Unit IV

Ocean Water Movement

Waves

- Waves are the **oscillatory movements** that result in the rise and fall of water surface.
- Waves are a kind of horizontal movements of the ocean water.
- They are actually the energy, not the water as such, which moves across the ocean surface.
- This energy for the waves is provided by the **wind**.
- In a wave, the movement of each water particle is in a circular manner.
- A wave has two major parts: the raised part is called as the **crest** while the low-point is called as the **trough**.

Tides

- Tide are the **periodical rise and fall of the sea levels**, once or twice a day, caused by the combined effects of the gravitational forces exerted by the sun, the moon and the rotation of the earth.
- They are a vertical movement of waters and are different from movements of ocean water caused by meteorological effects like the winds and atmospheric pressure changes.
- Note: The water movements which are caused by the meteorological effects like the said above are called as **surges** and they are not regular like tides.
- The moon's gravitational pull to a great extent is the major cause of the occurrence of tides (the moon's gravitational attraction is more effective on the earth than that of the sun).
- Sun's gravitational pull and the centrifugal force due to the rotation of earth are the other forces which act along with the moon's gravitational pull.

Types of Tides

TIDES BASED ON THE FREQUENCY

1. **Semi-diurnal Tide**: They are the most common tidal pattern, featuring two high tides and two low tides each day.
2. **Diurnal Tides**: Only one high tide and one low tide each day.
3. **Mixed Tide**: Tides having variations in heights are known as mixed tides. They generally occur along the west coast of North America.

TIDES BASED ON THE SUN, THE MOON, AND THE EARTH'S POSITIONS

1. **Spring Tides**: When the sun, the moon, and the earth are in a straight line, the height of the tide will be higher than normal. These are called as a spring tides. They occur twice in a month-one on the full moon (Poornima) and the other on the new moon (Amavasya).

2. **Neap Tides**: Normally after seven days of a spring tide, the sun and the moon become at a right angle to each other with respect to the earth. Thus, the gravitational forces of the sun and the moon tend to counteract one another. The tides during this period will be lower than the normal which are called as the neap tides. They also occur twice in a month- during the first quarter moon and the last quarter moon.

Ocean Currents

- The ocean currents are the horizontal flow of a mass of water in a fairly defined direction over great distances.
- They are just like a river flowing in an ocean.
- Ocean currents can be formed by the winds, density differences in ocean waters due to differences in temperature and salinity, gravity and events such as earthquakes.
- The direction of movement of an ocean current is mainly influenced by the rotation of the earth (**due to Coriolis force, most ocean currents in northern hemisphere move in clockwise manner and ocean currents in southern hemisphere move in an anti-clockwise manner**).

Types of Ocean Currents

WARM OCEAN CURRENTS:

- Those currents which flow from equatorial regions towards poles which have a higher surface temperature and are called warm current.
- They bring warm waters to the cold regions.
- They are usually observed on the east coast of the continents in the lower and middle latitudes of both hemispheres.
- In the northern hemisphere, they are also found on the west coast of the continents in the higher latitudes (E.g. Alaska and Norwegian Currents).

COLD OCEAN CURRENTS:

- Those currents which flow from polar regions towards equator have a lower surface temperature and are called cold currents.
- They bring cold waters into warm areas.
- These currents are usually found on the west coast of the continents in low and middle latitudes of both hemispheres.
- In the northern hemisphere, they are also found on the east coast in the higher latitudes (E.g. Labrador, East Greenland and Oyashio currents).

The ocean currents can be also classified as:

- **Surface Currents**: They constitute about 10% of all the waters in an ocean. These waters are occupied at the upper 400m of an ocean or the **Ekman Layer**. It is the layer of the ocean water which moves due to the stress of blowing the wind and this motion is thus called as **Ekman Transport**.
- **Deep Water Currents**: They constitute about 90% of the ocean water. They move around the ocean basin due to variations in the density and gravity.

Factors influencing the origin and nature of ocean currents

1. **Difference in density**

- As we all know, the density of sea water varies from place to place according to its temperature and proportion of salinity.

- The **density increases with an increase in salinity** and decreases with a decrease in salinity.
- But when **the temperature increases, density decreases** and when the temperature decreases density increases.
- This increase and decrease in density due to the differences in temperature and salinity causes the water to move from one place to another.
- Such a movements of water due to the differences in density as a function of water temperature and salinity is called as the **Thermohaline Circulation**.
- In polar regions, due to a lower temperature, the waters will be of high density. This causes the waters to sink to the bottom and then to move towards the less dense middle and lower latitudes (or towards the equatorial regions).
- They rise (upwelling) at the warm region and push the already existing less dense, warm water towards the poles.
- While considering the equatorial region, the high temperature in those regions causes the water to expand. Thus, the waters in these regions will be at a higher level than that of the middle and upper latitudes. This also creates a gradient and results in the movement of waters from equatorial region to middle and upper latitudes.

2. **The earth's rotation**

- Earth's rotation causes Coriolis force which deflects the air to its right in the northern hemisphere and to its left in the southern hemisphere-Ferrel's Law.
- Similarly, oceans water also affected by the Coriolis force and follows the Ferrel's Law.
- Hence, ocean currents in the northern hemisphere move in a clockwise (towards right) direction and ocean currents in southern hemisphere moves in an anti-clockwise (towards left) direction (In the Indian Ocean due to the impact of the Asian monsoon, the currents in the northern hemisphere do not follow this pattern of movements all time).

3. **The winds**

- The winds like trade winds and westerlies drive the ocean water in a steady flow in front of them.

- When the direction of the winds changes, the direction of the current also gets changed

Currents of the Atlantic Ocean

- To the north and south of the equator, there are two westward moving currents, i.e., the North and the South Equatorial Currents.
- Between these two, there is the counter equatorial current which moves from west to east.

ATLANTIC OCEAN: NORTHERN HEMISPHERE

- The South Equatorial Current bifurcates into two branches near the Cape De Sao Roque in Brazil and its northern branch joins the North Equatorial Current.
- A part of this combined current enters the Caribbean Sea and the Gulf of Mexico, while the remaining current passes along the eastern side of the West Indies as the **Antilles Current**.
- The part of the current which enters the Gulf of Mexico comes out from the Florida Straight and joins the Antilles current.
- This combined current moves along the south-eastern coast of the U.S.A and is known as the **Florida Current** up to Cape of Hatteras.
- Beyond Cape of Hatteras, it is known as the **Gulf Stream**.
- A cold current from the Arctic Ocean called **Labrador Current**, which flows along the eastern coast of Canada, meets the warm Gulf Stream near the north-east corner of U.S.A.
- The confluence of these two currents, one cold and the other warm, produce fog around the region and makes it the most important fishing ground in the world.
- The Gulf Stream then deflected eastward under the combined influence of the westerlies and the rotation of the earth.
- It then crosses the Atlantic Ocean as the warm North Atlantic Drift.
- In this journey, another cold current from the Arctic called as the East Greenland Current joins with the North Atlantic Drift.
- The North Atlantic Drift bifurcates into two branches on reaching the eastern part of the ocean.

- The northern branch continues as North Atlantic Drift; reaches the British Isles from where it flows along the coast of Norway as the warm **Norwegian Current** and enters the Arctic Ocean.
- The southern branch flows between Spain and Azores Island as the cold **Canaries Current**.
- The Canaries Current finally joins the North Equatorial Current and completes the circuit.

ATLANTIC OCEAN: SOUTHERN HEMISPHERE

- The South Equatorial Current turns south and flows along the eastern coast of South America as Brazil Current.
- At about 35^0 south latitude, due to the influence of westerlies and the rotation of the earth, the current moves eastward.
- A cold current called as the **Falkland Current** which flows along the south-eastern coast of South America from south to north joins with the current at this time.
- The Brazil Current moves eastward and crosses the Atlantic Ocean as **South Atlantic Current**.
- A part of the west wind drift or the Antarctic Circumpolar Current merges with the South Atlantic Current while crossing the Atlantic.
- Near the Cape of Good Hope, the South Atlantic Current is diverted northward as the Cold **Benguela Current**.
- Benguela Current finally joins with the South Equatorial Current and completes the circuit.

Currents of the Pacific Ocean

PACIFIC OCEAN: NORTHERN HEMISPHERE

- The North Equatorial Current turns northward and flows along the Philippines Islands, Taiwan, and Japan to form the warm **Kuro Shio** or **Kuro Siwo** current.
- Later, a cold current called **Oya Shio** or **Oya Siwo** which flows along the eastern coast of the Kamchatka Peninsula merges with the Kuro Shio Current (Okhotsk Current is a cold current which merges with the Oya Shio before its confluence with Kuro Shio).

- From south-east coast of Japan, the Kuro Shio current comes under the influence of westerlies and flow right across the ocean as the **North Pacific Current**.
- After reaching the west coast of North America, it bifurcates into two branches: the northern branch flows anti-clockwise along the coast of Alaska as warm **Alaska Current** and the southern branch moves southward along the coast of California as the cold **California Current**.
- California Current eventually joins with the North Equatorial Current and completes the circuit.

PACIFIC OCEAN: SOUTHERN HEMISPHERE

- In the South Pacific Ocean, the South Equatorial Current flows towards the west and turns southward as the **East Australian Current**.
- From Tasmania, it flows as the cold **South Pacific Current** from west to east and crosses the Pacific Ocean along with the West Wind Drift.
- On reaching the south-western coast of South America, it turns northward and flows as the cold **Peru Current** or **Humbolt Current**.
- The cold waters of the Peru Current are partially responsible for making the coast of the northern Chile and western Peru with very scanty rainfall.
- Peru Current eventually joins with the South Equatorial Current and completes the circuit.

Currents of the Indian Ocean

- The pattern of circulation of ocean currents in the Indian Ocean differs from the general pattern of circulation in the Atlantic and the Pacific Oceans.
- This is because the Indian Ocean is blocked by the continental masses in the north.
- The general pattern of circulation in the southern hemisphere of the Indian Ocean is anti-clockwise as that of the other oceans.

- In the northern hemisphere, there is a clear reversal of currents in the winter and summer seasons, which are completely under the influence of the seasonal changes of monsoon winds.

INDIAN OCEAN: NORTHERN HEMISPHERE DURING WINTER

- During winter, Sri Lanka divides the currents of the Arabian Sea from those of the Bay of Bengal.
- The **North East Monsoon Drift** flows westward just south of Sri Lanka with a countercurrent flow between it and the South Equatorial Current.
- During the winter season, in the northern section, the Bay of Bengal and the Arabian Sea are under the influence of North East Monsoon Winds.
- These North East Monsoon winds drive the waters of the Bay of Bengal and the Arabian Sea westward to circulate in an anti-clockwise direction.

INDIAN OCEAN: NORTHERN HEMISPHERE DURING SUMMER

- In summer, the northern part comes under the influence of the South West Monsoon.
- It results in an easterly movement of water in the Bay of Bengal and the Arabian Sea in a clockwise direction.
- This current is called as the **South West Monsoon Drift**.
- In the Indian Ocean, the summer currents are more regular than those of the winter.

INDIAN OCEAN: SOUTHERN HEMISPHERE

- In the southern part, the South Equatorial Current which flows from east to west is strengthened by its corresponding current of the Pacific Ocean.
- It then turns southward along the coast of Mozambique in Africa.
- A part of this current moving in between the African mainland and the Mozambique is called as the warm **Mozambique Current**.
- After the confluence of these two parts, the current is called as **Agulhas Current**.
- Agulhas Current merges with the West Wind Drift when it crosses the Indian Ocean.
- A branch of this merged current flows along the western coast of the Australia as cold **West Australian Current**.
- It later joins with the South Equatorial Current to complete the circuit.