



#### **Chapter Outline**

- 5.1 Introduction
- 5.2 Distribution of Land and Water in the Earth
- 5.3 Fresh water
- 5.4 Cryosphere

world

5.6

5.5 Oceans and Seas

Oceans of the



- **5.7** Maritime zones
- 5.8 Relief of ocean
- 5.9 Ocean temperature
- 5.10 Salinity of the ocean
- 5.11 Ocean movements

#### **5.1 Introduction**

"ீநீர்இன்று அமையாது உலகெனின் யார்யார்க்கும் வான்இன்று அமையாது ஒழுக்கு"

#### "World cannot survive without water and morality cannot exist without rain"

As thirukkural quotes, water is the most important resource in the world. Over 90% of the world's supply of fresh water is in Antarctica. You must know that 85% of the world population lives in the driest

## **Of Learning Objectives:**

- To understand the importance of hydrosphere
- Acquire knowledge on evolution of ocean and ocean relief features
- Appreciate the ocean movements and their influence on the earth's climate

half of the planet. Now we shall learn about the hydrosphere in detail.



Water is the most common substance found on earth. It is an important constituent of all life forms on the earth. Hydrosphere is one among the four spheres of the earth. The hydrosphere includes the water on the surface of the earth, the water below the surface called ground water and the water in the atmosphere above earth's surface. Oceans, rivers, lakes and glaciers form part of surface water. There is substantial

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amount of water under the surface of the earth. The atmosphere has water in all the three forms. (Solid, liquid, and gas). The total amount of water on the earth does not change over time. Water is constantly in motion within the spheres of the earth which is being transformed and reused all over the earth. The earth's hydrosphere, thus, acts as a closed system.

# **5.2 Distribution of Land and Water in the Earth**

Earth is covered by land and water. About 70.8% of its area (361million sq km) is covered by water and 29.2% (148 million sq km) of its area by land. About 96.5% of water is salty found in seas and oceans. Fresh water occupies only 2.5%. Saline ground water and saline lakes together form 1%.

#### 5.3 Fresh water

Fresh water is defined as water with a salinity of less than 1‰ compared to that of the oceans (i.e. below 0.35‰). Water with salinity between 0.35‰ and 1‰ is typically referred to as marginal water because it is marginal for many uses by humans and animals.

Considering the distribution of fresh water 68.6% of it is locked in Glaciers and icecaps. About 30.1% is stored as ground water and the remaining 1.5% is available as surface water.

Surface water includes ice and snow on the land and sea, water in the lakes, rivers, swamps and marshes, moisture in soil, atmosphere and biosphere. Rivers and lakes are the major sources of fresh water around the world, and are vital to the communities they serve. **Rivers**: Rivers generally have a source on a mountain either from a glacier, a spring or a lake. River Ganga has its source from Gangotri glacier in the Himalayas. River Cauvery has its source from a spring in Talacauvery located in Kodagu district of Karnataka. River Nile has its source near Lake Victoria in Uganda. The river flows through confined channel between two banks and ends up at the mouth which is either on a sea or lake. When rivers drain their water into a lake or an inland sea, it is said to be an inland drainage.

The Nile River in Africa is the longest river in the world. The Nile River flows through Egypt, Uganda, Ethiopia, Kenya, Tanzania, Democratic Republic of the Congo, Rwanda, Burundi, Sudan and Eritrea drains and into the Mediterranean Sea forming a delta to the north of Cairo city.

The river Amazon in South America, is the second longest river, and has the largest drainage basin of any river. The Amazon River flows through Peru, Colombia, and Brazil and drains into the Atlantic Ocean forming an estuarine delta.

The Yangtze River, which flows in China, is the longest river in Asia, and the third longest river in the world. The longest river system in the United States, the Mississippi-Missouri system is considered the fourth longest river in the world.



The total volume of water in rivers in the world is estimated at 2,120 km<sup>3</sup>. Asia

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excluding Middle East, has the largest run off of 13,300 km<sup>3</sup>/year followed by North America with 12,000 km<sup>3</sup> per year.

A nationwide water ΠΟ resources information "Generation system, KNOW? of Database and Implementation of Web Enabled Water Resources Information System country" (India-WRIS) in the contain all aspects of water resources and related data provide data and information in public domain through India-WRIS Web GIS portal.

Lakes: Lakes are larger bodies of water with outlet through a river or stream. Lakes

may have their origin through tectonic activity, volcanic activity, river, glacier and wave action or sometimes meteoric origin. Caspian Sea, Lake Baikal and Wular Lake have been formed by earth movements. Lake Baikal is the deepest freshwater lake in the world. Caspian Sea is the largest salt water lake in the world.

#### **Fact File**

Tmc ft, is the abbreviation for one thousand million cubic feet (1,000,000,000 = 1 billion), commonly used in India with reference to volume of water in a reservoir or river flow.

#### Activity: List the major rivers from the map, find their source and mouth.

Name of the river	Source	Countries through which they flow	Sea or ocean it drains into	Type (Delta or estuary)
Amazon. R				
Nile .R				
Yangtzekiang. R				
Ganga. R				



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Lagoon lakes are formed by wave deposition. Chilika Lake is the largest lagoon lake in India. Lonar Lake in Maharashtra is believed to be formed by depression created by meteor impact which hit during Pleistocene Epoch.



largest salt water lake in India.

Finland is known as land of thousand lakes.

Wetlands: Wetlands are areas of marsh, fen, peat land or water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed six metres. Marshes are shallow wetlands around lakes, streams, or the ocean where grasses and reeds are common, without trees. Rann of Kutch in India is a salt marsh.

A **swamp** is a wetland with lush trees and vines found in a low-lying area beside slowmoving rivers. **Pallikaranai** wetland is a fresh water swamp adjacent to the Bay of Bengal situated in the southern part of Chennai.

#### Groundwater

Groundwater is the most valuable resource for any country. The rain water that falls on the earth either runs off as surface water or percolates into the ground to recharge the groundwater. The permeable rocks that can hold water and allow water to pass through them are called **aquifers.** The upper part of the saturated zone of the aquifer is called the **water table**. The level of water table fluctuates according to seasons (Figure 5.1).



Figure 5.1 Ground water



If excessive water is taken from the aquifers along the coast, the

Saltwater intrusion

sea water enters the coastal aquifer. This process is termed as saltwater intrusion.

#### 5.4 Cryosphere

Cryosphere includes the water in frozen state. Glaciers, ice sheets, ice caps, lake and river ice, permafrost, seasonal snow and ice crystals in the atmosphere together form cryosphere. Earth's climate is highly influenced by the extent of cryosphere as it controls the energy budget of the earth (Figure 5.2).

Perennial ice cover is found in Greenland and Antarctica as ice sheets, as mountain glaciers and as permafrost in higher latitudes. **Permafrost** is the condition prevailing when water freezes above and below the ground, (including rock or soil) for more than two consecutive years. Most permafrost regions are located in high latitudes, but alpine permafrost may exist at high mountains in much lower latitudes.

#### **Fact File**

Mount Kilimanjaro (5895m) in Tanzania, Africa, located closer to the equator has permafrost.

Seasonal snow and ice crystals are confined to middle latitudes and high mountains in lower latitude. **Sea ice** is frozen ocean water. Its formation, growth and melting are all confined to the ocean. An **ice shelf** is a thick, floating slab of ice that forms where a glacier or ice flows



Figure 5.2 Cryosphere

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down a coastline. The world's largest ice shelves are the Ross Ice Shelf and the Filchner-Ronne ice shelf in Antarctica. **An iceberg** is ice floating in open water that has broken off from glaciers or ice shelf.

Carbon is removed from the atmospheric cycle by cryosphere during the formation of ice and is released when the ice melts.

#### 5.5 Oceans and Seas

The water in the oceans and seas is termed as marine water. Continuous water body that surrounds the continents, created by earth's internal force is known as Ocean. The term ocean takes its origin from the Greek word 'Oceaonus' meaning enormous river encircling the earth. The area of the World Ocean is 361 million square kilometre. The earth has at present five major oceans: The Pacific Ocean, the Atlantic Ocean, the Indian Ocean, the Arctic Ocean, and the Southern ocean (Figure 5.3). All these oceans are interconnected to form one Global Ocean or World Ocean. This nature of water to level up quickly has made it as a reference point to measure the height of the land features and the depth of the sea features.

#### Fact File

Mean Sea Level (MSL) is the average height of the surface of the sea for all stages of the tide. MSL is reference point to measure the height of land features and depth of the sea features. Sea is a body of saline water (generally a division of the world ocean) partly or fully enclosed by land. Marginal sea is a sea partially enclosed by islands, archipelagos, or peninsulas and extension of oceans towards land. They are generally shallow. Andaman Sea, Arabian Sea, Bay of Bengal, Java Sea, Persian Gulf and Red Sea are marginal seas of the Indian Ocean.

**Bay** is a water body surrounded on three sides by land and the fourth side (mouth) wide open towards an ocean.

**Gulf** is a large body of water, with a narrow mouth, that is almost completely surrounded by land. The world's largest gulf is the Gulf of Mexico. **Sound, creek, bight** and **cove** are bays which vary in size and depth.

**Strait** is a narrow channel of water, connecting two larger bodies of water. Palk Strait connects Gulf of Mannar and Bay of Bengal. **Isthmus** is a narrow strip of land connecting two larger land masses. Isthmus of Suez connects Africa and Asia.

Enclosed seas are seas that reach very deep into the continent stay connected with one or the other ocean of the world through straits. Mediterranean Sea is the best example for enclosed sea. Partly Enclosed Seas are those types of seas that are connected to the oceans by a very wide opening and have similar characters of the adjacent ocean. A series of islands may also occur between a partly enclosed sea and the ocean to which it is connected. Caribbean Sea is a perfect example.

Landlocked Seas are completely surrounded by landmass on all sides without any natural outlet. They are actually hyper saline lakes. Dead Sea

and Caspian Sea are good examples of landlocked seas. Jordon River and Volga River flow into Dead Sea and Caspian Sea respectively.

**Fjord** is a long indented bay with steep slope that has been created by the submergence of U shaped glacial valley. Example: sogne Fjord in Norway (203 km).

**Ria** is an indented bay with gradual slope formed by the submergence of V shaped river valley. George River in Sydney is the best example for Ria.

#### 5.6 Oceans of the world

#### 1. The Pacific Ocean

Pacific Ocean is the largest ocean in the world. It is bigger than all continents put together. Portuguese explorer Ferdinand Magellan in 1521 named the ocean Pacific Ocean meaning 'peaceful' because he felt the ocean to be calm after sailing from the Atlantic Ocean through the stormy and dangerous Strait of Magellan. Average depth of this ocean is 4,280 meters.



#### 2. The Atlantic Ocean

Atlantic Ocean is the second largest ocean of the world. The Atlantic Ocean's name refers to Atlas of Greek mythology. The North Atlantic Ocean was formed by the break-up of the supercontinent Pangaea and the south Atlantic was formed when the Gondwana land broke in the geological past.





#### Fact File

The Suez Canal, an artificial sealevel waterway in Egypt, connecting the Mediterranean Sea to the Red Sea through the Isthmus of Suez was officially opened on November 17, 1869.

#### 3. The Indian Ocean

The Indian Ocean is the third-largest in the world. It is named after India. Its calm open water has encouraged the sea trade earlier than the Atlantic or the Pacific Ocean.

## 4. The Southern Ocean (Antarctic Ocean)

The Southern Ocean is the world's fourth largest ocean. The Southern Ocean is the youngest ocean and was formed 30 million years ago when South America moved away from Antarctica, opening the Drake Passage (Figure 5.4). This ocean has the boundary where cold, northward flowing water from the Antarctic mixes with warmer sub Antarctic water. During summer in southern hemisphere over half of the Southern Ocean is covered with ice and icebergs.



Figure 5.4 Extension of Southern Ocean

#### 5. The Arctic ocean

The Arctic Ocean is shallower and smaller than the other four oceans. It is completely surrounded by Eurasia and North America. It is covered by ice completely in winter. The Arctic Ocean's surface temperature and salinity vary seasonally as the ice cover melts and freezes alternatively. Its salinity is the lowest on an average of the five major oceans. Bering Strait connects the Arctic Ocean with the Pacific Ocean while the Greenland Sea and the Labrador Sea connects it with the Atlantic. The deepest point

#### Fact File

The International Hydrographic Organization (IHO) is the intergovernmental organisation that surveys and produces charts for the world's seas, oceans and navigable waters. is Litke Deep in the Eurasian Basin, at 5,450 m.

#### 5.7 Maritime zones

The low-tide line forms the base line for marking maritime zones. Water landward of the baseline in defined as **internal waters** over which the state has complete sovereignty. A country's **territorial sea** extends up to 12 nautical miles (22.2 km) from its baseline (Figure 5.5). The **contiguous zone** is a zone of water extending from the outer edge of the territorial sea up to 24 nautical miles (44.4 km) from the baseline.

An Exclusive Economic Zone (EEZ) extends from the base line to a maximum of 200 nautical miles (370.4 km). A coastal nation has control of all economic resources within its exclusive economic zone, including fishing, mining and oil exploration. Everything beyond EEZ is called International Waters or the High Seas. No nation has sovereign rights over this area.

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Figure 5.5 Maritime Zones

#### **Fact File**

A nautical mile is based on the circumference of the earth, and is equal to one minute of a degree of latitude. A nautical mile is equivalent to 1,852 metres. Nautical miles are used in Navigational charts.

#### 5.8 Relief of ocean

The bottom of the ocean has a variety of landforms just as it is seen on the earth's surface. There are large mountain ridges, deep depressions, flat plains, basins and volcanoes (Figure 5.7). The configuration of an ocean floor is shown with the help of a 'Hypsometric curve' or 'Hypsographic curve'. It is a graph denoting the proportion of a landmass standing above or below the sea level.

#### **Fact File**

Indian National Centre for Ocean Information Services (INCOIS) with its Marine Satellite Information Services uses the remotely sensed sea surface temperature (SST) to identify the locations of fish aggregation. The details of the Potential Fishing Zones (PFZ) are then disseminated to the fishermen once in every three days along the Indian Coast by displaying the details in the Lighthouse in their respective regional language (Figure 5.6).

#### **Continental shelf**

Continental shelf is the seaward extension of land that lies under the sea water. It occupies 7% of the sea floor. The continental shelf slopes gently away from the land and is covered with shallow seas with an average depth of 200

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INDIA INDIA Arabian SRI LANKA Indian Ocean Not to scale TER LIMIT OF EXCLUSIVE 750 65°E 700 80 85 90 North Indian Ocean with Arabian Sea and Bay of Bengal .The dashed Lines demacrate India's EEZ, Which covers about 2 million sq,km, Which is roughly 60% of India's land area.India's coastline including islands is about 7000 km long.

Figure 5.6 India's Exclusive Economic Zone

fathoms. The width of the continental shelf varies according to the nature of the rock beneath the crust. If the crust is dynamic then the shelf would be narrow and vice versa. Continental shelves are formed due to either any one or combination of the factors like fluvial deposits, marine erosion, tectonic forces, and the fluctuations in sea level in the past. Continental shelves are well known for oil, natural gas, mineral deposits and coral reefs. World famous fishing grounds like Grand Bank are situated here. The world's widest continental shelf (1210 km long) is located along the coast of Siberia, in Russia.

Continental shelf on the east coast of India is formed by deltas of the Ganga, the Godavari, the Krishna and the Cauvery. On the West coast of India the continental shelves are formed due to faulting and consequent submergence.

#### **Continental Slope**

The zone of steep slope extending from the continental shelf to the deep sea plain or abyssal plain is called continental slope. The slope angle varies from 5° to 60°. It occupies 9% of sea floor. This is the region in oceans where

landslides, turbid currents, large sediment slumps, under water canyons, gorges cut by the currents and rivers occur. The deposit from the continental shelves immediately falls down here. The origin of continental slope is believed to be due to erosional, tectonic and aggradational processes.

#### **Continental rise**

The area between the continental slope and the sea floor is known as the continental rise. This part is noted for the accumulation of sediments similar to the alluvial fans near the foot hills in the land. It represents the boundary between continents and abyssal plain. It constitutes about 5% of the oceanic area.

#### Abyssal plain

The Abyssal plain is the vast area of flat terrain in the bottom of the oceans. It is the largest part of ocean relief covering more than 50% of the total area. There is an accumulation of very fine sediments on the floor. The sediments are combinations of fine particles of clay and microorganisms. As in the case of sedimentary rocks of earth's Continental shelf Guyot Guyot

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Figure 5.7 Major relief features of Ocean Floor



Figure 5.8 Ocean relief

surface these sediments are in layers and are used to trace geological events in the past.

#### Mid oceanic ridges

The mid-ocean ridges are submarine mountains. They are continuous and are connected to form a single global midoceanic ridge system. They are formed by the tectonic forces acting from within the earth. Mid oceanic ridges are located on the divergent plate boundaries where magma flows through the fissure to form new oceanic crust. They form the longest mountain range in the world extending for more than

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56,000 km long and has a maximum width of 800–1,500 km.

#### Ocean trench

The long, narrow, steep-sided depressions formed by tectonic forces beneath the abyssal plain are called Ocean trenches. Oceanic trenches actually extend 3 to 4 km below the level of the abyssal plain. There are 26 oceanic trenches in the world: 22 in the Pacific Ocean, 3 in the Atlantic Ocean and only one in the Indian Ocean. The Challenger Deep in the Mariana Trench, (10,994 m) in the Pacific Ocean is the deepest part of the earth. A trench forms along the convergent boundary where one plate subducts below the other (Figure 5.9).

#### Island

An island is a landmass surrounded by water on all sides. Islands may be formed on the continental shelf or as oceanic islands. Most of the oceanic islands are volcanic in origin. Group of islands

S. No	Name of the Trench	Location	Depth (in Metres)
1.	Challenger in Mariana Trench	North Pacific Ocean	10,994
2.	Aldrich or Tonga Trench	South Pacific Ocean	10,882
3.	Kurile Trench	North Pacific Ocean	10,554
4.	Tizar Romanche Trench	South Atlantic Ocean	7,761
5.	Sunda Trench	East of Indian Ocean	7,450
	Sauraa Caalaan aam	·	

Major Ocean Trenches of the world

Source: Geology.com



Figure 5.9 Ridges and Trenches of the world

formed by subduction of ocean plate are known as **archipelago**. Islands of Japan form an archipelago.

Marine organisms, the coral polyps colonize the tropical warm water and form islands known as **coral islands**. Lakshadweep Island in Indian Territory is made of corals. Andaman Nicobar islands are of volcanic origin.

#### **Guyots**

Flat topped volcanic hills submerged under the sea water are called **guyots**. It is a part of an underwater chain of volcanic mountains produced by slow plate movement.

#### Seamounts

Seamounts are conical, volcanic hills submerged under ocean water. It does

not reach to the water's surface. It is an isolated rise with an elevation of thousand metres or more from the surrounding sea floor and with a limited summit area. It occupies 4.39 percent of ocean region. Seamounts and guyots are most abundant in the North Pacific Ocean.

#### **Bottom relief of Pacific Ocean**

Continental shelf of the Eastern Pacific Ocean is very narrow due to the presence of trenches while those on the western coast are wide. Continental shelf adjoining coasts of Australia and Indonesia varies in width from 160 to 1,600 km. In the Pacific Ocean, the abyssal plains are very vast. Absence of mid oceanic ridges is the main reason for deep sea plains. Prominent submarine ridges of the Pacific Ocean are **Albatross plateau**, **Cocas ridge** and **Aleutian ridge**. Tasmania



Figure 5.9a Bottom relief of Pacific Ocean

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basin (New Zealand ) and east pacific basin are major basins of Pacific Ocean. Pacific Ocean has about 25,000 islands. There are number of archipelagos both in north and south Pacific Ocean. The Hawaii islands were formed by hotspot. The challenger deep in Mariana trench is the deepest part of Pacific Ocean (10994m).

#### **Bottom relief of Atlantic Ocean**

In the North Atlantic Ocean, extensive continental shelves are found around the shores of Newfoundland (Grand bank) and British islands (Dogger Bank). In the South Atlantic Ocean, a very extensive continental shelf is found between Bahia Blanca and Antarctica (Figure 5.10).

The most striking relief feature which is the 'S' shaped Mid–Atlantic ridge which extends for 16,000 km from Iceland in the north to Bouvet Island in the south. The ridge separates the Eurasian Plate and North American Plate in the North Atlantic, and the African Plate from the South American Plate in the South Atlantic. **Iceland** and **Faroe** are the few peaks of the Mid-Atlantic ridge.

The mid-Atlantic ridge divides the Atlantic Ocean into two major basins, i.e., East and West Atlantic basins. Other basins are Spanish basin, north and south Canary basin, Guinea basin, Brazilian basin and Labrador basin. **Puerto Rico Deep** (8,380 m) is the deepest of all deeps in the Atlantic Ocean. Other deeps are **Romanche Deep** and **South Sandwich Trench.** 

The West Indies is an island archipelago near the main land of North America. British Isles and Newfoundland are famous islands, formed on the continental shelf in the North Atlantic Ocean. Sandwich island, Georgia Island, Falkland and Shetland islands are islands in the South Atlantic Ocean.

#### **Bottom Relief of the Indian Ocean**

The Indian Ocean has continental shelf of varying width. Continental shelf along the coast of Arabian Sea, the Bay of Bengal and Andaman varies in width from 192km to 280km. A variety of coral reefs thrive in the warm tropical water of the Indian Ocean.

Indian Ocean has a continuous central ridge called the Arabic Indian ridge. Other important ridges include the East Indian ridge, West Australian ridge, South Madagascar ridge. Basins of Indian Ocean include Comoro basin, North Australian basin, South Indian basin and the Arab basin (Figure 5.11).

The average depth of the Indian Ocean is 3890m. Sunda deep near Java is the deepest part of this ocean (7450m). Madagascar and Sri Lanka are the most prominent islands present in Indian Ocean. Andaman and Nicobar islands in the Bay of Bengal are the raised part of mountains that are the extension of Arakan Yoma which forms a part of Himalayas. Reunion Island is located on a Hot spot.

#### **5.9 Ocean Temperature**

The measurement of degree of hotness or coldness of ocean water is referred to

as ocean temperature. Temperature is normally measured in the unit of degree Celsius by thermometers. The major source of heat





Figure 5.10 Bottom relief of Atlantic Ocean

energy for ocean water is the radiation from sun. The heating and cooling capacity of water differs significantly from that of land.

## Factors affecting horizontal distribution of ocean temperature

The factors affecting distribution of ocean temperature are latitude,

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Figure 5.11 Bottom relief of Indian Ocean



Figure 5.12 Horizontal Sea surface temperature in July 1997

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prevailing winds, ocean currents and local weather.

- 1. Latitude: The temperature of surface water decreases from equator towards the poles because of the slanting rays of the Sun pole ward.
- 2. Prevailing wind: Direction of the wind affects the distribution of temperature of ocean water. The off shore winds blowing from the land towards ocean or sea raise the temperature of ocean water. Winds blowing from snow covered regions in winter lower the surface temperature. In trade wind belt, the off shore winds initiate upwelling of cooler water from beneath and on shore winds pile up warm water to increase the temperature to certain extent.
- **3. Ocean currents:** Warm currents raise the temperature of the oceans where they flow whereas cold currents lower down the temperature. Gulf Stream (warm current) increases the temperature of the eastern part of North America and the west coast of Europe. Labrador cold current reduces the temperature near north eastern coast of North America.
- 4. Other Factors: Apart from these, some minor factors like submarine ridges, local weather conditions like storms, cyclones, hurricanes, fog, cloudiness, evaporation and condensation also affect the surface temperature of ocean water.

These images show the sea surface temperature in Celsius. The Figure 5.12 shows the sea surface temperature in July and the Figure 5.13 in January. Cold temperatures are shown in purple, moderate temperatures in aquatic green and warm temperatures in yellow to red. Landmass is shown by black colour. The diurnal range and annual range of temperature of ocean is much less than that of the land. The temperature of the sea surface is highest (27°C to 30°C) not near Equator but few degrees north of the Equator. The lowest temperature recorded is -1.9°C near the poles. The maximum and minimum annual temperatures of ocean water are recorded in August and February in the Northern hemisphere and reverse in case of the southern hemisphere.

## 5.9.2 Vertical distribution of temperature in oceans

The uppermost layer of ocean water is warm and well mixed surface layer with average temperature between 20°C and 25°C. The depth of this layer varies according to seasons. On an average this layer extends up to 200 m in tropical region. Beneath this layer lies the thermocline layer. This layer varies in depth between 200 metre to 1000 metre. This layer is unique that the temperature decreases rapidly with increasing depth. Below the thermocline temperature decrease is gradual up to 4000m. Beneath this depth the temperature of ocean water is constant at 4°C (Figure 5.14).

Upper mixed layer	~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~	Mixed layer :(Sea level to 200m
orr	200m	depth) Temperature is uniform
	1,000m	or changing slightly with depth
Deep Bottom Water		Thermocline layer:
		(200 –1000m depth)
		Temperature decreases
	2 500	rapidly with depth.
	2,500m	Deep water layer
		(below 1000m) :
		Temperature decreases slowly.
		Up to 4000 meters the
abyssal plain	5,000m	temperature of ocean water in

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Figure 5.13 Horizontal Sea surface temperature in January 1997

#### 5.10. Salinity of the ocean

**Salinity** is defined as the ratio between the weights of dissolved salts (in grams) per 1000 grams of water. It is expressed as part per thousand (‰) and has no units. Example: 30‰ means 30 grams in 1,000 grams of sea water. The average ocean salinity is 35‰.

**Sources of salt in the ocean:** Sea water is a weak but complex solution made up of many things including mineral salts and decayed biological marine organisms. Most of the ocean salts are derived from weathering and erosion of the earth's crust by the rivers. Some of the ocean salts have been dissolved from rocks and sediments below the sea floor, while others have escaped from the earth's crust through volcanic vents as solid and gaseous materials.

## Factors affecting the salinity of ocean water

The salinity of ocean water depends upon

- a) The rate of evaporation
- b) Amount of precipitation,
- c) Addition of fresh water flow from rivers
- d) Ice in Polar Regions
- e) Upwelling of deep water initiated by prevailing winds and
- f) Mixing of water by ocean currents.

#### **Distribution of salinity**

On an average the salinity decreases from equator towards the poles. The highest salinity is observed between 20° and 40° north latitudes because this zone is characterized by high temperature,

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high evaporation but less rain than the equatorial region.

The marginal areas of the oceans bordering the continents have lower salinity than their interior due to addition of fresh water to the marginal areas through the rivers (Figure 5.15).

Very high salinity is recorded in Lake Von, Turkey (330‰) Dead Sea (238‰) and Great Salt Lake, Utah, USA (220‰).

#### Fact File

Depth of water is measured in the unit 'Fathom'. One fathom is equal to 1.8 metre (six feet)



In partially enclosed seas, their bottom relief and the submarine ridges

with shallow water do not allow free mixing of open sea water. The temperature at the depth of 1800m in the Red Sea is higher than the temperature recorded at the same depth in the Indian Ocean.



Rakingreferstotheuse of a rake, a traditional wooden tool with the long handle and long

pointed wooden toothed spade at the bottom for collecting salt.



#### Activity

Identify regions of high salinity and low salinity.

Compare the salinity of Arabian Sea and Bay of Bengal and find the reason for the same.

Find out the reason for low salinity on east coast of Asia and West coast of North America.(Figure 5.15)

Why does the salinity vary along the west coast of South America?



#### Figure 5.15 Salinity of the Oceans

#### Fact File

Isohaline is an imaginary line drawn to join places having equal salinity.

Salinity of **Dead Sea** is 8.6 times saltier than other oceans. The shore of Dead Sea is 423m below sea level. It has the lowest elevation on land. The sea is 377m deep. The high salt content will make people float on the sea. The high salt content has made the Dead Sea devoid of life in it.



#### 5.11 Ocean movements

Water in the ocean is never in a state of rest. Ocean water is always in motion. It moves horizontally as well as vertically. The movement of ocean water takes place in three different ways as

- 1. Waves
- 2. Tides
- 3. Ocean currents.

#### Waves

The waves are oscillating movements in the ocean water which transfer energy from place to place. They are caused by friction of wind on the surface of water or any other disturbances' on the sea bottom.

#### **Parts of Waves**

- 1. **Crest**: The upper or highest part of a wave is called the crest. (Figure 5.16)
- 2. **Trough**: The lowest part of a wave is called the trough.
- 3. Wave height: The vertical distance between the crest and the trough is known as wave height.
- 4. Wave length: The horizontal distance between two crests or two troughs is known as wave length.

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- 5. **Wave amplitude**: Wave amplitude is one-half of the wave height.
- 6. Fetch: The distance of open water across which the wind can blow without interruption is called fetch.
- 7. **Frequency**: The number of wavelengths that pass a fixed point per unit of time is frequency. Example, 100 waves per sec per cm.
- 8. **Period**: The time taken by one wavelength to pass a fixed point is known as period.
- 9. Velocity: Refers to speed and direction.
- 10. **Steepness**: Steepness of the wave is equal to the height divided by length.(H/L)





#### Tides

The rhythmic rise and fall of the sea water due to gravitational pull of the moon and the sun is called a Tide. Isaac Newton (1642– 1727) was the first person to explain tides scientifically. The rise of seawater towards the land is known as High tide or flow tide. The fall of seawater more towards sea is known as 'Low tide water' or ebb tide. On any day there will be two high tides and two low tides. The highest high tide occurs on full moon day and new moon day. It is known as **spring tide** (Figure 5.17). Spring tide happens when the sun, earth and moon aligned in straight line. The lowest low tide is known as **neap tide**. It happens when the sun, earth and moon are positioned at right angles.



#### Figure 5.17 Tides

The movement of ocean water as a result of tidal action is known as a tidal current. In places of narrow coastal inlet these tidal currents flow rapidly through the mouth with greater height and velocity. For example in the Bay of Fundy, between Nova Scotia and New Brunswick of Canada, the difference between high and low tides is as high as 14m. Ports which utilize the tidal current for entry and exit of ships from the harbour are known as tidal ports. In India, Kolkatta and Kandla are examples of tidal harbours.

#### HOTS

Why does the **highest Tide** occur when the sun, earth and moon are aligned in a straight line?

The Gulf of Cambay and the Gulf of Kutch in Gujarat on the west coast have the maximum tidal range of 11m and 8m with average tidal range of 6.77m and

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5.23m respectively. Tides help to clear the sediments deposited by rivers on their bed and thus prevent siltation of harbours. The energy of the tides is used to generate electricity. Tidal power stations have been set up in UK, Canada, France and Japan. In India Gulf of Khambhat, Gulf of Kutch and Sundarbans have scope for tidal energy production.

#### **Ocean currents**

Large mass of moving water from one part of the ocean to another in a definite direction is called as ocean current. The movement is produced due to earth's rotation, temperature difference of ocean water, salinity, density and some extent due to air pressure and winds. Ocean currents can be classified on the basis of mode of origin, volume and velocity and boundaries.

In the order of velocity ocean currents can be classified as drifts, currents and streams.

**Drifts** are movement of surface water of low velocity influenced by prevailing winds.

**Currents** are movement of oceanic water in definite direction and greater velocity.

**Streams** are larger mass of water moving in a definite direction and much greater velocity than the drifts and currents. Ocean currents are distinguished by the temperature they possess.

When ocean currents originate from equator it is termed as **warm current**. Likewise when a current starts from polar region it is termed as **cold current**.

Vertical circulation of ocean water takes place due to difference in salinity

and temperature between the surface and the water deep below. Upwelling is an oceanographic phenomenon that involves movement of dense, cooler, and usually nutrient-rich water towards the ocean surface, replacing the warmer, usually nutrient-depleted surface water. Down welling is the process of accumulation and sinking of cold high saline water beneath warmer or fresher water.

#### Major ocean currents of the world

In every ocean, there is circulation of ocean water from Equator to pole and from pole to equator. The warm currents from the equator flows over the surface of ocean towards the pole and sink to the bottom of the ocean floor in the higher latitudes due to high density and flow towards the equator to complete the circulation. This large scale circulation is known as **gyre**. The gyre circulates is clockwise in the northern hemisphere and anti-clockwise in the southern hemisphere.

#### a) Ocean currents of the Pacific Ocean

#### 1. North Equatorial current.

North equatorial current originates from Revilla Gigedo island west of Mexico and flows towards the Philippines Island covering a distance of about 12,000 km from east west. It is a warm current. It derives from its water from the Californian current and the South east Monsoon drift which flows north along the Mexican coast. The volume of water increases from east to west as many small currents join it from right. It gets divided into two and the northern branch joins the Kuroshio Current and the southern

World -Ocean currents 150° 900 1200 1200 900 60° 300 300 600 150° -80° 80º -60 Berling in NAtlant N. Pacific C w York 40° California North North Atlantic Pacific Gyre Gyre 200-N Equatorial C N. Equatorial C. N. Equatoriat C S Equatorial C S. Equatorial C. S. Equatorial C. Walvis Bay 200 200-South Pacific Gyre South Indian Jela Durban Atlantic Ocean Gyre -400 40% Gyre 4 West Wind West Wind Drift East Wind Drift -600 60 East Wind Drift 80 120<sup>0</sup> 60 1200 150 Cold Curr Warm Current

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branch abruptly turns and forms the Pacific counter current.

#### 2. South equatorial current.

South equatorial current is originated due the action of the trade winds from east to west. It is a warm current. It extends for about 13,600km from east to west. It is stronger than the North equatorial current. It is further divided into many branches due to the presence of many islands and uneven surface topography.

#### 3. Kuroshio current (Black Tide)

It is a warm ocean current flowing in north easterly direction up to 30° N latitude and it carries warm water off the Formosa coast. It flows towards north and meets Oyashio cold current off the Kuril Islands. It is also called as **Japan current**.

#### 4. Oyashio Current( Parental Tide)

It originates from the Bering Strait and flows towards south carrying cold water. It is a cold current. It meets with Kuroshio warm current and Aleutian current.

#### 5. Californian Current.

Californian current is flowing towards south along the west coast of U.S.A between 23° N and 48° N latitudes. It is cold current which exhibits great amount of up welled water. When it enters the region of Trade winds, it is deflected to the right and joins the equatorial current.

#### 6. Peru Current.

Peru Current is perhaps the best studied ocean current of the Pacific Ocean. Alexander Von Humboldt in 1802 noted the details of the Peru Current. Hence, it is also known

as **Humboldt Current**. It is a cold current. It is flowing along the west coast of South America carrying cold water from northerly deflection of the Sub-Antarctica water moving in 40° S.

#### 7. El Nino or Counter current.

It is a warm counter ocean current of the pacific equatorial waters flowing south ward at 400 m depth to a distance about 180 km.

#### 8. West Wind Drift.

It is an easterly moving drift in the Pacific Ocean extending from Tasmania to the South American coast. It is a cold current. The speed of the drift is greater under the influence of Roaring Forties. It splits into two branches and one moves south around the Cape Horn into the Atlantic Ocean and the Other one moves northward along the Peruvian coast due to deflection and joins the Peru Current.

#### b) Currents of the Atlantic Ocean

#### 1. North equatorial current.

North equatorial current is flowing from east to west. It is a warm current. It is situated between  $5^{\circ}$  N –  $20^{\circ}$  N latitudes. After leaving the west coast of Africa, it attains its main characteristics. When it reaches the east coast of South America, it splits into two branches and one branch called Antilles current is moving along the coast of West Indies and other branch is diverted into the Caribbean sea.

#### 2. South Equatorial current.

It is flowing south of equator within  $0^{\circ}$  S –  $12^{\circ}$  S latitude in between the

coast of Africa and South America. It is a warm current. It is a northern continuation of Benguela current. It is stronger than the North equatorial ocean current. It is caused by the action of Trade winds.

# CASE STUDY

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#### The Sargasso Sea – Sea with landless border

The Sargasso Sea occupies about two thirds of the North Atlantic Ocean, stretching seven hundred miles wide and two thousand miles long. The only "sea" with absolutely no land around it, the Sargasso Sea got its name from common brown seaweed called Sargassum that floats in vast mats in its waters. The Sargasso Sea is surrounded only by ocean currents. It lies within the Northern Atlantic Subtropical Gyre. The Gulf Stream establishes the Sargasso Sea's western boundary, while the Sea is further defined to the north by the North Atlantic Current, to the east by the Canary Current, and to the south by the North Atlantic Equatorial Current. Since this area is defined by boundary currents, its borders are dynamic.



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#### 3. Gulf Stream.

Gulf Stream starts from the Gulf of Mexico and carries warm waters into the colder latitudes. It is a warm current. It bends with the coastline up to 40<sup>th</sup> parallel after which the direction is almost to the east, due to the force and the direction of the westerlies and the deflective force of the earth. It joins the labrador cold current near New Found land, Canada after passing through the strait of Florida. The Gulf Stream was discovered by Ponce de Leon in 1513.

#### 4. Canaries Current.

The ocean current flowing along the Western coast of North Africa between Maderia and Cape verde is known as the Canaries Current. It is a cold current. It is flowing towards south and merging with the North equatorial current.

#### 5. Labrador Current.

In the north Atlantic, a cold current flows from the Baffin Bay and Davis Strait towards south. It brings cold waters from polar zone and moves along the coast of green land.

#### 6. Benguela current.

It is a cold current flowing northward along the western coast of Africa is known as the Benguela current. It carries cold waters from sub-Antarctica surface water and mixes with south equatorial current.

#### C) Currents of the Indian Ocean

The south Indian gyre is formed by south equatorial current, Madagascar current west wind drift and west Australian current. To the north of equator the currents in the Arabian Sea and Bay of Bengal flow in the clockwise direction as southwest monsoon drift and in the anti-clockwise direction as northeast monsoon drift due to the influence of monsoon winds.

The Antarctic circumpolar current flows between 40° S to 60° S latitude. It flows from west to east influenced by the westerly and circles around entire Antarctica. There is a counter west ward current within this circum polar current.

#### d) Currents of the Southern ocean

The southern ocean surrounds the continent of Antarctica. The large oceans, the pacific, the Atlantic and the Indian Ocean merge into this circumglobal zone of water to their south. The movement of water in the southern ocean is in one sense a relatively simple, generally west-east circumpolar drift caused under the influence of northwesterly winds. This general flow sends offshoots to the three major oceans to its north. The Peru or Humboldt Current in the Pacific Ocean, the Falkland Current and the Benguela Current in the Atlantic Ocean and the West Australian Current in the Indian Ocean receive a part of their cold waters from the Southern Ocean. Besides the surface currents, there is also a very complex system of subsurface currents between the southern Ocean and the oceans to its north.



Generally the water moves from this ocean towards the equator on the surface and at great depths but at in remediate depth, there

is a movement of water from the equatorial areas towards the Southern Ocean.

S. No.	World's Fishing banks	Confluence of ocean currents
1.	The Grand bank (Atlantic Ocean, New foundland)	Gulf Stream and Labrador current
2.	The Agulhas bank (Atlantic Ocean, South west Africa)	Benguela cold current and Agulhas warm current
3.	The Dogger bank (Atlantic Ocean, North east of N.A)	North Atlantic drift and canary cold current
4.	The Reed bank (South China Sea, Pacific Ocean)	Kuroshio Warm current and Oyashio Cold Current
5.	The Pedro bank (India Ocean)	South Equatorial warm current and W. Australian cold current

#### The significance of Ocean Currents

- 1. Ocean currents play an important role in the earth's climate. They distribute energy and nutrients within the ocean.
- 2. Fog is formed where warm current and cold current meet. For example, when the Gulf Stream and Labrador Current meet near New Found land one of the densest fogs is formed.
- 3. The warm ocean current increases the temperature of an area where it flows to and Cold Ocean current decreases the temperature of the area.
- 4. The warm current brings heavy rainfall when the wind blows over it becomes warm while the cold current brings drought when the wind blows over it becomes cold and dry. For example, the wind blowing over the Peru Current is cold and dry causing the formation of the Atacama Desert located on the west coast of Peru.
- 5. It regulates the global temperature. It gives free navigation. The Gulf Stream keeps ports & harbours of Russia and Scandinavia navigable throughout the year. The Kuroshio Current makes ports on Japan navigable during winter.

- 6. It distributes minerals and pollution added to it becomes highly diluted and later negligible.
- 7. It helps in growth of juveniles of certain fish and its distribution to other countries from its place of origin. Some up welling and down welling are due to currents which bring minerals to photic zone used by phytoplankton. Major fishing grounds are located in the zones where cold current and warm current meet.

#### **El Nino**

El Nino is a phenomenon that occurs in the equatorial Pacific Ocean characterized by a positive sea surface temperature departure from normal (1971-2000 base period) in the region lying within the latitude 5°N to 5°S and longitudes 120° W to 170°W. This phenomenon occurs every two to seven years (Figure 5.19).

#### El Nino happens when

• Sea surface temperature increases between the central and eastern equatorial Pacific Ocean between the country Ecuador and the International Date Line

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Figure 5.19 Wind circulation during Normal and El Nino Conditions

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- The increase in temperature is sustained for a period of eighteen months to Two years.
- The temperature increase is up to 30 m beneath the ocean surface.
- When there is a modified vertical air circulation above the Pacific Ocean

#### **Global influence of El Nino**

El Nino effect is experienced at Global level. The change in air circulation affects the economy of different countries also. Global weather patterns are altered to such an extent that they affect eco system, agriculture, tropical cyclone, drought, forest fire, floods and flood related health hazards. El Nino influences the jet streams. Due to this phenomenon California experiences heavy rainfall, northern Europe experiences dry winter, Southern Europe experiences mild wet winters, there are less number of cyclones in Sea of Japan, and heavy rain in East Africa. South NO YOU KNOWP

InternationalResearchInstituteClimatePredictionCentrepredicts and forecasts

El Nino occurrences. Scientists are in the opinion that El Nino can cause Global Warming and it also increases the frequency of El Nino occurrence.

East Asia experiences severe drought and forest fire. Peru in South America receives heavy rainfall during El Nino.

Increase of temperature in the east Pacific Ocean is correlated with normal monsoon conditions in India while the increase of temperature in the central Pacific has high correlation with drought conditions in India. When temperature increases further to the west it suppresses the Indian Monsoon.

Normal Situation	El Nino Situation
Near equator the water of the Pacific	Near equator the warm water in the
Ocean is warmer in the western side	Pacific Ocean extends from western
and cooler in the eastern side due to	side to eastern side suppressing the
upwelling of the cold current.	upwelling of the cold water.
Air (Walker) circulation is dominant	Air (Walker) circulation is dominant in
in the western Pacific Ocean. The	the eastern part of Pacific Ocean. The
air ascends in the western side and	air ascends in the warm eastern Pacific
descends over the cooler eastern side	Ocean.
Heavy rain is experienced in the	Heavy rain is experienced in the
western warmer region and dry	eastern warmer region and dry
conditions prevail in the cooler region.	condition prevails in the western part.
The Southeast Asia and Australia receive heavy rain on normal years.	Southeast Asia and Australia experience dry weather conditions.
West coast of South America experiences dry weather.	West coast of South America receives heavy rainfall.

#### **Fact File**

Peruvian fishermen named the weather phenomenon El Nino meaning 'little boy' or 'New born Christ' and La Nina meaning 'Little girl' as the phenomenon was first noticed during Christmas time.

#### La Nina

La Nina is just the opposite to the condition of El Nino. When trade winds are strong, colder water up wells on the East Pacific Ocean, walker air circulation is confined to the west Pacific, wet condition in Southeast Asia and dry weather in South America is observed.

The difference in the atmospheric pressure between the west and east tropical Southern Pacific Ocean is referred to as Southern Oscillation. Meteorologists have established a close inter link between Southern Oscillation and occurrences of El Nino and La Nina events. The acronym **'ENSO'(El Nino Southern Oscillation)** is often used to study both the phenomena.

# GLOSSARY

- 1. Abyssal plains: An extremely large, flat, under water plain on the deep ocean floor.
- 2. Continental rise: is area between the continental slope and the sea floor.
- **3.** Exclusive Economic Zone (EEZ): extends from the base line to a maximum of 200 nautical miles (370.4 km).
- **4. Isthmus:** A narrow steep of land that connects two large land masses and separates two bodies of water.
- 5. Hot spot: An area is the mantle from where rocks melt and magma rises through circular to form volcano.
- **6. Permafrost:** is the condition prevailing when water freezes above and below the ground, (including rock or soil) for more than two consecutive years
- 7 **Trace elements:** A chemical element present in minute amount in a particular sample or environment.
- 8. Isohaline: is an imaginary line drawn to join places having equal salinity
- 9. Swell: is a type of wind-generated waves that is not affected by the local wind.
- **10. Reservoir:** A large lake use as a source of water supply

Eva	luation	In stand	c. Planetary winds	
I. Choose the correct		225/22	d. Revolution of earth	
ans	wer		9. ——is a warm current	
1.	River Ganga has its		a. Labrador b. Gulf stream	
	source from ——	727288	c. Oyashio d. Circum polar drift	
	a. Glacier	b. Spring	10. The only sea surrounded by water all	
	c. a Lake	d. Acquifer	sides is ———	
2.	The permeable rock	ts that can hold	a. The Dead Sea	
	water and allow wate	r to pass through	b. The Sargasso Sea	
	them are called	L. Catanata Janana	c. The South China Sea	
	a. Groundwater	d. A quifore	d. The Aral Sea	
2	C. ROCK	u. Aquilers	II. Very short answer	
5.	3. An —— is ice floating in open water that has broken off from glaciers or			
	ice shelf.	8	11. Define Permairost.	
	a. Ice shelf	b. Ice quake	12. Differentiate High Tide from Low Tide.	
	c. Iceberg	d. Sea ice	13. Define Contiguous Zone.	
4.	The ——Ocean is th	e youngest ocean.	14. Why is the Dead Sea called so?	
	a. Indian	b. Southern	15. How is a tide different from an ocean	
	c. Arctic	d. Atlantic	current	
5.	Mid oceanic ridges a	re located on the	III. Short answer	
	plate boundari	es	16. Write a short note on Exclusive	
	a. Divergent	b. Convergent	Economic Zone.	
	c. Transform	d. Subducted	17. Distinguish between sea mounts and	
6.	The temperature of	the sea surface	guyots.	
	is highest not near	Equator but few	18. Write briefly about the Abyssal plair	
	a South	h South cost	19. List the factors affecting salinity of a	
	a. South	d North	place.	
7	On the confluence of	f Gulf stream and	20. Write about the significance of ocean	
7.	Labrador current t	he fishing bank	currents.	
	found is ——	0	IV. Detailed answer	
	a. Dogger bank	b. Grand bank	1 Describe the relief of the accord with	
	c. Reed bank	d. Pedro bank	diagram.	
8.	<ol> <li>Tides are caused by ———</li> <li>a. Rotation of the earth</li> </ol>		21 Explain the factors affecting the	
			horizontal distribution of ocean	
	b. Gravitational pull	of moon and sun	temperature.	
		134	4	

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- 22. Draw the ocean currents of North Atlantic Ocean and bring out their influence on climate in North America and Europe.
- 23. Describe El Nino and its influence on climate.

#### **V. Practice**

- 1. Prepare a diorama of the relief of ocean using available materials and present it in the class.
- 2. Prepare a working model of warm and cold currents of the world and present it in the class.
- 3. Make a model of relief of the Indian Ocean and explain to the class.



- 1. Oceanography S. Lal
- 2. Oceanography for Geographers, R.C. Sharma and M.Vatal

- 3. Oceanography Savindra Singh
- 4. Oceanography Tamil version Subbiah

## Internet Resources

http://esminfo.prenhall.com/science/ geoanimations/animations/26\_NinoNina. html

https://en.wikipedia.org/wiki/Southern\_ Ocean

https://oceanservice.noaa.gov/education/ kits/currents/06conveyor2.html

https://www.youtube.com/ watch?v=q65O3qA0-n4

https://www.youtube.com/ watch?v=IVnkfvqwDcM

http://india-wris.nrsc.gov.in/wris.html

https://en.wikipedia.org/wiki/Southern\_ Ocean.

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## ICT CORNER

### **Ocean Currents Streams and Storms**

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Observe global Ocean currents and sea surface temperature anomaly.



### Steps

- Use the URL to reach ocean current page.
- Click 'earth' option from the left bottom side of the page. Click 'Play' button to start and stop the animation. Use 'Control' menu to change the date.
- Select 'Ocean' from 'Mode' menu and toggle between 'Currents' and 'Wave' menu from 'Animate' option to observe the global ocean currents.
- Select 'Currents' and 'SST' or 'SSTA' options from 'Overlay' menu to observe temperature anomaly. Roll the globe and zoom in and out to view the animation.



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