OCEAN CURRENTS

- These are dynamic motions of the ocean water mass which is induced by atmospheric (planetary winds) and suboceanic factors (temperature, salinity, and density).
- The ocean currents are like rivers over the sub-surface static mass of ocean water.

Types of Ocean Currents

Based on Relative Temperature

- (a) Cold currents
- These originate in the polar region and travel towards the lower latitudes as subsurface currents.
- (b) Warm Currents
- These originate at the equator and move towards the poles as surface currents due to their relatively lesser density.

Based on Volume and Velocity

- (a) If the volume is high to moderate, and it attains greater velocity than normal, then it is called a stream. For example, Gulf Stream.
- The volume of the Gulf Stream is due to the joining of two currents Antilles Current and Florida Current.
- (b) When the current is having a high volume, but low velocity, it is called a drift.
- For example, North Pacific drift and North Atlantic Drift.
- (c) Narrow currents with limited volume but high velocity is called a channel.
- For example, the English Channel and the Mozambique Channel

Map-Related Discussion

- West Wind Drift, Gulf Stream, and the English Channel.
- Warm currents are on the western margins of the ocean and cold currents are on the western margins of the continent.

Factors that determine the flow of Ocean Currents

- (a) Earth's gravity
- It is maximum at the poles and therefore, ocean currents witness a pull of water towards the pole.
- The cold water originating from the pole moves toward the equator as the compensatory current.
- (b) Rotation of the Earth
- Earth rotates from west to east, thus, there is the movement of north-equatorial and south-equatorial currents from east to west.
- The north and south equatorial currents, while moving from the western coast of the continents carry water and accumulate it along the eastern coast.
- They bifurcate, and one moves toward the northern hemisphere, and the other moves toward the southern hemisphere.
- Thus, there is the development of a counter-equatorial current that retraces the direction back.

- (c) Wind and Coriolis Effect
- Coriolis is a pseudo force that is least at the equator and the maximum at the poles.
- The Coriolis effect is primarily caused by the Earth's rotation which apparently deflects the moving mass of the water or air.
- Ocean currents move under the influence of planetary winds and are also subjected to the Coriolis effect.
- Ocean currents make a clockwise circulation in the northern hemisphere and an anticlockwise circulation in the southern hemisphere. These circulations are called gyres.
- (d) Configuration of the Coast
- This modifies the flow of the current.
- For example, the bifurcation of the south equatorial current into Florida and Brazillian current.
- The southwest monsoonal current and northeast monsoonal current take the shape of the northern Indian Ocean coast.
- (e) Temperature and Salinity
- The less dense current moving from the equator to the poles becomes saline and cold which increases its density along the higher latitude.
- (f) Ocean Botton Topography
- The mid-oceanic ridges, seamounts, and other such topography when increasing in height shall obstruct or diverge the flow of ocean currents.
- for example, Norwegian current and Icelandic current.

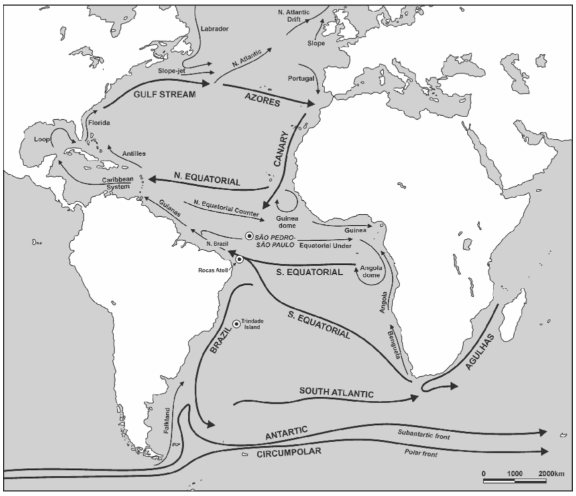
Note:

- Ocean Currents are well developed in the Pacific and Atlantic oceans, but not in the Indian Ocean region, due to the absence of North Indian Ocean Gyre.

OCEAN GYRE CIRCULATION

Atlantic Ocean

- Warm Currents
- (a) North Equatorial Current
- (b) South Equatorial Current
- (c) Norwegian Current
- (d) Florida Current
- (e) Antilles Current
- (f) Counter Equatorial Current
- (g) North Atlantic Drift
- Cold Ocean Currents
- (a) Canary Current
- (b) Beneguela Current
- (c) Falkland Current
- (d) West Wind Drift

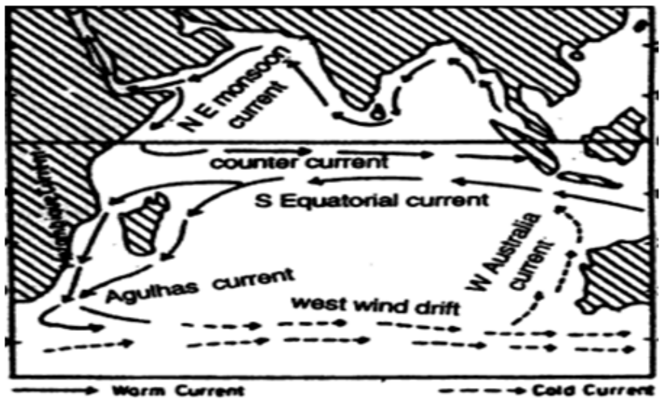


- Significance of Warm Currents
- (a) The northern Norwegian current that moves towards Norway and Russia, makes these regions ice-free throughout the year.
- For example, Murmansk is Russia's ice-free port.

- (b) North Atlantic Drift reaches western Europe and shall keep the winter mild (temperate latitude)- British type of climate. This shall also result in heat waves in summer.
- (c) Tropical cyclones get intensified due to more heat availability and the development of significant troughs along the tropics, under the influence of the gulf stream.
- (d) Warm currents along the Gulf of Mexico support the growth of tropical cash crops such as tobacco, cotton, and sugarcane.
- (e) The Gulf Stream meets the labrador current at the temperate latitude near Newfoundland. This facilitates large-scale fishing due to sufficient phytoplankton growth.
- <u>Significance of Cold Currents</u>
- (a) Labrador current brings nutrients which on mixing with the warm gulf stream harbors a good fishing platform.
- (b) Canary current flows through the coast of the Sahara desert inducing the desiccating effect.
- (c) Beneguela Current flows across the coast of Namib and Kalahari desert.

Indian Ocean Currents

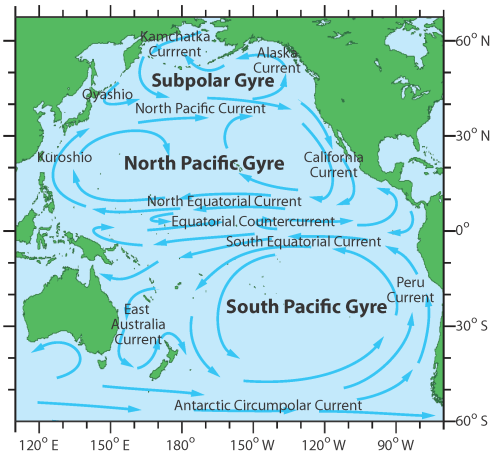
- <u>Warm Current</u>
- (a) South Equatorial Current
- (b) Madagascar Current
- (c) Agulhas Current
- (d) Mozambique Current
- <u>Cold Current</u>
- (a) West Wind drift
- (b) West Australian Current
- <u>Seasonal Current</u>
- (a) Southwest monsoonal currents
- (b) Northeast monsoonal currents



- <u>Significance</u>
- West Australian current flows along the coast of the Great Australian Desert.
- Prevailing secondary winds control the ocean currents in the Northern Indian Ocean.
- During summers the southwest monsoonal winds are responsible for southwest monsoonal currents.
- During winters the northeast monsoonal winds are responsible for northeast monsoonal currents.

Pacific Ocean

- Warm Currents
- (a) North Equatorial Current
- (b) South Equatorial Current
- (c) Counter Equatorial Current
- (d) Alaskan current
- (e) Kuroshio Current
- Cold Currents
- (a) Oyashio Current
- (b) West Wind Drift
- (c) Californian Current
- (d) Humboldt Current

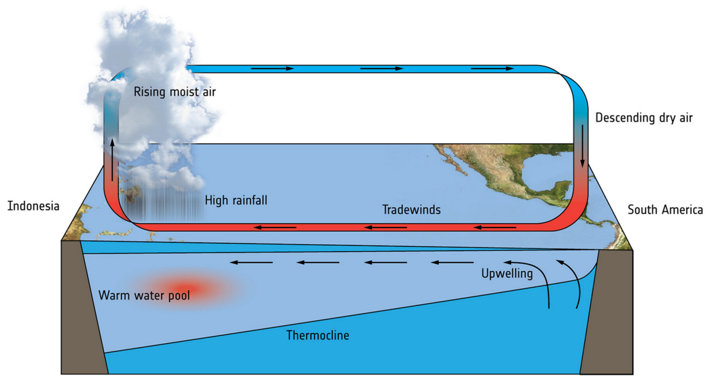


- Significance
- Oyashio and Kuroshio currents mix along the temperate latitude, providing fertile fishing grounds.
- East Australian Current provides the necessary warm temperature and low pressure for the formation of Willy Willy.
- The presence of warm currents is also a reason for providing the necessary temperatures for the coral reefs.
- Cold Californian Current washes along the coast of the Mojave and Sonoran desert.
- Cold Peruvian current- one of the strongest cold currents flows along the coast of the Atacama desert (the World's driest desert).

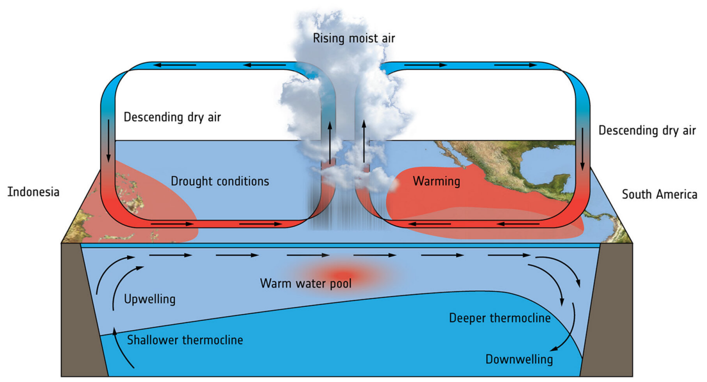
EL NINO AND LA NINA

Normal Conditions

- The off-shore trade winds that blow off the South American coast towards Australia, shall remove and carry the surface water from the coast of South America and towards Australia.
- It shall also influence the accumulation of warm waters of counter-equatorial current along the coast of Australia.
- To fill the vacuum along the South American Coast, the cold nutritious water rises from the sub-surface layers of the Ocean and this is called Peruvian or Humboldt cold current.



Normal conditions



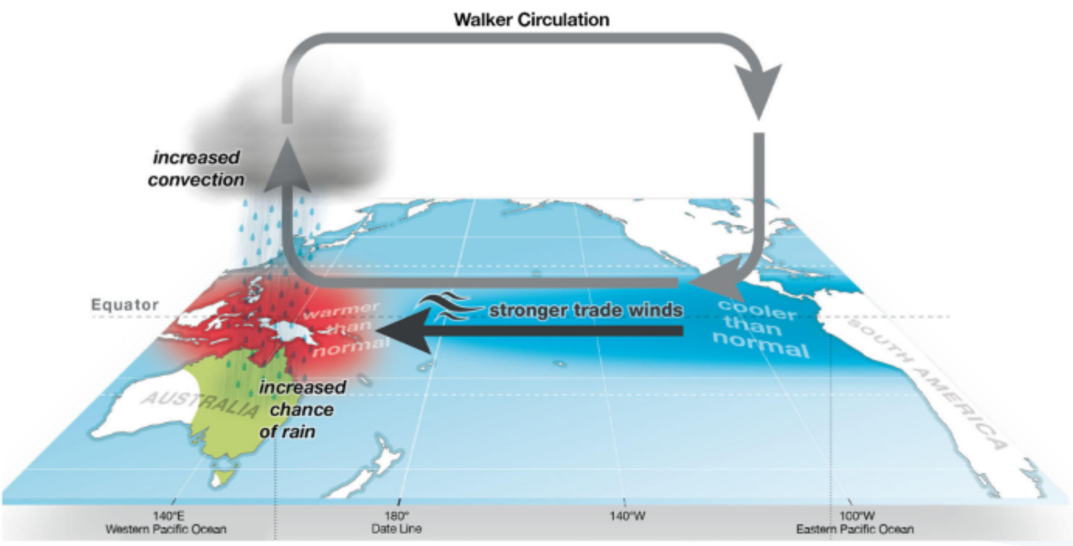
El Niño conditions

- The cold temperature of this current creates high pressure along the coast of South America resulting in descending air that shall cause the atmospheric stability.
- The water carried away from the Peruvian coast piles up at the Australian coast forming low pressure as it is warm water.
- Downwelling is also witnessed along the coast of Australia.
- Along the Australian Coast, the low pressure attracts winds which on convection condense and precipitate.
- This air circulation makes the walker cycle.

El Nino

- Abnormally weak off-shore trade winds witnessed along the South American Coast are incapable of pushing the warm surface water and the counter-equatorial current to accumulate along the Australian Coast.
- This shall result in the ceasing of the cold water upwelling along the South American Coast.
- This phenomenon that develops shall result in warm water (counter equatorial currents) piling up on the South American Coast.
- This shall result in the formation of low pressure that induces the convection of warm air, condensation, and precipitation.
- This heavy rainfall along the South American coast shall impact negatively:
- (a) No fishing possibility due to lack of upwelling.
- (b) Negative impact on the fertilizer industries- less bird population.
- (c) Heavy rainfall results in erosion on a massive scale.
- Along the Australian coast, since the warm water doesn't accumulate as in a normal cycle, such conditions shall result in high pressure.
- The air descends in this region, creating atmospheric stability.
- This will result in the following consequences:
- (a) Dry and drought conditions in India, Australia, and Indonesia.
- (b) The dry conditions result in forest fire.
- (c) It shall also impact the formation of Willy Willies.
- (d) It would have negative consequences on the corals- coral bleaching.

LA NINA

- 

- La Nina is an extreme condition of the normal walker cycle.
- Off-shore trade winds (South American Coast) become unusually strong carrying away extra water from the coast of Peru.
- It accumulates these warm waters along with the water of the counter equatorial current at the Australian Coast.
- This shall result in intensified upwelling and high pressure along the South American Coast.
- The accumulated warm surface water creates intensified low pressure along the coast of Australia.
- <u>Impact on the South American Coast</u>
- (a) Drought conditions.
- (b) Nutrient availability is more than normal upwelling.
- This is good for the fishing and fertilizer industries.
- <u>Impact on the Australian Coast</u>
- Heavy rainfall and floods all across India, Indonesia, and Australia.
- The El Nino and La Nina cycle is addressed as ENSO (El Nino Southern Oscillation).

LA NINA MODOKI

- The abnormally low temperature in the central Pacific creates high pressure and leads to subsidence of air.
- This subsiding air diverges and flows towards the low pressure along the coast of South America and Australia.
- Thus developed low-pressure engages in the convection of winds that results in condensation and precipitation.
- Unlike, El Nino or La Nina, Modoki develops two walker cells.

EL NINO MODOKI

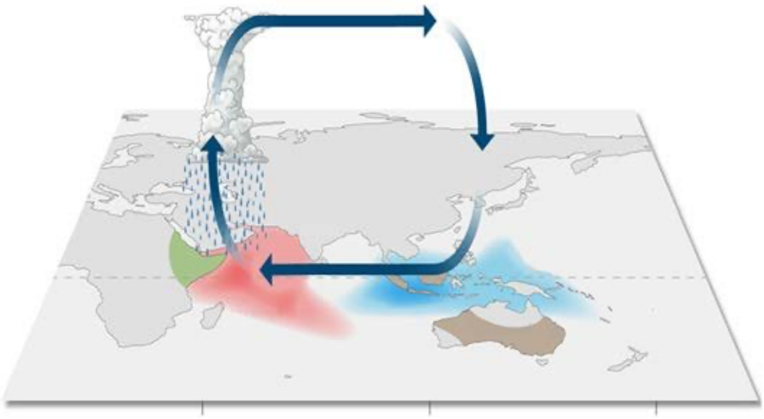
- Occasionally, an abnormally high-temperature region in the central Pacific develops intense low pressure.
- This attracts the winds from both coasts (relatively low temperatures and high pressure).
- At the zone of central Pacific low pressure, there is convection of winds that forms clouds and results in precipitation.
- On the other hand, it keeps both coasts dry and drought due to the atmospheric stability, and subsiding air.
- Thus it develops two walker cells and this phenomenon is known as El Nino Modoki.
- The occurrence of El Nino Modoki and La Nina Modoki is also known as <u>Anomalous Double Walker Oscillation.</u>

INDIAN OCEAN DIPOLE

- For a few years in the late 1990s, El Nino did not result in drought conditions in India.
- Similar events when studied led to the finding of ENSO type see-saw ocean-atmospheric type system in the Indian Ocean.
- This was called an Indian Ocean Dipole.
- There are two regions in the Indian Ocean along the equator:
- 1. Near the **coast of Africa** is the western pole in the Arabian Sea

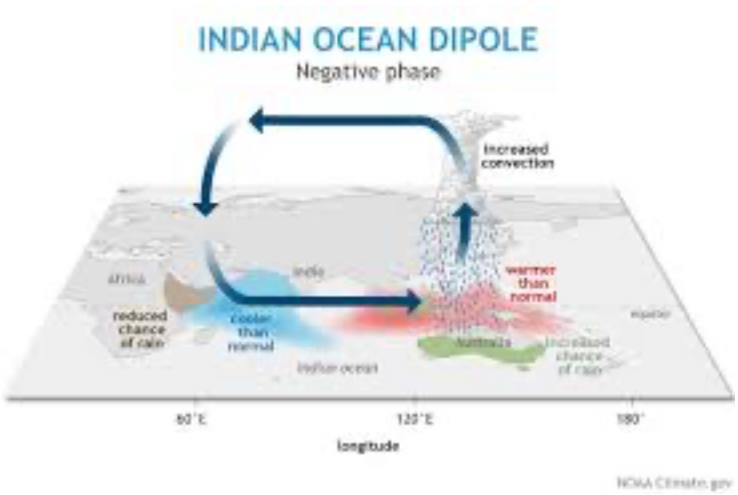
- 2. Along the region of **Indonesia** is the eastern pole in the Bay of Bengal.

POSITIVE DIPOLE



- The difference in sea surface temperature i.e. the **higher temperature on the western pole** develops mature low-pressure.
- This results in the advection of winds from the eastern poles and then convection around the western pole resulting in rainfall along the Arabian Sea including India.
- High pressure and subsiding air developed along the Bay of bengal; which result in dry and drought conditions due to atmospheric stability.
- The formation of cyclones is made possible along the Arabian Sea region due to the Warm Surface Temperature of the Arabian Sea.

NEGATIVE DIPOLE



- The development of high temperature and low pressure along the eastern pole attracts winds from the region of the western poll.
- The western poll developed high pressure and abnormally cooler condition of ocean water.
- The convection of moist wind across the eastern pole results in Heavy Rainfall along the Bay of Bengal region.
- In contrast, the subsiding air in the western pole results in dry conditions along the Arabian Sea.
- The formation of cycling is made easier along the Bay of Bengal due to warmer sea surface conditions.

ATLANTIC MERIDIONAL OVERTURNING CIRCULATION (AMOC)

- The recent Inter-governmental Panel on Climate Change (IPCC) report says that AMOC is losing stability and will weaken by the end of the century.
- **IPCC Report:** IPCC Publishes comprehensive Assessment Reports, Climate Change Impact and Future Risk Reports, and other special reports.
- They provide scientific, technical, and socio-economic knowledge on climate change.

- It also includes the options to reduce the rate of change and solutions for adaptation and mitigation.
- **AMOC:**
- The warm water of the gulf stream as it goes up the latitude cools down and becomes denser, the evaporation facilitated by the warm ocean current shall increase the salinity and result in making the water denser.
- This cold saline high-density water sinks at higher latitudes and flows towards the equator as sub-surface ocean currents.
- These currents are pulled back to the surface as they reach the tropics.

SIGNIFICANCE OF AMOC

- It **distributes heat and nutrients** across the ocean.
- The mild winter of Western Europe (British type of climate) is because of AMOC.
- Rainfall on the western coast of Europe is because of Gulf Stream.
- AMOC helps in **carbon sequestration** and global warming impact can be seen on it.
- The tropical cyclone eastern coast of North America and the Tropical Plantation of Tobacco, Sugarcane, and Cotton are majorly due to the normal circulation of AMOC.
- **Cause of Concern:** Weak Thermohaline Circulation due to Global Warming and Melting of Ice Sheets, especially in the Arctic and in the Greenland shall reduce the salinity which in turn decreases the density of water. Thus preventing the water from sinking to the bottom.
- **Consequences:**
- It shall leave with no distribution of heat and nutrients which in turn reduces the marine productivity.
- The halt in AMOC reduces carbon sequestration capacity.
- It shall have an impact on the dilution of the role of ocean currents on the Gulf type of climate, British type of climate, Laurentian type of climate, and desert type of climate.
- It results in the erratic formation of tropical cyclones along the eastern margin of tropical continents.
- While on the western margin since the upwelling of cold water is halted.
- Upwelling of nutrients seized, thus negative impact on fishing.

AMOC ROLE IN THE INDIAN OCEAN

- The rising temperature of the Indian Ocean Region is one possible solution to boost AMOC.
- This will result in increased precipitation in Indian Ocean Region as it draws more winds from across the region of the Atlantic.
- This can reduce the precipitation over the Atlantic which in turn shall increase the salinity of ocean currents.
- The saline warm current as it moves up the latitude shall cool down and sink facilitating the normal functioning of AMOC.
- Note: Extreme Rainfall in the Indian Ocean Region (High Temp and Low Pressure) over the Indian Ocean shall negatively impact, the Indian sub-continent monsoon.

TEMPERATURE AND SALINITY OF OCEANS

FACTORS AFFECTING THE TEMPERATURE OF OCEAN

- Factors affecting the distribution of temperature:

(i) Insolation and Latitude

- When the average exposure and intensity of insolation are higher than the temperature shall also be higher.
- The Torrid region shall receive greater insolation:
- (a) The Equatorial region due to atmospheric instability shall have relatively lesser insolation than the tropics.
- (b) The temperate region receives slanting rays thus less intensity insolation.
- (c) the frigid zone not only receives the least intensity but also lesser exposure time to insolation.

(ii) Seasons

- Insolation varies with the season thus the temperature variation.
- Summer receives more insolation thus increasing ocean water temperature and the opposite happens in the
- Winter.

(iii) Atmospheric stability and instability

- A stable atmosphere results in high temperature due to a clear cloudless sky while atmospheric instability results in lower temperature.
- (a)Tropics- Atmospheric stability- clear sky-high temperature
- (b)Equator- Atmospheric instability-cloudy sky- relatively lower temperature

(iv) Ocean Currents

- **The** eastern coast of the tropical region shall witness warm currents, and the water surrounding these warm currents shall witness a significant increase in the temperature.
- The opposite shall happen on the western coast of the tropical region due to the presence of cold currents.

(v) Land & Water Distribution

- The differential heating of land and water and dissipation of heat from land to water shall affect the ocean water temperature. The northern hemisphere ocean water is warmer than the southern hemisphere ocean water due to the differential distribution of land and water.
- The average temperature of the oceans in the Northern Hemisphere is 19°C whereas the average temperature of the oceans in the Southern Hemisphere is 16° C.
- The high temperature in the Northern Hemisphere is due to the presence of more landmass.

(vi) The shape of the water body

- Enclosed water bodies in the lower latitudes have higher temperatures than the open seas
- Due to a lesser mixing of water and a higher degree of heat being dissipated from the surrounding land. Example- **Persian Gulf Vs Bay of Bengal**
- Enclosed Seas or Water bodies in higher latitudes record lower temperatures than open seas, for example- the **North Sea Vs the Baltic Sea.**

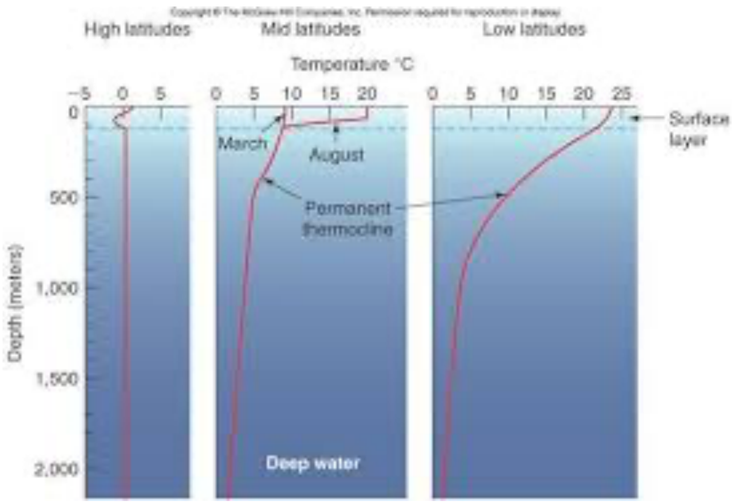
(vii) Onshore and offshore winds

- Offshore winds remove the surface water leading to the upwelling of the ocean bottom water.

- This shall reduce the ocean bottom temperature in this region. E.g. Peruvian coast during La Nina or normal conditions.
- Onshore winds pile up warm water along the coast resulting in increased temperatures. Eg. the Australian coast during La Nina and normal conditions.
- **(viii) Local phenomena** like cyclones can lower the surface water temperature

Vertical distribution of Ocean Water Temperature

- the vertical distribution of temperature divides the ocean into 3 layers:



(i) Euphotic or Photic Zone

- It extends from the surface up to 400 meters depth. Generally, the effective Photic zone is just 200 meters which is based on the ability of sunrays to penetrate.
- this region exhibits the maximum temperature of the ocean and shall depend upon insolation as follows:
- Tropics-25 degree celsius
- Temperate-16 degree celsius
- Polar-4 degree Celsius

(ii) Thermocline layers

- It is the zone of sudden decrease in temperature in this zone as there is a significant drop in the movement of water that is responsible for transferring heat.
- It extends from 400 meters to 1000 meters.

(iii) Stratospheric layer or the Cold Deep Water

- In the deep ocean waters, the temperature of the water shall remain 2-4 degrees Celsius.
- It extends from 1000 meters from the surface to the bottom of the ocean.
- the surface temperature to the deep ocean water temperature in the polar region shall remain near similar. this is mainly due to insignificant Photic Zone or heating of the surface layer.

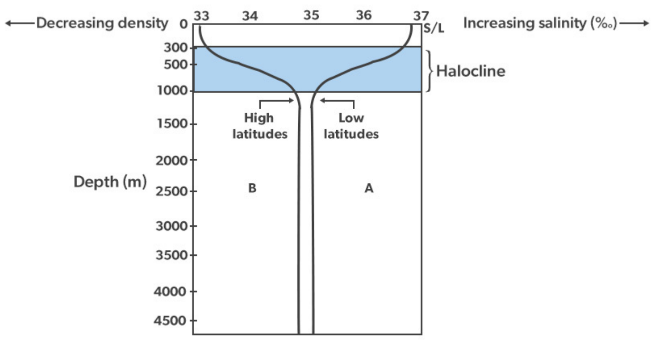
Ocean salinity

- **Factors affecting salinity**
- Insolation & Evaporation – increases salinity e.g. greater evaporation in the tropics increases salinity.
- Rainfall & influx of river water/melting glaciers - the equatorial region has more rainfall and less salinity (despite high insolation).

- Submarine volcanoes & ridges – in recent news, it was observed that the Mid-Atlantic Ridge area has relatively higher salinity than the surrounding region. It was due to ridges oozing brine.
- Ocean currents – warm currents increase salinity due to greater evaporation. Cold currents can dissolve more Ca due to exothermic reaction thus coral reefs are not found in cold waters.
- Atmospheric pressure – regions with higher atmospheric pressure have higher salinity due to atmospheric stability e.g. tropics. A region with lower atmospheric pressure exhibits lower salinity e.g. across the equator.
- Prevailing Winds – constant directional wind throughout the year increases evaporation.
- Marine life – it moderates ocean water temp and salinity e.g. the Sargasso Sea in the Central North Atlantic.
- **Sources of salinity (5:40 PM)**
- Sediments carried by rivers – rivers bring salt to oceans. It is generally rich in calcium salt but as it reaches the seawater, Ca is absorbed by marine life for exoskeleton formation.
- Undersea volcanic eruptions
- Meteorite impact.
- Marine life.
- Anthropogenic activities.

Vertical and horizontal distribution of salinity

- **Vertical distribution**
- The salinity level differentiates ocean water into 3 layers - Photic zone, halocline zone, and cold water.
- Photic zone – mixing of ocean water is significant. It extends up to a depth of 400 m from the surface. The salinity is significantly high as it is the zone of interaction with the source of salinity.
- Halocline – It exhibits a steep change in salinity level as water mixing halts.
- Cold deep water – deep ocean water below 1000 m from the surface. It exhibits constant salinity till the bottom.



- **The horizontal distribution**
- Salinity in the southern hemisphere is relatively higher than in the northern hemisphere due to freshwater influx by rivers in the northern hemisphere.
- **Latitudinal distribution**
- Equator - less salinity due to high precipitation despite high insolation.
- Tropics - more evaporation, relatively lesser precipitation - higher salinity.
- Temperate region - salinity reduces again. Slanting rays, lesser evaporation.

- Polar region – negligible evaporation, freshwater addition by rivers which should reduce salinity. But during the formation of icebergs the salt content is left behind. Thus overall the salinity increases.
- Near the deltas and estuaries salinity reduces.

Movement of Ocean water

- There are two types of movement of ocean water – Ocean currents, waves & tides

Waves

- The rise and fall of ocean water due to the frictional force of the winds (forms crest) and gravity (forms trough) results in the elliptical movement of water molecules.
- These are not the water molecules that are in motion but the energy that is travelling.
- This proves that waves are surface phenomena and are not observed affecting the bottom of the ocean.
- The height of the wave shall be very negligible in deep water and as it approaches the coast, it slows down, increases in height considerably, and breaks (Swash) forming white caps.
- The permanent winds result in steady and slow-speed waves that might have originated at very long distances. While local winds result in steep waves.
- Wave energy and tidal energy contribute to the renewable energy potential, in India, it is about 1/3rd of the total basket of renewable energy.
- Ministry of Earth Sciences along with the National Institute of Ocean Technology have taken the responsibility to work on it in Kanyakumari and Thiruvananthapuram.

Tides

- The periodic rise and fall of seawater level is mainly due to -
- The gravitational pull of the Sun.
- The gravitational pull of the Moon.
- The centrifugal force of the earth.
- High tide - the rise of seawater level and its movement towards the coast/land.
- Low tide - fall in seawater level and its movement away from the coast.
- Flow or flood – when the water level starts increasing from the low tide line to the high tide line.
- Ebb – when the water level recedes from the high tide line to the low tide line.
- Tidal range - the difference in water levels between high tide and low tide.

Mechanism of tides

- Tides are caused due to the gravitational force of both the sun and the moon. The proximity of the moon means it has more impact.
- A place (A) facing the moon witnesses a tidal bulge due to ocean water getting pulled by the gravitational force of the moon (lunar tide).
- Earth's rotation counters the gravitational force with equal and opposite centrifugal force (causing centrifugal high tide) at point B (in the diagram shown).
- Thus two high tides are created at the same time. This results in the pulling up of water from the other two ends C and D creating two low tides.
- Ideally, the tide should occur at an interval of 12 hours but the high tides are delayed by 26 minutes.

- As the earth rotates, the moon also revolves around the earth. When point A is realized back to its original position, the moon would have shifted. So, now point A to experience a high tide, has to wait for about 52 minutes. (the gap between two high tides is 12 H, 26 min, the gap between low tide and high tide - is 6 H, 13 min)

Types of tides

Spring tide

- When the Sun, moon, and Earth are in the same line it is referred to as the **Syzygy position**.
- In this, the gravitational forces of the sun and moon result in increasing the height of high tides.
- This occurs only during full moon day and new moon day when the moon is b/w the earth and the sun.
- High tide is higher than normal and low tide is lower than normal.

Neap tide

- When the sun, moon, and earth are placed in a perpendicular position to each other, it is called **quadrature**.
- In this position, the gravitational force of the sun and moon act opposite each other, thus, reducing the height of the tide by about 25% of the normal tide.
- The high tide is lower than the normal high tide and the low tide is higher than the normal low tide.

Tidal bore & tidal current

- when tide is channelised in bays/creeks/estuaries they are called tidal currents. Narrow-shaped bays/creeks result in greater magnitude. These help in harvesting of tidal energy e.g. Bay of Fundi, Gulf of Cambay, Sir Creek etc.
- Tidal bore – a type of tidal current where the tide enters with a greater vertical height against the water of the river forming a series of ripples.