SRIMAAN

TRB ASSISTANT PROFESSOR

Assistant Professor in Govt. Arts and Science Colleges and Govt. Colleges of Education in the Tamil Nadu Collegiate Educational Service

GEOGRAPHY

UNIT-3- OCEANOGRAPHY

TRB-ASST.PROF. STUDY MATERIALS

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TRB-ASSISTANT PROFESSOR

GOVT. ARTS & SCIENCE COLLEGES

GEOGRAPHY

UNIT-3: OCEANOGRAPHY

Relief of Oceans, Composition: Temperature, Density and Salinity, Circulation: Warm and Cold Currents, Waves, Tides, Sea Level Changes, Hazards: Tsunami and Cyclone

Geography of Environment Components: Ecosystem (Geographic Classification) and Human Ecology, Functions: Trophic Levels, Energy Flows, Cycles (geo-chemical, carbon, nitrogen and oxygen), Food Chain, Food Web and Ecological Pyramid, Human Interaction and Impacts, Environmental Ethics and Deep Ecology, Environmental Hazards and Disasters (Global Warming, Urban Heat Island, Atmospheric Pollution, Water Pollution, Land Degradation), National Programmes and Policies: Legal Framework, Environmental Policy, International Treaties, International Programmes and Polices (Brundtland Commission, Kyoto Protocol, Agenda 21, Sustainable Development Goals, Paris Agreement)

Oceans

Ocean Floor

- The floors of the oceans are rugged with the world' s largest mountain ranges, deepest trenches and the largest plains. These features are formed by the factors of tectonic, volcanic and depositional processes. A major portion of the ocean floor is found between 3-6 km below the sea level.
- The ocean floor basins are the result of tectonic processes. The ocean basins were formed from volcanic rock that was released from fissures located at the mid-oceanic ridges.
- The ocean basins are much younger than the oldest continental rocks.
- Thus, ocean relief is largely due to tectonic, volcanic, erosional and depositional processes and their interactions.
- Ocean relief features are categorised into major and minor relief features.
- Major ocean relief features include the continental shelf, the continental slope, the continental rise, and the Deep Sea Plain or the abyssal plain.
- In addition to these major relief features, there are several minor ocean relief features such as ridges, seamounts, guyots, canyons, atolls, coral reefs etc.

Continental Shelf:

- The gently sloping seaward extension of the continental plate is known as the continental shelf. These are the extended margins of the continent that are occupied by relatively shallow seas and gulfs.
- The Continental Shelf of all oceans together covers nearly 7.5% of the total area of the oceans.
- It has a gradient of 1° or less. It typically ends at a very steep slope, known as the shelf break.
- The sediments brought down by rivers, glaciers etc. are deposited on the continental shelves.
- The shelf is formed mainly due to submergence of a part of a continent, or due to relative rise in sea level, or due to the sedimentary deposits brought down by rivers.
- The average width of continental shelves varies between 70 – 80 km. The depth of the shelves also varies. It may be as shallow as 30 m in some areas while in some areas it is as deep as 600 m.
- The continental shelves are almost absent or very narrow along some of the margins like the coasts of Chile, the west coast of Sumatra, etc.
- It is almost 120 km wide along the eastern coast of USA. On the contrary, the Siberian shelf in the Arctic Ocean stretching to 1,500 km in width, is the largest in the world.

Continental Slope:

- The relief connecting the continental shelf to the ocean basins is known as the continental slope.
- It begins from the bottom of the continental shelf and sharply drops off into a steep slope.
- It has a gradient of 2-5°. The depth of the slope region varies between 200 and 3,000 m.
- The continental slope boundary indicates the end of the continents.
- Canyons and trenches are observed in this region.

Continental Rise:

- After the end of the continental slope, the new relief known as continental rise starts which has a gradient of 0.5° - 1°.
- With increasing depth, the rise becomes virtually flat and merges with the abyssal plain.

Deep Sea Plain or Abyssal Plain:

- These are gently sloping areas of the ocean basins.
- These are the flattest and smoothest regions of the world. The shallow water sediments bury the irregular topography.

- It covers nearly 40% of the ocean floor.
- The depths vary between 3,000 and 6,000 m.
- These plains are covered with fine-grained sediments like clay and silt.

Oceanic Deeps or Trenches:

- The ocean trenches are relatively steep-sided, narrow basins and they are the deepest parts of the oceans.
- They are of tectonic origin and are formed during ocean-ocean convergence and ocean continent convergence.
- They are nearly 3-5 km deeper than the surrounding ocean floor.
- The trenches run parallel to the bordering fold mountains or the island chains.
- The trenches are very common in the Pacific Ocean and form an almost continuous ring along the western and eastern margins of the Pacific. The Mariana Trench off the Guam Islands in the Pacific Ocean with a depth of more than 11 kilometres is the deepest trench.
- The trenches are associated with active volcanoes and strong earthquakes.

Mid-Oceanic Ridges or Submarine Ridges:

- A mid-oceanic ridge (MOR) is composed of two chains of mountains separated by a large depression.
- The mountain ranges have peaks as high as 2,500 m and some even reach above the ocean’ s surface.
- Running for a total length of 75,000 km, these ridges form the largest mountain systems on earth. These ridges are either broad, like a plateau, gently sloping or in the form of steep-sided narrow mountains.
- These oceanic ridge systems are of tectonic origin and provide evidence in support of the theory of Plate Tectonics.
- **Seamount:** Seamount is a mountain having volcanic origin with pointed summits, rising from the seafloor that does not reach the surface of the ocean. Their height can be 3,0004,500 m. Example- The Emperor seamount, an extension of the Hawaiian Islands in the Pacific Ocean.
- **Submarine Canyons**: These are deep valleys sometimes found cutting across the continental shelves and slopes, often extending from the

mouths of large rivers. Example - The Hudson Canyon is the best-known canyon in the world.

- **Guyots:** It is a flat-topped seamount which shows the evidences of gradual subsidence through stages to become flat-topped submerged mountains. More than 10,000 seamounts and guyots have been estimated to exist in the Pacific Ocean alone.
- **Atoll:** These are low islands found in the tropical oceans consisting of coral reefs surrounding a central depression. It may be a part of the sea (lagoon), or sometimes form enclosing a body of fresh, brackish, or highly saline water.

Ocean Currents

Currents: Permanent flow of water of distinct volume in the same direction all throughout in a definite path.

Gyre: When the water at the centre remains static, and currents flow around them in a circular fashion.

Factors influencing Ocean Currents

External factors:

Effect of air pressure: -

- Where the air pressure is high, the water level gets low there. But the density of water of that part increases. Conversely, in low air pressure areas, the water level becomes high, due to which the water moves from high water level to low water level.

Prevailing winds: -

- When air moves over ocean water, it moves water due to its friction.
- Most currents follow prevailing winds. For example, equatorial currents, driven by commercial winds, move from east to west. The Gulfstream in the Atlantic Ocean and the Kuroshio Current in the Pacific Ocean follow the westward direction. Due to changes in the direction of monsoon winds in the Indian Ocean twice a year, the direction of ocean currents changes after 6 months.

- When wind-induced currents reach the continental shores, the water level rises due to the increase in water content, due to which new streams are generated. The equatorial stream also causes excessive water accumulation in the Gulf of Mexico, causing the Gulfstream to emerge.

Rainfall and its distribution: -

- In areas where there is more rainfall, the water level gets elevated due to excessive water because the density of water decreases and vice versa where the rainfall is low where the water level gets low. In this way the high water level becomes low. In this way, currents start moving from high water level to low water level.
- Rainwater reduces the amount of salinity in the oceans, and thus there is a difference in density.
- For example, the equatorial belt receives more rainfall than the midlatitudinal belt. Due to which the water level of the oceans remains relatively high. Hence currents flow from oceans located in equatorial belt towards higher latitudes. Conversely, in low-lying areas, such as the subtropical high air pressure area, the water level remains low due to the high amount of evaporation and increases both the salinity and density of the water. Therefore, there is a flow of currents on the upper surface from the areas with high rainfall towards such areas, and the deep water streams move towards the equator below the surface.

Sunlight and evaporation: -

- The inter-relation of sunlight and evaporation directly or indirectly helps in the generation of currents.
- The lower latitudes receive a greater amount of sunlight than the higher latitudes, but due to the lack of evaporation here the surface water is lighter with lower salinity and density.
- Light water from these low latitudes flows towards high latitudes in the form of streams with fixed winds. Reduction in both salinity and density is found as a result of decreasing the amount of sunlight and decreasing the rate of evaporation at high latitudes. Therefore, cold water flows from the polar regions towards the middle latitudes.

Iceberg melting: -

- Due to excess of water obtained by melting of snow, the water level becomes high, the salinity decreases. From such areas to other areas where the water level is relatively low, the streams begin to flow. In such a situation, the water currents start moving towards the mid-latitudes from the poles. For example, East Greenland Stream.

Factors that bring changes in ocean currents

The direction and size of the coast: -

- When the continental sections obstruct the currents, the currents run parallel to the continental coast.
- The equatorial stream bifurcates into two parts near Cape San Roc when it hits the Brazilian coast. The monsoon currents in the Indian Ocean flow along the Indian coast.
- Gulf stream streams also follow the shape of the eastern coasts of the United States.
- The Kuroshio current flows in a manner consistent with the shape of the east coast of Asia.

Sea floor topography: -

- Currents have a great impact on the flow of streams due to cracks or other physical barriers present at the foothills of the oceans.
- Oceanic bottom relief has a special effect on the currents of the middle latitudes and the polar regions.
- Whenever there is a physical barrier in the path of deep water currents near the river, these currents generally turn to the right of their path in the northern hemisphere and to the left in the southern hemisphere. For example, the Gulf Stream near Scotland when Wally crosses the Thompson Ridge turns to the right. Similarly, the northern equatorial stream turns to the right while crossing the mid-Atlantic ridge.

Seasonal Changes: -

- Along with the monsoon winds, the pressure of the air pressure and the belts of the wind is displaced. Hence, the direction of currents also changes.
- The seasonal disturbance of monsoon winds changes the direction of the Indian Ocean currents. Similarly, changes in currents can also be observed due to seasonal changes in Mexicans on the west coast of Central America and in the North Atlantic

Ekman Spiral

Ekman Spiral is the outcome of Coriolis force on surface water movement. The wind-stress pushes the top layer of water. In exchange, this layer drags the layer underneath. Each deeper layer moves more slowly than the upper layer until the motion stops at a depth of about 100 metres. .

All layers of water in the Northern Hemisphere and in the Southern Hemisphere are deflected by Coriolis force to the right and left.

As a result, each successive layer shifts 45 degrees to the direction of the drag force. The diagram aptly captures this. That creates a twisting spiral effect. The spiral is known as the Ekman Spiral, and each layer that follows is called the Ekman layer.

The average movement of all the layers comes out to be 90 deg to the direction of the surface wind.

Types of Ocean Currents

- **Based on Depth**
  - **Surface currents-** Constitute about 10% of all the water in the ocean. Upper 400 m of the ocean
  - **Deepwater currents-** Constitute about 90% of the water. Move due to variation in density and salinity.
- **Based on Temperature**
  - **Cold Currents**- Bring cold water into warm water areas. Normally found on the west coast of the continents in the low & middle latitudes.
  - **Warm Currents**- Bring warm water to cold water areas. Usually found on the east coast of the continents in low and middle latitudes.

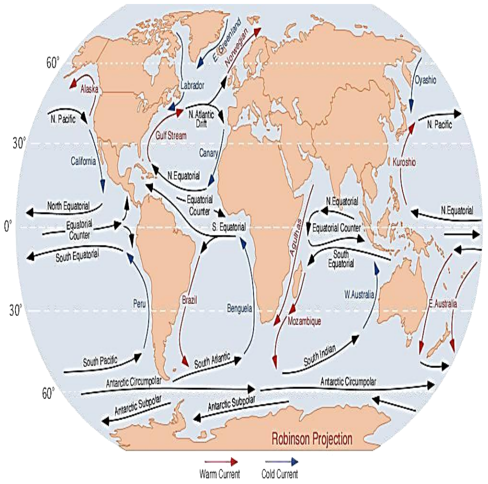
Currents of Atlantic Ocean

- North Equatorial Current (warm)
- South Equatorial Current (warm)
- Equatorial Counter Current
- Gulf Stream (warm)
- Florida Current (Warm)
- Canaries Current (Cold)
- Labrador Current (Cold)
- Brazilian Current (Warm)
- Falkland Current (Cold)
- South Atlantic Drift (Cold)
- Benguela Current (Cold)

Currents of Pacific Ocean

- North Equatorial Current (Warm)
- South Equatorial Current (Warm)

- Counter Equatorial Current (Warm)
- Kuroshio System (Warm)
- Oyashio Current (Cold)
- California Current (Cold)
- Peruvian or Humboldt Current (Cold)
- East Australia Current (Warm)
- North Pacific Drift (Warm)



Currents of Indian Ocean

- The North-East Monsoon Drift
- The South West Monsoon Drift
- Somali Current (Cold)
- Mozambique Current (Warm)
- Madagascar Current (Warm)
- Agulhas Current (Warm)

Salinity

Salinity refers to the amount of salt (in grams) dissolved in 1,000 grams (1 kg) of seawater. It is commonly expressed as parts per thousand (ppt) or o/oo.

A salinity of 7 ppt is considered the upper limit for "brackish water."

Even slight variations in ocean surface salinity can have significant impacts on the water cycle and ocean circulation.

Sources of Salts in Ocean Water

* Sediments carried by rivers contribute to the salt content.

* Submarine volcanism at Oceanic Ridges releases minerals into the water.

* Chemical reactions between rocks from geothermal vents or volcanoes and cold water.

* Erosion of oceanic rocks.

Distribution of Salinity

Vertical Distribution: Salinity changes with depth, leading to stratification. The halocline is a distinct zone where salinity increases sharply.

Horizontal Distribution: Salinity is highest near the tropics and decreases towards the equator and poles. Heavier rainfall near the equator incorporates freshwater, while less evaporation near the poles prevents water molecule removal.

Horizontal Distribution

- The salinity of normal ocean ranges between $33^{o}/_{oo}$ and $37^{o}/_{oo}$.
- In the landlocked Red Sea, it is as high as $41^{o}/_{oo}$, while in the estuaries and the arctic, the salinity fluctuates from $0\text{-}35^{o}/_{oo}$ seasonally.

- In hot & dry regions, where the evaporation is high, the salinity reaches to 70‰.
- The salinity variation of Pacific Ocean is mainly due to its shape and larger areal extent. Salinity decreases from 35‰-31‰ on the western parts of the northern hemisphere because of the influx of melted water from the arctic region. In the same way, after 15°20° south, it decreases to 33‰.
- The Atlantic Ocean's average salinity is approximately 36‰. The highest salinity is recorded between 15° & 20° latitudes. Maximum salinity is observed between 20° N and 30° N and 20° W- 60° W. It slowly decreases towards the north.
- Despite its location in higher latitudes, the North Sea records higher salinity because of more saline water brought in by the North Atlantic Drift.
- The Baltic Sea records low salinity by large quantities due to the influx of river waters.
- The Mediterranean Sea records greater salinity due to higher evaporation.
- Salinity is quite low in the Black Sea due to the influx of enormous amount of freshwater by rivers.

Types of Ocean Currents-Based on Depth

Ocean currents can be classified into two types based on their depth: surface currents and deep water currents.

Surface currents:€These currents make up about 10% of the ocean's water and occupy the upper 400 meters of the ocean.

Deep water currents:€Accounting for the remaining 90% of ocean water, deep water currents circulate within the ocean basins due to density and gravity variations.

At high latitudes, deep waters sink into the ocean basins where cold temperatures increase their density.

Primary Forces Responsible for Ocean Currents

Influence of Insolation: Solar heating causes water to expand, creating a slight gradient that leads to the flow of water from east to west.

Influence of Wind (Atmospheric Circulation): Wind pushes the ocean's surface water and affects its movement through friction. Magnitude and direction of ocean currents are influenced by wind, with monsoon winds playing a role in seasonal reversal of currents in the Indian Ocean.

Influence of Gravity: Gravity causes water to pile up and creates variations in gradient.

Influence of Coriolis Force: Coriolis force deflects water movement to the right in the northern hemisphere and to the left in the southern hemisphere. Gyres, large accumulations of water, form circular currents in all ocean basins. An example is the Sargasso Sea.

- The Indian Ocean averages salinity at $35^{o}/_{00}$ due to the influx of river water the low salinity trend is observed in the Bay of Bengal.
- The Arabian Sea exhibits higher salinity due to higher evaporation & a low influx of fresh water.

Secondary Forces Responsible for Ocean Currents

Secondary forces include temperature and salinity differences. Differences in water density impact vertical ocean currents.

Water with higher salinity and colder temperature is denser and tends to sink, while lighter and warmer water rises. Cold-water currents form as cold water from the poles sinks and slowly moves towards the equator.

Warm-water currents flow from the equator along the surface, replacing the sinking cold water and moving towards the poles.

Vertical distribution

- Salinity varies with depth but how it changes depends on the sea's position.
- Salinity at the surface increases by loss of water to ice or evaporation or decreased by the input of freshwaters such as from the rivers.
- Salinity at depth is fixed to a great extent because there is no way that the water is lost, or salt is added.
- There is a clear difference in the salinity between surface zones and deep zones of the oceans. The lower salinity water rests above the high salinity dense water.
- Generally, salinity increases with depth, and there is a distinct zone called the halocline, where salinity rises sharply.
- Other factors being constant, rising seawater salinity is causing an increase in its density. In general, high salinity seawater sinks beneath the lower salinity water. That results in salinity stratification.

Significance of Salinity:

- The freezing and boiling points in seawater are greatly influenced and regulated by the addition or subtraction of salts. Compared to freshwater the salt water freezes gradually. It is known that pure water freezes at the temperature of 0^{0}C freezing point. If seawater's salinity becomes $35^{o}/_{00}$, then it would freeze at – 1.91°C. In comparison, saline water boiling point (seawater) is higher than freshwater.
- Salinity and density of seawater are positively correlated, i.e. the salinity of seawater increases its density because solutes (here salts) in water have greater atomic weight than the molecules of freshwater.

This is why a person is seldom drowned in the seawater with very high salinity.

Relationship Between Salinity, Temperature, and Density

Temperature and density have an inverse relationship. As temperature increases, the space between water molecules increases, reducing salinity. Water reaches its maximum density at 4°C.

Density and salinity have a positive relationship. As density increases, so does salinity. Differences in density between warm and cold seawater drive ocean currents and upwelling. Warm seawater floats, while cold and dense seawater sinks.

- Evaporation is regulated by ocean salinity. Solutes (salts) in water actually lower the evaporation rate in the oceans. Thus more saline water evaporates less than less saline water. It may be suggested that evaporation also controls seawater salinity. More evaporation decreases seawater depth, and thus increases salt concentration (i.e., seawater salinity increases).
- Spatial variation in seawater salinity becomes a potent factor in the origin of ocean currents.
- The ocean salinity affects the marine organisms & plant community.
- Oceanic salinity plays a vital role in the growth and survival of marine organisms, circulation of oceanic currents and distribution of temperature and rainfall across the globe.

Oceanic Temperature

- The only source of heat on the entire planet is the sun. Which provides heat to both the site and the water.
- There is a difference in the rate of heating of the site and water because the site is hot and quick cooling while the water is late hot and late cold.
- Oceans have immense potential for storing solar energy and due to this, it also has special importance in keeping the heat budget of the Earth regular.
- Ocean water temperature varies from place to place at sea level. The temperature also varies from bottom to bottom.
- It is known as thermal layer.
- The heat from the equator towards the fumes generally decreases.

Factors influencing ocean water temperature are

Latitudinal extent of the seas

The seas located in the lower latitudes receive more sunlight and their absorption is also higher. In high latitudes, the opposite is true. But in the equatorial regions, despite the high sun, the temperature is found to be slightly lower due to rainfall throughout the year. The subtropical high pressure, clean sky, excessive radiation, low rainfall, etc. are helpful in maintaining high temperatures. Higher temperatures are found in areas of more longitudinal expanse of seas in lower latitudes, while lower temperatures are found in seas with more latitudinal expanses. Low temperatures are found in the Gulf of California while high temperatures occur in the Mediterranean Sea.

The process of ocean water heating and cooling

In fact, ocean water receives heat mainly through two methods -

1. by absorption of radiation of solar energy, and
2. By convection currents generated in the oceans due to the internal heat of the earth.

Similarly, ocean water is cooled by long-term heat radiation, convection currents and evaporation processes from its bottom. Virtually all the characteristics of ocean water temperature arise as a result of its heat and cooling interactions.

Salinity and density

Salinity increases the density of water and increasing the density increases the water's ability to absorb heat. But at the same time the high evaporation, the salinity and density of the black seas are also high. In fact, this interaction also has an effect on the temperature of the seas.

Ocean currents

When ocean currents carry cold water to hot water and hot water to cold water area, the sea temperature also increases and decreases respectively.

Relationship Between Density, Temperature and Salinity

- Density is the prime mover for the ocean water. Density is affected by Temperature and Salinity of the Ocean water; hence all three are main factors in the movement of ocean water.

- **Effect of Temperature:** Increase in temperature decreases the density and this less dense water move towards high-density ocean water as surface current while highdensity water sinks and moves as subsurface water and completes the cycle like water from equatorial region moves towards high latitudes.
- **Effect of Salinity:** Salinity increases, then density also increases which again moved as mentioned above, e.g. water from the Atlantic Ocean moves towards the Mediterranean Sea because the salinity of Mediterranean Sea is much higher than adjoining Atlantic Ocean. Same is the case when ocean water from the Red Sea moves toward the Arabian Sea via Babel Man deb strait. The salinity of Baltic sea decreases due to freshwater mixing from rives and a density decrease, and then this water moves toward the Northern Sea and current subsurface moves towards Baltic Sea.

Based on Temperature

Cold currents: These currents bring cold water from high latitudes to low latitudes. They are typically found on the west coast of continents in low and middle latitudes in both the Northern and Southern Hemispheres. In the Northern Hemisphere, they are present on the east coast in higher latitudes.

Warm currents: Warm currents transport warm water from low to high latitudes. They are commonly observed on the east coast of continents in low and middle latitudes in both hemispheres. In the Northern Hemisphere, they flow along the west coasts of continents in high latitudes.

General Characteristics of Ocean Currents

The movement of ocean currents follows a general pattern of **clockwise circulation in the northern hemisphere** and **counterclockwise circulation in the southern hemisphere**. This is due to the **deflective force of the Coriolis force**, following **Ferrel's law**.

An **exception** to this pattern is seen in the **northern Indian Ocean**, where the **current direction changes with the seasonal shift in monsoon winds**. **Warm currents tend to move towards cold seas** and vice-versa.

In **lower latitudes**, **warm currents flow along the eastern shores** and **cold currents along the western shores**. This **situation is reversed in higher latitudes**.

Convergence occurs when warm and cold currents meet, while divergence happens when a single current splits into multiple currents flowing in different directions.

The **shape and position of coastlines** play a significant role in guiding the direction of currents.

Currents exist not only on the ocean's surface but also below it, influenced by differences in salinity and temperature. For example, the heavy surface water of the Mediterranean Sea sinks and forms a sub-surface current that flows westward past Gibraltar.

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- **Effect of Density:** Water moves from low density to high density as in case of polar water where density is decreased by melting ice, and then it moves towards lower water as cold surface currents.
- **Thermocline**: Oceanic water layer in which water temperature decreases rapidly with increasing depth.
- **Pycnocline: It is** situated between the mixed layer and the deep layer. In this region, water density increases rapidly with depth because of changes in temperature and/or salinity.

Tides

- Tides are the periodical rise and fall of the sea level which happens once or twice a day, mainly due to the attraction of the sun and the moon.
- Movement of water caused by meteorological effects (winds and atmospheric pressure changes) are called **surges.**
- The major causes for the occurrence of tides are:
    - the **gravitational pull** of the moon to a great extent and the **gravitational pull** of the sun to a lesser extent.
    - the centrifugal force that acts to counterbalance the gravity.
- Together, the Gravitational Pull(G) and the Centrifugal Force(C) are responsible for creating the two major tidal bulges on the earth.
- Thus, the tide generating force = Gravitational Pull - Centrifugal Force = G – C
- Towards the side of the earth that faces the moon, a tidal bulge occurs as the gravitational pull is higher. On the opposite face of the earth that remains away from the moon, the gravitational attraction of the moon is less and, the centrifugal force causes a tidal bulge on that side.

- The surface of the earth that is nearest to the moon, the gravitational pull or the attractive force of the moon is greater than the centrifugal force. Thus, there is a net force causing a bulge towards the moon.
- The surface of the earth that is opposite to the moon, the centrifugal force is greater than the gravitational pull or the attractive force of the moon. Thus, there is a net force causing a bulge away from the moon.

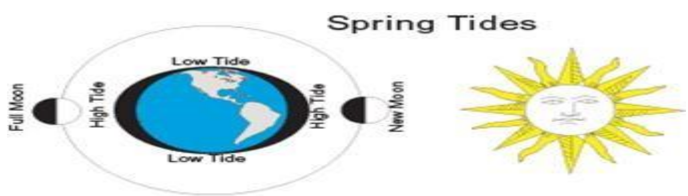
Types of Tides:

On the basis of frequency of occurrence, the tides are classified as:

1. **Semi-diurnal tide:** This is the most common tidal pattern in which **two high tides and two low tides occur of the approximately same height.**
2. **Diurnal tide:** One high tide and one low tide of approximately the same height occur during each day.
3. **Mixed tide:** These are the tides having variations in height. These tides generally occur along the **west coast of North America** and along the islands of the Pacific Ocean.

On the basis of the positions of the Sun, Moon and the Earth, the tides are classified as:

1. **Spring tides:** When the sun, the moon and the earth are in a straight line, the height of the tide will be higher. They are known as the **spring tides** and they occur **twice a month**, one on **full moon period**
   and another during **new moon period**.
2. **Neap tides:** When the sun and moon are at right angles to each other and



forces of the sun and moon tend to counteract one another, the neap tides occur. The moon' s attraction is more than twice that of the sun but, it is diminished by the counteracting force of the gravitational pull of the sun. Generally, there is an interval of **seven days** between the spring tides and neap tides. Like spring tides, neap tides also occur **twice a month.**

- **Ebb:** The time between the high tide and low tide, when the water level is falling, is called the ebb.
- **Flood:** The time between the low tide and high tide, when the tide is rising, is called the flood or flow.

Waves

- Waves are the energy which moves across the surface of the ocean in a horizontal and vertical motion. The winds blowing over the sea generates the wave.
- The wind provides energy to the waves. Higher the energy provided by the wind, higher is the size of the wave. The stronger wind creates greater friction on the surface of the sea and therefore the waves become bigger.
- The water in the waves do not move, but the wave as a whole move ahead.
- The characteristics of waves are determined by the strength of the wind, its duration and fetch, i.e., the distance a wave travels.
- The motion of the water beneath the waves is circular.

The waves are classified as:

Constructive waves:

- Constructive waves are flat and low in height and have a long wavelength. Their strong swash carries material up the beach, forming a berm. They have a low frequency of between 6 and 8 waves per minute. The wave energy dissipates over a wide area which results in a weak backwash.

Destructive waves:

- Destructive waves have a large wave height and short wavelength. They have tall breakers that have a high downward force and a strong backwash. Their frequency is high with between 13 and 15 waves per minute. Their strong downward energy helps erode beach material and cliffs. The strong backwash results in narrow beach profiles.

Tsunami

- Tsunami is a seismic sea wave. It is a Japanese word for Harbour wave. They are the water waves in oceans or seas having very long wavelength. Due to long wavelengths, they are commonly referred to as tidal waves. However, the attractions of the Moon and Sun play no role in their formation. Sometimes, they come ashore to great heights and may be extremely destructive.

Causes:

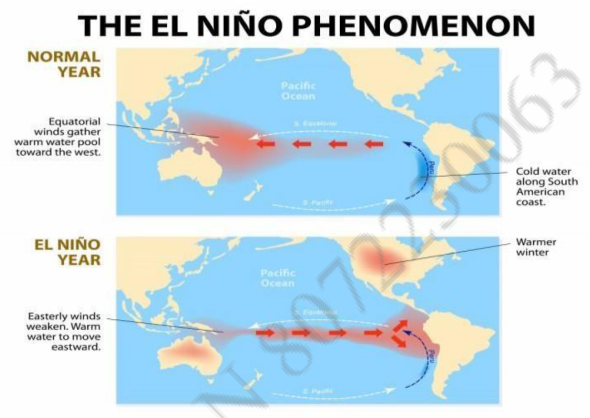
1. The sudden displacement of the seabed due to submarine earthquakes can cause the sudden raising or lowering of a large body of water. The tsunami that occured on 26th December 2004, was caused after an earthquake that displaced the seabed off the coast of Sumatra, Indonesia.
2. Large volcanic eruptions along shorelines.
3. A marine volcanic eruption generating an impulsive force that displaces the water column.
4. A submarine landslide during which the equilibrium sea-level is altered by sediment moving along the floor of the sea. Gravitational forces then propagate a tsunami.
5. Landslides along the coast.
6. High-intensity explosions.

Mechanism:

- Tsunami is caused due to an undersea earthquake that causes a buckling of the seafloor, near the subduction zones.
- As a plate plunges into the interior of the earth, it gets stuck against the edge of a continental plate for a while. As the stress builds up, the parts of the ocean floor snap upward and other areas sink downward.
- This causes waves to move outwards and a tsunami is caused.
- The Tsunami transforms as soon as it leaves deep waters and propagates into the shallow waters. As the depth of the water decreases, the speed of the tsunami reduces. However, the change in the total energy of the tsunami remains constant.
- The rate of energy loss of a wave is inversely related to its wavelength. Thus, tsunamis lose little energy as they propagate because of their very large wavelength.
- The height of the tsunami wave grows with a decrease in speed.
- A tsunami imperceptible in deep water may grow to several metres high and this is called the 'shoaling' effect.

El Nino

- El Niño phenomenon is the occasional development of warm ocean surface waters along the coast of Ecuador and Peru. El Niño means The Little Boy or Christ Child in Spanish.
- The upwelling of cold, nutrient-rich deep ocean water is significantly reduced when the warming occurs.
- The El Niño is linked to periodic warming in sea surface temperatures across the central and east-central Equatorial Pacific.
- The presence of El Niño can significantly influence weather patterns, ocean conditions, and marine fisheries across large portions of the globe for an extended period of time.



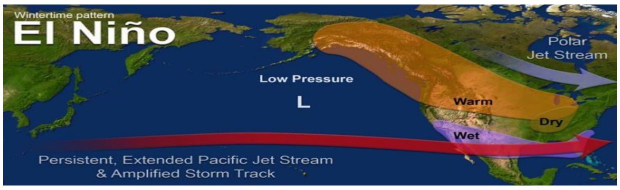
Normal Conditions

- In a normal year, low pressure develops in the region of northern Australia and Indonesia and a high-pressure system over the coast of Peru. This results in the strong movement of the trade winds over the Pacific Ocean from east to west.
- The easterly flow of the trade winds carrying warm surface waters westward brings thunderstorms to Indonesia and coastal Australia.
- The cold bottom nutrient-rich water upwells to the surface along the coast of Peru to replace the warm water that is pulled to the west.

During El Nino year

- During an El Niño year, the pressure drops over large areas of the central Pacific and along the South American coast.
- The low-pressure system is replaced by a weak high pressure in the western Pacific. This change in pressure pattern causes the trade winds to be reduced.
- The reduction allows the equatorial counter-current to accumulate warm ocean water along the coastlines of Peru and Ecuador.

- The accumulation of warm water along the coastlines of Peru and Ecuador causes the thermocline to drop in the eastern part of the Pacific Ocean which cuts off the upwelling of cold deep ocean water along the coast of Peru.
- Thus, the development of an El Niño brings drought to the western Pacific, rains to the equatorial coast of South America, and convective storms and hurricanes to the central
  - Pacific.



Impact of El Nino on monsoon in India

- There exists an inverse relationship between the El Nino and Indian monsoon.
- The occurrence of El Nino is associated with occurrences of droughts in India. The most prominent droughts in India are related to El Nino.
- However, not all El Nino years brings a drought in India. For instance, 1997-98 was a strong El Nino year but there was no drought because of the phenomenon known as the Indian Ocean Dipole.
- India's agrarian economy is directly impacted by the El Nino as it tends to lower the production of summer crops. This results in high inflation and low gross domestic product.

La Nina

- La Niña is an event during some years when the trade winds become extremely strong and an abnormal accumulation of cold water can occur in the central and eastern Pacific ocean.
- La Niña means The Little Girl in Spanish.
- La Niña represents periods of below-average sea surface temperatures across the eastcentral Equatorial Pacific.
- La Niña impacts tend to be opposite those of El Niño impacts. In the tropics, ocean temperature variations in La Niña also tend to be opposite those of El Niño.
- During a La Niña year, winter temperatures are warmer than normal in the Southeast and cooler than normal in the Northwest.

Effects of La Nina

- Abnormally heavy monsoons in India and Southeast Asia.
- Cool and wet winter weather in southeastern Africa.
- Wet weather in eastern Australia.
- Cold winter in western Canada and the northwestern United States.
- Winter drought in the southern United States.

Indian Ocean Dipole

- The Indian Ocean Dipole (IOD) is characterized 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 and peaks in October.
- A positive IOD is characterized by the winds over the Indian Ocean blowing from east to west, i.e., from Bay of Bengal towards the Arabian Sea. As a result, the Arabian Sea, i.e., western Indian Ocean near African Coast becomes much warmer and eastern Indian Ocean around Indonesia becomes colder and dry.
- A negative IOD is characterized by the reverse process which makes Indonesia much warmer and rainier.
- The negative IOD, i.e., the Arabian Sea being warmer than the Bay of Bengal results in more cyclones than usual in the Arabian Sea.
- The positive IOD results in stronger than usual cyclogenesis in the Bay of Bengal. Cyclogenesis in the Arabian Sea is suppressed.

TO BE CONTINUED……

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