DAILY CLASS NOTES

Geography

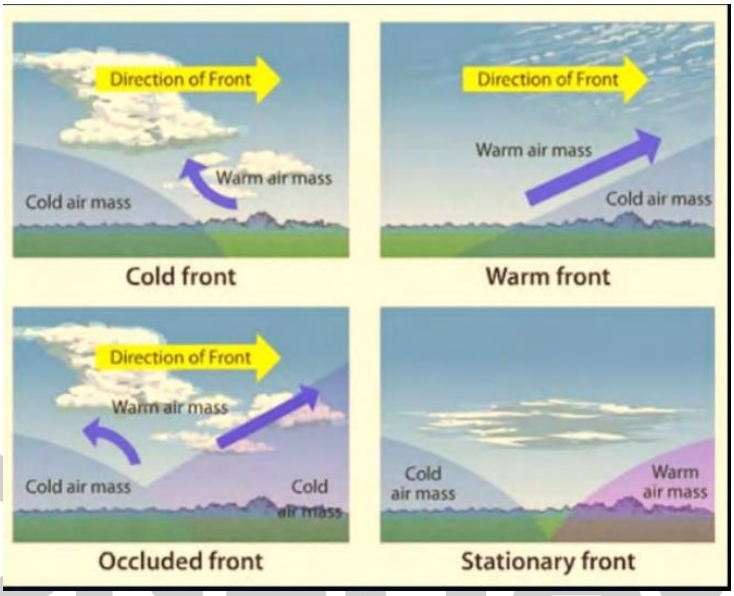
Lecture - 41

Cyclones

Cyclones

Fronts:

- Understanding Front Formation and Types of Fronts is **important to understand the formation of Mid-latitude cyclones** [temperate cyclones or extra-tropical cyclones] and the **dominant weather patterns of mid-latitudes.**
- Fronts are the **typical features of mid-latitudes weather** (temperate region – 30° - 65° North and South). They are uncommon (unusual) in **tropical and polar regions.**
- When **two different types of air masses meet,** the boundary zone between them is **called a Front.**
- A **temperature difference is essential** in the definition of a front because it implies a density difference.



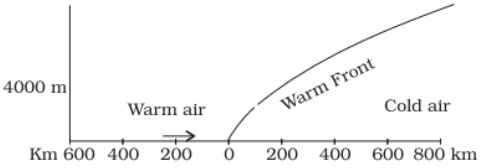
- Front is a **three-dimensional boundary zone** formed between two converging air masses with different physical properties (Temperature, Humidity, Density etc.).
- The two air masses don't merge readily due to the effect of the converging atmospheric circulation, relatively low diffusion coefficient and low thermal conductivity.

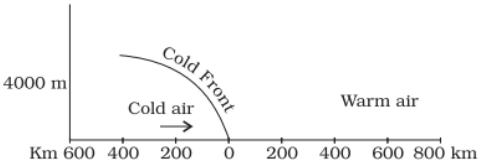
Front Formation:

- The process of formation of a front is known as **Frontogenesis** (war between two air masses), and the dissipation of a front is known as **Frontolysis** (one of the air masses wins against the other).
- Frontogenesis involves the **convergence of two distinct air masses.**
- Frontolysis involves the **overriding of one of the air masses by another.**
- In the **northern hemisphere,** Frontogenesis (convergence of air masses) happens in an **anti-clockwise direction and in the southern hemisphere, clockwise direction.** This is due to **the Coriolis effect.**
- **Mid-latitude cyclones or temperate cyclones or extra-tropical cyclones** occur due to frontogenesis.

General Characteristics of Fronts:

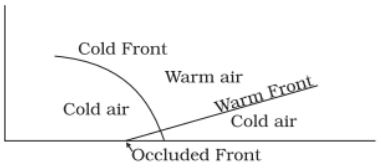
- **Large temperature difference:** The **temperature contrast influences the thickness of the frontal zone in an inversely proportional manner,** i.e., two air masses with higher temperature differences do not merge readily. So the front formed is less thick.
- **Pressure difference:** With a sudden change in temperature through the front, there is a change in pressure also. There is a bending of isobars.
- **Cloud formation:** The frontal activity is invariably associated with cloudiness and precipitation because of the ascent of warm air which cools down adiabatically, condenses and causes rainfall.
- **Precipitation:** The intensity of precipitation depends on the slope of ascent and the amount of water vapour present in ascending air.





Classification of Fronts:

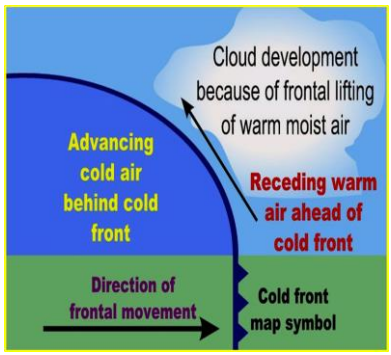
- Based on the mechanism of frontogenesis and the associated weather, the fronts can be studied under the following types:
  - **Stationary Front**
  - **Cold Front**
  - **Warm Front**
  - **Occluded Front**



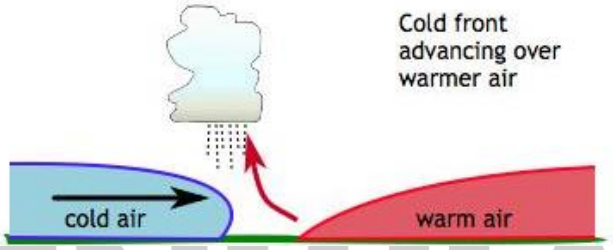
Name of Front	Front Symbols	Description of front formation	Weather associated with front	Diagram of the front
Cold Front		Separates faster – moving cold air, which pushes up from retreating warmer air.	Frequent rain. If temp changes quickly, violent weather like thunderstorms and tornados. Temp and humidity decrease after this front and high pressure builds as well.	
Warm Front		Slower moving warm air replaces retreating cooler air. Warm air gradually rises over cooler air, producing light rain.	Light to moderate rain. Warmer temperatures and higher humidity after the passage of the warm front.	
Stationary Front		Forms boundary between nonmoving cold air masses and warm air masses. Does not advance nor retreat.	Rain and humidity will be prominent. And the weather will be clear, because nothing is happening and no stronger front is coming in.	
Occluded Front		Occurs when a warm front is overtaken by a cold front.	High humidity and warm temps are left by the warm front and frequent rain and if sudden change in temp, violent storms will occur. After that temp and humidity will decrease.	

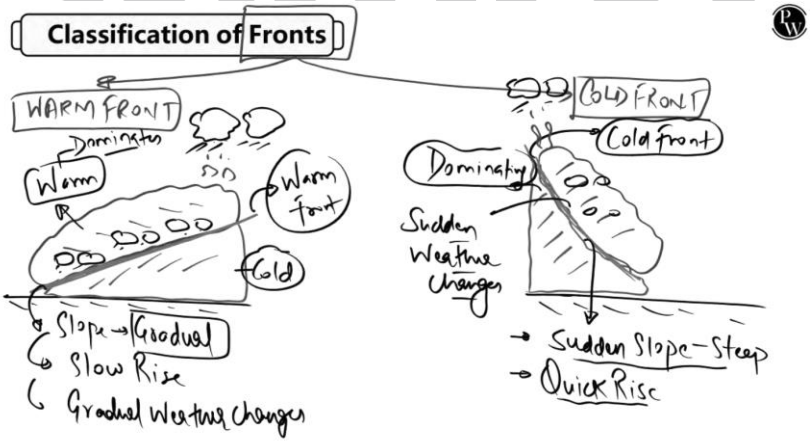
Cold Front:

- Such a front is formed when a **cold air mass replaces a warm air mass by advancing into it or when the warm air mass retreats and cold air mass advances** (cold air mass is the clear winner).
- In such a situation, the **transition zone between the two is a cold front.**
- Cold front **moves twice as quickly as a warm front** and can produce **sharper changes in weather conditions**.
- Frontolysis begins when the warm air mass is completely uplifted by the cold air mass.



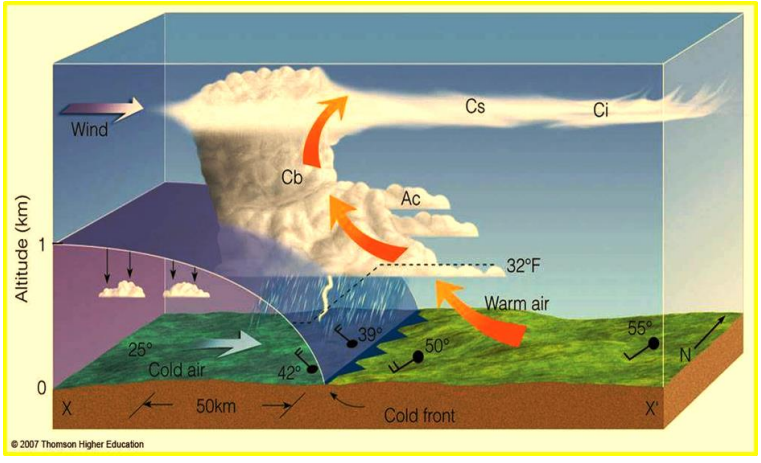
- This upward motion causes lowered pressure along the cold front and can cause the formation of a narrow line of showers and thunderstorms when enough moisture is present.
- **Since cold air is denser than warm air, it rapidly replaces the warm air preceding the boundary.**
- Cold fronts are usually **associated with low-pressure areas.**
- It produces sharper changes in weather. Temperatures can drop more than 15 degrees within the first hour.



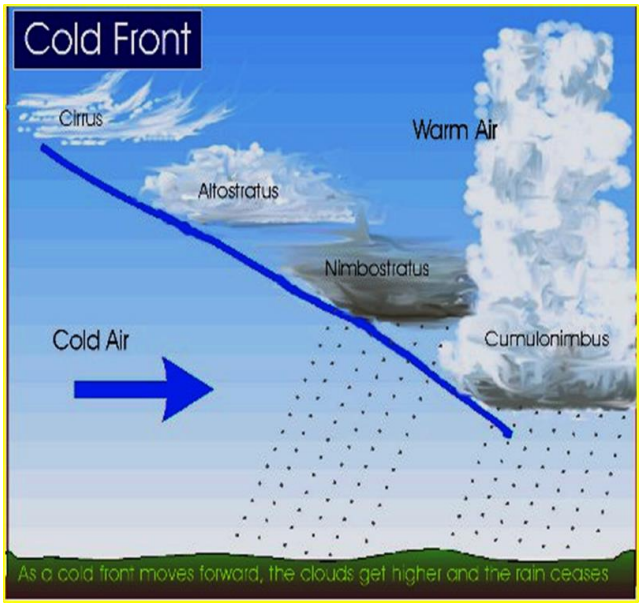


Weather Along a Cold Front

- The weather along such a front depends on a narrow band of cloudiness and precipitation.
- Severe storms can occur. During the summer months, thunderstorms are common in the warm sector.
- In some regions like the USA tornadoes occur in warm sectors.



- Produce sharper changes in weather.
- Temperatures can drop more than 15 degrees within the first hour.

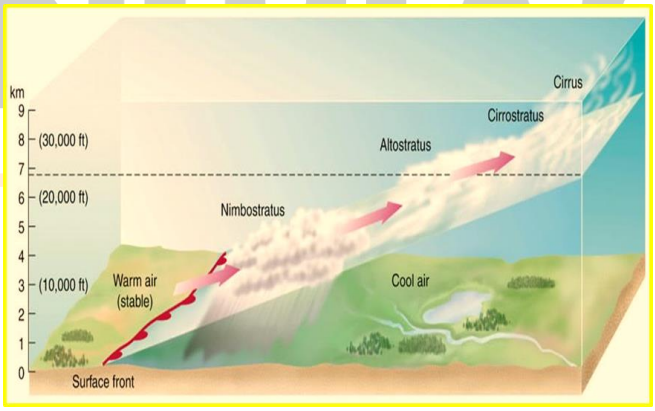


Cloud Formation Along a Cold Front:

- The approach of a cold front is marked by increased wind activity in the warm sector and the appearance of cirrus clouds, followed by lower, denser altocumulus and altostratus.
- At the actual front, dark nimbus and cumulonimbus clouds cause heavy showers.
- A cold front passes off rapidly, but the weather along it is violent.

Warm Front:

- It is a sloping frontal surface along which active movement of warm air over cold air takes place (warm air mass is too weak to beat the cold air mass).
- Being lighter, the **warm air mass** is unable to displace the cooler air mass and instead is **forced upward** along the upper boundary of the colder air.



- As the warm air moves up the slope, it condenses and causes precipitation but, unlike a cold front, the temperature and wind direction changes are gradual.
- Frontolysis (front dissipation) begins when the warm air mass makes way for cold air mass on the ground, i.e. when the warm air mass completely sits over the cold air mass.

Weather Along a Warm Front:

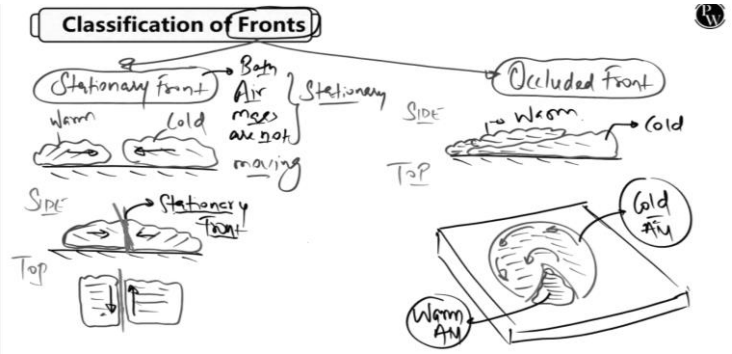
- Being lighter, the warm air mass is unable to displace the cooler air mass and instead is forced upward along the upper boundary of the colder air in a process known as Overrunning.
- As the air mass rises into regions of lower pressure, it expands and cools. As it cools, water vapour condenses and forms extensive cloud coverage.
- As the warm air moves up the slope, it condenses and causes precipitation but, unlike a cold front, the temperature and wind direction changes are gradual.

- The first clouds to form along the sloping surface of the cold air are high cirrus, which thicken to cirrostratus and altostratus.
- Such fronts cause moderate to gentle precipitation over a large area, over several hours.
- The passage of warm front is marked by rise in temperature, pressure and change in weather.

Clouds Along a Warm Front:

- With the approach, the hierarchy of clouds is- cirrus, stratus and nimbus. [No cumulonimbus clouds as the gradient is gentle]
- Cirrostratus Clouds ahead of the warm front create a halo around sun and moon.

Stationary Front:



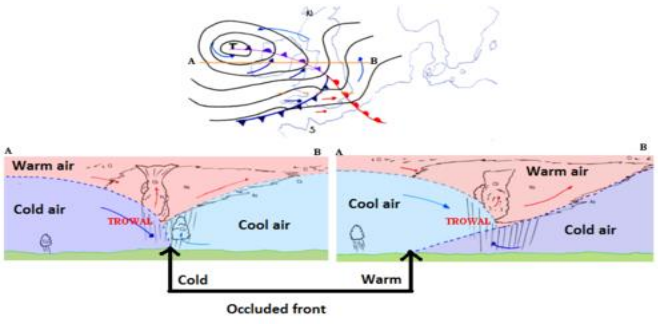
- When the surface position of a front **does not change** (when two air masses are unable to push against each other; a draw), a stationary front is formed.
- The wind motion on both sides of the front is **parallel** to the front.
- Warm or cold front stops moving, hence the name stationary front.
- Once this boundary resumes its forward motion, it becomes a warm front or cold front.

Weather Along a Stationary Front:

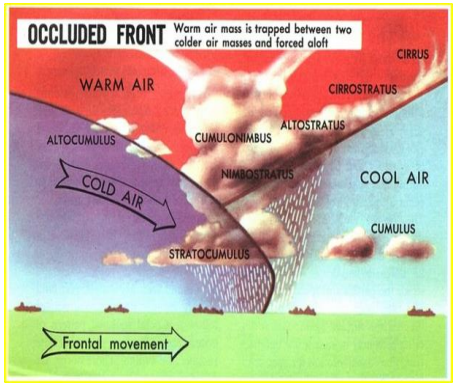
- Cumulonimbus clouds are formed. Overrunning of warm air along such a front causes frontal precipitation.
- Cyclones migrating along a stationary front can dump heavy amounts of precipitation, resulting in significant flooding along the front.

Occluded Front:

- **Occlusion:** Meteorological process by which the cold front of a rotating low-pressure system catches up the warm front, so that the warm air between them is forced upwards.
- Such a front is formed when a cold air mass overtakes a warm air mass and goes underneath it.

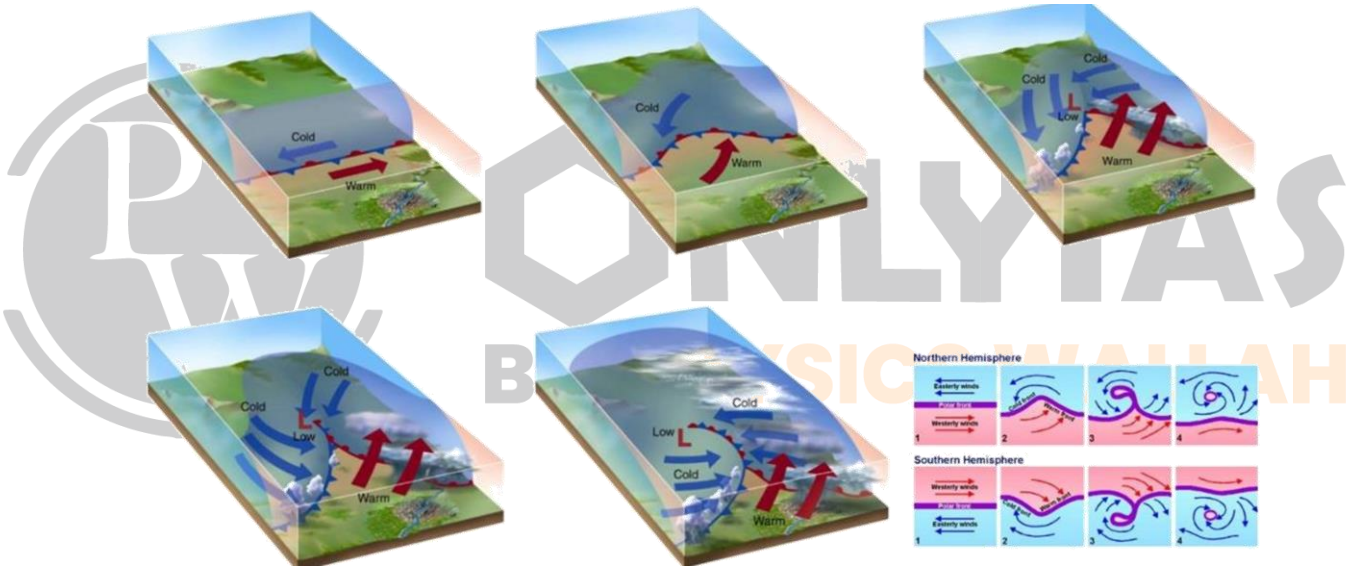


- Frontolysis begins when the warm sector diminishes and the cold air mass completely undertakes the warm sector on the ground.
- Weather along an occluded front is complex—a mixture of cold front type and warm front type weather. Such fronts are common in Western Europe.



Weather Along an Occluded Front:

- **Complex:** A mixture of cold front type and warm front type weather. Such fronts are common in west Europe.
- The formation of Mid-latitude cyclones [temperate cyclones or extra-tropical cyclones] involves the formation of an occluded front.



Clouds Along an Occluded Front:

- A combination of clouds formed at a cold front and warm front.
- Warm front clouds and cold front clouds are on opposite sides of the occlusion.

Cyclones:

- These are the low-pressure systems that are **surrounded by the isobars of increasing pressure outwards.**
- Cyclones are violent storms that originate over the **over oceans in the tropics as well in temperate regions.**

Tropical Cyclones	Temperate Cyclones
Form in tropical regions (5-25 degrees)	These are extra-tropical cyclones
Thermal origin due to the warming of the sea surface	Form in temperate regions (40-65 degrees), these are frontal cyclones originate along the fronts.
Very violent in nature, and have high-velocity winds	These are not much destructive and have relatively low-velocity winds.
Low pressure (around 880 mb)	Pressure around 990 mb
Originate over oceans but die out on land (travels from east to west), causing destruction in the coastal regions due to its less predictability.	These are predictable and form along the westerlies (travels from west to east)

Tropical Cyclone:

- Tropical cyclones are **violent storms that originate over oceans in tropical areas and move over to the coastal areas** bringing about large-scale destruction due to violent winds (squalls), very heavy rainfall (torrential rainfall), and storm surge.
- They are **irregular wind movements** involving the closed circulation of air around a low-pressure center.
- This **closed air circulation** (whirling motion) is a result of the rapid upward movement of hot air which is subjected to **Coriolis force.** The low pressure at the center is responsible for the wind speeds.
- The cyclonic wind movements are **anti-clockwise in the northern hemisphere and clockwise in the southern hemisphere** (This is due to Coriolis force).

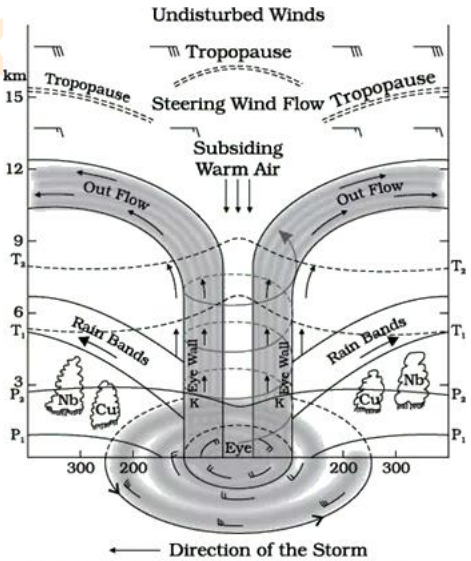


Fig: Vertical section of the tropical cyclone

- The wind field of a tropical cyclone may be **divided into three regions.**

- **First is a ring-shaped outer region,** typically having an outer radius of about 160 km (100 miles) and an **inner radius of about 30 to 50 km (20 to 30 miles).**
  - ✓ In this region the winds increase uniformly in speed toward the centre.
- **Second** is the **Eyewall** where Wind speeds attain their maximum value. This is typically 15 to 30 km (10 to 20 miles) from the centre of the storm.
- **Third** is the **Eye**, the region surrounding the eyewall, where wind speeds decrease rapidly and the air is often calm.

- **Squall-** A sudden violent gust of wind or localized storm, especially one bringing rain, snow, or sleet.
- **Torrent-** A strong and fast-moving stream of water or other liquid.

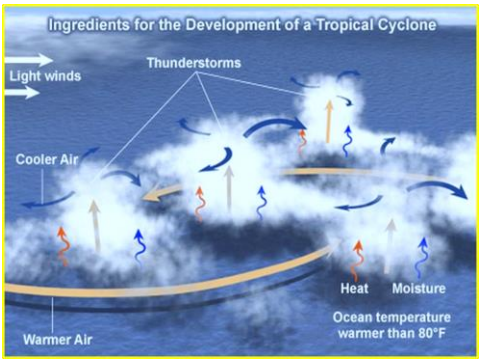
Conditions Favourable for Tropical Cyclone Formation:

1. Large sea surface with temperature higher than 27° C,
2. Presence of the Coriolis force enough to create a cyclonic vortex,
3. Small variations in the vertical wind speed,
4. A pre-existing weak low-pressure area or low-level-cyclonic circulation,
5. Upper divergence above the sea level system,

1. Good Source of Latent Heat:

- Ocean waters having temperatures of 27° C or more is the source of moisture that feeds the storm.
- The condensation of moisture releases enough latent heat of condensation to drive the storm.
- The storms draw energy from the surface waters of the ocean, and as more heat (energy) is stored in these upper waters, the cyclones have a larger source of energy on which to draw.

2. Coriolis Force:



- The Coriolis force is zero at the equator (no cyclones at the equator because of zero Coriolis Force) but it increases with latitude. Coriolis force at 5° latitude is significant enough to create a storm [cyclonic vortex].
- About 65 percent of cyclonic activity occurs between 10° and 20° latitude.

3. Low-level Disturbances:

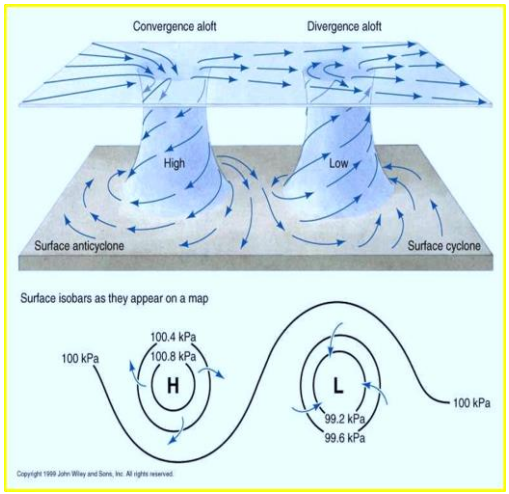
- Low-level disturbance (thunderstorms- they are the seeds of cyclones) in the form of easterly wave disturbances in the Inter-Tropical Convergence Zone (ITCZ) should pre--exist for the formation of a cyclone.

4. Temperature Contrast Between Air Masses:

- Trade winds from both hemispheres meet along the inter-tropical front.
- Temperature contrasts between these air masses must exist when the ITCZ is farthest, from the equator.
- Thus, the convergence of these air masses of different temperatures and the resulting instability are the prerequisites for the origin and growth of violent tropical storms.

5. Wind Shear:

- Wind Shear is the difference between wind speeds at different heights.
- Tropical cyclones develop when the wind is uniform.
- Because of weak vertical wind shear, cyclone formation processes are limited to the latitude equatorward of the subtropical jet stream.
- In the temperate regions, wind shear is high due to westerlies and this inhibits convective cyclone formation.



6. Upper Tropospheric Divergence:

- A well-developed divergence in the upper layers of the atmosphere is necessary so that the rising air currents within the cyclone continue to be pumped out and low pressure is maintained at the center.

7. **Humidity Factor:**
   - High Humidity (around 50 to 60 percent) is required in the mid-troposphere since the presence of moist air leads to the formation of a cumulonimbus cloud.
   - Such conditions exist over the equatorial doldrums, especially in the Western margins of oceans (this is because of the east-to-west movement of ocean currents), which have great moisture, and carrying capacity because the trade winds continuously replace the saturated air.
8. **Fujiwhara Effect:**
   - When two cyclones approach one another, their centers will begin orbiting cyclonically about a point between the two systems.
   - The two vortices will be attracted to each other, and eventually spiral into the centre point and merge.
   - When the two vortices are of unequal size, the larger vortex will tend to dominate the interaction, and the smaller vortex will orbit around it.
   - This phenomenon is called the Fujiwhara effect.

Why Tropical Cyclones Do Not Form in the Eastern Tropical Oceans?

- The depth of warm water (26-27°C) should extend for 60-70 m from the surface of the ocean/sea, so that deep convection currents within the water do not churn and mix the cooler water below with the warmer water near the surface.
- The above condition occurs only in western tropical oceans because of **warm ocean currents** (easterly trade winds push ocean waters towards west) that flow from the east towards west forming a thick layer of water with temperatures greater than 27°C. This supplies enough moisture to the storm.
- The cold currents lower the surface temperatures of the eastern parts of the tropical oceans making them unfit for the breeding of cyclonic storms.
  - [**Exception:** During strong El Nino years, strong hurricanes occur in the eastern Pacific. This is due to the accumulation of warm waters in the eastern Pacific due to weak Walker Cell].
- The temperature of the Bay of Bengal is more than the Arabian sea due to the mixing of rivers which keeps the surface water warm. Thus, there are more cyclones in the Bay of Bengal than in the Arabian sea.

Why do Cyclones Occur Mostly in Late Summer?

- ❖ Generally tropical cyclones occur in April-May and August-October.
- ❖ Cyclones in April-May: are less deadly (because the sea surface temperature is not high enough). And in August-October are more deadly (oceans heat slowly and sea surface temperature rises to 27 degrees celsius by August end or mid-September).
- ❖ Whirling motion is enhanced when the doldrums (region within ITCZ) over oceans are farthest from the equator.
- ❖ Temperature in the late summer is near about 26-27° C
- ❖ Due to the high specific heat of water, and mixing, the ocean waters in the northern hemisphere attain maximum temperatures in August. (Continents attain maximum temperatures in June-July).

Characteristics of Tropical Cyclones:

1. Size and Shape:

- ➢ Tropical Cyclones have **symmetrical elliptical shapes** (2:3 ratio of length and breadth) with steep pressure gradients.
- ➢ They have a compact size—80 km near center, which may develop up to 300 km to 1500 km.

2. Wind Velocity and Strength:

- ➢ Wind velocity, in a tropical cyclone, is more in poleward margins than at center and is more over oceans than over landmasses, which are scattered with physical barriers.
- ➢ The wind velocity may range from nil to 1200 km per hour.

3. Path of Tropical Cyclones:

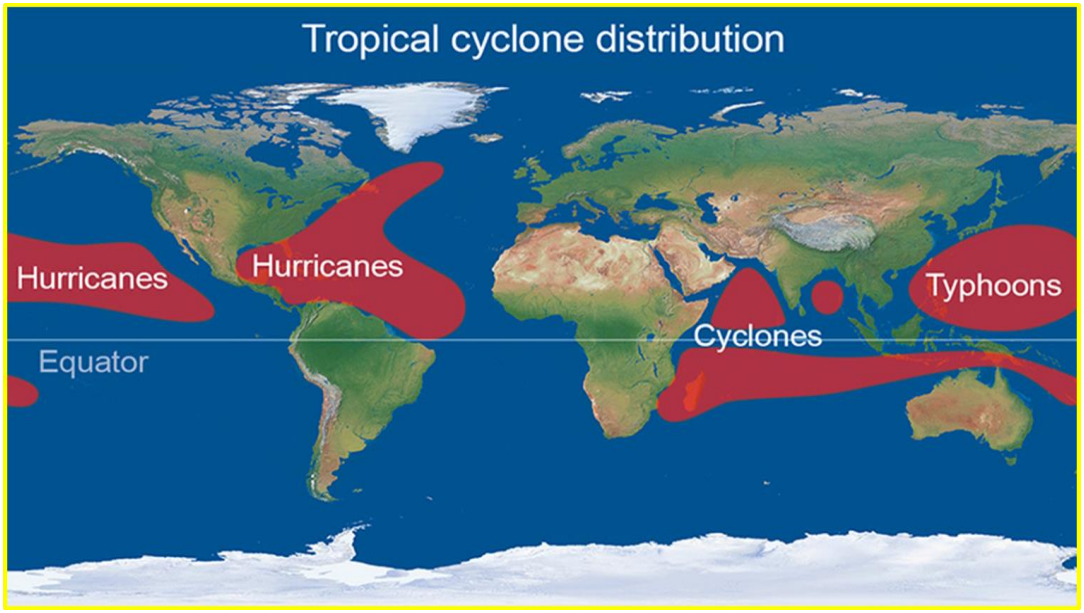
- ➢ These cyclones start with a westward movement, but turn northwards around 20° latitude.
- ➢ They turn further north-eastwards around 25° latitude, and then eastwards around 30° latitude. They then lose energy and subside.
- ➢ Tropical Cyclones follow **a parabolic path, their axis being parallel to the isobars.**
- ➢ Coriolis Force or earth's rotation, easterly and westerly winds influence the path of a Tropical Cyclone.
- ➢ Tropical Cyclones **die at 30° latitude because of cool ocean waters and increasing wind shear due to westerlies.**

Types of Tropical Cyclones:

Tropical Disturbance	❖ In the 5-20 degrees latitude. ❖ In the North Pacific Ocean and Caribbean Sea
Tropical Depressions	❖ In 0-5 degrees latitude ❖ In India, Northern America etc. ❖ Speed of the wind is 30-40 Km per hour ❖ Low-pressure regions and low-intensity storms are there.
Tropical Storms	❖ When the depression and disturbance take big form. ❖ In the Bay of Bengal, Arabian sea, Carrabian sea etc. ❖ Wind velocity is 50-120 Km Per hour. ❖ Huge destruction due to high intensity. ❖ Example: Supercyclones of Odisha 1999 etc. ❖ Low-pressure system.
Typhoons and Hurrican and Cyclones	❖ When velocity is greater than 120 Km per hour or more. ❖ Violent and destructive. ❖ Hurricanes- USA ❖ Typhoon - South China Sea ❖ Taifu - Japan Coast ❖ Willy Willys - Australia

Regional Names for Tropical Cyclones:

Regions	What they are called
Indian Ocean	Cyclones
Atlantic	Hurricanes
Western Pacific and South China Sea	Typhoons
Western Australia	Willy-willies



Categories of Tropical Cyclones:

Category	Wind speed	Damage	Examples
1	74-95 mph	tree damage; broken shutters and fences	e.g. Hurricane Gaston which hit South Carolina in 2004
2	96-110 mph	downed trees, road signs, traffic lights; broken windows and chimneys	e.g. Frances which hit Florida in 2004
3	111-130 mph	large trees uprooted; mobile homes and small airplanes destroyed	e.g. Ivan which hit Alabama in 2004
4	131-155 mph	roofs torn off; piers destroyed and seawalls breached	e.g. Charley which hit Florida in 2004; Harvey which hit Texas in 2017
5	156+ mph	nearly all trees snapped or uprooted; buildings entirely destroyed landscapes denuded	e.g. Andrew which hit Florida in 1992; Typhoon Haiyan/Super Typhoon Yolanda which hit the Philippines in 2013

❍❍❍❍