PRINCIPLES OF OCEANOGRAPHY

CODE - 18KP1G03

UNIT I

Oceanography: Nature, scope and significance - Hypsometric curve - Relief of ocean floor: Continental shelf, continental slope, deep sea, plains, ocean deeps, Sea mounts, guyots and submarine canyons.

INTRODUCTION

The ocean is a huge body of saltwater that covers about 71 percent of the Earth's surface. The planet has one global ocean, though oceanographers and the nations of the world have divided it into distinct geographic regions: the Pacific, Atlantic, Indian, and Arctic oceans. In recent years, some oceanographers have determined that the seas around Antarctica deserve their own designation: the Southern Ocean.

An estimated 97 percent of the world's water is found in the ocean. Because of this, the ocean has considerable impact on weather, temperature, and the food supply of humans and other organisms. Despite its size and impact on the lives of every organism on Earth, the ocean remains a mystery. More than 80 percent of the ocean has never been mapped, explored, or even seen by humans. A far greater percentage of the surfaces of the moon and the planet Mars have been mapped and studied than our own ocean floor have.

Definition of oceanography

Oceanography, scientific discipline concerned with all aspects of the world's oceans and seas, including their physical and chemical properties, their origin and geologic framework, and the life forms that inhabit the marine environment.

Oceanography is a science that deals with the oceans and includes the delimitation of their extent and depth, the physics and chemistry of their waters, marine biology, and the exploitation of their resources.

Oceanography applies chemistry, geology, meteorology, biology, and other branches of science to the study of the ocean. It is especially important today as climate change, pollution, and other factors are threatening the ocean and its marine life. Oceanography is an interdisciplinary science that involves the study of the entire ocean, from the shallow coastal areas to the deepest trenches. It involves geology, biology, chemistry, and physics.

According to H.A. Marmer: "Oceanography the science of the sea, includes primarily the study of the form and nature of the oceans basins, the characteristics of the water in these basins and the movement to which this water are subject to."

According to J. Proud man: "Oceanography studies the fundamental principles of dynamics and thermo- dynamics in relation to the physical and biological properties of the sea water."

Oceanography, also known as **oceanology**, is the study of the physical and biological aspects of the ocean. It is an important Earth science, which covers a wide range of topics, including ecosystem dynamics; ocean currents, waves, and geophysical fluid dynamics; plate tectonics and the geology of the sea floor; and fluxes of various chemical substances and physical properties within the ocean and across its boundaries. These diverse topics reflect multiple disciplines that oceanographers blend to further knowledge of the World Ocean and understandingofprocesseswithin astronomy, biology, chemistry, climatology, geography, geolog y, hydrology, meteorology and physics.

Nature of oceanography

1. Dynamic
2. Descriptive
3. Interdisciplinary

Oceanography is the study of the physical, chemical, and biological features of the ocean, including the ocean's ancient history, its current condition, and its future. In a time when the ocean is threatened by climate change and pollution, coastlines are eroding, and entire species of marine life are at risk of extinction, the role of oceanographers may be more important now than it has ever been.

Indeed, one of the most critical branches of oceanography today is known as biological oceanography. It is the study of the ocean's plants and animals and their interactions with the marine environment. But oceanography is not just about study and research. It is also about using that information to help leaders make smart choices about policies that affect ocean health. Lessons learned through oceanography affect the ways humans use the sea for transportation, food, energy, water, and much more.

Of course, oceanography covers more than the living organisms in the sea. A branch of oceanography called geological oceanography focuses on the formation of the seafloor and how it changes over time. Geological oceanographers are starting to use special GPS technology to map the seafloor and other underwater features. This research can provide critical information, such as seismic activity, that could lead to more accurate earthquake and tsunami prediction.

In addition to biological and geological oceanography, there are two other main branches of sea science. One is physical oceanography, the study of the relationships between the seafloor, the coastline, and the atmosphere. The other is chemical oceanography, the study of the chemical composition of seawater and how it is affected by weather, human activities, and other factors.

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Marine geology focuses on the structure, features, and evolution of the ocean basins. Marine ecology, also called biological oceanography, involves the study of the plants and animals of the sea, including life cycles and food production.

Oceanography is the sum of these several branches. Oceanographic research entails the sampling of seawater and marine life for close study, the remote sensing of oceanic processes with aircraft and Earth orbiting satellites, and the exploration of the seafloor by means of deep sea drilling and seismic profiling of the terrestrial crust below the ocean bottom.

Scope of oceanography

1. Study of ocean and sea
2. Aquatic life
3. Human settlement
4. Defense and security
5. International trade
6. Mineral extraction
7. Tourism development
8. Oceanic hazards
9. Hydrological cycle
10. Fishing
11. Coastal environment
12. Ocean water movement
13. Heat budget
14. Wind system
15. Climate change

This branch of climatology is concerned with the scope of the oceanographical knowledge to practical problems of the oceans.

It analyses the relationship of oceanography to other sciences.

Applied oceanography can be of great help for many problems related to coastal industries, shore communities (settlements), military and naval establishments, ports and harbours, and other ocean problems.

The main purpose is to find out the ways and means to make use of our knowledge for the betterment of human life and the life in the oceans.

Data derived from the work of Oceanographers is used in marine engineering, in the design and building of oil platforms, ships, harbors, and other structures that allow us to use the ocean safely.

Oceanographic data management is the discipline ensuring that oceanographic data both past and present are available to researchers.

Oceanography has moved into the spotlight of urgent social concern, because of the oceans' impact on issues such as global climate change, biodiversity, and even national security. This new volume points to improved partnerships between ocean scientists, federal agencies, and the oceanographic institutions as the key to understanding the oceans and their effects on our lives.

The need of study of various oceans is present in our world that is why the demand of **oceanographers** is increasing day after day. The **oceanographers** study the ocean waters and their effects on sea life, the weather and many others. The need of study of various oceans is present in our world that is why the demand of oceanographers is increasing day after day. The oceanographers study the ocean waters and their effects on sea life, the weather and many others. The oceanographers can work in the fields ranging from conservation to the oil industry. Job duties vary depending on the specialization in this field of courses. A good place for an eligible oceanographer is to start from bachelor's degree and relevant work experience in particular. The demand for jobs arises from the need for environmental protection and water management.

Significance of Oceanography

Biodiversity

Mangrove, Salt Marshes, Sea grass, Beds and Coral Reefs or just a few of the ocean environment support a large number of different species of organism have a high biodiversity. Estuaries are brackish water system that empty there water into the world oceans, and support many, many fishes and many other living organisms. Along with the coral reefs, estuaries sustain 75% of all commercial fishes and shellfish during some point of their life cycles. Mangroves not only act as nurseries for commercially important marine species, they also act as a filtration system for coastal water.

Natural Resources

The floor of ocean habitat is not as well-known as coral reefs or coastal areas, but it is very important to all other organisms that live on the bottom of the oceans. The continental shells and ocean floor is store house of many important minerals including natural gas oil.

Transportation

The oceans are not only important to sustain life, but also help in the moving of materials that we use more than 95% of U.S. foreign trade passes through U.S ports and Harbours. Without barges, commercial ships transportation of goods from place to place would be much more difficult and expensive. Cities which have good natural harbours have always had an advantage, and even today are some of the largest cities in the world.

Climate and Weather

Warm ocean water provides the energy to fuel storm system that provides fresh water which is necessary to land dwelling organisms. The oceans effect climate and global weather as the air passes over the warm water, rises due to warming. When it is cold condensation of water take place and create rainfall. If the air passes or a cooler water, it becomes cools and sinks. Air removes from high to low pressure areas. Warm air moves with the Gulf Stream toward the northern Europe. Thus, the winters and northern Europe are not intolerable.

Economy

The ocean is also important to our economy. One of every six U.S. jobs is marine-related, and more than 66% of the world populations lives within 100 km of the coastline. Real state, occupation, recreation and many other services associated with the ocean generate 54 billion dollars in goods and services per year. Revenue related to the ocean is produced throw, kelp, food, recreation, and moaning, shipping and biomedical products.

Source of trade Routes

The trade between different countries confined to the oceans and it determined different routes which joining different countries

Source of food Supply

Oceans are most important source of food supply including red algae, sponges, fish's etc. sponges and cartilage from the sharks or being used in medicine to help fight the battle against cancer.

Source of Salt

Oceans are major source of salt which is use for different purposes. And which is necessary to many marine organisms.

Source of Water vapour

Another most important function of oceans is the formation of water vapours.

- **Political importance of oceans.**
- **Source of ecosystem**
- **Strategic importance**
- **Source of atmospheric circulation**

Importance of Oceanography

1. Throughout history humans have been directly or indirectly influenced by the oceans.
2. Ocean waters serve as a source of food and valuable minerals.
3. Ocean waters serve as vast highways for transport and commerce
4. Increasingly, people are turning to the oceans for their food supply either by direct consumption or indirectly by harvesting fish that is then processed for livestock feed.
5. It has been estimated that as much as 10% of human protein intake comes from the oceans.
6. Other biological products of the oceans are also commercially used.
7. For example, pearls taken from oysters are used in jewellery, and shells and coral have been widely used as a source of building material.
8. Ocean water is processed to extract commercially valuable minerals such as salt, bromine, and magnesium.
9. Extensive deposits of petroleum-bearing sands.

10. On the deep ocean floor manganese nodules, formed by the precipitation of manganese oxides and other metallic salts around a nucleus of rock or shell, represent a potentially rich and extensive resource.
11. Ocean water itself could prove to be a limitless source of energy in the event that nuclear fusion reactors are developed, since the oceans contain great quantities of deuterium.
12. The oceans also have become more important for recreational use, as each year more people are attracted to the sports of swimming, fishing, scuba diving, boating, and water skiing.

Oceanography is **significant** to geography because the fields have overlapped in terms of navigation, mapping and the physical and biological study of Earth's environment.

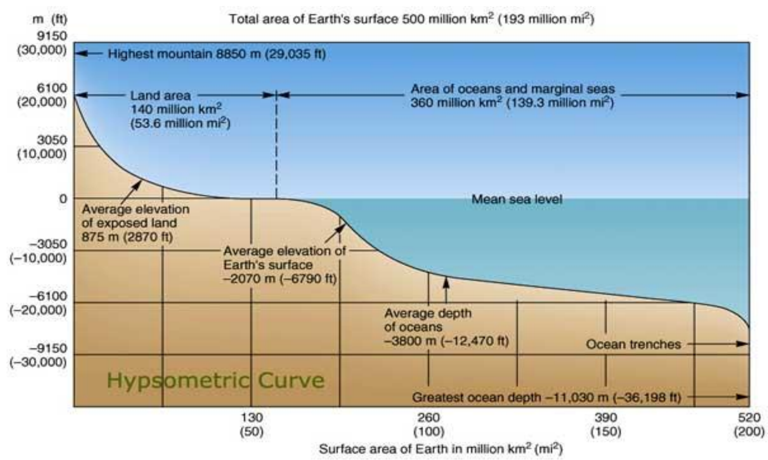
Oceanography in the Next Decade

- Pressing marine research problems and offers recommendations for how they may be solved.
- Recent discoveries and research needs in four sub disciplines - physical, chemical, geological, and biological.
- Coastal oceanography, which is important because of growing coastal populations.
- The infrastructure of oceanography, with a wealth of information about human, equipment, and financial resources.
- A blueprint for more productive partnerships between academic oceanographers and federal agencies.
- This comprehensive look at challenges and opportunities in oceanography will be important to researchers, faculty, and students in the field as well as federal policymakers, research administrators, and environmental professionals.

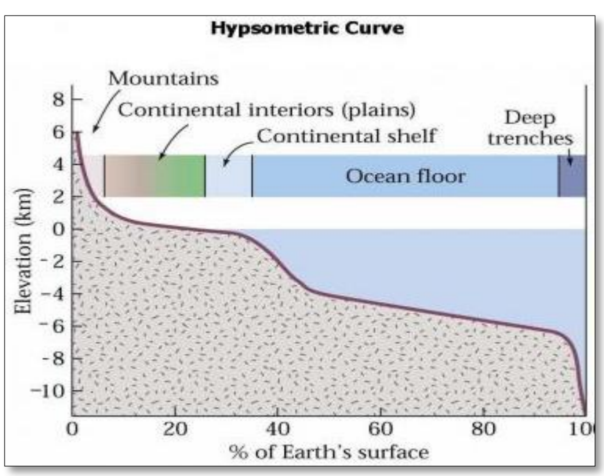
HYPSOMETRIC CURVE

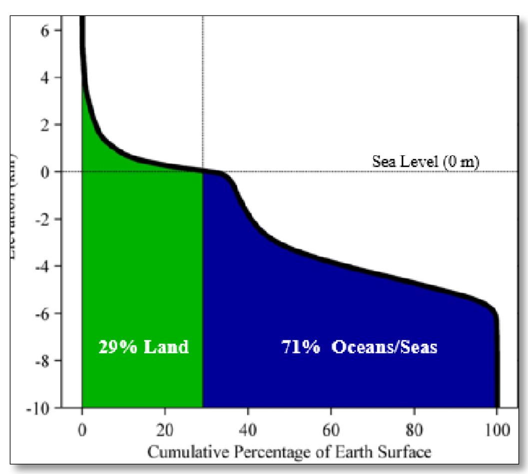
Hypsometric curve also called Hypsographic **Curve**, cumulative height frequency **curve** for the Earth's surface or some part thereof. A **hypsometric curve** is essentially a **graph** that shows the proportion of land area that exists at various elevations by plotting relative area against relative height.

A **hypsometric curve** is a graphical representation showing on the abscissa the basin areas situated above various altitudes. If necessary, the basin areas can be given as percentages of the total. The **hypsometric curve** has also been termed the drainage basin relief graph.



This refers to a graphical representation used to show the share of the earth's land area that is at various heights above or below sea level. The curve suggests that most of the earth's land area is located at predominantly two levels. In contrast to the normal distribution curve, the vast majority of the earth's land area is a little over sea level, while a little less, but still considerable, proportion of the remaining land is located at about 5,000 m below sea level.





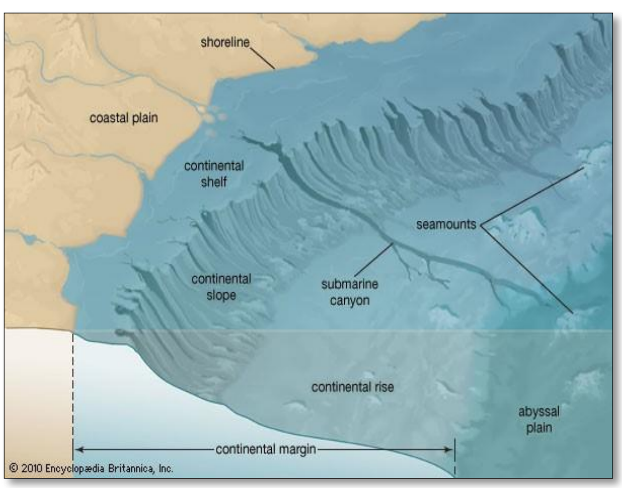
The hypsometric curve is the graph given here. This curve is typically used to demonstrate that the Earth has two types of crust, continental and oceanic. The curve shows the percentage of the Earth's surface above any elevation. The horizontal axis, labeled "% of Earth's surface," gives the percentage while the vertical axis shows elevation above or below sea level. The hypsometric curve has been attributed to the significant difference in the densities of the materials that make up the continents and the sea bed.

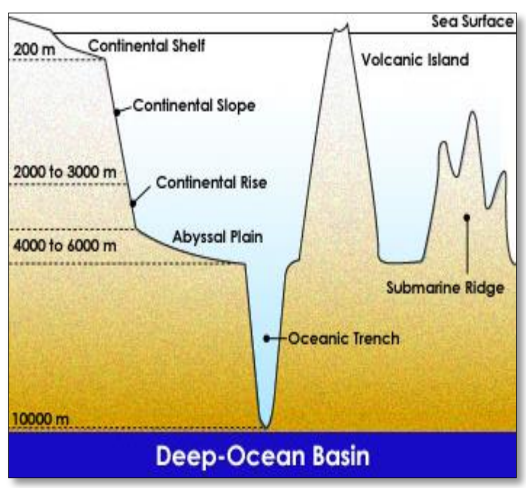
RELIEF OF OCEAN FLOOR

The relief features of the oceans are quite different from the continental features because the Oceanic crust is less than 60-70- million years old whereas continental features are of Proterozoic age (Over 1 Billion years old).

Oceanic Topography

The Oceanic relief features are in the form of mountains, basins, plateaus, ridges, canyons and trenches beneath the ocean water. These forms are called Submarine Relief. The ocean relief can be divided into various parts such as Continental Shelf, Continental Slope, Continental Rise or Foot, Deep Ocean basins, Abyssal plains & Abyssal Hills, Oceanic Trenches, Seamounts and Guyots.





Significance of Oceanic Relief

1. It controls the motion of sea water.

2. It influences the oceanic movement in the form of currents.

3. It helps in the navigation and fishing.

CONTINENAL SHELF

- The Continental marginal areas submerged under oceanic water with average water depth of 100 fathoms (1 fathom – 6 feet) and gently sloping (1°-3°) towards the sea are called Continental Shelves.
- Continental Shelf is the extended margin of each continent occupied by relatively shallow seas and gulfs.
- It is the shallowest part of the ocean showing an average gradient of 1° or even less.
- The shelf typically ends at a very steep slope, called the shelf break.
- The continental shelves are covered with variable thicknesses of sediments brought down by rivers, glaciers, wind, from the land and distributed by waves and currents.
- Massive sedimentary deposits received over a long time by the continental shelves, become the source of fossil fuels.

Economic significance - Continental shelf

- Most commercial exploitation from the sea, such as metallic-ore, non-**metallic ore, and hydrocarbon extraction,** takes place on the continental shelf.
- The shallowness enables sunlight to penetrate through the water, which encourages the growth of minute plants and other microscopic organisms – planktons (food for fishes). Thus continental shelves are the **richest fishing grounds** in the world. E.g. Grand Banks of Newfoundland, the North Sea and the Sunda shelf.
- Their limited depth and gentle slope increase the height of tides. Since ships can only enter and leave port on the tide, most of the World's **greatest seaports** including Southampton, London, Hong Kong, Singapore and Rotterdam are located on Continental Shelves.

CONTINENTAL SLOPE

- The zone of steep slope extending from the Continental shelf to the deep sea plains is called **Continental Slope** which varies from 5°to more than 60° at different places.
- At the edge of the Continental Shelf, there is an abrupt change of gradient, forming the **Continental Slope**.
- The Continental Slope connects the continental shelf and the ocean basins.
- The most significant reliefs on the continental slopes are found between 20°N and 50°N latitudes and on 80°N and 70°S latitudes.
- Generally, the steep gradient of the continental slopes does not allow any marine deposits.
- It begins where the bottom of the continental shelf sharply drops off into a steep slope.
- The **gradient** of the slope region varies between **2-5°.**
- The depth of the slope region varies between **200** and **3,000 m**.
- The slope boundary indicates the end of the continents.
- **Submarine Canyons** and **trenches** are significant reliefs in this region, generally transverse to the continental shelves and the coasts.

DEEP SEA PLAIN

- Deep Sea Plain is the flat and rolling submarine plain lying two or three miles below sea level, and covering **two-thirds of the ocean floor**, generally termed as **Abyssal Plains**.
- These are **gently sloping** areas of the ocean basins cover 75% of the total area of the ocean to the other.
- These are the flattest and smoothest regions of the world. (Modern sounding services reveal that abyssal plain is not being level and it has extensive submarine plateaux ridges, trenches, guyots basins and oceanic islands)
- The depths vary between 3,000 and 6,000 m.
- These plains are covered with fine-grained sediments like clay and silt.

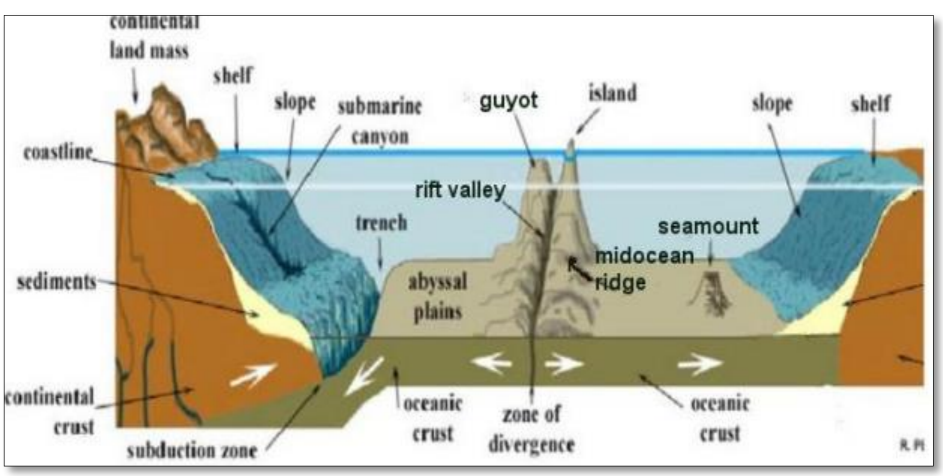
- The submarine ridges with steep side-slopes reach the sea level and even project above the water surface and appear as islands. E.g. Mid Atlantic ridge.

OCEANIC DEEPS OR TRENCHES

- Ocean deeps represent depressions and trenches (reaches depth of 5,000 fathoms) on the ocean floors, are the deepest parts of the ocean basins.
- Ocean deeps are grouped into
- Deeps: very deep but less extensive depressions.
- Trenches: long and narrow linear depressions.

(E.g. Mariana Trench located to the west of Philippines in the North Pacific Ocean is the deepest trench (11,000 metres)).

- These are generally located parallel to the coasts facing mountains and along the islands. They are more often found close to the continents, particularly in the Pacific Ocean.
- The trenches are relatively steep sided, narrow basins. They are some 3-5 km deeper than the surrounding ocean floor.
- They occur at the bases of continental slopes and along island arcs and are associated with active volcanoes and strong earthquakes. That is why they are very significant in the study of plate movements.
- As many as 57 deeps have been explored so far; of which 32 are in the Pacific Ocean; 19 in the Atlantic Ocean and 6 in the Indian Ocean.



MINOR RELIEF FEATURES

Apart from the above mentioned major relief features of the ocean floor, some minor but significant features predominate in different parts of the oceans.

I. MID-OCEANIC RIDGES

- A mid oceanic ridge is composed of two chains of mountains separated by a large depression.
- The mountain ranges can have peaks as high as 2,500 m and some even reach above the ocean's surface.
- Iceland, a part of the mid- Atlantic Ridge, is an example.

II. SEAMOUNT

- It is a mountain with pointed summits, rising from the seafloor that does not reach the surface of the ocean.
- Seamounts are volcanic in origin.
- These can be 3,000-4,500 m tall.
- The Emperor seamount, an extension of the Hawaiian Islands in the Pacific Ocean, is a good example.

III. SUBMARINE CANYONS

- These are long, narrow and very deep valleys located on the continental shelves and slopes with vertical walls resembling the continental canyons are called submarine canyons.
- They are sometimes found cutting across the continental shelves and slopes, often extending from the mouths of large rivers.
- Submarine canyons are classified on the morphogenesis as
    - Glacially eroded canyons
    - Non-glacial canyons
    - The Hudson Canyon is the best known canyon in the world.

IV. GUYOTS

- It is a flat topped seamount.
- They show evidences of gradual subsidence through stages to become flat topped submerged mountains.
- It is estimated that more than 10,000 seamounts and guyots exist in the Pacific Ocean alone.

UNIT II

Major Relief features of the Atlantic, Pacific and Indian Ocean floor

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Relief features of Oceans

1. **Pacific Ocean,**
2. **Atlantic Ocean and**
3. **Indian Ocean**

- **The Pacific Ocean**
  - North and Central Pacific
  - West and South-West Pacific
  - South-East Pacific
- **The Atlantic Ocean**
  - Continental Shelf
  - Mid-Atlantic Ridge
  - Seamounts and guyots
  - Trenches
- **The Indian Ocean**
  - Submarine ridges
  - Islands
  - Continental Shelf
  - Trenches
  - Straits
  - Marginal seas

PACIFIC OCEAN

The **Pacific Ocean** is the largest and deepest of Earth's oceanic divisions. It extends from the Arctic Ocean in the north to the Southern Ocean (or, depending on definition, to Antarctica) in the south and is bounded by the continents of Asia and Australia in the west and the Americas in the east.

At 165,250,000 square kilometers (63,800,000 square miles) in area (as defined with an Antarctic southern border), this largest division of the World Ocean—and, in turn, the hydrosphere—covers about 46% of Earth's water surface and about 32% of its total surface area, making it larger than all of Earth's land area combined (148,000,000 square kilometers).

The centers of both the Water Hemisphere and the Western Hemisphere are in the Pacific Ocean. Ocean circulation (caused by the Coriolis effect) subdivides it into two largely independent volumes of water, which meet at the equator: the North(ern) Pacific Ocean and South(ern) Pacific Ocean. The Galápagos and Gilbert Islands, while straddling the equator, are deemed wholly within the South Pacific.

Its mean depth is 4,000 meters (13,000 feet). Challenger Deep in the Mariana Trench, located in the western north Pacific, is the deepest point in the world, reaching a depth of 10,928 meters (35,853 feet). The Pacific also contains the deepest point in the Southern Hemisphere, the Horizon Deep in the Tonga Trench, at 10,823 meters (35,509 feet). The third deepest point on Earth, the Sirena Deep, is also located in the Mariana Trench.

The western Pacific has many major marginal seas, including the South China Sea, the East China Sea, the Sea of Japan, the Sea of Okhotsk, the Philippine Sea, the Coral Sea, and the Tasman Sea.

- Largest and deepest ocean.
- Covers about **one-third** of the earth's surface.
- Average depth is generally around **7,300 metres**.
- Its shape is roughly **triangular** with its apex in the north at the **Bering Strait**.
- Many marginal seas, bays and gulfs occur along its boundaries.
- Nearly 20,000 islands dot this vast ocean.

North and Central Pacific

- Characterized by **maximum depth** and a large number of **deeps, trenches and islands.**

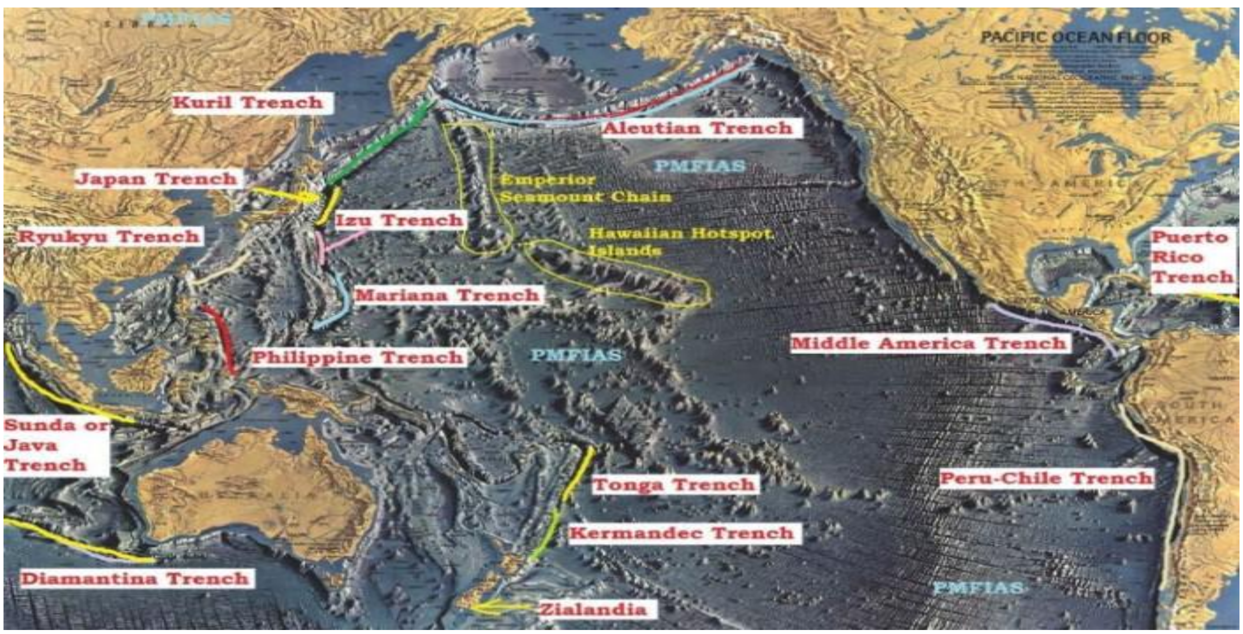
- Some well-known trenches are **Aleutian** and **Kuril**.
- There are also a large number of **seamounts** and **guyots**. [Hawaiian Hotspot]

West and South-West Pacific

- Average depth is about **4,000 m.**
- It is marked by a variety of islands, marginal seas, continental shelves and submarine trenches.
- **Mariana Trench** and **Mindanao Trench** are very deep with a depth of more than 10,000 metres.

South-East Pacific

- This part is conspicuous for the **absence of marginal seas**, and has submarine ridges and plateaus.
- The **Tonga** and **Atacama** trenches are prominent.



Relief: The Pacific basin may conveniently be divided into three major physiographic regions: the eastern, western, and central Pacific regions.

Eastern region

The eastern Pacific region, which extends southward from Alaska to Tierra del Fuego, is relatively narrow and is associated with the American cordilleran system of almost unbroken mountain chains, the coastal ranges of which rise steeply from the western shores of North and South America. The continental shelf, which runs parallel to it, is narrow, while the adjacent continental slope is very steep. Significant oceanic trenches in this region are the Middle America Trench in the North Pacific and the Peru-Chile Trench in the South Pacific.

Western region

The seaward boundary of the western Pacific region is marked by a broken line of oceanic trenches, extending from the Aleutian Trench in the north through the Kuril and Japan trenches and southward to the Tonga and Kermadec trenches, terminating close to the northeast of North Island, New Zealand. Its structure is more complex than that of the eastern region. Characteristically associated with the ocean trenches of the western region are festoons of either peninsulas or islands or both. The islands, which include those of Japan as well as numerous smaller islands, represent the upper parts of mountain systems that rise abruptly from the deep ocean floor. The island clusters of the western Pacific form the boundaries of the several wide and deep continental seas of the region.

Central region

The central Pacific region lies between the boundaries of the eastern and western regions. The largest and the most geologically stable of the structural provinces of the Earth's crust, it is characterized by expansive areas of low relief, lying at a general depth of about 15,000 feet (4,600 metres) below the surface.

Principal ridges and basins

To the east of longitude 150° W, the relief of the ocean floor is considerably less pronounced than it is to the west. In the eastern Pacific the Cocos Ridge extends southwestward from the Central American isthmus to the Galapagos Islands. To the south of the Galapagos lies the Peru Basin, which is separated by the extensive Sala y Gómez Ridge from the Southeast Pacific Basin, which in turn is separated from the Southwest Pacific Basin by the East Pacific Rise and indeterminate Pacific-Antarctic Ridge, which runs from the Sala y Gómez Ridge to Antarctica in the vicinity of 150° W.

Extending southward from the Tasman Basin (between New Zealand and eastern Australia) is the Macquarie Ridge, which forms a major boundary between the deep waters of the Pacific and Indian oceans. The Hawaiian Ridge extends westward from Hawaii to the 180° meridian.

The submerged parts of the series of ridges that are capped by the island archipelagoes of the western Pacific are continuous and are to be found at depths of less than about 2,000 feet (610 metres). These ridges include the Aleutian Ridge in the northwestern Pacific; the series of ridges extending southward through the Kuril, Bonin, and Mariana island groups, and the archipelagoes of Yap and Palau; those extending eastward from New Guinea, including the Bismarck Archipelago and the Solomon and Santa Cruz island chains; and, finally, the ridges extending southward, from which rise the Samoa, Tonga, Kermadec, and Chatham island groups, as well as Macquarie Island.

Landmasses and islands

The Pacific Ocean has most of the islands in the world. There are about 25,000 islands in the Pacific Ocean. The islands entirely within the Pacific Ocean can be divided into three main groups known as Micronesia, Melanesia and Polynesia. Micronesia, which lies north of the equator and west of the International Date Line, includes the Mariana Islands in the northwest, the Caroline Islands in the center, the Marshall Islands to the east and the islands of Kiribati in the southeast.

Melanesia, to the southwest, includes New Guinea, the world's second largest island after Greenland and by far the largest of the Pacific islands. The other main Melanesian groups from north to south are the Bismarck Archipelago, the Solomon Islands, Santa Cruz, Vanuatu, Fiji and New Caledonia.

The largest area, Polynesia, stretching from Hawaii in the north to New Zealand in the south, also encompasses Tuvalu, Tokelau, Samoa, Tonga and the Kermadec Islands to the west, the Cook Islands, Society Islands and Austral Islands in the center, and the Marquesas Islands, Tuamotu, Mangareva Islands, and Easter Island to the east.

Islands in the Pacific Ocean are of four basic types: continental islands, high islands, coral reefs and uplifted coral platforms. Continental islands lie outside the andesite line and include New Guinea, the islands of New Zealand, and the

Philippines. Some of these islands are structurally associated with nearby continents. High islands are of volcanic origin, and many contain active volcanoes. Among these are Bougainville, Hawaii, and the Solomon Islands.

The coral reefs of the South Pacific are low-lying structures that have built up on basaltic lava flows under the ocean's surface. One of the most dramatic is the Great Barrier Reef off northeastern Australia with chains of reef patches. A second island type formed of coral is the uplifted coral platform, which is usually slightly larger than the low coral islands. Examples include Banaba (formerly Ocean Island) and Makatea in the Tuamotu group of French Polynesia.

The islands of the western region—including the Aleutians, the Kurils, the Ryukyus, Taiwan, the Malay Archipelago (including New Guinea), and New Zealand—are continental in character. Geologically, they consist partly of sedimentary rocks, and their structures are similar to those of the coastal mountain ranges of the adjacent continent.

A geologically important boundary between the continental, or “high,” islands and the numerous truly oceanic, or “low,” islands of the Pacific is the Andesite Line, a region of intense volcanic and seismic activity. In the northern and western Pacific the Andesite Line follows close to seaward the trend of the island arcs from the Aleutians southward to the Yap and Palau arcs, thence eastward through the Bismarck, Solomon, and Santa Cruz archipelagoes, and thence southward through the Samoa, Tonga, and Chatham groups and Macquarie Island to Antarctica. Islands to the west of the line are rich in andesite, a type of intrusive igneous rock; islands to the east (oceanic side) of it are essentially of basalt, an extrusive igneous rock.

The numerous oceanic islands of the Pacific are unevenly distributed. They lie, in the main, between the Tropics of Cancer and Capricorn and occur in great numbers in the western Pacific. The northernmost chain of oceanic islands is associated with the Hawaiian Ridge. The Hawaiian archipelago consists of about 2,000 islands, although the term Hawaiian Islands is usually applied to the small group that lies at the eastern end of the archipelago.

The numerous small islands of Micronesia lie mainly north of the Equator and to the west of the 180° meridian. Nearly all are coralline; the principal groups are the Marianas, the Marshalls, the Carolines, Kiribati (Gilbert Islands), and Tuvalu (Ellice Islands).

To the south of Micronesia lies Melanesia, which consists mostly of small coral islands. The region’s physiography is dominated by a group of large continental islands, however, including New Guinea. The principal Melanesian island groups are the Bismarck Archipelago, the Solomons, Vanuatu (New Hebrides), New Caledonia, and Fiji.The immense area of Polynesia includes the Hawaiian Islands, the Phoenix Islands, Samoa, Tonga, the Cook Islands, the Society Islands, Tuamotu, and the Marquesas.

Bottom deposits

Apart from the narrow coastal zone of the eastern region and the broad continental seas of the western region, the Pacific is floored with pelagic (oceanic) material derived from the remains of marine plants and animals that once inhabited the waters lying above. Red or brown radiolarian ooze is found along the zone of the Pacific North Equatorial Current, east of longitude 170° W, and on the floors of some deep Indonesian basins.

A belt of diatom ooze occurs between latitudes 45° and 60° S and across the North Pacific, between Japan and Alaska. Calcareous globigerina ooze occurs in the shallower parts of the South Pacific, the dissolving power of the seawater at great depths being sufficient to dissolve calcareous material to such an extent that these oozes are not generally found at depths in excess of about 15,000 feet (4,600 metres). Silica-containing material, such as radiolarian and diatom ooze, is found at greater depths, but even these siliceous remains are dissolved at very great depths, where the characteristic deposit is red clay. Red clay, which covers no less than half of the Pacific floor, is believed to be formed of colloidal (extremely finely divided) clays derived essentially from the land.

On the abyssal plains, where sediments accumulate slowly, chemical and biological processes lead to the formation of metal-bearing coatings around objects such as the ear bones of fishes. The nodules so formed contain manganese, iron, nickel, copper, cobalt, and traces of other metals such as platinum. They cover large areas of the ocean floor in the Pacific. Similar processes form coatings, called manganese crusts, on the rock surfaces of seamounts.

Among the many different forms of land-derived muds (formed by the erosive action of rivers, tides, and currents) that floor the continental shelves and slopes of the Pacific, the yellow mud of the Yellow Sea is of particular interest. The mud is conveyed to the seabed by the Huang He, which drains a vast area of northern China blanketed with loess, a fine-grained soil.

The Atlantic Ocean

The **Atlantic Ocean** is the second-largest of the world's oceans, with an area of about 106,460,000 km^2 (41,100,000 sq mi). It covers approximately 20 percent of Earth's surface and about 29 percent of its water surface area. It is known to separate the "Old World" from the "New World" in European perception of the World.

The Atlantic Ocean occupies an elongated, S-shaped basin extending longitudinally between Europe and Africa to the east, and the Americas to the west. As one component of the interconnected World Ocean, it is connected in the north to the Arctic Ocean, to the Pacific Ocean in the southwest, the Indian Ocean in the southeast, and the Southern Ocean in the south (other definitions describe the Atlantic as extending southward to Antarctica). The Atlantic Ocean is divided into two parts, by the Equatorial Counter Current, with the North(ern) Atlantic Ocean and the South(ern) Atlantic Ocean at about 8°N.

- The Atlantic is the **second largest** ocean after the Pacific.
- It is roughly **half** the size of the Pacific Ocean.
- It's shape resembles the letter '**S'**.
- In terms of **trade**, it is the most significant of all oceans.

Continental Shelf

- It has prominent continental shelf with varying widths.
- The length of the continental shelf is maximum in Northern Atlantic coasts.
- The largest width occurring off north-east America and north-west Europe.
- Grand banks continental shelf is the most productive continental shelf in the world. [Recall fishing industry in Laurentian Climate]

- The Atlantic Ocean has numerous marginal seas occurring on the shelves, like the Hudson Bay, the Baltic Sea, and the North Sea, and beyond the shelves like the Gulf of Florida (Mexican Gulf).

Mid-Atlantic Ridge

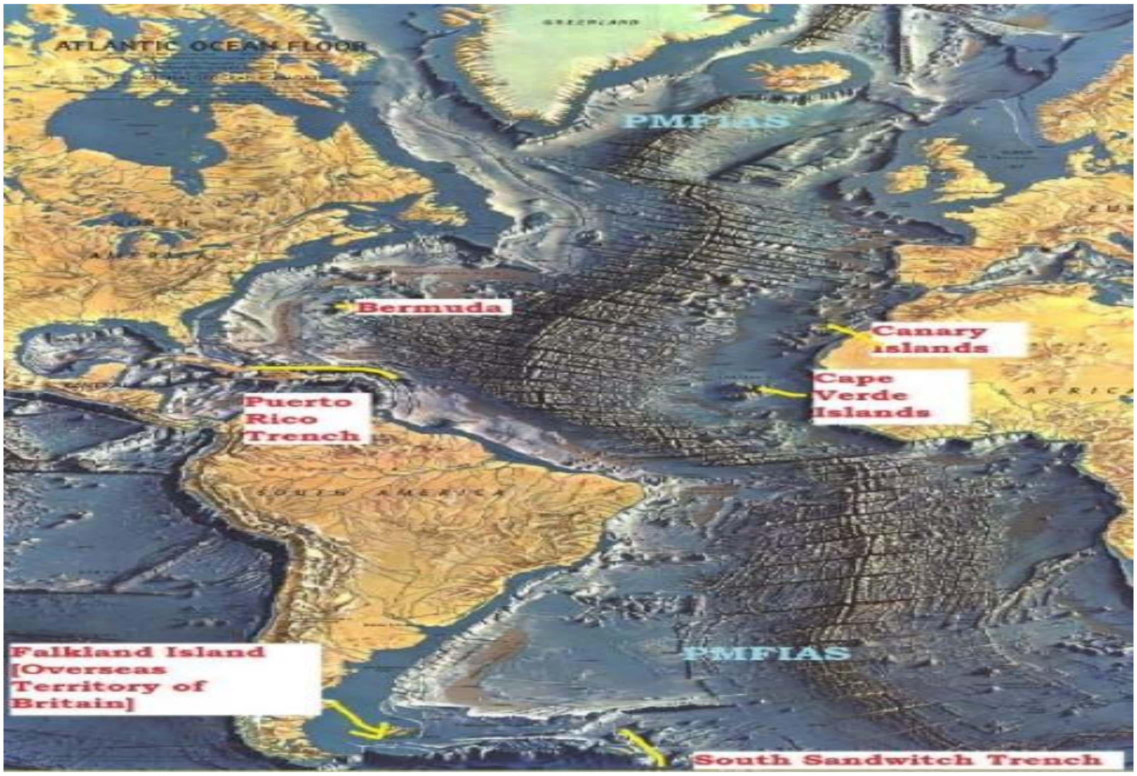
- The most remarkable feature of the Atlantic Ocean is the Mid-Atlantic Ridge which runs from north to the south paralleling the 'S' shape of the ocean.
- The ridge has an average height of 4 km and is about **14,000 km long.**

Seamounts and guyots

- They are present in significant numbers but not as significant as in pacific ocean.
- Several seamounts form islands of the mid-Atlantic. Examples include **Pico Island of Azores, Gape Verde Islands, Canary Islands etc.**.
- Also, there are coral islands like **Bermuda** and volcanic islands like, **St Helena** etc..

Trenches

- Atlantic Ocean **lacks** significant troughs and trenches, which are most characteristic to the Pacific Ocean.
- **North Cayman** and **Puerto Rico** are the two troughs and **Romanche** and **South Sandwich** are the two trenches in the Atlantic Ocean.



Mid-Atlantic Ridge

The MAR divides the Atlantic longitudinally into two-halves, in each of which a series of basins are delimited by secondary, transverse ridges. The MAR reaches above 2,000 m (6,600 ft) along most of its length, but is interrupted by larger transform faults at two places: the Romanche Trench near the Equator and the Gibbs Fracture Zone at 53°N. The MAR is a barrier for bottom water, but at these two transform faults deep water currents can pass from one side to the other.

The MAR rises 2–3 km (1.2–1.9 mi) above the surrounding ocean floor and its rift valley is the divergent boundary between the North American and Eurasian plates in the North Atlantic and the South American and African plates in the South Atlantic. The MAR produces basaltic volcanoes in Eyjafjallajökull, Iceland, and pillow lava on the ocean floor. The depth of water at the apex of the ridge is less than 2,700 m (1,500 fathoms; 8,900 ft) in most places, while the bottom of the ridge is three times as deep.

The MAR is intersected by two perpendicular ridges: the Azores–Gibraltar Transform Fault, the boundary between the Nubian and Eurasian plates, intersects the MAR at the Azores Triple Junction, on either side of the Azores microplate, near the 40°N. A much vaguer, nameless boundary, between the North American and South American plates, intersects the MAR near or just north of the Fifteen-Twenty Fracture Zone, approximately at 16°N.

In the 1870s, the Challenger expedition discovered parts of what is now known as the Mid-Atlantic Ridge, or: An elevated ridge rising to an average height of about 1,900 fathoms [3,500 m; 11,400 ft] below the surface traverses the basins of the North and South Atlantic in a meridianal direction from Cape Farewell, probably its far south at least as Gough Island, following roughly the outlines of the coasts of the Old and the New Worlds.

The remainder of the ridge was discovered in the 1920s by the German Meteor expedition using echo-sounding equipment. The exploration of the MAR in the 1950s led to the general acceptance of seafloor spreading and plate tectonics.

Most of the MAR runs under water but where it reaches the surfaces it has produced volcanic islands. While nine of these have collectively been nominated a World Heritage Site for their geological value, four of them are considered of "Outstanding Universal Value" based on their cultural and natural criteria: Þingvellir, Iceland; Landscape of the Pico Island Vineyard Culture, Portugal; Gough and Inaccessible Islands, United Kingdom; and Brazilian Atlantic Islands: Fernando de Noronha and Atol das Rocas Reserves, Brazil.

Ocean floor

Continental shelves in the Atlantic are wide off Newfoundland, southernmost South America, and north-eastern Europe. In the western Atlantic carbonate platforms dominate large areas, for example, the Blake Plateau and Bermuda Rise. The Atlantic is surrounded by passive margins except at a few locations where active margins form deep trenches: the Puerto Rico Trench (8,376 m or 27,480 ft maximum depth) in the western Atlantic and South Sandwich Trench (8,264 m or 27,113 ft) in the South Atlantic. There are numerous submarine canyons off north-eastern North America, Western Europe, and north-western Africa. Some of these canyons extend along the continental rises and farther into the abyssal plains as deep-sea channels.

In 1922 a historic moment in cartography and oceanography occurred. The USS *Stewart* used a Navy Sonic Depth Finder to draw a continuous map across the bed of the Atlantic. This involved little guesswork because the idea of sonar is straight forward with pulses being sent from the vessel, which bounce off the ocean floor, then return to the vessel. The deep ocean floor is thought to be fairly flat with occasional deeps, abyssal plains, trenches, seamounts, basins, plateaus, canyons, and some guyots. Various shelves along the margins of the continents constitute about 11% of the bottom topography with few deep channels cut across the continental rise.

The mean depth between 60°N and 60°S is 3,730 m (12,240 ft), or close to the average for the global ocean, with a modal depth between 4,000 and 5,000 m (13,000 and 16,000 ft). In the South Atlantic the Walvis Ridge and Rio Grande Rise form barriers to ocean currents. The Laurentian Abyss is found off the eastern coast of Canada.

The Indian Ocean

The Indian Ocean is the third-largest of the world's oceanic divisions, covering 70,560,000 km^2 (27,240,000 sq mi) or 19.8% of the water on Earth's surface. It is bounded by Asia to the north, Africa to the west and Australia to the east. To the south it is bounded by the Southern Ocean or Antarctica, depending on the definition in use. Along its core, the Indian Ocean has some large marginal or regional seas such as the Arabian Sea, the Laccadive Sea, the Somali Sea, Bay of Bengal, and the Andaman Sea. Smaller and less deep than the Atlantic Ocean.

Coasts and shelves

In contrast to the Atlantic and Pacific, the Indian Ocean is enclosed by major landmasses and an archipelago on three sides and does not stretch from pole to pole and can be likened to an embayed ocean. It is centred on the Indian Peninsula and although this subcontinent has played a major role in its history the Indian Ocean has foremostly been a cosmopolitan stage interlinking diverse regions by innovations, trade, and religion since early in human history.

The active margins of the Indian Ocean have an average depth (land to shelf break) of 19 ± 0.61 km (11.81 ± 0.38 mi) with a maximum depth of 175 km (109 mi). The passive margins have an average depth of 47.6 ± 0.8 km (29.58 ± 0.50 mi). The average width of the slopes of the continental shelves are 50.4–52.4 km (31.3–32.6 mi) for active and passive margins respectively, with a maximum depth of 205.3–255.2 km (127.6–158.6 mi).

Australia, Indonesia, and India are the three countries with the longest shorelines and exclusive economic zones. The continental shelf makes up 15% of the Indian Ocean. More than two billion people live in countries bordering the Indian Ocean, compared to 1.7 billion for the Atlantic and 2.7 billion for the Pacific (some countries border more than one ocean).

Submarine ridges

- Submarine ridges in this ocean include the Lakshadweep-Chagos Ridge [Reunion Hotspot], the Socotra-Chagos Ridge, the Seychelles Ridge, the South Madagascar Ridge, Carlsberg Ridge etc..

- These ridges divide the ocean bottom into many basins. Chief among these are the Central Basin, Arabian Basin, South Indian Basin, Mascarene Basin, West Australian and South Australian Basins.

Islands

- Most of the islands in the Indian Ocean are continental islands and are present in the north and west.
- These include the Andaman and Nicobar, Sri Lanka, Madagascar and Zanzibar. The Lakshadweep and Maldives are coral islands and Mauritius and the Reunion Islands are of volcanic origin. The eastern section of the Indian Ocean is almost free from islands.

Continental Shelf

- The ocean's continental shelves are narrow, averaging 200 kilometres (120 mi) in width.
- An exception is found off Australia's northern coast, where the shelf width exceeds 1,000 kilometres (620 mi).
- The average depth of the ocean is 3,890 m (12,762 ft).

Trenches

- Linear deeps are almost absent. Few exceptions are Sunda Trench, which lies to the south of the island of Java and Diamantina Trench, west of Australia.
- Its deepest point is Diamantina Deep in Diamantina Trench, at 8,047 m. Sunda Trench off the coast of Java is also considerably deep.

Straits

- Most of the straits in Indian Ocean are important trade roots.

- The major choke points include *Bab el Mandeb*, *Strait of Hormuz*, the Lombok Strait, the *Strait of Malacca* and the Palk Strait.

Marginal seas

Along the east coast of Africa, the Mozambique Channel separates Madagascar from mainland Africa, while the Sea of Zanj is located north of Madagascar.

On the northern coast of the Arabian Sea, Gulf of Aden is connected to the Red Sea by the strait of Bab-el-Mandeb. In the Gulf of Aden, the Gulf of Tadjoura is located in Djibouti and the Guardafui Channel separates Socotra island from the Horn of Africa. The northern end of the Red Sea terminates in the Gulf of Aqaba and Gulf of Suez. The Indian Ocean is artificially connected to the Mediterranean Sea through the Suez Canal, which is accessible via the Red Sea. The Arabian Sea is connected to the Persian Gulf by the Gulf of Oman and the Strait of Hormuz. In the Persian Gulf, the Gulf of Bahrain separates Qatar from the Arabic Peninsula.

Along the west coast of India, the Gulf of Kutch and Gulf of Khambat are located in Gujarat in the northern end while the Laccadive Sea separates the Maldives from the southern tip of India. The Bay of Bengal is off the east coast of India. The Gulf of Mannar and the Palk Strait separates Sri Lanka from India, while the Adam's Bridge separates the two. The Andaman Sea is located between the Bay of Bengal and the Andaman Islands.

In Indonesia, the so-called Indonesian Seaway is composed of the Malacca, Sunda and Torres Straits. The Gulf of Carpentaria of located on the Australian north coast while the Great Australian Bight constitutes a large part of its southern coast.

- Arabian Sea

- Persian Gulf
- Red Sea
- Gulf of Oman
- Gulf of Aden
- Strait of Bab-el-Mandeb connecting Arabian Sea
- Gulf of Kutch
- Gulf of Khambat
- Palk Strait connecting Arabian Sea and Bay of Bengal
- Bay of Bengal
- Andaman Sea
- Malacca Strait
- Mozambique Channel
- Great Australian Bight
- Gulf of Mannar
- Laccadive Sea

Indian Ocean

UNIT III

Sea water temperature: Horizontal and vertical distribution - Salinity: Controlling factors - Horizontal and vertical distribution.

HORIZONTAL AND VERTICAL DISTRIBUTION OF OCEAN TEMPERATURE

Distribution of temperature across the latitudes over the surface of the earth is called its horizontal distribution. On maps, the horizontal distribution of temperature is commonly shown by isotherms. Isotherms are line connecting points that have an equal temperature.

The distributional pattern of temperature of ocean water is studied in two ways viz.

- Horizontal distribution (temperature of surface water) and
- Vertical distribution (from surface water to the bottom).

Since the ocean has three dimensional shape, the depth of oceans, besides latitudes, is also taken into account in the study of temperature distribution. **The following factors affect the distribution of temperature of ocean water.**

- **Latitudes**

The temperature of surface water decreases from equator toward the poles because the sun's rays become more and more slanting and thus the amount of insolation decreases pole ward accordingly. The temperature of surface water between 40°N and 40°S is lower than air temperature but it becomes higher than air temperature between 40°Latitude and the poles in both the hemispheres.

- **Unequal distribution of land and water**

The temperature of ocean water varies in the northern and the southern hemispheres because of dominance of land in the northern hemisphere and water in the southern hemisphere. As far as surface temperature is concerned, it has the following implications:

- The oceans in the northern hemisphere receive more heat due to their contact with larger extent of land than their counterparts in the southern hemisphere and thus the temperature of surface water is comparatively higher in the northern hemisphere than the southern hemisphere.
- **The isotherms** are not regular and do not follow latitudes in the northern hemisphere because of the existence of both warm and cold landmasses whereas they (isotherms) are regular and follow latitudes in the southern hemisphere because of the dominance of water.

The temperature in the enclosed seas in low latitudes becomes higher because of the influence of surrounding land areas than the open seas e.g., the average annual temperature of surface water at the equator is 26.7°C whereas it is 37.8°C in the Red Sea and 34.4°C (94°F) in the Persian Gulf.

- **Prevailing wind**

Wind direction largely affects the distribution of temperature of ocean water. The winds blowing from the land towards the oceans and seas (i.e. offshore winds) drive warm surface water away from the coast resulting into upwelling of cold bottom water from below. Thus, the replacement of warm water by cold water introduces longitudinal variation in temperature. Contrary to this, the onshore winds pile up warm water near the coast and thus raise the temperature.

- **Ocean currents**

  Surface temperatures of the oceans are controlled by warm and cold currents. Warm currents raise the temperature of the affected areas whereas cool currents lower down the temperature.

- **Other factors**

  Other factors include the following:

  Submarine ridges

- Local weather conditions such as storms, cyclones, hurricanes, fog, cloudiness, evaporation and condensation

- **Location and Shape of area:** The enclosed seas in the low latitudes record relatively higher temperature than the open seas whereas the enclosed seas have lower temperature than the open seas in the high latitudes.

Horizontal Distribution of Temperature

- The average temperature of surface water of the oceans is about 27°C and it gradually decreases from the equator towards the poles.
- The rate of decrease of temperature with increasing latitude is generally 0.5°C per latitude.
- The horizontal temperature distribution is shown by isothermal lines, i.e., lines joining places of equal temperature.
- Isotherms are closely spaced when the temperature difference is high and vice versa.
- For example, in February, isothermal lines are closely spaced in the south of Newfoundland, near the west coast of Europe and North Sea and then isotherms widen out to make; a bulge towards north near the coast of Norway.

- The cause of this phenomenon lies in the cold Labrador Current flowing southward along the North American coast which reduces the temperature of the region more sharply than in other places in the same latitude; at the same time the warm Gulf Stream proceeds towards the western coast of Europe and raises the temperature of the west coast of Europe.

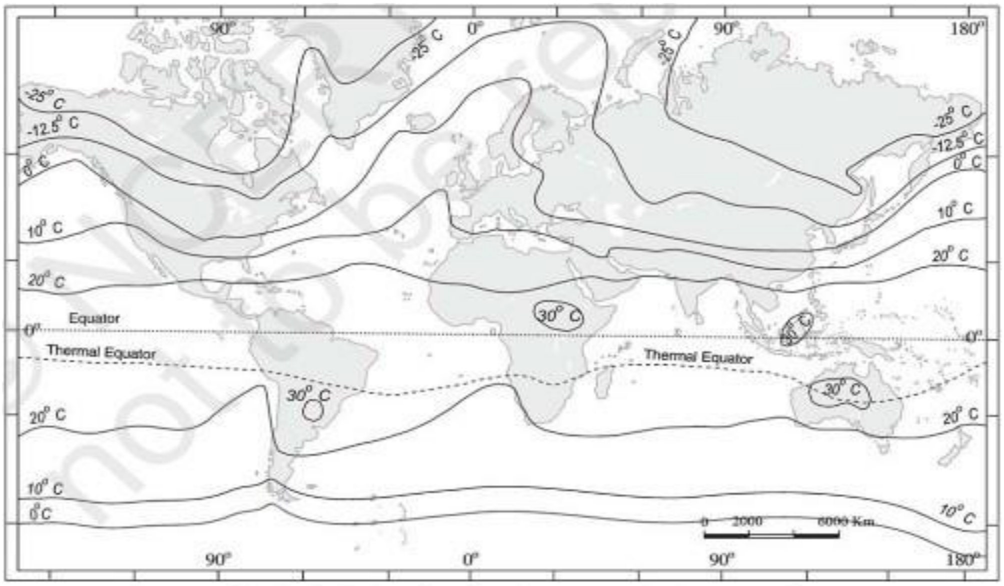


Figure 9.4 (a) : The distribution of surface air temperature in the month of January

Average temperature of surface water of the oceans is 26.7°C and the temperature gradually decreases from equator towards the poles. The rate of decrease of temperature with increasing latitudes is generally 0.5°C per latitude. The average temperatures become 22°C at 20° N and S latitudes, 14°C at 40° N and S latitude, and 0°C near the poles. I have already mentioned above that the oceans in the northern hemisphere record relatively higher average temperature than in the southern hemisphere. Please note that the highest temperature is not recorded at the equator rather it is a bit north of it.

Also we should note that the average annual temperature of all the oceans is 17.2°C. The average annual temperatures for the northern and southern hemispheres are 19.4°C and 16.1°C respectively. The variation of temperatures in the northern and southern hemispheres is because of unequal distribution of land and water as Northern hemisphere is made up of more land, while the southern hemisphere is made up of more oceans.

In Northern Atlantic, there is a very low decrease of temperature with increasing latitudes towards north. This is because of the Gulf Stream currents which are warm currents. However, in southern Atlantic, the decrease of temperature with increasing latitude is more pronounced. The table shows the variations of three major oceans:

Latitudes	Pacific Ocean	Atlantic Ocean	Indian Ocean
0-10°	26	25.2	27
10-20°	25	23.2	26.9
20-30°	21.5	21.2	22.5
30-40°	17	17	17
40-50°	11.1	9	8.7
50-60°	5	1.8	1.6
60-70°	-1.3	-1.3	-1.5

Vertical Distribution of Temperature

The maximum temperature of the oceans is always on the surface because it directly receives the insolation. The heat is transmitted to the lower sections of the oceans through the mechanism of conduction**.**

Solar rays very effectively penetrate up to 20m depth and they seldom go beyond 200m depth. Consequently, the temperature decreases from the ocean surface with increasing depth but the rate of decrease of temperature with increasing depth is not uniform everywhere. The temperature falls very rapidly up to the depth of 200m and thereafter the rate of decrease of temperature is slowed down.

On this basis, oceans are vertically divided into three zones as follows:

Photic Zone or Euphotic Zone

- This is the upper layer of the ocean. The temperature is relatively constant and is 100 meters deep. The **photic zone** receives adequate solar insolation.

- **Aphotic zone** extends from 200 m to the ocean bottom; this zone does not receive adequate sunrays.

Thermocline

Thermocline lies between 100-1000 meters. There is a steep fall in the temperature.

- The profile shows a boundary region between the surface waters of the ocean and the deeper layers.
- The boundary usually begins around 100 – 400 m below the sea surface and extends several hundred of meters downward.
- This boundary region, from where there is a rapid decrease of temperature, is called the **thermocline**. About 90 per cent of the total volume of water is found below the thermocline in the deep ocean. In this zone, temperatures approach 0° C.

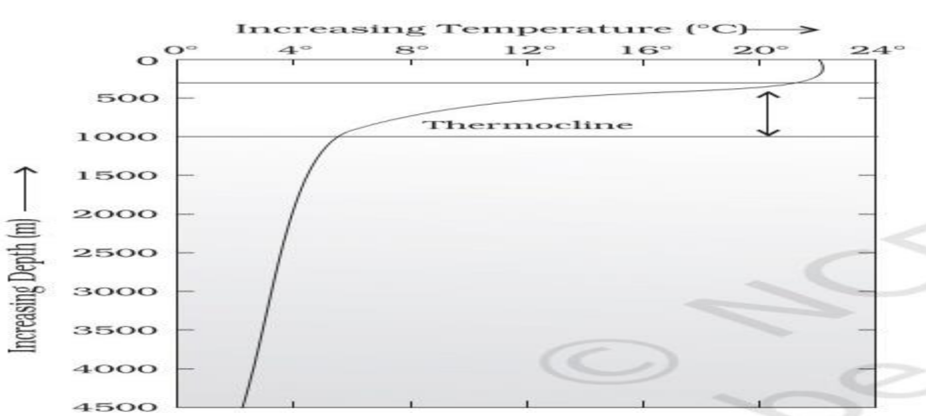


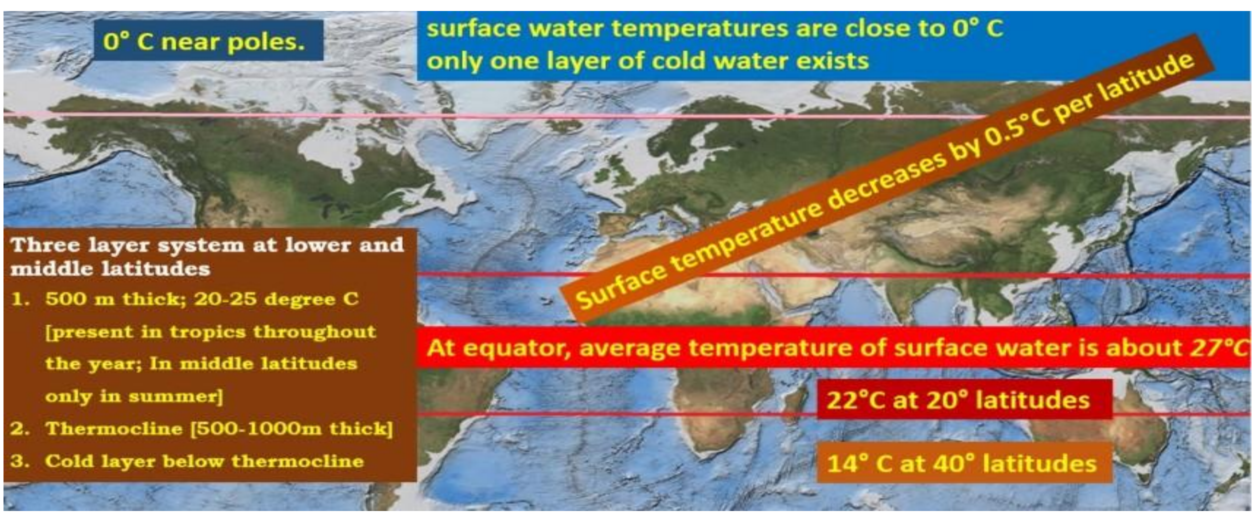
Figure 13.3 : Thermocline

Deep Zone

Below 1000 meters is the deep zone. Here, the temperature is near zero °C. Please note that near bottom, the temperature of water never goes to 0°C. It is always 2-3°C.

Three-Layer System

- The temperature structure of oceans over middle and low latitudes can be described as a three-layer system from surface to the bottom.
- The first layer represents the top layer of warm oceanic water and it is about 500m thick with temperatures ranging between 20° and 25° C. This layer, within the tropical region, is present throughout the year but in mid-latitudes it develops only during summer.
- The second layer called the thermocline layer lies below the first layer and is characterized by rapid decrease in temperature with increasing depth. The thermocline is 500 -1,000 m thick.
- The third layer is very cold and extends up to the deep ocean floor. Here the temperature becomes almost stagnant.



General behavior

- In the Arctic and Antarctic circles, the surface water temperatures are close to 0° C and so the temperature change with the depth is very slight (ice is a very bad conductor of heat). Here, only one layer of cold water exists, which extends from surface to deep ocean floor.

Important Observations

- Sea temperature decreases with increasing depth but the rate of decrease of temperature is not uniform.
- The change in sea temperature below the depth of 1000m is negligible. The maximum change in temperature is between 100-1000 meters which is called Thermocline or Pycnocline.
- Diurnal and annual ranges of temperature cease after a depth of 30 feet and 600 feet respectively.
- The rate of decrease of temperature with increasing depth from equator towards the poles is not uniform.

  Though, the surface temperature of the oceans decreases from equator to the poles, the temperature at the ocean bottom is uniform at all latitudes. However, some studies have shown that the coldest bottom temperatures, just below — 0.25°C, occur at 60-70°S, near the Antarctic continent.

Source of Heat in Oceans

- The sun is the principal source of energy (Insolation).
- The ocean is also heated by the inner heat of the ocean itself (earth's interior is hot. At the sea surface, the crust is only about 5 to 30 km thick). But this heat is negligible compared to that received from sun.

How does deep water marine organisms survive in spite of absence of sunlight?

- Photic zone is only about few hundred meters. It depends on lot of factors like turbidity**,** presence of algae etc..
- There are no enough primary producers below few hundred meters till the ocean bottom.
- At the sea bottom, there are bacteria that make use of heat supplied by earth's interior to prepare food. So, they are the primary producers.
- Other organisms feed on these primary producers and subsequent secondary producers.
- So, the heat from earth supports wide ranging deep water marine organisms.

But the productivity is too low compared to ocean surface.

Why is diurnal range of ocean temperatures too small?, Why oceans take more time to heat or cool?

- The process of heating and cooling of the oceanic water is slower than land due to **vertical and horizontal mixing** and **high specific heat of water**.
- (More time required to heat up a Kg of water compared to heating the same unit of a solid at same temperatures and with equal energy supply).

The ocean water is heated by three processes.

1. Absorption of sun's radiation.
2. **The conventional currents:** Since the temperature of the earth increases with increasing depth, the ocean water at great depths is heated faster than the upper water layers. So, convectional oceanic circulations develop causing circulation of heat in water.

3. Heat is produced due to friction caused by the surface wind and the tidal currents which increase stress on the water body.

The ocean water is cooled by

1. Back radiation (heat budget) from the sea surface takes place as the solar energy once received is reradiated as long wave radiation (terrestrial radiation or infrared radiation**)** from the seawater.
2. Exchange of heat between the sea and the atmosphere if there is temperature difference.
3. Evaporation: Heat is lost in the form of latent heat of evaporation (atmosphere gains this heat in the form of latent heat of condensation).

Factors Affecting Temperature Distribution of Oceans

- **Insolation:** The average daily duration of insolation and its intensity.
- **Heat loss:** The loss of energy by reflection, scattering, evaporation and radiation.
- **Albedo:** The albedo of the sea (depending on the angle of sun rays).
- **The physical characteristics of the sea surface:** Boiling point of the sea water is increased in the case of higher salinity and vice versa [Salinity increased = Boiling point increased = Evaporation decreased].
- **The presence of submarine ridges and sills [Marginal Seas]:** Temperature is affected due to lesser mixing of waters on the opposite sides of the ridges or sills.
- **The shape of the ocean:** The latitudinally extensive seas in low latitude regions have warmer surface water than longitudinally extensive sea

[Mediterranean Sea records higher temperature than the longitudinally extensive Gulf of California].

- **The enclosed seas** (Marginal Seas – Gulf, Bay etc.) in the low latitudes record relatively higher temperature than the open seas; whereas the enclosed seas in the high latitudes have lower temperature than the open seas.
- Local weather conditions such as cyclones.
- **Unequal distribution of land and water:** The oceans in the northern hemisphere receive more heat due to their contact with larger extent of land than the oceans in the southern hemisphere.
- **Prevalent winds** generate horizontal and sometimes vertical ocean currents: The winds blowing from the land towards the oceans (off-shore winds-moving away from the shore) drive warm surface water away from the coast resulting in the upwelling of cold water from below (This happens near Peruvian Coast in normal years. El-Nino).
- Contrary to this, the onshore winds (winds flowing from oceans into continents) pile up warm water near the coast and this raises the temperature (This happens near the Peruvian coast during El Nino event)(In normal years, North-eastern Australia and Western Indonesian islands see this kind of warm ocean waters due to Walker Cell or Walker Circulation).
- **Ocean currents:** Warm ocean currents raise the temperature in cold areas while the cold currents decrease the temperature in warm ocean areas. **Gulf stream (warm current)** raises the temperature near the eastern coast of North America and the West Coast of Europe while the **Labrador current (cold current)** lowers the temperature near the north-east coast of North America (Near Newfoundland). All these factors influence the temperature of the ocean currents locally.

The rate of decrease of temperature with depths is greater at the equator than at the poles.

- The surface temperature and its downward decrease is influenced by the upwelling of bottom water (Near Peruvian coast during normal years).
- In cold Arctic and Antarctic regions, sinking of cold water and its movement towards lower latitudes is observed.
- In equatorial regions the surface, water sometimes exhibits lower temperature and salinity due to high rainfall, whereas the layers below it have higher temperatures.
- The enclosed seas in both the lower and higher latitudes record higher temperatures at the bottom.
- The enclosed seas of low latitudes like the **Sargasso Sea**, the **Red Sea** and the **Mediterranean Sea** have high bottom temperatures due to high insolation throughout the year and lesser mixing of the warm and cold' waters.
- In the case of the high latitude enclosed seas, the bottom layers of water are warmer as water of slightly higher salinity and temperature moves from outer ocean as a sub-surface current.
- The presence of submarine barriers may lead to different temperature conditions on the two sides of the barrier. For example, at the Strait of Bab-el-Mandeb, the submarine barrier (sill) has a height of about 366 m. The subsurface water in the strait is at high temperature compared to water at same level in Indian ocean. The temperature difference is greater than nearly 20° C.

Sunspot

- Sunspots are **temporary phenomena** on the **photosphere** of the Sun that appear visibly as dark spots compared to surrounding regions.

- They correspond to concentrations of **magnetic field** that inhibit convection and result in reduced surface temperature compared to the surrounding photosphere.
- Sunspots usually appear as pairs, with each spot having the opposite magnetic polarity of the other.
- Although they are at temperatures of roughly 3,000–4,500 K (2,700–4,200 °C), the contrast with the surrounding material at about 5,780 K (5,500 °C) leaves them clearly visible as dark spots.

Sunspot activity cycles about every **eleven years**. The point of highest sunspot activity during this cycle is known as Solar Maximum, and the point of lowest activity is Solar Minimum.

SALINITY

NATURE OF SEA WATER

The water in the oceans and above the oceans are found in 3 states, namely i) in liquid state, ii) in solid state i.e. in the form of ice such as the cryosphere of the Arctic Ocean, and the Southern Ocean (Antarctic Ocean). Cryosphere represents the frozen surfaces of the oceans, as well as the continents, and iii) in gaseous state, i.e. in the form of water vapour above the ocean surface.

Salinity is defined as the ratio between the weight of the dissolved materials and the weight of the sample sea water. It is generally defined as the total amount of solid materal in grams contained in one kg of sea water and is expressed as part per thousand % e.g. 40% means 40 grams of salt in total 1000 grams of water. The average salinity in the oceans and the seas is 35%, but it varies spatially and temporally in different oceans, seas and lakes.

There are many chemicals in seawater that make it salty. Most of them get there from rivers carrying chemicals dissolved out of rock and soil. The main one is sodium chloride, often just called salt. Seawater is water from a sea or ocean. On average, seawater in the world's oceans has a salinity of approximately 3.5%, or 35 parts per thousand. This means that for every 1 litre (1000 ml) of seawater there are 35 grams of salts (mostly, but not entirely, sodium chloride) dissolved in it.

Why salinity and temperature are measured?

The commonest way to record salinity is to measure the amount of salt in 1,000 g of water, so it is referred to as ‘parts per thousand’ or ppt. Most of the ocean has a salinity of between 34 ppt and 36 ppt.

Some properties of water are changed by having salt in it:

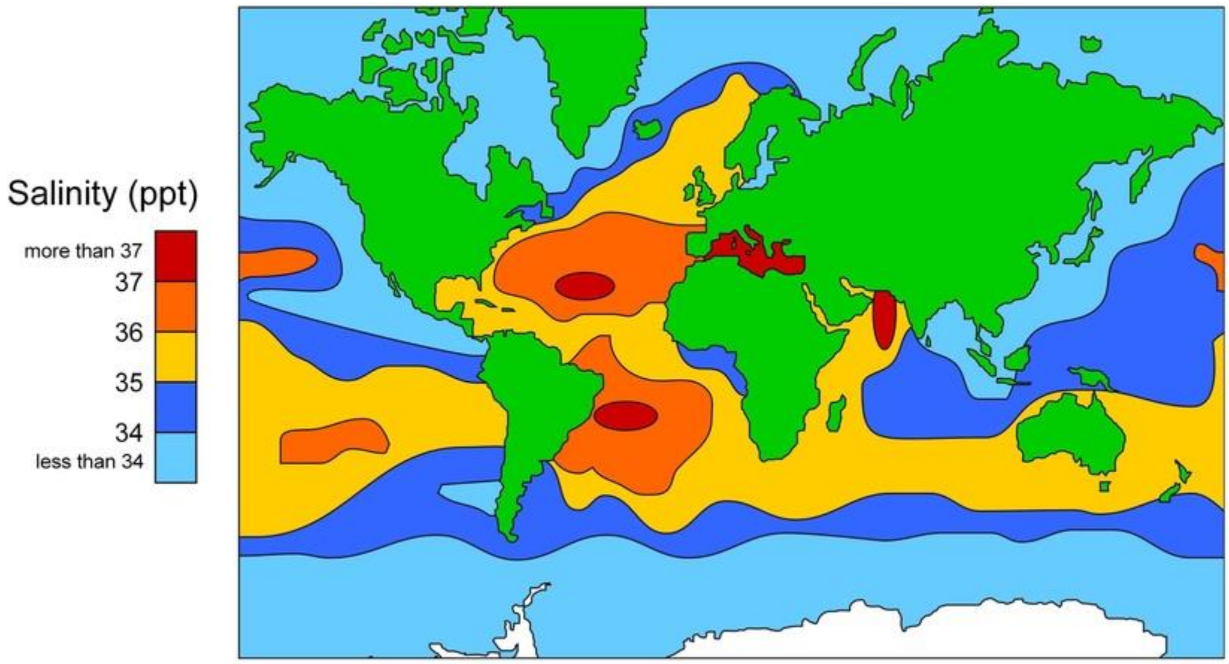
- Salt makes seawater more dense than freshwater.
- Salty water needs to be colder than freshwater before it freezes.

Variation in salinity

The salinity of the ocean varies from place to place, especially at the surface. Much of the ocean has salinity between 34 ppt and 36 ppt, but there are places that tend to be higher or lower.

Places of higher salinity

There are parts of the ocean where hardly any rain falls but warm dry winds cause lots of evaporation. This evaporation removes water – when water vapour rises into the atmosphere, it leaves the salt behind, so the salinity of the seawater increases. This causes the seawater to become denser. You can see on the map that the north and south Atlantic have high salinity – these are areas where there are strong winds and not much rain.



The Mediterranean Sea in Europe has very high salinity – 38 ppt or more. It is almost closed from the main ocean, and there is more evaporation than there is rain or extra freshwater added from rivers.

Places of lower salinity

Some parts of the ocean have lots of rain. The freshwater added at the surface dilutes the seawater, reduces the salinity and so makes the seawater less dense. Seawater can also be less saline near land, where rivers add freshwater.

The ocean around Antarctica has a low salinity of just below 34ppt, and around the Arctic it is down to 30ppt in places. Thawing icebergs add freshwater – icebergs that have broken off ice sheets formed over land do not contain salt, and the freezing of seawater into ice floes removes more salt.

What happens when salinity changes?

The difference between 34 ppt and 36 ppt salinity doesn't sound very much, but it is enough to cause a difference in density. Even slightly denser seawater sinks below less dense water.

However, the effect is greater if the salty water gets cold, as temperature has a greater effect on density than salinity does. A combination of high salinity and low temperature makes seawater so dense that it sinks to the bottom of the ocean and flows across ocean basins as deep, slow currents.

Factors influencing salinity of a given region

- **Temperature**
  Higher temperatures are associated with high salinity. This is because high temperatures cause a high rate of evaporation of freshwater. As freshwater evaporates, the concentration of salt increases. This will give rise to more saline water in that region.
  Ex: the Red Sea is one of the most saline bodies.

- **Currents**
  The ocean currents continuously indulge in bringing new water and taking away old water. This creates a sort of water circulation. The ocean currents that bring fresh water to reduce the salinity of a given region. Similarly, warm currents are more saline in nature.
  Ex: Labrador Current reduces salinity.

- **Rainfall**

  The amount of rainfall in a given region adds freshwater to the existing sea water. This addition of freshwater will reduce the concentration of salts in the water. This phenomenon is usually observed in areas of heavy rainfall. Ex: Salinity levels in the equator are very low due to high rainfall.

- **Freshwater inflow**

  Seas and oceans with large river inflow have a low level of salinity. Rivers bring continuous freshwater to the seas, that plays a major role in reducing the salt levels in the water.

  Ex: Bay of Bengal is less saline in comparison to the Arabian sea due to drainage of the large river such as Ganges, Brahmaputra, Irrawaddy, etc into it.

- **Enclosure of land**

  The seas with enclosure of land surrounding it are found to be more saline as compared to open seas. This is because land prevents the free mixing of new water and also it plays an important role in dispensing heat into the water body to increase evaporation levels.

  Ex: The Persian Gulf is highly saline due to the surrounding land.

Horizontal Distribution of Salinity

Horizontal distribution of Oceanic salinity is studied in relation to latitudes.

Latitudinal Distribution: On an average salinity decreases from equator towards the poles. It appears that highest salinity should be recorded at equator due to high temperature and evaporation but high temperature and evaporation but high rainfall reduces the relative proportions of salt. The highest salinity is observed between 20^0 -40^0 N latitudes because this zone is characterized by high temperature, high evaporation high evaporation but less rainfall than the equatorial portion.

The average salinity of 35% is recorded between 10^0 – 30^0 latitudes in Southern hemisphere. The zone between 40^0-60^0 latitudes in both the hemisphere records low salinity where it is 31% and 33%. In the northern and southern hemisphere respectively. Salinity further reduces in the polar zone due to influx of melt-water. On an average the north and south hemisphere record average salinity of 34% and 35% respectively.

It is also noted that marginal areas of the oceans bordering the continents have lower salinity than their central parts due to addition of fresh water to the marginal areas through the rivers.

Latitude Distribution of Salinity

Latitudinal Zones	Salinity (%)
70^0 -50^0 N	30-31
50^0-40 ^{0}N	33-34
40^0-15 ^{0}N	35-36
15^0-10 ^{0}N	34.5-35
10^0-30 ^{0}S	35-36
30^0-50 ^{0}S	34-35
50^0-70 ^{0}S	33-34

1. The salinity for normal Open Ocean ranges between 33% and 37 %.
2. The highest salinity is recorded between 15° and 20° latitudes.
3. Maximum salinity (37%) is observed between 20° N and 30° N and 20° W – 60° W.
4. The salinity gradually decreases towards the north.
5. The salinity sometimes reaches up to 70 % in the hot and dry regions where evaporation is high.
6. The salinity variation in the Pacific Ocean is largely due to its shape and larger areal stretch.
7. In the landlocked Red Sea, the salinity is 41% which considerably high.
8. The salinity in the estuaries and the Arctic varies from 0 – 35 %, seasonally.
9. Due to the influx of melted water from the Arctic region, the salinity decreases from 35 % – 31% on the western parts of the northern hemisphere.

10. The North Sea records higher salinity due to more saline water brought by the North Atlantic Drift despite its location in higher latitudes.
11. Due to the influx of river waters in the large amount, the Baltic Sea records low salinity.
12. The Mediterranean Sea accounts for the higher salinity due to high evaporation.
13. Salinity is very low in the Black Sea due to massive freshwater influx by rivers.
14. The average salinity of the Indian Ocean is 35 %.
15. The low salinity trend in the Bay of Bengal is due to the influx of river water.
16. But the Arabian Sea displays higher salinity due to the low influx of fresh water and high evaporation.

Regional Distribution of Salinity

Pacific Ocean

The regional distribution of salinity is due to its shape and larger area extent. Salinity remains 34.85% near the equator. It increases to 35% between 15 -20 ^{0} latitudes in the northern hemisphere and around 36% in the southern hemisphere. Salinity decreases to 31% in the western part of northern hemisphere and 34% near Manchuria because of influx of melting water brought by Oyashio current coming form the Bering Strait helped by the weakening of Kuroshio warm current. After 15-20^0 S it again decreases to Peruvian and Chilean coast 33%.

Atlantic Ocean

The average salinity of the Atlantic Ocean 35.67%. The highest salinity is recorded between 15-20 ^{0} latitudes. Salinity recorded at 5^0 N, 15^0 N and 15^0 S are 34.98%, 36% and 37.77% respectively. It indicated that salinity increases from equator towards the tropics of cancer and Capricorn . The central zone of the N.Atlantic ocean located between 20 ^{0} N and 30 ^{0} and 20 ^{0}W – 60^0 W records maximum salinity 37% and it gradually decreases further northward but with varying trends.

Maximum salinity of 37% in the southern Atlantic is found in a region demarcated by 12^0 S -20^0 S latitudes and 40^0 W -15^0 W longitudes, salinity thereafter decreases southward gradually.

The North Sea in spite of its location in higher latitudes records 34% salinity due to more saline water brought by the North Atlantic Drift. Baltic Sea records low salinity due to influx of river water. The Mediterranean sea records high salinity due to evaporation and little mixture of Atlantic water. Salinity reduced to 17.18% in the Black Sea due to enormous volume of fresh water brought by the rivers like the Dneiper and the Danube etc.

Indian Ocean

Here the average salinity is 35% is found between 0 -10 N but it gradually decreases northward in the Bay of Bengal 33.5% due to influx of immense volume of fresh water brought by the river Ganga. Arabian sea has 36% salinity due to higher rates of evaporation and low influx of fresh water. The partially enclosed seas have higher salinity e.g., 37% at the heat and 40% in the interior of the Persian Gulf. The Red sea records the highest salinity 36% to 41% because of low precipitation and very high evaporation.

Very high salinity is found in Great Salt lake (220%, Utah USA), Lake Van (330%, Turkey), Dead Sea (238%) etc.

Vertical Distribution of Salinity

The following characteristic may be stated:

a) Salinity increases with increasing depth in high latitudes or we can say that there is positive relationship between the amount of salinity and depth because of presence of denser water below.

b) The trend of increase in salinity with increase in depth is confined to 200 fathoms from the surface in middle latitudes beyond which it decreases with increasing depths.
c) Salinity is low at the equator due to high rainfall and transfer of water through equatorial currents but higher salinity is noted below the water surface. It again becomes low at the bottom, and also

1. Salinity changes with depth, but the way it changes relies on the position of the sea.
2. Salinity at the surface of the sea is decreased by the input of fresh waters or increased by the loss of water to ice or evaporation.
3. Salinity at depth is fixed as neither water nor salt can be added in it.
4. There is a marked difference in the salinity between the surface zones and the deep zones of the oceans.
5. The lower saline water remains above the higher saline dense water.
6. Salinity, usually, increases with depth and there is a distinct zone called the halocline, where salinity increases abruptly.
7. The increasing salinity of seawater causes an increase in the density of water.
8. High salinity seawater, usually, sinks below the lower salinity water. This leads to stratification by salinity.

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UNIT IV

Dynamics of ocean water: Waves - Tides - Ocean currents: Types - Currents in the Atlantic, Pacific and Indian Ocean.

INTRODUCTION

Ocean dynamics define and describe the motion of **water** within the **oceans**. **Ocean** temperature and motion fields can be separated into three distinct layers: mixed (surface) layer, upper **ocean** (above the thermocline), and deep **ocean**.

The ocean water is dynamic. Its physical characteristics like temperature, salinity, density and the external forces like of the sun, moon and the winds influence the movement of ocean water. The horizontal and vertical motions are common in ocean water bodies. The horizontal motion refers to the ocean currents and waves. The vertical motion refers to tides. Ocean currents are the continuous flow of huge amount of water in a definite direction while the waves are the horizontal motion of water. Water moves ahead from one place to another through ocean currents while the water in the waves does not move, but the wave trains move ahead.

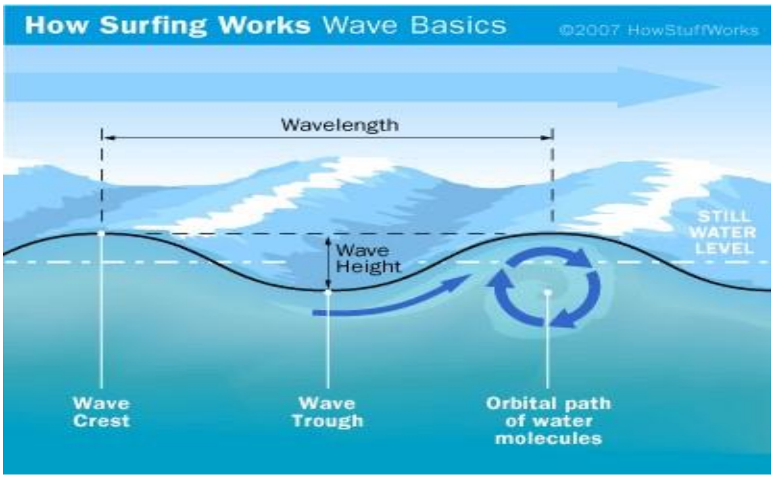
WAVES

In science, a wave is defined as a transfer of energy. Ocean waves are called mechanical waves because they travel through a medium. The medium in this case is water. The water doesn't actually travel with the wave, but only moves up and down. It's the energy that travels with the wave

Waves are created by energy passing through water, causing it to move in a circular motion. Wind driven **waves**, or surface **waves**, are created by the friction between wind and surface water. As wind blows across the surface of the **ocean** or a lake, the continual disturbance creates a **wave** crest.

Ocean waves are called mechanical waves because they travel through a medium. The medium in this case is water. The water doesn't actually travel with the wave, but only moves up and down. It's the energy that travels with the wave.

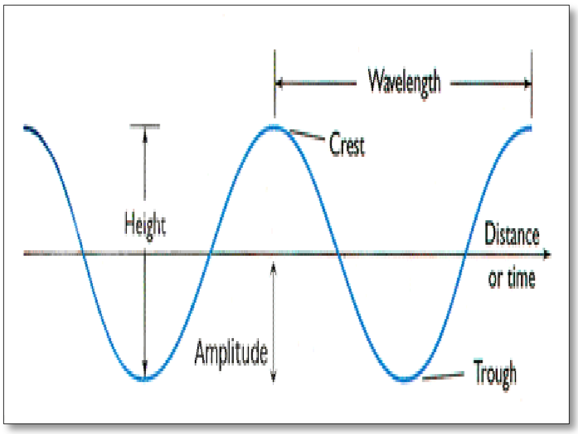
Waves are created by energy passing through water, causing it to move in a circular motion. However, water does not actually travel in waves. Waves transmit energy, not water, across the ocean and if not obstructed by anything, they have the potential to travel across an entire ocean basin.

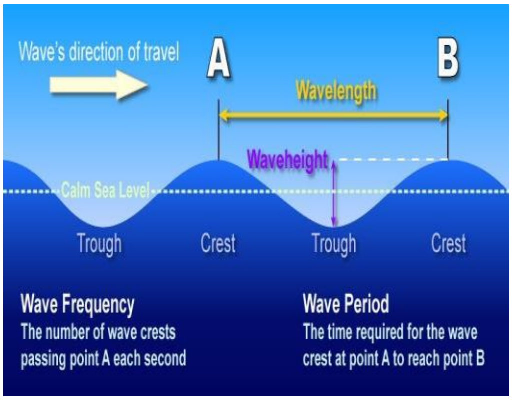


Ocean waves are caused by wind moving across the surface of the water. The friction between the air molecules and the water molecules causes energy to be transferred from the wind to the water. This causes waves to form. In science, a wave is defined as a transfer of energy.

Wave Characteristics

- Crest - Highest point of the wave.
- Trough - Lowest point of the wave.
- Wavelength - Distance from one crest/trough to the next (m)
- Wave Height - Height from trough to crest (m)
- Wave steepness – ratio of wave height to wave length.
- Amplitude - distance from the centre of wave to the bottom of the trough (m)



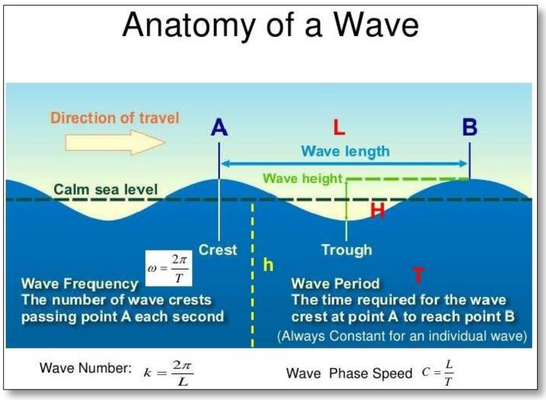


Speed of Waves:

The speed of a wave is determined by the number of waves passing a point per second and the length of the wave.

- Speed in any given medium is constant.
- Speed = frequency • wavelength (f • λ)

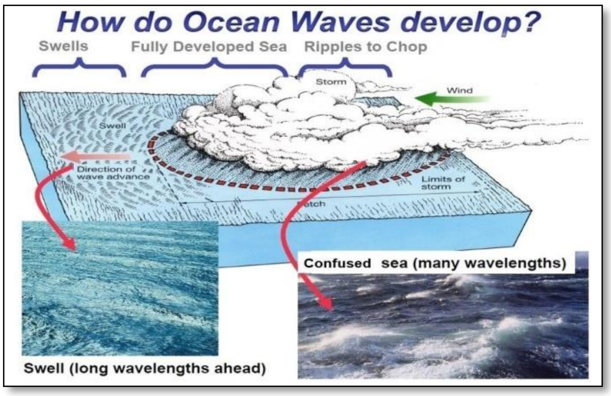
The speed of all ocean waves is controlled by gravity, wavelength, and water depth. Most characteristics of ocean waves depend on the relationship between their wavelength and water depth. Wavelength determines the size of the orbits of water molecules within a wave, but water depth determines the shape of the orbits.



Waves are created by frictional drag as the wind blows over the surface of the ocean.

Energy from the wind begins to rotate the water, turning it in a forward moving circle. In this way the wave can move forward and will continue doing so until it either reaches an obstacle, like land, or it runs out of energy, eg: the wind stops.

The two main factors that determine the size and power of a wave are the strength of the wind and the distance over which it blows. A strong wind blowing over hundreds of miles of ocean will create a more powerful wave than a weak wind blowing for just a few miles.



Five factors influence the formation of the flow structures in wind waves

- **Wind speed or strength** relative to wave speed – the wind must be moving faster than the wave crest for energy transfer
- **The uninterrupted distance of open water** over which the wind blows without significant change in direction (called the *fetch*)
- **Width of area** affected by fetch (at right angle to the distance)
- **Wind duration** – the time for which the wind has blown over the water.
- **Water depth –** the distance from the surface to bottom

TYPES OF WAVES

Wind waves

Wind waves, or **wind**-generated **waves**, are water surface **waves** that occur on the free surface of bodies of water. They result from the **wind** blowing over an area (or fetch) of fluid surface. **Waves** in the oceans can travel thousands of miles before reaching land. Wind waves are caused by the friction between local winds and surface water. They are directly caused by the wind in that location.

Swell waves

Over time and distance, sustained wind strength and duration build up a large amount of energy beneath the ocean's surface, forming deeper waves known as swells. Such energy can enable swells to travel thousands of miles across the ocean without changes in height or shape, until they reach a distant shore as breaking waves. Swell waves are an example of gravity waves, or oscillations of matter driven by gravitational force.

Breaking waves : Breaking waves a breaking wave or breaker is a wave whose amplitude reaches a critical level at which some process can suddenly start to occur that causes large amounts of wave energy to be transformed into turbulent kinetic energy.

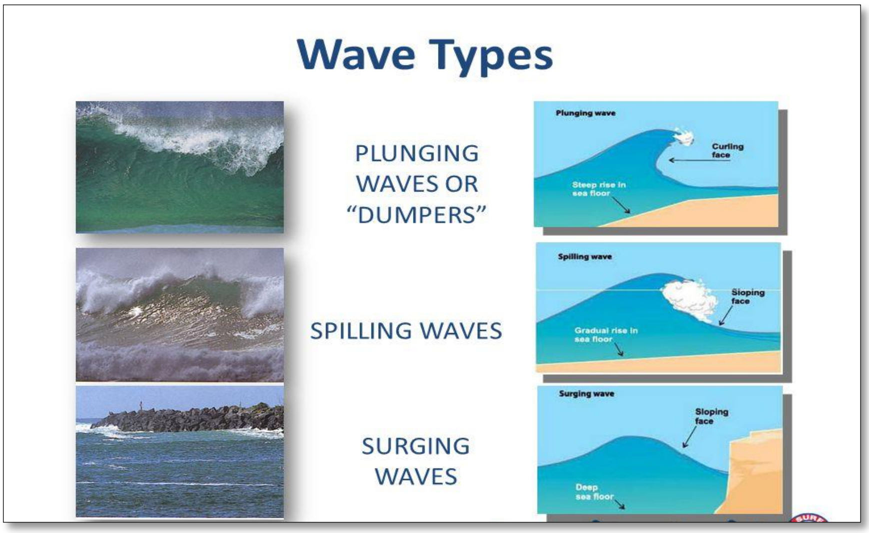
• Spilling breakers

•Plunging breaker

•Surging breakers

Plunging Breakers

Plunging breakers occur as waves approach moderate to steep bottoms. The wave becomes steeper than a spilling breaker and the crest falls as a well-defined curl, falling forward with considerable energy. The tube that forms as these waves hit the shore at an angle and progress across the shoreline is what surfers love.



Spilling Breakers

Spilling breakers occur as waves travel across a gently sloping bottom (i.e., gently sloping sea floor near the beach). The wave breaks long and slow, losing its energy as white water spilling from the crest down the front of the wave.

Surging Breakers

Surging breakers occur when long wave period, low amplitude waves approach moderately steep shores. The wave doesn't spill or curl; it builds up and then slides rapidly up the beach with less foam or spray than the other two breakers.

Surfing waves

The surf is what you see when you stand on the beach and look at the ocean — waves rising and breaking on the shore.

Surfing is a surface water pastime in which the wave rider, referred to as a surfer, rides on the forward part, or face, of a moving wave, which usually carries the surfer towards the shore.

It's also what you do when you ride those waves.

- Surf means "crashing waves“.
- It is a barrel like wave where the wave is hollow when it is breaking.
- For some surfers it's the be all and end all of surfing. Is sometimes called a "tube."

Tidal waves

Tidal waves are generated by ocean tides and therefore indirectly by the gravitational forces of the moon and sun. Tidal waves are considered predictable events because ocean tides are predictable events.

Square waves

Square waves are a consequence of the intersection of two seas, also known as cross sea or grid waves. A weather pattern in the region causes the waves to form this way and at different angles. When two opposing swells collide, a unique pattern emerges.

A cross sea (also referred to as a squared sea or square waves) is a sea state of wind generated ocean waves that form nonparallel wave systems. This may occur when water waves from one weather system continue despite a shift in wind. Waves generated by the new wind run at an angle to the old.

Tsunamis

Tsunamis are long period oceanic waves driven by gravitational force. They are typically generated by an underwater geological event, such as an earthquake, volcanic eruption, or a submarine landslide. Melting glaciers can also induce landslides which have the potential to generate tsunamis. The resulting abrupt change in sea surface height from such an event sends a set of long waves propagating outward from the point of origin. As the waves approach the coastline and the water shoals, they are amplified and can be extremely destructive, depending on the shape of the coastline and the bathymetry (the underwater equivalent of topography). In particular, as the tsunami enters the shoaling water, the wavelength shortens, the speed decreases, and the amplitude increases, whilst the period remains constant.

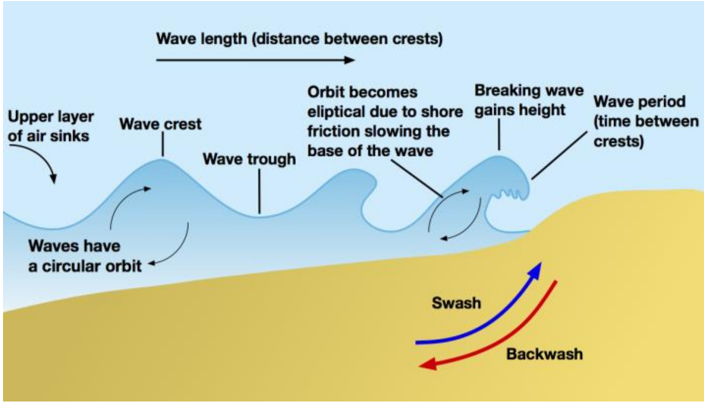
Wave types

Generally waves can also be classified into constructive or destructive.

When a wave breaks, water is washed up the beach. This is called the swash. Then the water runs back down the beach, which is called the backwash. With a constructive wave, the swash is stronger than the backwash. With a destructive wave, the backwash is stronger than the swash.

Swash: When a wave breaks and the water travels up the beach this is called the swash. Swash pushes sediment up the beach away from the sea.

Backwash: When the water from the waves starts to run back down the beach it is called the backwash. Backwash pulls beach material towards the sea.



Constructive waves

Constructive waves predominate in calmer weather conditions when less energy is being transferred to the water. They are less powerful than destructive waves and don't break as violently. Constructive waves will sometimes not seem to break at all but just run up the beach losing energy as they do so. The swash is more powerful than the backwash, so more material is carried up the beach than is pulled back down it. This leads to an increase in beach sediments. If there are not many waves each wave will be able to complete both its swash and backwash without interference from the next wave coming up the beach. Sediment that has been pushed up the beach by the swash will be deposited up shore, and the backwash will drain away into the sand. When the next wave breaks its swash will deposit more material without it being 'captured' by the backwash of the preceding wave. Typically, between 6 and 9 constructive waves will break every minute.

Destructive waves

Destructive waves are formed by strong winds with large fetch areas. These waves have high energy levels that have been built up by travelling long distances and being exposed to strong winds. When they reach land they tend to break strongly and remove material from the shoreline. The swash is not as strong as the backwash so the overall effect is to erode beach material. You will see destructive waves if you visit the coast during or shortly after a storm. The swash of the wave tends to push material up the shore and the backwash tends to wash it back again. If there are a lot of waves they catch up with each other on the beach and the backwash of one wave will tend to meet the swash of the next wave. This will limit the motion of the water up the beach and pull some material back out to sea. Less material will be pushed up the beach. The backwash will be the most powerful process and there will be a net loss of material from the beach. Typically between 11 and 15 destructive waves will break every minute.

Characteristic	Constructive	Destructive
Energy	Low	High
Swash	Strong	Weak
Backwash	Weak	Strong
Wave height	Low	High
Beach shape caused by this type of wave	Wide and flat	Steep and narrow
Frequency	Low (6-8 per minute)	High (10-14 per minute)

Importance of ocean waves

Waves are a very important and necessary part of the workings of our planet; the motions they create perform a vital role in transporting energy around the globe and shaping the coastlines.

Ocean waves are important as they:

1. Create beaches 2.Waves pound rocks and erode them 3. Increase adaptability and strength of creatures 4. Increasing biodiversity 5. At the surface, exchange of climate gases occur

6. Stabilizing climate temperatures.

Ocean waves are very important for weather forecasting and climate modeling as well as for coastal communities, shipping routes and offshore industry. Ocean waves are thought to play a role in weather forecasting such as improving hurricane intensity forecasts by regulating surface friction. Adding an ocean wave component to the 'next generation' of climate and weather models will provide an opportunity to address long standing biases.

Recent studies of coupling atmosphere-ocean-wave models have shown improvements in the simulation of North Atlantic sea surface temperatures in climate models. Extreme ocean waves continue to be a threat for coastal communities and the offshore industry.

How ocean waves will change in the future will be of great interest to decision makers for coastal communities, shipping routes and the offshore industry.

Large waves are a draw for surfers, scientists and spectators alike to locations around the world. They bring money through tourism to shops, restaurants and other businesses. Also included though is waves' "non market" value the amount that people are willing to pay to make sure they exist in the future.

We depend upon the ocean for the following uses:

- Navigation and exploration
- Humans have travelled the seas since they first built sea going craft.
- Travel
- Trade
- Food
- Fishing
- Leisure
- Extractive industries
- Power generation

TIDES

Tides are the periodic rise and fall of the waters of the ocean and its inlets, produced by the attraction of the moon and sun, and occurring about every 12 hours. The regular rise and fall of the ocean's waters are known as tides. Along coasts, the water slowly rises up over the shore and then slowly falls back again. When the water has risen to its highest level, covering much of the shore, it is at high tide. When the water falls to its lowest level, it is at low tide. Some lakes and rivers can also have tides.

The biggest waves in our oceans are the tides. These are caused by the gravitational forces between the earth and the sun and the moon. The moon has the biggest influence because it is close. It essentially pulls up a bulge in the ocean on the side of the earth closest to it. It actually pulls up the land too, but not as much. There is also a bulge on the side opposite the moon.

The regular rise and fall of the ocean's waters are known as tides. Along coasts, the water slowly rises up over the shore and then slowly falls back again. When the water has risen to its highest level, covering much of the shore, it is at high tide. When the water falls to its lowest level, it is at low tide. Some lakes and rivers can also have tides.

The alternating advance and retreat of seawater along a coastline is called a tide. High tide is when water advances to its furthest extent onto the shoreline. Low tide is when it recedes to its furthest extent. Some freshwater rivers and lakes can have tides, too. A high tide that is significantly higher than normal is called a king tide. It often accompanies a new moon and when the moon is closest to the Earth.

Tides are very long period waves that move through the oceans in response to the forces exerted by the moon and sun. Tides originate in the oceans and progress toward the coastlines where they appear as the regular rise and fall of the sea surface. When the highest part, or crest of the wave reaches a particular location, high tide occurs; low tide corresponds to the lowest part of the wave, or its trough. The difference in height between the high tide and the low tide is called the tidal range.

CHARACTERISTICS OF TIDES

- A horizontal movement of water often accompanies the rising and falling of the tide. This is called the tidal current.

- The incoming tide along the coast and into the bays and estuaries is called a flood current;
- the outgoing tide is called an ebb current.
- The strongest flood and ebb currents usually occur before or near the time of the high and low tides.
- The weakest currents occur between the flood and ebb currents and are called slack tides.
- In the open ocean tidal currents are relatively weak.
- Near estuary entrances, narrow straits and inlets, the speed of tidal currents can reach up to several kilometers per hour
- Because the Earth's surface is not uniform, tides do not follow the same patterns in all places.
- The shape of a seacoast and the shape of the ocean floor both make a difference in the range and frequency of the tides.
- Along a smooth, wide beach, the water can spread over a large area.
- The tidal range may be a few centimeters.
- In a confined area, such as a narrow, rocky inlet or bay, the tidal range could be many meters.
- The lowest tides are found in enclosed seas like the Mediterranean or the Baltic.
- They rise about 30 centimeters (about a foot). The largest tidal range is found in the Bay of Fundy, Canada.
- There, the tides rise and fall almost 17 meters (56feet).

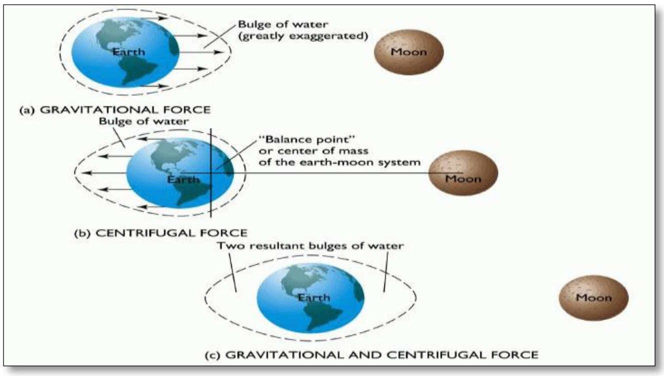
Tides are the short term periodic rise and fall of the world's oceans. They result from the gravitational interaction between the Earth, the moon and to a lesser extent, the Sun. Different parts of the world experience different tidal regimes. Around the UK, there are mostly two high tides and two low tides each day: this is called a semi-diurnal regime. Other parts of the world have a diurnal tidal regime with only one high tide and one low tide each day. The difference in height between high tide and low tide is called the tidal range.

Most shorelines experience two high and two low tides within a twenty four hour period, though some areas have just one of each.

A coastline's physical features, such as a wide sandy beach or a rocky cave, along with the depth of the water just offshore, affect the height of the tides.

Causes of Tides

- Forces that contribute to tides are called tidal constituents. The Earth's rotation is a tidal constituent.
- The major tidal constituent is the moon's gravitational pull on the Earth.
- The closer objects are, the greater the gravitational force is between them.
- Although the sun and moon both exert gravitational force on the Earth, the moon's pull is stronger because the moon is much closer to the Earth than the sun is.
- The moon's tidal force has a much greater effect on the surface of the ocean, of course.
- Water is liquid and can respond to gravity more dramatically.



1) The moon's gravitational pull on the earth is one of the main factor that causes high and low tides. The side of the earth closest to the moon experiences the moon's pull the strongest, and this causes the seas to rise, creating high tides.

Twice each month, the moon lines up with the Earth and sun. These are called the new moon and the full moon. When the moon is between the Earth and the sun, it is in the sun's shadow and appears dark. This is the new moon. When the Earth is between the sun and moon, the moon reflects sunlight. This is the full moon.

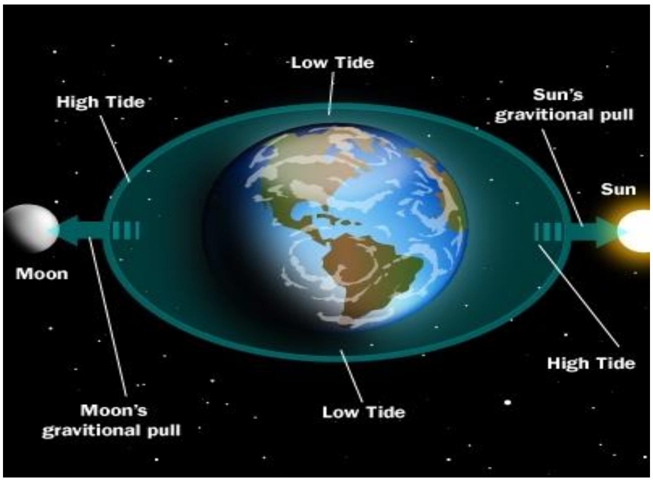
2) On the side facing away from the moon, the **rotational force of the earth** is stronger than the moon's gravitational pull. The rotational force causes water to pile up as the water tries to resist that force, so high tides form on this side, too. Elsewhere on the earth, the ocean recedes, producing low tides.

Because of centrifugal force (more an effect of the earth and moon revolving together than an actual force), the ocean on the side of the earth opposite the moon is sort of thrown outward.

Since it takes 24 hours for the earth to complete a rotation, plus we have to catch up a little because while the earth was rotating, the moon was revolving around the earth, we are directly under a bulge, or experiencing high tide, about every 6 1/2 hours.

3) The **gravitational attraction of the sun** also plays a small role in the formation of tides.

Tides move around the earth as bulges in the ocean.



Types of tides

High tides

The tidal force exerted by the moon is strongest on the side of the earth facing the moon. It is weakest on the side of the earth facing the opposite direction. These differences in gravitational force allow the ocean to bulge outward in two places at the same time.

- One bulge occurs on the side of the earth facing the moon. This is the moon's direct tidal force pulling the ocean toward it.
- The other bulge occurs on the opposite side of the earth. Here, the ocean bulges in the opposite direction of the moon, not toward it.

Low tides and ebb tides

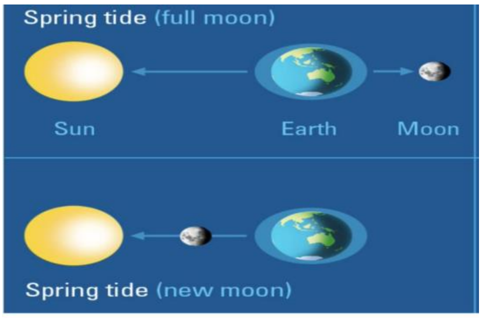
One high tide always faces the moon, while the other faces away from it. Between these high tides are areas of lower water levels low tides. The flow of water from high tide to low tide is called an ebb tide. Most tides are semidiurnal, which means they take place twice a day. For example, when an area covered by the ocean faces the moon, the moon's gravitational force on the water causes a high High tide.

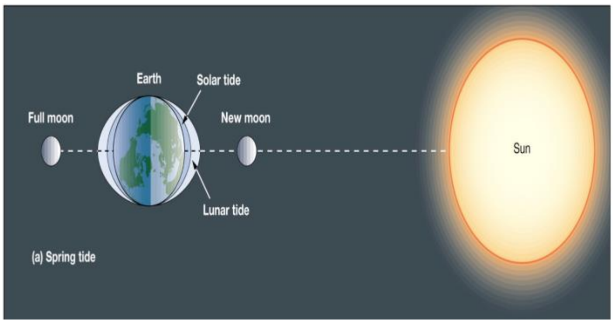
As the earth rotates, that area moves away from the moon's influence and the tide ebbs. Now it is low tide in that area. As the earth keeps rotating, another high tide occurs in the same area when it is on the side of the earth opposite the moon (low high tide). The earth continues spinning, the tide ebbs, another low tide occurs, and the cycle (24 hours long) begins again.

Twice daily tides like this are called semidiurnal tides. It is also possible to have only one high and one low tide per day. That would be a diurnal tide.

Spring tides

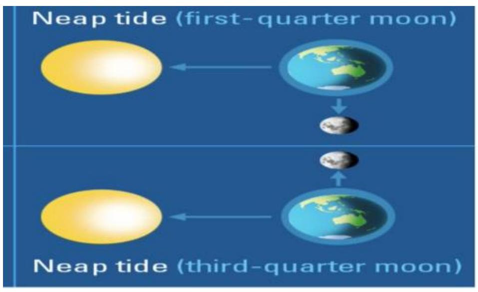
When the sun, moon and earth are all lined up, the sun's tidal force works with the moon's tidal force. The combined pull can cause the highest and lowest tides, called spring tides. Spring tides happen whenever there is a new moon or a full moon

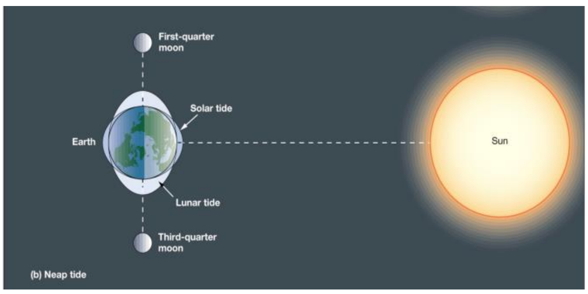




Neap tides

In the period between the two spring tides, the moon faces the earth at a right angle to the sun. When this happens, the pull of the sun and the moon are weak. This causes tides that are lower than usual. These tides are known as neap tides.





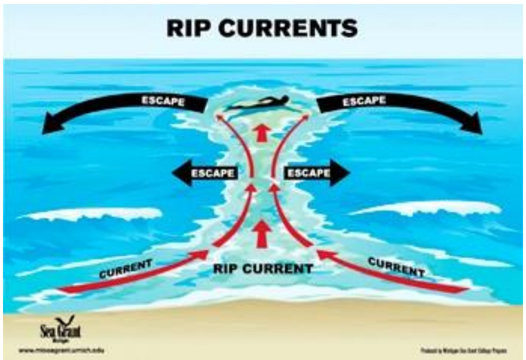
A red tide is another term for an algal bloom. Algae are microscopic sea creatures. When billions of red algae form, or “bloom,” in the ocean, the waves and tides appear red. The term **red tide** is most often used in the US to refer to Karenia brevis blooms in the eastern Gulf of Mexico, also called the Florida **red tide**.These blooms have been documented since the 1800s, and occur almost annually along Florida's coasts.

Rip tides are strong ocean currents running along the surface of the water.

A rip tide runs from the shore back to the open ocean.

Rip tides can be helpful to surfers, who use them to avoid having to paddle out to sea.

Rip tides can also be very dangerous to swimmers, who can be swept out to sea.



Tidal features

1. Tidal bore

Tides produce some interesting features in the ocean.

A tidal bore occurs along a coast where a river empties into the ocean or sea.

The tidal bore is a strong tide that pushes up the river, against the river's current. This is a true tidal wave.

2. Pororoca

The huge tidal bore of the amazon river is called the *pororoca*.

The *pororoca* is a wave up to 4 meters (13 feet) tall,

Traveling at speeds of 15 kilometers (9 miles) per hour.

The *pororoca* travels 10 kilometers (6 miles) up the amazon.

3. INTERTIDAL ZONE

Tides driven by the gravitational pull of the moon create a unique marine ecosystem known as the intertidal zone where animals must be able to survive waves and daily dry periods.

The land in the tidal range is called the intertidal zone.

4. TIDE POOLS

- The intertidal zone is often marked by tide pools.
- Tide pools are areas that are completely underwater at high tide but remain as pockets of seawater when the tide ebbs.
- Tide pools are home to some of the ocean's richest biodiversity.
- Tides form tide pools.
- These small pools of water are often left behind among the rocks at low tide.
- They can include a diverse population of tiny plants and animals that may serve as food for larger species.

IMPORTANCE OF TIDES

- Tides affect other aspects of oceanic life, including the reproductive activities of fish and ocean plants.
- Floating plants and animals ride the tidal currents between the breeding areas and deeper waters.
- The tides help remove pollutants and circulate nutrients ocean plants and animals need to survive.
- Predicting tides is very important for shipping and travel across oceans.
- Ships decide which channels they may navigate by calculating their own weight, the depth of the ocean and an area's tidal range.
- Errors in navigation can strand ships along shores or on sand banks.
- Tides affect marine ecosystems by influencing the kinds of plants and animals that thrive in what is known as the intertidal zone.

- Because the area is alternately covered and uncovered by the ocean throughout the day, plants and animals must be able to survive both underwater and out in the air and sunlight. They must also be able to withstand crashing waves.
  Tidal zone foods

- Crabs, mussels, snails, sea weed and other edible sea life inhabit the tidal zone.
- Small tide pools may also contain small fish and sea vegetables.
- The sea lives found in these regions are often harvested for food.
- Without the regular washing of the tides, these complex and abundant creatures would die and food resources would diminish.

NAVIGATION

Tides affect the depth and currents in and around coastal areas. Ships may need to navigate the waters during high tide in some areas or risk running aground. Pilots take into consideration the water level, width of channels and direction of the water flow to determine the best time to travel. Pilots may choose to travel when tides are at ebb in order to get tall loads under bridges.

Tidal flows can also help or impede the progress of a ship in the water. Pilots can take advantage of the current to get the craft where it needs to go. A thorough understanding of how tides affect navigation and how to use the tides in navigation can improve the productivity of marine and inland shipping.

WEATHER

Tides and tidal currents affect the weather by stirring the ocean waters. The tides and tidal currents mix arctic water that can't absorb lots of sunlight with warmer topic water that does. The stirring produces more predictable and habitable climate conditions and balances temperatures on the planet.

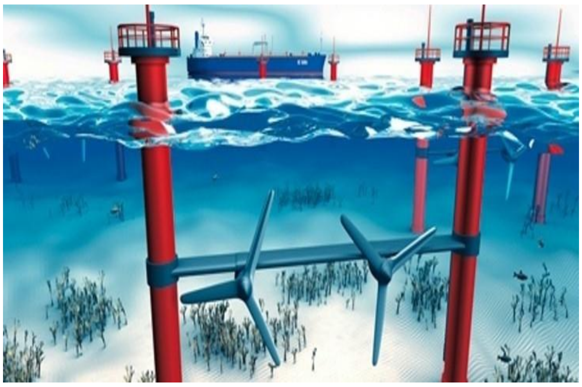
TIDES AND PEOPLE

- Tidal energy is a renewable resource that many engineers and consumers hope will be developed on a large scale.
- Now, small programs in Northern Ireland, South Korea, and the U.S. state of Maine are experimenting with harnessing the power of tides.

- There are three different types of tidal power. All of these use tidal energy generators to convert that power into electricity for use in homes and industry.

TIDAL ENERGY

Two high tides and two low tides occur during every 24 hour period. The predictability of the tides, fast movement of water during the inflow and outflow can provide a source of renewable energy to communities living along the coast. Hydroelectric plants can exploit the water flow in ways similar to those used on rivers.



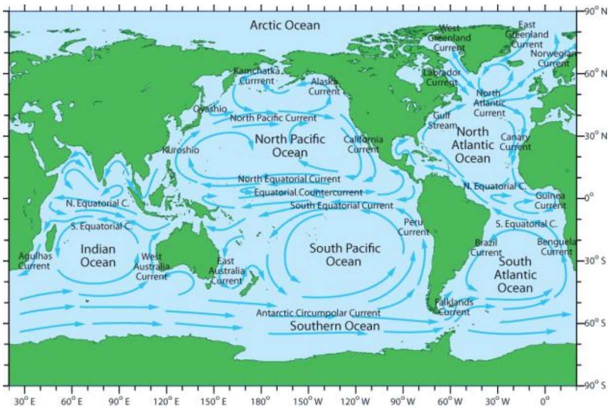
OCEAN CURRENTS

Ocean currents are the continuous, predictable, directional movement of seawater driven by gravity, wind (Coriolis Effect), and water density. Ocean water moves in two directions: horizontally and vertically. Horizontal movements are referred to as currents, while vertical changes are called up wellings or down wellings. This abiotic system is responsible for the transfer of heat, variations in biodiversity, and Earth's climate system.

An **ocean current** is any more or less permanent or continuous, directed movement of **ocean water** that flows in one of the Earth's **oceans**. The **currents** are generated from the forces acting upon the **water** like the earth's rotation, the wind, the temperature and salinity differences and the gravitation of the moon.

An **ocean current** is a continuous, directed movement of sea water generated by a number of forces acting upon the water, including wind, the Coriolis effect, breaking waves, cabbeling, and temperature and salinity differences. Depth contours, shoreline configurations, and interactions with other currents influence a current's direction and strength. Ocean currents are primarily horizontal water movements.

The modern **definition of ocean currents** describes the movement of ocean water flowing continuously. The definition also portrays currents as a kind of conveyor belt moving warm water from the tropics to the cold poles, and then from the cold poles back to the tropics. This movement and change in temperature greatly affect the Earth's climate.



Effects of Ocean Currents

The effects of ocean currents on the globe are significant and far reaching. Ocean currents regulate the Earth's climate and make up for the difference in solar energy radiation hitting the surface of the planet.

As such, water current **distributes heat**. The ocean absorbs most of the sun's radiation on Earth, in contrast to the atmosphere and to land. The climates of the Earth are regulated by this heat distribution and therefore are moderated.

An ocean current flows for great distances and together they create the global conveyor belt, which plays a dominant role in determining the climate of many of Earth's regions. More specifically, ocean currents influence the temperature of the regions through which they travel.

Types of Ocean Currents

Warm Currents

Warm ocean currents flow away from the equatorial region on the western side of ocean basins. The Gulf Stream in the North Atlantic and the Kuroshio Current in the North Pacific are examples of warm currents. Of all the warm currents, the Gulf Stream has been studied most extensively. A narrow, intense flow of warm water, the Gulf Stream begins in the Caribbean Sea and follows the east coast of the United States northward around Cape Hatteras, North Carolina. There the current veers northeastward across the Atlantic Ocean, where it is called the North Atlantic Drift. The current carries warm water to Iceland and the British Isles. As a result, these places have warmer climates than they would otherwise. (Hence there are palm trees along the coast of Ireland.) The Gulf Stream forms the western and northern boundary of the Sargasso Sea, which is located in the middle of the North Atlantic Ocean. An area of warm water and light winds, the Sargasso Sea has relatively calm seas. Great amounts of floating brown seaweed called sargassum are typically found on the surface water there. Similar conditions exist in other oceans, but nowhere are they as well developed as in the North Atlantic.

Cold Currents

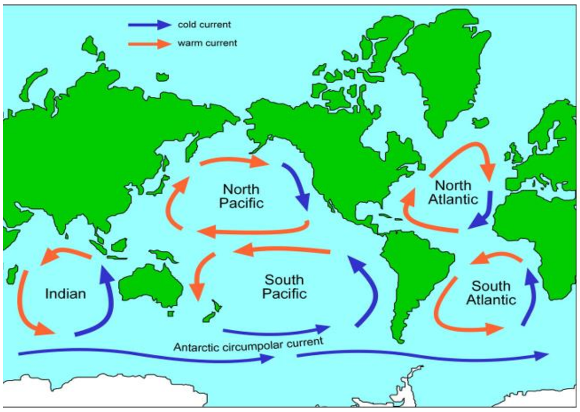
Cold currents flow toward the equator on the eastern side of ocean basins. Examples of cold ocean currents include the Canary Current in the North Atlantic, the California Current in the North Pacific, and the Benguela Current in the South Atlantic. Cold currents can also flow out of far northern regions. The Labrador Current flows out of Baffin Bay and past Labrador, the coastal part of the Canadian province of Newfoundland. The current carries icebergs from Baffin Bay, creating a hazard for ships in the North Atlantic. The Labrador Current meets the Gulf Stream off the coast of Newfoundland. When warm, moist air from the Gulf Stream blows over the cold Labrador Current, water vapor condenses. This results in some of the thickest fogs in the world. Two other important cold currents originate in northern regions. The East Greenland Current flows into the North Atlantic through the Strait of Denmark. The Oyashio Current flows through the Bering Strait between Siberia and Alaska and into the North Pacific.

Surface currents are wind driven ocean currents that occur in the upper parts of the ocean. Surface currents affect the circulation of heat and fresh water. While wind moves surface currents, the Coriolis force affects the direction in which they travel.

The *Gulf Stream* is a famous type of ***western boundary current***, a fast surface current that moves toward the North Pole along the eastern edge of North America. It then moves southward along the western edge of Europe. The Gulf Stream moderates the temperatures of Europe.

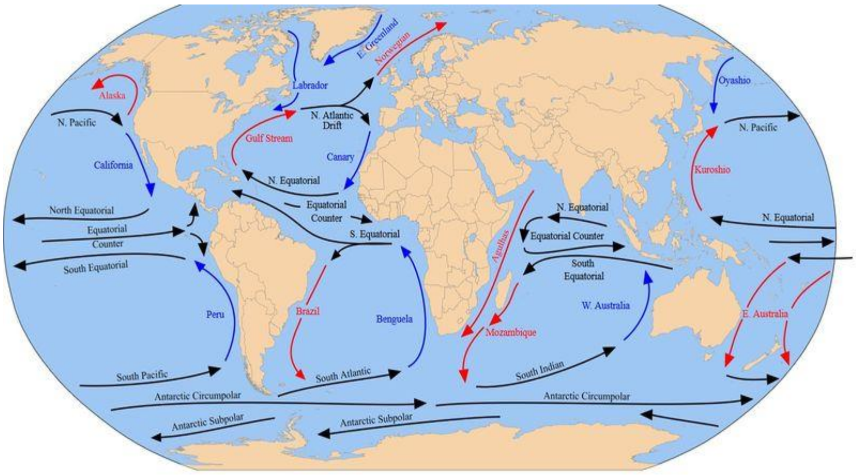
Eastern boundary currents are not as fast as western boundary currents. They tend to be shallower and wider, and they move cold water to tropical regions. One example of an Eastern boundary current is the *California current*.

Gyres are surface currents that center in ocean basins. These immense currents rotate in a clockwise fashion in the Northern Hemisphere, whereas in the Southern Hemisphere, they move counterclockwise.

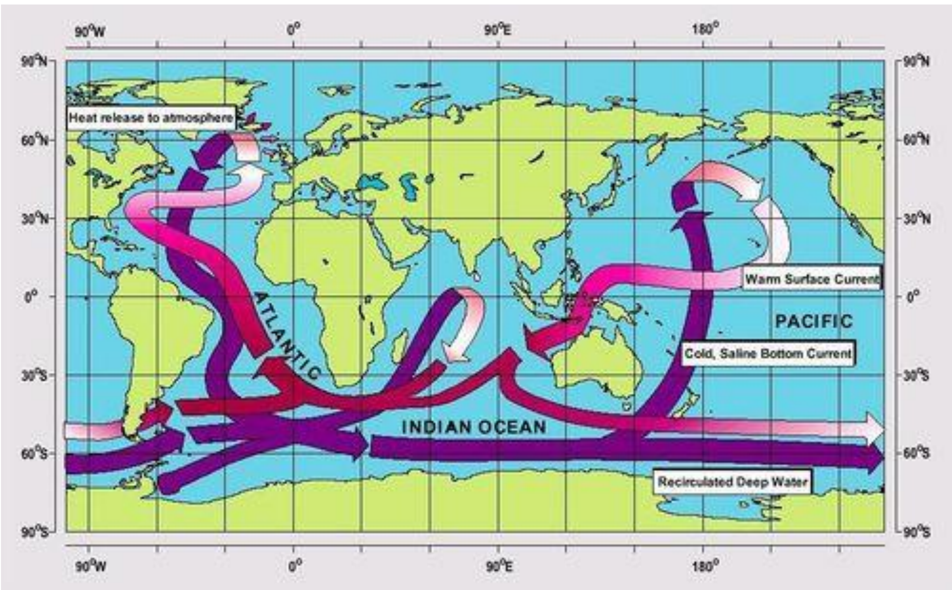


Ocean surface currents

The most famous ocean current, the *Gulf Stream*, is a vast moving mass of water, transporting an enormous amount of heat from the Caribbean across the ocean to Europe. It passes by the US east coast as a narrow jet, due to the northward increase of the Coriolis Effect and then spreads out as a meandering current over the ocean while generating a series of meso scale eddies and whirls. The North Atlantic Gyre is completed by the *Canary Current* in the Eastern Atlantic that transports relatively cold water south and west. The *Kuroshio* is a warm boundary current in the north-western Pacific, similar to the *Gulf Stream*. It is part of the large gyre formed by the *California Current* and the *North Equatorial Current*. The *North Equatorial Current* and *South Equatorial Current* are driven by the easterly trade winds over the Pacific. The Southern Pacific Gyre is completed by the warm *West Australian Current* and the cold *Peru Current*.



Thermohaline circulation OR Deep ocean circulation is primarily driven by density differences. It is called *thermohaline circulation*, because density differences are due to temperature and salinity. Density differences are small and the flow velocity is low, of the order of a few cm/s. However, the water masses moving around by thermohaline circulation are huge. Water fluxes are of the order of 20 million m3/s. Density gradients alone is not sufficient for sustaining the deep ocean circulation.



Importance of deep ocean circulation

The deep ocean is a huge storehouse of heat, carbon, oxygen and nutrients. Deep ocean circulation regulates uptake, distribution and release of these elements. The low overturning rate stabilizes our global climate. By carrying oxygen into the deeper layers it supports the largest habitat on earth.

IMPORTANCE OF OCEAN CURRENTS

By redistributing heat over the globe, ocean currents have a major impact on the global climate. They cause the relative mildness of the Western European climate, for example. Ocean and atmospheric currents form a coupled dynamic system. Ocean currents not only distribute heat, but they also play a crucial role in the global ecosystem by storing CO_2 and recycling nutrients.

Human Activities and Ocean Currents

Humans have relied upon ocean currents in vastly different ways over the course of history. Human survival owes much to ocean currents, without which the Earth might not be habitable. Ocean currents regulate climate and prevent it from becoming overly extreme**.**

People have used ocean currents to **explore the Earth**. Ocean currents affect the shipping industry, commercial and recreational fishing, and recreational navigation for boats. Having updated information on currents is directly related to how safely people can dock or navigate along coasts.

Ocean currents play a role in the **distribution of pollution**, such as oil spills. Oil and fuel tends to remain on the surface of the ocean, so knowing the current helps determine where such pollution might travel.

Safety operations such as rescues use currents to help look for missing people or other objects in the sea. Swimmers must educate themselves about ocean currents to avoid rip tides and other hazards.

Effects on climate and ecology

Ocean currents are important in the study of marine debris, and vice versa. These currents also affect temperatures throughout the world. For example, the ocean current that brings warm water up the north Atlantic to northwest Europe also cumulatively and slowly blocks ice from forming along the seashores, which would also block ships from entering and exiting inland waterways and seaports, hence ocean currents play a decisive role in influencing the climates of regions through which they flow.

Cold ocean water currents flowing from polar and sub Polar Regions bring in a lot of plankton that are crucial to the continued survival of several key sea creature species in marine ecosystems. Since plankton is the food of fish, abundant fish populations often live where these currents prevail.

Ocean currents are also very important in the dispersal of many life forms.

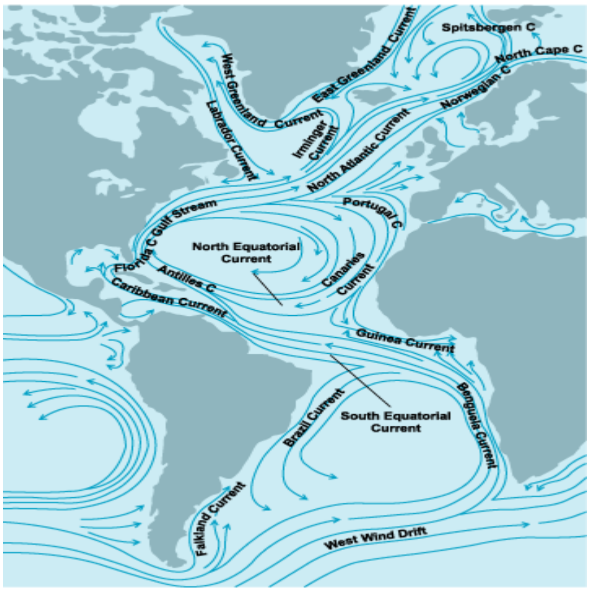
Economic importance

Knowledge of surface ocean currents is essential in reducing costs of shipping, since traveling with them reduces fuel costs. In the wind powered sailing ship era, knowledge of wind patterns and ocean currents was even more essential. A good example of this is the Agulhas Current, which long prevented sailors from reaching India. In recent times, around the world sailing competitors make good use of surface currents to build and maintain speed. Ocean currents can also be used for marine power generation, with areas off of Japan, Florida and Hawaii being considered for test projects.

<u>ATLANTIC OCEAN CURRENTS</u>

North Equatorial Current (warm)

North equatorial current is a significant Pacific and Atlantic Ocean current that flows east-to-west between about 10° north and 20° north. This current is generated because of upwelling of cold-water near the west coast of Africa. This warm current is also pushed westward by the cold Canary current.



On an average, the north equatorial warm current flows from east to west but this saline current is deflected northward when it crosses the mid-Atlantic Ridge near 15°N latitude. It again turns southward after crossing over the ridge. This current, after being obstructed by the land barrier of the east coast of Brazil, is bifurcated into two branches viz. Antilles current and Caribbean current. The Antilles current is diverted northward and flows to the east of West Indies islands, and helps in the formation of Sargass Sea eddy while the second branch known as the Caribbean current enters the Gulf of Mexico and becomes Gulf Stream.

South Equatorial Current (warm)

The South Equatorial Current is a significant Pacific, Atlantic, and Indian Ocean current that flows east-to-west between the equator and about 20 degrees south. In the Pacific and Atlantic Oceans, it extends across the equator to about 5 degrees north. South equatorial current flows from the western coast of Africa to the eastern coast of South America between the equator and 20°S latitude. This current is more constant, stronger and of greater extent than the north equatorial current. In fact, this current is the continuation of the cold **Benguela current.** This warm current is bifurcated into two branches due to obstruction of land barrier in the form of the east coast of Brazil.

The northward branch after taking north-westerly course merges with the north equatorial current near Trinidad while the second branch turns southward and continues as Brazil warm current parallel to the east coast of South America. This current is basically originated under the stress of trade winds.

Equatorial Counter Current

Equatorial Counter Current is a significant ocean current in the Pacific and Indian oceans that flows west-to-east at approximately five degrees north. The Counter Currents result from balancing the westward flow of water in each ocean by the North and South Equatorial currents.

In El Nino years, Equatorial Counter current intensifies in the Pacific Ocean.

The Equatorial Counter current flows from west to east in between the westward flowing strong north and south equatorial currents. This current is less developed in the west due to stress of trade winds. In fact, the counter current mixes with the equatorial currents in the west but it is more developed in the east where it is known as the **Guinea Stream**. The Equatorial Counter current carries relatively higher temperature and lower density than the two equatorial currents. Several ideas have been put forth to explain the origin of the Equatorial Counter current. According to some scientists this current is originated because of the influence of the westerlies which blow from west to east in the calm zone of the doldrums or in the convergence zone of the north east and south east trade winds.

Gulf Stream

The Gulf Stream is a system of several currents moving in north easterly direction. This current system originates in the Gulf of Mexico around 20°N latitude and moves in north easterly direction along the eastern coast of North America and reaches the western coasts of Europe near 70°N latitude. This system, named Gulf Stream because of its origin in the Mexican Gulf, consists of

- Florida current from the strait of Florida to Cape Hatteras,
- Gulf Stream from Cape Hatteras to the Grand Bank, and
- North Atlantic Drift (current) from Grand Bank to the Western European coast.

North Equatorial Current flows westward off the coast of northern Africa. When this current interacts with the northeastern coast of South America, the current forks into two branches. One passes into the Caribbean Sea, while a second, the Antilles Current, flows north and east of the West Indies. These two branches rejoin north of the Straits of Florida. Thus, Florida current is in fact, the northward extension of the north equatorial current. This current flow through Yucatan channel into the Gulf of Mexico, thereafter the current moves forward through Florida Strait and reaches 30°N latitude. Thus, the Florida warm current contains most of the characteristics of the equatorial water mass.

The trade winds blow westward in the tropics, and the westerlies blow eastward at mid-latitudes. This wind pattern applies a stress to the subtropical ocean surface with negative curl across the North Atlantic Ocean. The resulting Sverdrup transport is Equator ward. Because of conservation of potential vorticity caused by the northward-moving winds on the subtropical ridge's western periphery and the increased relative vorticity of northward moving water, transport is balanced by a narrow, accelerating pole ward current, which flows along the western boundary of the ocean basin, outweighing the effects of friction with the western boundary current known as the Labrador Current. The conservation of potential vorticity also causes bends along the Gulf Stream, which occasionally break off due to a shift in the Gulf Stream's position, forming separate warm and cold eddies. This overall process, known as western intensification, causes currents on the western boundary of an ocean basin, such as the Gulf Stream, to be stronger than those on the eastern boundary.

As a consequence, the resulting Gulf Stream is a strong ocean current. It transports water at a rate of 30 million cubic meters per second through the Florida Straits. As it passes south of Newfoundland, this rate increases to 150 million cubic meters per second.

The average temperature of water at the surface is 24°C while the salinity is 3.6%. The temperature never falls below 6.5°C. The current becomes narrow while passing through the Florida Strait but thereafter its width increases and current flows close to coast.

Canary Current (Cold)

The Canary current, a cold current, flows along the western coast of North Africa between Maderia and Cape Verde. In fact, this current is the continuation of North Atlantic Drift which turns southward near the Spanish coast and flows to the south along the Coast of Canaries Island. The average velocity of this current is 8 to 30 nautical miles per day. This current brings cold water of the high latitudes to the warm water of the low latitudes and finally merges with the north equatorial current. The Canary cold current ameliorates the otherwise hot weather conditions of the western coasts of North Africa.'

Labrador Current (Cold)

The Labrador Current, an example of cold current, originates in the Baffin Bay and Davis Strait and after flowing through the coastal waters of Newfoundland and Grand Bank merges with the Gulf Stream around 50°W longitude. The flow discharge rate of the current is 7.5 million ml of water per second. This current brings with it a large number of big icebergs as far south as Newfoundland and Grand Bank. These icebergs present effective hindrances in the oceanic navigation. Dense fogs are also produced due to the convergence of the Labrador cold current and the Gulf Stream near Newfoundland.

Brazil Current (Warm)

The Brazil current is characterized by high temperature and high salinity. This current is generated because of the bifurcation of the south equatorial current because of obstruction of the Brazilian coast near Sun Rock. The northern branch flows northward and merges with the north equatorial current while the southern branch known as the Brazil current flows southward along the east coast of South America up to 40°S latitude. Thereafter it is deflected eastward due to the deflective force of the rotation of the earth and flows in easterly direction under the influence of westerlies. The Falkland cold current coming from south merges with Brazil current at 40° S.

Falkland Current (Cold)

The cold waters of the Antarctic Sea flows in the form of Falkland cold current from south to north along the eastern coast of South America up to Argentina. This current becomes most extensive and developed near 30°S latitude. This current also brings numerous icebergs from the Antarctic area to the South American coast.

South Atlantic Drift (Cold)

The eastward continuation of the Brazil current is called South Atlantic Drift. This current is originated because of the deflection of the Brazil warm current eastward at 40°8 latitude due to the deflective force of the rotation of the earth. The South Atlantic Drift, thus, flows eastward under the influence of the westerlies. This current is also known as the Westerlies Drift or the Antarctic Drift.

Benguela Current (Cold)

The Benguela current, a cold current, flows from south to north along the western coast of south Africa. In fact, the South Atlantic Drift turns northward due to obstruction caused by the southern tip of Africa. Further northward, this current merges with the South Equatorial Current.

INDIAN OCEAN CURRENTS

The circulation current of Indian Ocean is different from the Pacific and the Atlantic Ocean. The Indian Ocean is surrounded by huge landmass of Eurasia in the north and is only half the ocean. Hence the circulation in the South Indian Ocean is similar to the other two oceans while the circulation in the North Indian Ocean is completely different. The monsoon winds also play a peculiar role in the reversal of the direction of currents in the North Indian Ocean.

The Indian Ocean gyre is composed of two major currents: the **South Equatorial Current**, and the West Australian Current. Normally moving counter clockwise, in the winter the Indian Ocean gyre reverses direction due to the seasonal winds of the South Asian Monsoon.

Currents in the Indian Ocean include the following:

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

- Madagascar Current (Warm)
- Agulhas Current (Warm)
- West Australian Current (Cold)

The North Indian Ocean Circulation

The currents in the North Indian Ocean are affected by the landmass of Eurasia and the monsoon winds. Hence there is a change in the direction of the currents from season to season in response to the seasonal rhythm of the monsoons.

Summer Circulation

- The North Equatorial current and counter equatorial current is absent in summer.
- Due to the influence of south west monsoon and the absence of north east trade winds, a strong current flows from west to east in the summer season.
- The **South West monsoon Drift** originates is summer and from June to September, the North Equatorial current is replaced by an easterly movement of water.
- Thus the circulation of currents is in a clockwise direction.
- **Somali current** is also formed in summer by the eastward movement of water caused by the South West monsoon Drift. It flows from the 'Horn of Africa' in the north east of Africa. It is a cold current and due to the region of upwelling, Somali and its neighbouring countries are arid.

Winter Circulation

- **North Equatorial current** is formed in winter under the influence of North east trade winds.

- It originates from the south of Indonesia and flows from east to west towards the south of Srilanka.
- The **North East Monsoon Drift** is also formed in winter starting from December when the North East monsoon causes westwards and southwards drift along the eastern coasts of India and along the Arabian coast.
- This generates an anti clockwise circulation in the Arabian Sea and the Bay of Bengal.

Southern Indian Ocean

The circulation in South Indian Ocean is continuous unlike North Indian Ocean and is not affected by the change of seasons.

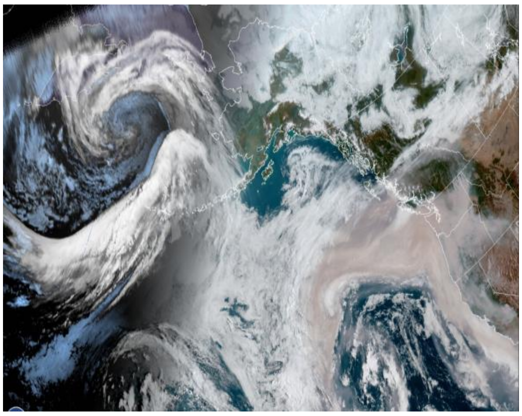
- **South Equatorial Current:** The South East Trade winds originate the South Equatorial Current. It flows from east to west and is a warm current. The flow of this current is strengthened by the South Pacific Equatorial current through Indonesia.
- **Equatorial Counter Current:** At the equator, there is upwelling in winter due to North and South Equatorial currents and this causes the generation of Equatorial counter current.
- The South Equatorial current splits into two branches by the Madagascar Island: **The Madagascar current and the Mozambique current.**
- These flow along the east of Madagascar and east of Mozambique respectively to converge at the Cape of Agulhas. Henceforth this current is known as **Agulhas current.**
- All the three currents are warm currents.
- The Agulhas current joined by the **West Wind Drift** or the Antarctic Circumpolar Current and is deviated to its justify by the landmass of Australia.
- This flows as the **West Australian current** along the west coast of Australia in the northern direction to finally reach the South Equatorial current, thus completing the anti-clockwise circulation in the South Indian Ocean.
- Since it is formed by West Wind Drift, West Australian current is a cold current.

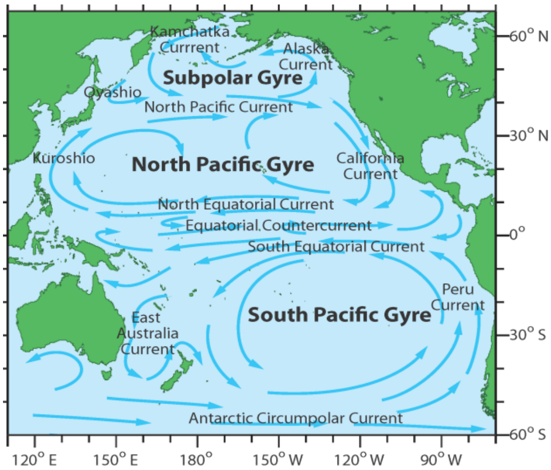
PACIFIC OCEAN CURRENTS

Pacific Ocean Currents includes various cold and warm current which moves clockwise circulation in Northern Pacific Ocean and Anticlockwise circulation in South Pacific Ocean thereby influencing the climatic pattern in the coastal regions. The currents are mentioned below

North Equatorial Current (Warm)

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





Equatorial Currents

- These start on the west coast of Central America and under the influence of the prevailing trade winds traverse east to west.
- Due to larger expanse of the Pacific ocean and absence of any obstructing landmass, the volume of water in the Equatorial Pacific currents is much larger than that of the Equatorial Atlantic currents.

Equatorial Counter Current

- Due to the convergence of a large mass of water from the equatorial currents in the western Pacific near Indonesia and Australia, there is piling up water due to which the sea level rises by a few centimeters.
- This creates an equatorial Countercurrent between the North Pacific and South Pacific Current.
- This current flows from West to East.

Since all the above currents originate and flow near the equator, they are warm currents.

Kuroshio Current

- The North Equatorial Current under the influence of the North-east Tradewinds flows off the coasts of Philippines and Formosa as the Kuroshio current in the East China Sea.
- This is also known as Kuru Siwo or Japan Current.
- Most of it lies in the subtropical high-pressure belt and is under the influence of the westerlies.
- Since it carries the equatorial waters, it is a Warm current.

North Pacific Drift

- The warm waters of the Kuroshio Current are carried pole wards as the North Pacific Drift.
- This current keeps the ports of Alaska ice-free in winter.
- This current splits into two: The Alaskan current and the California Current.

Alaskan Current

- This results from the northward diversion of the North Pacific Drift.
- This current is relatively warm compared to the surrounding waters of the region.
- It flows along the coast of British Columbia and Alaskan Panhandle.

Californian Current

- The south branch of the North Pacific Drift flows as the cold Californian current along the coast of Western U.S.A and joins the North Equatorial Current.

- This completes the clockwise circulation of the currents in the Northern Pacific.
- This cold current is one of the reasons for the dry conditions along the West coast of the USA and the state of California.

Oyashio Current

- Also known as Oya Siwo, Okhotsk or the Kurile current is a cold subarctic current flowing from the Bering Strait.
- It flows southwards in a counter-clockwise direction and joins the Kuroshio current off the Japanese island of Hokkaido.
- Since this region forms the convergence of warm and cold water currents, it has ecological and economic significance to Japan.

North Pacific Gyres

- The Northen Pacific Gyres include the North Pacific Subtropical Gyre and North Pacific Subpolar Gyre.
- The North Pacific Subtropical Gyre is one of the largest ecosystems on the Earth, with phytoplankton and marine organisms.
- It is surrounded by:
  - Kurushio current on the West,
  - North Pacific Drift on the North,
  - California current on the East and
  - North Equatorial Current on the South.
- The North Pacific Subpolar Gyre is composed of the north-flowing Alaskan current and Aleutian current also known as Sub-arctic current and the south-flowing Oyoshio current.
- The North Pacific Drift separates the North Pacific Subtropical and Subpolar Gyres.

East Australian Current

- The South Equatorial current flows from east to west in the Southern Hemisphere and on reaching the landmass of Australia and under the influence of South East, Trade winds flows southwards as the East Australian Current.

- As this carries the Equatorial waters into temperate regions, it is a warm current.

South Pacific Current

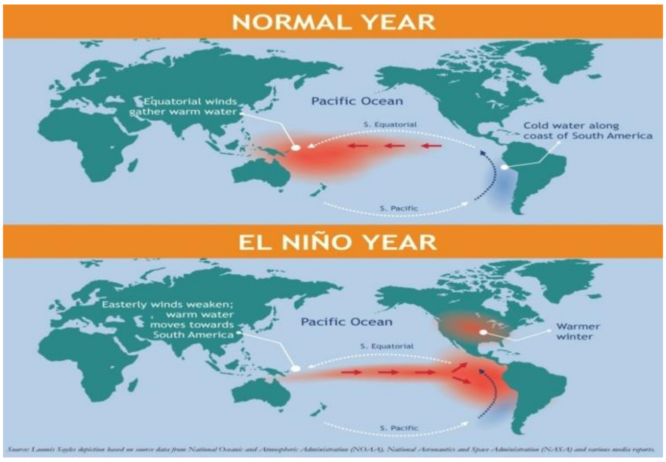
- The East Australian current turns eastwards towards New Zealand under the influence of Westerlies in the Tasman Sea.
- It then merges with the West Wind Drift or the Antarctic Circumpolar Current as the South Pacific Current.

Peruvian Current

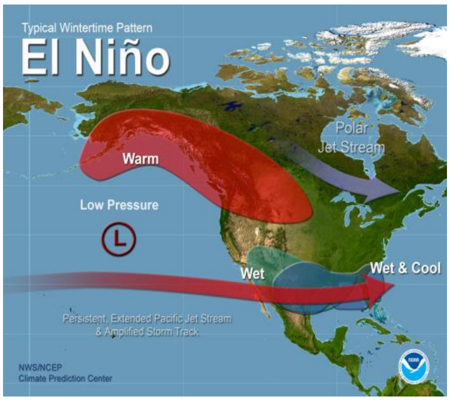
- The South Pacific Current is obstructed by the tip of Southern Chile and flows northwards as the Peruvian current.
- This is also known as the Humboldt Current.
- Since it brings waters of the West wind Drift it is a cold current.
- The cold water chills any winds that blow on-shore so that Chilean and Peruvian coast are practically rainless.
- The Peruvian current eventually links up with the South Equatorial Current completing the anti-clockwise circulation in the South Pacific Ocean.

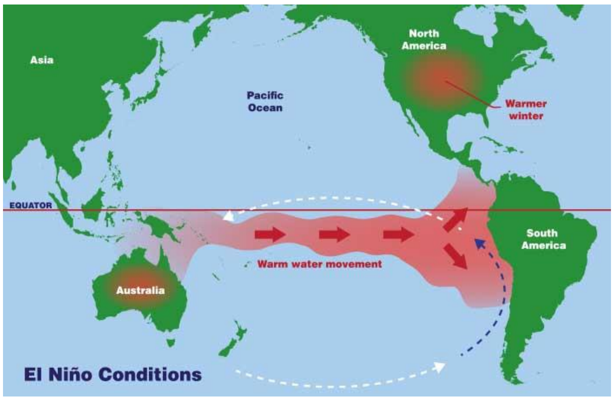
El Nino

El Nino means *The Little Boy*, or *Christ Child* in Spanish. El Nino was originally recognized by fishermen off the coast of Peru in South America in the 1600s, with the appearance of unusually warm water in the Pacific Ocean. The name was chosen based on the time of year (around December) during which these warm waters events tended to occur. The term El Nino refers to the large scale ocean atmosphere climate interaction linked to a periodic warming in sea surface temperatures across the central and east central Equatorial Pacific.



Typical El Nino effects are likely to develop over North America during the upcoming winter season. Those include warmer than average temperatures over western and central Canada, and over the western and northern United States. Wetter than average conditions are likely over portions of the U.S. Gulf Coast and Florida, while drier than average conditions can be expected in the Ohio Valley and the Pacific Northwest. The presence of El Nino can significantly influence weather patterns, ocean conditions, and marine fisheries across large portions of the globe for an extended period of time.





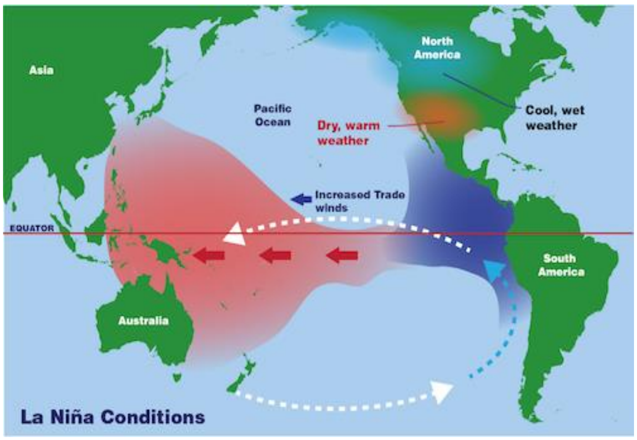
In 1982 and 1983 and again in 1997 and 1998, well recorded El Nino events turned the world's weather upside down. The west coasts of the United States and Peru received record rainfall and flooding, while hurricanes raged in Mexico, Hawaii, and Tahiti. Severe drought and heat struck Australia, Asia, Indonesia, and Africa, causing crop failures, starvation, and forest fires.

El Ninos are part of a recurring weather cycle that is beyond the control of humanity and appears to have occurred for millennia. Thanks to improved research abilities in recent years and the deployment of moored instruments to sense mid ocean conditions, scientists are now able to better understand and predict these climate phenomena.

La Nina

La Nina means *The Little Girl* in Spanish. La Nina is also sometimes called *El Viejo*, *anti-El Nino*, or simply "*a cold event*."La Nina episodes represent **periods of below average sea surface temperatures** across the east central Equatorial Pacific. Global climate La Nina impacts tend to be opposite those of El Nino impacts. In the tropics, ocean temperature variations in La Nina also tend to be opposite those of El Nino. During a La Nina year, winter temperatures are warmer than normal in the Southeast and cooler than normal in the Northwest. La Nina conditions recur every few years and can persist for as long as two years.

La Nina is less understood than El Nino, but it also can have a devastating effect. Under certain conditions, the trade winds are stronger than normal, causing surface waters in the equatorial Pacific to be colder than average, with upwelling occurring as far as the Central Pacific.



Below average sea surface temperatures commonly occur following an El Nino and appear to be associated with weather events opposite that of El Nino. **Monsoons** in the Indian Ocean are wetter than normal while summers in North America are hot and dry. However, winters in northern North America have set records for cold temperatures and snowfall, with an increase in devastating tornadoes in the south during La Nina events.

El Nino and La Nina are opposite phases of what is known as the *El Nino-Southern Oscillation* (**ENSO**) cycle. The ENSO cycle is a scientific term that describes the fluctuations in temperature between the ocean and atmosphere in the east-central Equatorial Pacific (approximately between the International Date Line and 120 degrees West).

La Nina is sometimes referred to as the *cold phase* of ENSO and El Nino as the *warm phase* of ENSO. These deviations from normal surface temperatures can have large scale impacts not only on ocean processes, but also on global weather and climate.

UNIT V

Ocean deposits: Types - Coral reefs: Conditions for growth and types - International Coastal Research Center (ICRC) - Integrated Coastal and Marine Area Management (ICMAM).

OCEAN DEPOSITS

The unconsolidated sediments, derived from various sources, deposited at the sea floors are included in ocean deposits. The study of ocean (marine) deposits includes the consideration of types of sediments, their sources, methods of their transportation, horizontal distribution, lithological successions or vertical variations in their distribution and composition etc.

The sediments derived from weathering and erosion of continental rocks are transported to the oceans by rivers, winds etc. Volcanic eruptions also provide sediments. Besides, the decay and decomposition of marine organisms (both plants and animals) also contribute sediments to ocean deposits.

Types of Ocean Deposits

There are unconsolidated sediments, deposited on the ocean floor. These are ocean deposits. They vary from location to location. The study of ocean deposits is important in understanding the rocks exposed on the earth's surface which were once laid under sea.

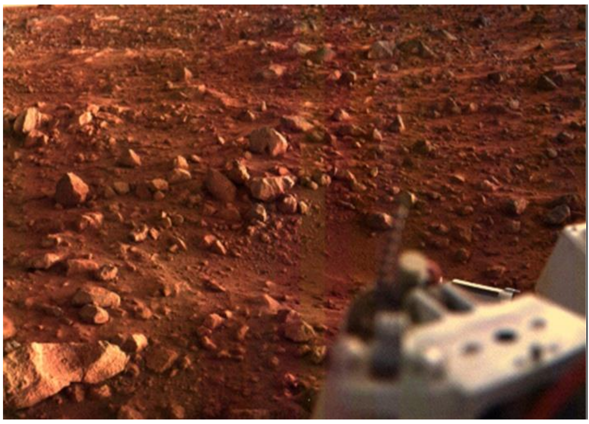
Two Types

The ocean deposits can broadly be divided into two types: the terrigenous deposits and the pelagic deposits.

1. Terrigenous Deposits:

Terrigenous deposits are derived from the wear and tear of land and volcanic and organic products. The greater part of the deposits on the continental shelf and slopes is derived from rock material let loose by disintegration and decomposition by the agents of weathering and carried to sea by the agents of erosion, such as running water, wind, etc.

The process and extent of disintegration depends on the nature of rock material, climate and time taken. The larger particles of the terrigenous deposits are found near the shore and the finer ones carried deeper. The extent to which they are carried outwards depends on the size of rock material and the strength of sea waves and currents.



On the basis of size of particles, the terrigenous deposits may be categorised into three classes: mud, sand and gravel. Mud refers to the finest particles which comprise the minute particles of rock forming minerals, principally quartz. Murray has classified the mud deposits into blue, green and red types, based on the colour of constituents. Sand refers to the coarser particles, while gravel has even bigger particles.

Volcanic Products:

In volcanic regions the deposits of continental shelf and slope consist chiefly of products of volcanism, which are subject to chemical and mechanical weathering and are carried to the ocean by actions of running water and wind. The volcanic deposits differ from the ordinary terrigenous deposits in one respect: they are made of pyroclastic volcanic products and lava, rather than quartz.

Organic Products Such deposits consist of shells and skeletons of various plants and animals that live and grow on the sea floor and are changed into mud and sand by chemical and mechanical processes. They differ from the ordinary terrigenous deposits in the sense that they consist of calcium carbonate only.

Terrigenous deposits include:
(1) Blue mud,
(2) Red mud,
(3) Green mud,
(4) Coral mud,
(5) Volcanic mud,
(6) Gravel, and
(7) Sand.

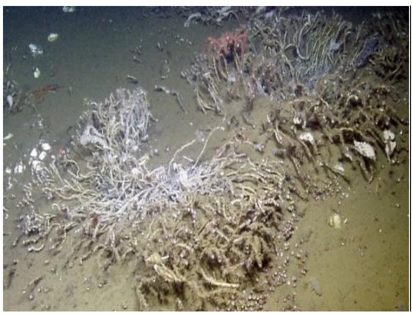
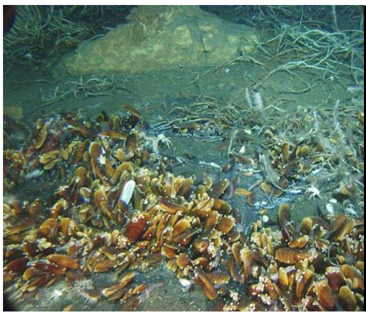
 

2. Pelagic Deposits:

Pelagic deposits are the most conspicuous of all deposits—covering about 75% of the total sea floor. This is because, except for fine volcanic ash, little terrigenous material is carried into the deeps. The pelagic deposits consist of both organic and inorganic material.

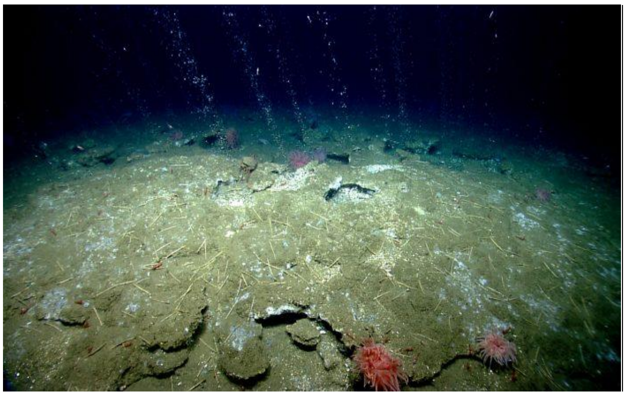
Organic Material:

This is in the form of a kind of liquid mud, called ooze, which contains shells and skeletons of various marine organisms. The ooze is said to be calcareous when the shell is made of calcium carbonate. The calcareous ooze may be either pteropod ooze or globogerina ooze. Most parts of the Indian and Atlantic Oceans have calcareous ooze as deposits . When the shell is made of silica, the ooze is said to be siliceous ooze, which can be either the diatom type or the radiolarian type of ooze. The southern fringes of the Indian and the Atlantic Oceans have the siliceous type of ooze.

Inorganic Material:

This is in the form of red clay, which is apparently of a volcanic origin. The chief constituents of red clay are silicon and aluminium dioxide, while other constituents include iron, manganese, phosphorus and radium. The red clay is the most widely spread pelagic deposit and covers 38% of the sea floor. The red clay covers more than half of the Pacific floor.




Pelagic deposits include:

(1) Red clay,

(2) Radiolarian ooze,

(3) Diatom ooze,

(4) Globigerina ooze, and

(5) Pteropod ooze.

CORAL REEFS

Coral reefs are large underwater structures composed of the skeletons of colonial marine invertebrates called coral. The coral species that build reefs are known as hermatypic or "hard" corals because they extract calcium carbonate from seawater to create a hard, durable exoskeleton that protects their soft, sac like bodies. Other species of corals that are not involved in reef building are known as “soft” corals. These types of corals are flexible organisms often resembling plants and trees and include species such as sea fans and sea whips.

Coral reefs are some of the most diverse ecosystems in the world. Coral polyps, the animals primarily responsible for building reefs, can take many forms: large reef building colonies, graceful flowing fans, and even small, solitary organisms. Thousands of species of corals have been discovered; some live in warm, shallow, tropical seas and others in the cold, dark depths of the ocean.


Each individual coral is referred to as a polyp. Coral polyps live on the calcium carbonate exoskeletons of their ancestors, adding their own exoskeleton to the existing coral structure. As the centuries pass, the coral reef gradually grows, one tiny exoskeleton at a time, until they become massive features of the marine environment.

Corals are found all over the world's oceans, from the Aleutian Islands off the coast of Alaska to the warm tropical waters of the Caribbean Sea. The biggest coral reefs are found in the clear, shallow waters of the tropics and subtropics. The largest of these coral reef systems, the Great Barrier Reef in Australia, is more than 1,500 miles long (2,400 kilometers).

Coral reef diversity

Because of the diversity of life found in the habitats created by corals, reefs are often called the "rainforests of the sea." About 25% of the ocean's fish depend on healthy coral reefs. Fishes and other organisms shelter, find food, reproduce, and rear their young in the many nooks and crannies formed by corals.


The Northwest Hawaiian Island coral reefs, which are part of the "Papahanaumokuakea" National Marine Monument, provide an example of the diversity of life associated with shallow water reef ecosystems. This area supports more than 7,000 species of fishes, invertebrates, plants, sea turtles, birds, and marine mammals. Deep water reefs or mounds are less well known, but also support a wide array of sea life in a comparatively barren world.

Coral characteristics

Shallow water reef building corals have a symbiotic relationship with photosynthetic algae called zooxanthellae, which live in their tissues. The coral provides a protected environment and the compounds zooxanthellae need for photosynthesis. In return, the algae produce carbohydrates that the coral uses for food, as well as oxygen. The algae also help the coral remove waste. Since both partners benefit from association, this type of symbiosis is called mutualism.

Deep sea corals live in much deeper or colder oceanic waters and lack zooxanthellae. Unlike their shallow water relatives, which rely heavily on photosynthesis to produce food, deep sea corals take in plankton and organic matter for much of their energy needs.

Great Barrier Reef

The largest coral reef in the world, the Great Barrier Reef, is home to at least 400 individual species of coral and thousands of different species of fish, mollusks, sea snakes, sea turtles, whales, dolphins, birds and more. As with the other coral reefs of the world, this incredible ecological hotspot is under threat.


Types of Coral Reefs Formation

Scientists generally divide coral reefs into four classes: fringing reefs, barrier reefs, atolls, and patch reefs.

Fringing reefs grow near the coastline around islands and continents. They are separated from the shore by narrow, shallow lagoons. Fringing reefs are the most common type of reef that we see.


Barrier reefs also parallel the coastline but are separated by deeper, wider lagoons. At their shallowest point, they can reach the water's surface forming a "barrier" to navigation. The Great Barrier Reef in Australia is the largest and most famous barrier reef in the world.

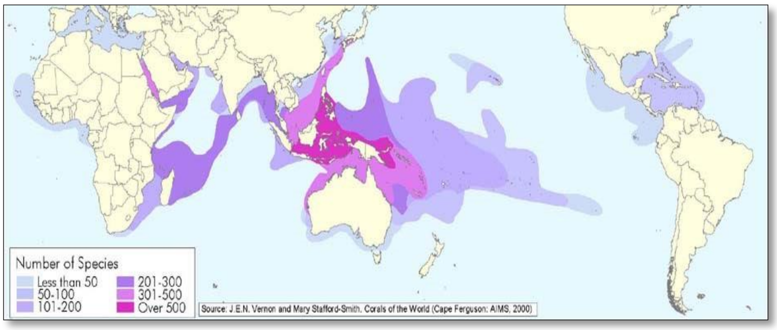
Atolls are rings of coral that create protected lagoons and are usually located in the middle of the sea. Atolls usually form when islands surrounded by fringing reefs sink into the sea or the sea level rises around them (these islands are often the tops of underwater volcanoes). The fringing reefs continue to grow and eventually form circles with lagoons inside.



Patch reefs are small, isolated reefs that grow up from the open bottom of the island platform or continental shelf. They usually occur between fringing reefs and barrier reefs. They vary greatly in size, and they rarely reach the surface of the water.

Distribution of coral reef

Coral reefs are found in more than 100 countries around the world. Most reefs are located between the Tropics of Cancer and Capricorn, in the Pacific Ocean, the Indian Ocean, the **Caribbean Sea**, the Red Sea, and the Persian Gulf. Corals are also found farther from the equator in places where warm currents flow out of the tropics, such as in Florida and southern Japan. Worldwide, coral reefs cover an estimated 110,000 square miles (284,300 square kilometers).



Distribution of coral reef

Ideal Conditions for Coral Growth

- **Shallow water:** Coral require fairly good amount of **sunlight** to survive. The ideal depths for coral growth are 45 m to 55 m below sea surface, where there is abundant sunlight available.
- **Sunlight:** Corals need to grow in shallow water where sunlight can reach them. Corals depend on the zooxanthellae (algae) that grow inside of them for oxygen and other things, and since these algae needs sunlight to survive, corals also need sunlight to survive. Corals rarely develop in water deeper than 165 feet (50 meters).
- **Stable climatic conditions:** Corals are highly susceptible to quick changes. They grow in regions where climate is significantly stable for a long period of time.

- **Clear salt water:** Clear salt water is suitable for coral growth, while both fresh water and highly saline water are harmful. Corals need clear water that lets sunlight through; they don't thrive well when the water is opaque. Sediment and plankton can cloud water, which decreases the amount of sunlight that reaches the zooxanthellae.
- **Perpetual Warm water**: Reef-building corals require warm water conditions to survive. Different corals living in different regions can withstand various temperature fluctuations. Corals thrive in **tropical waters** [30°N and 30°S latitudes, The temperature of water is around 20°C] where diurnal and annual temperature ranges are very narrow.
- **Little or no pollution:** Corals are highly fragile and are vulnerable to climate change and pollution and even a minute increase in marine pollution can be catastrophic. Sediment can create cloudy water and be deposited on corals, blocking out the sun and harming the polyps. Wastewater discharged into the ocean near the reef can contain too many nutrients that cause seaweeds to overgrow the reef.
- **Abundant Plankton:** Adequate supply of oxygen and microscopic marine food, called **plankton [phytoplankton]**, is essential for growth. As the plankton is more abundant on the **seaward side**, corals grow rapidly on the seaward side.

Benefits of coral reef ecosystems

Coral reefs protect coastlines from storms and erosion, provide jobs for local communities, and offer opportunities for recreation. They are also are a source of food and new medicines. Over half a billion people depend on reefs for food, income, and protection. Fishing, diving, and snorkeling on and near reefs add hundreds of millions of dollars to local businesses. The net economic value of the world's coral reefs is estimated to be nearly tens of billions offsite links of U.S. dollars per year. These ecosystems are culturally important to indigenous people around the world.

Threats to coral reef ecosystems

Unfortunately, coral reef ecosystems are severely threatened. Some threats are natural, such as diseases, predators, and storms. Other threats are caused by people, including pollution, sedimentation, unsustainable fishing practices, and climate change, which is raising ocean temperatures and causing ocean acidification. Many of these threats can stress corals, leading to coral bleaching and possible death, while others cause physical damage to these delicate ecosystems.

INTERNATIONAL COASTAL RESEARCH CENTER (ICRC)

The **International Coastal Research Center** is located in Otsuchi Bay on northern Japan's Pacific coast. The cold Oyashio and warm Kuroshio currents foster high productivity and biodiversity in and around Otsuchi Bay. The large earthquake and tsunami on March 11, 2011 resulted in serious disturbance to the nearby coastal ecosystem. It is very important to monitor physical, chemical, and biological aspects of the ecosystem as it recovers. Thus, we intend to reconstruct the ICRC in Otsuchi in order to contribute significantly to international coastal research.

ICRC (before earthquake and tsunami)

Tsunami swallows ICRC building

Research Contents

- ❖ **Coastal Ecosystem Section**

  The coastal ecosystem section investigates mechanisms of formation and maintenance of the high productivity and biodiversity in coastal seas, focusing on oceanic and tidal currents, atmospheric and climatological conditions, and historical environmental changes.

- ❖ **Coastal Conservation Section**

  The coastal conservation section aims to provide a framework for conservation, restoration, and sustainability of coastal ecosystems by focusing on the life history and behavioral ecology of coastal marine organisms and dynamics of bioelements in the coastal areas.

- ❖ **Coastal Ecosystem Restoration Section**

  The section "Coastal Ecosystem Restoration" investigates the effects of the mega-earthquake and massive tsunami events of March 11, 2011, on coastal ecosystems and organisms, and monitors the secondary successions of damaged ecosystems.

- **Coastal Marine and Social Science Section**

  Under construction
- **Regional Linkage Section**

  The regional linkage division endeavors to coordinate academic programs of coastal marine science by establishing a network of scientific collaboration between domestic and foreign universities, institutes, and organizations.

Activities of ICRC

ICRC has been actively promoting coastal marine science since it was founded in Otsuchi Town, Kamihei gun, Iwate Prefecture in 1973, and has been used by many researchers and students both from Japan and around the world as a shared facility (about 4,000 annually). After the Great East Japan Earthquake and tsunami, AORI believes that the following are **ICRC's roles:**

1st, Growing hand-in-hand with the local community,

2nd, Becoming a place where people interact, and

3rd, Advancing science, that leads the world.

ICRC is resolved to play a central role in research, education, and human resource development relating to marine environments and ecosystems, and contribute to the restoration of the rich coastal marine environment of the Tohoku region.

Support Project

AORI is preparing to restart ICRC's research activities. However, reconstructing the Center and creating an environment that supports of developmental research activities to respond to unprecedented events will require at least several more years and large cost outlays. The support project was established with the aim of assisting the reconstruction and research activities of the ICRC.

National Centre for Coastal Research

In 1997, Government of India implemented Environment Management Capacity Building (EMCB) programme for a period of five years, funded by the International Development Association through the World Bank. The Department of Ocean Development (DOD) established a Project Directorate i.e., Integrated Coastal and Marine Area Management (ICMAM), at Chennai in January 1998 with the approval of Cabinet Committee on Economic

Affairs to implement the EMCB programme. After completion of the World Bank assignment, it was decided by DOD to continue the activities of ICMAM PD.

In order to provide a long term organisational framework to continue these research activities, the Project Directorate is designated as the "National Centre for Coastal Research (NCCR)" an attached office of MoES. NCCR, is envisaged to develop and improve the country's capabilities in addressing the challenging problems prevailing in the coastal zone, which have societal, economical and environmental implications. These activities of NCCR would be an integral part of the Ministry's mission to offer scientific and technical support to coastal communities and stakeholders for integrated and sustainable use of resources towards socio-economic benefit of the society.

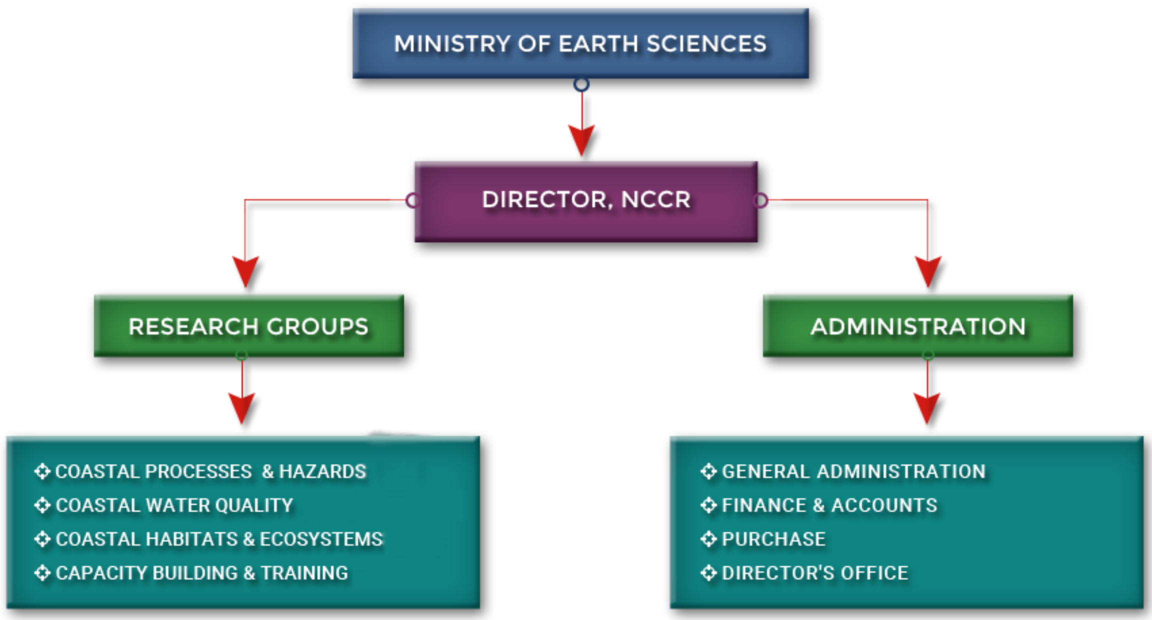
Vision

To be a centre of excellence for coastal research and offer scientific, advisory and outreach services to the coastal states and stakeholders for sustainable management of the coastal areas.

Mission

To carry out multi disciplinary research related to coastal water quality, coastal process, shoreline management, coastal hazards-vulnerability and coastal ecosystems for the benefit of society and environment.

ORGANIZATION SETUP OF NATIONAL CENTRE FOR COASTAL RESEARCH (NCCR)



Integrated Coastal and Marine Area Management (Ministry of Earth Sciences) is providing scientific and technical support for **coastal** states for implementing the **ICMAM** concept and ecosystem based **management** for sustainable use of resources.

Activities:

The Integrated Coastal and Marine Area Management Project Directorate (ICMAM PD), an attached office of Ministry of Earth Sciences (MoES), Government of India, was established at Chennai during Jan.1998 for implementing IDA assisted Environment Management Capacity Building Project. The directorate is working towards a)developing and improving capability to understand the critical coastal parameters, processes and phenomena, which have significant societal, economic and environmental benefitsand
b)providing scientific and technical support for coastal states for implementing the ICMAM concept and ecosystem based management for sustainable use of resources.

Integrated Coastal and Marine Area Management (ICMAM)

- The Department has taken up an infrastructure development and capacity building programme to facilitate adoption of the concept of ICMAM in the coming years. The programme focuses on development of expertise in ICMAM oriented activities and dissemination of knowledge gained to the users like coastal States through organised training programmes. Towards accomplishing these objectives, the following priority activities are beingundertaken:

CapacityBuilding

This component is funded by the World Bank in the form of a International Development Association (IDA) credit under the project "Environment Management Capacity Building" which is co ordained by the Ministry of Environment and Forests. The Capacity building activities are being carried in the following areas:

- Development of GIS based information system for critical habitats containing all information necessary to prepare management plans.
- Determination of waste load allocation based on waste assimilation characteristics of selected estuaries (Tapi estuary, Ennore creek, coastal waters).
- Development of EIA guidelines for major coastal developmental activities and processes.

- Development of model ICMAM plans for Chennai, Goa and Gulf of Kutchch.

The details of activities carried out during the year 1998-99 under the above projects are given below:

A. Development of GIS based information system for critical habitats,

B. Determination of Waste Assimilation Capacity in Ennore Creek and Coastal waters and Tapi estuary,

C. Development of guidelines for Environmental Impact Assessment for coastal projects

D. Preparation of Model Integrated Coastal and Marine Area Management Plans for Chennai,

COASTAL RESEARCH

In 1997, Government of India implemented Environment Management Capacity Building (EMCB) programme for a period of five years, funded by the International Development Association through the World Bank. The Department of Ocean Development (DOD) established a Project Directorate i.e., Integrated Coastal and Marine Area Management (ICMAM-PD), at Chennai in January,1998 with the approval of Cabinet Committee on Economic Affairs to implement the EMCB programme. After completion of the World Bank assignment, it was decided by DOD to continue the activities of ICMAM, as a long term R&D activity with a mandate to promote research addressing issues related to coastal processes, ecosystems, shoreline erosion, pollution, hazards and coastal vulnerability.

The projects implemented included preparation of model ICMAM plans, GIS-based information for critical habitats, determination of waste assimilation capacity, development of EIA guidelines, determination of 'no impact zone', determination of use classification for coastal waters, shoreline management plans for selected locations, ecosystem modelling for coastal habitats, marine ecotoxicology and storm surge inundation modelling. The activities were long term in nature and continued through subsequent five year plans with expanded scope and wider geographical coverage.

The major activities of the centre are as follows:

1. Coastal Processes & Hazards
2. Coastal Water Quality
3. Coastal Habitats & Ecosystems
4. Capacity Building & Training

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