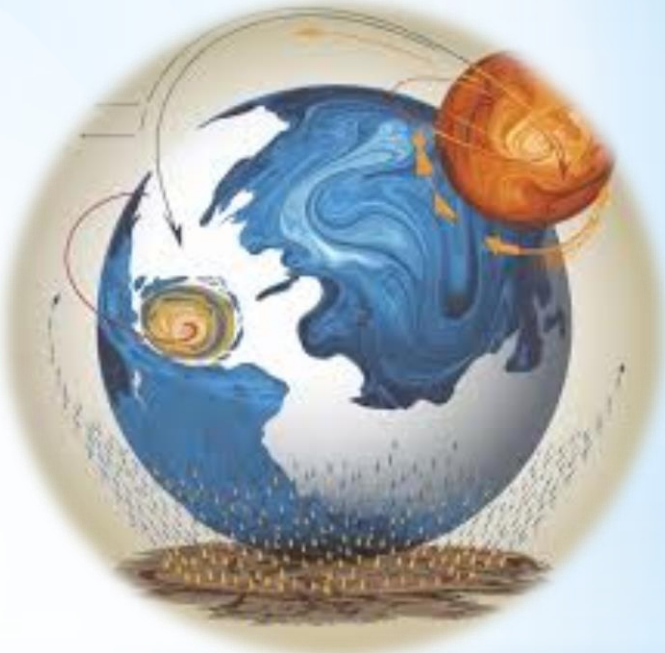
Basics of Atmospheric Pressure, Winds and Indian Monsoon Mechanism



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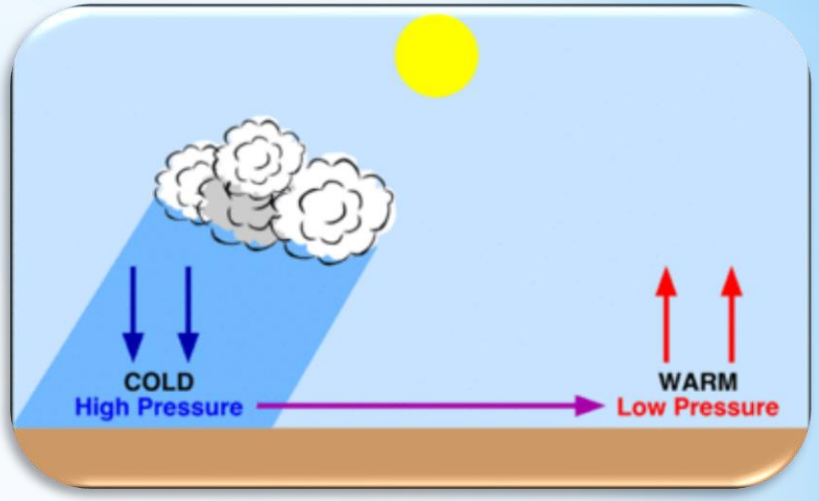
Introduction: Monsoon

Atmospheric Pressure:

Atmospheric pressure is the force exerted by the weight of the air above a given point on the Earth's surface.



Measured by:

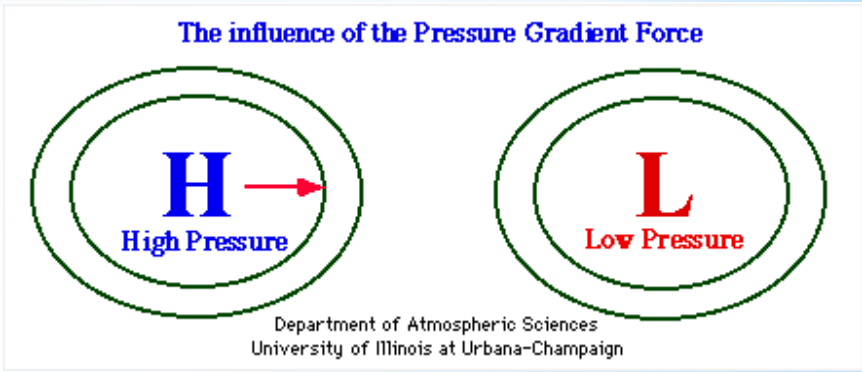
A **barometer** (unit: **millibar** or **hPa**).

High Pressure Area (HPA):

Cool, dry air sinks → clear skies.

Low Pressure Area (LPA):

Warm air rises → cloud formation and rain.



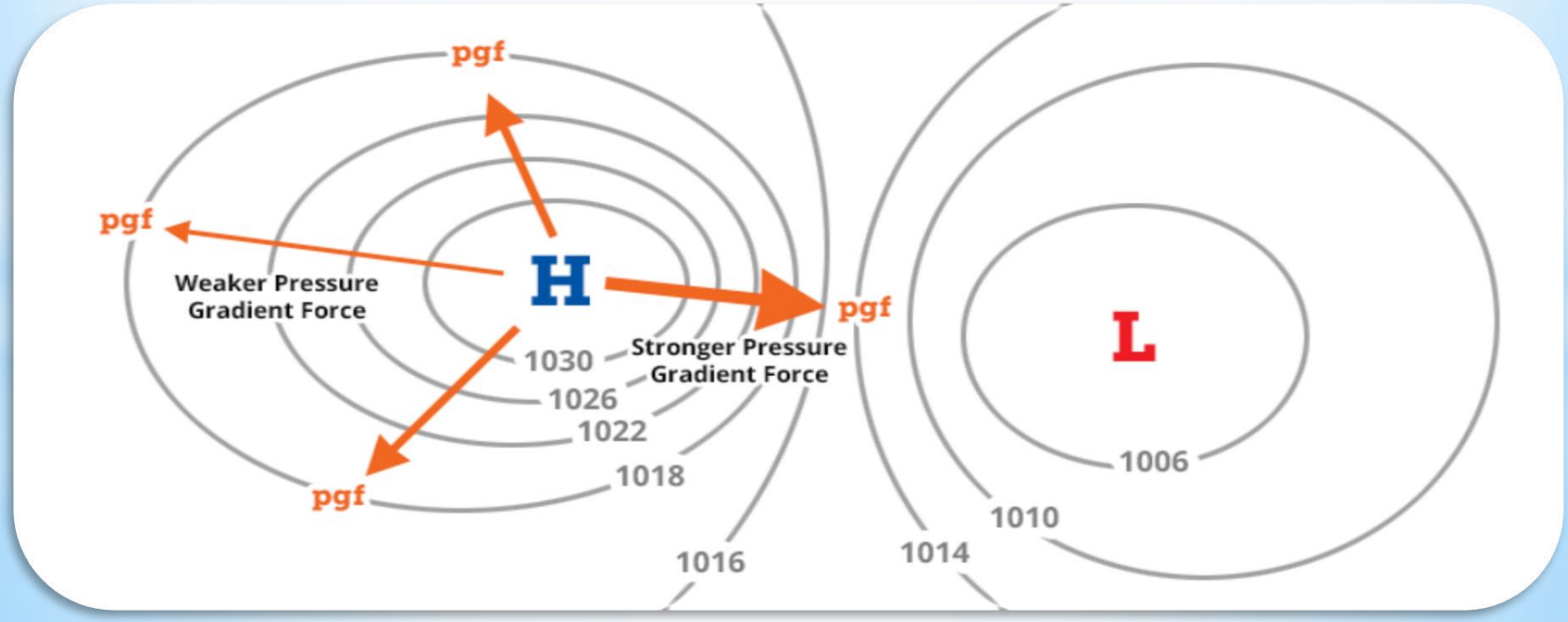
What is Pressure Gradient Force?

The **Pressure Gradient Force (PGF)** is the force that results from differences in atmospheric pressure across a horizontal distance. It causes air to move **from high pressure to low pressure.**

- **Magnitude**

Greater pressure difference over a short distance means **stronger PGF**, hence **stronger winds**.

- **closely spaced isobars** (lines of equal pressure) indicate a **strong pressure gradient**, leading to **strong winds**.

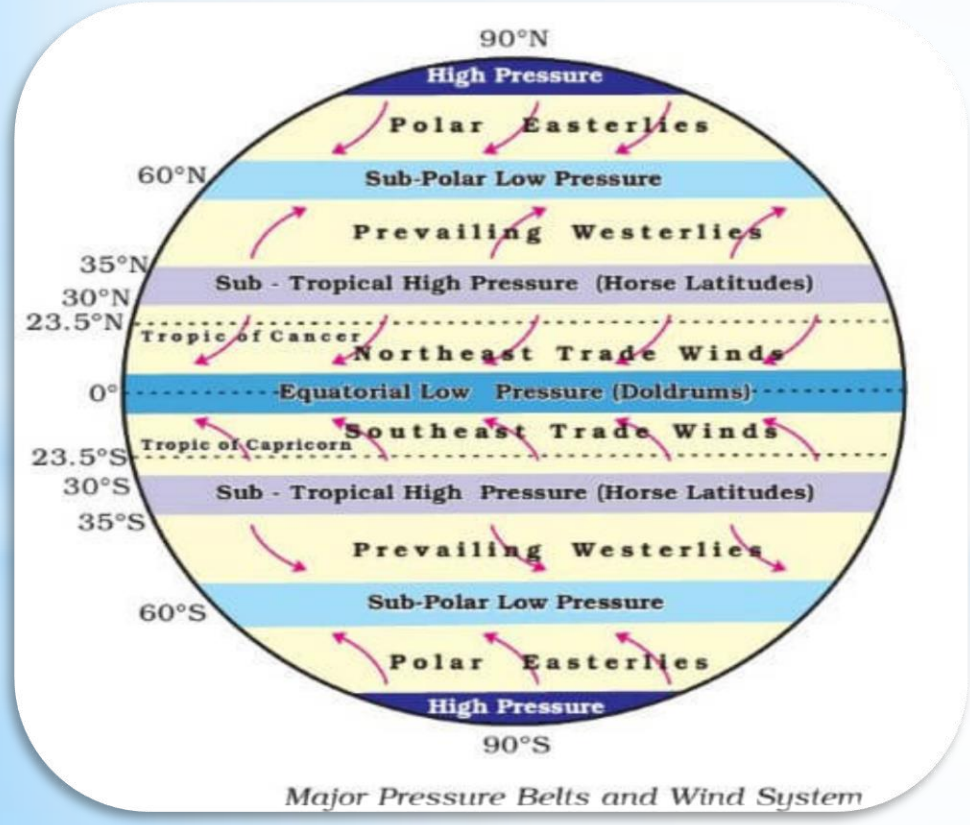


Pressure Belts of the Earth

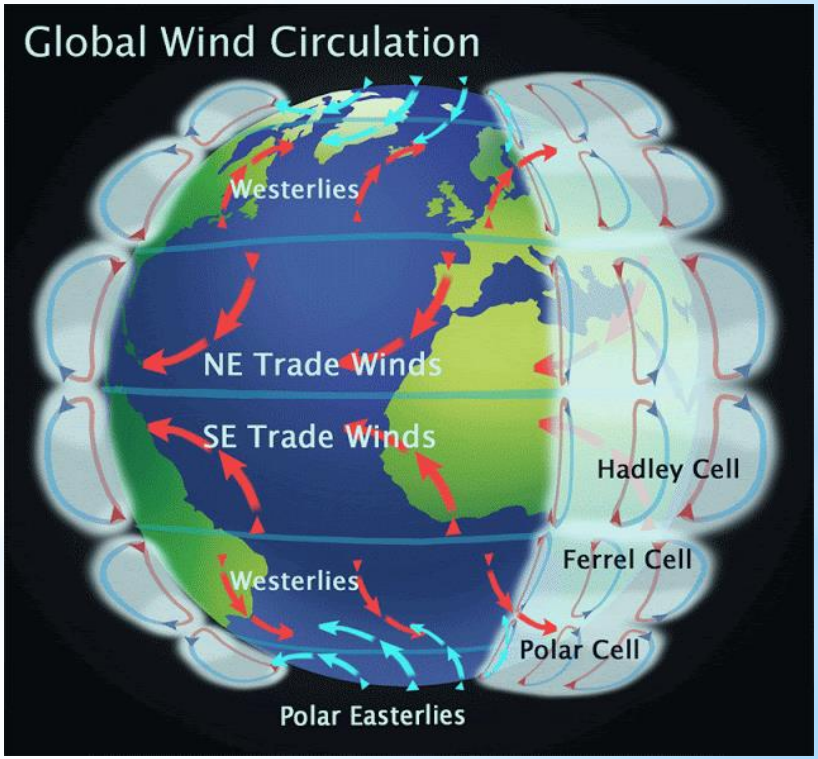
- Due to the uneven heating of the Earth and its rotation, pressure belts are formed. These are horizontal zones of high and low pressure around the globe.

Planetary Wind System

- Planetary winds are the large-scale winds that blow between these pressure belts. They blow consistently in the same direction due to the pressure gradient and the Coriolis effect (caused by Earth's rotation).



Major Pressure Belts and Wind System



Coriolis force

Coriolis force is an apparent force caused by the earth's rotation. The Coriolis force is responsible for deflecting winds towards the right in the northern hemisphere and towards the left in the southern hemisphere.

$$Fc = 2 \cdot m \cdot \Omega \cdot v \cdot \sin(\phi)$$

Where:

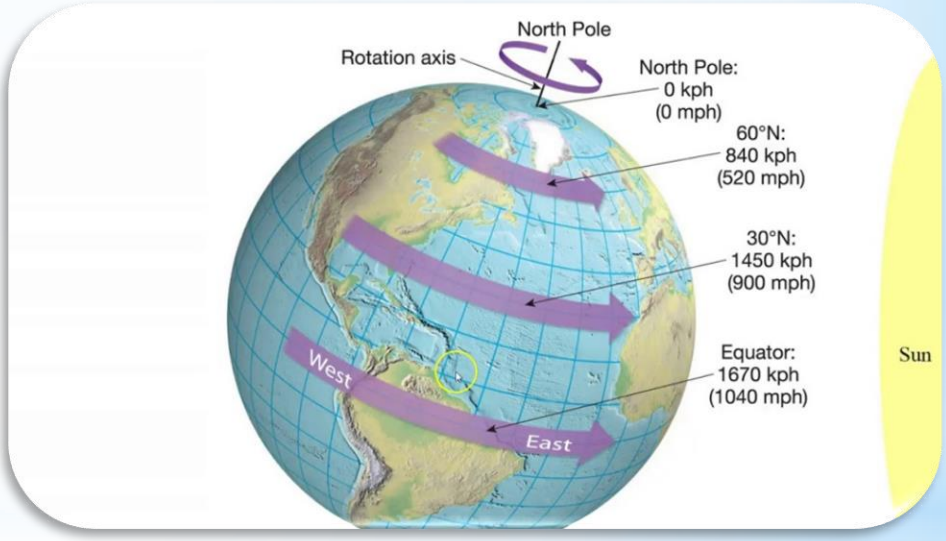
Fc= Coriolis force

m = mass of object

Ω= angular velocity of Earth

v = speed of the object

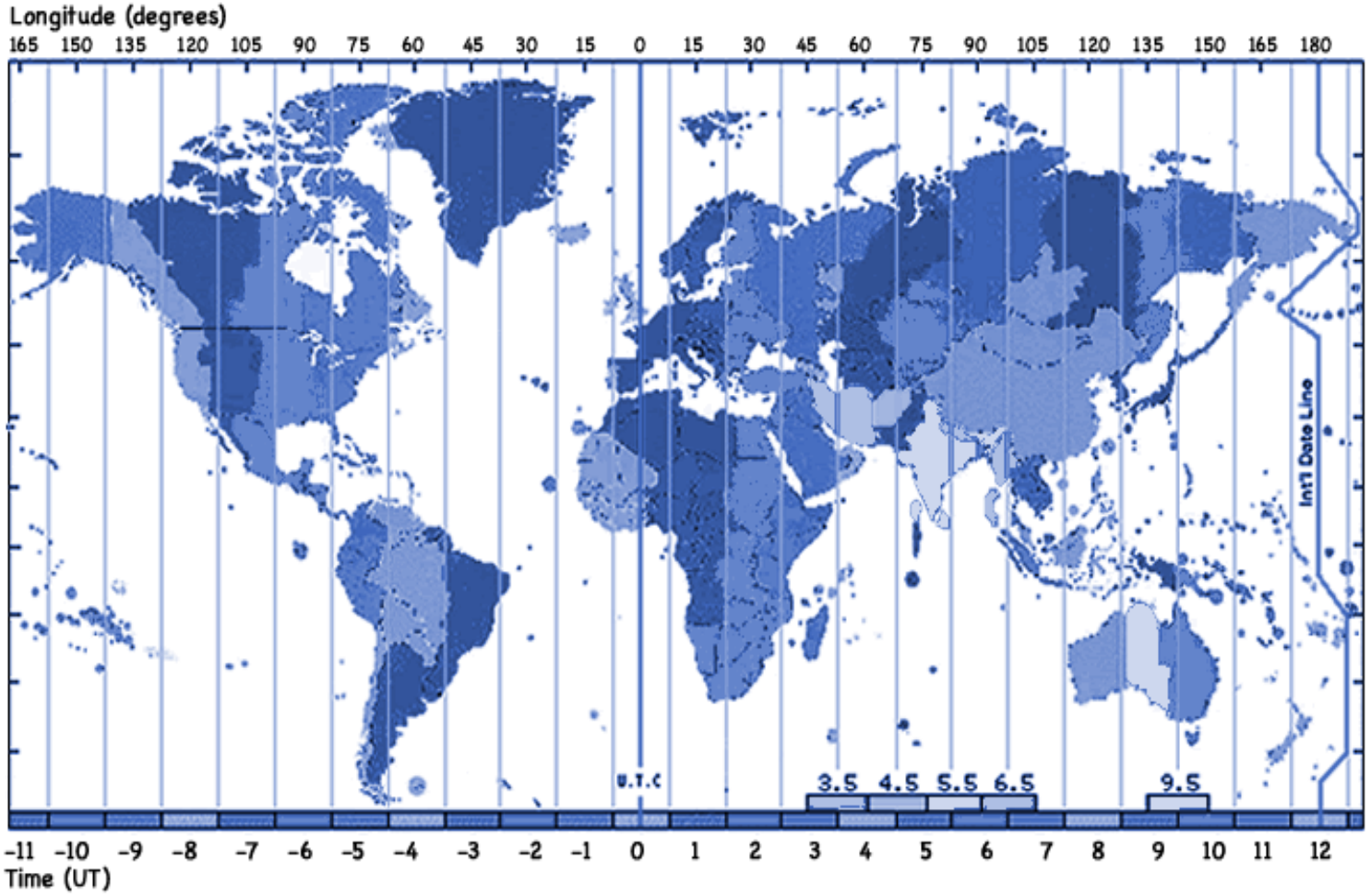
ϕ = latitude

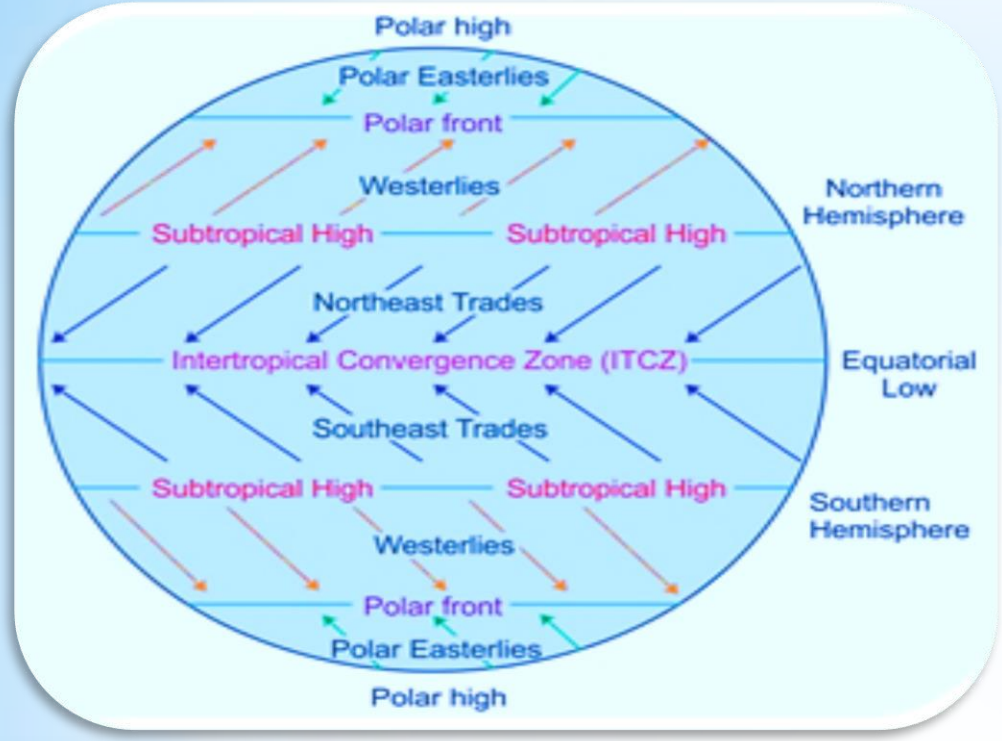


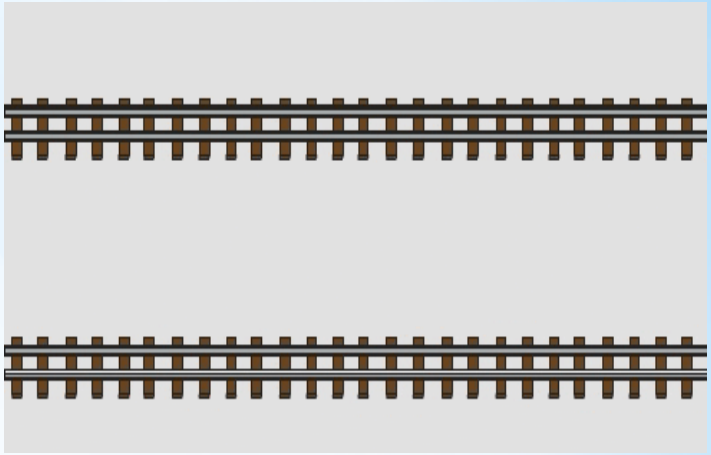
Important Characteristics:

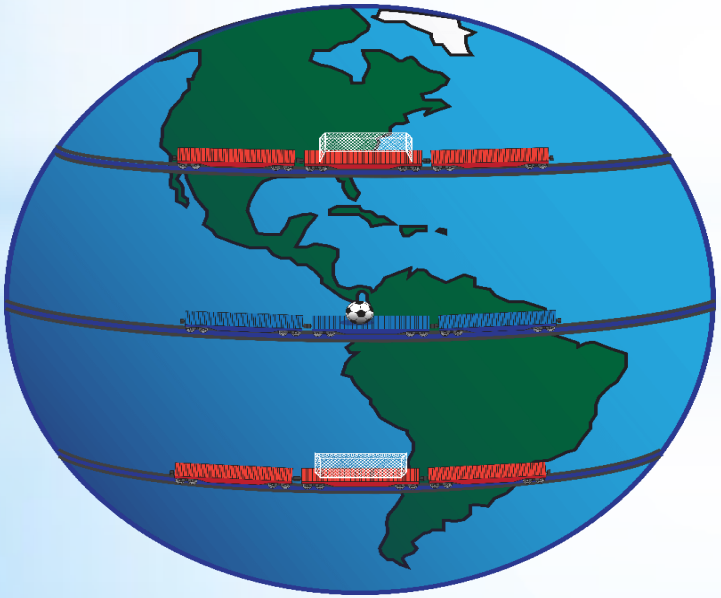
- *Zero at the **equator***
- *Maximum at the **poles***
- *Affects **only direction**, not speed*
- *Stronger for **faster moving objects***

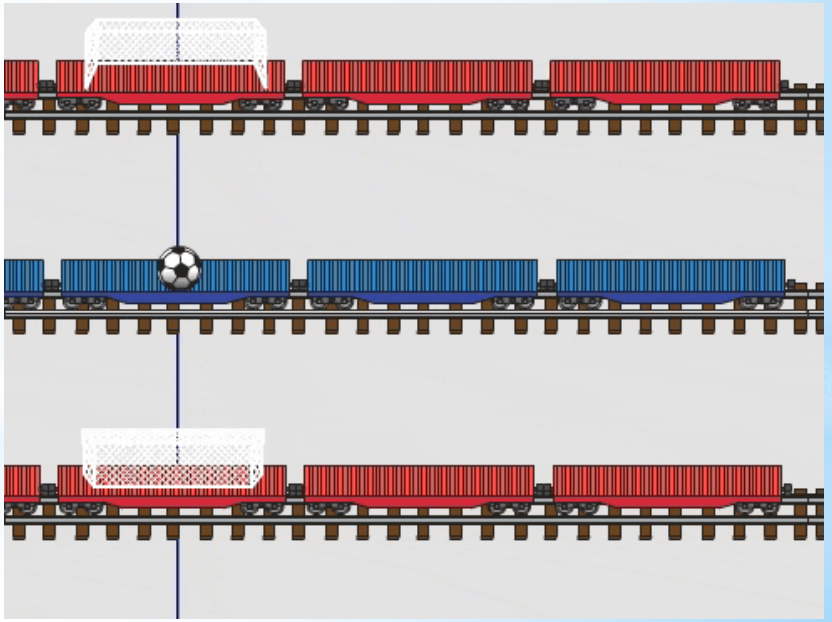
Time and Longitude




Polar high
Polar Easterlies
Polar front
Westerlies
Subtropical High
Subtropical High
Northern Hemisphere
Northeast Trades
Intertropical Convergence Zone (ITCZ)
Equatorial Low
Southeast Trades
Subtropical High
Subtropical High
Southern Hemisphere
Westerlies
Polar front
Polar Easterlies
Polar high

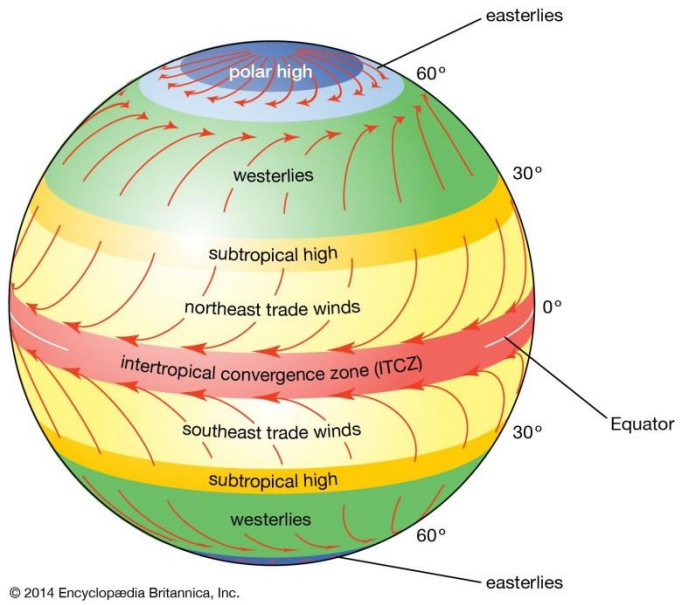


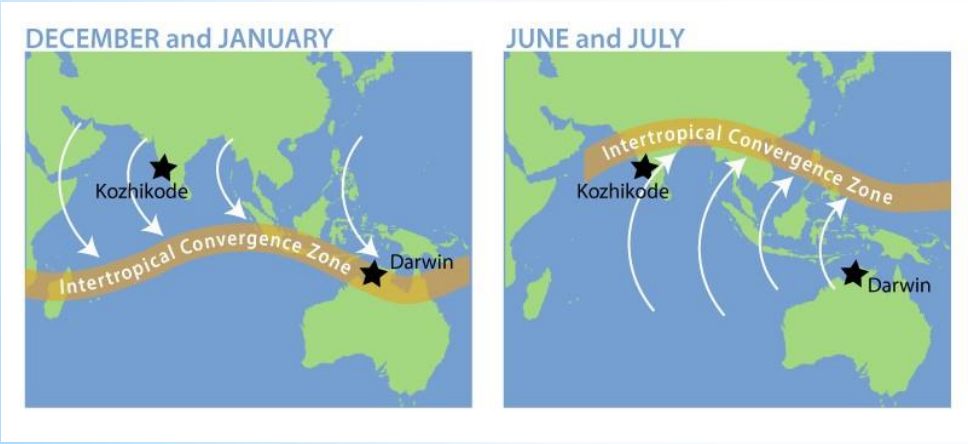




What is ITCZ?

ITCZ stands for Inter-Tropical Convergence Zone.
It is a narrow zone near the equator where the northeast and southeast trade winds meet.





What is a Jet Stream?

- A jet stream is a fast-moving, narrow band of air that flows high in the upper atmosphere (troposphere).They are like rivers of strong wind blowing from west to east around the Earth.

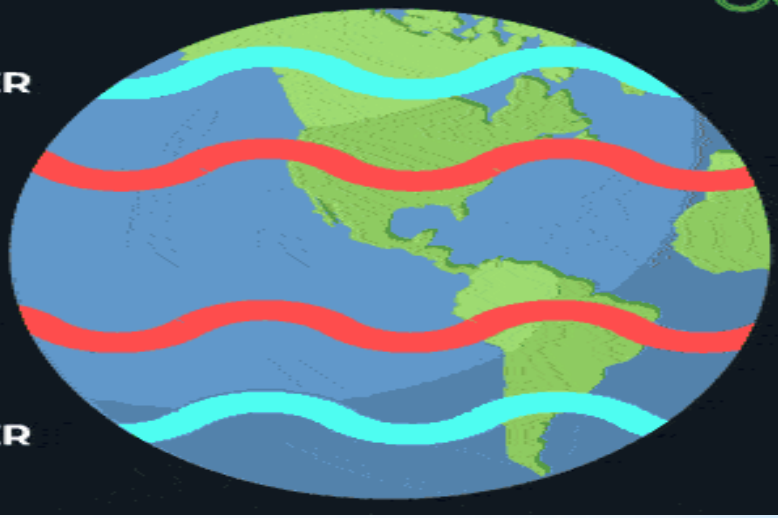
Key Features:

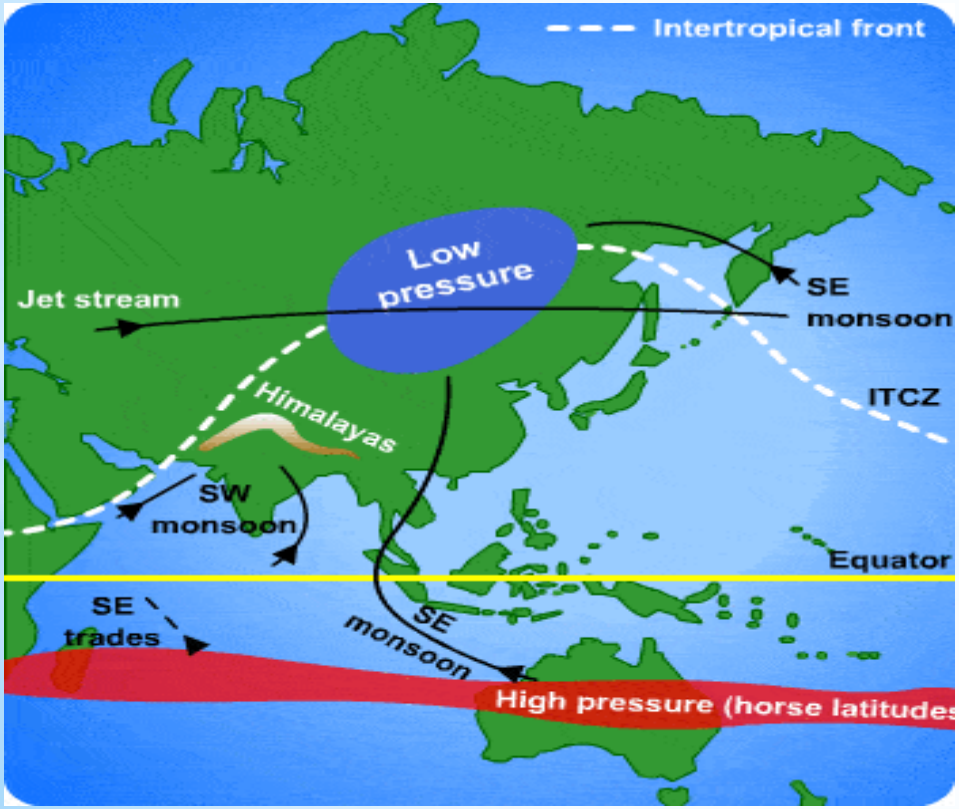
- Found at 9–16 km above Earth's surface (near tropopause)
- Wind speeds can reach 150–400 km/h or more
- Flow from west to east due to Earth's rotation
- Can influence weather patterns and aircraft routes

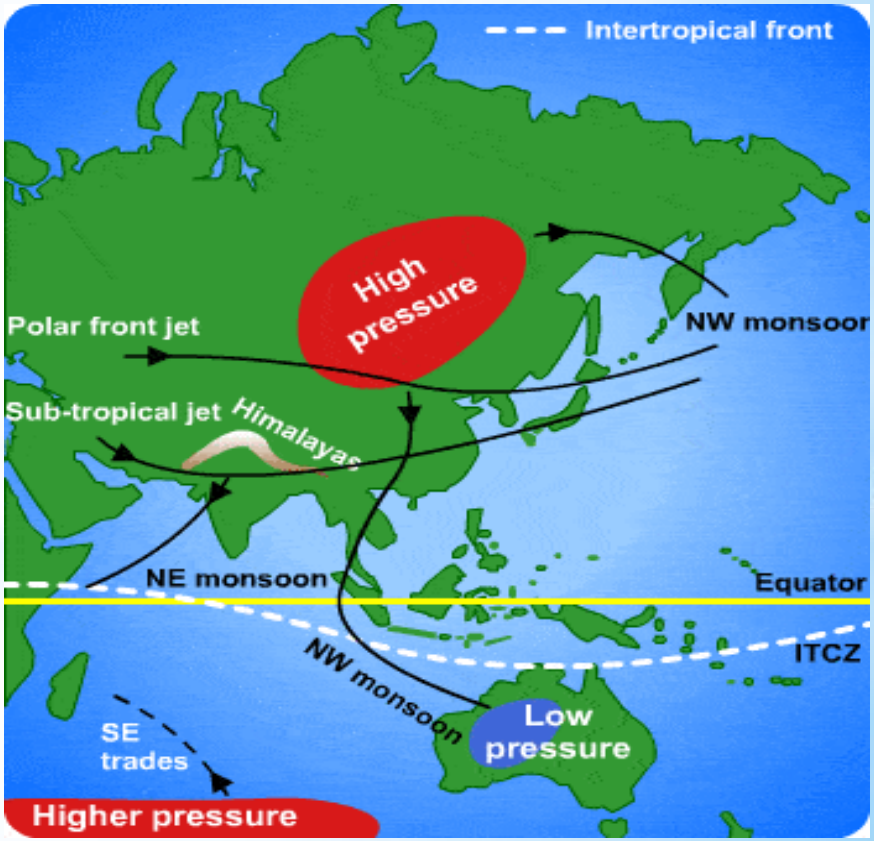
Main Types of Jet Streams:

- **Polar Jet Stream**
  - Found around **60° latitude**
  - Strong and more active in **winter**
- **Subtropical Jet Stream**
  - Found near **30° latitude**
  - Higher up and weaker than polar jets

Jet Stream

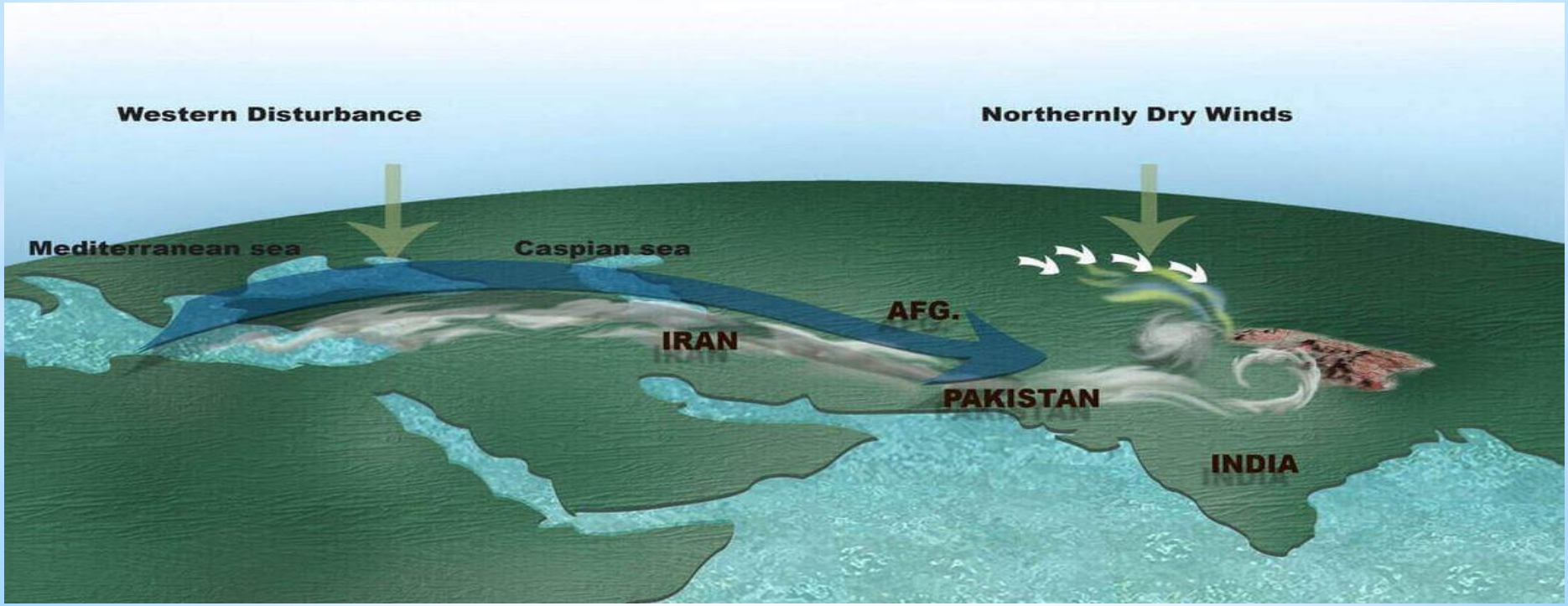

COLDER
WARMER
WARMER
COLDER

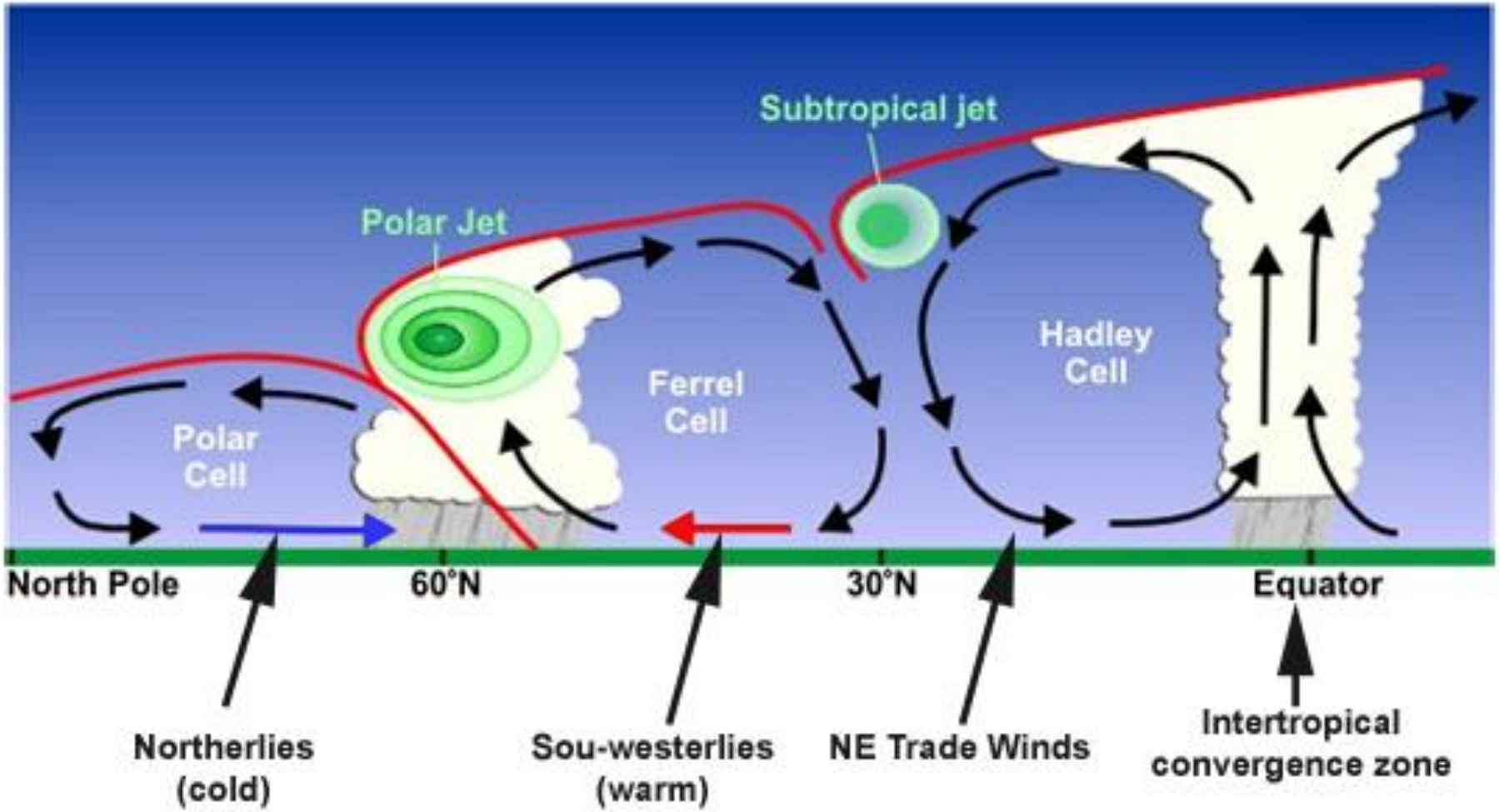

Intertropical front
Low pressure
Jet stream
SE monsoon
ITCZ
Himalayas
SW monsoon
Equator
SE trades
SE monsoon
High pressure (horse latitudes


Intertropical front
High pressure
Polar front jet
NW monsoon
Sub-tropical jet
Himalayas
NE monsoon
Equator
ITCZ
NW monsoon
Low pressure
SE trades
Higher pressure

Western disturbances:

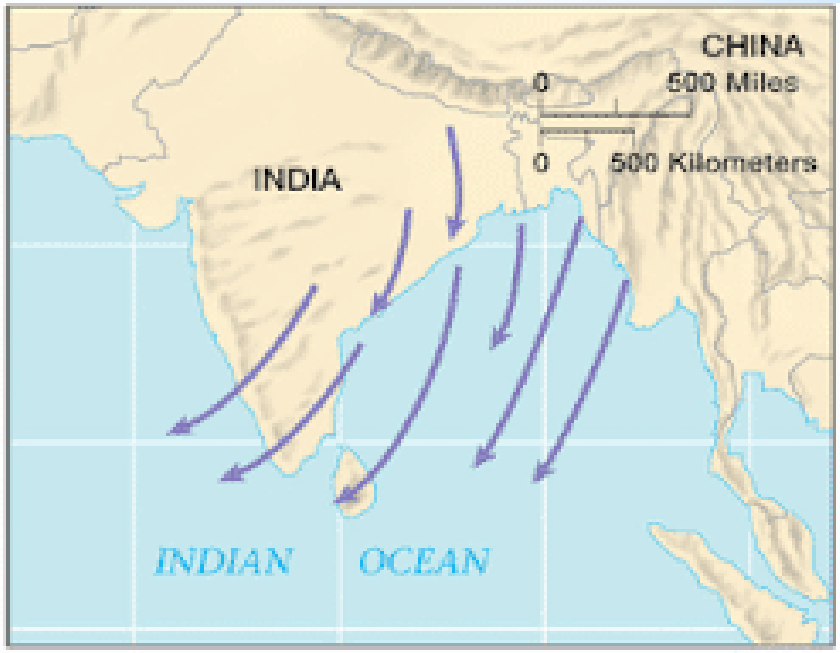
Western disturbances are extratropical weather systems that originate in the Mediterranean region and move eastwards, bringing winter rainfall and snowfall to northwestern parts of the Indian subcontinent. They are essentially low-pressure systems embedded within the westerly winds. Their formation and movement are influenced by factors like temperature differences between air masses, the subtropical westerly jet stream, and the presence of moisture.




Subtropical jet
Polar Jet
Hadley Cell
Ferrel Cell
Polar Cell
North Pole
60°N
30°N
Equator
Northerlies (cold)
Sou-westerlies (warm)
NE Trade Winds
Intertropical convergence zone

Traditional Theory (Differential Heating and Cooling Theory) Proposed by Halley (1686).

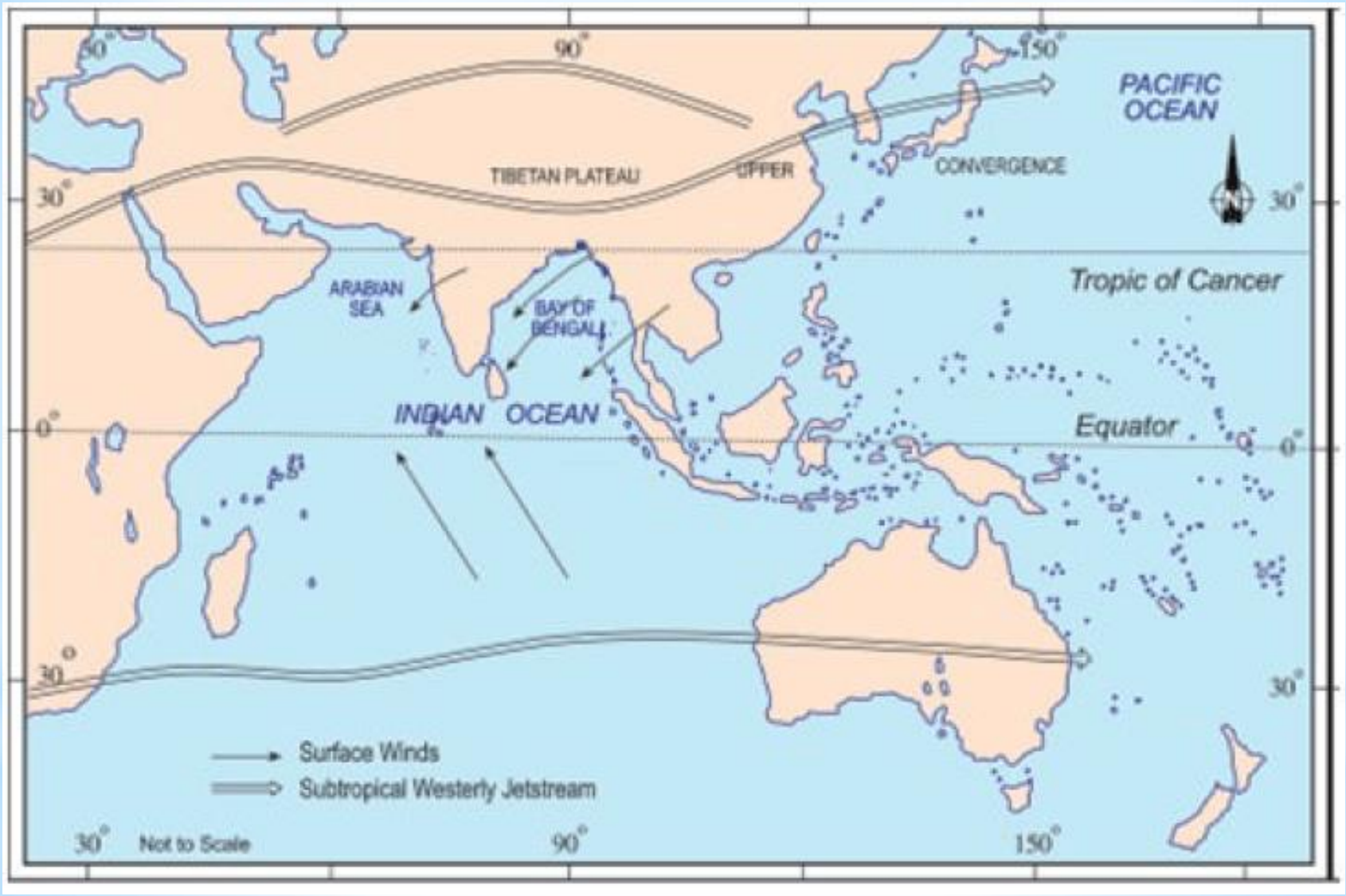
Main Idea:
Land heats up **faster** than the ocean in summer → low pressure over land, high pressure over ocean.
Result:
Moist air from ocean rushes toward land → **monsoon winds** and **rainfall**.
▫ ▫ In winter, this reverses.



Summer _____ Winter

2. Jet Stream Theory Proposed in the 1950s–60s.

- Main Idea:
  The Tibetan Plateau heats up → forms a high-pressure zone in the upper atmosphere.
  This affects the position of the Tropical Easterly Jet (TEJ) and Subtropical Westerly Jet (STJ).
- Result:
  These jet streams help pull the monsoon winds into India.
- Jet streams guide and trigger the monsoon onset.


90°
150°
PACIFIC OCEAN
TIBETAN PLATEAU
UPPER
CONVERGENCE
30°
N
30°
Tropic of Cancer
ARABIAN SEA
BAY OF BENGAL
INDIAN OCEAN
0°
Equator
0°
30°
30°
Surface Winds
Subtropical Westerly Jetstream
30°
Not to Scale
90°
150°

El Niño–Southern Oscillation (ENSO) Theory

Main Idea:

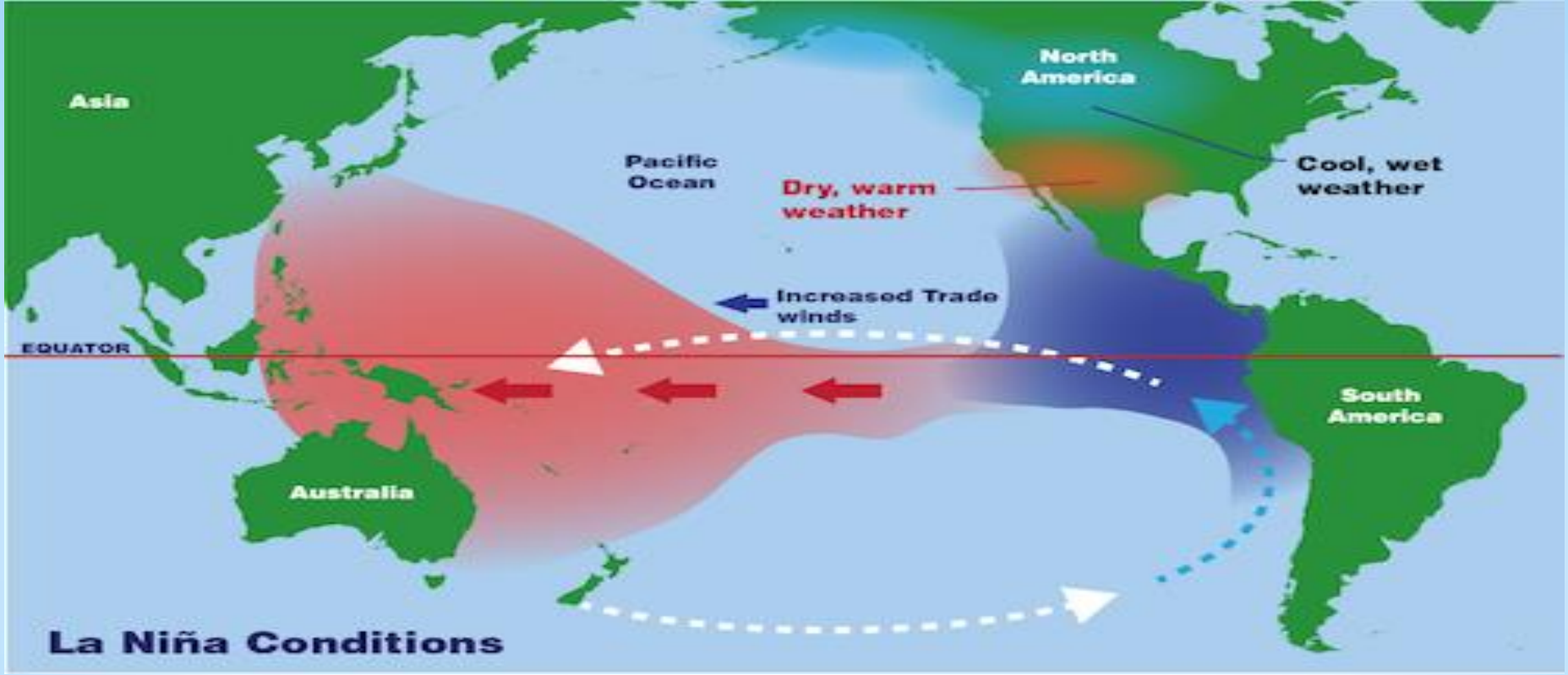
Changes in **sea surface temperatures** in the **Pacific Ocean** affect monsoon rains.

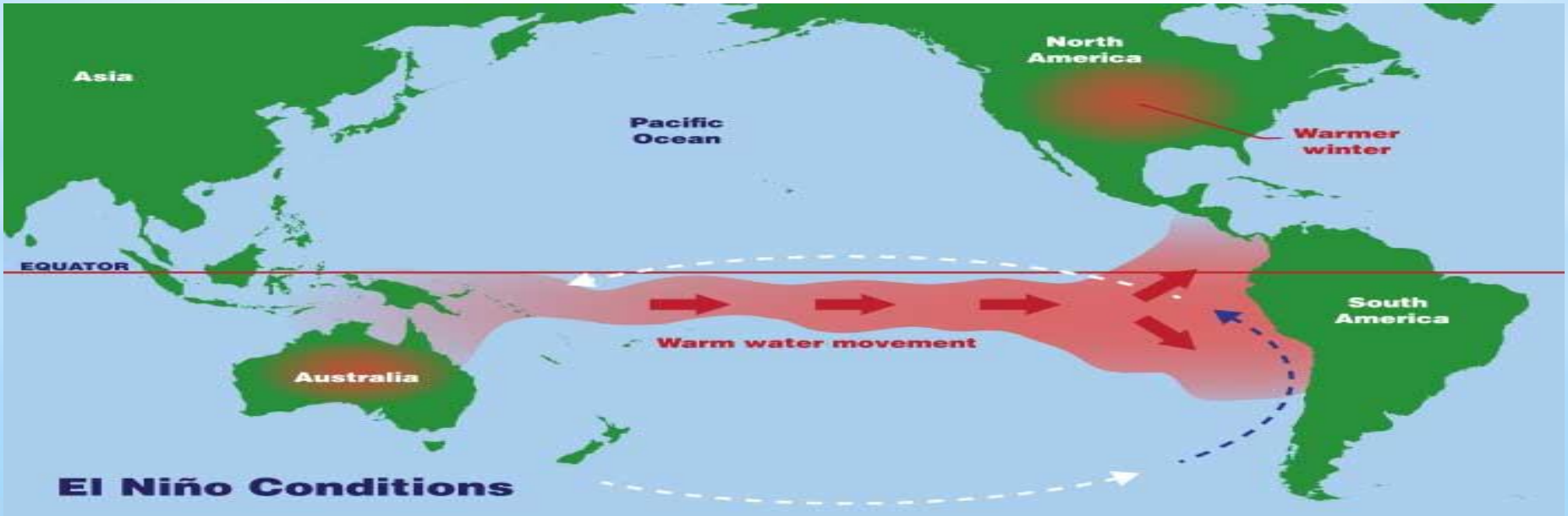
Result:

El Niño (warm Pacific): weak monsoon

La Niña (cool Pacific): strong monsoon

Monsoon is influenced by **global ocean-atmosphere systems**.


Asia
North America
Pacific Ocean
Cool, wet weather
Dry, warm weather
Increased Trade winds
EQUATOR
South America
Australia
La Niña Conditions


Asia
North America
Pacific Ocean
Warmer winter
EQUATOR
South America
Warm water movement
Australia
El Niño Conditions

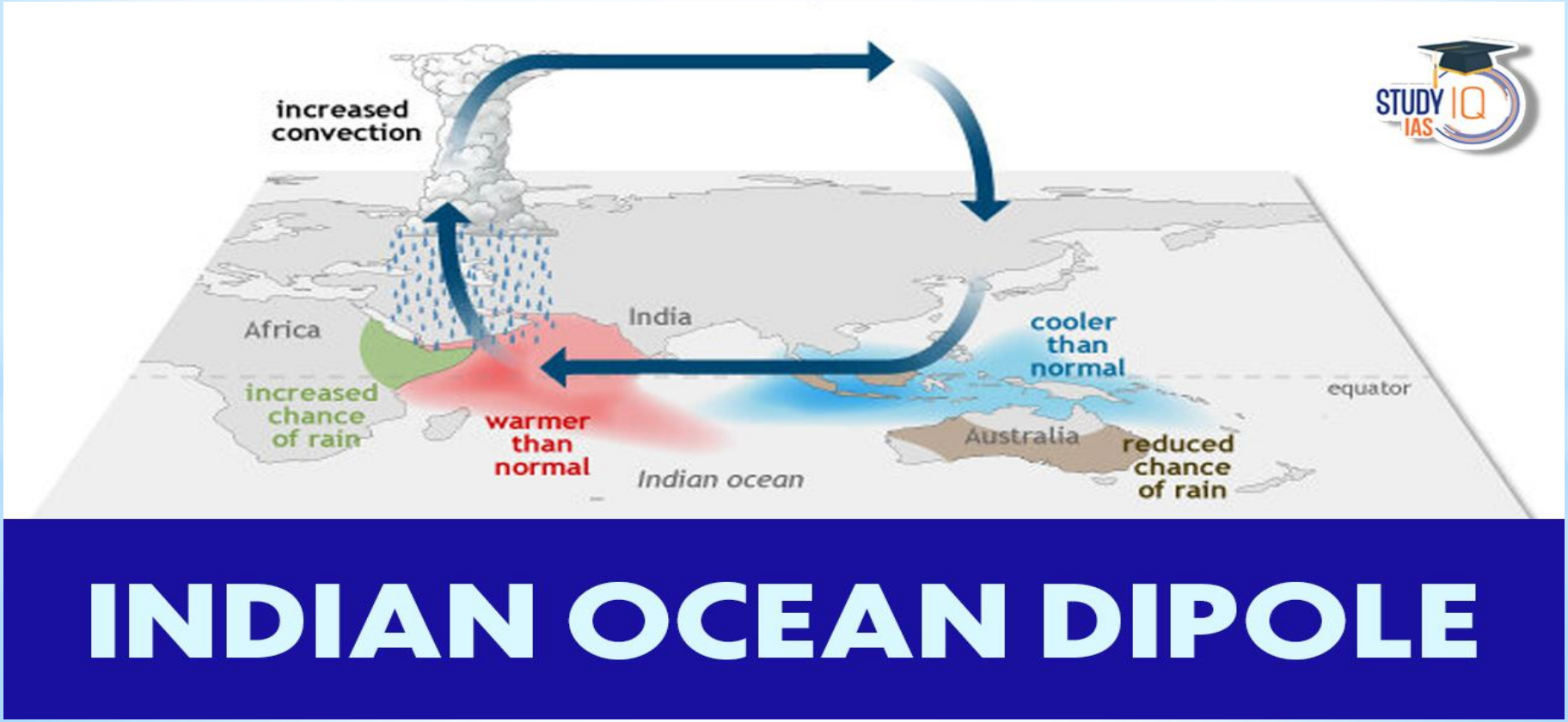
Indian Ocean Dipole (IOD) Theory

Main Idea:

Temperature difference between **western and eastern Indian Ocean** also affects monsoon.

Positive IOD: more rain

Negative IOD: less rain



References

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Thank you!