OCENANIC MOVEMENTS :THE OCEAN CURRENTS

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THE OCEAN CURRENTS

INTRODUCTION

Seas and Oceans are dynamic ecosystems. Oceans are very vast bodies of water representing a major portion of the hydrosphere. Air-sea interface is an interactive interface. The wind blowing on the surface of the ocean has the greatest effect on the movement of surface water. The sunlight falling on the ocean surface has a very significant impact on the temperature of the sea water. These factors induce the oceanic water masses to move and circulate. Both Vertical and horizontal movement of both surface and deep water masses happen in the world's oceans. They are called as Ocean currents. The Ocean water circulation is an important aspect of study in oceanography. We need to understand the oceanic currents, waves and tides and their distribution on the globe. This lesson is focused to learn about ocean water currents.

MEASUREMENT OF OCEAN CURRENTS

When Benjamin Franklin, was a postmaster in the American colonies. In his time, all the letters and postal packages were transported across the continents through oceans by boats. He heard some complaints in 1769 that the mail boat from North America which went to Europe reached much faster than the mail boat which was traveling in the opposite direction. The boats travelling from Europe to North America took weeks longer than the mail boats which were heading towards the opposite direction.

He took these complaints very seriously. Since, he was the postmaster, the mail delivery was very important to him. Franklin wanted to figure out what was going on with the delayed mail delivery system. Benjamin Franklin crossed the Atlantic several times by boat. He took the temperature measurements and making other observations of the ocean. He discovered that an ocean current was the reason behind the delay. Boats going towards Europe were speeded up by the prevailing current of that region. The Boats that were going towards the North America were slowed down by the oceanic current flowing in the opposite direction. He called that oceanic current as the Gulf Stream.

FIRST MAP OF CURRENTS

The map that was made by Benjamin Franklin about the Gulf Stream in 1770 was the first map ever made of this ocean current. Mapping this current's path was very helpful for all the sailors. Franklin noticed many features that made the Gulf Stream water different from the surrounding ocean. One of the most characteristic feature of the Gulf stream was its difference in temperature. The knot (pronounced as not) is a unit of speed used in oceanographic studies.

KNOTS AND NAUTICAL MILES

One knot is equal to one nautical mile per hour or 1.852 kmph. One knot speed is equal to 0.514444444 metre / second. The abbreviation kn is preferred by the International Hydrographic Organization (IHO), which includes every major sea- faring nation. Measurements of ocean currents are carried out by a variety of methods.

One popular way to measure ocean currents is to determine the water's velocity at one fixed place in the ocean. This type of measurement is called Eulerian, in honor of the Swiss mathematician Leonhard Euler. This is accomplished by using the electro- mechanical current meters. Current meters measure the velocity of water flow at a single depth. The modern Acoustic Doppler Current Profiler (ADCP) also can provide a profile of velocity of water flow along with the details of water depth. In addition, Current measurements are also done using radar-based equipment.

CURRENT MEASUREMENTS

Another direct way to measure ocean currents, is by tagging a lighter material with floats or using color dyes. The Near-surface ocean currents are measured by so-called drifters. Drifters are buoys which ride at the ocean surface and are drogues at some depth to negate the direct effects of wind. Tracking this drifter (by satellite, radar, radio, sound, etc.) will give a description of the ocean current. Sverdrup (Sv) is the basic unit of volume transport used in physical oceanography. It is equal to one million cubic meters of water flowing per second.

OCEAN WATER CURRENTS

Currents are large-scale water movements occurring everywhere in the world. They normally move in certain specific directions. It is due to this circulation the atmospheric moisture is replenished in the atmosphere of Earth. Because ocean currents circulate water worldwide, they have a significant impact on the movement of energy and moisture between the oceans and the atmosphere. As a result, they are important to the world's weather.

FORCING MECHANISMS

Currents are referred according to their forcing mechanisms. They may be either wind driven or thermohaline. Many marine life rely on these currents to move from one location to another whether it is for breeding or for food or for adaptation purposes. Today, ocean currents are also gaining importance due to the possibility of harnessing alternative energy sources. Because the ocean water is dense, it carries enormous amount of energy that could possibly be captured and co inverted into a usable form through the use of turbine generators.

CAUSES OF OCEAN CURRENTS

The unequal heating of the earth's surface and the movement of water masses along the surface by winds are responsible for the development of currents. Currents are the reflections of the ocean water circulations. The factors responsible for the oceanic water masses to circulate are wind, salinity, density, temperature, ocean morphology and relief, and the earth's rotation.

The mechanisms responsible for creation of ocean currents are:

a) Global movement of Winds & Coriolis Force
b) Ekman flow
c) Temperature and Density differences
d) Geostrophic influences- Pressure gradient
e) Upwelling and the
f) Configuration of ocean floors.

PROPERTIES

An ocean current is a continuous, directed movement of seawater generated by the forces acting upon it. Ocean currents can flow for great distances, and together they create the great flow of the water masses. Surface ocean currents can be very large. Surface ocean currents flow in a regular pattern, but they are not all the same. Some currents are deep and narrow. Other currents are shallow and wide. Currents are often affected by the shape of the ocean floor. Some move quickly while others move more slowly. A current can also change somewhat in depth and speed over time. ocean currents show typical flow patterns

MAJOR OCEAN CURRENTS

Currents are of two general categories as surface water currents and deep water currents.

There are several factors and processes involved in the generation and movement of these two kinds of ocean currents. In addition, there are specific names given to the currents which are distributed at different parts of the globe. They are:

1. Equatorial currents
2. Boundary currents
3. Circumpolar currents.

In addition to these, there are some terminologies used to denote the oceanic currents. They are:
Periodic currents, seasonal current, coastal current, longshore current, offshore current, inshore current and drift currents.

SURFACE WINDS

The water mass present at the ocean surface is moved primarily by winds. Winds blow in certain directions and patterns. Oceanic water masses are also moved due to the Earth's rotation and by the Coriolis Effect. Wind-driven circulation is the large-scale oceanic circulation that results from the actions of the wind. There are two-components involved as

a) directly-driven Ekman component and

b) an indirect component, geostrophic balance with pressure systems.

The speed of surface currents is greatest closer to the ocean's surface and decreases at about 100 meters below the surface. This makes up to 10 % of the oceanic water masses. Because surface currents travel over long distances, the Coriolis force also plays a role in their movement and deflects them, further aiding in the creation of their circular pattern. Finally, gravity plays a role in the movement of surface currents because the top of the ocean is uneven.

DEEP WATER CURRENTS

Deep water currents are another category of ocean currents. They are also called as thermohaline circulation. They are found below 400 meters and make up about 90% of the ocean. Like surface currents, gravity plays a dominant role in the creation of deep water currents. This is mainly caused by density differences in the oceanic water masses.

KINDS OF CURRENTS

The Oceanic Currents are classified according to the force that makes them to flow.
The various kinds of currents include:

a) Tidal Currents

b) Density Currents

c) Wind Driven Currents

d) Gyres

e) Rip Currents and

f) Cold surface currents.

TIDAL CURRENTS

Tidal currents, as their name suggests, are generated by tides. Tides are essentially long, slow waves created by the gravitational pull of the moon, and to a lesser degree, the sun, on the earth's surface. Since the moon is so much closer to the earth than the sun, its pull has more influence on the tides. The tidal Currents are caused by flooding of water, flowing from one location to another. Normally, the flow speed of these tidal currents is small (typically less than 0.5 m/s). Tidal currents flow closer to the coasts.

TIDAL CURRENTS

Tidal currents differ from the regular oceanic currents in that they don't flow as a continuous stream. They also switch directions every time when there is tide transitions between the high tide and the low tide. Although tides and tidal currents don't have much impact in the open oceans, they can create a rapid current flow of up to 25 kilometers per hour when they flow in and out of narrower areas like bays, estuaries and harbors.

DENSITY CURRENTS

A less dense substance will always lie above a more dense substance. When you have water of two different densities meeting, the lower density (less dense) water will move on top of the higher density (more dense) water. The different densities actually cause the water to move, forming a density current. In the oceans, the deep, bottom currents are colder and saltier than the surface currents. Density differences are a function of temperature and salinity.

ROLE OF GRAVITY

Density currents are driven by gravity. Density differences in a fluid in a gravitational field leads to pressure differences that drive flows. The density Currents are created due to variation in the density of water. The more dense, saline water normally starts flowing under the less dense water. This is called a density current. It is mainly driven by the difference in densities between the two water masses. These flows are a few cm per second or less.

WIND DRIVEN CURRENTS

The Wind Driven Currents are the strongest currents in the world. As the name implies, they are mainly driven by the winds. The wind can cause surface flow of nominally 2.5% of the wind speed (10 m/s wind speed may generate => 25 cm/s of surface flow). This is known as wind drift. A current can also change its courses somewhat in depth and speed over time. Winds are able to move the top 400 meters of the ocean creating surface ocean currents. Surface currents are mostly caused by the wind because it creates friction as it moves over the water. This friction then forces the water to move in a spiral pattern, creating gyres. In the northern hemisphere, gyres move clockwise and in the southern they spin counterclockwise.

GYRES

Gyres are yet another types of currents in the oceans. These are "circular", large-scale, ocean flow patterns. They result from wind forcing, buoyancy forcing, and the Coriolis acceleration. Since the Coriolis acceleration changes with latitude, gyre circulations are not symmetric and the flow on the western boundaries is stronger.

Gyres flow in clockwise direction in the oceans of Northern Hemisphere and in counterclockwise direction in the Southern Hemisphere oceans. This happens mainly because of the Coriolis Effect creating surface ocean currents. Near the Earth’s poles, gyres tend to flow in the opposite direction. Some of the ocean currents move quickly, while others move more slowly.

TYPES OF GYRES

Gyres are of various kinds as:

a) Subtropical gyres

b) Subpolar gyres and

c) Recirculation gyres.

Subtropical gyres are found in all the world's oceans at mid- latitudes. Subpolar gyres have the opposite circulation and are found poleward of subtropical gyres. Recirculation gyres are flows associated with major ocean currents and consists of water that recirculates in a closed pattern around most of the ocean basin.

Large-scale recirculation gyres are associated with fast western boundary currents.

Mesoscale recirculation’s are associated with meandering currents.

RIP CURRENTS

Rip Currents are currents seen closer to the beaches when the waves tend to carry water towards the coasts. Changes in the bottom topography (e.g. sand banks) can cause water to be moved toward the beach without allowing the water to return to the deeper sea. The flow of water going back towards the deeper sea then occurs quite suddenly in the form of a narrow (<5 m wide) current moving quite fast (up 2 m/s). these are called as rip currents.

COLD SURFACE CURRENTS

The next type of currents are the cold surface currents. These currents come from polar and temperate latitudes, and they tend to flow towards the equator.

Like warm surface currents, the cold surface currents are driven mainly by atmospheric forces and are influenced by the earth's rotation.

THERMOHALINE CIRCULATION

Warm water holds less salt than cold water. So, it is less dense. When it is less dense, it rises towards the surface of the oceans. When it is cold, it becomes denser and this salt laden water sinks down below. As the warm water rises up, the cold water is forced to move away through upwelling and fill the void left by the warm waters. By contrast, when the cold water rises, it too leaves a void and the rising warm water is then forced to fill up the gap, through down welling. These are called as thermohaline circulation. This thermohaline circulation is induced by differences in temperature (thermos) and salinity (haline). Thermohaline circulation is known as the Global Conveyor Belt because its circulation of warm and cold water acts as a submarine river and moves the water masses throughout the oceans. This is one of the very unique phenomena of the oceanic water masses.

EKMAN TRANSPORT

Surface winds and ocean currents are intimately related to each other. Winds normally blow across water and drag on the surface. This sets a thin layer of water to move and tries to drag on the water present below. This process continues downward, and transfer the momentum continuously downwards towards the deep layers. The energy is lost in the process. As a result, the current speed decreases with depth. Since earth rotates, the movements of the surface waters are deflected to the right of the wind in the northern hemisphere. The change in current direction and speed with increasing depth forms a spiral. This is called as Ekman Spiral. It is named after the pioneering work of the Swedish Oceanographer, V.W. Ekman, who laid the foundation for dynamical theories of wind-driven ocean circulation.

Ekman transport is the total average flow, integrated over depth, resulting in flow that set up the large-scale ocean gyres.

UPWELLING

There are places in the ocean where water from the deep sea travels up to the surface. These are called areas of upwelling. Coastal upwelling is usually induced by Ekman transport. The other significant component of large-scale ocean circulation flow is wind-driven and is known as Ekman flow. Upwelling is a mechanism which brings the cold, nutrient-rich water from the depths up to the surface. Earth's rotation and strong seasonal winds push the surface water away from some coasts, so water rises on the edges of continents to replace it. Upwelling also happens as a part of El Niño (ENSO) events in the Pacific Ocean off the coast of Ecuador and Peru. This has an impact on weather, changing the pattern of precipitation in many areas of the world.

DOWNWELLING

Downwelling is the opposite of upwelling - surface waters pushing down into deeper areas of the ocean. This happens when winds cause Ekman transport to push water toward a coast and then deeper in the ocean.

GEOSTROPHIC CURRENTS

Geostrophic currents are controlled by a balance between a pressure gradient force and the Coriolis deflection. In addition to these, the seafloor topography and the shape of the ocean's basins have a greater impact on the surface and deep water currents. These conditions may restrict the flow between the basin areas where water can move and "funnel" it into another basin area. Surface ocean currents carry heat from place to place in the Earth system. This affects the regional climatic conditions as we ll.

DISTRIBUTION OF OCEANIC CURRENTS

Based on their flow patterns and their geographic location, ocean currents are named differently in different regions. As the current circulations in the northern hemisphere is different from those of the southern hemisphere, the global distribution of major currents are listed according to their locations to the north of equator or south ofthe equator.

EQUATORIAL CURRENTS

The North Equatorial Current is a significant Pacific and Atlantic Ocean current that flows east-to-west between about 10° north and 20° north. 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. On the equator, the South Equatorial Current is driven directly by the trade winds which blow from east towest.

EQUATORIAL COUNTER CURRENT

Equatorial currents are typically accompanied by countercurrents, which flow on the surface in a direction opposite to that of the main current. The Equatorial Counter Current is an eastward moving, wind-driven flowing 10-15 m deep current found in the Atlantic, Indian, and Pacific Oceans. These exist on either side of the equator. They are called as the North equatorial and South Equatorial currents. These currents flow between 3 and 6 kilometers per day and usually extend 100 to 200 meters in depth below the ocean surface. In addition, there are three Equatorial Counter Currents, which flow towards the east. These are a partial return of the waters carried westward by the North and South Equatorial currents. This could be seen in all the three oceans.

NORTH EQUATORIAL COUNTERCURRENT

The North Equatorial Countercurrent (NECC), flows west-to-east at about 3-10°N in the Atlantic and Pacific basins. It is located between the North Equatorial Current (NEC) and the South Equatorial Current (SEC).

BOUNDARY CURRENTS

Boundary currents flow parallel to the continental margins, usually in north-south directions. Boundary currents on the western sides of the ocean basins will be strong. Boundary currents on the eastern sides of the ocean basins will be weak. The dynamics of the Boundary currents are determined by the presence of a coastline. They fall into two distinct categories as, western boundary currents and eastern boundary currents.

WESTERN BOUNDARY CURRENTS

The western boundary currents are currents flowing from the equator to high latitudes regions in the northern and southern hemispheres. The Western boundary currents are warm, deep, narrow, and fast flowing currents that form on the west side of ocean basins due to *western intensification*. They carry warm water from the tropics poleward.

They have specific names associated with their location as:

North Atlantic - Gulf Stream;

North Pacific - Kuroshio;

South Atlantic - Brazil;

South Pacific - East Australia; and

Indian Ocean - Agulhas.

All of these currents are generally narrow, jet like flows that travel at speeds between 40 and 120 kilometers per day. The Western Boundary Currents are the deepest ocean surface flows, usually extending to 1000 meters below the ocean surface.

EASTERN BOUNDARY CURRENTS

Eastern boundary currents are relatively shallow, broad and slow- flowing. They are found on the eastern side of oceanic basins, adjacent to the western coasts of continents. They flow from high latitudes towards the equator. These are cold water currents. They also have specific names associated with their location as:

North Atlantic - Canary;

North Pacific - California;

South Atlantic - Benguela;

South Pacific - Peru; and

Indian Ocean - West Australia.

All of these currents are generally broad, shallow moving flows that travel at speeds between 3 and 7 kilometers per day.

In the Northern Hemisphere, the east flowing North Pacific Current and North Atlantic Drift move the waters of western boundary currents to the starting points of the eastern boundary currents.

ANTARCTIC CIRCUMPOLAR CURRENT

The currents moving along the polar and sub-polar regions are called as circumpolar currents. These are smaller current flows. The Southern Ocean has no meridional boundaries and its waters are free to circulate around the world. It serves a s a conveyor belt for the other oceans exchanging waters between them. The Antarctic Circumpolar Current (ACC) is an ocean current that flows clockwise from west to east around Antarctica. An alternative name for this is the West Wind Drift. It is the dominant water circulation feature of the Southern Ocean. The current is circumpolar due to the lack of any landmass connecting with Antarctica. This condition keeps the warm ocean waters away from Antarctica, enabling that continent to maintain its huge ice sheet.

NORTH ATLANTIC REGIONS

The distribution of oceanic currents of the North Atlantic Ocean from north pole to south pole are:

1. East Greenland Currents
2. Irminger Current (flowing North + West)
3. West Greenland Current (flowing North)
4. Labrador Current (flowing South + East)
5. Gulf Stream (flowing North)
6. North Atlantic Current (flowing South west)
7. Canaries Current (flowing South west)
8. North Equatorial Current (flowing West)
9. Antilles Current (flowing North West)
10. Guiana Current (flowing North West)
11. Caribbean Current (flowing North West)
12. Equatorial Counter Current (flowing along the Equator towards East)
13. Guinea Current (flowing East).

SOUTH ATLANTIC REGIONS

The distribution of oceanic currents of the South Atlantic are:

1. South Equatorial Current (West)
2. Brazil Current (South)
3. Falkland Current (North)
4. Antarctica Circumpolar Current (East)
5. Benguela Current (North).

INDIAN OCEAN

The distribution of oceanic currents of the Indian Ocean are:

1. Mozambique Current (South)
2. Agulhas Current (South)
3. West Australian Current (West)
4. South Equatorial Current (West)
5. Somali Current (North)
6. Monsoon Drift (East).

SOUTH PACIFIC OCEAN

The distribution of oceanic currents of the South Pacific Ocean are :

1 East Australian Current (South)

2 Humboldt Current (North)

3 Peru Current (North – North West)
4 Equatorial Current (West)
5 South Equatorial Counter Current (E)
6 South Equatorial Current (West).

NORTH PACIFIC OCEAN

The distribution of oceanic currents of the North Pacific Ocean are:

1 Alaska Current (South West)
2 Aleutian Current (South West)
3 Oyashio Current (South)
4 Kuroshio Current (North East)
5 Kuroshio Extension (North East)
6 California Current (South)
7 North Equatorial Current (West)
8 North Equatorial Counter Current (East).

THE GULF STREAM

The Gulf Stream is a surface current that runs between the United States and Europe in the North Atlantic Ocean. Smaller spinning rings of water called eddies can form from surface ocean currents. The Gulf Stream is a warm current. It originates in the Gulf of Mexico. It moves northward towards Europe. Since it is full of warm water, the sea surface temperatures are warm. Because of this, it keeps the places of Europe warmer than other areas located at similar latitudes. The Gulf Stream carries 4500 times more water than the Mississippi River. Each second, ninety million cubic meters of water is carried past Chesapeake Bay (US) in the Gulf Stream.

THE HUMBOLDT CURRENT

The Humboldt Current is another example of a current that affects the weather. When this cold current is normally present off the coast of Chile and Peru, it creates extremely productive waters and keeps the coast cool and northern Chile arid.

THE LABRADOR CURRENT

The Labrador Current, which flows south out of the Arctic Ocean along the coasts of Newfoundland and Nova Scotia, is famous for moving icebergs into shipping lanes in the North Atlantic.

THE AGULHAS CURRENT

The Agulhas Current is a warm water current runs south along the east coast of southern Africa. The amount of water transported amounts to about 70 million cubic metres per second, making it one of the largest western Boundary Currents in the world. The Agulhas's has tributaries. The tributaries include the Mozambique Current, the East Madagascar Current, and anti-clockwise re-circulatory flow in the SW Indian Ocean.

BENGUELA CURRENT

Benguela Current is a cold, wide current that flows northwards along the west coast of southern Africa. It is an Eastern Boundary Current and forms the eastern flank of the South Atlantic Gyre.

THE INDIAN OCEAN GYRE.

The Indian Ocean Gyre, is located in the Indian Ocean. It is one of the five major oceanic gyres. In the winter, it is reversed due to the South Asian Monsoon. Like the other gyres, it contains a garbage patch.

THE INDIAN MONSOON CURRENT

The **Indian Monsoon Current** refers to the seasonally varying ocean current regime found in the tropical regions of the northern Indian Ocean. During winter, the flow of the upper ocean is directed westward from near the Indonesian Archipelago to the Arabian Sea. During the summer, the direction reverses, with eastward flow extending from Somalia into the Bay of Bengal. These variations are due to changes in the wind stress associated with the Indian monsoon.

THE NORTH ATLANTIC GYRE

The North Atlantic Gyre, located in the Atlantic Ocean, is one of the five major oceanic gyres. It is a circular system of ocean currents that stretches across the North Atlantic from near the equator almost to Iceland, and from the east coast of North America to the west coasts of Europe and Africa.

THE BEAUFORT GYRE

The Beaufort Gyre is a wind-driven ocean current located in the Arctic Ocean polar region. The gyre contains both ice and water. It accumulates fresh water by the process of melting the ice floating on the surface of the water

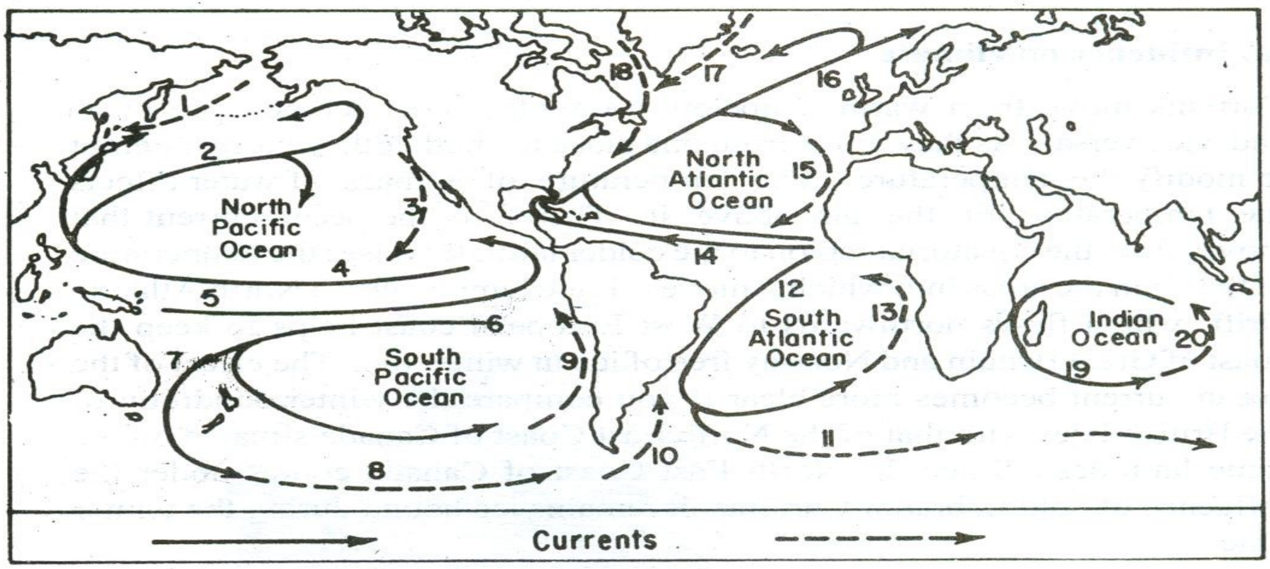
OCEAN EDDIES AND RINGS

Eddies with horizontal diameters varying in size from 50-150km have their own pattern of surface currents. They form rings due to western boundary currents like the gulf streams. At the equator and along the ocean boundaries, shallow undercurrents exist, flowing in a direction counter to that at the surface. These types of currents may affect the operation of submarines or trawlers. One good example is the equatorial undercurrent.

CONCLUSION

Currents are also important for marine life because they transport most of the marine creatures all around the world. Currents affect the water temperature in marine ecosystems. Currents play a major role in controlling the climate. Currents play an important role in the navigation of ships. Knowledge of ocean currents is essential to carry out the movement of ships, reduction in their shipping costs and fuel consumption. Knowledge of surface ocean currents is essential in reducing costs of shipping, since traveling with them reduces fuel costs.

Fig. 1: Ocean Currents



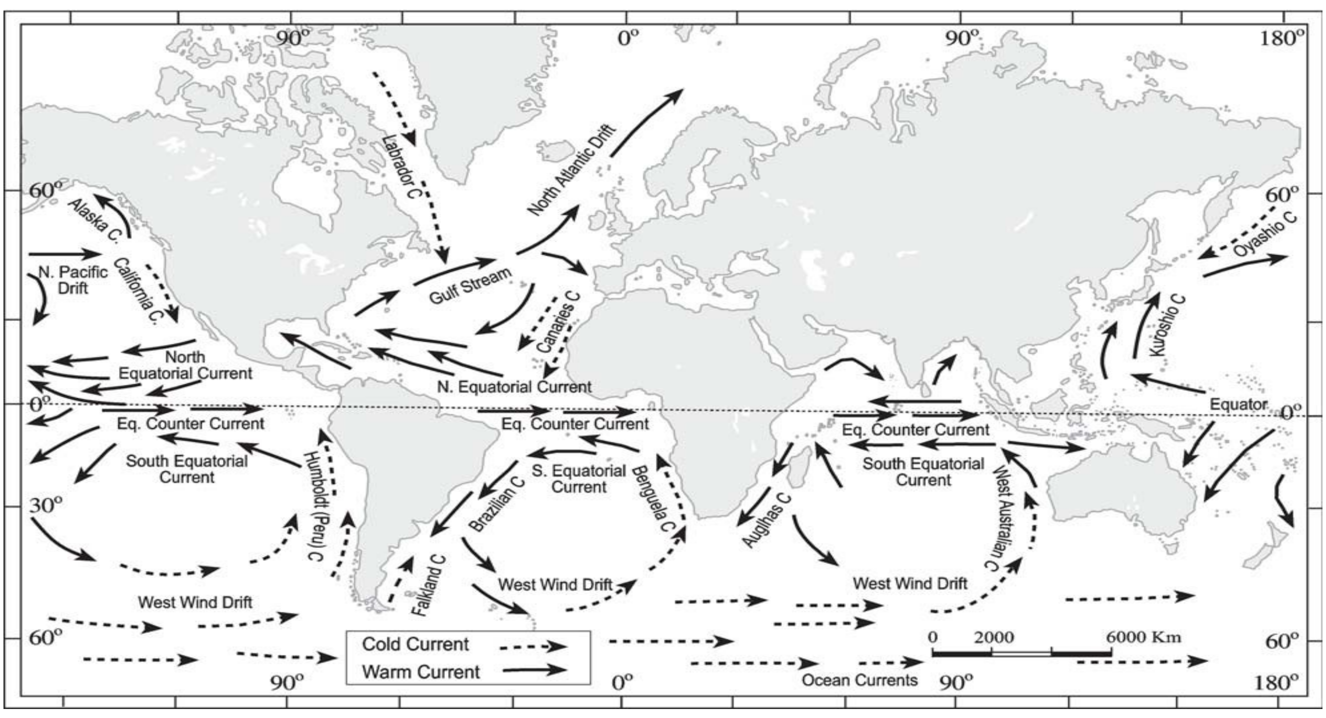


Fig. 2: Major Currents in the Pacific, Atlantic and Indian Oceans.