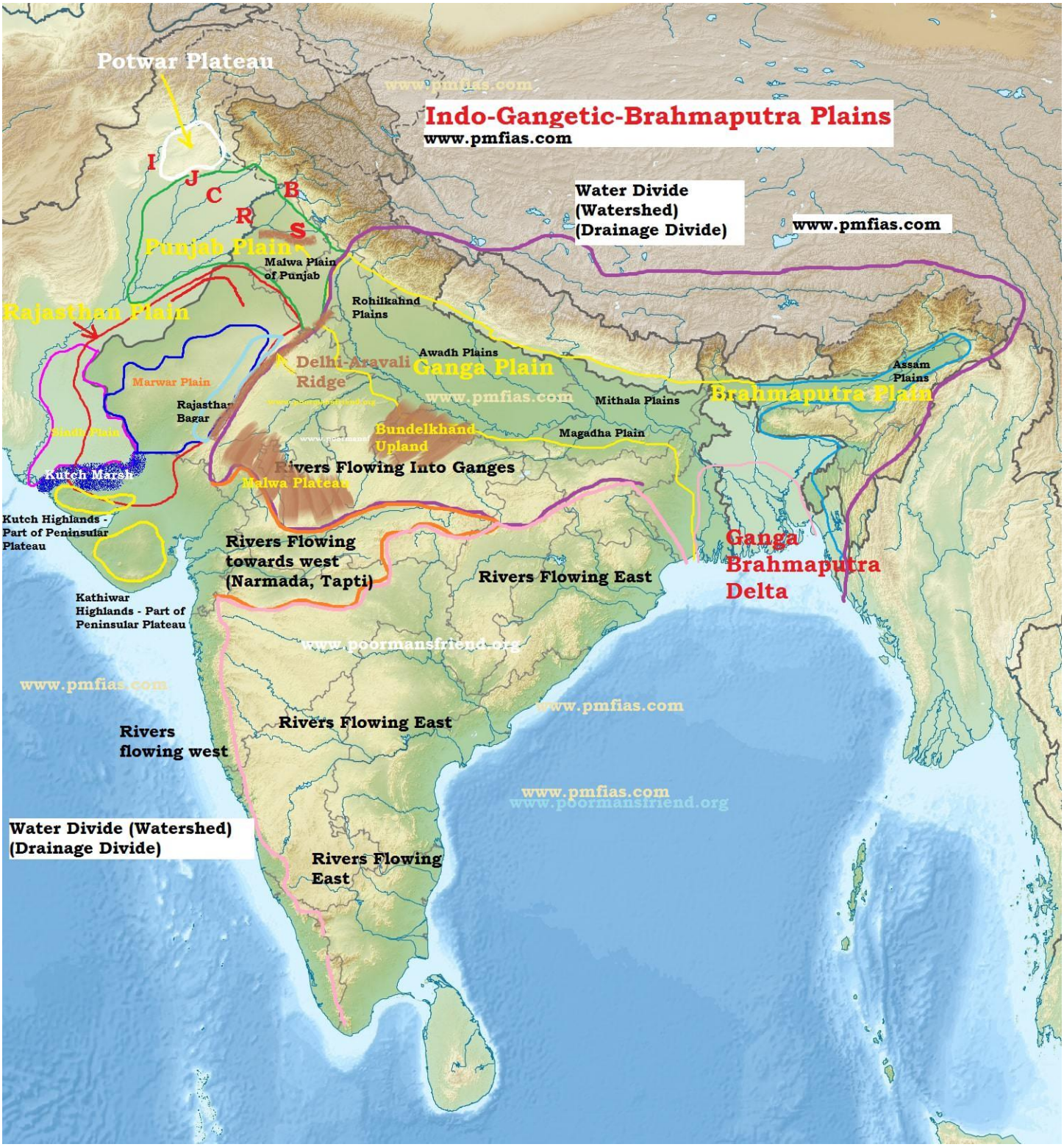
	• The road now passes through the tunnel, and the Banihal Pass is no longer used for road transport. • Another 11 km long tunnel provides a **railway link between Banihal and Kazigund**. It was thrown open to railway transport in 2013.	
Chang-La	Ladakh with Tibet	• altitude of 5360 m • This has a temple dedicated to Chang-La Baba after whom the temple has been named
Khardung La	**near Leh in the Ladakh range**	• 5602 m • **The world's highest motorable road passes through this pass** • remains closed in winter due to heavy snowfall
Lanak La	India and China (Akasai-Chin area of Jammu and Kashmir)	• this pass provides passage between Ladakh and Lhasa. • A road to connect Xinjiang Province with Tibet has been constructed by the Chinese
Pir-Panjal pass	across the Pir Panjal range	• provides the shortest and the easiest metal road between Jammu and Kashmir Valley. • But this route had to be closed down as a result of the partition of the subcontinent.
Qara Tag La	Indo-China border across the Karakoram Range	• located at an elevation of over six thousand metres
Imis La	Ladakh region of India and Tibet in China	
Pensi La	**a vital link between the Kashmir Valley and Kargil**	• remains closed to traffic from November to mid-May due to heavy snowfall
Zoji La	**important road link between Srinagar on one side and Kargil and Leh on the other side**	• The road passing through this pass has been designated at the National Highway (NH-1D) • **Border Road Organisation (BRO)** is responsible for maintaining the road and cleaning it off snow during winter. • In spite of all these efforts, the road through this pass remains closed from December to mid-May
Himachal Pradesh		
Bara Lacha La	Himachal Pradesh and Jammu and Kashmir	• Elevation: 4,890 m • National highway connecting Mandi in Himachal Pradesh with Leh in Jammu and Kashmir passes through this pass. • Being situated at high altitude, it remains snow covered in winter and is not used as a transport route.
Debsa Pass	link between Kullu and Spiti districts	• elevation of 5270 m above sea level • It offers a much easier and shorter alternative route to traditional Pin-Parbati Pass route between Kullu and Spiti
Rohtang Pass	road link between Kullu, Lahul and Spiti Valleys	• Elevation: 3979 m • Border Road Organisation (BRO) is responsible for constructing and maintaining roads in this area. • **Rohtang pass is a great tourist attraction,** and traffic jams are very common because this route is widely used

		by the military, public and private vehicles.
Shipki La	Himachal Pradesh and Tibet	• Elevation: 6000 m • Remains closed in the winter season (Nov - Apr)
Uttarakhand		
Lipu Lekh	trijunction of Uttarakhand (India), Tibet (China) and Nepal borders	• **Kailash-Mansarovar pilgrims use this pass**.
Mana Pass	Uttarakhand with Tibet	• elevation of 5610 • Situated a little north of Badhrinath • Remains closed in the winter season (Nov - Apr)
Mangsha Dhura	Uttarakhand with Tibet	• **It is used by pilgrims going to Kailash-Mansarowar**
Niti Pass	Uttarakhand with Tibet	• Remains closed in the winter season (Nov - Apr)
Muling La	Uttarakhand and Tibet	• situated in the north of Gangotri at an elevation of 5669 m in the Great Himalayas
Passes of the Eastern Himalayas		
Sikkim		
Nathu La	Sikkim with Tibet	• altitude of 4310 m • it forms part of an offshoot of the **ancient Silk Route** • an important trade route between India and China • It was closed after the Chinese aggression on India in 1962 but was reopened in 2006 as the governments of the two countries decided to enhance their trade through land routes
Jelep La	Sikkim-Bhutan border	• altitude of 4538 m • passes through Chumbi Valley • an important link between Sikkim and Lhasa
Arunachal Pradesh		
Bom Di La	Arunachal Pradesh with Bhutan	• altitude of 4331 m • Situated at an altitude of 4331 m near the eastern boundary of Bhutan in the Greater Himalayas, this pass **connects Arunachal Pradesh with Lhasa (Tibet)**
Dihang Pass	Arunachal Pradesh and Myanmar.	• elevation of more than 4000 m it provides passage
Yonggyap Pass	Arunachal Pradesh with Tibet	
Dipher Pass (Diphu pass)	trijunction of India, China and Myanmar	• easy access between Arunachal Pradesh and Mandalay in Myanmar. • It is an important land trade route between India and Myanmar and remains open throughout the year.
Kumjawng Pass	Arunachal Pradesh with Myanmar	
Hpungan Pass		
Chankan Pass		



Major Passes in Himalayas and Indian Sub-continent

4. Indo-Gangetic-Brahmaputra Plain



Indo-Gangetic-Brahmaputra Plains

4.1 The formation of Indo-Gangetic-Brahmaputra Plain

- The formation of the Indo-Gangetic plain is closely related to the formation of Himalayas.

Indo-Gangetic-Brahmaputra trough

- The rivers which were previously flowing into **Tethys sea** (before Indian Plate collided with Eurasian) deposited a huge amount of sediments in the **Tethys Geosyncline (a huge depression)**.
- The Himalayas are formed out of these sediments which were uplifted, folded and compressed due to northern movement of Indian Plate.
- Northern movement of the Indian Plate also **created a trough** to the south of Himalayas.

Depositional Activity

- During the initial stages of upliftment of sediments, the already existing rivers changed their course several times and they were **rejuvenated** each time (perpetual youth stage of rivers).
- The rejuvenation is associated with intense headward and vertical downcutting of the soft strata overlying the harder rock stratum.
- Headward erosion and vertical erosion of the river valley in the initial stages, lateral erosion in later stages contributed a huge amount of conglomerates (rock debris, silt, clay etc.) which were carried downslope.

***Headward erosion**: Erosion at the origin of a stream channel, which causes the origin to move back away from the direction of the stream flow, and so causes the stream channel to lengthen.*

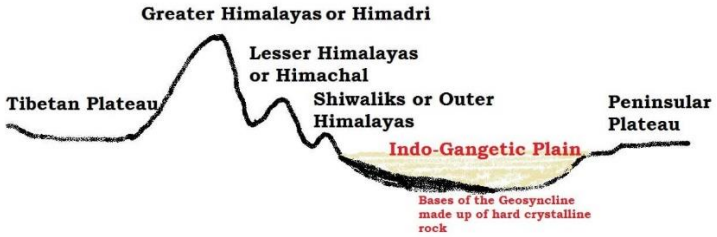
- These conglomerates were deposited in the **depression (Indo-Gangetic Trough or Indo-Gangetic syncline) (the base of the geosyncline is hard crystalline rock)** between peninsular India and the convergent boundary (the region of present-day Himalayas).

New rivers and more alluvium

- The raising of the Himalayas and the subsequent formation of glaciers gave rise to many new rivers.
- These rivers along with glacial erosion supplied more alluvium which intensified the filling of the depression.
- With the accumulation of more and more sediments (conglomerates), the Tethys sea started receding.
- With the passage of the time, the depression was completely filled with alluvium, gravel, rock debris (conglomerates) and the Tethys completely disappeared leaving behind a monotonous aggradational plain.

***Monotonous**: featureless topography; **Aggradational plain**: plain formed due to depositional activity.*

- Upper peninsular rivers have also contributed to the formation of plains, but to a very small extent.
- During recent times (since a few million years), depositional work of three major river systems viz., the Indus, the Ganga and the Brahmaputra have become predominant.
- Hence this arcuate (curved) plain is also known as **Indo-Gangetic-Brahmaputra Plain**.



Elevation of the major physiographic divisions of India

4.2 Features of Indo-Gangetic-Brahmaputra Plain

- Indo-Gangetic-Brahmaputra Plain is the **largest alluvial tract of the world**.
- It stretches for about **3,200 km** from the mouth of the Indus to the mouth of the Ganga.
- Indian sector of the plain accounts for **2,400 km.**
- The northern boundary is well marked by the **Shiwaliks** and the southern boundary is a wavy irregular line along the northern edge of Peninsular India.
- The western border is marked by **Sulaiman and Kirthar ranges**.

- On the eastern side, the plains are bordered by **Purvanchal hills**.
- It is widest in the west where it stretches for about 500 km. Its width decreases in the east.
- The thickness of the alluvium deposits also varies from place to place. The maximum depth of the alluvium up to the basement rocks is about 6,100 m (not uniform and varies greatly from place to place).
- **Extreme horizontality** of this monotonous plain is its chief characteristic.
- Its average elevation is about 200 m above mean sea level, highest elevation being 291 m above mean sea level near **Ambala** (**This elevation forms the drainage divide or watershed between Indus system and Ganga system**).
- Its average gradient from Saharanpur to Kolkata is only 20 cm per km and it decreases to 15 cm per km from Varanasi to the Ganga delta.

Divisions of Indo-Gangetic-Brahmaputra Plain

- Geologically, the alluvium of the Great plain of India is divided into newer or younger khadar and older bhangar soils.

The Bhabar

- It is a **narrow, porous, northernmost** stretch of Indo-Gangetic plain.
- It is about 8-16 km wide running in an east-west direction **along the foothills** (alluvial fans) of the Shiwaliks.
- They show a remarkable continuity from the **Indus to the Tista**.
- Rivers descending from the Himalayas deposit their load along the foothills in the form of **alluvial fans**.
- These alluvial fans (often pebbly soils) have merged together to build up the **bhabar belt.**
- The **porosity** of bhabar is the most unique feature.
- The porosity is due to deposition of huge number of **pebbles and rock debris** across the alluvial fans.
- The **streams disappear once they reach the bhabar region because of this porosity**.
- Therefore, the area is marked by **dry river courses** except in the rainy season.
- The Bhabar belt is comparatively **narrow in the east** and extensive in the west.

The area is not suitable for agriculture, and only big trees with large roots thrive in this belt.

The Terai

- Terai is an **ill-drained, damp (marshy) and thickly forested narrow tract** to the south of Bhabar running parallel to it.
- The Terai is about15-30 km wide.
- The underground streams of the Bhabar belt **re-emerge** in this belt.

This thickly forested region provides shelter to a variety of wildlife. (Jim Corbett National Park in Uttarakhand and Kaziranga National Park in Assam lie in terai region)

The Terai Marshes

- The Terai is more marked in the eastern part than in the west because the eastern parts receive a comparatively higher amount of rainfall.
- The terai soils are silty and **rich in nitrogen** and organic matter but are **deficient in phosphate.**
- Most of the Terai land, especially in Punjab, Uttar Pradesh and Uttarakhand, has been turned into agricultural land which gives good crops of **sugarcane, rice and wheat.**

The Bhangar

- The Bhangar is the **older alluvium** along the river beds **forming terraces higher than the flood plain.**
- The terraces are often impregnated with calcareous concretions (beds of lime nodules) known as **'Kankar'.**

- **'The Barind plains'** in the deltaic region of Bengal and the **'bhur formations'** in the middle Ganga and Yamuna doab are regional variations of Bhangar.

Bhur *denotes an elevated piece of land situated along the banks of the Ganga river especially in the upper Ganga-Yamuna Doab.*
This has been formed due to the accumulation of wind-blown sands during the hot, dry months of the year.

- Bhangar contains fossils of animals like rhinoceros, hippopotamus, elephants, etc.
- The soil is of a more clayey composition and is generally dark coloured.

The Khadar

- The Khadar is composed of **newer alluvium** and forms the **flood plains** along the river banks.
- A **new layer of alluvium is deposited** by river flood almost every year.
- This makes them the **most fertile soils of Ganges**.
- They are sandy clays and loams, drier and more leached and less calcareous.

Reh or Kollar

- Reh or Kollar comprises **saline efflorescences** of drier areas in Haryana.
- Reh areas have spread in recent times with increase in irrigation (capillary action brings salts to the surface).

Regional Divisions of the Great Plains

1. **Sindh Plain**
2. **Rajasthan Plain.**
3. **Punjab Plain.**
4. **Ganga Plain.**
5. **Brahmaputra Plain.**
6. **Ganga-Brahmaputra Delta**

Sindh Plain (Pakistan)

- Mainly formed of **Bhangar Plains**.
- Dhors: Long narrow depressions which are the remnants of the course of former rivers.
- Dhand: Alkaline lakes on some dhors.

Rajasthan Plain

- Occupied by Thar or the Great Indian Desert.
- This plain is an **undulating plain (wave-like)** whose average elevation is about 325 m.
- The desert region is called **Marusthali** and forms a greater part of the **Marwar plain**.
- It has a few outcrops of gneisses, schists and granites which proves that geologically it is a part of the Peninsular Plateau. It is only at the surface that it looks like an aggradational plain.
- In general, the eastern part of the Marusthali is rocky while its western part is covered by shifting sand dunes locally known as **dhrian.**
- The eastern part of the Thar Desert up to the Aravalli Range is a semi-arid plain known as **Rajasthan Bagar**.
- It is drained by a number of **short seasonal streams** originating from the Aravallis and supports agriculture in some patches of fertile tracts**.**
- **Luni** is an important seasonal stream which flows into Rann of Kutch. The tract north of the Luni is known as **thali** or **sandy plain.**

Saline Lakes

- North of the Luni, there is inland drainage having several saline lakes. They are a source of common salt and many other salts.
- **Sambhar**, Didwana, Degana, Kuchaman, etc. are some of the important lakes. The largest is the Sambhar lake near Jaipur.

Punjab Plain

- This plain is formed by five important rivers of the Indus system.
- The plain is primarily made up of **'doabs' — the land between two rivers**.
- The depositional process by the rivers has united these doabs giving a homogenous appearance.

- Punjab literally means "(The Land of) Five Waters" referring to the following rivers: the **Jhelum, Chenab, Ravi, Sutlej, and Beas**.
- The average elevation of the plain is about 250 m above mean sea level.
- The eastern boundary of Punjab Haryana plain is marked by subsurface **Delhi-Aravali ridge.**
- The northern part of this plain (Shiwalik hills) has been intensively eroded by numerous streams called **Chos**. This has led to enormous gullying.
- To the south of the Satluj river, there is **Malwa plain** of Punjab.
- The area between the Ghaggar and the Yamuna rivers lies in Haryana and often termed as '**Haryana Tract**'. It acts as water-divide between the Yamuna and the Satluj rivers.

The only river between the Yamuna and the Satluj is the Ghaggar which is considered to be the present day successor of the legendary Saraswati River.

Ganga Plain

- This is the largest unit of the Great Plain of India stretching from Delhi to Kolkata (about 3.75 lakh sq km).
- The Ganga along with its large number of tributaries originating in the Himalayans have brought large quantities of alluvium from the mountains and deposited it here to build this extensive plain.
- The peninsular rivers such as Chambal, Betwa, Ken, Son, etc. joining the Ganga river system have also contributed to the formation of this plain.
- Rivers flow sluggishly in the lower sections of Ganges as a result of which the area is marked by local prominences such as **levees, bluffs, oxbow lakes, marshes, ravines**, etc.
- Almost all the rivers keep on shifting their courses making this area prone to frequent floods.
- The **Kosi river** is very notorious in this respect. It has long been called the **'Sorrow of Bihar'**.

Regional divisions of Ganga plains

- **Rohilkhand plains**
- **Avadh Plains**
- **Mithila Plain**
- **Magadh Plain.**

Ganga-Brahmaputra Delta

- This is the **largest delta** in the world.
- The slope of the land here is a mere 2 cm per km. Two-thirds of the area are below 30 m above mean sea level (Highly vulnerable to sea level changes).
- The seaward face of the delta is studded with a large number of estuaries, mudflats, mangrove swamps, sandbanks, islands and forelands.
- A large part of the coastal delta is covered by **tidal forests**. These are called the **Sundarbans** because of the predominance of Sundari trees here.

Brahmaputra Plain

- This is also known as the Brahmaputra valley or **Assam Valley** or **Assam Plain** as most of the Brahmaputra valley is situated in Assam.
- Its western boundary is formed by the Indo-Bangladesh border as well as the boundary of the lower Ganga Plain. Its eastern boundary is formed by **Purvanchal hills.**
- It is an **aggradational plain** built up by the depositional work of the Brahmaputra and its tributaries.
- The innumerable tributaries of the Brahmaputra river coming from the north form a number of alluvial fans.
- Consequently, the tributaries branch out in many channels giving birth to river meandering leading to the formation of **bill and ox-bow lakes**.
- There are large marshy tracts in this area. The alluvial fans formed by the coarse alluvial debris have led to the formation of terai or semi-terai conditions.

The significance of the Plain

- This one-fourth of the land of the country hosts half of the Indian population.

- Fertile alluvial soils, flat surface, slow-moving perennial rivers and favourable climate facilitate the intense agricultural activity.
- The extensive use of irrigation has made Punjab, Haryana and western part of Uttar Pradesh the granary of India (**Prairies** are called the granaries of the world).
- The entire plain except the Thar Desert has a close network of roads and railways which has led to large scale industrialisation and urbanisation.
- Cultural tourism: There are many religious places along the banks of the sacred rivers like the Ganga and the Yamuna which are very dear to Hindus.
- Here flourished the religions of Buddha and Mahavira and the movements of Bhakti and Sufism.

5. Peninsular Plateau

- Peninsular Plateau is an aggregation of several smaller plateaus and hill ranges.
- The Peninsular Plateau is one of the oldest landforms of the earth.
- It is a highly stable block composed mostly of the **Archaean gneisses and schists**.
- Since a few hundred million years, it has never been submerged beneath the sea except in a few places.
- It covers a total area of about **16 lakh square km**.
- The average height of the plateau is **600-900 m** above sea level (varies from region to region).
- Most of the peninsular rivers flow west to east indicating its general slope.
- **Narmada-Tapti** are the exceptions which flow from east to west in a **rift**.

5.1 Minor Plateaus in the Peninsular Plateau

Marwar Plateau or Mewar Plateau

- It is the plateau of eastern Rajasthan (**Marwar plain** is to the west of Aravallis whereas Marwar plateau is to the east).
- The average elevation is 250-500 m above sea level, and it slopes down eastwards.
- It is made up of sandstone, shales and limestones of the Vindhyan period.
- The **Banas river**, along with its tributaries **(Berach river, Khari rivers)** originate in the Aravalli Range and flow towards northwest into **Chambal river**.
- The erosional activity of these rives makes the plateau top appear like a **rolling plain**.

Rolling Plain: *'Rolling plains' are not completely flat: there are slight rises and fall in the landform. Ex: Prairies of USA*

Central Highland

- Also called the **Madhya Bharat Pathar** or **Madhya Bharat Plateau**.
- It is to the east of the Marwar or Mewar Upland.
- Most of the plateau comprises the basin of the **Chambal river** which flows in a **rift valley.**
- The **Kali Sindh**, flowing from **Rana Pratap Sagar**, The **Banas** flowing through Mewar plateau and The **Parwan** and the **Parbati** flowing from Madhya Pradesh are its main tributaries.
- It is a rolling plateau with rounded hills composed of sandstone. Thick forests grow here.
- To the north are the **ravines or badlands** of the Chambal river (they are typical to Chambal river basin).

Bundelkhand Upland

- Yamuna river to the north, Madhya Bharat Pathar to the west, Vindhyan Scarplands to the east and south-east and Malwa Plateau to the south.
- It is the old dissected (divided by a number of deep valleys) upland of the 'Bundelkhand gneiss' comprising of **granite** and **gneiss**.
- Spreads over five districts of Uttar Pradesh and four districts of Madhya Pradesh.

Minor Plateaus in the Peninsular Plateau

- The average elevation of 300-600 m above sea level, this area slopes down from the Vindhyan Scarp toward the Yamuna River.
- The erosional work of the rivers flowing here have converted it into an undulating (wave-like surface) area and rendered it **unfit for cultivation**.
- The region is characterised by senile (characteristic of or caused by old age) topography.
- Streams like **Betwa, Dhasan** and **Ken** flow through the plateau.

Malwa Plateau

- The Malwa Plateau roughly forms a triangle based on the Vindhyan Hills, bounded by the Aravalli Range in the west and Madhya Bharat Pathar to the north and Bundelkhand to the east.
- This plateau has two systems of drainage; one towards the Arabian sea (The **Narmada**, the **Tapti** and the **Mahi**), and the other towards the Bay of Bengal (**Chambal** and **Betwa**, joining the Yamuna).
- In the north, it is drained by the Chambal and many of its right bank tributaries like the Kali, the Sindh and the Parbati. It also includes the upper courses of the Sindh, the Ken and the Betwa.
- It is composed of extensive **lava flow and is covered with black soils**.
- The general slope is towards the north (decreases from 600 m in the south to less than 500 m in the north).
- This is a rolling plateau dissected by rivers. In the north, the plateau is marked by the **Chambal ravines**.

Baghelkhand

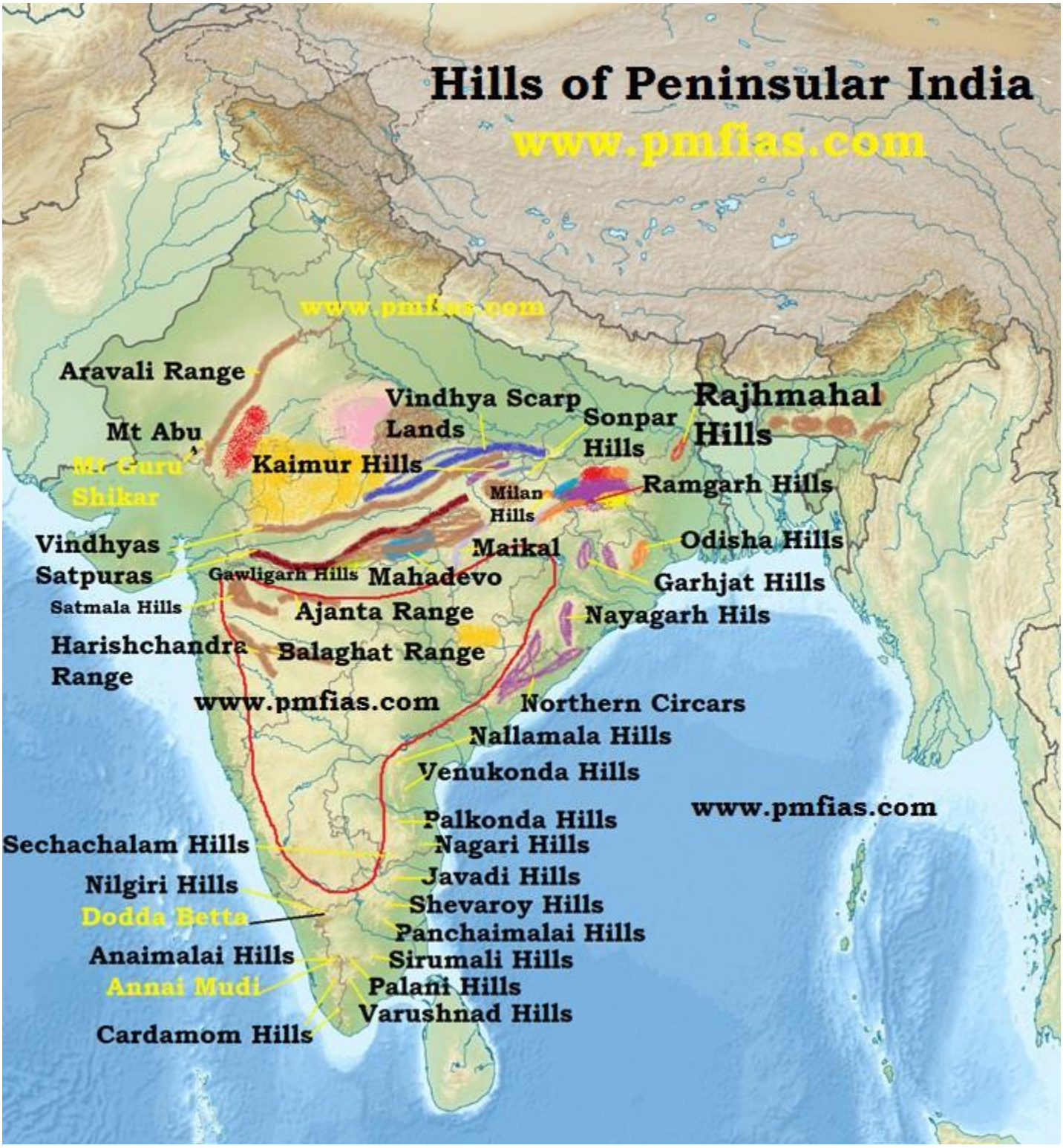
- North of the **Maikal Range** is the Baghelkhand.
- Made of limestones and sandstones on the west and granite in the east.
- It is bounded by the Son river on the north.
- The central part of the plateau acts as a water divide between the **Son** drainage system in the north and the **Mahanadi** river system in the south.
- The region is uneven with general elevation varying from 150 m to 1,200 m.

Chotanagpur Plateau

- Chotanagpur plateau represents the north-eastern projection of the Indian Peninsula.
- Mostly in Jharkhand, the northern part of Chhattisgarh and Purulia district of West Bengal.
- The **Son River** flows in the north-west of the plateau and joins the Ganga.
- The average elevation of the plateau is 700 m above sea level.
- This plateau is composed mainly of **Gondwana rocks.**
- The plateau is drained by numerous rivers and streams in different directions and presents a **radial drainage pattern**.
- Rivers like the **Damodar**, the **Subarnrekaha**, the **North Koel**, the **South Koel** and the **Barkar** have developed extensive drainage basins.
- The **Damodar river** flows through the middle of this region in a **rift valley from west to east**. **Gondwana coal fields** which provide the bulk of coal in India are situated here.
- North of the Damodar river is the **Hazaribagh plateau** with an average elevation of 600 m above mean sea level. This plateau has isolated hills. It looks like a peneplain due to large scale erosion.
- The **Ranchi Plateau** to the south of the Damodar Valley rises to about 600 m above mean sea level. Most of the surface is rolling where the city of Ranchi (661 m) is located.
- At places, it is interrupted by **monadnocks** (an isolated hill or ridge of erosion-resistant rock rising above a peneplain. Ex: Ayers Rock in Australia) and conical hills.
- The **Rajmahal Hills** forming the northeastern edge of the Chotanagpur Plateau are mostly made of basalt and are covered by lava flows.
- They run in a north-south direction and rise to an average elevation of 400 m (highest mount is 567 m).
- These hills have been dissected into separate plateaus.

Meghalaya Plateau

- The peninsular plateau extends further east beyond the Rajmahal hills to from **Meghalaya** or the **Shillong plateau**. The eastward extinction is known as **Karbi Anglong plateau**.
- **Garo-Rajmahal Gap** separates this plateau from the main block.



Major Hill Ranges of the Peninsular Plateau

- This gap was formed by **down-faulting** (normal fault: a block of earth slides downwards).
- It was later filled by sediments deposited by the Ganga and Brahmaputra.
- Its western boundary more or less coincides with the Bangladesh border.
- The western, central and the eastern parts of the plateau are known as the **Garo Hills** (900 m), the **Khasi-Jaintia Hills** (1,500 m) and the **Mikir Hills** (700 m).
- **Shillong (1,961 m) is the highest point of the plateau.**

Deccan Plateau

- It covers an area of about **five lakh square km.**
- It is triangular in shape and is bounded by the **Satpura** and the **Vindhya** in the north-west, the **Mahadev** and the **Maikal** in the north, the **Western Ghats** in the west and the **Eastern Ghats** in the east.
- Its average elevation is 600 m.
- It rises to 1000 m in the south but dips to 500 m in the north.
- Its general slope is from west to east which is indicated by the flow of its major rivers.
- Rivers have further subdivided this plateau into a number of smaller plateaus.

Maharashtra Plateau

- The Maharashtra Plateau lies in Maharashtra.
- It forms the northern part of the Deccan Plateau.
- Much of the region is underlain by **basaltic rocks** of lava origin **(Most of the Deccan Traps lies in this region).**
- The area looks like a rolling plain due to weathering.
- The horizontal lava sheets have led to the formation of typical Deccan Trap topography (step-like).

Step like appearance of Deccan Traps

- The broad and shallow valleys of the Godavari, the Bhima and the Krishna are flanked (bordered on the opposite sides) by flat-topped steep-sided hills and ridges.
- The entire area is covered by black cotton soil known as **regur**.

Karnataka Plateau

- The Karnataka Plateau is also known as the **Mysore plateau**.
- Lies to the south of the Maharashtra plateau.
- The area looks like a rolling plateau with an average elevation of 600-900 m.
- It is highly dissected by numerous rivers rising from the Western Ghats.
- The general trend of the hills is either parallel to the Western Ghats or across it.
- The **highest peak (1913 m) is at Mulangiri in Baba Budan Hills in Chikmagalur district.**
- The plateau is divided into two parts called **Malnad** and **Maidan.**
- The Malnad in Kannada means hill country. It is dissected into deep valleys covered with dense forests.
- The Maidan, on the other hand, is formed of rolling plain with low granite hills.
- The plateau tapers between the Western Ghats and the Eastern Ghats in the south and merges with the **Nilgiri hills** there.

Telangana plateau

- Its average elevation is 500-600 m.
- The southern part is higher than its northern counterpart.
- The region is drained by three river systems, the Godavari, the Krishna and the Penneru.
- The entire plateau is divided into Ghats and the Peneplains (a vast featureless, undulating plain which the last stage of the deposition process).

Chhattisgarh Plain

- The Chhattisgarh **plain** is the only plain worth the name in the Peninsular plateau.
- It is a saucer-shaped depression drained by the **upper Mahanadi**.
- The whole basin lies between the **Maikal Range** and the **Odisha hills**.
- The region was once ruled by **Haithaivanshi Rajputs** from whose thirty-six forts (Chhattisgarh) it derives its name.

- The general elevation of the plain ranges from 250 m in the east to 330 m in the west.

5.2 Hill Ranges of the Peninsular Plateau

- Most of the hills in the peninsular region are of the **relict type (residual hills).**
- They are the remnants of the hills and horsts formed many million years ago (horst: uplifted block; graben: subsided block).
- The plateaus of the Peninsular region are separated from one another by these hill ranges and various river valleys.

Aravalli Range

- They are aligned in north-east to south-west direction.
- They run for about 800 km between **Delhi** and Palanpur in **Gujarat.**
- They are one of the **oldest (very old) fold mountains** of the world and the oldest in India.
- After its formation, its summits were nourishing glaciers, and several summits were probably higher than the present-day Himalayas.
- Now they are relict (remnants after severe weathering and erosion since millions of years) of the world's oldest mountain formed as a result of folding.
- They continue up to **Haridwar** buried under the alluvium of Ganga Plains.
- The range is conspicuous in Rajasthan (continuous range south of Ajmer where it rises to 900 m.) but becomes less distinct in Haryana and Delhi (characterised by a chain of detached and discontinuous ridges beyond Ajmer).
- According to some geographers, one Branch of the Aravallis extends to the Lakshadweep Archipelago through the Gulf of Khambhat and the other into Andhra Pradesh and Karnataka.
- Its general elevation is only 400-600 m, with few hills well above 1,000 m.
- At the south-west extremity, the range rises to over 1,000 m. Here **Mt. Abu (1,158 m)**, a small hilly block, is separated from the main range by the **valley of the Banas**.
- **Guru Shikhar (1,722 m)**, the highest peak, is situated in Mt. Abu.
- **Pipli Ghat**, Dewair and Desuri passes allow movement by roads and railways.

Vindhyan Range

- The Vindhyan Range, overlooking (have a view of from above) the Narmada valley, rises as an escarpment (a long, steep slope at the edge of a plateau or separating areas of land at different heights) flanking (neighbouring on one side) the northern edge of the Narmada-Son Trough (the rift through which the Narmada river flows)(trough is opposite of ridge. It is a narrow depression).
- It runs more or less parallel to the **Narmada Valley** in an east-west direction from Jobat in Gujarat to Sasaram in Bihar for a distance of over 1,200 km.
- The general elevation of the Vindhyan Range is 300 to 650 m.
- Most parts of the Vindhyan Range are composed of horizontally bedded sedimentary rocks of ancient age.
- The Vindhyas are continued eastwards as the **Barner** and **Kaimur hills**.
- This range acts as a watershed between the Ganga system and the river systems of south India.
- The rivers **Chambal, Betwa** and **Ken,** rise within 30 km of the Narmada.

Satpura Range

- Satpura range is a series of seven mountains ('Sat' = seven and 'pura' = mountains)
- It runs in an east-west direction south of the Vindhyas and in between the Narmada and the Tapti, roughly parallel to these rivers.
- It stretches for a distance of about 900 km.
- Parts of the Satpuras have been folded and upheaved. They are regarded as structural uplift or **'horst'**.
- **Dhupgarh (1,350 m)** near **Pachmarhi on Mahadev Hills** is the highest peak.

- **Amarkantak (1,127 m) is another important peak.**

Western Ghats (or The Sahyadris)

- They form the western edge of the Deccan tableland.
- Run from the Tapti valley (21° N latitude) to a little north of Kanniyakumari (11° N latitude) for a distance of 1,600 km.
- The Western Ghats are steep-sided, terraced, flat-topped hills presenting a stepped topography facing the Arabian Sea coast.
- This is due to the horizontally bedded lavas, which on weathering, have given a characteristic **'landing stair aspect'** to the relief of this mountain chain.
- The Western Ghats abruptly rise as a sheer wall to an average elevation of 1,000 m from the Western Coastal Plain.
- But they slope gently on their eastern flank and hardly appear to be a mountainn when viewed from the Deccan tableland.
- South of Malabar, the Nilgiris, Annamalai, etc. present quite different landscape due to the difference in geological structure.

The northern section

- The northern section of the Ghats from Tapti valley to a little north of Goa is made of horizontal sheets of **Deccan lavas (Deccan Traps)**.
- The average height of this section of the Ghats is 1,200 m above mean sea level, but some peaks attain more heights.
- **Kalasubai (1,646 m)** near **Igatpuri, Salher (1,567 m)** about 90 km north of Nashik**, Mahabaleshwar (1,438 m)** and **Harishchandragarh (1,424 m)** are important peaks.
- **Thal ghat** and **Bhor ghat** are important passes which provide passage by road and rail between the **Konkan Plains** in the west and the Deccan Plateau in the east.

Konkan coast == Maharashtra coast and Goa coast
Malabar Coast == Kerala and Karnataka coast

The Middle Sahyadri

- The Middle Sahyadri runs from 16°N latitude up to Nilgiri hills.
- This area is covered with **dense forests**.
- The western scarp is considerably dissected by headward erosion of the west flowing streams.
- The average height is 1200 m, but many peaks exceed 1500 m.
- The **Vavul Mala (2,339 m)**, the **Kudremukh (1,892 m)** and **Pushpagiri (1,714 m)** are important peaks.
- The Nilgiri Hills which join the Sahyadris near the tri-junction of Karnataka, Kerala and TN, rise abruptly to over 2,000 m.
- They **mark the junction of the Western Ghats with the Eastern Ghats**.
- **Doda Betta (2,637 m) and Makurti (2,554 m)** are important peaks of this area.

The southern section

- The southern part of the Western Ghats is separated from the main Sahyadri range by **Pal ghat Gap** (**Palakkad Gap**).
- The high ranges terminate abruptly on either side of this gap.
- **Pal ghat Gap** it is a **rift valley**. This gap is used by a number of roads and railway lines to connect the plains of Tamil Nadu with the coastal plain of Kerala.
- It is through this gap that moist-bearing clouds of the south-west monsoon can penetrate some distance inland, bringing rain to the Mysore region.
- South of the Pal ghat Gap there is an intricate system of steep and rugged slopes on both the eastern and western sides of the Ghats.
- **Anai Mudi (2,695 m)** is the highest peak in the whole of southern India.
- Three ranges radiate in different directions from Anai Mudi. These ranges are the **Anaimalai (1800-2000 m)** to the north, the **Palani (900-1,200 m)** to the north-east and the **Cardamom Hills** or the **Ealaimalai** to the south.

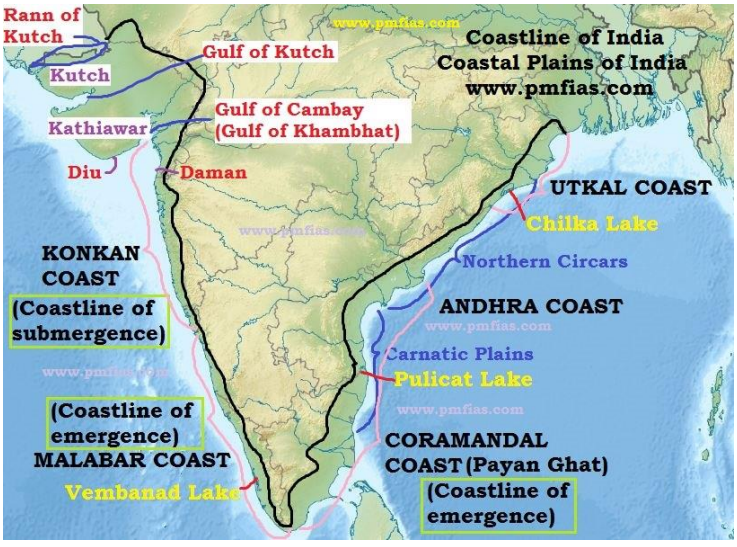
Eastern Ghats

- The Eastern Ghats run almost parallel to the east coast of India leaving **broad plains** between their base and the coast.
- It is a **chain of highly broken and detached hills** starting from the **Mahanadi** in Odisha to the **Vagai** in Tamil Nadu. They almost disappear between the Godavari and the Krishna.
- They neither have structural unity nor physiographic continuity. Therefore, these hill groups are generally treated as independent units.
- It is only in the northern part, between the Mahanadi and the Godavari that the Eastern Ghats exhibit true mountain character. This part comprises the **Maliya** and the **Madugula Konda** ranges.
- The peaks and ridges of the Maliya range have a general elevation of 900-1,200 m, and **Mahendra Giri (1,501 m)** is the tallest peak here.
- The Madugula Konda range has higher elevations ranging from 1,100 m and 1,400 m with several peaks exceeding 1,600 m**. Jindhagada Peak (1690 m)** in Araku Valley **Arma Konda (1,680 m), Gali Konda (1,643 m) and Sinkram Gutta (1,620 m)** are important peaks.
- Between the Godavari and the Krishna rivers, the Eastern Ghats lose their hilly character and are occupied by **Gondwana formations** (**KG Basin is here**).
- The Eastern Ghats reappear as more or less a continuous hill range in Cuddapah and Kurnool districts of Andhra Pradesh where they are called as **Nallamalai Range** (Naxalite hideout in AP) with a general elevation of 600-850 m.
- The southern part of this range is called the **Palkodna range**.
- To the south, the hills and plateaus attain very low altitudes; only **Javadi Hills** and the **Shevroy-Kalrayan Hills** form two distinct features of 1,000 m elevation.
- The **Biligiri Rangan Hills** in Coimbatore district attain a height of 1,279 m.
- Further south, the Eastern Ghats merge with the Western Ghats.

The significance of the Peninsular Plateau

- Primary Mineral Base of India: There are huge deposits of iron, manganese, copper, bauxite, chromium, mica, gold, etc.
- **98 per cent of the Gondwana coal deposits of India** are found in the Peninsular Plateau.
- Besides, there are large reserves of **slate, shale, sandstones, marbles,** etc.
- A large part of the north-west plateau is covered with fertile black lava soil which is extremely useful for growing cotton.
- Some hilly regions in south India are suitable for the cultivation of plantation crops like **tea, coffee, rubber, etc**.
- Some low lying areas of the plateau are suitable for growing rice.
- The highlands of the plateau are covered with different types of forests which provide a large variety of forest products.
- The rivers originating in the Western Ghats offer a great opportunity for developing hydroelectricity and providing irrigation facilities to the agricultural crops.
- The plateau is also known for its hill resorts such as **Udagamangalam (Ooty), Panchmarhi, Kodaikanal, Mahabaleshwar, Khandala, Matheron, Mount Abu,** etc.

6. Coastline of India



Coastline of India

- India has a coastline of **7516.6 Km (6100 km of mainland coastline + coastline of 1197 In-**

dian islands) touching 13 States and Union Territories (UTs).
- The straight and regular coastline of India is the result of faulting of the Gondwanaland during the Cretaceous period.
- As such the coast of India **does not offer many sites for good natural harbours.**

Indented coastlines of Europe provide good natural harbours whereas African and Indian coastlines are not indented.

- The Bay of Bengal and the Arabian Sea came into being during the **Cretaceous or early Tertiary period after the disintegration of Gondwanaland.**

6.1 East Coast of India

- Lies between the Eastern Ghats and the Bay of Bengal.
- It extends from the Ganga delta to Kanyakumari.
- It is marked by deltas of rivers like the Mahanadi, the Godavari, the Krishna and the Cauvery.
- **Chilka lake** and the **Pulicat lake (lagoon)** are the important geographical features of the east coast.

Regional Names of The East Coast of India

- In Orissa (Odisha) it is known as **Utkal coast**.
- From the southern limit of the Utkal plain, stretch the **Andhra coast**.
- In the south of the Andhra plain is the **Tamil Nadu coast.**
- The Tamil Nadu coast and parts of Andhra coast together are known as **Coramandal Coast** or **Payan Ghat**.

6.2 West Coast of India

- The west coast strip extends from the **Gulf of Cambay (Gulf of Khambhat)** in the north to **Cape Comorin** (Kanyakumari).
- Starting from north to south, it is divided into (i) the **Konkan coast**, (ii) the **Karnataka coast** and (iii) the **Kerala coast**.
- It is made up of alluvium brought down by the **short streams** originating from the Western Ghats.
- It is dotted with a large number of **coves (a very small bay), creeks** (a narrow, sheltered waterway such as an inlet in a shoreline or channel in a marsh) **and a few estuaries**.
- The **estuaries, of the Narmada and the Tapti,** are the major ones.
- The Kerala coast (**Malabar Coast**) has some **lakes, lagoons and backwaters**, the largest being the **Vembanad Lake**.

Regional Names of The West Coast of India

- **Konkan coast ➔ Maharashtra coast and Goa coast.**
- **Malabar Coast ➔ Kerala and Karnataka coast.**

6.3 Coastlines of Emergence and Submergence

- Coastline of emergence is formed either by an uplift of the land or by the lowering of the sea level.
- The coastline of submergence is an exact opposite case.
- **Bars, spits, lagoons, salt marshes, beaches, sea cliffs and arches** are the typical features of emergence.
- The east coast of India, especially its south-eastern part (Tamil Nadu coast), appears to be a coast of emergence.
- The west coast of India, on the other hand, is both emergent and submergent.
- The northern portion of the coast is submerged as a result of faulting and the southern portion, that is the Kerala coast, is an example of an emergent coast.

Coromandel coast (Tamil Nadu) ➔ Coastline of emergence
Malabar coast (Kerala Coast) ➔ Coastline of emergence
Konkan coast (Maharashtra and Goa Coast) ➔ Coastline of submergence

6.4 Western Coastal Plains of India

- Rann of Kachchh in the north to Kanyakumari in the South.
- These are **narrow plains** with an average width of about **65 km.**

Kutch and Kathiawar region

- Kutch and Kathiawar, though an extension of Peninsular plateau (because Kathiawar is made of the Deccan Lava and there are tertiary rocks in the Kutch area), they are still treated as an integral part of the Western Coastal Plains as they are now levelled down.
- The Kutch Peninsula was an island surrounded by seas and lagoons. These seas and lagoons were later filled by sediment brought by the Indus River which used to flow through this area. Lack of rains in recent times has turned it into an arid and semi-arid landscape.
- Salt-soaked plain to the north of Kutch is the **Great Rann**. Its southern continuation, known as the **Little Rann** lies on the coast and south-east of Kachchh.
- The Kathiawar Peninsula lies to the south of the Kachchh. The central part is a highland of **Mandav Hills** from which small streams radiate in all directions (**Radial Drainage**). **Mt. Girnar (1,117 m)** is the highest point and is of volcanic origin.
- The **Gir Range** is located in the southern part of the Kathiawar peninsula. It is covered with dense forests and is famous as the home of the **Gir lion.**

Gujarat Plain

- The Gujarat Plain lies east of Kachchh and Kathiawar and slopes towards the west and south-west.
- Formed by the rivers **Narmada, Tapti, Mahi** and **Sabarmati**, the plain includes the southern part of Gujarat and the coastal areas of the Gulf of Khambhat.
- The eastern part of this plain is fertile enough to support agriculture, but the greater part near the coast is covered by windblown loess (heaps of sand).

Konkan Plain

- The Konkan Plain south of the Gujarat plain extends from Daman to Goa (50 to 80 km wide).
- It has some features of marine erosion including cliffs, shoals, reefs and islands in the Arabian Sea.
- The **Thane creek** around Mumbai is an important embayment (a recess in a coastline forming a bay) which provides an **excellent natural harbour**.

Karnataka Coastal Plain

- Goa to Mangalore.
- It is a **narrow plain** with an average width of 30-50 km, the maximum being 70 km near Mangalore.
- At some places, the streams originating in the Western Ghats descend along steep slopes and make waterfalls.
- The **Sharavati** while descending over such a steep slope makes an impressive waterfall known as **Gersoppa (Jog) Falls** which is **271 m high.** (**Angel falls** (979 m) in Venezuela is the highest waterfall on earth. **Tugela Falls** (948 m) in Drakensberg mountains in South Africa is the second highest.)
- Marine topography is quite marked on the coast.

Kerala Plain

- The Kerala Plain is also known as the **Malabar Plain**.
- Between Mangalore and Kanyakumari.
- This is much **wider** than the Karnataka plain. It is a low lying plain.
- The existence of lakes, lagoons, backwaters, spits, etc. is a significant characteristic of the Kerala coast.
- The backwaters, locally known as **kayals** are the shallow **lagoons or inlets** of the sea, lying parallel to the coastline.

- The largest among these is the **Vembanad Lake** which is about 75 km long and 5-10 km wide and gives rise to a 55 km long spit (Marine Landforms).

6.5 Eastern Coastal Plains of India

- Extending from the **Subarnarekha** river along the West Bengal-Odisha border to Kanyakumari.
- A major part of the plains is formed as a result of the alluvial fillings of the littoral zone (relating to or on the shore of the sea or a lake) by the rivers Mahanadi, Godavari, Krishna and Cauvery comprising some of the largest deltas.
- In contrast to the West Coastal Plains, these are **extensive plains** with an average width of 120 km.
- This plain is known as the **Northern Circars** between the Mahanadi and the Krishna rivers and **Carnatic** between the Krishna and the Cauvery rivers.

Utkal Plain

- The Utkal Plain comprises coastal areas of Odisha.
- It includes the Mahanadi delta.
- The most prominent physiographic feature of this plain is the **Chilka Lake.**
- It is the **biggest lake and biggest brackish (salt) water (lagoon) lake** in the country and its area varies between 780 sq km in winter to 1,144 sq km in the monsoon months. Its length is around 64 km.
- South of Chilka Lake, low hills dot the plain.

- **Vembanad Lake (Kerala)** is the **longest lake in India** with a length of 96 km.
- **Wular Lake** (Jammu and Kashmir), is the **largest freshwater lake of India** (260 sq km).
- **Gobind Ballabh Pant Sagar (Rihand Dam)** (UP), is the largest human-made lake of India by volume.
- **Shivaji Sagar Lake of Koyna Dam** is the largest human-made lake of India by surface area.
- **Rajasthan's Sambhar Lake** is the largest inland saltwater lake of India (200 sq km).

- **Tso Lhamo Lake** (Sikkim) is India's highest lake (5,330 m) in India.

Andhra Plain

- South of the Utkal Plain and extends up to **Pulicat Lake.** This lake has been barred by a long sand spit known as **Sriharikota Island** (ISRO launch facility).
- The most significant feature of this plain is the delta formation by the rivers Godavari and Krishna.
- The two deltas have merged and formed a single physiographic unit.
- The combined delta has advanced by about 35 km towards the sea during recent years. This is clear from the present location of the **Kolleru Lake which was once a lagoon** at the shore but now lies far inland (Coastline of Emergence).
- This part of the plain has a straight coast and badly lacks good harbours with the exception of **Vishakhapatnam** and **Machilipatnam.**

Tamil Nadu Plain

- The Tamil Nadu Plain stretches for 675 km from Pulicat lake to Kanyakumari along the coast of Tamil Nadu. Its average width is 100 km.
- The most important feature of this plain is the Cauvery delta where the plain is 130 km wide.
- The fertile soil and large scale irrigation facilities have made the Cauvery delta the granary of South India.

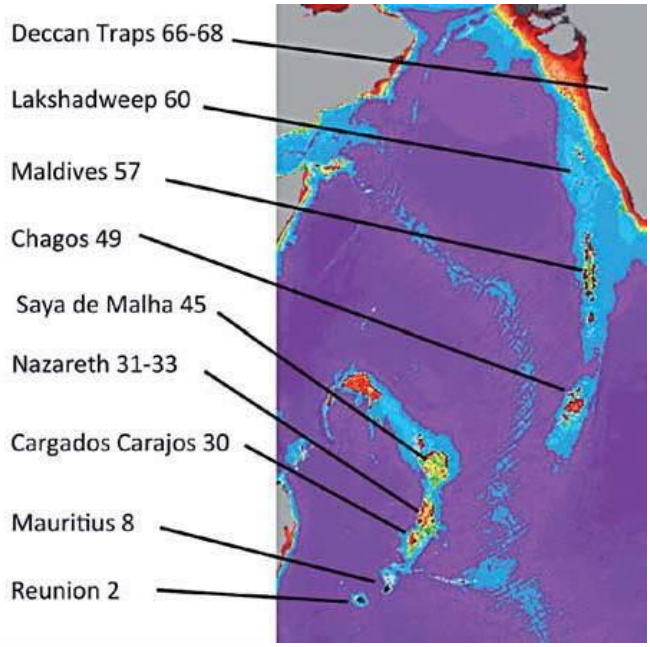
6.6 The significance of the Coastal Plains

- Large parts of the coastal plains of India are covered by fertile soils on which different crops are grown. Rice is the main crop of these areas.
- Coconut trees grow all along the coast.
- The entire length of the coast is dotted with big and small ports which help in carrying out the trade.
- The sedimentary rocks of these plains are said to contain large deposits of mineral oil (KG Basin).

- The sands of Kerala coast have a large quantity of **monazite** which is used for **nuclear power.**
- Fishing is an important occupation of the people living in coastal areas.
- Low lying areas of Gujarat are famous for producing salt.
- Kerala backwaters are important tourist destinations.
- Goa provides good beaches. This is also an important tourist destination.

7. Indian Islands

- The major island groups of India are Andaman and Nicobar Archipelago (a chain of islands similar in origin) in Bay of Bengal and Lakshadweep islands in the Arabian Sea.
- Andaman and Nicobar Islands were formed due to the **collision between Indian Plate and Burma Minor Plate (part of Eurasian Plate) (Similar to the formation of Himalayas).**
- Andaman and Nicobar Islands are the southward extension of **Arakan Yoma range (Myanmar) (Arakan Yoma in itself is an extension of Purvanchal Hills**).
- Lakshadweep Islands are **coral islands**. These islands are a part **Reunion Hotspot volcanic chain.**



Reunion Hotspot volcanic chain

- Other than these two groups there are islands in Indo-Gangetic Delta (they are more a part of the delta than islands) and between India and Sri Lanka (Remnants of Rama Setu or Adams Bridge; formed due to submergence).

Rama Setu or Adams Bridge

7.1 Andaman and Nicobar Islands

- This archipelago is composed of 265 big and small islands (203 Andaman islands + 62 Nicobar Islands).
- The Andaman and Nicobar Islands extend from 6° 45' N to 13° 45' N and from 92° 10' E to 94° 15' E for a distance of about 590 km.
- The Andaman Islands are divided into three main islands, i.e. **North, Middle** and **South.**
- **Duncan passage** separates Little Andaman from South Andaman.
- The Great Andaman group of islands in the north is separated by the **Ten Degree Channel** from the Nicobar group in the south (Prelims 2014).
- **Port Blair**, the capital of Andaman Nicobar Islands, lies in the **South Andaman**.
- Among the Nicobar Islands, the **Great Nicobar** is the largest.
- It is the southernmost island and is very close to Sumatra island of Indonesia.
- The **Car Nicobar** is the northernmost island.
- Most of these islands are made of tertiary sandstone, limestone and shale resting on basic and ultrabasic volcanoes (Similar to the Himalayas).

- **The Barren Island (the only active volcano in India) and Narcondam Islands (an extinct or dormant volcano)**, north of Port Blair, are **volcanic islands**.
- Some of the islands are fringed with **coral reefs**. Many of them are covered with thick forests. Most of the islands are mountainous.
- **Saddle peak (737 m)** in **North Andaman** is the highest peak.

Andaman and Nicobar Islands

7.2 Lakshadweep Islands

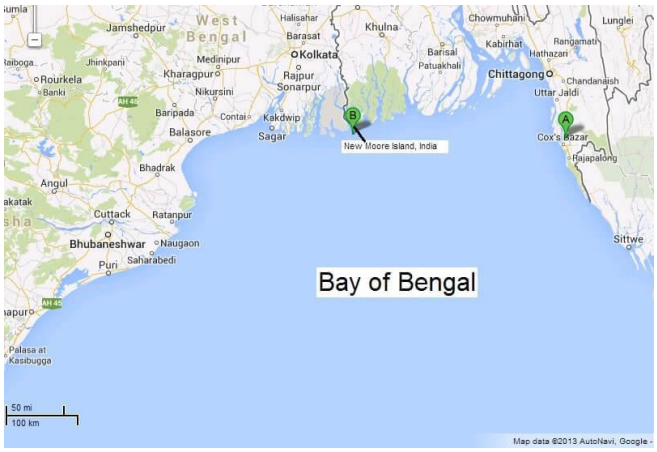
- In the Arabian Sea, there are three types of islands.
  (1) **Amindivi Islands**
  (2) **Laccadive Islands** (consisting of five major islands including **Kavaratti**) and
  (3) **Minicoy**.
- At present these islands are collectively known as Lakshadweep.
- The Lakshadweep Islands are a group of 25 small islands.
- They are widely scattered about 200-500 km south-west of the Kerala coast.
- **Amindivi Islands** are the northernmost while the **Minicoy island is the southernmost**.
- All are tiny islands of coral origin (coral depositions on atolls) and are surrounded by **fringing reefs**.
- **Androtт** (4.9 sq km) is the largest Island. **Minicoy** (4.5 sq km) is the second largest.
- Most of the islands have low elevation and do not rise more than five meters above sea level (extremely vulnerable to sea level change).
- Their topography is flat and relief features such as hills, streams, valleys, etc. are **absent.**

Lakshadweep Islands

7.3 New Moore Island

- It is a small uninhabited offshore sandbar landform in the Bay of Bengal, off the coast of the Ganges-Brahmaputra Delta region.
- It emerged in the Bay of Bengal in the aftermath of the **Bhola cyclone in 1970**. It keeps on emerging and disappearing.
- Although the island was uninhabited and there were no permanent settlements or stations located on it, both **India and Bangladesh claimed sovereignty over it because of speculation over the existence of oil and natural gas in the region**.

- The issue of sovereignty was also a part of the larger dispute over the **Radcliffe Award** methodology of settling the maritime boundary between the two nations.



New Moore Island

8. Drainage Systems of India

The contribution of Water by Various Rivers

River	% Contribution of water
Brahmaputra	**~ 40**
Ganga	**~ 25**
Godavari	**~ 6.4**
Mahanadi	**~ 3.5**
Krishna	**~ 3.4**
Narmada	~ 2.9
Rest	~ 20

Drainage Systems Based on the Size of the Catchment Area

Division	Size of catchment area in sq km
Major river	20,000
Medium river	20,000 – 2,000
Minor river	2,000 and below

Length of some important Indian Rivers

Sl. No.	River	Length (km)
1.	**Brahmaputra (916 km in India)**	**2,900 (Longest river of India)**
2.	**Indus (1114 km in India)**	**2,880 (2nd Longest river of India)**
3.	**Ganga**	**2,525 (Longest river in India – river length within Indian boundaries)** (Length measured along the Bhagirathi and the Hooghly – this entire course lies within India)
4.	**Godavari**	**1,465 (2nd Longest river in India)**
5.	Krishna	1,400
6.	Narmada	1,312
7.	Yamuna	1211
8.	Mahanadi	851
9.	Kaveri	800
10.	Tapi (Tapti)	724

Government websites are showing different data.
I am going with http://www.india-wris.nrsc.gov.in/wrpinfo/index.php?title=Basins

Drainage Systems Based on Origin

- The Himalayan Rivers: **Perennial rivers**: Indus, the Ganga, the Brahmaputra and their tributaries.
- The Peninsular Rivers: **Non-Perennial rivers**: Mahanadi, the Godavari, the Krishna, the Cauvery, the Narmada and the Tapti and their tributaries.

Drainage Systems Based on the Type of Drainage

- Himalayan rivers, Deccan rivers and Coastal rivers that drain into the sea.
- Rivers of the inland drainage basin (**endorheic basin**). Streams like the **Sambhar in western Rajasthan** are mainly seasonal in character, draining into the inland basins and salt lakes. In the Rann of Kutch, the only river that flows through the salt desert is the **Luni**.

8.2 Drainage Systems Based on Orientation to the sea

- The Bay of Bengal drainage (Rivers that drain into the Bay of Bengal) (East flowing rivers)
- The Arabian sea drainage (Rivers that drain into the Arabian sea) (West flowing rivers).

The Bay of Bengal drainage	The Arabian Sea drainage
Rivers that drain into the Bay of Bengal	Rivers that drain into the Arabian sea
East flowing rivers	West flowing rivers
~ 77 per cent of the drainage area of the country is oriented towards the Bay of Bengal	~ 23 per cent of the drainage area of the country is oriented towards the Arabian sea
The Ganga, the Brahmaputra, the Mahanadi, the Godavari, the Krishna, the Cauvery, the Penneru, the Penneiyar, the Vaigai, etc.	The Indus, the Narmada, the Tapti, the Sabarmati, the Mahi and the large number of swift flowing western coast rivers descending from the Sahyadris.

- The area covered by The Bay of Bengal drainage and Arabian Sea drainage are not proportional to the amount of water that drains through them.
- **Over 90 per cent of the water drains into the Bay of Bengal; the rest is drained into the Arabian Sea or forms inland drainage.**

Factors responsible for the Lopsided distribution

(Why the Bay of Bengal receives more fresh water compared to the Arabian Sea?)

- The Arabian Sea drainage or Western drainage receive less rainfall (Rajasthan, Haryana and Punjab receive very low rainfall).
- The Eastern drainage or the Bay of Bengal drainage receives rainfall both from South-west and North-east monsoons.
- Most of the Himalayan waters (perennial rivers) flow into eastern drainage (Ganges and Brahmaputra).
- Indian Rivers that flow into the Arabian Sea are seasonal or non-perennial (Luni, Narmada, etc.).
- The occurrence of more cyclonic rainfall in the eastern parts is another major reason.

8.3 Major River System or Drainage Systems in India

- The rivers Narmada and Tapti flow almost parallel to each other but empty themselves in opposite directions (West flowing).
- The two rivers make the valley rich in alluvial soil, and **teak forests** cover much of the land.

Himalayan Rivers

1. Indus River System
2. Brahmaputra River System
3. Ganga River System

- The major Himalayan Rivers existed even before the formation of Himalayas, i.e. before the **collision of Indian Plate with the Eurasian plate**. (**Antecedent Drainage**)
- They were flowing into the **Tethys Sea.** These rivers had their source in the now **Tibetan region.**
- The **deep gorges of the Indus, the Sutlej, the Brahmaputra** etc. indicate that these rivers are **older than the Himalayas**.
- They continued to flow throughout the building phase of the Himalayas; their banks were rising steeply while the beds went lower and lower due to vertical erosion (Vertical downcutting was significant and was occurring at a rate faster than the rising of Himalayas), thus cutting deep gorges.
- Thus, many of the Himalayan Rivers are typical examples of **antecedent drainage**.

Peninsular River Systems

- Godavari River System
- Krishna River System
- Cauvery River System

- Mahanadi River System

West Flowing Peninsular River Systems

- Narmada River System
- Tapti River System
- Rivers flowing down the Western Ghats into the Arabian Sea

8.4 Indus River System

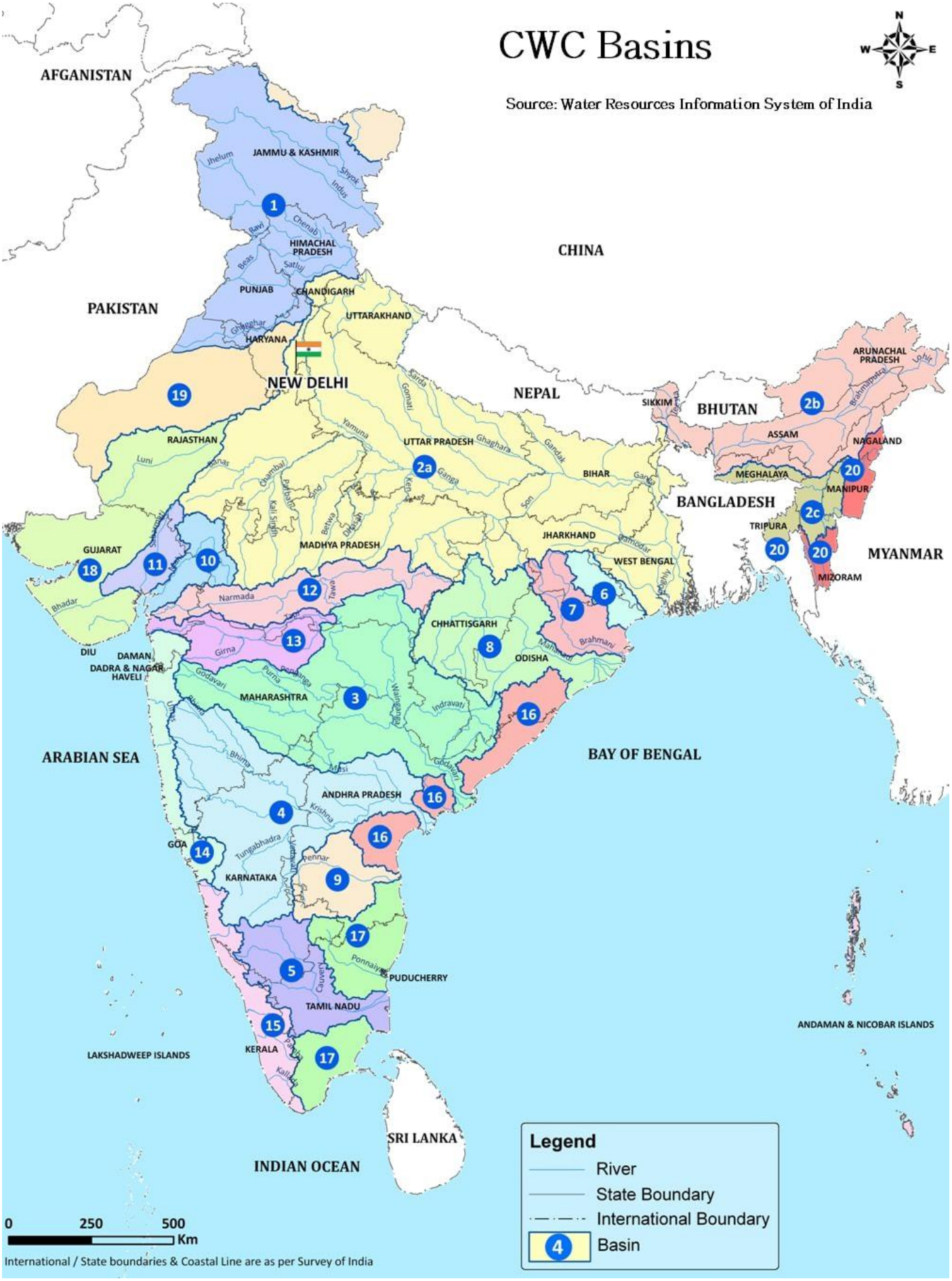
- Indus is called as **Sindhu** in Sanskrit.

Major Rivers	Source	Length
Indus	• **Kailas Range (Close to Manasarovar Lake)**	• **1114 km in India (2880 km total)**
Jhelum	• **Verinag**	• **720 km**
Chenab	• **Bara Lacha Pass**	• **1180 km**
Ravi	• **Near Rohtang Pass**	• **725 km**
Beas	• **Near Rohtang Pass**	• **460 km**
Sutlej	• **Manasarovar-Rakas Lakes**	• **1050 km in India (1450 km total)**

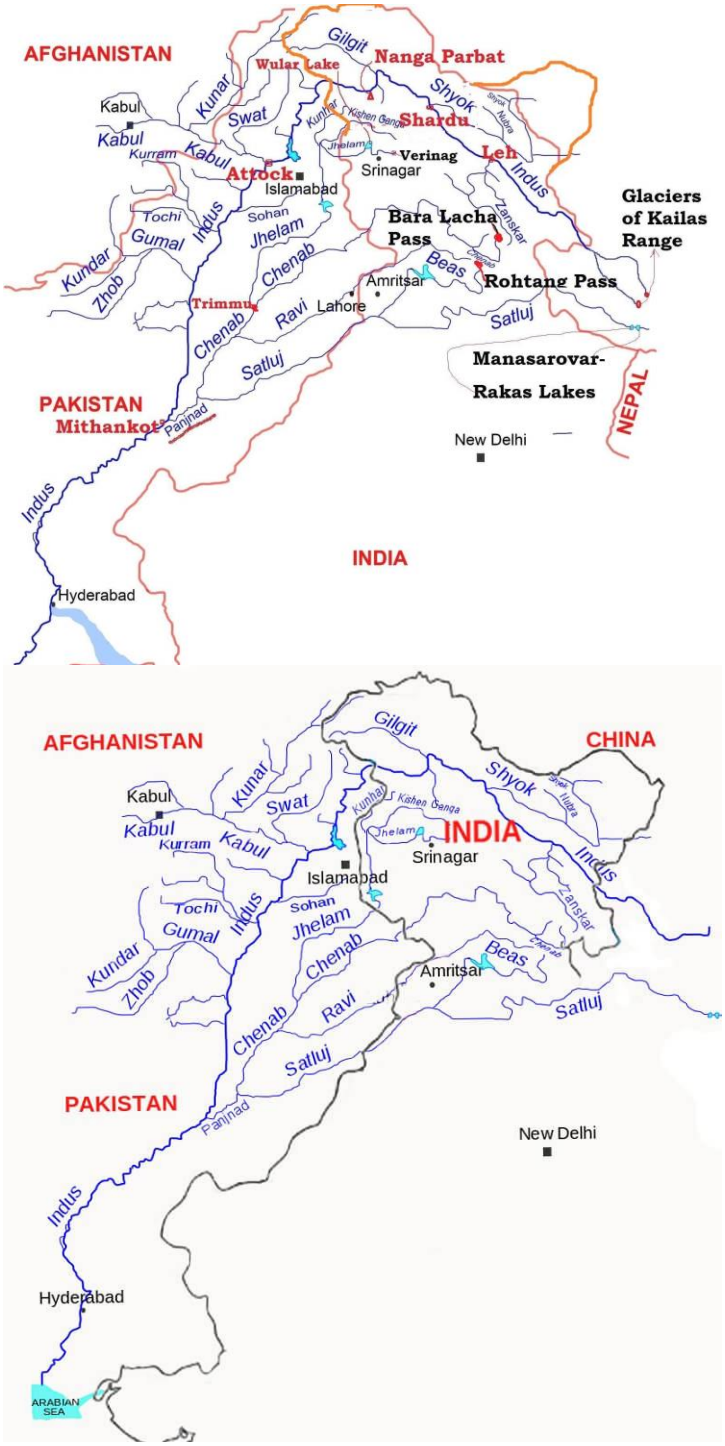
Descending order according to length: Indus – Sutlej – Chenab – Ravi – Jhelum – Beas.
Left to Right: Indus – Jhelum – Chenab – Ravi – Beas – Sutlej.

- The entire country has been divided into 22 basins as per the Central Water Commission.
- The names of the basins along with their id and area are given in the table.

Sl. No	Basin Code	Basin Name	Area (sq.km)	Rank
1	**1**	**Indus (Up to border)**	**3,21,289**	**3**
2	**2A**	**Ganga**	**8,61,452**	**1**
3	**2B**	**Brahmaputra**	**1,94,413**	**6**
4	2C	Barak and others	41,723	
5	**3**	**Godavari**	**3,12,812**	**4**
6	**4**	**Krishna**	**2,58,948**	**5**
7	5	Cauvery	81,155	11
8	6	Subernarekha	29,196	
9	7	Brahmani and Baitarni	51,822	
10	8	Mahanadi	1,41,589	7
11	9	Pennar	55,213	
12	10	Mahi	34,842	
13	11	Sabarmati	21,674	
14	12	Narmada	98,796	9
15	13	Tapi (Tapti)	65,145	12
16	14	West flowing rivers from Tapi to Tadri	55,940	
17	15	West flowing rivers from Tadri to Kanyakumari	56,177	
18	16	East flowing rivers between Mahanadi and Pennar	86,643	10
19	17	East flowing rivers between Pennar and Kanyakumari	1,00,139	8
20	18	West flowing rivers of Kutch and Saurashtra including Luni	3,21,851	2
21	19	Area of inland drainage in Rajasthan		
22	20	Minor rivers draining into Myanmar & Bangladesh	36,202	


CWC Basins
Source: Water Resources Information System of India
N
W
E
S
AFGANISTAN
PAKISTAN
CHINA
NEPAL
BHUTAN
BANGLADESH
MYANMAR
SRI LANKA
INDIAN OCEAN
ARABIAN SEA
BAY OF BENGAL
JAMMU & KASHMIR
HIMACHAL PRADESH
PUNJAB
CHANDIGARH
UTTARAKHAND
HARYANA
NEW DELHI
RAJASTHAN
UTTAR PRADESH
BIHAR
SIKKIM
ARUNACHAL PRADESH
ASSAM
NAGALAND
MEGHALAYA
MANIPUR
TRIPURA
MIZORAM
JHARKHAND
WEST BENGAL
ODISHA
CHHATTISGARH
MADHYA PRADESH
GUJARAT
DIU
DAMAN
DADRA & NAGAR HAVELI
MAHARASHTRA
GOA
KARNATAKA
ANDHRA PRADESH
TAMIL NADU
PUDUCHERRY
KERALA
LAKSHADWEEP ISLANDS
ANDAMAN & NICOBAR ISLANDS
Jhelum
Shyok
Indus
Ravi
Chenab
Beas
Satluj
Ghaggar
Yamuna
Sarda
Gomati
Ghaghara
Gandak
Ganga
Son
Damodar
Brahmaputra
Luni
Banas
Chambal
Parbathi
Kali Sindh
Betwa
Ken
Tapi
Narmada
Mahanadi
Brahmani
Godavari
Purna
Penganga
Wainganga
Indravati
Girna
Bhadar
Bhima
Krishna
Tungabhadra
Vaigai
Pennar
Ponnaiyar
Cauvery
Kalinadi
0
250
500
Km
International / State boundaries & Coastal Line are as per Survey of India
Legend
River
State Boundary
International Boundary
Basin

Major Rivers and Lakes of India



Indus River System

Indus River

- India got her name from Indus.
- It flows in the north-west direction from its source **(Glaciers of Kailas Range –** Kailash range in Tibet near Lake Manasarovar**)** till the **Nanga Parbat** Range.
- Its total drainage area is about 1,165,000 square km (more than half of it lies in semiarid plains of Pakistan).
- Dhar River joins it near Indo-China border.
- After entering J&K, it flows **between** the **Ladakh** and the **Zaskar Ranges**.
- It flows through the regions of Ladakh, Baltistan and Gilgit.
- The **gradient of the river in J&K is very gentle** (about 30 cm per km).
- Average elevation at which the Indus flows through JK is about **4000 m** above sea level.
- It is joined by the **Zaskar River at Leh** (these kind of points are important for prelims).
- Near **Skardu**, it is joined by the **Shyok** at an elevation of about 2,700 m.
- The **Gilgit, Gartang, Dras, Shiger, Hunza** are the other Himalayan tributaries of the Indus.
- It crosses the Himalayas (ends its mountainous journey) through a 5181 m deep gorge, lying north of the **Nanga Parbat.** It takes a sharp southerly bend here **(syntaxial bend).**
- **Kabul river** from Afghanistan joins Indus near **Attock.** Thereafter it flows through the **Potwar plateau** and crosses the **Salt Range** (South Eastern edge of Potwar Plateau).
- Some of the important tributaries below Attock include the **Kurram, Toch** and the **Zhob-Gomal.**
- Just above **Mithankot**, the Indus receives from **Panjnad (Panchnad)**, the accumulated waters of the five eastern tributaries—the **Jhelum, the Chenab, the Ravi, the Beas and the Sutlej.**
- The river empties into the Arabian Sea south of **Karachi** after forming a huge delta.

Jhelum River

- The Jhelum has its source in a **spring at Verinag** in the south-eastern part of the **Kashmir Valley.**
- It flows northwards into **Wular Lake** (north-western part of Kashmir Valley).
- From Wular Lake, it changes its course southwards. At **Baramulla,** the river enters a gorge in the hills.

- The river forms steep-sided narrow gorge through **Pir Panjal Range** below **Baramula**.
- At **Muzaffarabad**, the river takes a sharp hair-pin bend southward.
- After that, it forms the India-Pakistan boundary for 170 km and emerges at the Potwar Plateau near Mirpur.
- After flowing through the spurs of the Salt Range, it **debouches (emerge from a confined space into a wide, open area)** on the plains near the city of Jhelum.
- It joins the Chenab at **Trimmu.**
- The river is **navigable for about 160 km** out of a total length of 724 km.

Chenab River

- The Chenab originates from near the **Bara Lacha Pass** in the **Lahul-Spiti** part of the **Zaskar Range.**
- Two small streams on opposite sides of the pass, namely **Chandra** and **Bhaga**, form its headwaters at an altitude of 4,900 m.
- The united stream **Chandrabhaga** flows in the north-west direction through the **Pangi valley**, parallel to the Pir Panjal range.
- It enters the plain area near **Akhnur** in Jammu and Kashmir.
- It joins the **Sutlej** after receiving the waters of Jhelum and Ravi rivers.

Ravi River

- The Ravi has its source in **Kullu hills** near the **Rohtang Pass** in Himachal Pradesh.
- It drains the area between the **Pir Panjal** and the **Dhaola Dhar ranges**.
- After crossing Chamba, it takes a south-westerly turn and **cuts a deep gorge in the Dhaola Dhar range**.
- It enters Punjab Plains near **Madhopur** and later enters Pakistan below Amritsar.
- It debouches into the Chenab a little above **Rangpur in Pakistani Punjab**.

Beas River

- The Beas originates **near the Rohtang Pass**, at a height of 4,062 m above sea level, on the **southern end of the Pir Panjal Range, close to the source of the Ravi.**
- It crosses the Dhaola Dhar range, and it takes a south-westerly direction and meets the Sutlej river at **Harike in Punjab.**
- It is a comparatively small river which is only 460 km long but **lies entirely within the Indian territory.**

Sutlej River

- The Sutlej rises from the **Manasarovar-Rakas Lakes** in western Tibet at the height of 4,570 m within 80 km of the source of the Indus.
- Like the Indus, it takes a north-westerly course up to the **Shipki La** on the Tibet-Himachal Pradesh boundary.
- It cuts deep gorges where it pierces the Great Himalaya and the other Himalayan ranges.
- Before entering the Punjab plain, it cuts a gorge in Naina Devi Dhar, where the famous **Bhakra dam (also known as Bhakra-Nangal Dam. The dam forms the Gobind Sagar reservoir)** has been constructed.
- The Beas joins it **at Harike.**
- From near **Ferozepur to Fazilka** it forms the boundary between India and Pakistan for nearly 120 km.
- During its onward journey, it receives the collective drainage of the Ravi, Chenab and Jhelum rivers.
- It joins the Indus a few kilometres above **Mithankot.**

Indus water treaty

- India and Pakistan share the waters of the Indus river system according to the Indus Water Treaty signed between the two countries on **19th September 1960.**
- According to this treaty, India can utilise only **20 per cent of its total discharge of water.**

8.5 Ganga River System

River System of India

Indus	Indus	Indus	Indus	Indus	Indus			Penganga	Penganga	Godavari
Chenab	Chenab	Chenab	Chenab	Panchnad				Godavari	Godavari	
Jhelum	Jhelum							Manjara		
Kishenganga										
Ravi	Ravi	Ravi						Bhima	Krishna	Krishna
Satluj	Satluj	Satluj	Satluj					Krishna		
Beas	Beas							Tungbhadra	Tungbhadra	
Yamuna	Yamuna	Yamuna	Ganga	Ganga	Ganga	Ganga	Ganga	Ganga	Hugli	Hugli
Chambal									Ganga	Padma
Betwa	Betwa									
Ganga	Ganga	Ganga								
Gomati	Gomati	Gomati	Gomati							
Ghaghra	Ghaghra	Ghaghra	Ghaghra	Ghaghra						
Son	Son	Son	Son	Son	Son					
Gandak	Gandak	Gandak	Gandak	Gandak	Gandak	Gandak				
Kosi	Kosi	Kosi	Kosi	Kosi	Kosi	Kosi	Kosi			
Brahmputra	Brahmputra	Brahmputra	Brahmputra	Brahmputra	Brahmputra	Brahmputra	Brahmputra	Brahmputra	Brahmputra	
Luni	Sabarmati	Mahi	Narmada	Tapti	Mahanadi	Pennar	Cauveri	Vaigai	Brahmani	Saryu

NG

Ganga River System

River	Source
Bhagirathi (Ganga)	**Gangotri glacier**
Yamuna	**Yamnotri glacier on the Bandarpunch Peak**

Chambal	**Janapao Hills in the Vindhya Range**
Banas	**Aravalli Range**
Betwa	Bhopal district
Ken	Barner Range
Son	**Amarkantak Plateau**
Damodar (Sorrow of Bengal)	**Chotanagpur plateau**
Ramganga River	Garhwal district of Uttarakhand
Ghaghra River	Gurla Mandhata peak, south of Manasarovar in Tibet (river of the trans-Himalayan origin)
The Kali River (the border between Nepal and Uttarakhand)	Glaciers of trans-Himalayas
Gandak River	Tibet-Nepal border
Burhi Gandak	Sumesar hills near the India-Nepal border
Kosi ('Sorrow of Bihar')	Tumar, Arun and Sun Kosi unite at Triveni north of the Mahabharata Range to form the Kosi.

Ganga River

- The **Ganga** originates as **Bhagirathi** from the **Gangotri glacier** in Uttar Kashi District of Uttarakhand at an elevation of 7,010 m.
- **Alaknanda** River joins **Bhagirathi** at **Devaprayag**.
- **From Devapryag the river is called as Ganga**.

- The Ganges was ranked as the fifth most polluted river of the world in 2007.
- Pollution threatens many fish species and amphibian species and the endangered **Ganges river dolphin (Blind Dolphin)**.

Major tributaries of Alaknanda

- **East Trisul** (joins Alaknanda at Karan Prayag)
- **Pindar** (rises from Nanda Devi)
- **Mandakini or Kali Ganga** (joins Alaknanda at Rudra Prayag)
- **Dhauliganga**
- **Bishenganga.**
  (**Kishenganga** is the tributary of Jhelum)

Major tributaries of Bhagirathi

- **Bheling**

- Ganga **debouches** (emerge from a confined space into a wide, open area) from the hills into plain area at **Haridwar.**
- It is joined by the **Yamuna** at **Prayagraj** (**Allahabad**).
- Near Rajmahal Hills it turns to the south-east.
- At Farraka, it bifurcates into **Bhagirathi-Hugli in West Bengal** and **Padma-Meghna in Bangladesh** (it ceases to be known as the Ganga after Farraka).
- Brahmaputra (or the **Jamuna** as it is known here) joins Padma-Meghna at **Goalundo.**
- The total length of the Ganga river from its source to its mouth (measured along the Hugli) is 2,525 km.

Ganga-Brahmaputra Delta

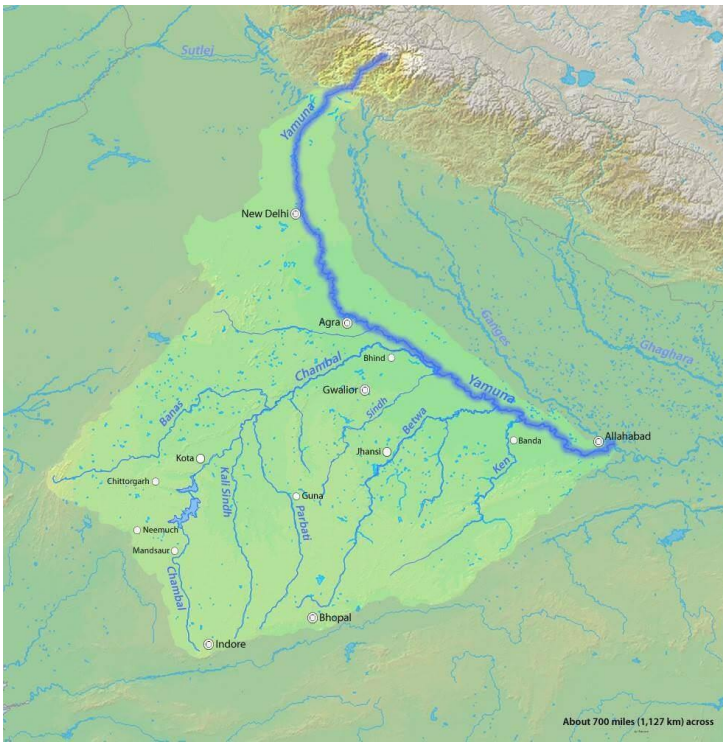
- Before entering the Bay of Bengal, the Ganga, along with the Brahmaputra, forms the **largest delta of the world** between the **Bhagirathi/Hugli** and the **Padma/Meghna** covering an area of 58,752 sq km.
- The coastline of the delta is a highly indented area.
- A major part of the delta is a **low-lying swamp** which is flooded by marine water during high tide.

Right Bank Tributaries of The Ganga

- Most of them **except the Yamuna** originate in the peninsular region.

Yamuna River

- Largest and most important tributary.
- It originates from the **Yamunotri glacier on the Bandarpunch Peak** in the Garhwal region in Uttarakhand at an elevation of about 6,000 meters.
- It cuts across the **Nag Tibba**, the **Mussoorie** and the Shiwalik ranges.
- It emerges out of the hilly area and enters plains near **Tajewala.**
- Its main affluent in the upper reaches is the **Tons** which also rises from the **Bandarpunch glacier**.
- It joins the Yamuna below Kalsi before the latter leaves the hills.
- At this site, the water carried by the Tons is twice the water carried by the Yamuna.



Yamuna River System

Non – Peninsular Tributaries	Peninsular Tributaries
1. **Rishiganga** 2. **Uma** 3. **Hanuman Ganga** 4. **Tons** 5. **Hindon**	Most of the Peninsular rivers flow into the Yamuna between Agra and Allahabad. 1. **Chambal** 2. **Sind** 3. **Betwa** 4. **Ken.**

- It unites with the Ganga near **Triveni Sangam, Prayagraj (Allahabad).**
- The total length of the Yamuna from its origin till Allahabad is 1,376 km.
- It creates the highly fertile alluvial, **Yamuna-Ganges Doab** region between itself and the Ganges in the Indo-Gangetic plain.

Chambal River

- The Chambal rises in the highlands of **Janapao Hills** (700 m) in the **Vindhyan Range**.
- It flows through the **Malwa Plateau.**
- It joins the Yamuna in **Etawah district** of Uttar Pradesh.
- The river flows much below its banks due to severe erosion because of poor rainfall, and numerous deep ravines have been formed in the Chambal Valley, giving rise to **badland topography**.
- The total length of the river is 1,050 km.

Dams on the Chambal

- **The Gandhi Sagar dam** is the first of the four dams built on the Chambal River, located on the Rajasthan-Madhya Pradesh border.
- **The Rana Pratap Sagar** dam is located downstream of Gandhi Sagar dam.
- **The Jawahar Sagar Dam** is located downstream of Rana Pratap Sagar dam.
- **The Kota Barrage** is the fourth in the series located upstream of Kota City in Rajasthan.

***Keoladeo National Park** is supplied with water from the Chambal river irrigation project.*

The Banas

- The Banas is a tributary of the Chambal.
- It originates in the southern part of the **Aravalli Range.**

- It joins the Chambal on **Rajasthan – Madhya Pradesh border** near **Sawai Madhopur**.

The Sind

- The Sind originates in **Vidisha Plateau** of Madhya Pradesh.
- It flows for a distance of 415 km before it joins the Yamuna.

The Betwa

- The Betwa rises in **Bhopal district (Vindhyan Range)** and joins the Yamuna near **Hamirpur.**
- **The Dhasan** is its important tributary.

The Ken

- The Ken river rising from the **Barner Range** of Madhya Pradesh joins the Yamuna near Chila.

The Son

- The Son River rises in the **Amarkantak Plateau**.
- Its **source is close to the origin of the Narmada**.
- It passes along the **Kaimur Range.**
- It joins the Ganga near Danapur in Patna district of Bihar.
- The important tributaries of the Son are the Johilla, the Gopat, the Rihand, the Kanhar and the North Koel.
- Almost all the tributaries **join it on its right bank.**

Damodar River

- The Damodar river rises in the hills of the **Chotanagpur plateau** and **flows through a rift valley**.
- Rich in mineral resources, the valley is home to large-scale mining and industrial activity.
- It has a number of tributaries and sub-tributaries, such as **Barakar, Konar, Bokaro, Haharo, etc.**
- The **Barakar** is the most important tributary of the Damodar.
- Several dams have been constructed in the valley, for the generation of hydroelectric power. The valley is called **"the Ruhr of India".**
- The first dam was built across the Barakar River, a tributary of the Damodar river.
- It used to cause devastating floods as a result of which it earned the name **'Sorrow of Bengal'.** Now the river is tamed by constructing numerous dams.
- It joins the **Hugli River** 48 km below Kolkata.

Left Bank Tributaries of The Ganga River

- These rivers originate in the Himalayas.
- The major tributaries apart from the Yamuna, are **the Ramganga, the Gomati, the Ghaghra, the Gandak, the Burhi Gandak, the Bagmati, and the Kosi.**

Ramganga River

- The Ramganga river rises in the **Garhwal** district of Uttarakhand.
- It joins the Ganga at **Kannauj.**

Ghaghra River

- Its source is near **Gurla Mandhata peak, south of Manasarovar in Tibet (river of the trans-Himalayan origin).**
- It is known as the **Karnaili** in Western Nepal.
- Its important tributaries are the **Sarda, the Sarayu (also known as Sarju) (Ayodhya is located on its bank) and the Rapti.**
- The river bed is sandy and sudden bends start occurring in the stream.
- The river has a high flood frequency and has shifted its course several times.

Kali River

- Rises in the high glaciers of **trans-Himalaya.**
- It forms the **boundary between Nepal and Kumaon.**
- It is known as the **Sarda** after it reaches the plains.
- It joins the **Ghaghra.**

Gandak River

- Originates near the Tibet-Nepal border at a height of 7,620 m
- It receives a large number of tributaries in Nepal Himalaya.
- Its important tributaries are the **Kali Gandak, the Mayangadi, the Bari and the Trishuli.**
- It debouches into the plains at **Tribeni.**
- It flows into Ganga at **Hajipur in Bihar**.

Burhi Gandak

- Originates from the western slopes of **Sumesar hills near the India-Nepal border**.
- It joins the Ganga near Monghyr town.

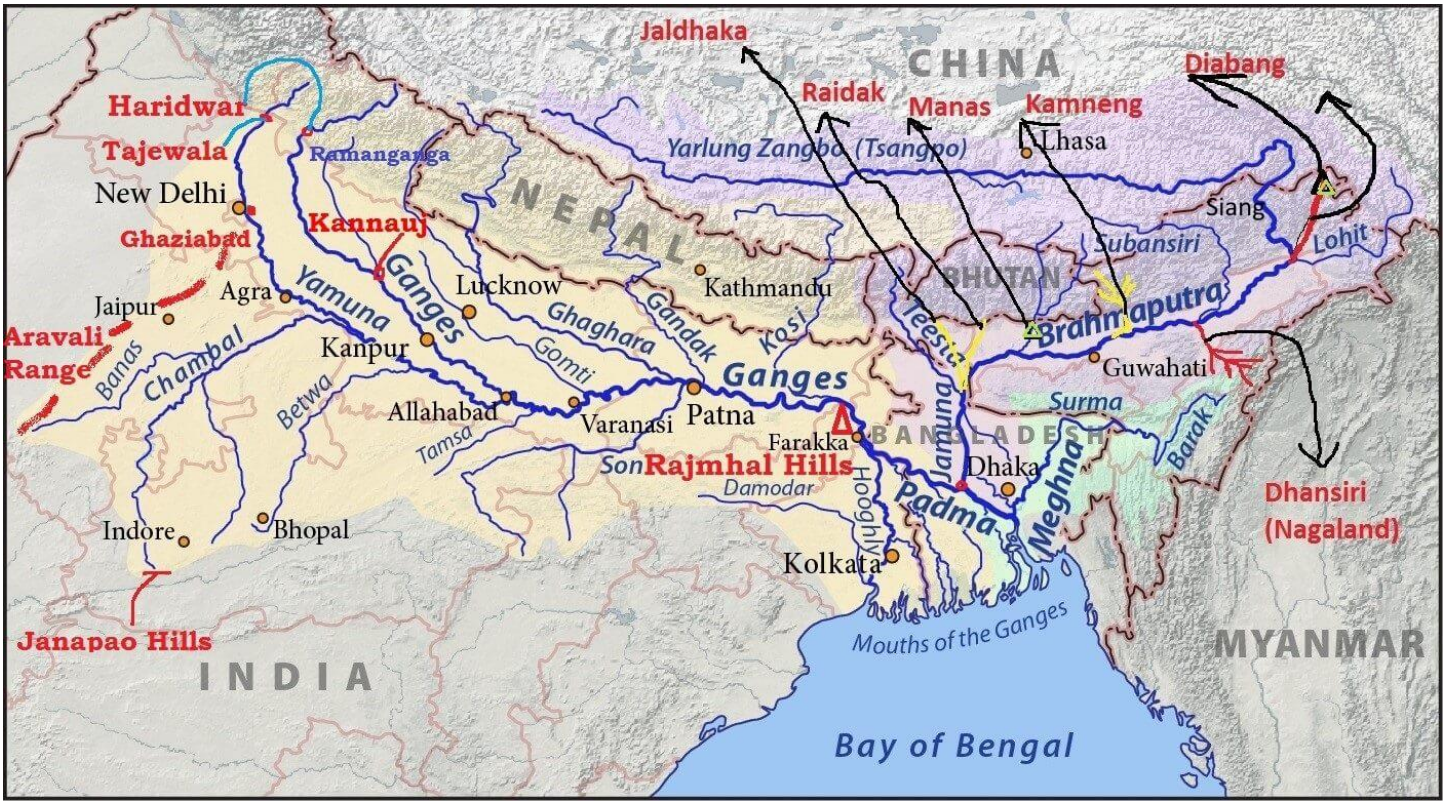
Kosi River

- The Kosi river consists of seven streams namely and is popularly known as **Saptkaushiki.**
- These streams flow through **eastern Nepal** which is known as the **Sapt Kaushik region.**
- The sources of seven streams of the Kosi are located in snow-covered areas which also receive heavy rainfall.
- Consequently, a huge volume of water flows with tremendous speed.
- Seven streams mingle with each other to form three streams named the Tumar, Arun and Sun Kosi.
- They unite at **Triveni** north of the **Mahabharata Range** to form the Kosi.
- The joins the Ganga near **Kursela.**
- Soon after debouching onto the plain the river becomes sluggish.
- Large scale deposition of eroded material takes place in the plain region.
- The **river channel is braided, and it shifts its course frequently**.
- This has resulted in frequent devastating floods and has converted large tracts of cultivable land into wasteland in Bihar. Thus, the river is often termed as the **'Sorrow of Bihar'.**
- In order to tame this river, a barrage was constructed in 1965 near Hanuman Nagar in Nepal.
- Embankments for flood control have been constructed as a joint venture of India and Nepal.

8.6 Brahmaputra River System

Region	Name
Tibet	**Tsangpo (meaning 'The Purifier')**
China	**Yarlung Zangbo, Jiangin**
Assam Valley	**Dihang or Siong, South of Sadiya: Brahmaputra**
Bangladesh	**Jamuna River**
	Padma River: Combined Waters of Ganga and Brahmaputra
	Meghana: From the confluence of Padma and Meghna

- The Brahmaputra (meaning the son of Brahma). It is 2,900 km in length.
- Source: **Chemayungdung glacier (Kailas Range)** at an elevation of about 5,150 m.
- Its source is very close to the sources of **Indus and Sutlej**.
- **Mariam La** separates the source of the Brahmaputra from the Manasarovar Lake.
- The Brahmaputra flows eastwards in Southern Tibet for about 1,800 km.
- In Tibet, it passes through the **depression formed by the Indus-Tsangpo Structure Zone** between the Great Himalayas in the south and the Kailas Range in the north.
- In spite of the exceptionally high altitude, the Tsangpo has a **gentle slope.**
- The river is sluggish and has a wide navigable channel for about 640 km.
- It receives a large number of tributaries in Tibet. The first major tributary is the **Raga Tsangpo** meeting the Tsangpo near **Lhatse Dzong**.
- The river **Ngangchu** flows through the trade centre of **Gyantse** in the south and joins the main river.



Ganga and Brahmaputra River System

- Towards the end of its journey in Tibet, its course abruptly takes a southward turn around **Namcha Barwa (7,756 m) (Syntaxial Bend).**
- Here it cuts across the eastern Himalaya through the **Dihang or Siang Gorge** and emerges from the mountains near **Sadiya** in the Assam Valley.
- Here it first flows under the name of **Siong and then as the Dihang**.
- In the north-eastern parts of Assam Valley, it is joined by two important tributaries viz, the **Dibang (or Sikang)** from the north and **Lohit from the south**.
- From Sadiya (Assam Valley) onwards, this mighty river is known as the **Brahmaputra.**
- The main streams merging with the Brahmaputra from the north are, **Subansiri, Kameng, Dhansiri (north), Raidak, Tista** etc.
- The Tista was a tributary of the Ganga before the floods of 1787 after which it diverted its course eastwards to join the Brahmaputra.
- The Brahmaputra has a **braided channel** (flow into shallow, interconnected channels divided by deposited earth) for most of its passage through Assam where channels keep shifting. It carries a lot of silt, and there is **excessive meandering.**
- The river is nearly 16 km wide at **Dibrugarh** and forms many islands, the most important of which is **Majuli (world's largest river island)**. It is 90 km long and measures 20 km at its widest.
- With rainfall concentrated during the monsoon months, only the river has to carry enormous quantities of water and silt which results in disastrous floods. The Brahmaputra is thus truly a **River of Sorrow**.
- The river is navigable for a distance of 1,384 km up to **Dibrugarh** from its mouth and serves as an excellent inland water transport route.
- The Brahmaputra bends southwards and enters Bangladesh near Dhubri.
- It flows for a distance of 270 km in the name of **Jamuna river** and joins the Ganga at **Goalundo.**
- The united stream of the Jamuna and the Ganga flows further in the name of **Padma.**
- About 105 km further downstream, the Padma is joined on the left bank by the **Meghna**, originating in the mountainous region of Assam.

- From the confluence of Padma and Meghna, the combined river is known as the **Meghna** which makes a very broad estuary before pouring into the Bay of Bengal.
- **Left Bank Tributaries: Dibang, Lohit, Dhansiri, Kolong.**
- **Right Bank Tributaries: Kameng, Manas, Raidak, Jaldhaka, Teesta, Subansiri**

8.7 Peninsular River System or Peninsular Drainage

- **Rivers that drain into the Bay of Bengal: The Mahanadi, the Godavari, the Krishna, the Cauvery** and several smaller rivers drains south-east into the Bay of Bengal.
- **Rivers that drain into the Arabian Sea: The Narmada, the Tapti, the Mahi** flowing west as well as several small streams originating from the Western Ghats flow westwards into the Arabian Sea.
- **Rivers that drain into the Ganges:** Tributaries of the Ganga and the Yamuna such as the **Chambal, the Betwa, the Ken, the Son and the Damodar** flow in the north-easterly direction.
- Peninsula rivers are much **older** than the Himalayan rivers.
- The peninsular drainage is mainly **concordant** except for few rivers in the upper peninsular region.
- They are **non-perennial** rivers with a maximum discharge in the rainy season.
- The peninsular rivers have reached a **mature stage** and have almost reached their base level **(vertical downcutting is negligible).**
- The rivers are characterized by **broad and shallow valleys.**
- The river banks have gentle slopes except for a limited tract where faulting forms steep sides.
- The main **water divide** in peninsular rivers is formed by the Western Ghats.
- The velocity of water and the **load carrying capacity of the streams is low** due to a low gradient.
- Most of the major rivers of the peninsula such as the Mahanadi, the Godavari, the Krishna and the Cauvery flow eastwards and drain into the Bay of Bengal. These rivers make **deltas at their mouths.**
- But the west flowing rivers of Narmada and Tapti as well as those originating from the Western Ghats and falling in the Arabian Sea form **estuaries in place of deltas**.
- There are few places where rivers form superimposed and rejuvenated drainage which are represented by **waterfalls.**
- Examples: The **Jog (289 m) on the Sharvati river**, **Yenna (183 m) of Mahabaleshwar**, **Sivasamundram (101 m) on the Cauvery river**, **Gokak (55 m) on the Gokak river**, **Kapildhara (23 m) and Dhuandar (15 m) on the Narmada river** are the major waterfalls in the Peninsular India.

Evolution of the Peninsular Drainage

Theory 1 (most probable)

- Geologists believe that the **Sahyadri-Aravalli axis** was the main water divide in the past.
- According to one hypothesis, the existing peninsula is the remaining half of the bigger landmass.
- The Western Ghats were located in the middle of this landmass.
- So, one drainage was towards east flowing into the Bay of Bengal and the other towards west draining into the Arabian Sea.
- The western part of the Peninsula cracked and submerged in the Arabian Sea during the early **Tertiary period (coinciding with the formation of Himalayas).**
- During the collision of the Indian plate, the Peninsular block was subjected to subsidence in few regions creating a series of **rifts (trough, faults).**
- **The now west flowing rivers of the Peninsula, namely the Narmada and the Tapti flow through these rifts.**
- **Straight coastline**, **steep western slope of the Western Ghats**, and the **absence of delta formations on the west coast** make this theory a possibility.

Theory 2

- It is believed that the west flowing peninsular rivers do not flow in the valleys formed by the rivers themselves.
- Rather they have occupied two fault rifts in rocks running parallel to the Vindhyas.
- These faults are supposed to be **caused by the bend of the northern part of the Peninsula at the time of upheaval of the Himalayas.**
- Peninsular block, south of the cracks, tilted slightly eastwards during the event thus giving the orientation to the entire drainage towards the Bay of Bengal.
- Criticism: Tilting should have increased the gradient of the river valleys and caused some **rejuvenation** of the rivers. This type of phenomenon is absent in the Peninsula, barring a few exceptions such as waterfalls.

Comparison: Himalayan River System & Peninsular River System

Features	The Himalayan River System	The Peninsular River System
Origin	• These rivets originate from the lofty Himalayan ranges and are named as the Himalayan rivers.	• These rivers originate in the hills of Peninsular Plateau and are named as Peninsular rivers.
Catchment area	• These rivers have **large basins and catchment areas**. • The total basin area of the Indus, the Ganga and the Brahmaputra are **11.78**, 8.61 and 5.8 lakh square kilometres respectively.	• These rivers have comparatively **small basins and catchment areas.** • The Godavari has the largest basin area of 3.12 lakh square kilometres.
Valleys	• The Himalayan rivers flow through deep V-shaped valleys called gorges. • These gorges have been carved out by down cutting carried on side by side with the uplift of the Himalayas.	• The Peninsular rivers flow in comparatively shallow valleys. • These are more or less completely graded valleys. • The rivers have little erosional activity to perform.
Drainage Type	• These are examples of **antecedent drainage**.	• These are examples of **consequent drainage**.
Water Flow	• The Himalayan rivers are perennial in nature, i.e., water flows throughout the year in these rivers. • These rivers receive water both from the monsoons and snow-melt. • The perennial nature of these rivers makes them useful for irrigation.	• The Peninsular rivers receive water only from rainfall and water flows in these rivers in rainy season only. • Therefore, these rivers are seasonal or non-perennial. • As such these rivers are much less useful for irrigation.
Stage	• These rivers flow across the young fold mountains and are still in a **youthful stage**.	• These rivers have been flowing in one of the oldest plateaus of the world and have **reached maturity**.
Meanders	• When they enter the plains, there is a sudden reduction in the speed of flow of water. • Under these circumstances, these rivers form meanders and often shift their beds.	• The **hard rock surface and non-alluvial character** of the plateau permits little scope for the formation of meanders. • As such, the rivers of the Peninsular Plateau follow **more or less straight courses**.
Deltas and Estuaries	• The Himalayan rivers form big deltas at their mouths.	• Some of the Peninsular rivers, such as the **Narmada and the Tapti form estuaries**.

	• Ganga-Brahmaputra delta is the **largest in the world**.	• Other rivers such as the **Mahanadi, the Godavari, the Krishna and the Cauvery form deltas**. • Several small streams originating from the Western Ghats and flowing towards the west enter the Arabian Sea without forming any delta.

East Flowing Peninsular Rivers

- **Mahanadi River**
- **Godavari River**
- **Krishna River**
- **Kaveri (Cauvery) River**
- **Pennar River**
- **Subarnarekha River**
- **Brahmani River**
- **Sarada River**
- **Ponnaiyar River**
- **Vaigai River**

Mahanadi River

Tributaries of Mahanadi River

- The Mahanadi basin extends over states of **Chhattisgarh and Odisha** and comparatively smaller portions of **Jharkhand**, Maharashtra and Madhya Pradesh, draining an area of 1.4 lakh Sq.km.
- Its upper course lies in the saucer-shaped basin called the **Chhattisgarh Plain.**
- It is bounded by the Central India hills on the north, by the Eastern Ghats on the south and east and by the **Maikal range** on the west.
- The **Mahanadi (Great River)** has its source in the northern foothills of **Dandakaranya in Rai-**

pur District of Chhattisgarh at an elevation of 442 m.

- The Mahanadi is one of the major rivers of the peninsular rivers, in water potential and **flood-producing capacity**, it ranks second to the Godavari.
- Other small streams draining directly into the **Chilka Lake** also forms the part of the Mahanadi basin.
- The major part of the basin is covered with agricultural land.
- It is one of the **most-active silt-depositing** streams in the Indian subcontinent.
- After receiving the **Seonath River**, it turns east and enters Odisha state.
- At Sambalpur, the **Hirakud Dam** (one of the largest dams in India) on the river has formed a human-made lake 35 miles (55 km) long.
- It enters the Odisha plains near Cuttack and enters the Bay of Bengal at False Point by several channels.
- **Puri**, **at one of its mouths**, is a famous pilgrimage site.

Tributaries of Mahanadi River

- Left bank Tributaries: The **Seonath**, the **Hasdeo**, the **Mand** and the **Ib.**
- Right bank Tributaries: The **Ong**, the **Tel** and the **Jonk.**

Projects on Mahanadi River

- Two important projects completed during the pre-plan period in the basin are the **Mahanadi main canal** and **Tandula reservoir in Chhattisgarh**.
- During the plan period, the **Hirakud dam, Mahanadi delta project, Hasdeo Bango, Mahanadi Reservoir Project** were completed.

Industry in Mahanadi River Basin

- Three important urban centres in the basin are **Raipur, Durg and Cuttack**.
- Mahanadi basin, because of its **rich mineral resource** and **adequate power resource**, has a favourable industrial climate.
- The Important industries presently existing in the basin are the **Iron and Steel plant at Bhilai**, **aluminium factories at Hirakud and Korba**, **etc**.
- Other industries based primarily on agricultural produce are sugar and textile mills.
- Mining of coal, iron and manganese are other industrial activities.

Floods in Mahanadi River Basin

- The basin is subject to **severe flooding** occasionally in the delta area due to an inadequate carrying capacity of the channels.
- The multi-purpose **Hirakud dam** provides some amount of flood relief by storing part of flood water.
- However, the problem persists.

Godavari River

- The Godavari is the **largest river system of Peninsular India** and is revered as **Dakshin Ganga.**
- The Godavari basin extends over states of **Maharashtra, Telangana, Andhra Pradesh, Chhattisgarh and Odisha** in addition to smaller parts in Madhya Pradesh, Karnataka and Union territory of Puducherry (Yanam) having a total area of ~ 3 lakh Sq.km.
- The basin is bounded by **Satmala hills**, the **Ajanta range** and the **Mahadeo hills** on the north, by the Eastern Ghats on the south and the east and by the Western Ghats on the west.
- The Godavari River rises from **Trimbakeshwar in the Nashik district** of Maharashtra about 80 km from the Arabian Sea at an elevation of 1,067 m.
- The total length of Godavari from its origin to outfall into the Bay of Bengal is 1,465 km.

Tributaries of Godavari River

- The left bank tributaries are more in number and **larger** in size than the right bank tributaries.

- The **Manjra** (724 km) is the only important right bank tributary. It joins the Godavari after passing through the **Nizam Sagar reservoir.**
- Left Bank Tributaries: **Dharna, Penganga, Wainganga, Wardha, Pranahita** (conveying the combined waters of **Penganga, the Wardha and Wainganga), Pench, Kanha, Sabari, Indravati etc.**
- Right Bank Tributaries: **Pravara, Mula, Manjra, Peddavagu, Maner** etc.
- Below Rajahmundry, the river divides itself into two main streams, the **Gautami Godavari** on the east and the **Vashishta Godavari** on the west and forms a large delta before it pours into the Bay of Bengal.
- The delta of the Godavari is of the **lobate type** with a round bulge and many distributaries.

Tributaries of Godavari River

Mineral Resources in Godavari Basin

- The upper reaches of the Godavari drainage basin are occupied by the **Deccan Traps** containing minerals like **magnetite, epidote, biotite, zircon, chlorite** etc. (metallic minerals).
- The middle part of the basin is principally composed of **phyllites, quartzites, amphiboles and granites (rocks).**
- The downstream part of the middle basin is occupied mainly by sediments and rocks of the **Gondwana group**.
- The Gondwanas are principally detritals (organic matter produced by decomposition or loose matter produced by erosion) with some thick **coal seams. E.g. Singareni Coal Seam (Telangana).**

- The Eastern Ghats dominate the lower part of the drainage basin and are formed mainly from the **Khondalites**.

Projects on Godavari River

- Important projects completed during the plan period are **Srirama Sagar, Godavari barrage, Upper Penganga, Jaikwadi, Upper Wainganga, Upper Indravati, Upper Wardha.**
- Among the on-going projects, the prominent ones are **Prnahita-Chevala** and **Polavaram.**

Industry in Godavari Basin

- The major urban centres in the basin are **Nagpur, Aurangabad, Nashik, Rajahmundry.**
- **Nashik and Aurangabad** have a large number of industries especially the **automobiles.**
- Other than this, the industries in the basin are mostly based on agricultural products such as rice milling, cotton spinning and weaving, sugar and oil extraction.
- Cement and some small engineering industries also exist in the basin.

Floods and Droughts in Godavari Basin

- Godavari basin faces flooding problem in its lower reaches.
- The coastal areas are cyclone-prone.
- The delta areas face drainage congestion due to flat topography.
- A large portion of Maharashtra falling **(Marathwada)** in the basin is **drought prone.**

Krishna River

- The Krishna is the second largest east flowing river of the Peninsula.
- The Krishna Basin extends over Maharashtra, Telangana, Andhra Pradesh, and Karnataka having a total area of ~2.6 lakh km^2.
- It is bounded by **Balaghat range** on the north, by the Eastern Ghats on the south and the east and by the Western Ghats on the west.
- The Krishna River rises from the **Western Ghats** near **Jor village of Satara district of Maharashtra** at an altitude of 1,337 m just north of **Mahabaleshwar.**
- The total length of the river from origin to its outfall into the Bay of Bengal is 1,400 km.
- The Krishna forms a large delta with a shoreline of about 120 km.
- The Krishna delta appears to merge with that formed by the Godavari and extends about 35 km into the sea.

Tributaries of Krishna River

- Right bank: **the Ghatprabha, the Malprabha and the Tungabhadra.**
- Left Bank: **the Bhima, the Musi and the Munneru.**
- The **Koyna** is a small tributary but is known for **Koyna Dam**. This dam was perhaps the main cause of the devastating **earthquake** (6.4 on the richter scale) in 1967 that killed 150 people.
- The Bhima originates from the **Matheron Hills** and joins the Krishna near Raichur.
- The Tungabhadra is formed by the unification of the **Tunga** and the **Bhadra** originating from **Gangamula** in the **Central Sahyadri**.
- At Wazirabad, it receives its last important tributary, the **Musi, on whose banks the city of Hyderabad is located**.

Projects on Krishna River

- Important ones are the **Tungabhadra, Ghataprabha, Nagarjunasagar, Malaprabha, Bhima, Bhadra** and **Telugu Ganga.**
- The major Hydro Power stations in the basin are **Koyna, Tungabhadara, Sri Sailam, Nagarjuna Sagar, Almatti, Naryanpur, Bhadra.**
- Tungabhadra is a major inter-States project in the basin.

Resources in Krishna Basin

- The basin has rich mineral deposits, and there is good potential for industrial development.
- **Krishna Godavari Basin (K-G Basin)** is known for the D-6 block where Reliance Industries discovered the **biggest natural gas reserves in India** in 2003.

Industry in Krishna Basin

- The major urban centres in the Basin are **Pune, Hyderabad.**
- Hyderabad is the state capital of Telangana and is now a major IT hub.
- Pune in Maharashtra has a number of **automobiles and IT industry** and is a major education centre.

Tributaries of Krishna River

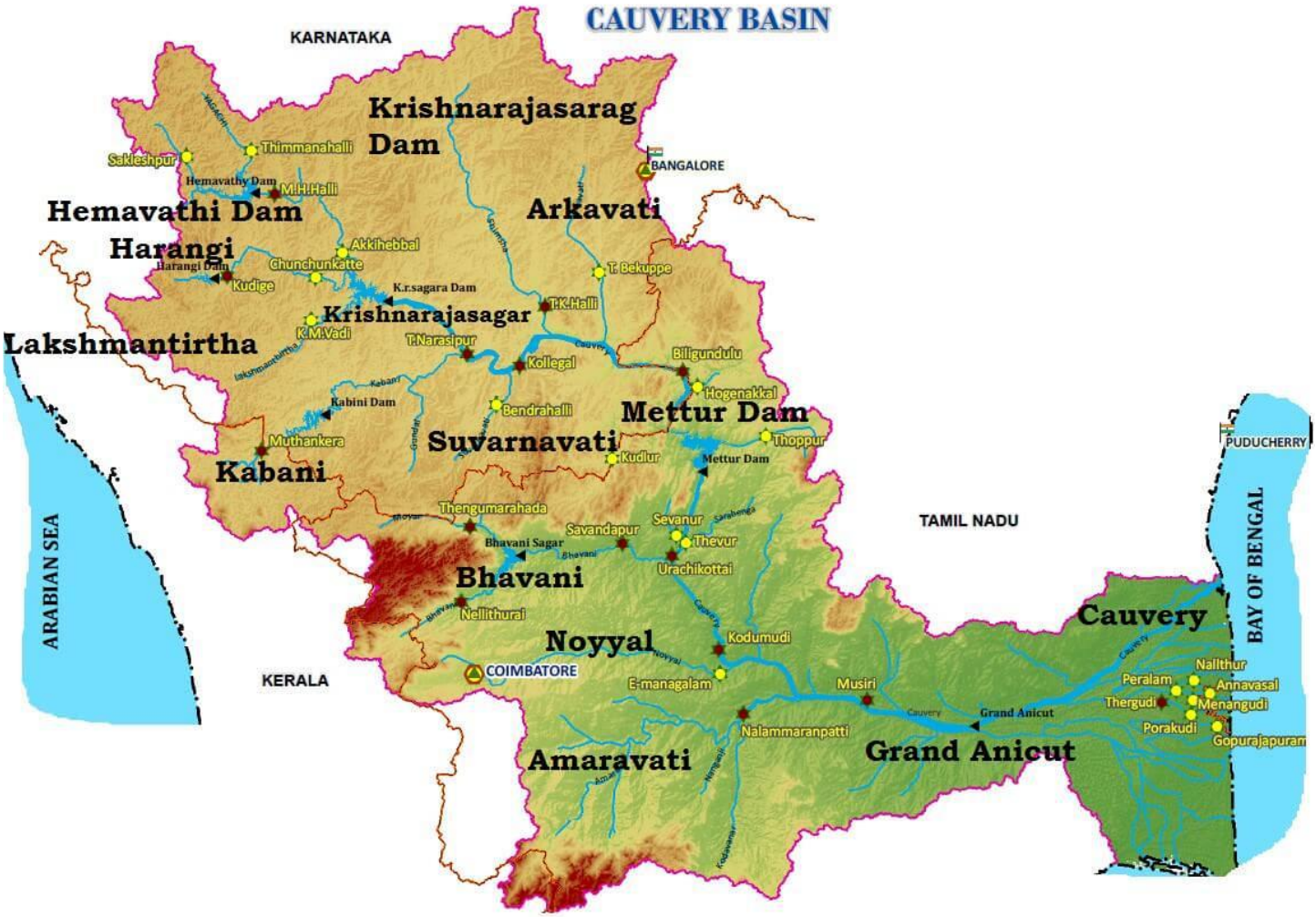
Drought and Floods in Krishna Basin

- Some parts of the basin are **drought-prone.**
- The delta area of the basin is subject to flooding.
- It has been observed that the river bed in the delta area is continuously raised due to silt deposition resulting in a reduction in carrying capacity of the channel.
- The coastal cyclonic rainfall of high intensity and short duration makes the flood problem worse.

Cauvery River

- The Kaveri (Cauvery) is designated as the **Dakshin Ganga** or **the Ganga of the South.**

The Godavari *is known as Dakshin Ganga for its size and Kaveri is also sometimes referred to as Dakshin Ganga because of its spiritual significance. But if you have to choose only one among these then Godavari is the* ***Dakshin Ganga*** *or* ***the Ganga of the South.***



Tributaries of the Cauvery River

- The Cauvery River rises at an elevation of 1,341 m at **Talakaveri** on the **Brahmagiri range, Kodagu (Coorg) district of Karnataka.**
- The Cauvery basin extends over states of **Tamil Nadu, Karnataka, Kerala** and **Union Territory of Puducherry** draining an area of 81 thousand km^2.
- It is bounded by the Western Ghats on the west, by the Eastern Ghats on the east and the south and by the ridges separating it from Krishna basin and Pennar basin on the north.
- The Nilgiris, an offshoot of Western Ghats, extend Eastwards to the Eastern Ghats and divide the basin into two natural regions, i.e., Karnataka plateau in the North and the Tamil Nadu plateau in the South.
- Physiographically, the basin can be divided into three parts – the Western Ghats, the Plateau of Mysore and the Delta.
- The delta area is the most fertile tract in the basin. The principal soil types found in the basin are black soils, red soils, laterites, alluvial soils, forest soils and mixed soils.
- **Red soils** occupy large areas in the basin. Alluvial soils are found in the delta areas.
- The basin in Karnataka receives rainfall mainly from the S-W Monsoon and partially from N-E Monsoon.
- The basin in Tamil Nadu receives good flows from the North-East Monsoon.
- Its upper catchment area receives rainfall during summer by the south-west monsoon and the lower catchment area during the winter season by the retreating north-east monsoon.
- It is, therefore, **almost a perennial river** with comparatively fewer fluctuations in flow and is **very useful for irrigation** and hydroelectric power generation.

- Thus, the Cauvery is **one of the best-regulated rivers,** and most of its irrigation and power production potential already stands harnessed.

Tributaries of the Cauvery River

- Left Bank: the **Harangi**, the **Hemavati**, the **Shimsha** and the **Arkavati**.
- Right Bank: **Lakshmantirtha**, the **Kabbani**, the **Suvarnavati**, the **Bhavani**, the **Noyil** and the **Amaravati** joins from the right.
- The river descends from the South Karnataka Plateau to the Tamil Nadu Plains through the **Shivanasamudram waterfalls (101 m high).**
- At Shivanasamudram, the river branches off into two parts and falls through a series of falls and rapids.
- The falls at this point is utilised for power generation by the power station at Shivanasamudram.
- The two branches of the river join after the fall and flow through a wide gorge which is known as **Mekedatu (Goats leap) (Mekedatu falls is here)**.
- At **Hogennekkal Falls**, it takes Southerly direction and enters the **Mettur Reservoir.**
- Below Mettur reservoir the river widens with sandy bed and flows as **Akhanda Cauvery.**
- In the last stage, the river divides into two parts, the Northern branch being called **'The Coleron'** and Southern branch remains as Cauvery, and from here the Cauvery Delta begins.
- After flowing for about 16 Kms, the two branches join again to form '**Srirangam Island**'.
- On the Cauvery, branch lies the **"Grand Anicut"** said to have been constructed by a Chola King in 1st Century A.D.
- Below the Grand Anicut, the Cauvery branch splits into two, Cauvery and **Vennar**.

Floods in Cauvery Basin

- The Cauvery basin is fan-shaped in Karnataka and leaf-shaped in Tamil Nadu. The run-off **does not drain off quickly** because of its shape, and therefore **no fast raising floods occur** in the basin.

Projects on Cauvery River

- During the pre-plan period, many projects were completed in this basin which included **Krishnarajasagar** in Karnataka, **Mettur dam** and **Cauvery delta system** in Tamil Nadu.
- Lower **Bhavani, Hemavati, Harangi, Kabini** are important projects completed during the plan period.

Industry in Cauvery Basin

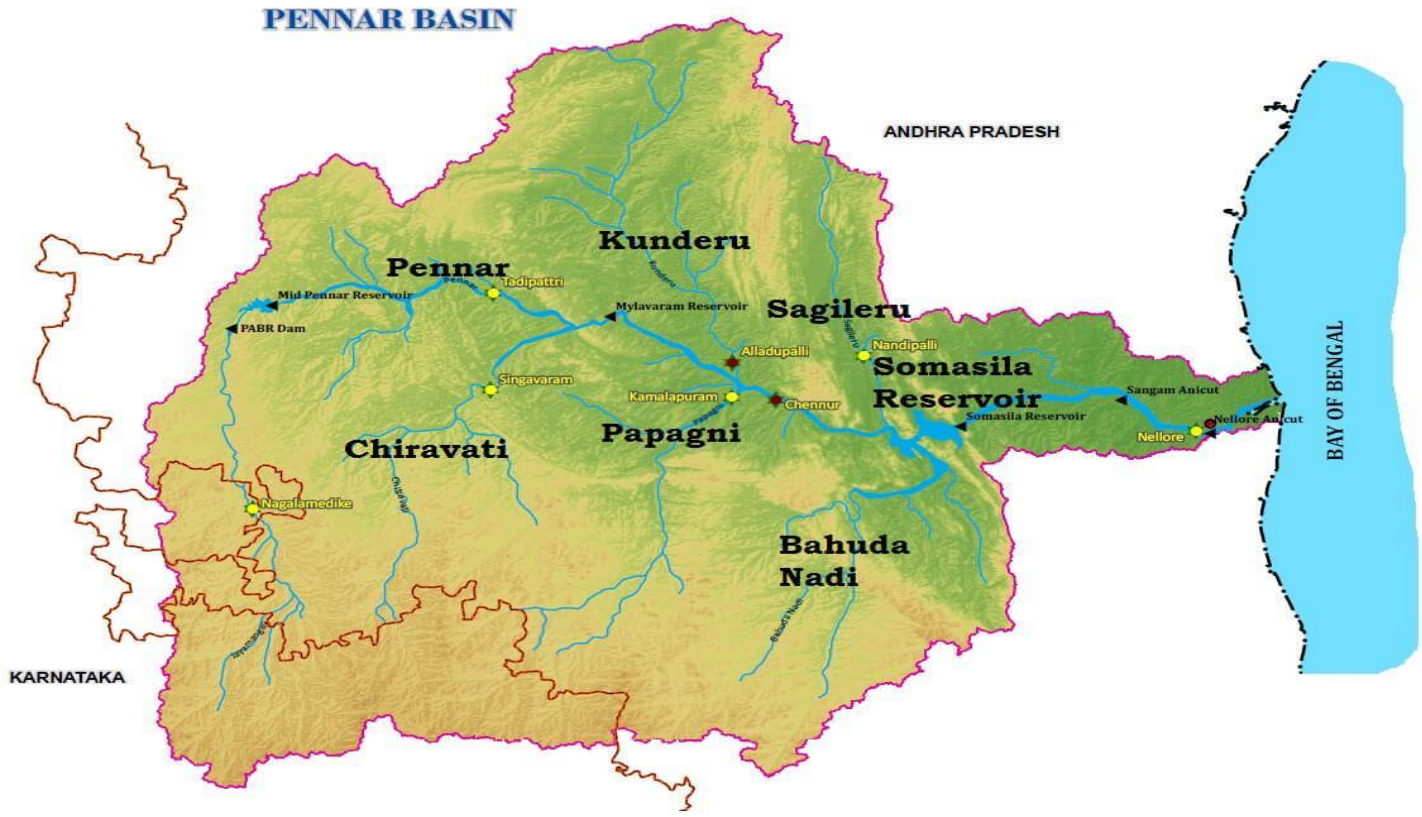
- The city of Bangalore is situated just outside this basin.
- Important industries in the basin include the **cotton textile industry in Coimbatore** and Mysore, cement factories in Coimbatore and Trichinapally and industries based on mineral and metals.
- The **Salem steel plant** and many engineering industries in Coimbatore and Trichinapally are also situated in this basin.

Pennar River

- The Pennar (also known as **Uttara Pinakini**) is one of the major rivers of the peninsula.
- The Pennar rises in the **Chenna Kesava hill** of the **Nandidurg range**, in **Chikkaballapura district** of **Karnataka** and flows towards east eventually draining into the Bay of Bengal.
- The total length of the river from origin to its outfall in the Bay of Bengal is 597 km.
- Located in peninsular India, the Pennar basin extends over states of Andhra Pradesh and Karnataka.
- The fan-shaped basin is bounded by the **Erramala range** on the north, by the **Nallamala** and **Velikonda** ranges of the Eastern Ghats on the east, by the **Nandidurg hills** on the south and by the narrow ridge separating it from the Vedavati valley of the Krishna Basin on the west.
- The other hill ranges in the basin to the south of the river are the **Seshachalam (famous for Red Sanders)** and **Paliconda ranges.**

Tributaries of Pennar River

- Left Bank: the **Jayamangali**, the **Kunderu** and the **Sagileru.**



Tributaries of Pennar River

Subarnarekha Basin

Minor East flowing rivers in Peninsular India

- Right bank: the **Chiravati**, the **Papagni** and the **Cheyyeru.**

Projects on Pennar River

- Tungabhadra high-level canal in Krishna basin irrigates areas in Pennar basin also. The only major project in the basin is the **Somasila project.**

Industry in Pennar Basin

- The only important town in the basin is **Nellore.**
- With limited water and power potential and mineral resources, the scope for industrial development is limited in the basin. There are no major industries.

Subarnarekha

- The Subarnarekha originates from the **Ranchi Plateau in Jharkhand** forming the boundary between West Bengal and Odisha in its lower course.
- It joins the Bay of Bengal forming an **estuary between the Ganga and Mahanadi deltas**.
- Its total length is 395 km.

Brahmani River

- The Brahmani river comes into existence by the confluence of the **Koel** and the **Sankh rivers** near **Rourkela**. It has a total length of 800 km.
- The basin is bounded in the North by Chhotanagpur plateau, in the West and South by the Mahanadi basin and in the East by the Bay of Bengal.
- The basin flows through Jharkhand, Chhattisgarh and Orissa States and drains into the Bay of Bengal.

Sarada River

- The river Sarada, an East flowing medium-sized river, lies in the district of Visakhapatnam of Andhra Pradesh.

Ponnaiyar River

- The Ponnaiyar is a small stream which is confined to the coastal area only.
- It covers a small area in the state of Tamil Nadu, Karnataka and Andhra Pradesh.
- The Basin is bounded on the North-West and South by various ranges of the Eastern Ghats like the Velikonda Range, the Nagari hills, the Javadu Hills, the Shevaroy hills, the Chitteri hills and the Kalrayan hills and in the East by the Bay of Bengal.

Vaigai River

- South of the Cauvery delta, there are several streams, of which the Vaigai is the longest.
- The Vaigai basin is an important basin among the 12 basins lying between the Cauvery and Kanyakumari.
- This basin is bounded by the Varushanadu hills, the Andipatti hills, the Cardaman hills and the Palani hills on the West and by the Palk Strait and Palk Bay on the East.

West Flowing Rivers of Peninsular India

- The west flowing rivers of Peninsular India are fewer and smaller as compared to their east flowing counterparts.
- The two major west flowing rivers are the **Narmada** and the **Tapti.**
- This exceptional behaviour is because **these rivers didn't form valleys** and **instead, they flow through faults (linear rift, rift valley, trough) created due to the bending of the northern peninsula during the formation process of Himalayas**.
- These faults run parallel to the **Vindhyas** and the **Satpuras**.
- The **Sabarmati, Mahi** and **Luni** are other rivers of Peninsular India which flow westwards.
- Hundreds of small streams originating in the **Western Ghats** flow swiftly westwards and join the Arabian Sea.
- Peninsular rivers which fall into the Arabian Sea **do not form deltas, but only estuaries.**
- This is due to the fact that the west flowing rivers, especially the Narmada and the Tapti **flow**

through hard rocks and hence do not carry any good amount of silt.

- Moreover, the **tributaries of these rivers are very small,** and hence they don't contribute any silt.
- Hence these rivers are not able to form distributaries or a delta before they enter the sea.

Estuary

Estuary

- An estuary is a partially enclosed body of water along the coast where freshwater from rivers and streams meets and mixes with salt water from the ocean.
- Estuaries and the lands surrounding them are places of transition from land to sea and fresh water to salt water.
- **Primary productivity in estuaries is very high**. Fishing is a dominant occupation around estuaries. Most of the estuaries are good **bird sanctuaries**.
- **Although influenced by the tides, they are protected from the full force of ocean waves, winds, and storms by such landforms as barrier islands or peninsulas**. (**estuaries make good ports. E.g. New York Harbour is at the mouth of the Hudson River; Mormugao port in Goa at the mouth of the Zuari river and Mondovi river**)
- Estuarine environments are among the most productive on earth, **creating more organic matter each year than comparably-sized areas of forest, grassland, or agricultural land**.
- The tidal, sheltered waters of estuaries also support unique communities of plants and animals.
- Estuaries benefits for tourism and recreational activities.
- Water draining from uplands carries sediments, nutrients, and other pollutants to estuaries. As the water flows through estuaries, the sediments and pollutants are filtered out.
- Salt marsh grasses and other estuarine plants also help prevent erosion and stabilise shorelines (**Mangroves**).

Narmada River

- The Narmada is the **largest west flowing river** of peninsular India.
- The Narmada flows westwards through a **rift valley between the Vindhyan Range on the north and the Satpura Range on the south**.
- It rises from **Maikala range near Amarkantak** in **Madhya Pradesh**, at an elevation of about 1057 m.
- Narmada basin extends over states of **Madhya Pradesh, Gujarat, Maharashtra and Chhattisgarh**.
- It is bounded by the Vindhyas on the north, **Maikala range on the east**, Satpuras on the south and by the Arabian Sea on the west.
- Its total length from its source in **Amarkantak** to its estuary in the **Gulf of Khambhat** is 1,310 km.
- The hilly regions are in the upper part of the basin, and lower middle reaches are broad and fertile areas well suited for cultivation.
- **Jabalpur** is the only important urban centre in the basin.
- The river slopes down near Jabalpur where it cascades (a small waterfall, especially one in a series) 15 m into a gorge to form the **Dhuan Dhar (Cloud of Mist) Falls.**
- Since the gorge is composed of marble, it is popularly known as the Marble Rocks.

- Near Maheshwar, the river again descends from another small fall of 8 m, known as the **Sahasradhara Falls**.
- There are several islands in the estuary of the Narmada of which **Aliabet** is the largest.

Tributaries of Narmada River

- Since the river flows through a narrow valley confined by precipitous (dangerously high or steep) hills, it **does not have many tributaries**.
- The absence of tributaries is especially noted on the right bank of the river where the **Hathni River** is the only exception. The other right bank tributaries are the **Orsang, the Barna and the Kolar**.
- A few left bank tributaries drain the northern slopes of the Satpura Range and join the Narmada at different places.
- The major Hydro Power Project in the basin are **Indira Sagar, Sardar Sarovar, Omkareshwar, Bargi & Maheshwar.**

Tributaries of Narmada River

Tapti River

- The Tapti (also known as the Tapti) is the **second largest west flowing river** of Peninsular India and is known as 'the twin' or 'the handmaid' of the Narmada.
- It originates near **Multai reserve forest in Madhya Pradesh** at an elevation of 752 m.
- Flows for about 724 km before entering into the Arabian Sea through the **Gulf of Cambay (Gulf of Khambhat).**
- The Tapti River along with its tributaries flows over the plains of **Vidharbha, Khandesh** and Gujarat and large areas in the state of **Maharashtra** and a small area in Madhya Pradesh and Gujarat.
- Situated in the Deccan plateau, the basin is bounded by the **Satpura range** on the north, **Mahadev hills** on the east, **Ajanta Range** and the **Satmala hills** on the south and by the Arabian Sea on the west.
- The hilly region of the basin is well forested while the plains are broad and fertile areas suitable for cultivation.
- There are two well defined physical regions, in the basin, viz hilly region and plains; the hilly regions comprising **Satpura, Satmalas, Mahadeo, Ajanta** and **Gawilgarh hills** are well forested.
- The plain covers the **Khandesh areas** (Khandesh is a region of central India, which forms the northwestern portion of Maharashtra state) which are broad and fertile suitable for cultivation primarily.

Tributaries of Tapti River

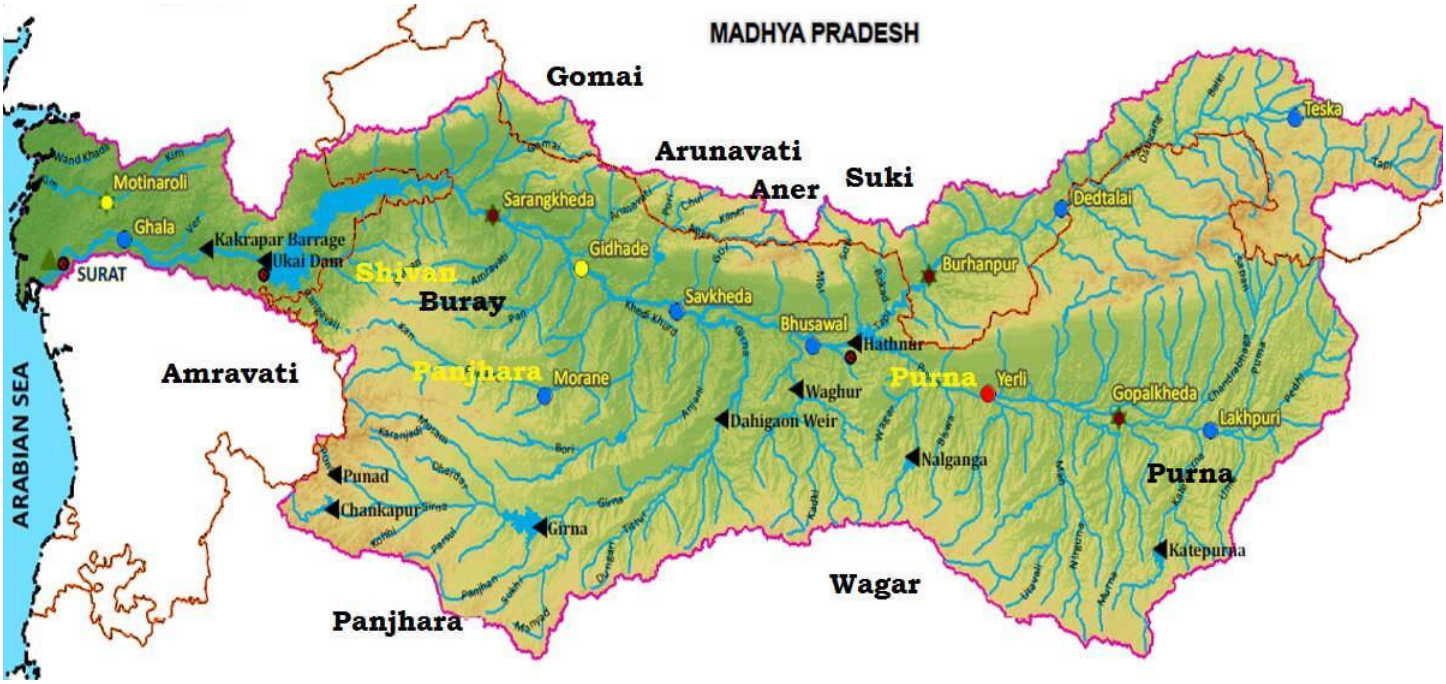
- Right Bank: the **Suki**, the **Gomai**, the **Arunavati** and the **Aner**.
- Left Bank: the **Vaghur**, the **Amravati**, the **Buray**, the **Panjhra**, the **Bori**, the **Girna**, the **Purna**, the **Mona** and the **Sipna**.

Projects on Tapti River

- Hathnur Dam of Upper Tapti Project (Maharashtra)
- Kakrapar weir and Ukai Dam of Ukai Project (Gujarat)
- Girna Dam and Dahigam Weir of Girna Project (Maharashtra)

Industry in the Tapti Basin

- Important industries in the basin are **textile factories in Surat** and **paper and newsprint factory at Nepanagar.**



Tributaries of Tapti River

Sabarmati River

- The Sabarmati is the name given to the combined streams the **Sabar** and **Hathmati**.
- The Sabarmati basin extends over states of Rajasthan and Gujarat.
- The basin is bounded by **Aravalli hills** on the north and north-east, by Rann of Kutch on the west and by Gulf of Khambhat on the south.
- The basin is roughly triangular with the Sabarmati River as the base and the source of the **Vatrak River** as the apex point.
- Sabarmati originates from **Aravalli hills** at an elevation of 762 m near village Tepur, in **Udaipur district of Rajasthan.**
- The total length of the river from origin to outfall into the Arabian Sea is 371 km.
- Rainfall varies from a meagre few mm in Saurashtra to over 100 cm in the southern part.
- Left bank tributaries: the Wakal, the Hathmati and the Vatrak.
- Right bank tributaries: the Sei.
- Projects: Sabarmati reservoir (Dharoi), Hathmati reservoir and Meshwo reservoir project are major projects completed during the plan period.

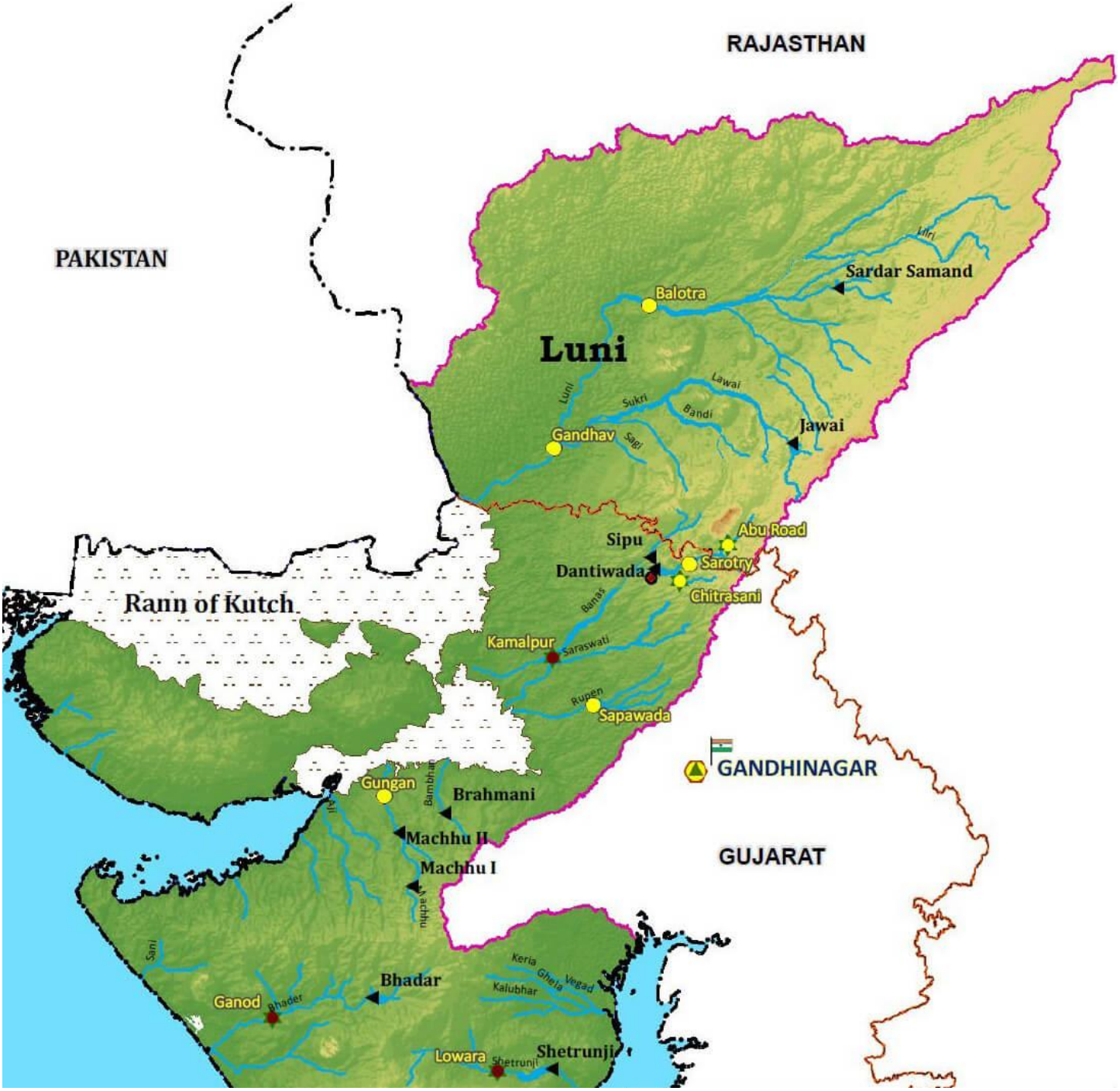
Industry in Sabarmati Basin

- **Gandhinagar** and **Ahmedabad** are the important urban centres in the basin.
- **Ahmedabad** is an industrial city situated on the **banks of Sabarmati**.
- Important industries are textiles, leather and leather goods, plastic, rubber goods, paper, newsprint, automobile, machine tools, drugs and pharmaceuticals etc.
- The industrial city of Ahmedabad poses the danger of water pollution.

Sabarmati River

MAHI BASIN

Mahi Basin



Luni Basin

Mahi River

- The Mahi basin extends over states of **Madhya Pradesh, Rajasthan and Gujarat**.
- It is bounded by **Aravalli hills** on the north and the north-west, by **Malwa Plateau** on the east, by the **Vindhyas** on the south and by the Gulf of Khambhat on the west.
- It originates from the northern slopes of Vindhyas at an altitude of 500 m in **Dhar district of Madhya Pradesh.**
- The total length of Mahi is 583 km.
- It drains into the Arabian Sea through the **Gulf of Khambhat**.
- Hydro Power stations are located in Mahi Bajaj Sagar dam and at Kadana Dam.

- **Vadodara** is the only important urban centre in the basin. There are not many industries in the basin.

Luni River

- The Luni or the **Salt River** (Lonari in Sanskrit) is named so because its water is brackish below Balotra.
- Luni is the only river basin of any significance in Western Rajasthan, which forms the bulk of arid zone.
- Luni originates from western slopes of the **Aravalli ranges** at an elevation of 772 m near **Ajmer** flowing in South West direction and traversing a course of 511 km in Rajasthan; it finally flows into the **Rann of Kachchh (it gets lost in the marsh)**.
- The peculiarity of this river is that it **tends to increase its width** rather than deepening the bed because the banks are of soils, which are easily erodible whereas beds are of sand.
- The floods develop and disappear so rapidly that they have no time to scour the bed.

West flowing Rivers of the Sahyadris (Western Ghats)

- About six hundred small streams originate from the Western Ghats and flow westwards to fall into the Arabian Sea.
- The western slopes of the Western Ghats receive heavy rainfall from the south-west monsoons and are able to feed such a large number of streams.
- Although only about 3% of the areal extent flow swiftly down the steep slope and some of them make waterfalls.
- The **Jog or Gersoppa Falls** (289 m) made by the **Sharavati river** is the most famous waterfall of India.

Ghaggar River – Inland Drainage

- Some rivers of India are not able to reach the sea and constitute inland drainage.
- Large parts of the **Rajasthan desert** and parts of **Aksai Chin** in **Ladakh** have inland drainage.
- The **Ghaggar** is the most important river of **inland drainage**.
- It is a seasonal stream which rises on the lower slopes of the Himalayas and forms boundary between **Haryana and Punjab.**
- It gets lost in the dry sands of Rajasthan near Hanumangarh after traversing a distance of 465 km.
- Earlier, this river was an affluent of the Indus, the dry bed of the old channel is still traceable.
- Its main tributaries are the Tangri, the Markanda, the **Saraswati** and the Chaitanya.
- It contains a lot more water in the rainy season when its bed becomes 10 km wide at places.
- Most of the streams draining western slopes of the Aravalli Range dry up immediately after they enter the sandy arid areas to the west of this range.

1. Indian Monsoons

- The term monsoon has been derived from the Arabic word **mausin** or from the Malayan word **monsin** meaning **'season'**.
- Monsoons are **seasonal winds** (**Periodic Winds** or **Secondary winds**) which **reverse** their direction with the change of season.
- The monsoon is a double system of seasonal winds – They flow from sea to land during the summer (south-west monsoon winds) and from land to sea during winter (north-east monsoon winds).
- Monsoon winds can be called as **land and sea breeze** on a large scale or **convection cells** on a large scale.
- Monsoons are peculiar to Indian Subcontinent, South East Asia, parts of Central Western Africa etc.
- They are more pronounced in the Indian Subcontinent compared to any other region.
- **India, Indonesia, Bangladesh, Myanmar etc. receive most of the annual rainfall during south-west monsoon season whereas South East China, Japan etc., during north-east rainfall season**.

- South-west monsoons bring intense rainfall to most of the regions in India and **north-east monsoons bring rainfall to mainly south-eastern coast** of India (Southern coast of Andhra Pradesh and the coast of Tamil Nadu).
- South-west monsoons are formed due to intense low-pressure system formed over the Tibetan plateau.
- North-east monsoons are associated with high-pressure cells over **Tibetan** and **Siberian plateaus.**

Factors responsible for south-west monsoon formation

- Intense heating of Tibetan plateau during summer months.
- Permanent high-pressure cell in the South Indian Ocean (east to north-east of Madagascar in summer).

Factors that influence the onset of south-west monsoons

- Above points +
- Subtropical Jet Stream (STJ).
- Tropical Easterly Jet (African Easterly Jet).
- Inter Tropical Convergence Zone.

Factors that influence the intensity of south-west monsoons

- **Strengths of Low pressure over Tibet and high pressure over the southern Indian Ocean.**
- **Somali Jet (Findlater Jet).**
- **Somali Current (Findlater Current).**
- **Indian Ocean branch of Walker Cell.**
- **Indian Ocean Dipole.**

Factors responsible for north-east monsoon formation

- **Formation and strengthening of high-pressure cells over Tibetan plateau and Siberian Plateau in winter.**
- **Westward migration and subsequent weakening of high-pressure cell in the Southern Indian Ocean.**
- **Migration of ITCZ to the south of India.**

Theories that tried to explain the Mechanism of Indian Monsoons

- The origin of monsoons is not fully understood.
- There are several theories that tried to explain the mechanism of monsoons.

Classical Theory

- The first scientific study of the monsoon winds was done by **Arab traders**.
- Arab traders used the sea route to carry out the trade with India and monsoon patterns were of prime importance for them.
- In the tenth century, **Al Masudi**, an Arab explorer, gave an account of the **reversal of ocean currents and the monsoon winds** over the north Indian Ocean.
- In the seventeenth century, Sir Edmund Halley explained the monsoon as resulting from **thermal contrasts** between continents and oceans due to their differential heating.

Indian Monsoons – Classical Theory: Sir Edmund Halley's Theory

This theory considers Indian Monsoons as **Land and Sea Breeze on a large scale**.

Summer Monsoon

- In summer the sun's apparent path is vertically over the Tropic of Cancer resulting in high temperature and low pressure in Central Asia.
- The pressure is sufficiently high over the Arabian Sea and Bay of Bengal. Hence winds flowed from Oceans flow towards landmass in summer.
- This air flow from sea to land bring heavy rainfall to the Indian subcontinent.

Winter Monsoon

- In winter the sun's apparent path is vertically over the Tropic of Capricorn.
- The northwestern part of India grows colder than Arabian Sea and Bay of Bengal and the flow of the monsoon is reversed.

Drawbacks

- The monsoons do not develop equally everywhere on earth, and the thermal concept of Halley fails to explain the intricacies of the monsoons such as the **sudden burst** of monsoons, **delay** in onset of monsoons sometimes, etc.

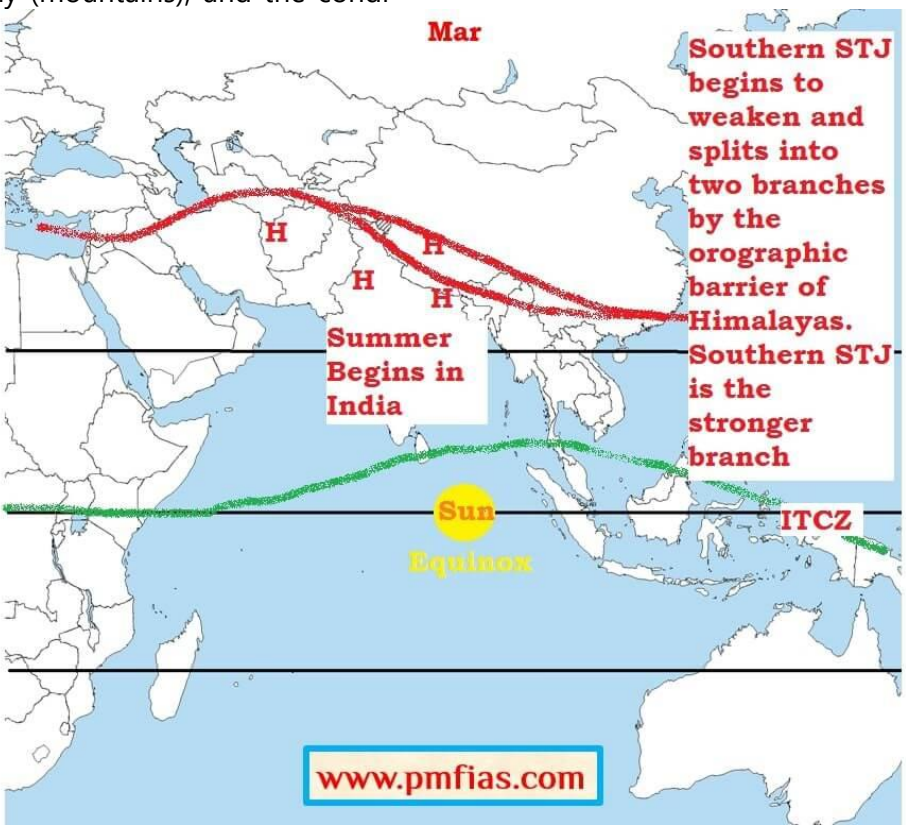
1.2 Mechanism of Indian Monsoons – Based on Modern Theories

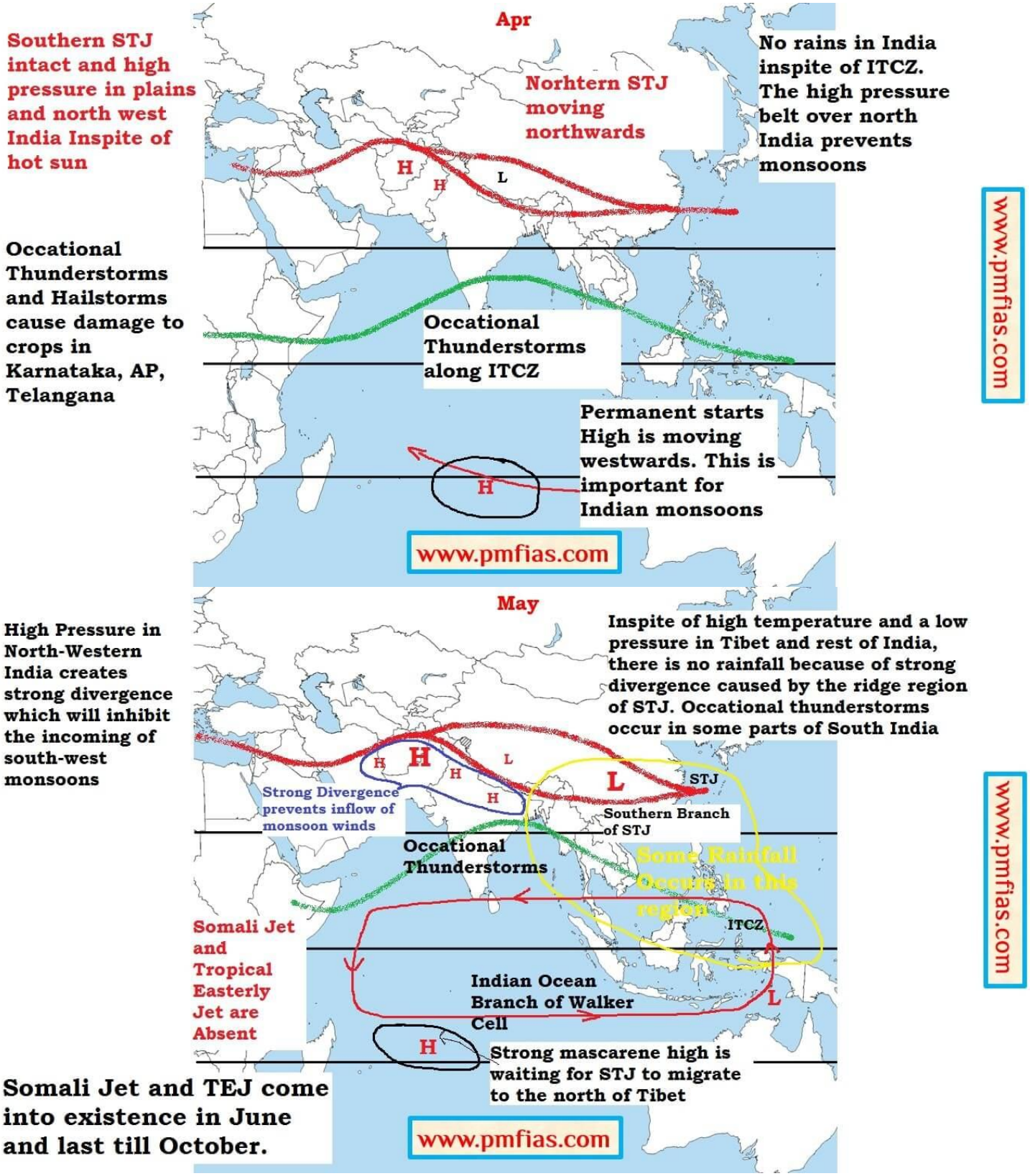
Modern Theories

- Besides differential heating, the development of monsoon is influenced by the shape of the continents, orography (mountains), and the conditions of **air circulation in the upper troposphere (jet streams).**

March to May

- As the summertime approaches, there is increased solar heating of the Indian subcontinent and the Tibetan Plateau.
- **During March to May, the building up of the monsoon cell is blocked by the STJ** which tends to blow to the south of the Himalayas.
- Northwest India and Plains region are occupied by Subtropical High-Pressure Belt. **This high-pressure belt undermines the influence of low-pressure cell over Tibet**.
- **As long as the STJ is in this position the development of summer monsoons is inhibited (the high-pressure belt stays over north India)**.





Between Late May and Early June

- In the peak summer months (25th of May – 10th of Jun), with the apparent northward movement of the sun, the southern branch of the Sub-Tropical Jetstream (STJ), which flows to the south of the Himalayas, **shifts to the north of the Himalayas**.
- When the sun's position is about to reach the Tropic of Cancer (June), the STJ shifts to the

north of the Tibetan Plateau (1st of Jun – 20th of June).

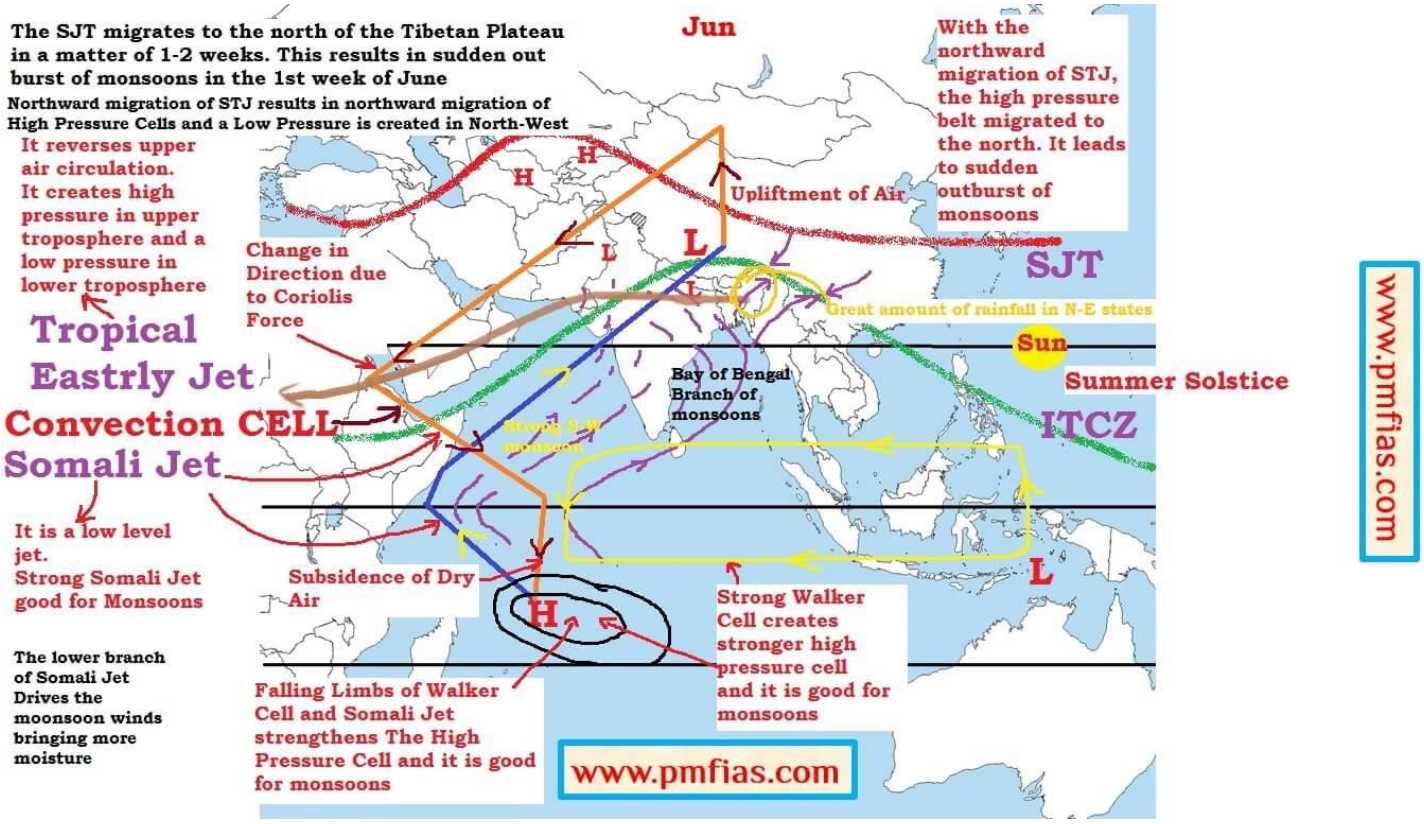
- **The ITCZ is close to its peak position over the Tibetan Plateau**.
- The altitude of the mountains initially disrupts the jet, but once it has cleared the summits, it is able to reform over central Asia.
- Its movement towards the north is one of the main features associated with the onset of the monsoon over India.

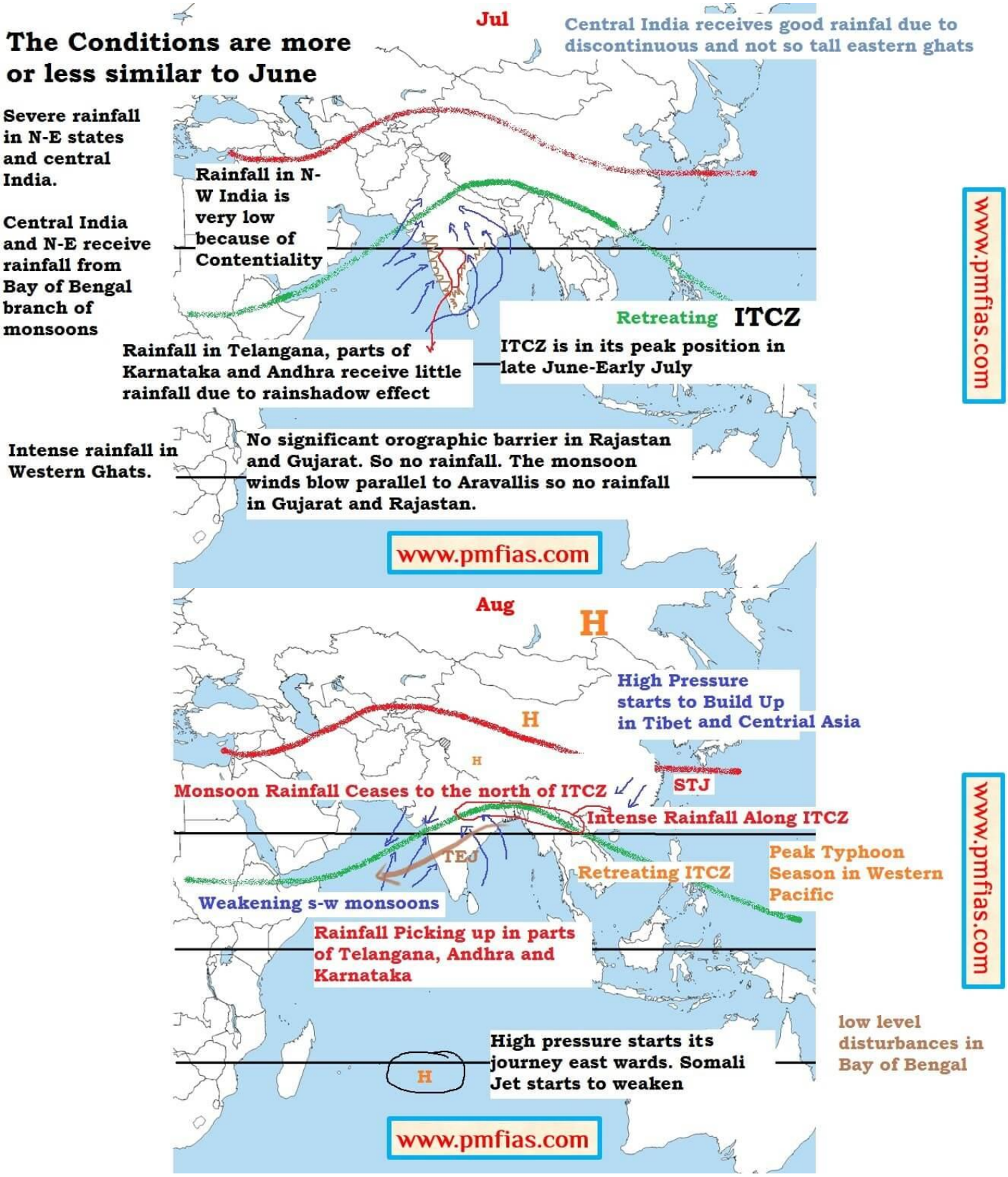
The onset of Monsoons (1st or 2nd week of June)

- **With the northward shift of STJ, an Easterly Jet is formed over the Indian plains**. It generally forms in the **first week of June and lasts till late October**.
- It can be traced in the upper troposphere right up to the west coast of Africa.
- The northward shift of STJ and ICTZ **moves the subtropical high-pressure belt to the north of the Tibetan Plateau,** and **the Easterly Jet creates a low-pressure region in the Indian plains** (Easterly Jet creates anticyclonic conditions in upper troposphere).
- With the STJ out of the way (high-pressure belt migrates to the north of Tibet) the **subcontinental monsoon cell develops very quickly indeed, often in a matter of a few days**.
- The low pressure in the northern plains coupled with the intense low of the Tibetan Plateau leads to the sudden onset of south-west monsoons (1st of Jun – 20th of June).
- The **monsoon cell** is situated between the Indian Ocean (North of Madagascar) (High-Pressure Cell) and Tibetan plateau (Low-Pressure Cell).

Rainy season

- **The sub-tropical easterly jet fluctuates between the plains region of India and peninsular India varying the intensity of rainfall from location to location**.
- Warmth and moisture are fed into the cell by a lower level tropical jet stream **(Somali Jet)** which brings with its air masses laden with moisture from the Indian Ocean.




Jul
Central India receives good rainfal due to discontinuous and not so tall eastern ghats
The Conditions are more or less similar to June
Severe rainfall in N-E states and central India.
Central India and N-E receive rainfall from Bay of Bengal branch of monsoons
Rainfall in N-W India is very low because of Contentiality
Retreating ITCZ
ITCZ is in its peak position in late June-Early July
Rainfall in Telangana, parts of Karnataka and Andhra receive little rainfall due to rainshadow effect
Intense rainfall in Western Ghats.
No significant orographic barrier in Rajastan and Gujarat. So no rainfall. The monsoon winds blow parallel to Aravallis so no rainfall in Gujarat and Rajastan.
www.pmfias.com
Aug
H
High Pressure starts to Build Up in Tibet and Centrial Asia
Monsoon Rainfall Ceases to the north of ITCZ
STJ
Intense Rainfall Along ITCZ
TEJ
Peak Typhoon Season in Western Pacific
Retreating ITCZ
Weakening s-w monsoons
Rainfall Picking up in parts of Telangana, Andhra and Karnataka
low level disturbances in Bay of Bengal
High pressure starts its journey east wards. Somali Jet starts to weaken
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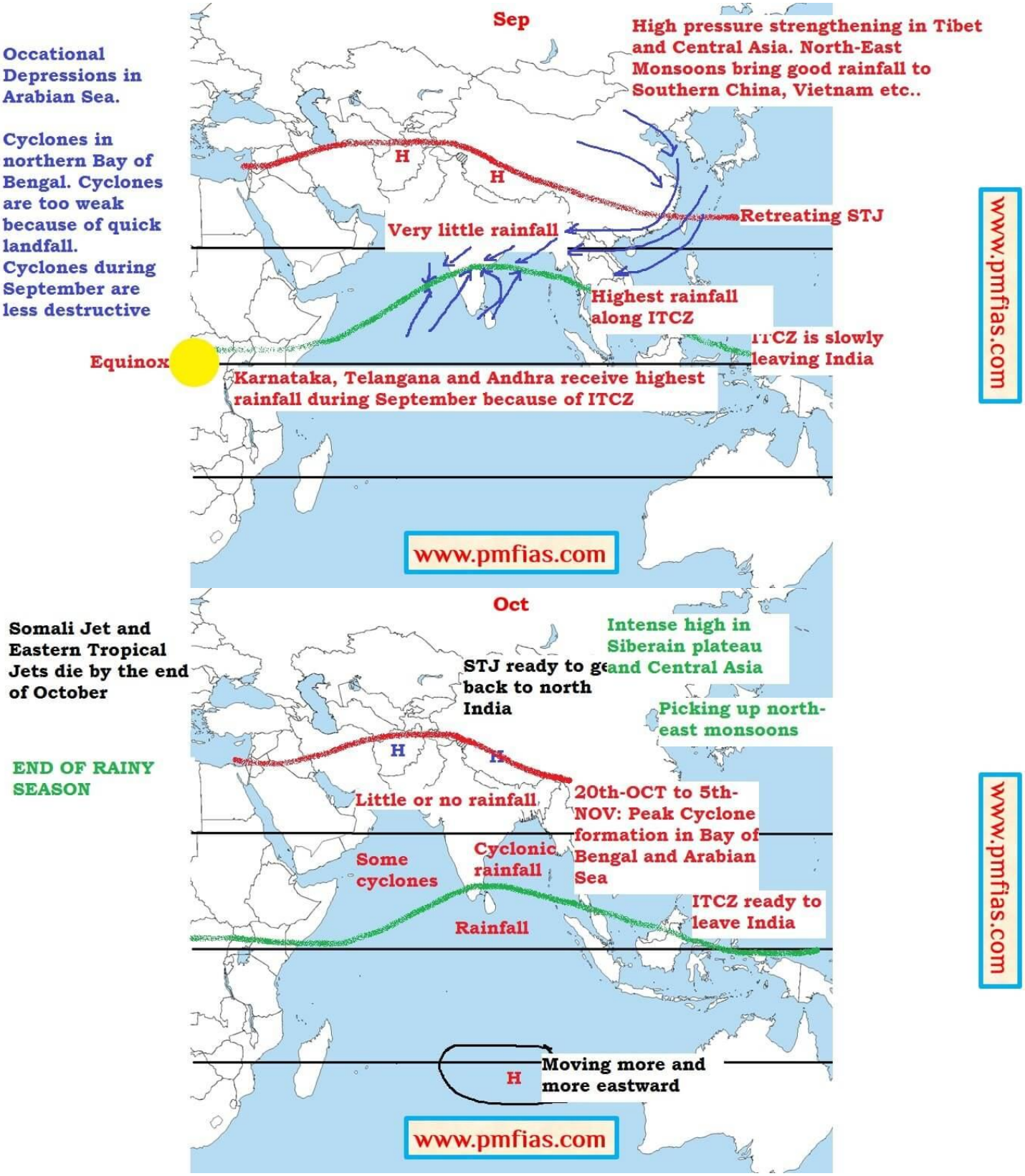
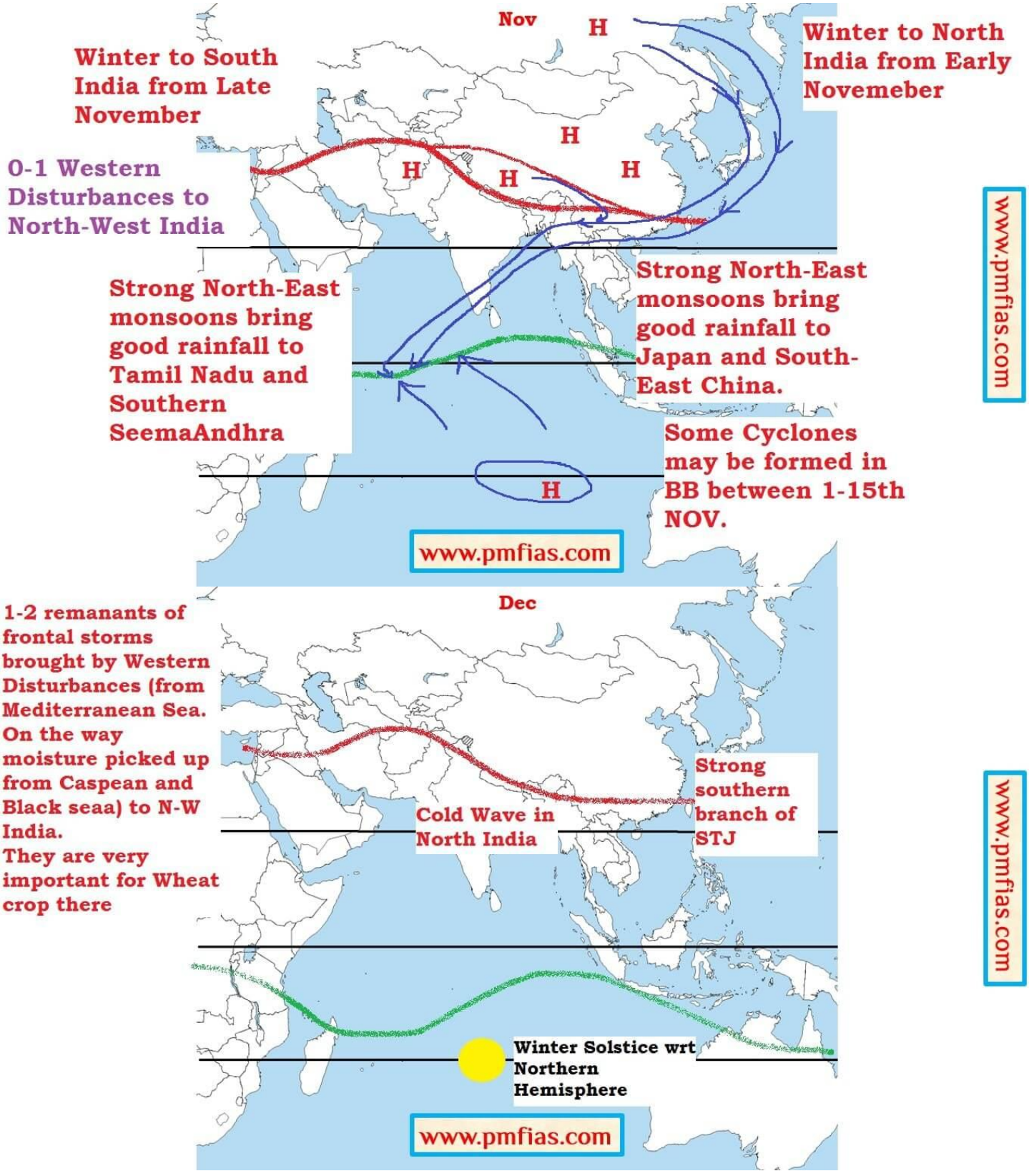
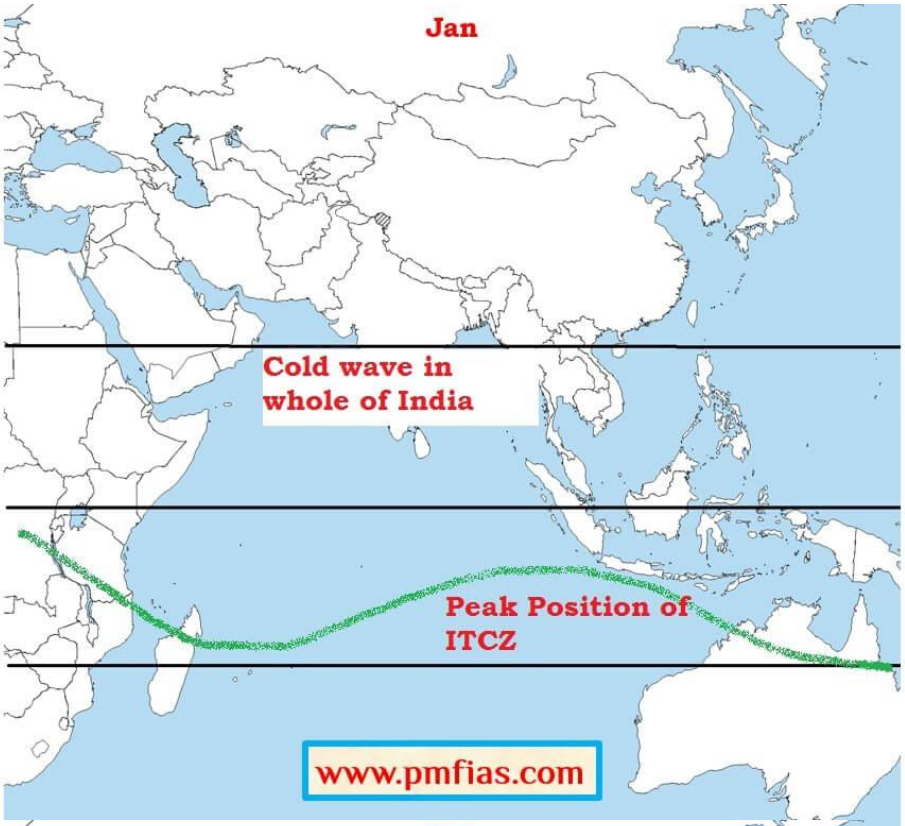
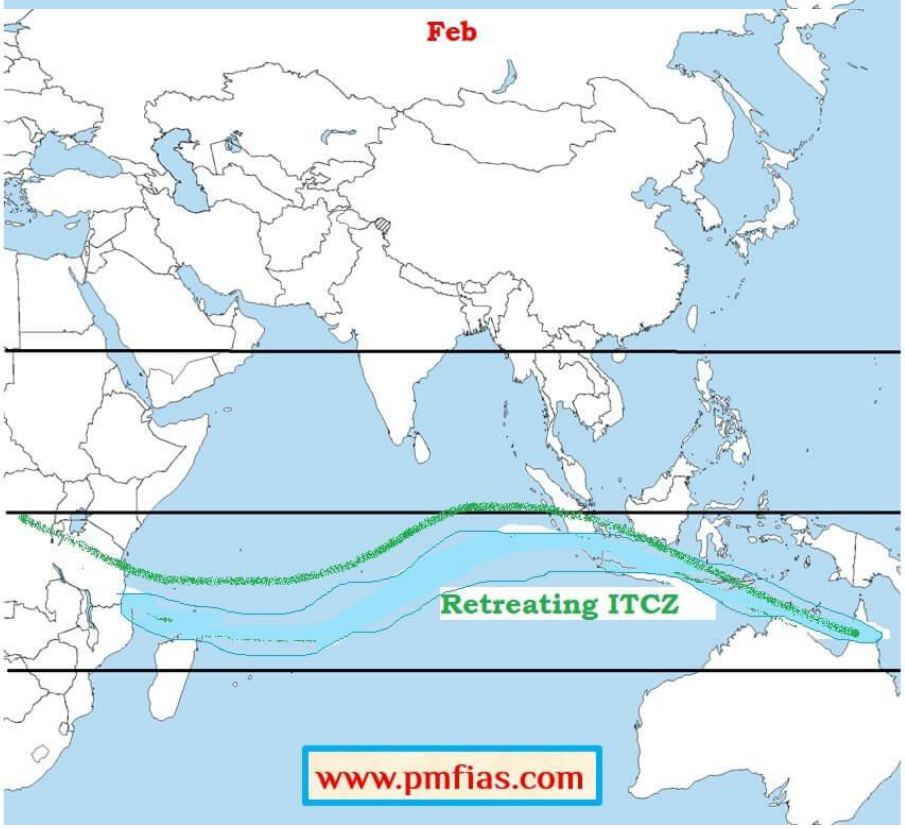




SIMILAR TO DECEMBER



Similar to DEC and JAN



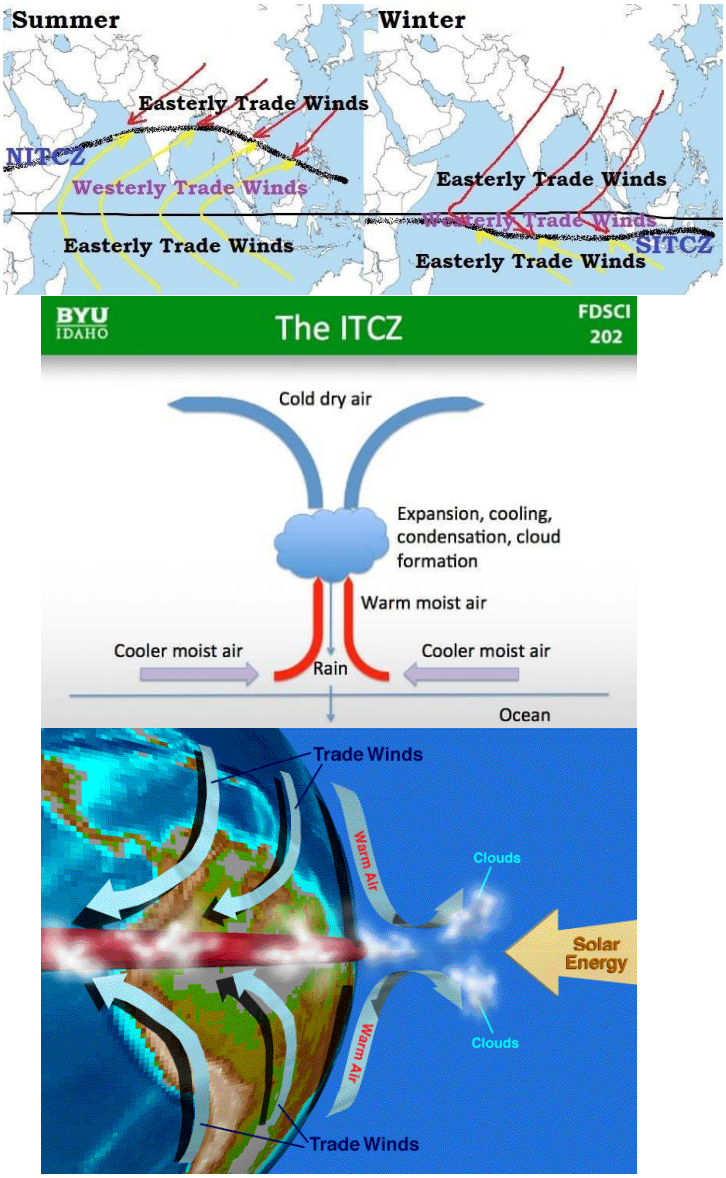
The end of Monsson season

- The end of the monsoon season is brought about when the atmosphere over the Tibetan Plateau begins to cool (August – October), this enables the **STJ to transition back across the Himalayas**.
- With the southward shift of ITCZ, **subtropical high-pressure belt returns to the Indian plains, and the rainfall ceases**.

- This leads to the formation of an **anticyclonic winter monsoon cell typified by sinking air masses over India and relatively moisture free winds that blow seaward**.
- This gives rise to relatively settled and dry weather over India during the winter months.

Indian Monsoons – Role of ITCZ (Inter-Tropical Convergence Zone)

- The southeast trade winds in the southern hemisphere and the northeast trade winds in the northern hemisphere meet each other near the equator.
- The meeting place of these winds is known as the **Inter-Tropical Convergence Zone (ITCZ).**



Inter-Tropical Convergence Zone (ITCZ)

- This is the region of ascending air, **maximum clouds** and **heavy rainfall**.
- The location of ITCZ **shifts** north and south of the equator with the change of season.
- In the summer season, 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 the southwest to a northeast direction under the influence of **Coriolis force**.
- These displaced trade winds are called **south-west monsoons** when they blow over the Indian sub-continent.
- The front where the south-west monsoons meet the north-east trade winds is known as the **Monsoon Front (ITCZ). Rainfall occurs along this front.**
- In 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 (maximum rainfall)**.
- The seasonal shift of the ITCZ has given the concept of Northern Inter-Tropical Convergence Zone (NITCZ) in summer (July – rainy season) and Southern Inter-Tropical Convergence Zone (SITCZ) in winter (Jan – dry season).
- **NITCZ is the zone of clouds and heavy rainfall** that affect India.

Indian Monsoon Mechanism – Jet Stream Theory

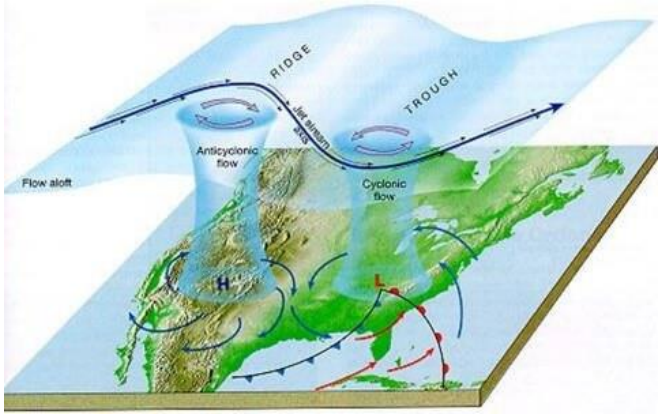
Indian Monsoons – Modern theory: Air Mass Theory

- According to this theory, the monsoon is simply a **modification of the planetary winds of the tropics.**
- The theory is based on the migration of ITCZ based on seasons.

Indian Monsoon Mechanism – Modern Theory: Jet Stream Theory.

- Jet stream Theory is the latest theory regarding the origin of the monsoons.

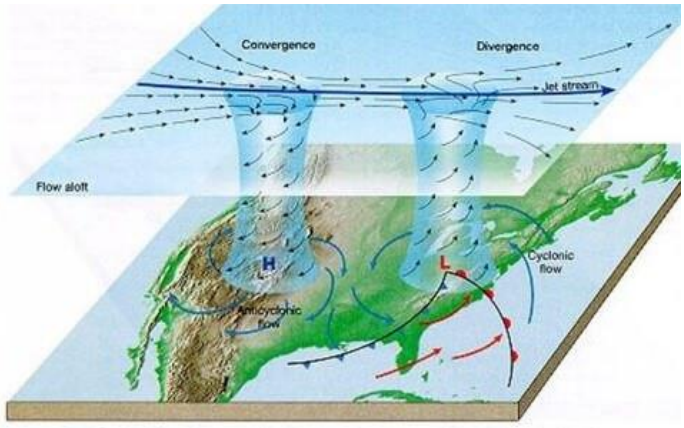
- To understand how Jet streams, affect Indian monsoons, we need to know the basic mechanism of Jet Stream induced weather conditions.



Trough and Ridge of a Jet Stream

How Jet Streams Affect Weather?

- Jet streams have distinct **peaks (ridges)** and **troughs.**
- Ridges occur where the warm air mass pushes against the cold air mass. Troughs occur where cold air mass drops into warm air.
- The **region on earth below the trough is at low pressure** and the region **below ridge is at high pressure**.
- This condition occurs due to the weakening of jet stream due to lesser temperature contrast between sub-tropics and temperate region (our concern is STJ only).
- Usually, the **trough region (the region exactly below the jet stream trough) creates a cyclonic condition (low pressure)** at the surface of earth whereas the **ridge regions creates an anticyclonic condition**.



Jet Streak

- These ridges and troughs give rise to **jet streaks** which are also responsible for cyclonic and anticyclonic weather conditions at the surface.
- The winds leaving the jet streak are rapidly **diverging**, creating a lower pressure at the upper level (Tropopause) in the atmosphere.
- The air below rapidly replaces the upper outflowing winds. This, in turn, creates the **low pressure at the surface**.
- This surface low pressure creates conditions where the surrounding surface winds rush inwards.
- The **Coriolis effect** creates the cyclonic rotation (cyclonic vortex) that is associated with depressions (low-pressure cells).
- The winds entering the jet streak are rapidly converging because of the high pressure at the upper level (Tropopause) in the atmosphere.
- This convergence at upper troposphere leads to divergence (high pressure) at the surface (anticyclonic condition).
- The Coriolis effect creates the anticyclonic rotation that is associated with **clear weather.**

But how does this mechanism of jet streams influence Indian Monsoons?

Indian Monsoon Mechanism – Role of Sub-Tropical Jet Stream (STJ)

- **Sub-Tropical Jet stream plays a significant role in both hindering the monsoon winds as well as in quick onset of monsoons**.

STJ – Sub-Tropical Jet Stream

- The sub-tropical Jet stream is a narrow band of fast moving air flowing from **west to east (Westerlies).**
- STJ in northern hemisphere flows between 25° to 35° N in the upper troposphere at the height of about 12-14 km (the height of each portion of the jet stream varies when there is meandering. Their path is sometimes influenced by the Greater Himalayas).

- The wind speeds in a westerly jet stream are commonly 150 to 300 kmph with extreme values reaching 400 kmph.

The burst of monsoons depends upon the upper air circulation which is dominated by STJ.

Seasonal Migration of Sub-Tropical Jet Stream – STJ

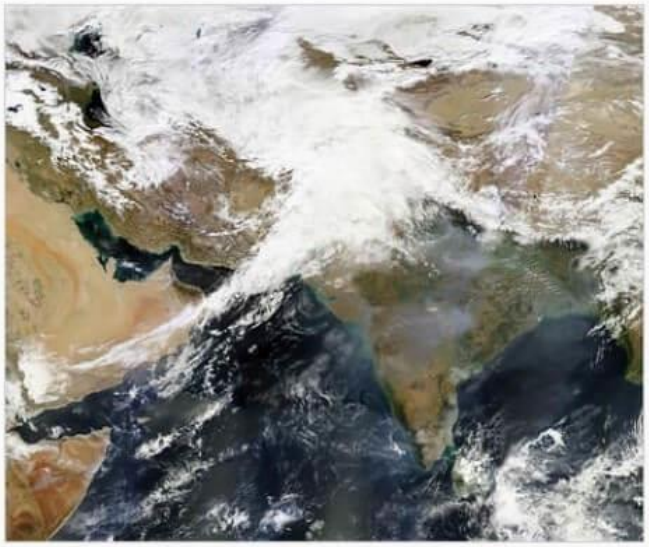
- In winter STJ flows along the southern slopes of the Himalayas, but in summer it shifts northwards, rather dramatically, and flows along the northern edge of Himalayas in early June and late summer (July-August) along the northern Tibetan Plateau.
- The periodic movement of the Jet stream is often the indicator of the onset (STJ shits to the north of Himalayas in a matter of days) and subsequent withdrawal (STJ returns to its position – south of Himalayas) of the monsoon.
- Northward movement of the subtropical jet is the first indication of the onset of the monsoon over India.

Sub-Tropical Jet Stream – STJ in Winter

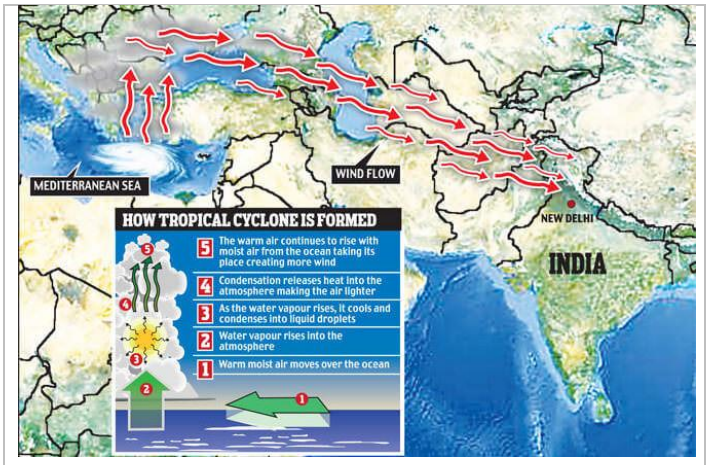
- Westerly jet stream blows at a very high speed during winter over the sub-tropical zone.
- This jet stream is **bifurcated** by the Himalayan ranges (physical barrier) and Tibetan Plateau (thermal barrier).
- The two branches reunite off the east coast of China.
- The northern branch of this jet stream blows along the northern edge of the Tibetan Plateau.
- The southern branch blows to the south of the Himalayan ranges along 25° north latitude.
- A **strong latitudinal thermal gradient (differences in temperature)**, along with other factors, is responsible for the development of southerly jet.
- The southern branch is stronger, with an average speed of about 240 kmph compared with 70 to 90 kmph of the northern branch.
- **Air subsiding beneath this upper westerly current gives dry out blowing northerly winds from the subtropical anticyclone over north-western India and Pakistan**.

Western Disturbances

- Meteorologists believe that the **southern branch of jet stream** exercises a significant influence on the winter weather conditions in India.
- The **southern branch of the jet stream** is responsible for steering of the **western depressions (Western Disturbances)** from the Mediterranean Sea.
- These **depressions are residual frontal cyclones** which move at the height of 2000 meters from the mean sea level. On the way, they pick up moisture from the Caspian Sea and the Black Sea.
- On an average, 4 to 6 cyclonic waves reach north-western India between October and April each year.
- Some of the depressions continue eastwards, redeveloping in the zone of jet stream confluence about 30° N, 105° E (near the east coast of China).



Original – A strong Western Disturbance affecting northern India, Pakistan and Afghanistan. Strong Western Disturbances in winter like the one pictured bring moderate to heavy rain in low-lying areas and heavy snow to mountainous areas of the Indian Subcontinent.



Path of Western Disturbances

Weather associated with Western Disturbances

- The arrival of these temperate storms (remnants of temperate cyclones) (western disturbances) causes **precipitation** leading to an **abrupt decrease in air temperature** over North-West India.
- **Winter rain and heat storms in north-western plains, occasional heavy snowfall in hilly regions and cold waves in the whole of northern plains are caused by these disturbances**.

Importance of Western Disturbances

- The western disturbances affect weather conditions during the winter season up to Patna (Bihar) and give occasional rainfall which is **highly beneficial for the standing rabi crops (wheat, barley, mustard, gram, lentil, etc.).**

Why there are no south-west monsoons during winter?

- **Reason 1:** ITCZ has left India (the winds that blow over India are mostly offshore — land to land or land to the ocean — so they carry no moisture).
- **Reason 2:** During winter, the southern branch of STJ is strong and is to the south of Himalayas. The ridge of the jet lies over north-western India and is associated with **strong divergence of winds and creates a high-pressure region** (sub-tropical high-pressure belt) over entire north India. (This is how the mechanism of jet streams influence Indian Monsoons in winter season)
- **Reason 3:** There is already a strong high pressure over Tibet. (High Pressure due to STJ + High Pressure over Tibet = strong divergence = no rainfall)

Sub-Tropical Jet Stream – STJ in Summer

- With the beginning of summer in March, the STJ (upper westerlies) start their northward march.
- The southerly branch of STJ remains positioned south of Tibet, although weakening in intensity.
- The weather over northern India becomes hot, dry and squally due to larger incoming solar radiation and hot winds like the **loo.**
- Over India, the **Equatorial Trough (ITCZ)** pushes northwards with the weakening of the STJ (upper westerlies) south of Tibet, but the **burst of the monsoon does not take place until the upper-air circulation has switched to its summer pattern**.
- **By the end of May, the southern jet breaks and later it is diverted to the north of Tibet Plateau, and there is a sudden burst of monsoons (the ridge moves northwards into Central Asia = high pressure over north-west India moves northwards into Central Asia = makes way for south-west monsoon winds).**
- **An Easterly jet emerges over peninsular India with the northward migration of STJ.**
- The upper air circulations are reversed with the emergence of Easterly jet (convergence in upper layers is replaced by divergence == divergence in lower layers is replaced with convergence == high pressure at lower layers is replaced by low-pressure system).
- The easterly winds become very active in the upper troposphere, and they are associated with westerly winds in the lower troposphere (south-west monsoon winds).
- Western and eastern jets flow to the north and south of the Himalayas respectively. The eastern jet becomes powerful and is stationed at 15° N latitude.

- This results in more active south-west monsoon and heavy rainfall is caused.

Why no south-west monsoons in March-May (summer)?

- There is good sun's insolation from March-May but still, there are no s-w monsoons.

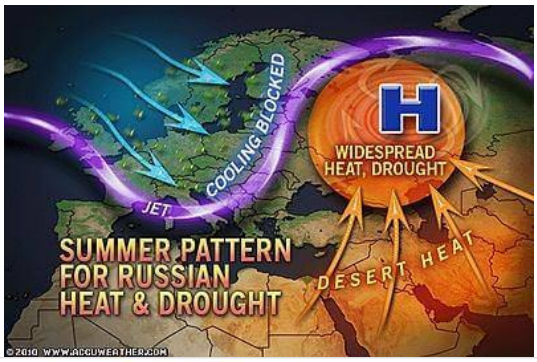
Reason: The ridge region of the Southern branch of STJ creates strong divergence (high pressure) in north-west India. The diverging air blocks incoming winds and prevents strong convergence of winds along ITCZ.

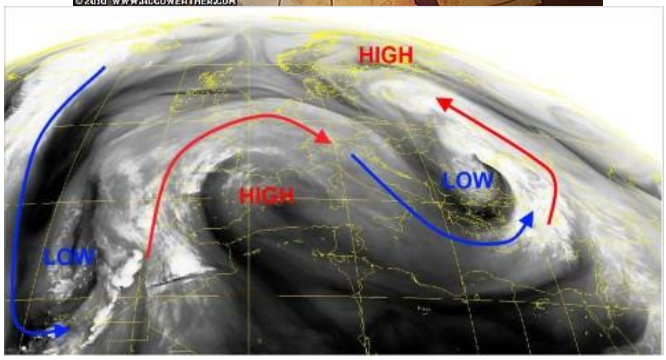
- During the summer season in the Northern Hemisphere, low-pressure areas develop at the ground surface near Peshawar (Pakistan) and north-west India due to intense heating of ground surface during April, May, and June.
- As long as the position of the upper air jet stream is maintained above the surface low pressure (to the south of Himalayas), the **dynamic anti-cyclonic conditions persist over north-west India**.
- **The winds descending from the upper air high pressure (because of the ridge of STJ) obstructs the ascent of winds from the surface low-pressure areas, with the result that the weather remains warm and dry.**
- This is why the months of April and May are generally dry and rainless in spite of high temperatures (low pressure on land) and high evaporation.

Cloudburst in Jammu and Kashmir, Himachal Pradesh, Uttarakhand

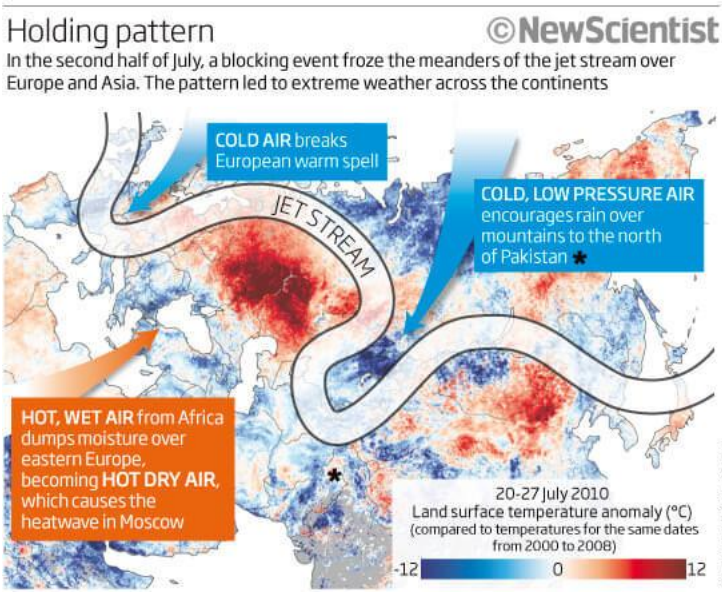
Cloudburst

- A cloudburst is an **intense torrential rainfall** brought by a thunderstorm that lasts for a relatively short duration (few minutes to few hours).
- Cloudburst leads to **flash floods** and causes a lot of damage to life and property.
- Every intense rainfall is not a Cloudburst. Cloudburst specifically occurs when an air mass with **high humidity is struck at a place due to various reasons.**
- In 2010, South-Western strip of Russia (Caucasus Region, Moscow etc.) saw higher than normal temperatures (highest in the last 100 years), and there were **numerous cloudbursts in Jammu and Kashmir**.
- A strong upper-atmospheric high was located over European Russia towards the beginning of summer.
- It diverted the jet stream (meandering of Sub-Tropical Jet Stream) and its rain-giving train (trough) of summer storms farther north than usual, giving much of Southern European Russia drought conditions.
- In addition, southern desert heat from central Asia, the Arabian Peninsula and North Africa began to flow northward, which strengthened this ridge of STJ and tightened its hold over the region.





Trough and Ridge Region in Meandering Sub-Tropical Jet Stream



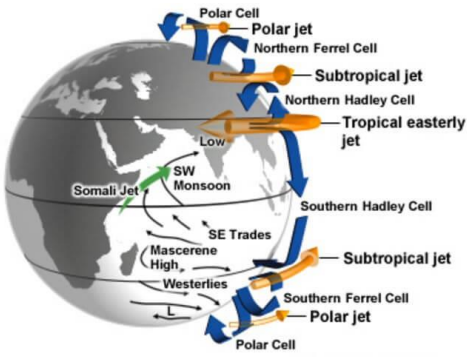
- The stalled system prevented weather systems being drawn across Russia and the obstacle acted as a barrier **trapping hot air to the south and cold air to the north**.
- The consequence of this static mass of hot air was the heat wave that devastated Russia.
- With the jet stream stalled the **Sub-Tropical Jet was unable to transit across the Himalayas** as it would do ordinarily, the monsoon cell to the south, fed by warmer waters in the Indian Ocean, had nowhere to go and as a consequence it deposited vast amounts of rain over Pakistan, Himachal Pradesh and Jammu and Kashmir and this led to extensive flooding.

Indian Monsoons – Role of Tropical Easterly Jet (TEJ) (African Easterly Jet)

- The establishment and maintenance of the TEJ are not fully understood, but it is believed that the jet may be caused by the uniquely **high temperatures and heights** over the Tibetan Plateau during summer.
- The TEJ plays an important role in **kick-starting southwest monsoon**.
- This jet descends over the Indian Ocean (near Madagascar) and intensifies its high-pressure cell so as to move as south-west monsoon.

Tropical Easterly Jet (TEJ)

- There are major high-velocity winds in the lower troposphere called **low-level jets (LLJs).**
- In the tropics, the most prominent of these are the **Somali Jet** and the **African Easterly Jet (Tropical Easterly Jet).**
- The TEJ is a unique and dominant feature of the northern hemispheric summer over southern Asia and northern Africa. The TEJ is **found near between 5° and 20°N**.
- It is fairly persistent in its direction, and intensity from June through the beginning of October.
- TEJ comes into existence quickly after the STJ has shifted to the north of the Himalayas (Early June).
- TEJ flows from east to west over peninsular India at 6 – 9 km and over the Northern African region.
- The formation of TEJ results in the **reversal of upper air circulation patterns (High-pressure switches to low pressure)** and leads to the quick onset of monsoons.
- Recent observations have revealed that the intensity and duration of heating of Tibetan Plateau has a direct bearing on the amount of rainfall in India by the monsoons.
- When the summer temperature of air over Tibet remains high for a sufficiently long time, **it helps in strengthening the easterly jet and results in heavy rainfall in India**.
- **The easterly jet does not come into existence if the snow over the Tibet Plateau does not melt. This hampers the occurrence of rainfall in India.**
- **Therefore, any year of thick and widespread snow over Tibet will be followed by a year of weak monsoon and less rainfall.**



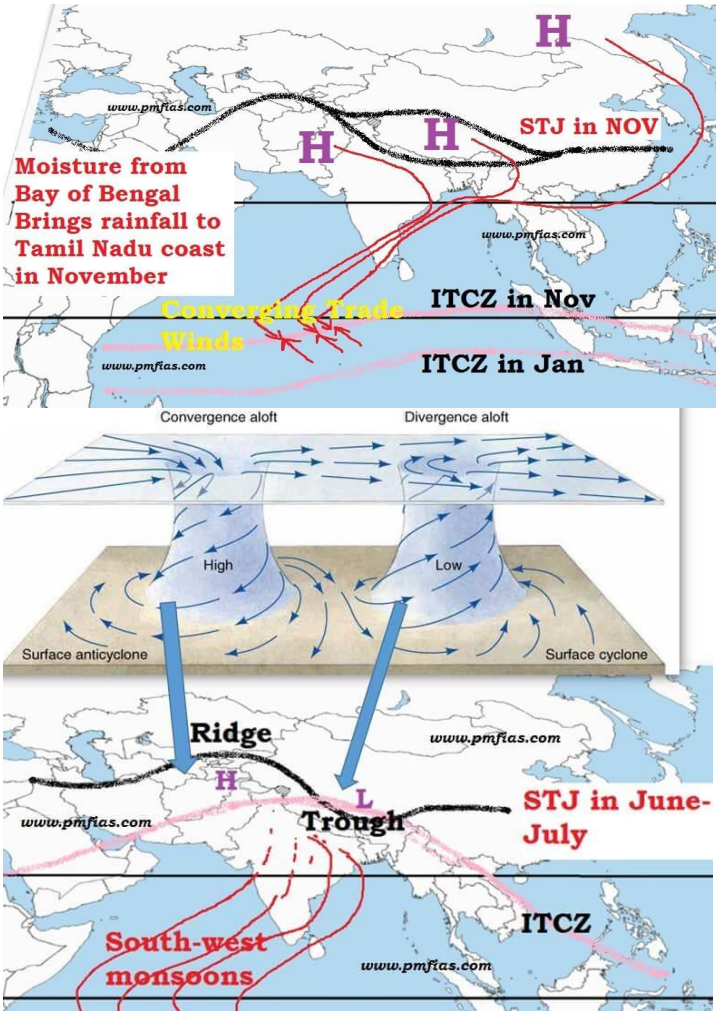
Permanent and Temporary Jet Streams

Indian Monsoons – Role of Tibet

- The Tibetan Plateau is an enormous block of highland acting as a formidable barrier.
- Tibet gets heated in summer and is 2 to 3 °C warmer than the air over the adjoining regions.
- Because the Tibet Plateau is a source of heat for the atmosphere, it generates an area of rising air (**convergence**) (intense low-pressure cell).
- During its ascent, the air spreads outwards in the upper troposphere (divergence) and gradually sinks (subsidence) over the equatorial part of the Indian Ocean (**monsoon cell**).
- It finally approaches the west coast of India as a return current from a south-westerly direction and is termed as equatorial westerlies.
- It picks up moisture from the Indian Ocean and causes rainfall in India and adjoining countries.
- The plateau also affects the atmosphere in two ways: **(a) as a mechanical barrier and (b) as a high-level heat source.**
- At the beginning of June, the subtropical jet stream is completely withdrawn from India and occupies a position along 40° N (to the north of Tibetan Plateau).
- The plateau **accentuates** the northward displacement of the jet stream. Hence the burst of monsoon in June is prompted by the Himalayas and not by the thermally induced low-pressure cell over Tibet.

(Tibetan plateau is responsible for south-west monsoons. But it is the STJ that facilitates sudden outburst of monsoons with its sudden northward migration)

- In the middle of October, the plateau proves to be the most important factor in causing the advance of the jet south of the Himalayas or bifurcating it into two parts.
- In winter Tibetan Plateau cools rapidly and produces a high-pressure cell. (Cyclonic condition over Tibet ceases, and an anticyclonic condition is established).
- **The high-pressure cell over Tibet strengthens N-E monsoons**.

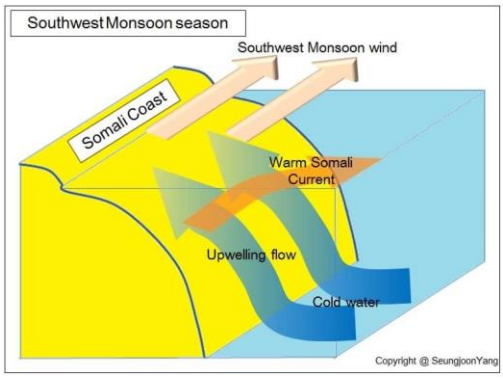


Indian Monsoons – Role of Tibet and STJ

Indian Monsoons – Role of Somali Jet

- The progress of the southwest monsoon towards India is greatly aided by the onset of Somali jet that transits Kenya, Somalia and Sahel.
- It was observed to flow from Mauritius and the northern part of the island of Madagascar before reaching the coast of Kenya at about 3º S.
- **It strengthens permanent high near Madagascar and also helps to drive S-W monsoons towards India at a greater pace and intensity (it intensifies the monsoon cell).**
- **The current in the Arabian Sea associated with the Somali Jet is called as Findlater Current. Its direction is influenced by the monsoon winds. It reverses its direction with the monsoon winds.**

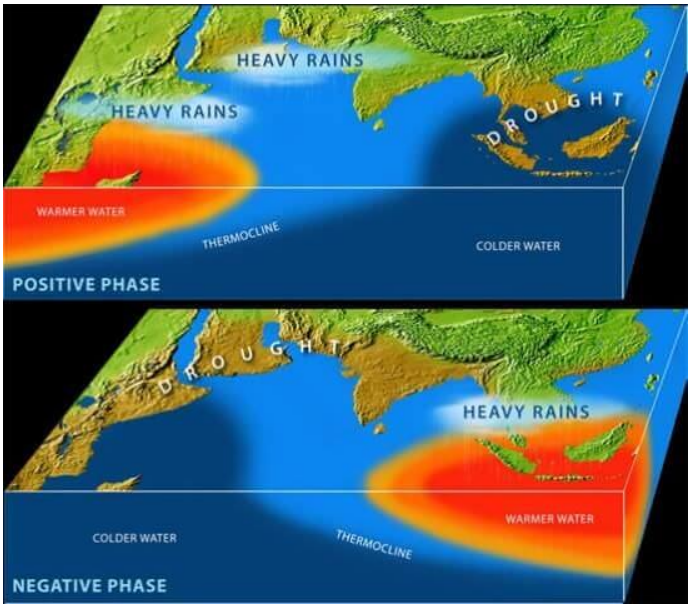
- **Findlater Current** in s-w monsoon season creates a **zone of coastal upwelling near the horn of Africa (good for fishing).**
- **It doesn't have a significant impact on Indian Monsoons because the zone of upwelling is very small unlike in the case of Indian Ocean Dipole**.



Somali Current (Wikipedia)

Indian Monsoons – Role of Indian Ocean Dipole

- Indian Ocean Dipole is a recently discovered phenomena that have a significant influence on Indian monsoons.
- Indian Ocean Dipole is an SST anomaly (Sea Surface Temperature Anomaly – different from normal) that occurs occasionally in Northern or Equatorial Indian Ocean Region (IOR).
- The Indian Ocean Dipole (IOD) is defined by the difference in sea surface temperature between two areas (or poles, hence a dipole) – **a western pole in the Arabian Sea (western Indian Ocean)** and an **eastern pole in the eastern Indian Ocean south of Indonesia**.
- IOD develops in the equatorial region of Indian Ocean from April to May **peaking in October**.
- With positive IOD winds over the Indian Ocean blow from east to west (from Bay of Bengal towards the Arabian Sea).
- This results in the Arabian Sea (the western Indian Ocean near the African Coast) being much warmer and eastern Indian Ocean around Indonesia becoming colder and dry.
- In the negative dipole year, the reverse happens to make Indonesia much warmer and rainier.
- Positive IOD is good for Indian Monsoons as more evaporation occurs in warm water.
- Similar to ENSO, the atmospheric component of the IOD is named as Equatorial Indian Ocean Oscillation (**EQUINOO**) (Oscillation of pressure cells between the Bay of Bengal and the Arabian Sea).
- During the positive phase of the 'Equatorial Indian Ocean Oscillation (EQUINOO),' there is enhanced cloud formation and rainfall in western part of the equatorial ocean near the African coast while such activity is suppressed near Sumatra.



Indian Ocean Dipole

Projects to understand monsoons

ISMEX

- Two more experiments were conducted, jointly, by India and the former USSR in 1973 and 1977, with limited participation from other countries.
- These experiments are known as the Indo-Soviet Monsoon Experiment (ISMEX) and Monsoon-77 respectively.

MONEX

- Data collection effort was made under the aegis of MONEX-1979.
- It was organised jointly by many researching organizations and the World Meteorological Organisation (WMO) under their World Weath-

er Watch (WWW) programme.
- It is so far the largest scientific effort made to understand monsoons.

Details are not necessary. Remember the names. They can be asked in prelims. MONEX was asked in previous papers.

2. Indian Climate

- India's climate closely resembles the climate that of a tropical country although its northern part (north of tropic of cancer) is situated in the **temperate belt.**
- The Indian subcontinent is separated from the rest of Asia by the **lofty Himalayan ranges** which block the **cold air masses** moving southwards from Central Asia.
- As a result, during winters, the northern half of India is warmer by **3°C to 8°C** than other areas located on the same latitudes.
- During summer, due to over the head position of the sun, the climate in the southern parts resemble equatorial dry climate.
- The north Indian plains are under the influence of hot, dry wind called **'loo'** blowing from the **Thar, Baloch and Iranian Deserts**, increasing the temperatures to a level comparable to that of the southern parts of the country.
- Thus, the whole of India, south of the Himalayas can be climatically treated as a tropical country.
- The seasonal reversal of winds in Arabian Sea and Bay of Bengal give India a typical **tropical monsoon climate.**
- Thus, Indian climate, to be precise, is **tropical monsoon type (a distinct wet and dry climate)** rather than just a tropical or half temperate climate.

2.1 Features of Indian Climate

- India has high regional climatic diversity because of its topographical diversity (location, altitude, distance from sea and relief).

Typical Indian Climate

Rainfall

- The climate in most of the regions is characterized by **distinct wet and dry seasons**.
- Some places like **Thar desert, Ladakh have no wet season**.
- Mean annual rainfall varies substantially from region to region.
- **Mawsynram and Cherrapunji** in Meghalaya receive around 1,100 cm of annual rainfall while at Jaisalmer the annual rainfall rarely exceeds 12 cm.
- The Ganga delta and the coastal plains of Odisha see intense rainfall in July and August while the Coromandel Coast (Tamil Nadu coast and Southern AP coast) goes dry during these months.
- Places like Goa, Hyderabad and Patna receive south-west monsoon rains by the first quarter of June while the rains are awaited till early July at places in Northwest India.

Temperature

- Diurnal and annual temperature ranges are substantial.
- **Highest diurnal temperature ranges occur in the Thar desert,** and the **highest annual temperature ranges are recorded in the Himalayan regions**.
- Both diurnal and mean annual temperature ranges are **least in coastal regions**.

- In December, the temperature may dip to –40°C at some places in J&K while in many coastal regions average temperature is 20-25°C.
- Winters are moderately cold in most of the regions while the summers are extremely hot.
- Himalayan regions experience brutal winters while the summers are moderate.

2.2 Factors Influencing Indian Climate

- Latitudinal location
- Distance from the Sea
- The Himalayas
- Physiography
- Monsoon Winds
- Upper Air Circulation
- El Nino and La Nina
- Tropical Cyclones and Western Disturbances

Latitudinal location

- The mainland of India extends between **8°N to 37°N.**
- Areas south of the Tropic of Cancer are in tropics and hence receive high solar insolation.
- The summer temperatures are extreme, and winters temperatures are moderate in most of the regions.
- The northern parts, on the other hand, lie in the warm temperate zone. They receive comparatively less solar insolation.
- But summer is equally hot in north India because of **hot local wind called loo**.
- Winter is very cold due to **cold waves brought by the western disturbances.**
- Some places in Himalayas record low temperatures particularly in winter.
- Coastal regions see moderate climatic conditions irrespective of latitudinal position.

Distance from the Sea

- Coastal regions have a moderate or equable or maritime climate whereas interior locations are deprived of the moderating influence of the sea and experience extreme or continental climate.
- The monsoon winds first reach the coastal regions and hence bring a good amount of rainfall.

Himalayas

- The Himalayas act as a **climatic divide** between India and Central Asia.
- During winter, Himalayas **protect India from cold and dry air masses of Central Asia.**
- During monsoon months these mountain ranges act as an **effective physical barrier for rain-bearing south-west monsoon winds (Orographic Rainfall).**
- **The Himalayas divide the Bay of Bengal branch of monsoon winds into two branches – one branch flowing along the plain regions towards north-west India and the other towards South-East Asia.**
- If the Himalayas were not present, the monsoon winds would simply move into China, and most of north India would have been a desert.

Why rainfall decreases from east to west in plains region (Indus-Ganga Plains)?

- As the monsoon winds move from east to west, the moisture levels decrease due to successive rainfall at each low-pressure regions.
- By the time winds reach western parts of the plains (Delhi, Haryana etc.) all the moisture in the monsoon winds in **exhausted.**

Then how come Haryana and Punjab not deserts like Rajasthan?

- They receive rainfall due to Western Disturbances in winter. (In summer the rainfall is very low.)

Physiography

- Physiography is the most important factor that determines the mean annual rainfall received by a region.

Why are some parts in peninsular India semi-arid?

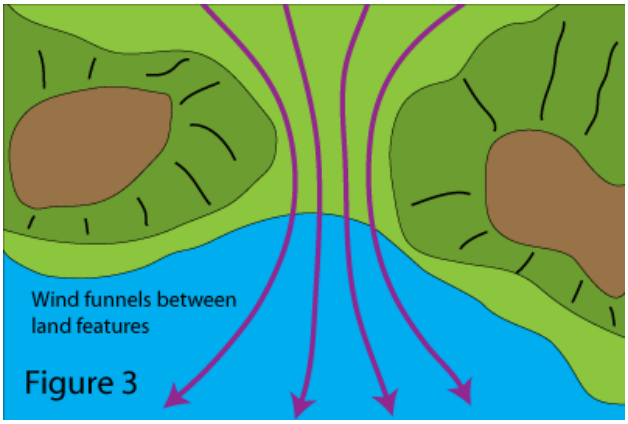
- Places on the **windward side of an orographic barrier receive a great amount of rainfall** whereas **those on the leeward side remain arid to semi-arid due to rain-shadow effect.**
- Example: The south-west monsoon winds from the Arabian sea strike almost **perpendicular** at the Western Ghats and cause copious rainfall in the Western Coastal plain and the western slopes of the Western Ghats.
- On the contrary, vast areas of Maharashtra, Karnataka, Telangana, Andhra Pradesh and Tamil Nadu lie in **rain-shadow or leeward side of the Western Ghats** and receive scanty rainfall.

Why no significant rainfall in Gujarat and Rajasthan? Explain the formation of Thar Desert?

- Monsoons winds flowing in Rajasthan and Gujarat are **not obstructed by any orographic barrier,** and hence these regions receive no rainfall.
- Monsoon winds blow **almost parallel to Aravallis,** and also, they are not of imposing height to cause orographic effect except for some places like **Mount Abu**; hence there is no orographic rainfall.
- **No convection cell or vertical wind movements** arise in Rajasthan and Gujarat: Monsoon winds blow towards low-pressure cells in Tibet, and hence only horizontal wind movements exist in Gujarat and Rajasthan.
- **Sub-tropical high-pressure belt**: In winter the region experiences strong divergence because of the STJ – Sub-Tropical Jet.

How come Cherrapunji and Mawsynram receive abnormally high rainfall?

- **Mawsynram** and **Cherrapunji (both the places in Khasi Hills, Meghalaya)** are the wettest places on earth with mean annual rainfall over 1100 cm.
- Copious rainfall in these places is due to the **funnelling effect** followed by **orographic upliftment** (**Khasi Hills**).
- Funnelling effect: clouds are channelled into a narrow region between mountains and hence the cloud density is extraordinary.



Funnelling Effect

Monsoon Winds

- The most dominating factor of the Indian climate is the 'monsoon winds'.

Important features of Indian Monsoons are

1. **Sudden onset (sudden burst)**
2. **Gradual progress**
3. **Gradual retreat**
4. **Seasonal reversal of winds**

- The complete reversal of the monsoon winds brings about a **sudden change in the seasons.**
- The harsh summer season is suddenly gives way to monsoon or rainy season.
- The south-west monsoons from the Arabian Sea and the Bay of Bengal bring rainfall to the country.
- The north-eastern winter monsoon does not cause much rainfall except along the Coromandel coast (TN coast) after getting moisture from the Bay of Bengal.

Upper Air Circulation

The changes in the upper air circulation over Indian landmass is brought about by Jet streams.

Westerly Jet Stream

- Westerly jet stream blows at a very high speed during winter over the **sub-tropical zone.**

- The southern branch of the jet stream exercises a significant influence on the winter weather conditions in India.
- This jet stream is responsible for bringing **western disturbances** from the Mediterranean region into the Indian sub-continent.
- Winter rain and heat storms in north-western plains and **occasional heavy snowfall** in hilly regions are caused by these disturbances.
- These are generally followed by cold waves in the whole of northern plains.

Easterly Jet Stream

- The reversal in upper air circulation takes place in summer due to the apparent shift of the sun's vertical rays in the northern hemisphere.
- The westerly jet stream is replaced by the easterly jet stream which **owes its origin to the heating of the Tibet plateau**.
- This helps in the **sudden onset of the south-west monsoons**.

Tropical Cyclones and Western Disturbances

- Tropical cyclones originate in the Bay of Bengal and the Arabian Sea and the influence large parts of peninsular India.
- Majority of the cyclones originate in the **Bay of Bengal** and influence the weather conditions during the south-west monsoon season **(low-intensity cyclones).**
- Some cyclones are born during the retreating monsoon season, i.e., in October and November **(high-intensity cyclones)** and influence the weather conditions along the eastern coast of India.
- The western disturbances originate over the Mediterranean Sea and travel eastward under the influence of westerly jet stream.
- They influence the winter weather conditions over most of Northern-plains and Western Himalayan region.

El-Nino, La Nina and ENSO

El Nino

- **Adversely affects monsoon rainfall and cyclogenesis in the Bay of Bengal**.
- **Good for cyclogenesis in the Arabian Sea**.
- Droughts are common during El Nino events due to less monsoonal and cyclonic rainfall.

La Nina

- **Good for monsoons and cyclogenesis in the Bay of Bengal**.
- **Suppressed cyclogenesis in the Arabian Sea**.
- **Floods are common**.

ENSO

- Southern Oscillation is simply the oscillation or alternating positions of low pressure and high-pressure cells over eastern and western Pacific.
- Southern Oscillation coinciding with El Nino is called ENSO or El Nino Southern Oscillation. (SO usually coincides with EL Nino. This is why El Nino is usually referred to as ENSO)
- ENSO = (warm water in eastern Pacific + low pressure over eastern Pacific) + (cool water in western Pacific + high pressure in western Pacific)
- Climatic conditions are same as El Nino.

2.3 Indian Climate – Seasons

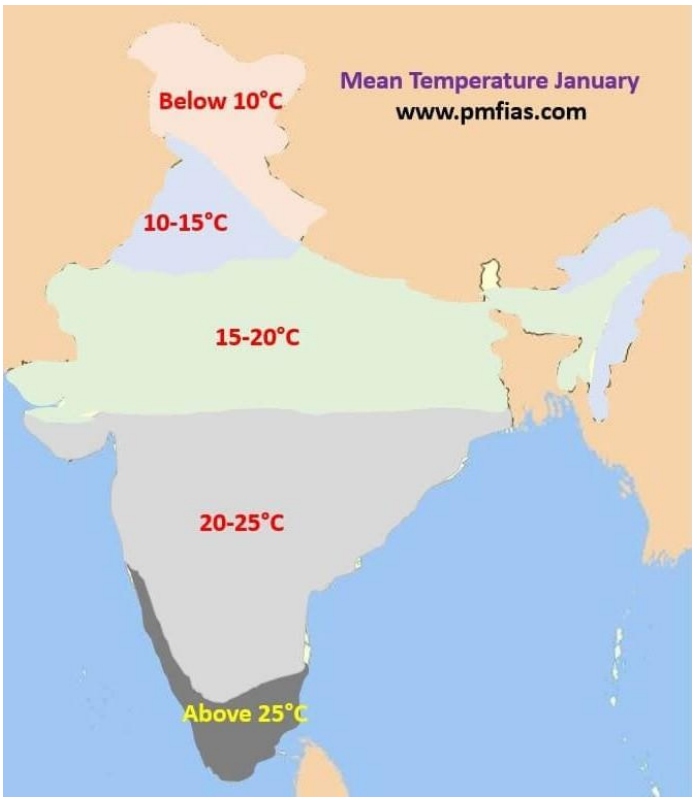
- The cold weather season or winter season,
- The hot weather season or summer season,
- The south-west monsoon season or Rainy season, and
- The season of the retreating monsoon or cool season.

Winter Season in India

- **November to March. January** is the coldest month.
- Sun's apparent path is to the south of the equator.
- **Clear sky, pleasant weather, low temperature, low humidity, high range of**

temperature, cool and slow north-east trade winds.

- The diurnal range of temperature, especially in interior parts of the country, is very high.



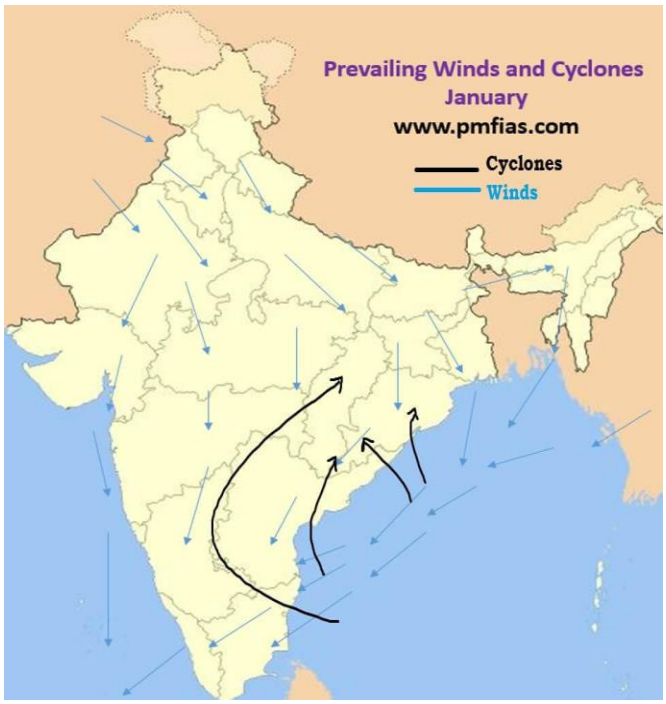
Mean Temperature in January

The temperature in Winter Season

- The isotherm of 20°C runs roughly parallel to the Tropic of Cancer.
- To the south of this isotherm, the temperatures are above 20 °C.
- Here there is no distinctly defined winter weather.
- Some parts of Kerala and Tamil Nadu typically experience temperatures near 30 °C.
- To the north mean temperatures are below 21 °C and the winter weather is distinct.
- The mean minimum temperature is about 5 °C over north-west India and 10 °C over the Gangetic plains.
- **Dras Valley** in Kashmir is the coldest place in India.
- The minimum temperature recorded at Dras was – 45 °C in 1908.

The pressure in Winter Season

- **High air pressure prevails over large parts of north-west India** due to low temperatures coupled with divergence induced by the ridge of the STJ.
- Pressure is comparatively lower in south India.
- The winds start blowing from high-pressure area of the north-west to low-pressure area of the south-east.
- The wind velocity is low due to a low pressure gradient.



Prevailing winds and Cyclones paths in January

Western Disturbances in Winter Season

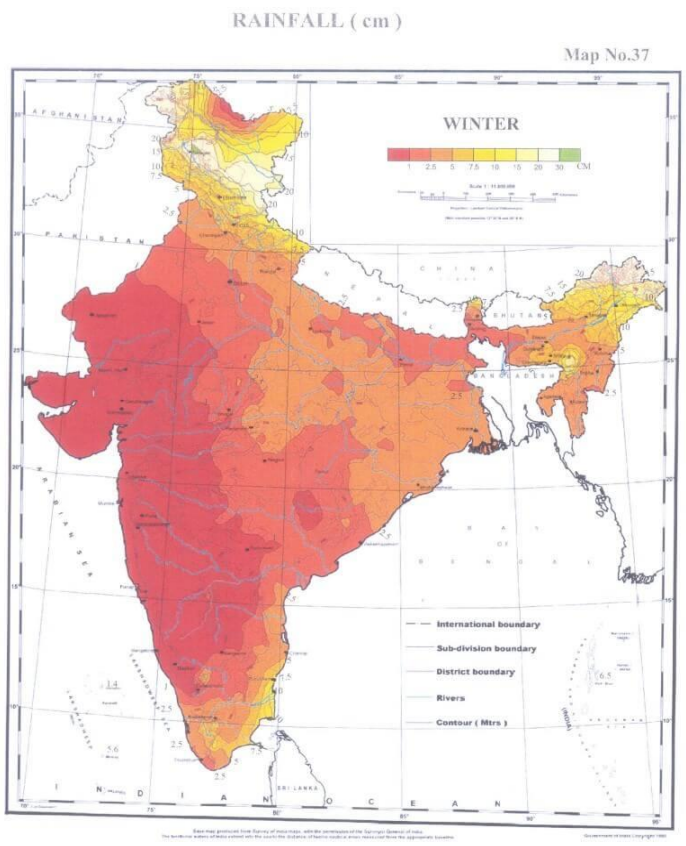
- The spell of fine weather over north-western and northern India is often broken due to the inflow of western disturbances.
- They intensify over Rajasthan, Punjab, and Haryana.
- They move eastwards across the sub-Himalayan belt up to Arunachal Pradesh.
- They **cause light rain in the Indus-Ganga plains and snowfall in the Himalayan belt**.
- After the passage of the disturbance, widespread fog and cold waves lowering the minimum temperature by **5° to 10°C** below normal are experienced.

Tropical Cyclones in Winter Season

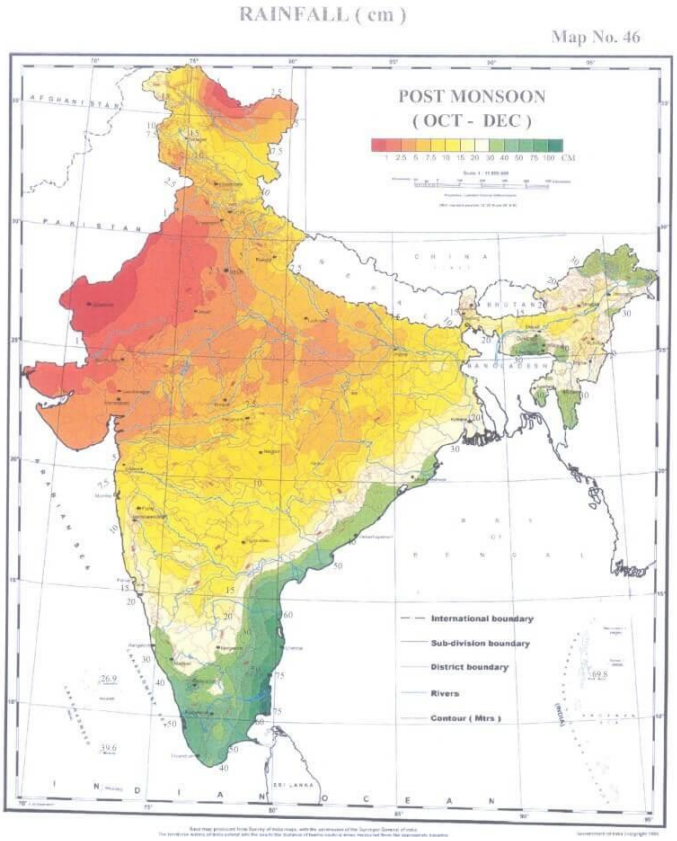
- This is the season of **least tropical cyclone activity**.
- The frequency of tropical cyclones decreases with the advancement of the season.
- This is due to **low sea surface temperature and exit of ITCZ farthest south.**
- The **storms which are born in the Bay of Bengal strike Tamil Nadu and bring heavy rainfall**.
- Some of them cross the southern peninsula over to the Arabian Sea.
- Some storms originate in the Arabian Sea and move towards either north or west.

Precipitation in Winter Season

- The retreating winter monsoons pick up some **moisture while crossing the Bay of Bengal and cause winter rainfall in Tamil Nadu, south Andhra Pradesh, south-east Karnataka and south-east Kerala (Usually in the first weeks of November).**
- Most of it occurs along the south-eastern coast of Tamil Nadu and adjoining parts of Andhra Pradesh.



Precipitation in Winter Season



Precipitation in NE Monsoon Season

- The western disturbances also cause a little rainfall in north-west India.
- The amount of rainfall gradually decreases from the north and north-west to the east (it is opposite in rainy season).
- The north-eastern part of India also gets rainfall during the winter months.

Summer Season in India

- **March to June**.
- High temperature and low humidity are the chief characteristics.
- It is sometimes referred to as the **pre-monsoon period.**

The temperature in Summer Season

- High sun's insolation due to the apparent movement of sun between the equator and the Tropic of Cancer.

- The **southern parts of the country are distinctly warmer in March and April** whereas, **in June, north India has higher temperatures**.
- In March, the highest temperatures occur in the southern parts (40-45 °C).
- In April the highest temperature of about 45 °C is recorded in the northern parts of Madhya Pradesh.
- In May the highest temperature shifts to Rajasthan where temperatures as high as 48 °C may be recorded.
- In June the maximum temperature is in Punjab and Haryana.
- The highest temperatures recorded are **50.5 °C at Alwar** on 10th May 1956 and **50.6 °C at Ganganagar** on 14th June 1935.
- The **highest temperatures are recorded just before the onset of the southwest monsoons** (late May).
- The diurnal range of temperature is also very high. It may be as high as 18°C in some parts.
- The temperatures along the west coast are comparatively lower than those prevailing on the east coast due to the prevailing westerly winds.
- Northern and central parts of India experience heat waves in this season.

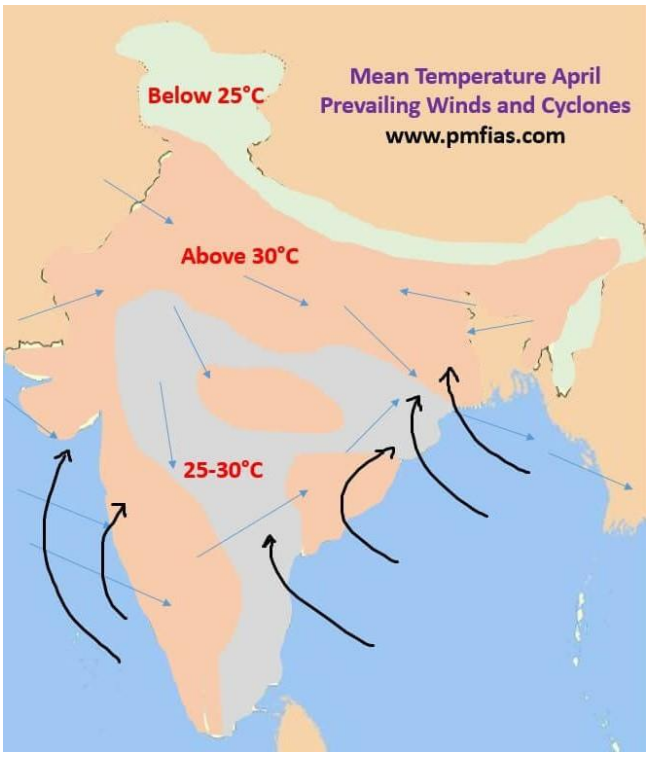
(A heat wave is an abnormally high temperature experienced by a region. A temperature increase of the order of 6° to 7 °C above normal is termed as 'moderate' and 8 °C and more as 'severe' heat wave)

- The heat waves strike by the end of April, and their maximum occurrence is in May.
- Most of the heat waves develop over Rajasthan, Punjab and Haryana (location far away from the sea). From here they spread over Uttar Pradesh and Bihar.
- The strong northwesterly winds (caused due to strong divergence in north-west India) with a long land journey over hot regions check the onward march of the sea breeze over the eastern coastal belt and create heatwave conditions over Odisha and Andhra Pradesh.
- Heat waves are rare over the peninsula south of 13 °N latitude due to maritime conditions prevailing there.

The pressure in Summer Season

- The atmospheric pressure is low all over the country due to high temperature.
- But **strong dynamically induced divergence over north-west India prevents the onset of south-west monsoons**.

Winds in Summer Season



Prevailing winds and Cyclones paths in April

- There is a marked change in the direction and speed of the winds from winter.
- The winds are by and large light and variable.

Loo

- Loo winds originate over **Iranian, Baloch and Thar deserts.**
- In May and June, the high temperature in northwest India builds steep pressure gradient.
- Hot, dust-laden and strong wind known as loo blows.
- Loo normally starts blowing by 9.00 A.M., increases gradually and reaches maximum intensity in the afternoon.
- It blows with an average speed of 30-40 km per hour and persists for days.

Andhis

- The strong dust storms resulting from the convective phenomena are locally known as **andhis (blinding storms).** They move like a solid wall of dust and sand.
- The wind velocity often reaches 50-60 kmph, and the visibility is reduced to a few metres.
- Such dust storms are common in Rajasthan, Haryana, Punjab, Jammu region, Delhi, Uttar Pradesh, Bihar and Madhya Pradesh.
- They are short-lived. The squall and showers which follow these storms bring down the temperature sharply temporarily.

Frontal Thunderstorms in Summer Season

- The strong convectional movements related to the westerly jet stream lead to thunderstorms in the **eastern and north-eastern part of the country**.
- They normally originate over Chota Nagpur plateau and are carried eastwards by westerly winds.
- The areas with the highest incidence of thunderstorms are Assam, Arunachal Pradesh, Nagaland, Mizoram, Manipur, Tripura, Meghalaya, West Bengal and the adjoining areas of Odisha and Jharkhand.

Norwesters and Thunderstorms in Summer Season

- In West Bengal and the adjoining areas of Jharkhand, Odisha and Assam, the direction of squalls is mainly from the northwest, and they are called **norwesters.**
- They are often very violent with squall speeds of 60 to 80 km per hour.
- The rainfall brought by the norwesters is known as the **spring storm showers.**
- **Hailstones** sometimes accompany showers and occasionally attain the size of a golf ball.
- They cause heavy damage to standing crops, livestock and even lead to loss of human lives.
- However, they are, sometimes, useful for tea, jute and rice cultivation. In Assam, these storms are known as **Tea Showers and Barodoli Chheerha.**
- The period of maximum occurrence of these storms is the month of Vaisakh (mid-March to mid-April), and hence, they are locally known as **Kalabaisakhis,** the black storms or a mass of dark clouds of Vaiasakha.

Convectional Thunderstorms in Summer Season

- In the south, the thunderstorms occur in Kerala and adjoining parts of Karnataka and Tamil Nadu, particularly during evenings and nights.
- In Karnataka, they are called **cherry blossoms or blossom showers** due to their effect on the coffee plantations.
- Such showers are called **mango showers** in Kerala, Tamil Nadu and Andhra Pradesh because they are very beneficial to mango crop.

Western Disturbances in Summer Season

- Their frequency and intensity gradually decrease with the advancement of summer.
- Approximately 4, 3 and 2 western disturbances visit north-west India in March, April and May respectively.
- They cause snowfall in higher reaches of the Himalayas.

Tropical Cyclones in Summer Season

- Tropical cyclones originate in the Bay of Bengal and the Arabian Sea.
- A few cyclones are formed in the Bay of Bengal in the month of March, but they do not affect the mainland of India.
- Their frequency rises steeply in April, and the number of cyclones originating in May is more than double than those originating in April.
- About **three-fourths** of the tropical cyclones are born in the Bay of Bengal, and the rest originate in the Arabian Sea.
- Most of the depressions in April originate to the south of 10 °N while those originating in May are born to the north of this latitude.

- Most of the storms of this season initially move west or north-west, but later they recurve northeast and strike **Bangladesh and the Arakan Coast of Myanmar.**
- Very few hit the Indian coast while some dissipate over the sea itself.
- The coastal areas of Bangladesh and Arakan Coast of Myanmar are liable to be hit by tropical storms in May. Many of them are quite severe and cause heavy damage to life and property.
- In the Arabian Sea, major storms are formed in May between 7° and 12° N latitudes.
- Most of them move away from the Indian coast in a north-westerly direction and dissipate in the sea.
- Few originate close to the Indian coast. They move towards the north-east and hit somewhere along the west coast of India.

Precipitation in Summer Season

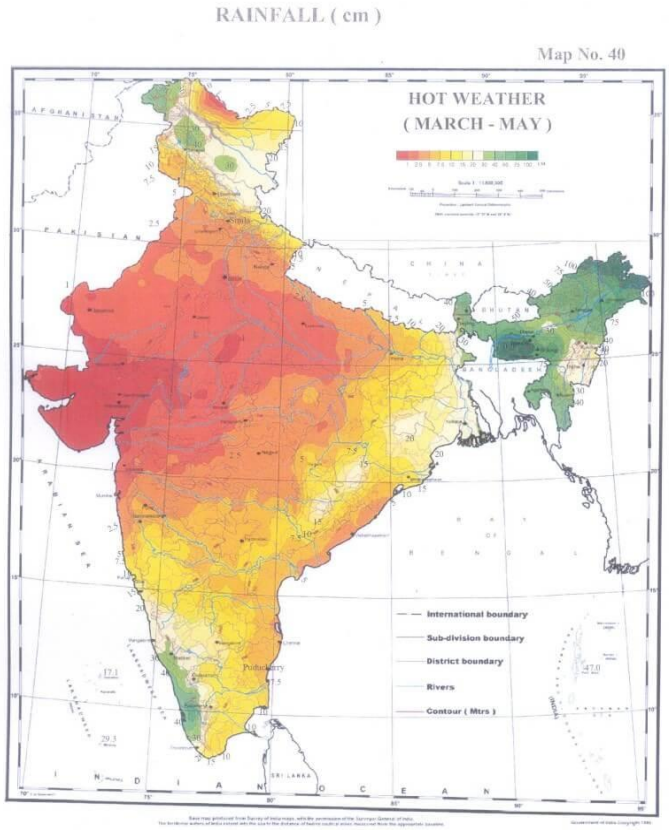
- This season is not totally rainless (only one per cent of the annual rainfall).
- In the north-eastern parts of the country, dust storms bring little rainfall.
- The precipitation in Kashmir is mainly in the form of snow caused by western disturbances.
- The norwesters bring some rainfall in Assam, West Bengal and Odisha. The intensity of rainfall is high.
- Coastal areas of Kerala and Karnataka receive rainfall from thunderstorms.

Rainy Season – South West Monsoon Season

- South West Monsoon Season – **June to mid-September.**
- South West Monsoon Season is also known as a **hot-wet season.**

The temperature during South West Monsoon Season

- Sudden onset of South West Monsoons leads to a significant fall in temperature (3° to 6 °C).
- The temperature remains less uniform throughout the rainy season.
- The temperature rises in September with the cease of south-west monsoons.
- There is a rise in temperature whenever there is a **break in the monsoons**.
- The diurnal range of temperature is small due to clouds and rains.
- The highest temperatures are experienced at places west of the Aravalli (38° to 40 °C). This is due to the lack of clouds and hot continental air masses.
- Other parts of Northwest India also have temperatures above 30 °C.
- The temperatures are quite low over the Western Ghats due to heavy rainfall.
- The coastal areas of Tamil Nadu and adjoining parts of Andhra Pradesh have temperatures above 30 °C as they receive little rainfall during this season.

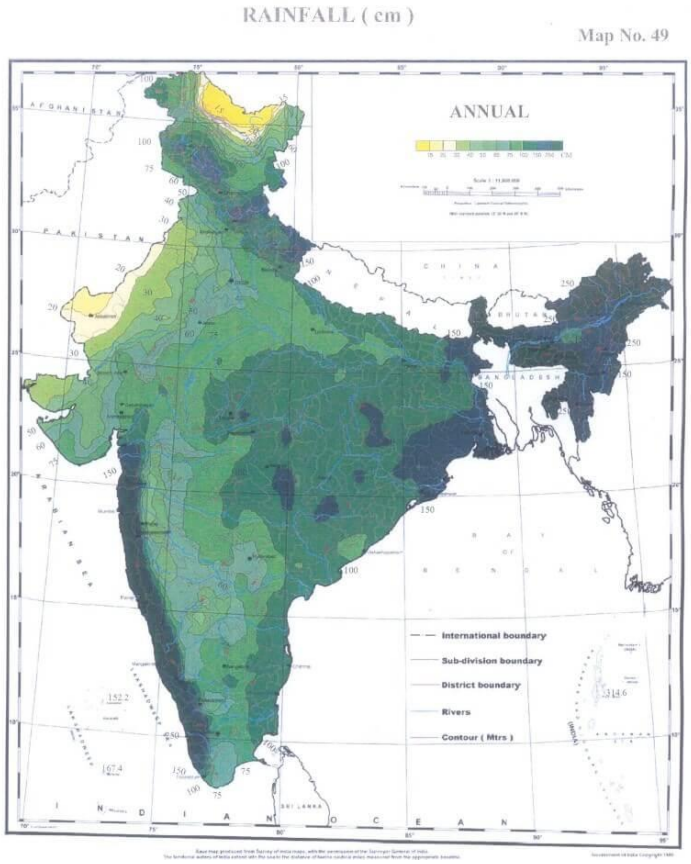


Precipitation in Summer (March to May)

Pressure and Winds During South West Monsoon Season

- Low-pressure conditions prevail over northwest India due to high temperature.
- ITCZ (monsoon trough) lies along the Ganga plain.
- There are frequent changes in its location depending upon the weather conditions.
- The atmospheric pressure increases steadily southwards.
- Over the peninsular region, due to the pressure gradient between north and south, winds blow in **a southwest to northeast** direction from Arabian sea and Bay of Bengal.
- Their direction undergoes a change in Indo-Gangetic plain where **they move from east to west**.

Rainfall During South West Monsoon Season



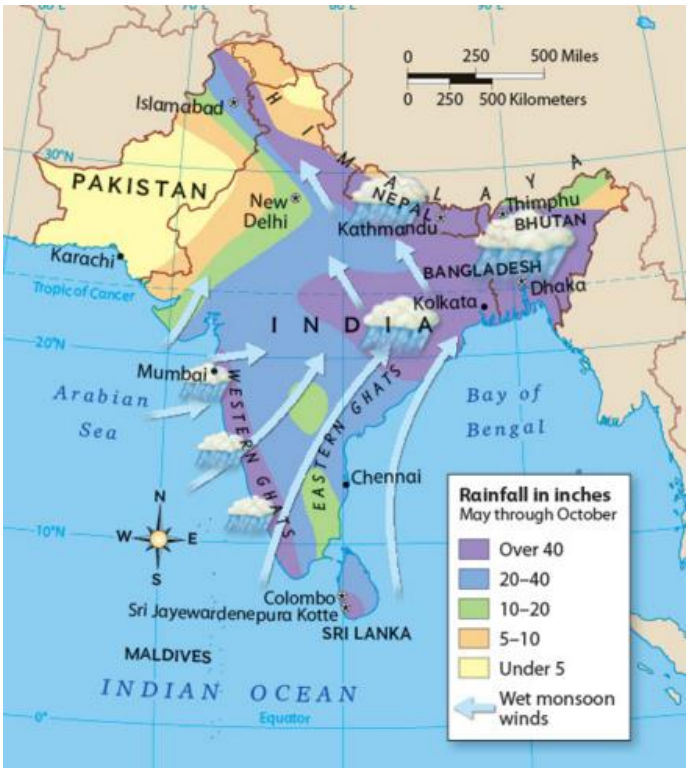
Precipitation in South West monsoon Season

- Three-fourths of the total annual rainfall is received during this season.
- The average rainfall over the plains of India in this season is about 87 per cent.

- Normal date of the arrival of the monsoon is **20th May in Andaman and Nicobar Islands**.
- The advance of the monsoon is **much faster in the Bay of Bengal than in the Arabian Sea.**
- The normal date of onset of the southwest monsoon over **Kerala, i.e. the first place of entry in the mainland of India is 1st June**.
- The monsoons advance quickly accompanied with a lot of thunder, lightning and heavy downpour. This sudden onset of rain is termed as **monsoon burst.**
- Sometimes monsoons are delayed, or they come much earlier than normal.
- Normally the onset occurs between 29th May and 7th June.

South West Monsoon – Arabian Sea branch and Bay of Bengal branch

- Monsoon winds beyond south Kerala progress in the form of two branches viz. the **Arabian Sea branch** and the **Bay of Bengal branch.**



South West Monsoon – Arabian Sea branch and Bay of Bengal branch

- The Arabian Sea branch gradually advances northwards. It reaches Mumbai by 10th June.

- The Bay of Bengal branch spreads rather rapidly over most of Assam. The normal date of its arrival at Kolkata is 7th June.
- On reaching the foothills of the Himalayas, the Bay branch is **deflected westward by the Himalayan barrier,** and it advances up the Gangetic plain.
- The two branches merge with each other mostly **around Delhi** to form a single current.
- Both the branches reach Delhi more or less at the **same time**.
- By the end of June, the monsoon is usually established over most parts of the country.
- By mid-July, the monsoon extends into Kashmir and the remaining parts of the country.
- By this time, it reaches Kashmir; it has **shed most of its moisture.**
- Arabian Sea branch of the monsoon is much powerful than the Bay of Bengal branch for reasons:
    1. **The Arabian Sea is larger than the Bay of Bengal, and**
    2. **the entire Arabian Sea current advances towards India, whereas only a part of the Bay of Bengal current, enters India, the remainder proceeding to Myanmar, Thailand and Malaysia.**

The Arabian Sea branch of the southwest monsoons is divided into three distinct streams on arriving in the mainland of India.

- The first stream strikes the west coast of India and gives extremely heavy rainfall of over 250 cm.
- It strikes perpendicular to the Western Ghats causing plentiful Orographic Rainfall (400 to 500 cm annual rainfall on the windward side).
- Rainfall is drastically reduced to about 30-50 cm on the leeward side of the crest.
- There is a narrow belt of marked aridity on the immediate leeward side of the Western Ghats. But once it is passed, the air starts rising again and the amount of rainfall increases further east.
- The second stream enters **Narmada—Tapti troughs (narrow rift valley)** and reaches central India.
- It does not cause much rain near the coast due to the absence of major orographic obstacle across the rift.
- Some parts of central India receive rainfall from this stream (Ex: Nagpur).
- The third stream moves parallel to the Aravalli Range without causing much rainfall.
- Consequently, the whole of Rajasthan is a desert area.
- However, **some orographic effect is occurring on the south-eastern edge of the Aravalli Range**. **Mount Abu** gets about 170 cm rainfall while the surrounding plains have only 60 to 80 cm rainfall.

The Bay of Bengal Branch of the southwest monsoon is divided into two distinct streams.

- The first stream crosses the **Ganga-Brahmaputra delta** and reaches **Meghalaya**.
- Here that the orographic effect results in intense rainfall.
- Cherrapunji receives an annual rainfall of 1,102 cm, a major portion of which occurs from June to August.
- **Mawsynram (present champion)** located at 1,329 m above sea level just 16 km to the west of **Cherrapunji (X champion)** records higher annual rainfall of 1,221 cm.
- Both the stations are located on the southern slopes of the **Khasi hills** at the northern end of a deep valley running from south to north.
- The second stream of the Bay of Bengal branch moves along **Himalayan foothills** as they are deflected to the west by the Himalaya and brings widespread rainfall to Ganga plain.
- The rainfall by this stream is characterized by a **steady decline** as we move from east to west up the plain. (Previous Prelims Question)
- The **Tamil Nadu coast** remains relatively dry during the south-west monsoon period because of
    1. **rain shadow effect of the Arabian Sea current and**
    2. **Bay of Bengal current which flows parallel to the coast.**

Break in the South West Monsoons

- During July and August, there are certain periods when the monsoons become weak.
- Rainfall practically ceases over the country outside the Himalayan belt and southeast peninsula.
- This is known as a **break in the monsoon.**
- During the break period, heavy rainfall occurs over the sub-Himalayan regions and the southern slopes of the Himalayas.
- On an average one or two breaks do occur during the rainy season.
- 85 out of 100 years there is a break in the monsoons.

What causes monsoon break?

- The breaks are believed to be brought about by the northward shifting of the **monsoon trough (minimum low-pressure cells in ITCZ) to the foothills of Himalayas.**
- This leads to a **sharp decrease in rainfall over most parts of the country but increases along the Himalayas and parts of Northeast India and the Southern Peninsula**.
- Breaks are likely to occur during the **second week of August** and last for a week.
- The breaks can also occur due to tropical cyclones which originate in the Bay of Bengal.

The monsoon trough is a portion of the Intertropical Convergence Zone as depicted by a line on a weather map showing the locations of minimum sea level pressure, and as such, is a convergence zone between the wind patterns of the southern and northern hemispheres.

Depressions in South West Monsoon Season

- A major part of the South West Monsoon rainfall is generated by depressions (intense low pressure) originating in the Arabian Sea and Bay of Bengal. Some depressions develop over land also.
- About 3-4 depressions are formed per month from June to September.
- Almost all of them are sucked inward through the deltas of great rivers (depressions need moisture to be alive), the Ganga, the Mahanadi, the Godavari, the Krishna and the Cauvery and cause heavy rain in these areas.
- The location of depressions strongly coincides with the latitudinal position of ITCZ.
- Most of the depression originate to the west of 90º E in the Bay of Bengal and move in the north-west direction.
- In the Arabian Sea in June-July, the depressions move either in the north-west or in the northerly direction and may affect west Gujarat or Maharashtra.
- Storms during August and September are rare and are formed close to Maharashtra-Gujarat coast.
- Most of the rainfall in central and northern parts of the country is caused by these depressions.
- The absence of depressions or a change in their tracks result in deficit or no rain.

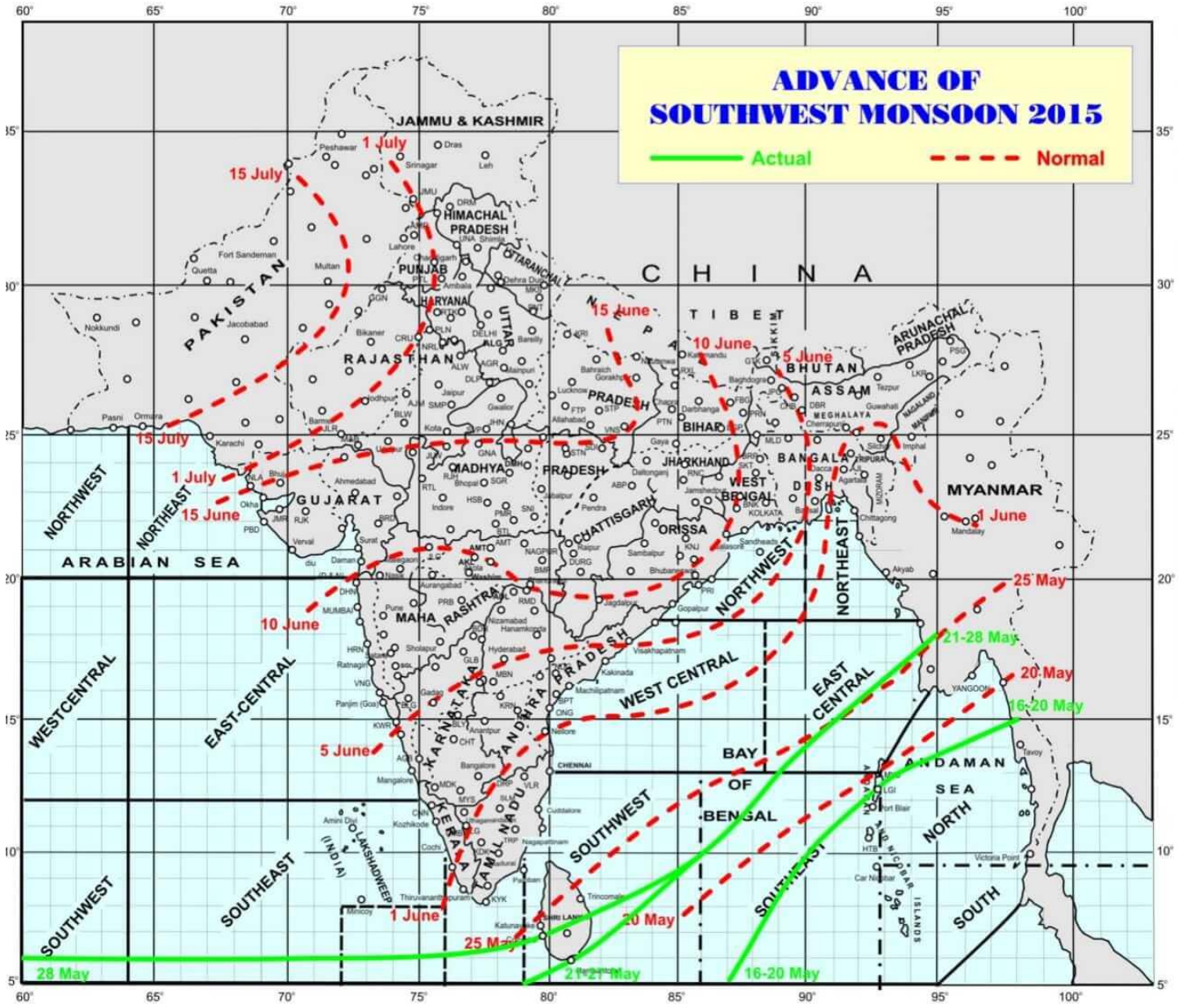
Chief Characteristics of South West Monsoon Rainfall

- A major part of monsoon rains is received between **June and September.**
- Monsoonal rainfall is largely governed by **relief and is orographic** in its mode.
- The amount of rainfall decreases with increasing distance from the sea.
- The rainless interval during south-west monsoon season is known as breaks.
- There are large scale spatial variations in the distribution of rainfall.
- Monsoons often fail to keep the date. Sometimes the monsoons withdraw before the scheduled time causing considerable damage to the crops.

North East Monsoon Season – Retreating Monsoon Season

- Starts with the beginning of the withdrawal of southwest monsoon (middle of September – November).
- The monsoons withdraw from the extreme north-west end of the country in September, from the peninsula by October and from the extreme south-eastern tip by December.

Advance and Withdrawal of South West Monsoons



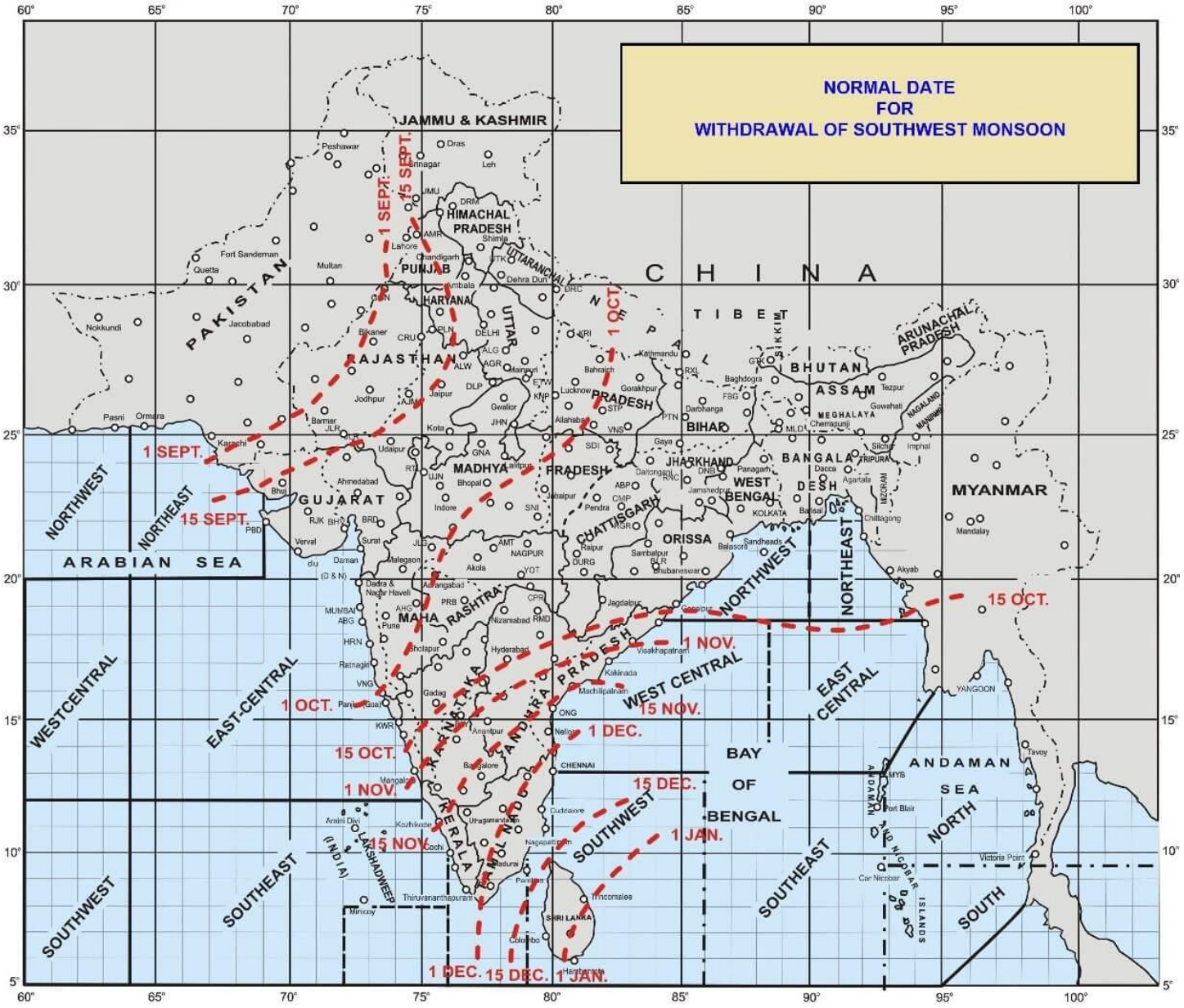
- In Punjab, the south-west monsoons reach in the first week of July and withdraw from there in the second week of September.
- The south-west monsoons reach Coromandel coast in the first week of June and withdraw from there only in the middle of December.
- Unlike the sudden burst of the advancing monsoons, the **withdrawal is rather gradual** and takes about three months.

The temperature during Retreating Monsoon Season

- With the retreat of the monsoons, the clouds disappear, and the sky becomes clear.
- The day temperature starts falling steeply.
- The diurnal range of temperature increases due to the lack of cloud cover.

Pressure and Winds during Retreating Monsoon Season

- As the monsoons retreat, the monsoon trough weakens and gradually shifts southward.
- Unlike south-west monsoon, the onset of the north monsoon is not clearly defined.



Advance and Withdrawal Dates of South West Monsoons

- The direction of winds over large parts of the country is influenced by the local pressure conditions.

Cyclones during Retreating Monsoon Season

- **Most severe and devastating tropical cyclones** originate in the Indian seas especially in the Bay of Bengal.
- The highest frequency of the cyclones is in the month of October and the first half of November.

More cyclones are born in October and then in November, and more cyclones originate in the Bay of Bengal than in the Arabian Sea.

- In October, the Cyclones of the Bay of Bengal originate between 8°N and 14°N.
- Initially, they move in west or north-westerly direction, but many of them later recurve and move towards the north-east.
- Near 55 per cent of the Bay storms cross or affect the Indian coast.
- The area's most vulnerable to these storms include the coastal belts of Tamil Nadu, Andhra Pradesh, Odisha and West Bengal.

- Many of the cyclones which strike the eastern coast of India, south of 15°N latitude cross the southern Peninsula and enter the Arabian Sea.
- During this process, they may weaken, but on re-entry over the Arabian sea they intensify into cyclonic storms.
- The storms of Arabian sea originate between 12°N and 17°N latitudes in October and between 8° N and 13° N latitudes in November.
- Generally, they move away from the coast in a north-westerly direction. But about 25% of them later recurve northeast and strike the **Maharashtra or Gujarat coast.**
- In north-west India, the western disturbances produce clouding and light rainfall in the otherwise fine weather.
- The precipitation is in the form of snow in higher reaches of Jammu and Kashmir, Himachal Pradesh and in Kumaon Hills.

Precipitation during Retreating Monsoon Season

- The humidity and cloud cover are much reduced with the retreat of the south-west monsoons, and most parts of the country remain without much rainfall.
- October-November is the **main rainy season in Tamil Nadu** and adjoining areas of **Andhra Pradesh** to the south of the Krishna delta as well as a secondary rainy period for Kerala.
- The retreating monsoons absorb moisture while passing over the **Bay of Bengal** and cause this rainfall.

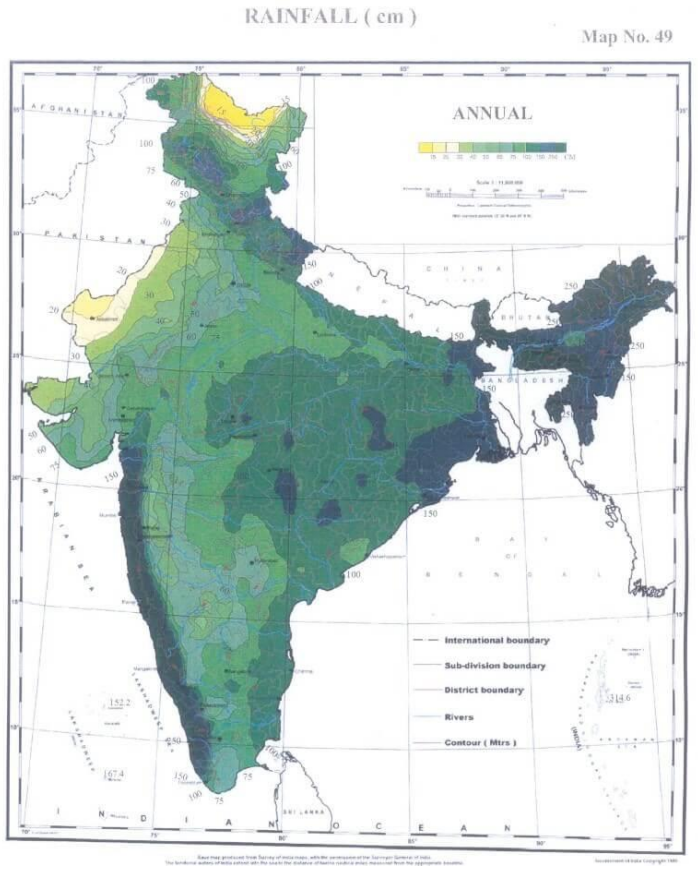
Annual Rainfall (South West Monsoons + Retreating Monsoons)

Isohyet (the line joining places of equal rainfall) [Compare this with isotherm (temperature), isobar (pressure)]

Areas of very high rainfall

- Areas receiving an annual rainfall of 200 cm and above.
- These include the western side of Western Ghats (Thiruvananthapuram in the south to Mumbai in the north).
- The average annual rainfall in this belt is 200-400 cm.
- Assam, Nagaland, Meghalaya, Mizoram, Arunachal Pradesh, Sikkim, parts of Manipur, Tripura and north-eastern tip of West Bengal also receive 200 cm or more, with isolated pockets receiving over 400 cm.

Meghalaya (the abode of clouds) is the wettest part of the country with Mawsynram and Cherrapunji getting 1,221 and 1,102 cm of annual rainfall respectively.



Average Annual Rainfall (South West Monsoons + Retreating Monsoons)

Areas of high rainfall

- 100-200 cm annual rainfall.
- Eastern slopes of the Western Ghats, the major part of the northern plain, Odisha, Madhya Pradesh, Andhra Pradesh and Tamil Nadu.

Areas of low rainfall

- 50-100 cm annual rainfall.
- Large parts of Gujarat, Maharashtra, western Madhya Pradesh, Andhra Pradesh, Karnataka, eastern Rajasthan, Punjab, Haryana and parts of Uttar Pradesh.

Areas of very low rainfall

- These are desert and semi-desert areas receiving less than 50 cm of annual rainfall.
- They include large areas of western Rajasthan, Kachchh and most of Ladakh region of Jammu and Kashmir.

2.4 Climatic Regions of India

- While classifying Indian climatic regions, most geographers have given more importance to **rainfall** than to temperature as variations in rainfall are much more marked than those of temperature.

Here we will see two classifications – Stamp's and Koppen's. For GS this is more than enough.

Stamp's Classification of Climatic Regions of India

- Stamp used **18 °C isotherm** of mean monthly temperature for January to divide the country into two broad climatic regions, viz., **temperate or continental zone** in the north and **tropical zone** in the south.
- This line runs roughly across the root of the peninsula, more or less along or parallel to the Tropic of Cancer.
- The two major climatic regions are further divided into eleven regions depending upon the amount of rainfall and temperature.

Temperate or Continental India

1. The Himalayan region (heavy rainfall)
2. The north-western region (moderate rainfall)
3. The arid low land
4. The region of moderate rainfall
5. The transitional zone

Tropical India

1. Region of very heavy rainfall
2. Region of heavy rainfall
3. Region of moderate rainfall
4. The Konkan Coast
5. The Malabar Coast
6. Tamil Nadu

Stamp's Classification of Climatic Regions of India

Temperate or Continental India		
Region	**Avg Temperature**	**Annual Rainfall**
Himalayan Region	Sumer = 4-7 °C Winter = 13-18 °C	East = Over 200 cm West = much less
North-western Region Northern parts of Punjab and southern parts of Jam-	Summer = 16 °C Winter = 24 °C	Below 200 cm

mu and Kashmir		
Arid Lowland Thar desert of Rajasthan, south western part of Haryana and Kachchh of Gujarat	Winter = 16-24 °C Summer = 48 °C	Below 40 cm
Region of moderate rainfall Punjab, Haryana, western Uttar Pradesh, Union Territory of Delhi, north-west Plateau area of Madhya Pradesh and eastern Rajasthan	Winter = 15-18 °C Summer = 33-35 °C	40-80 cm
Transitional Zone Eastern Uttar Pradesh and Bihar	Winter = 15-19 °C Summer = 30-35 °C	100-150 cm
Tropical India		
Region of very heavy rainfall Meghalaya, Assam, Tripura, Mizoram and Nagaland	Winter = 18 °C Summer = 32-35 °C	Over 200
Region of heavy rainfall Chhattisgarh, Jharkhand, Gangetic West Bengal, Odisha and coastal Andhra Pradesh	Winter = 18-24 °C Summer = 29-35 °C	100-200 cm
Region of moderate rainfall between Western and Eastern Ghats	Winter = 18-24 °C Summer = 32 °C	50-100 cm
Konkan Coast Mumbai in the north to Goa in the south	Annual = 24-27 °C.	Over 200 cm
Malabar Coast Goa to Kanyakumari	Annual = 27 °C	Over 250 cm
Tamil Nadu Tamil Nadu and adjoining areas of Andhra Pradesh	Annual = 24 °C	100 to 150 cm (Retreating monsoon)

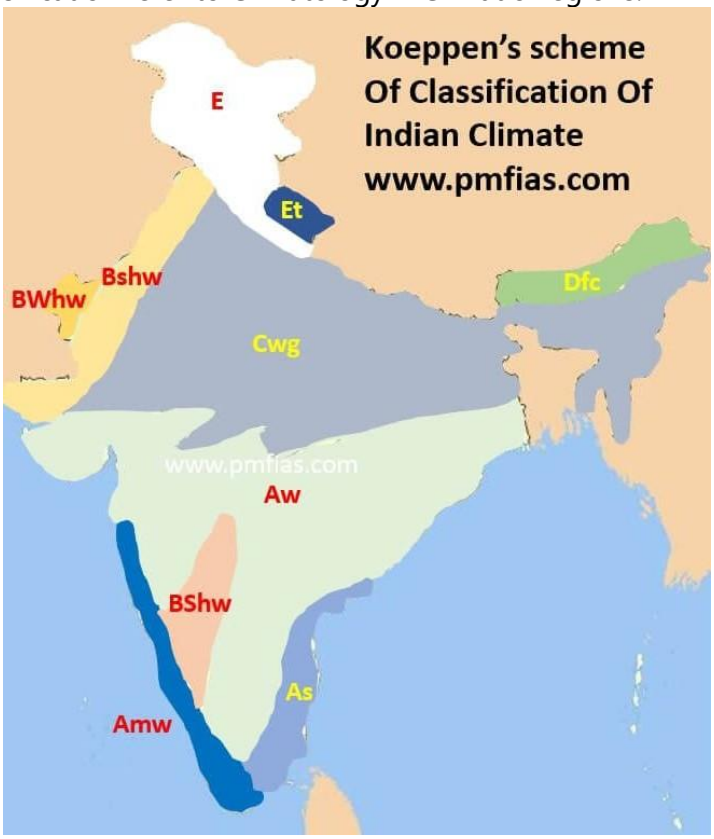
Koppen's Classification of Climatic Regions of India

- Koppen identified a close relationship between the distribution of vegetation and climate.
- He selected certain values of temperature and precipitation and related them to the distribution of vegetation and used these values for classifying the climates.
- Koppen divided India into nine climatic regions making use of the above scheme.

Koppen's Scheme – Climatic Regions of India		
Climate type	**Region**	**Annual rainfall**
Amw: Monsoon type with short dry winter season	Western coastal region, south of Mumbai	over 300 cm
As: Monsoon type with dry season in high sun period	Coromandel coast: Coastal Tamil Nadu and adjoining areas of Andhra Pradesh	75-100 cm Wet winters Dry summers
Aw: Tropical Savanah type	Most parts of the peninsular plateau barring Coromandel and Malabar coastal strips	75 cm
BShw: Semi-arid Steppe type	Some rain shadow areas of Western Ghats, large part of Rajasthan and contiguous areas of Haryana and Gujarat	12-25 cm
BWhw: Hot desert type	Most of western Rajasthan	less than 12 cm
Cwg: Monsoon type with dry winters	Most parts of the Ganga Plain, eastern Rajasthan, Assam and in Malwa Plateau	100-200 cm
Dfc: Cold, Humid winters	Sikkim, Arunachal Pradesh and parts of Assam	~200 cm

type with shorter summer		
Et: Tundra Type	Mountain areas of Uttarakhand The average temperature varies from 0 to 10°C	Rainfall varies from year to year.
E: Polar Type	Higher areas of Jammu & Kashmir and Himachal Pradesh in which the temperature of the warmest month varies from 0° to 10°C	Precipitation occurs in the form of snow

For more information on Koppen's Scheme of Classification refer to Climatology > Climatic Regions.



Koppen's Classification of Climatic Regions of India

3. Natural Vegetation of India

- **Climate, soil and topography** are the major factors that influence Natural Vegetation of a place.
- The main climatic factors are **rainfall and temperature**.
- The amount of annual rainfall has a great bearing on the type of vegetation.

Annual Rainfall	Type of Vegetation
200 cm or more	**Evergreen Rain Forests**
100 to 200 cm	**Monsoon Deciduous Forests**
50 to 100 cm	**Drier Deciduous or Tropical Savanna**
25 to 50 cm	**Dry Thorny Scrub (Semi-arid)**
Below 25 cm	**Desert (Arid)**

- Temperature is the major factor in the Himalayas and other hilly regions with an elevation of more than 900 metres.
- As the temperature falls with altitude in the Himalayan region the vegetal cover changes with altitude from **tropical to sub-tropical, temperate and finally alpine.**
- The soil is an equally determining factor in a few regions. **Mangrove forests, swamp forests** are some of the examples where the soil is the major factor.
- Topography is responsible for certain minor types, e.g. **alpine flora, tidal forests, etc.**

3.1 Classification of Natural Vegetation of India

- Classification of Natural Vegetation of India is primarily based on spatial and annual variations in rainfall.
- Temperature, soil and topography are also considered.
- India's vegetation can be divided into 5 main types and 16 sub-types as given below.

A. Moist Tropical Forests

1. Tropical Wet Evergreen
2. Tropical Semi-Evergreen
3. Tropical Moist Deciduous
4. Littoral and Swamp

B. Dry Tropical Forest

1. Tropical Dry Evergreen
2. Tropical Dry Deciduous

3. Tropical Thorn

C. Montane Sub-Tropical Forests

1. Sub-tropical broad leaved hill
2. Sub-tropical moist hill (pine)
3. Sub-tropical dry evergreen

D. Montane Temperate Forests

1. Montane Wet Temperate
2. Himalayan Moist Temperate
3. Himalayan Dry Temperate

E. Alpine Forests

1. Sub-Alpine
2. Moist Alpine scrub
3. Dry Alpine scrub

Forest Type in India	% of Total Area
Tropical Moist Deciduous	**37**
Tropical Dry Deciduous	**28**
Tropical Wet Evergreen	**8**
Sub-Tropical Moist Hill	**6**
Tropical Semi-Evergreen	**4**
Rest below 4 %	

A. Moist Tropical Forests

Tropical Wet Evergreen Forests or Rain Forests

Climatic Conditions

- Annual rainfall **exceeds 250 cm.**
- The annual temperature is about 25-27 °C
- The **dry season is distinctly short**.

Characteristics

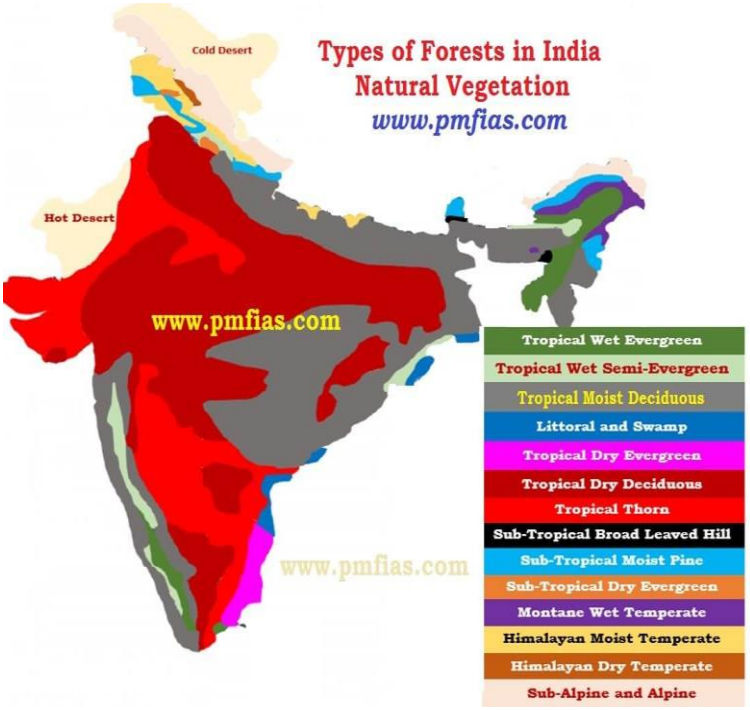
- Evergreen: Due to high heat and high humidity, the trees of these forests **do not shed their leaves together**.
- **Vegetation is mesophytic**: **Plants adapted to neither too dry nor too wet type climate or soil.**

Hydrophytic plants*: plants like water lily or pondweed that grow in saturated soil*

Xerophytic plants*: plants like cactus that grow in extremely dry soil.*

Mesophytic plants: *ordinary plants that* ***exist between the two extremes.***

- Lofty: The trees often reach 45-60 metres in height.
- Thick Canopy: From the air, the tropical rain forest appears like a thick canopy of foliage.
- All plants struggle upwards for sunlight resulting in a peculiar layer arrangement.
- Less undergrowth: The sunlight cannot reach the ground due to thick canopy. The undergrowth is formed mainly of bamboos, ferns, climbers, orchids, etc.



Classification of Natural Vegetation of India

Distribution

- **The western side of the Western Ghats (500 to 1370 metres above sea level).**
- **Some regions in the Purvanchal hills.**
- **In the Andaman and Nicobar Islands.**

Timber

- Hardwood: The timber of these forests is fine-grained, hard and durable but is hard to exploit.

- The important species of these forests are **mahogany, mesua, white cedar, jamun, canes, bamboo** etc.

Tropical Semi-Evergreen Forests

- They are **transitional forests** between tropical wet evergreen forests and tropical deciduous forests.
- They are comparatively drier areas compared to tropical wet evergreen forests.

Climatic Conditions

- Annual rainfall is 200-250 cm.
- Mean annual temperature varies from 24 to 27 °C.
- The **dry season is not short** like in tropical evergreen forests.

Distribution

- Western coast, Assam, Lower slopes of the Eastern Himalayas, Odisha and Andamans.

Characteristics

- The semi-evergreen forests are less dense.
- They are more **gregarious (living in flocks or colonies – more pure stands)** than the wet evergreen forests.
- These forests are characterized by many species.
- Trees usually have **buttressed trunks with abundant epiphytes.**

Tress with buttressed trunks and epiphytes

- The important species are **laurel, rosewood, mesua, thorny bamboo** – Western Ghats; **white cedar, Indian chestnut, champa, mango,** etc. – Himalayan region.

Timber

- Hardwood: Similar to that in tropical evergreen forests except that these forests are less dense with **more pure stands** (timber industry here is better than in evergreen forests).

Tropical Moist Deciduous Forests

Climatic Conditions

- Annual rainfall 100 to 200 cm.
- Mean annual temperature of about 27 °C.
- Spring (between winter and summer) and summer are dry.

Characteristics

- The trees **drop their leaves during the spring and early summer** when sufficient moisture is not available.
- The general appearance is bare in extreme summers (April-May).
- Tropical moist deciduous forests present irregular top storey (25 to 60 m).
- Heavily buttressed trees and **fairly complete undergrowth**.
- These forests occupy a much larger area than the evergreen forests, but **large tracts under these forests have been cleared for cultivation**.

Distribution

- The belt running along the Western Ghats surrounding the belt of evergreen forests.
- A strip along the Shiwalik range including terai and bhabar from 77° E to 88° E.
- Manipur and Mizoram.
- Hills of eastern Madhya Pradesh and Chhattisgarh.
- Chota Nagpur Plateau.
- Most of Odisha.
- Parts of West Bengal and
- Andaman and Nicobar Islands.

Timber

- These provide valuable timer like **Teak.**
- The main species found in these forests are **teak, sal, laurel, rosewood, amla, jamun, bamboo**, etc.
- It is **comparatively easy to exploit these forests due to their high degree of gregariousness (more pure stands).**

Littoral and Swamp Forests

- They can survive and grow both in fresh as well as **brackish water** (The mixture of seawater and fresh water in estuaries is called brackish water, and its salinity can range from 0.5 to 35 ppt).
- Occur in and around the deltas, estuaries and creeks prone to **tidal influences (delta or tidal forests).**
- Littoral (relating to or on the shore of the sea or a lake) forests occur at several places along the coast.
- Swamp forests are confined to the **deltas of the Ganga, the Mahanadi, the Godavari** (**Coringa Wildlife Sanctuary**)**, the Krishna and the Cauvery**.
- Dense mangroves occur all along the coastline in sheltered estuaries, tidal creeks, backwaters, salt marshes and mudflats. It provides useful fuelwood.
- The most pronounced and the densest is the **Sundarbans in the Ganga delta** where the predominant species is **Sundri (Heriteera)**.

Timber

- It provides hard and durable timber which is used for construction, building purposes and making boats.
- The important species found in these forests are **sundri, agar, rhizophora**, etc.

B. Dry Tropical Forests

Tropical Dry Evergreen Forests

Distribution

- Along the coasts of Tamil Nadu.

Climatic Conditions

- The annual rainfall of 100 cm (mostly from the north-east monsoons).
- Mean annual temperature is about 28 °C.
- The growth of evergreen forests in areas of such low rainfall is a bit strange.

Characteristics

- Short-statured trees, up to 12 m high, with complete canopy.
- Bamboos and grasses not conspicuous.
- The important species are **jamun, tamarind, neem,** etc.
- Most of the land under these forests have been cleared for agriculture or **casuarina plantations.**

Casuarina plantation

- It resembles feathery conifer in general appearance.
- They are rapid-growing, carefree species that can grow in various climates.
- They have the ability to **fix atmospheric nitrogen**.

Distribution

- Casuarina is the most popular farm forestry in the states of Andhra Pradesh, Tamil Nadu, West Bengal, Odisha, Maharashtra, Gujarat, and Karnataka.

Benefits

- Reduces damage in the event of natural calamities.
- Line planting in the coastal areas helps in controlling the wind force.

Casuarina plantation

- It is a suitable species for wasteland development because of its adaptability to a wide range of habitats, fast growth, salt tolerant, drought resistant, ability to reclaim land and stabilise sand dunes.

Tropical Dry Deciduous Forests

Climatic Conditions

- Annual rainfall is 100-150 cm.

Characteristics

- These are similar to moist deciduous forests and **shed their leaves in dry season**.
- The major difference is that they can grow in areas of comparatively less rainfall.
- They represent a transitional type – moist deciduous on the wetter side and thorn forests on the drier side.
- They have closed but uneven canopy.
- The forests are composed of a mixture of a few species of deciduous trees rising up to a height of 20 metres.
- Undergrowth: Enough light reaches the ground to permit the growth of grass and climbers.

Distribution

- They occur in an irregular wide strip running from the foot of the Himalayas to Kanyakumari except in Rajasthan, Western Ghats and West Bengal.
- The important species are **teak, axlewood, rosewood, common bamboo, red sanders, laurel,** etc.
- Large tracts of this forest have been cleared for agricultural purposes.
- These forests have suffered from overgrazing, fire, etc.

Tropical Thorn Forests

Climatic Conditions

- Annual rainfall less than 75 cm.
- Humidity is less than 50 per cent.
- The mean temperature is 25-30 °C.

Characteristics

- The trees are low and widely scattered.
- **Acacias** and **Euphorbias** are very prominent.
- The Indian wild date is common. Some grasses also grow in the rainy season.

Distribution

- Rajasthan, south-western Punjab, western Haryana, Kutch and neighbouring parts of Saurashtra.
- Here they degenerate into desert type in the Thar desert.
- Such forests also grow on the leeside of the Western Ghats covering large areas of Maharashtra (Vidarbha), Karnataka (Hyderabad-Karnataka), Telangana, Andhra Pradesh and Tamil Nadu.
- The important species are **neem, babul, cacti**, etc.

C. Montane Sub-Tropical Forests

Sub-tropical Broad-leaved Hill Forests

Climatic conditions

- Mean annual rainfall is 75 cm to 125 cm.
- Average annual temperature is 18-21 °C.

Distribution

- Eastern Himalayas to the east of 88°E longitude at altitudes varying from 1000 to 2000 m.

Characteristics

- Forests of **evergreen species**.
- Commonly found species are **evergreen oaks, chestnuts, ash, beech, sals and pines**.
- Climbers and epiphytes (a plant that grows non-parasitically on a tree or other plant) are common.

- These forests are not so distinct in the southern parts of the country. They occur only in the **Nilgiri and Palni hills** at 1070-1525 metres above sea level.
- It is a "stunted rain-forest" and is not so luxuriant as the true tropical evergreen.
- The higher parts of the Western Ghats such as Mahabaleshwar, the summits of the Satpura and the Maikal Range, highlands of Bastar and Mt. Abu in the Aravalli Range carry sub-types of these forests.

Sub-tropical Moist Pine Forests

Distribution

- Western Himalayas between 73°E and 88°E longitudes at elevations between 1000 to 2000 metres above sea level.
- Some hilly regions of Arunachal Pradesh, Manipur, Naga Hills and Khasi Hills.

Timber

- **Chir or Chil** is the most dominant tree which forms pure stands.
- It provides **valuable timber** for furniture, boxes and buildings.
- It is also used for producing resin and turpentine.

Sub-tropical Dry Evergreen Forests

Distribution

- Found in the Bhabar, the Shiwaliks and the western Himalayas up to about 1000 metres above sea level.

Climatic Conditions

- Annual rainfall is 50-100 cm (15 to 25 cm in December-March).
- The summers are sufficiently hot, and winters are very cold.

Characteristics

- Low scrub forest with small evergreen stunted trees and shrubs.
- Olive, acacia modesta and pistacia are the most predominant species.

D. Montane Temperate Forests

Montane Wet Temperate Forests

Climatic Conditions

- Grows at a height of 1800 to 3000 m above sea level.
- Mean annual rainfall is 150 cm to 300 cm.
- Mean annual temperature is about 11 to 14 °C.

Distribution

- Higher hills of Tamil Nadu and Kerala, in the Eastern Himalayan region.

Characteristics

- These are closed evergreen forests. Trunks have a large girth.
- Branches are clothed with mosses, ferns and other epiphytes.
- The trees rarely achieve a height of more than 6 metres.
- Deodar, Chilauni, Indian chestnut, birch, blue pine, oak, hemlock, etc. are important species.

Himalayan Moist Temperate Forests

Climatic Conditions

- Annual rainfall varies from 150 cm to 250 cm

Distribution

- Occurs in the temperate zone of the Himalayas between 1500 and 3300 metres.
- Cover the entire length of this mountain range in Kashmir, Himachal Pradesh, Uttarakhand, Darjeeling and Sikkim.

Characteristics

- Mainly composed of **coniferous species.**

- Species occur in mostly pure strands.
- Trees are 30 to 50 m high.
- **Pines, cedars, silver firs, spruce**, etc. are most important trees.
- They are fairly open forests with shrubby undergrowth including oaks, rhododendrons and some bamboos.

Timber

- It provides fine wood which is of much use for construction, timber and railway sleepers.

Himalayan Dry Temperate Forests

Climatic Conditions

- Precipitation is below 100 cm and is mostly in the form of snow.

Characteristics

- **Coniferous forests with xerophytic shrubs** in which **deodar, oak, ash, olive,** etc are the main trees.

Distribution

- Such forests are found in the inner dry ranges of the Himalayas where south-west monsoon is very feeble.
- Such areas are in **Ladakh, Lahul, Chamba, Kinnaur, Garhwal and Sikkim**.

E. Alpine Forests

- Altitudes ranging from 2,900 to 3,500.
- These forests can be divided into (1) sub-alpine; (2) moist alpine scrub and (3) dry alpine scrub.
- The sub-alpine forests occur as lower alpine scrub and grasslands.
- It is a mixture of coniferous and broad-leaved trees in which the coniferous trees attain a height of about 30 m while the broad-leaved trees reach only 10 m.
- Fir, spruce, rhododendron, etc. are important species.
- The moist alpine scrub is a low evergreen dense growth of rhododendron, birch etc. which occurs from 3,000 metres and extends up to snowline.
- The dry alpine scrub is the uppermost limit of scrub xerophytic, dwarf shrubs, over 3,500 metres above sea level and found in the dry zone. Juniper, honeysuckle, artemesia etc. are important species.

4. Biogeography – Soils

- Soil is the thin top layer on the earth's crust comprising rock particles mixed with organic matter.
- **Pedology** is the study of soils in their natural environment.
- **Pedogenesis** is the natural process of soil formation that includes a variety of processes such as weathering, leaching, calcification etc.
- The Soil formation is mainly related to the parent rock material, surface relief, climate and natural vegetation.

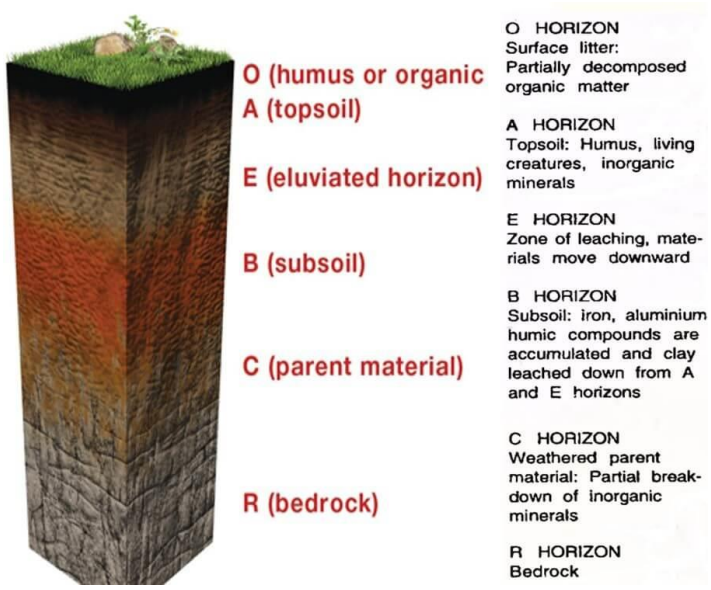
4.1 Soil Types: Sandy, Clayey & Loamy

- The soil is classified on the basis of the proportion of particles of various sizes.
  1) If the soil contains a greater proportion of big particles, it is called **sandy soil.**
  2) If the proportion of fine particles is relatively higher, then it is called **clayey soil.**
  3) If the amount of large and fine particles is about the same, then the soil is called **loamy.**
- Water can drain quickly through the spaces between the sand particles.
- So, sandy soils tend to be light in colour, well aerated and dry.
- Clay particles, being much smaller, pack tightly together, **leaving little space for air**.
- Unlike sandy soil, water can be held in the tiny gaps between the particles of clay.
- So, clay soils have little air. But they are heavy as they **hold more water** than the sandy soils.

- The best topsoil for growing plants is loam.
- Loamy soil is a mixture of sand, clay and another type of soil particle known as silt.
- Silt occurs as a deposit in river beds. The size of the silt particles is between those of sand and clay.
- The loamy soil also has **humus** in it. It has the **right water holding capacity** for the growth of plants.
- **Clayey and loamy soils are both suitable for growing cereals like wheat, and gram. Such soils are good at retaining water.**
- **For paddy, soils rich in clay and organic matter and having a good capacity to retain water are ideal.**
- **For lentils (masoor) and other pulses, loamy soils, which drain water easily, are required.**
- **For cotton, sandy loam or loam, which drain water easily and can hold plenty of air, are more suitable.**

4.2 Soil Profile (Soil Horizon)

- A vertical section through different layers of the soil is called the soil profile.
- Each layer differs in feel (texture), colour, depth and chemical composition.
- These layers are referred to as horizons.
- A soil horizon is a layer generally parallel to the soil surface, whose physical characteristics differ from the layers above and beneath.
- Horizons are defined in most cases by obvious physical features, chiefly colour and texture.
- The **uppermost horizon is generally dark in colour as it is rich in humus and minerals**.
- The humus makes the soil fertile and provides nutrients to growing plants.
- This layer is generally soft, porous and can retain more water. It is called the **topsoil or the A-horizon**.
- The next layer has a **lesser amount of humus but more of minerals**.
- This layer is generally harder and more compact and is called the **B-horizon or the middle layer**.
- The third layer is the C-horizon, which is made up of small lumps of rocks with cracks.



Soil Profile (Soil Horizon)

O Horizon

- Layers dominated by **organic material**.
- Some O layers consist of undecomposed or partially decomposed litter (such as leaves, needles, twigs, moss, and lichens).
- They may be on top of either mineral or organic soils.

A Horizon or Surface soil

- It is part of the top soil.
- In this layer, **organic matter is mixed with mineral matter**.
- It is the layer of mineral soil with the **most organic matter accumulation and soil life**.
- This layer is depleted of (eluviated of) iron, clay, aluminium, organic compounds, and other soluble constituents.
- When depletion is pronounced, a lighter coloured "E" subsurface soil horizon is apparent at the base of the "A" horizon.

E horizon

- "E" stands for an eluviated layer.
- It is the horizon that has been significantly **leached** of clay, iron, and aluminium oxides, which leaves a concentration of resistant minerals, such as quartz, in the sand and silt sizes.

- These are present only in older, well-developed soils, and generally, occur between the A and B horizons.

B Horizon or Subsoil

- It is a subsurface layer reflecting a chemical or physical alteration of parent material.
- This layer **accumulates all the leached minerals** from A and E horizon.
- Thus iron, clay, aluminium and organic compounds accumulate in this horizon (illuviation (opposite of eluviation)).

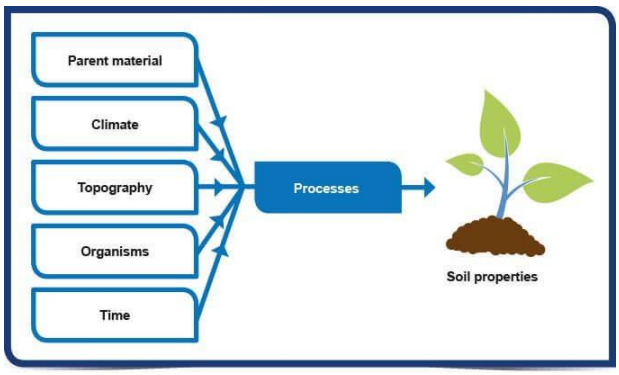
C Horizon or Parent rock

- Weathered parent material accumulates in this layer, i.e. the parent material in sedimentary deposits.
- It is a layer of large unbroken rocks.
- This layer may accumulate more soluble compounds (inorganic material).

R Horizon or Bedrock

- This layer denotes the layer of partially weathered bedrock at the base of the soil profile.
- Unlike the above layers, R horizons largely comprise continuous masses of hard rock.
- Soils formed in situ will exhibit strong similarities to this bedrock layer.
- These areas of bedrock are under 50 feet of the other profiles.

4.3 Factors that influence soil formation in Indian Conditions



Parent Material

- The rocks from which soils are formed are called **parent materials**.
- In most of the cases, the parent material determines the **colouration, mineral composition and texture of the soil.**
- In some cases, the soil formed may or may not have the same physical properties as the parent rock.
- Climatic factors induce chemical changes which also affect the physical properties of the soil.
- The surface rocks are exposed to the process of weathering. In this process, the rocks are converted into fine grains and provide a base for the soil formation.
- In Indian Conditions, parent material is generally categorized into:
  1. ***Ancient crystalline and metamorphic rocks***
  2. ***Cuddapah and Vindhyan rocks***
  3. ***Gondwana rocks***
  4. ***Deccan basalts***
  5. ***Tertiary and Mesozoic sedimentary rocks of extra peninsular India {Rock System}***

Ancient crystalline and metamorphic rocks

- They are the **Oldest rocks** (pre-Cambrian era) (formed due to solidification of molten magma about 4 billion years ago).
- They form the **'Basement Complex'** of peninsular India.
- They are basically **granites, gneisses and schists**.
- These rocks are rich in **ferromagnetic materials** and give rise to **red soils** on weathering.
- The red colour of these soils is due to the presence of **iron oxide.**

Cuddapah and Vindhyan rocks

- They are **ancient sedimentary rocks** (4000 m thick).
- On weathering they give **calcareous** (containing calcium carbonate) and **argillaceous** (consisting of or containing clay) soils.

- The soil is mostly devoid of metalliferous minerals.

Gondwana rocks

- These rocks are also **sedimentary** in nature, and they are much younger.
- On weathering, they give rise to comparatively **less mature soils.**
- The soil is more or less of uniform character but of **low fertility.**

Deccan basalts

- A volcanic outburst over a vast area of Peninsular India gave rise to Deccan Traps.
- Basaltic lava flowed out of fissures covering a vast area of about ten lakh sq km.
- Basalts are rich in **titanium, magnetite, aluminium and magnesium.**
- Consequently, the weathering of these rocks has given rise to soils of **darker colour.**
- The soil is fertile with **high moisture holding capacity** and is popularly known as **regur or black cotton soil.**

Tertiary and Mesozoic sedimentary rocks

- Rocks of extra peninsular (plains and Himalayas) India have given rise to soils with **high porosity.**
- These soils are generally immature recent and sub recent rocks, result in **alluvial soils on weathering.**
- Alluvial fertile soils consist of fine silts and clay. These soils have **little relation with the original rocks.**
- On the other hand, **the soils of the peninsular plateau are generally coarse-grained and are closely related to the parent rocks**. The peninsular soils are generally less fertile.

Relief

- The relief is the most important factor for soil formation in places with steep slopes like the hilly regions, edges of plateaus etc.
- Soil erosion on barren slopes is rampant, and it hinders soil formation. Example: **Chambal ravines**, higher reaches of the Himalayas where there is minimal or no forest cover (most on the steep southern slopes) etc.
- The areas of low relief or gentle slope generally experience deposition and have deep soils. Example: Indo-Gangetic plain.
- The exceptions in the plateau are river basins where the soil layers are sufficiently deep.

Climate

- Temperature and rainfall are the most important factors in soil formation.
- They determine the effectiveness of weathering of the parent material, the quantity of water seeping through the soil and the type of microorganisms present therein.
- Two different parent materials may develop the same soil in the same type of climate.
- Similarly, the same parent material may produce two different types of soils in two different types of climates.
- **The crystalline granites produce laterite (reddish clayey soils) soil in relatively moist parts of the monsoonal region and non-laterite soil in drier areas.**
- **Hot summer and low rainfall develop black soil as is found in some parts of Tamil Nadu irrespective of the parent rock.**
- **In Rajasthan, both granite and sandstone give birth to sandy soil under arid climate.**
- In arid and semi-arid regions, evaporation always exceeds precipitation. There is little vegetation, and the soils badly lack humus content. Hence the soils are invariably of **light colour.**
- In Rajasthan and the adjoining arid and semi-arid regions, an excess of evaporation makes soils **lime accumulating**.
- Hence the soil is **pedocal** in nature (It is a class of soil which forms in semiarid and arid regions. It is **rich in calcium carbonate** and has **low soil organic matter**).
- In cold climates of the Himalayan region, the process of vegetation **decay is very slow,** and the soils are **acidic in nature.**

In areas of heavy rainfall and high temperature, the soils are red or lateritic. Why?

- Torrential rainfall during the rainy season washes the upper soil and **leaches** the materials into the deeper horizon.
- During the dry summer season, the evaporation exceeds precipitation, and through **capillary action, iron and aluminium oxides** are transported to the surface making the soil red.
- In areas of alternate wet and dry climate, the leached material which goes deep down in the horizon is brought up, and the blazing sun bakes the topsoil so hard that it resembles a brick.
- Therefore, this soil is called **lateritic which means brick.**

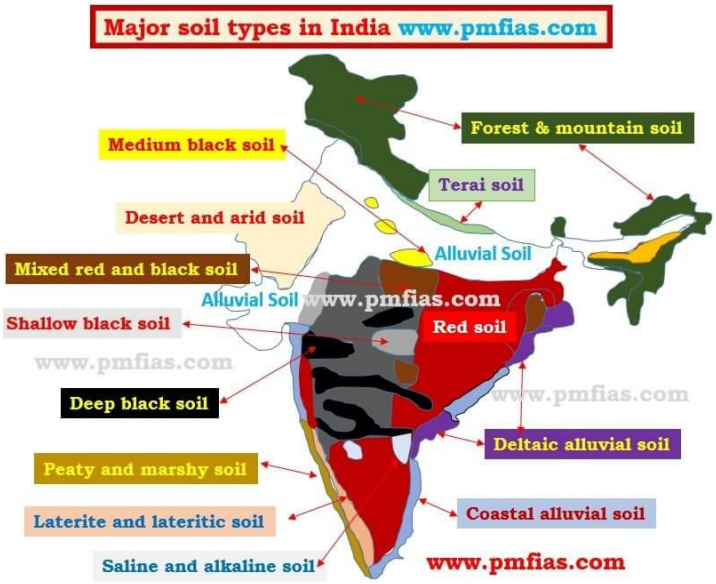
Natural Vegetation

- Natural vegetation reflects the combined effects of relief and climate.
- The formation and development of soil is very much influenced by the growth of vegetation.
- The decayed leaf material adds much-needed humus to soil thereby increasing its fertility.
- The **densely forested areas contain some of the best soils in India**.
- There is a close relationship between the vegetation types and soil types in India.

4.4 Major Soil Groups of India

- Geologically, Indian soils can broadly be divided into soils of peninsular India and soils of extra-peninsular India.
- **The soils of Peninsular India are formed by the decomposition of rocks in situ**, i.e. directly from the underlying rocks.
- Soils of Peninsular India are transported and re-deposited to a limited extent and are known as **sedentary soils.**
- **The soils of the Extra-Peninsula (Indo-Gangetic-Brahmaputra plains) are formed due to the depositional work of rivers and wind**. They are very deep. They are often referred to as **transported or azonal soils.**

- Major soil groups:
  (1) Alluvial soils
  (2) Black soils
  (3) Red soils
  (4) Laterite and Lateritic soils
  (5) Forest and Mountain soils
  (6) Arid and Desert soils
  (7) Saline and Alkaline soils
  (8) Peaty and Marshy soils



Major Soil Groups of India

Alluvial Soils

- Alluvial soils are formed mainly due to **silt deposited by Indo-Gangetic-Brahmaputra rivers (transported or azonal soils)**.
- In coastal regions, some alluvial deposits are formed due to wave action.
- Rocks of the Himalayas form the parent material.
- They are the **largest soil group covering about 15 lakh sq km or about 45.6 per cent** of the total area.
- They support more than 40% of India's population by providing the most productive agricultural lands.

Characteristics of Alluvial Soils

- They are **immature and have weak profiles** due to their recent origin.

- Most of the soil is **loamy.** Sandy and clayey soils are not uncommon.
- Pebbly and gravelly soils are rare.
- **Kankar (calcareous concretions)** beds are present in some regions along the river terraces.
- The soil is **porous** because of its loamy (equal proportion of sand and clay) nature.
- Porosity and texture provide **good drainage** and other conditions favourable for agriculture.
- These soils are constantly replenished by the recurrent floods.

Chemical properties of Alluvial Soils

- The proportion of nitrogen is generally low.
- The proportion of potash, phosphoric acid (phosphate) and alkalis (lime) are adequate.
- The proportion of Iron oxide and lime vary within a wide range.

Distribution of Alluvial Soils in India

- They occur all along the Indo-Gangetic-Brahmaputra plains except in few places where the top layer is covered by desert sand.
- They also occur in deltas of the Mahanadi, the Godavari, the Krishna and the Cauvery, where they are called **deltaic alluvium** (coastal alluvium).
- Some alluvial soils are found in the Narmada, Tapti valleys and Northern parts of Gujarat.

Crops in Alluvial Soils

- They are mostly flat and regular soils and are best suited for agriculture.
- They are **best suited to irrigation and respond well to the canal and well/tube-well irrigation**.
- They yield splendid crops of **rice, wheat, sugarcane, tobacco, cotton, jute, maize, oilseeds**, etc.

Geological Divisions of alluvial soils

- Geologically, the alluvium of the Great plain of India is divided into **newer or younger khadar** and **older bhangar soils**.

Black Soils

- The parent material for most of the black soil are the volcanic rocks that were formed in the Deccan Plateau (Deccan and the Rajmahal trap).
- In Tamil Nadu, gneisses and schists form the parent material. The former are sufficiently deep while the later are generally shallow.
- These are the region of high temperature and low rainfall. It is, therefore, **a soil group typical to the dry and hot regions of the Peninsula**.

Characteristics of Black Soils

- A typical black soil is highly argillaceous (containing clay) with a large clay factor, 62 per cent or more.
- In general, black soils of uplands are of low fertility while those in the valleys are very fertile.
- The black soil is highly **retentive of moisture**.
- It swells greatly on accumulating moisture.
- In the rainy season, the soil gets very sticky and hence ploughing, and other agricultural activities demand more effort.
- In summer, the moisture evaporates the soil shrinks and is seamed with broad and deep cracks.
- The lower layers can still retain moisture. The cracks permit **oxygenation** of the soil to sufficient depths.

Colour of Black Soils

- The black colour is due to the presence of a small proportion of **titaniferous magnetite or iron and black constituents of the parent rock.**
- In Tamil Nadu and parts of Andhra Pradesh, the black colour is derived from crystalline schists and basic gneisses.
- Various tints of the black colour may be found in this group of soils.

Chemical Composition of Black Soils

- 10 per cent of alumina,
- 9-10 per cent of iron oxide,

- 6-8 per cent of lime and magnesium carbonates,
- potash is variable (less than 0.5 per cent) and
- **phosphates, nitrogen and humus are low.**

Distribution of Black Soils

- Spread over **5.46 lakh sq km (16.6 per cent of the total area) across** Maharashtra, Madhya Pradesh, parts of Karnataka, Telangana, Andhra Pradesh, Gujarat and Tamil Nadu.

Crops in Black Soils

- These soils are best suited for cotton crop. Hence these soils are called as **regur and black cotton soils.**
- Other major crops grown on the black soils include wheat, jowar, linseed, virginia tobacco, castor, sunflower and millets.
- Rice and sugarcane are equally important where irrigation facilities are available.
- Large varieties of vegetables and fruits are also successfully grown on the black soils.
- This soil has been used for growing a variety of crops for centuries without adding fertilisers and manures, with little or no evidence of exhaustion.

Red Soils

- Red soils along with its minor groups form one of the **largest soil group of India.**
- The main parent rocks are crystalline and **metamorphic rocks** like acid granites, gneisses and quartzites.

Characteristics of Red Soils

- The texture of these soils can vary from sand to clay, the majority being loams.
- On the uplands, the red soils are poor, gravelly, and porous. But in the lower areas, they are rich, deep dark and fertile.

Chemical Composition of Red Soils

- They are **acidic** mainly due to the nature of the parent rocks. The alkali content is fair.
- They are poor in lime, magnesia, **phosphates, nitrogen** and humus.
- They are fairly rich in **potash and potassium.**

Colour of Red Soils

- The red colour is due to the presence of **iron oxide.**
- The colour is more due to the **wide diffusion** rather than the high percentage of iron oxide content.

Distribution of Red Soils

- These soils mostly **occur in the regions of low rainfall**.
- They occupy about **3.5 lakh sq km (10.6 per cent)** of the total area of the country.
- These soils are spread on almost the whole of **Tamil Nadu.**
- Other regions with red soil include parts of Karnataka, south-east of Maharashtra, Telangana, Andhra Pradesh, Madhya Pradesh, Chhattisgarh, Odisha, Chota Nagpur plateau; parts of south Bihar, West Bengal, Uttar Pradesh; Aravallis and the eastern half of Rajasthan (Mewar or Marwar Plateau), parts of North-Eastern states.

Crops in Red Soils

- The red soils are **mostly loamy** and hence **cannot retain water** like the black soils.
- The red soils, with the proper use of fertilisers and irrigation techniques, give a good yield of cotton, wheat, rice, pulses, millets, tobacco, oilseeds, potatoes and fruits.

Laterite – Lateritic Soils

- Laterite soils are mostly the **end products of weathering.**
- They are formed under conditions of **high temperature and heavy rainfall with alternate wet and dry periods**.
- Heavy rainfall promotes **leaching (nutrients gets washed away by water)** of soil whereby

lime and silica are leached away, and a soil rich in oxides of iron and aluminium compounds is left behind.
- 'Laterite' means brick in Latin. **They harden greatly on losing moisture**.
- Laterite soils are red in colour due to little clay and more gravel of red sand-stones.

The chemical composition of Laterite – Lateritic Soils

- Laterite soils are rich in **bauxite or ferric oxides.**
- They are very **poor** in lime, magnesia, **potash and nitrogen.**
- Sometimes, the **phosphate** content may be **high** in the form of **iron phosphate.**
- In wetter places, there may be higher content of humus.

Distribution of Laterite – Lateritic Soils

- Laterite soils cover an area of **2.48 lakh sq km**.
- The continuous stretch of laterite soil is found on the summits of Western Ghats at 1000 to 1500 m above mean sea level, Eastern Ghats, the Rajmahal Hills, Vindhyan, Satpuras and Malwa Plateau.
- They are well developed in south Maharashtra, parts of Karnataka etc. and are widely scattered in other regions.

Crops in Laterite – Lateritic Soils

- **Laterite soils lack fertility** due to **intensive leaching.**
- When manured and irrigated, some laterites are suitable for growing **plantation crops** like tea, coffee, rubber, cinchona, coconut, arecanut, etc.
- In some areas, these soils support **grazing grounds and scrub forests.**

The economic value of Laterite – Lateritic Soils

- Laterite and lateritic soils provide **valuable building material.**
- These soils can be easily cut into cakes but hardens like iron when exposed to air.
- As it is the end-product of weathering, it cannot be weathered much further and is durable.

Forest – Mountain Soils

- These soils occupy about **2.85 lakh sq km or 8.67%** of the total land area of India.
- They are mainly **heterogeneous soils** found on the hill slopes covered by forests.
- The formation of these soils is mainly governed by the characteristic deposition of organic matter derived from forests and their character changes with parent rocks, ground-configuration and climate.
- Consequently, they **differ greatly even if they occur in close proximity to one another.**

Distribution of Forest – Mountain Soils

- In the Himalayan region, such soils are mainly found in valleys, less steep and north facing slopes. The south-facing slopes are very steep and exposed to denudation and hence do not support soil formation.
- Forest soils occur in Western and Eastern Ghats also.

Chemical properties of Forest – Mountain Soils

- The forest soils are very **rich in humus.**
- They are **deficient in potash, phosphorus and lime**.
- They require a good deal of fertilisers for high yields.

Crops in Forest – Mountain Soils

- They are suitable for **plantations** of tea, coffee, spices and tropical fruits in the peninsular forest region.
- Wheat, maize, barley and temperate fruits are grown in the Himalayan forest region.

Arid – Desert Soils

- The desert soils consist of **aeolian sand** (90 to 95 per cent) and clay (5 to 10 per cent).
- They cover a total area of 1.42 lakh sq km (4.32%).
- The presence of sand inhibits soil growth.
- Desertification of neighbouring soils is common due to the intrusion of aeolian sand (wind action).

Distribution of Arid – Desert Soils

- Occur in arid and semi-arid regions of Rajasthan, Punjab and Haryana.
- The sand here is blown from the Indus basin and the coast by the prevailing south-west monsoon winds.
- Sandy soils without clay factor are also common in coastal regions of Odisha, Tamil Nadu and Kerala.

Chemical properties of Arid – Desert Soils

- They are usually poor in organic matter.
- Some desert soils are **alkaline** with varying degree of soluble salts like **calcium carbonate.**
- Calcium content increases downwards, and the subsoil has ten times more calcium.
- The **phosphate** content of these soils is as **high** as in normal alluvial soils.
- Nitrogen is originally low, but some of it is available in the **form of nitrates.**

Crops of Arid – Desert Soils

- **Phosphates and nitrates make these soils fertile wherever moisture is available**.
- There is a possibility of reclaiming these soils if proper irrigation facilities are available.
- In large areas, only the drought resistant and salt tolerant crops such as barley, cotton, millets, maize and pulses are grown.

Saline – Alkaline Soils

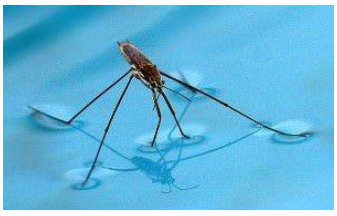
- In Saline and Alkaline Soils, the topsoil is **impregnated** (soak or saturate with a substance) with **saline and alkaline efflorescences** (become covered with salt particles).
- Undecomposed rock fragments, on weathering, give rise to **sodium, magnesium and calcium salts and sulphurous acid.**
- Some of the salts are transported in solution by the rivers.
- **In regions with the low water table, the salts percolate into subsoil** and in regions with good drainage, the salts are wasted away by flowing water.
- But in places where the **drainage system is poor**, the water with high salt concentration becomes stagnant and deposits all the salts in the topsoil once the water evaporates.
- In regions with the **high sub-soil water table**, injurious salts are transferred from below by the **capillary action as a result of evaporation in the dry season**.

Capillary action

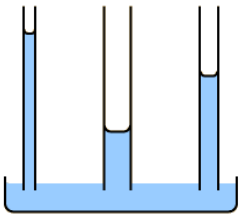
- Capillary action is the **ability of a liquid to flow in narrow spaces without the assistance of, and in opposition to, external forces like gravity**.
- The force behind capillary action is **surface tension.**

Surface tension

- Surface tension is the elastic tendency of liquids (a membrane-like surface) that makes them acquire the least surface area possible.
- Surface tension causes insects (e.g. water striders), usually denser than water, to float and stride on the water surface.

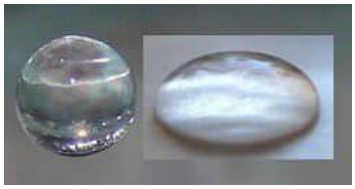


- Surface tension offers the necessary buoyant force (buoyancy) required for an object to float in water (Ships float because of difference in density as well as surface tension).



What gives water droplet its shape?

- When a water droplet is freely falling, it acquires a spherical shape.
- When a water drop is on a surface, it acquires the shape of a hemisphere (half a sphere).
- All this is due to **surface tension.**



This kind of trivial GK can help with many exams.

Distribution of Saline – Alkaline Soils

- Saline and Alkaline Soils occupy 68,000 sq km of area.
- These soils are found in **canal irrigated areas** and **areas of a high sub-soil water table**.
- Parts of Andhra Pradesh, Telangana, Karnataka, Bihar, Uttar Pradesh, Haryana, Punjab (**side effects of improper or excess irrigation**), Rajasthan and Maharashtra have this kind of soils.
- The accumulation of these salts makes the soil infertile and renders it unfit for agriculture.
- In Gujarat, the areas around the Gulf of Khambhat are affected by the **sea tides** carrying salt-laden deposits. Vast areas comprising the estuaries of the Narmada, the Tapi, the Mahi and the Sabarmati have thus become infertile.
- Along the coastline, saline sea waters infiltrate into coastal regions during **storm surges** (when cyclones make landfall) and make the soil unfit for cultivation.
- The low lying regions of coastal Andhra Pradesh and Tamil Nadu face this kind of soil degradation.

Peaty – Marshy Soils

- These are soils with a **large amount of organic matter** and a **considerable amount of soluble salts.**
- The **most humid regions** have this type of soil.
- They are black, heavy and **highly acidic.**

Distribution of Peaty – Marshy Soils

- Kottayam and Alappuzha districts of Kerala.
- Also occur in the coastal areas of Odisha and Tamil Nadu, Sundarbans of West Bengal, in Bihar and Almora district of Uttarakhand.

Chemical Properties of Peaty – Marshy Soils

- They are deficient in potash and phosphate.

Crops of Peaty – Marshy Soils

- Most of the peaty soils are under water during the rainy season but as soon the rains cease; they are put under paddy cultivation.