

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

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.

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.

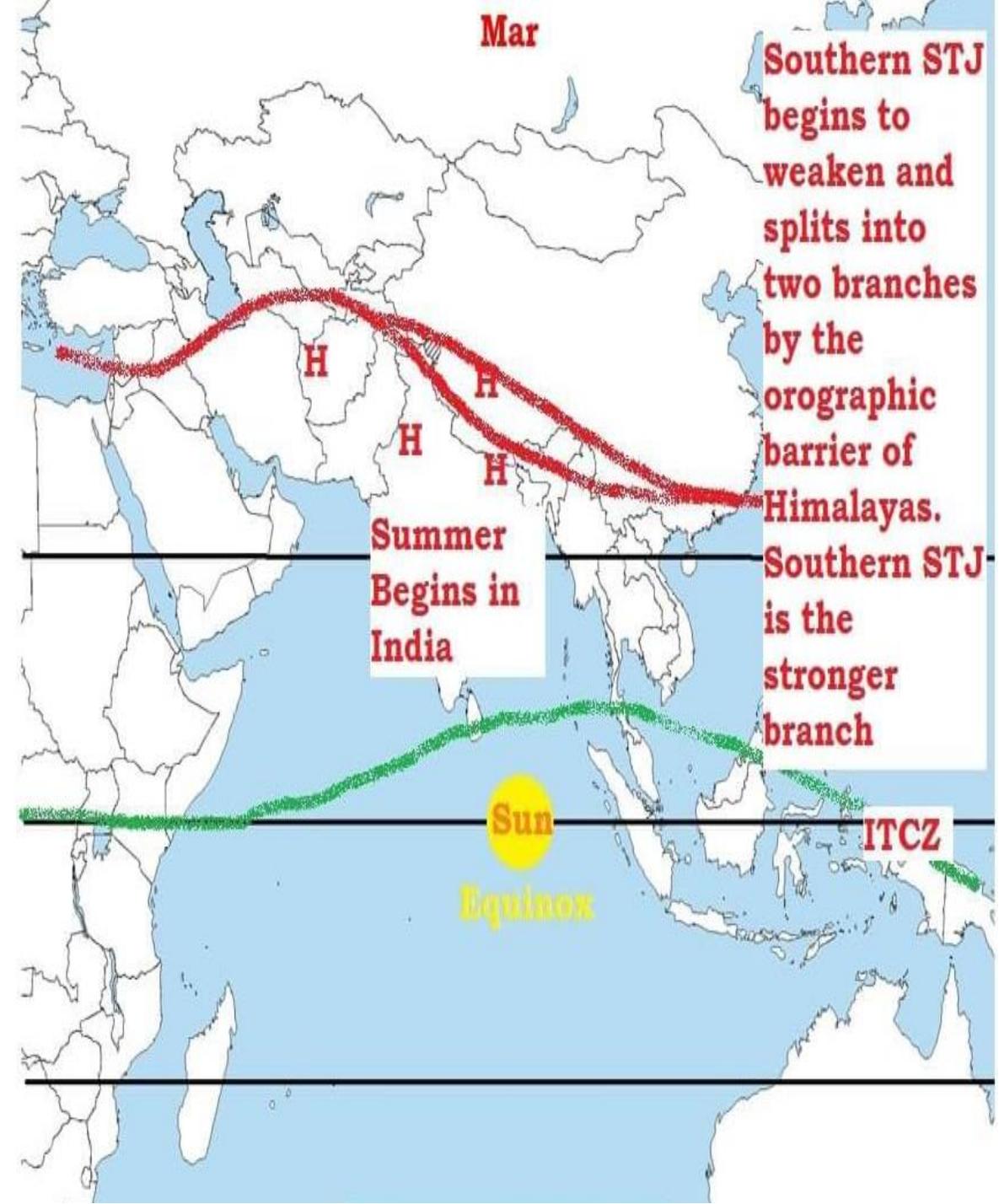
Mechanism of Indian Monsoons – Based on Modern Theories

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).**

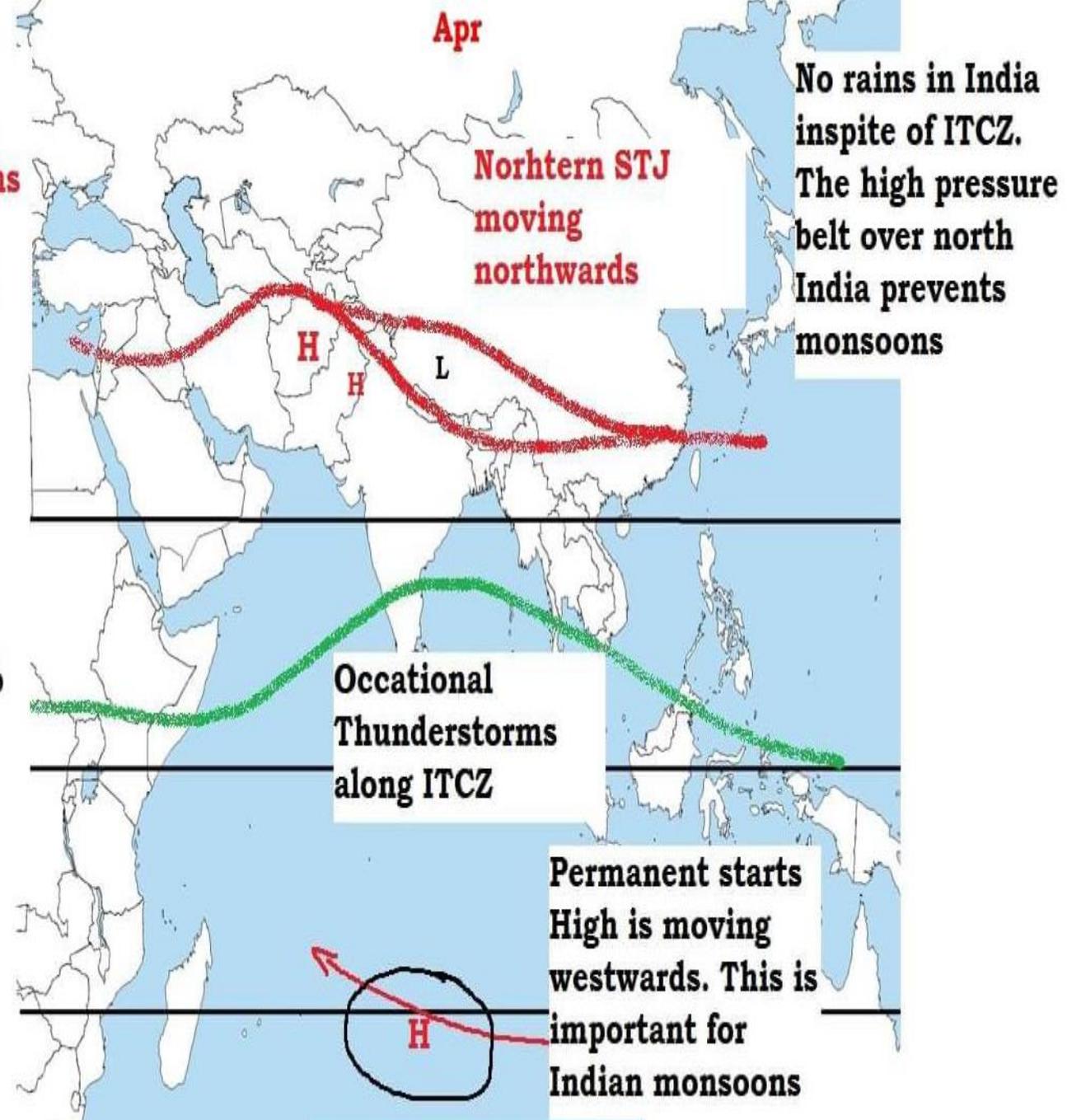


In the peak summer months (25th of May – 10th of Jun), with the apparent northward movement of the sun, the southern branch of the Sub-Tropical Jetstream (STJ), which flows to the south of the Himalayas, **shifts to the north of the Himalayas.**

- 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.

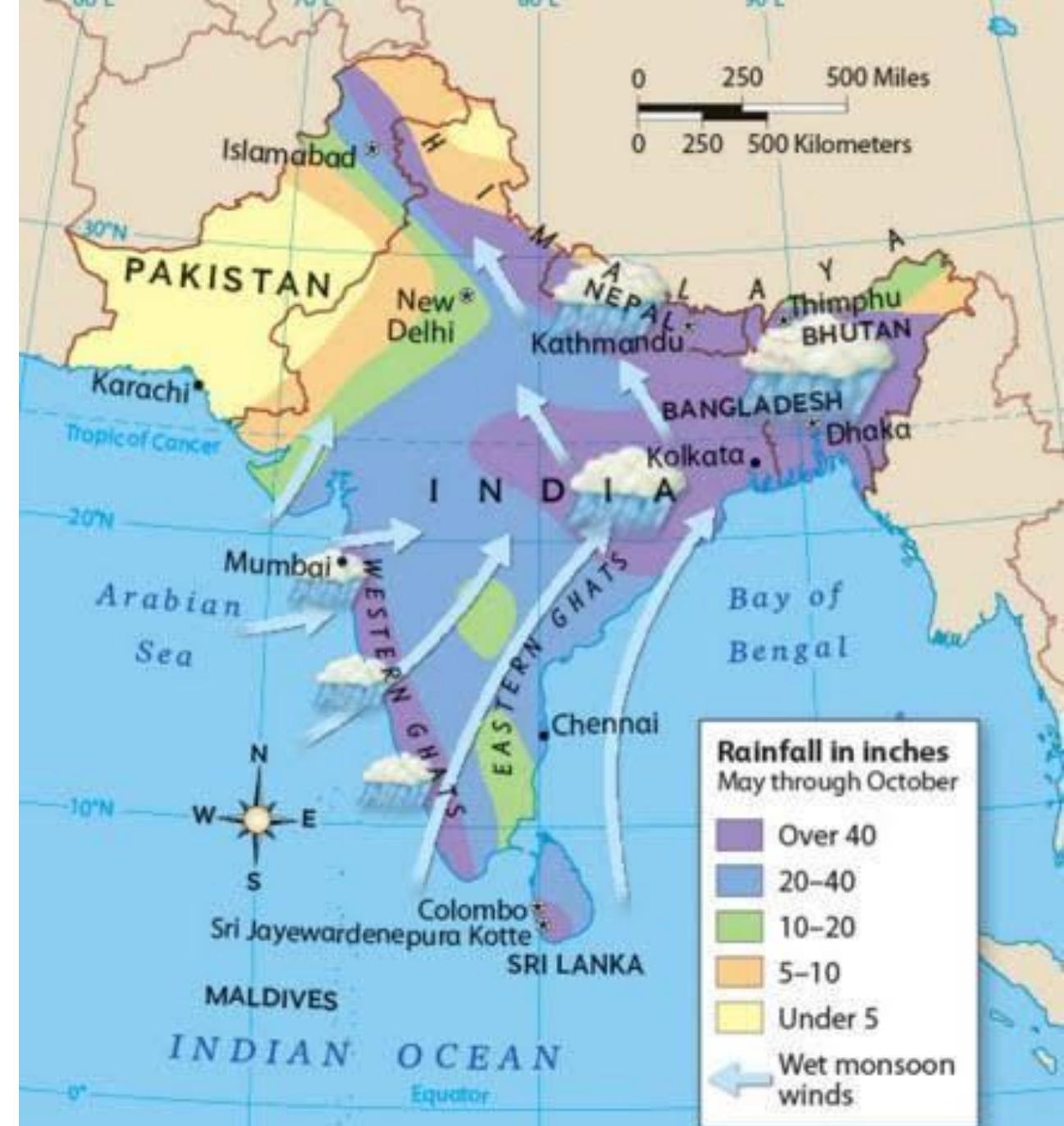
Southern STJ intact and high pressure in plains and north west India In spite of hot sun

Occasional Thunderstorms and Hailstorms cause damage to crops in Karnataka, AP, Telangana



The onset of Monsoons (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).



The end of Monsoon 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.**

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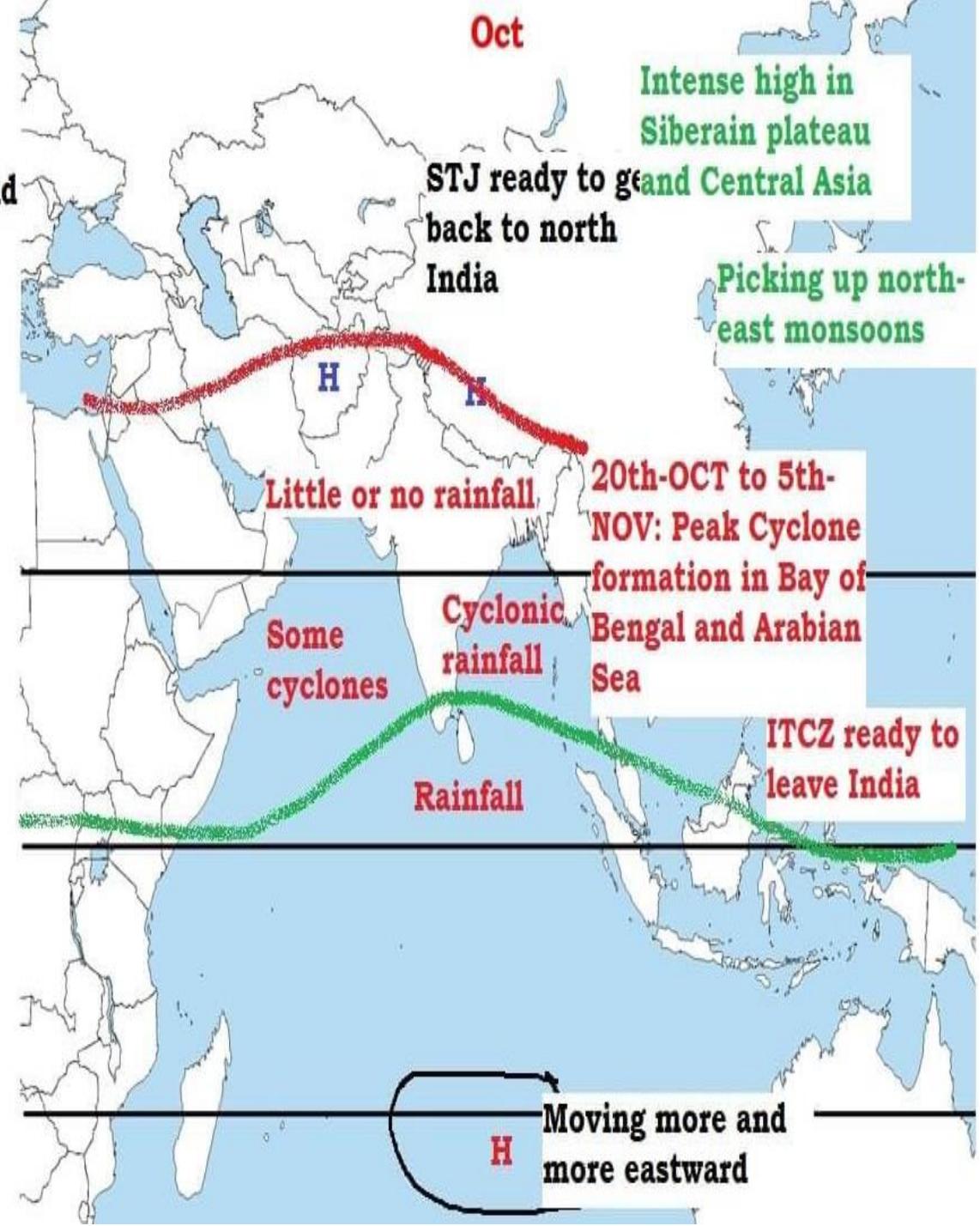
- With the southward shift of ITCZ, **subtropical high-pressure belt returns to the Indian plains, and the rainfall ceases.**

- 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

Somali Jet and Eastern Tropical Jets die by the end of October

END OF RAINY SEASON



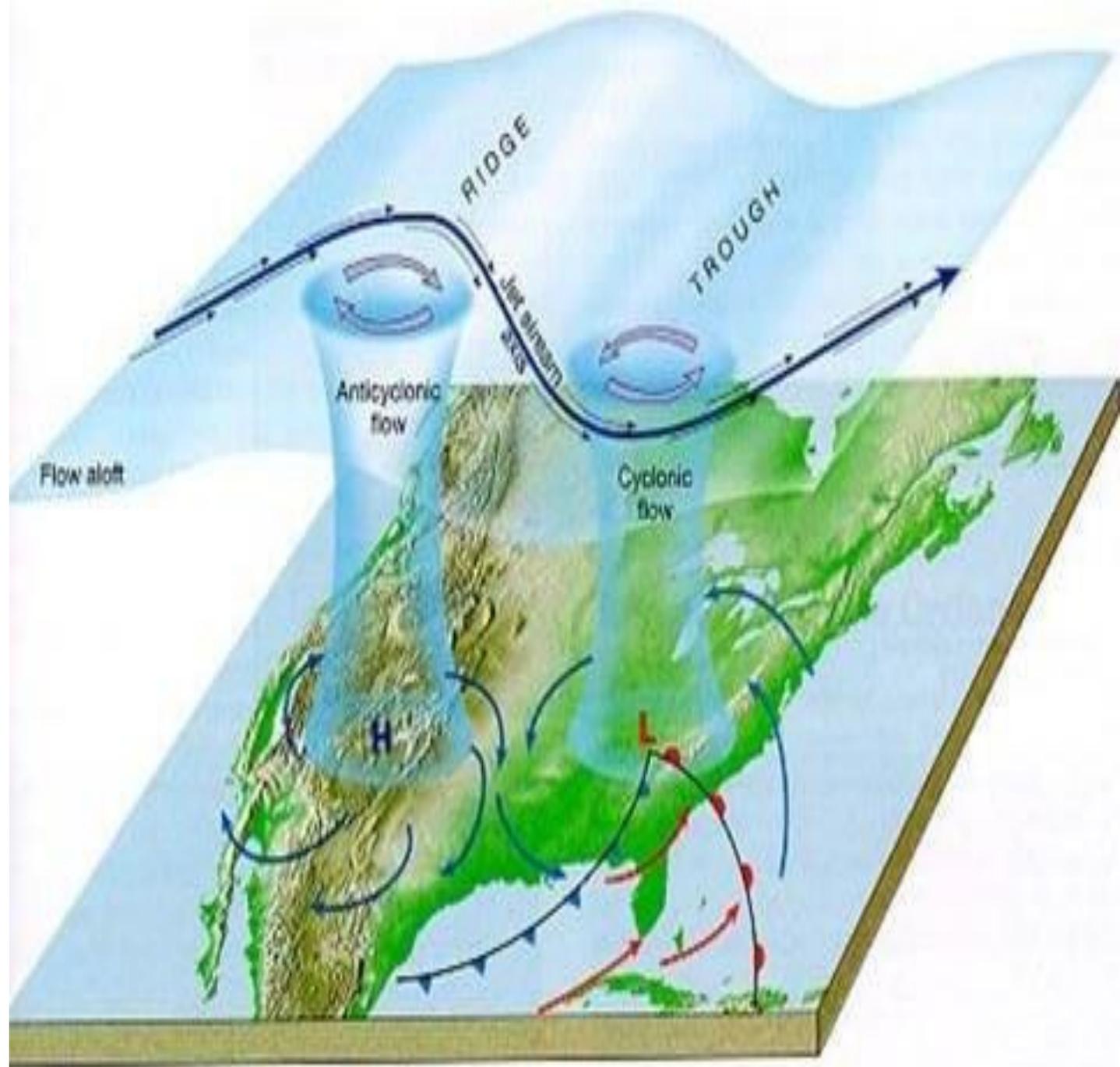
Indian Monsoon Mechanism – Jet Stream Theory

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.

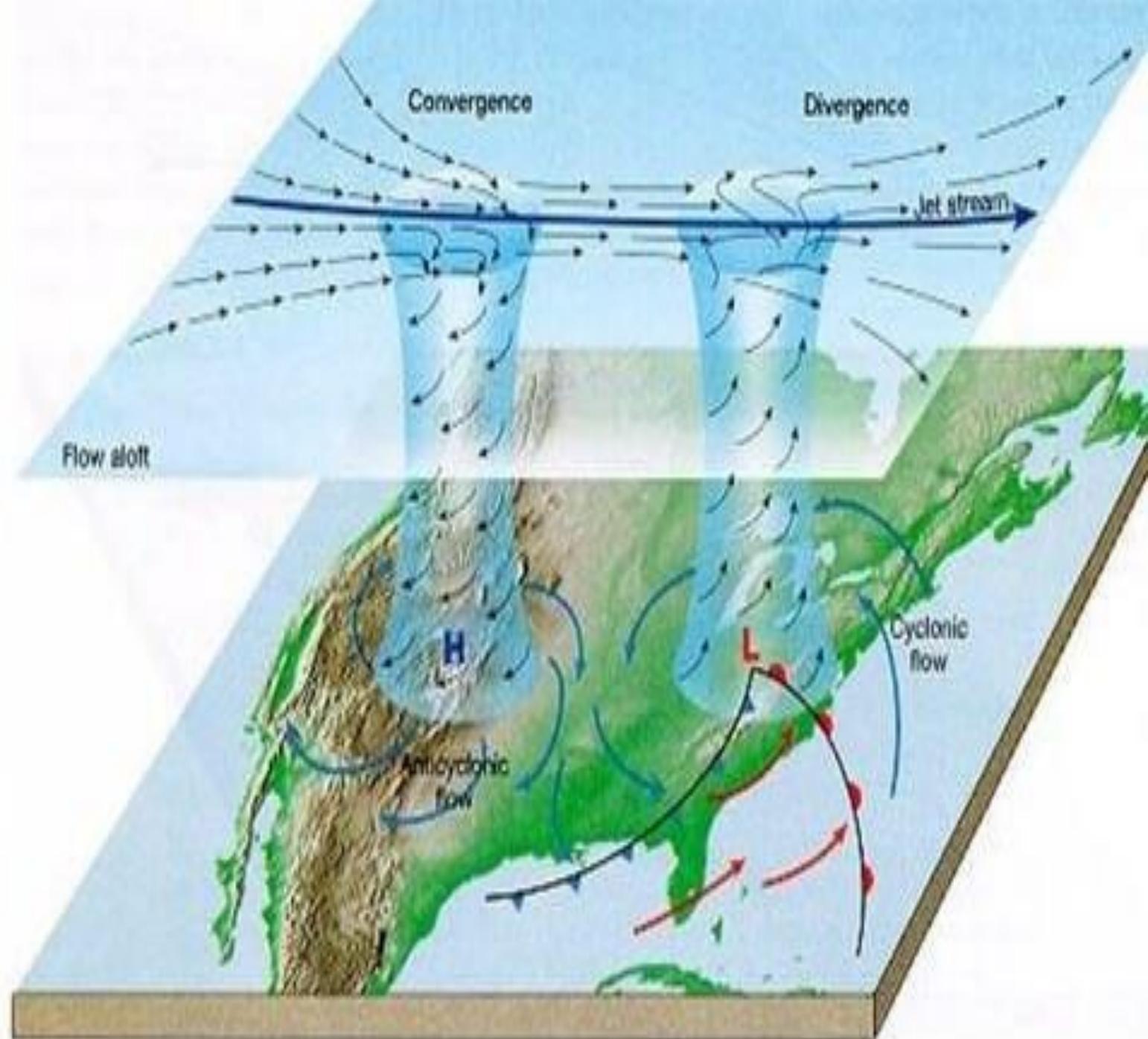
Indian Monsoon Mechanism – Modern Theory: Jet Stream Theory.

- 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.



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 subtropics 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**.

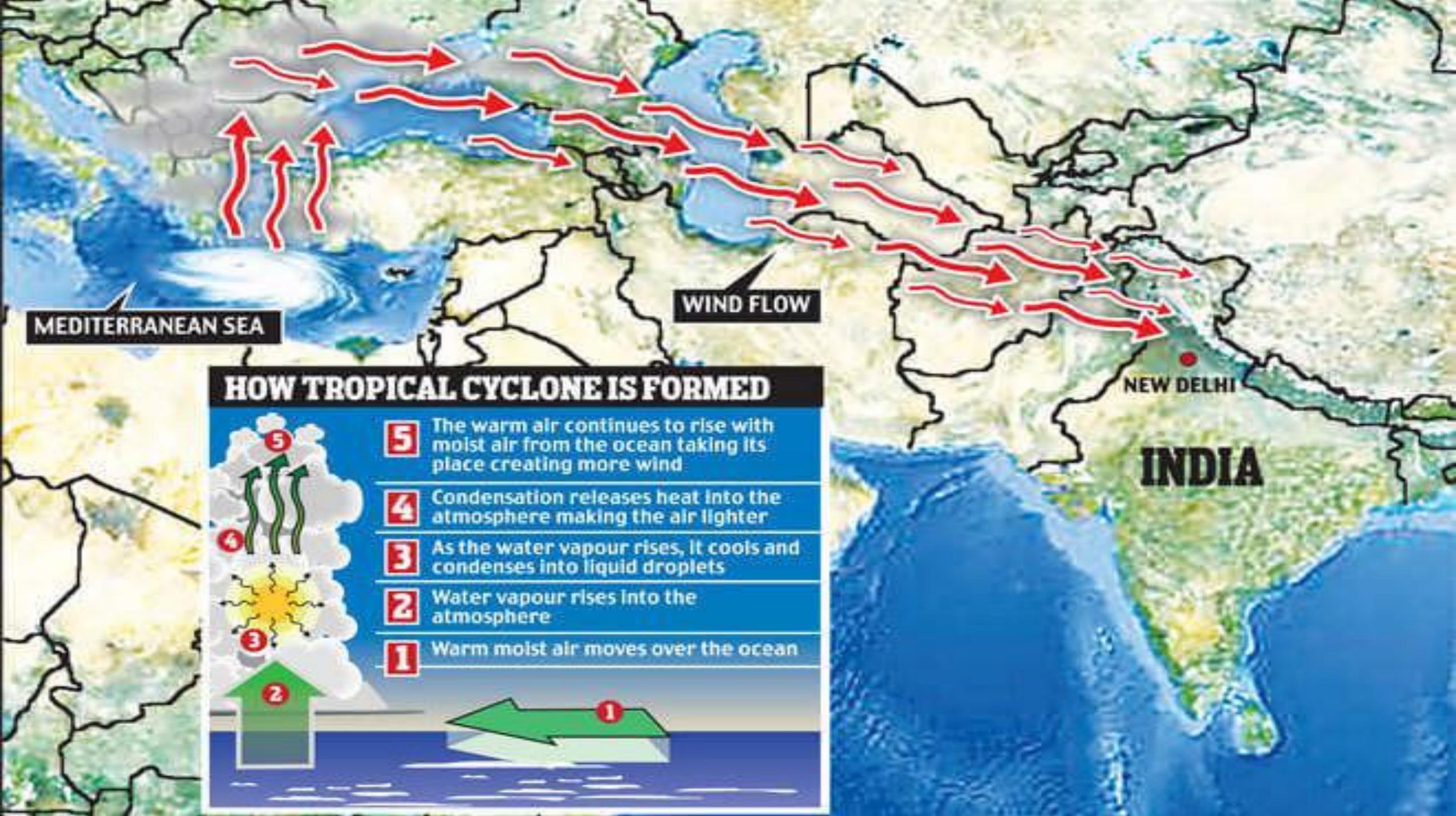


These ridges and troughs give rise to **jet streaks** which are also responsible for cyclonic and anticyclonic weather conditions at the surface.

- 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)

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).



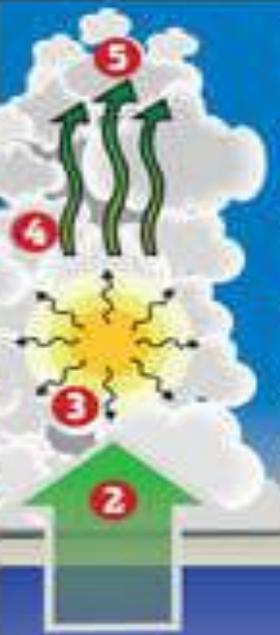
MEDITERRANEAN SEA

WIND FLOW

NEW DELHI

INDIA

HOW TROPICAL CYCLONE IS FORMED



- 5** The warm air continues to rise with moist air from the ocean taking its place creating more wind
- 4** Condensation releases heat into the atmosphere making the air lighter
- 3** As the water vapour rises, it cools and condenses into liquid droplets
- 2** Water vapour rises into the atmosphere
- 1** Warm moist air moves over the ocean

- 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.)**.

