Geography Optional - 2024

PHYSICAL PROPERTIES OF OCEANS

NEETU SINGH

Salinity

The amount of dissolved material present in the ocean water is collectively termed as salinity. It is one of the important physical properties of ocean water. As it is affected by the temperature of rainfall received in particular area and on the other hand affect the temperature of that area. In technical terms it is the ratio between the weight of dissolved material and weight of sample sea water expressed as gms. Per thousand grams. **The average salinity of the sea water is 35 part per thousand.** At the simplest level, salinity is the total amount of dissolved material in grams in one kilogram of sea water. Thus salinity is a dimensionless quantity. It has no units. The variability of dissolved salt is very small, and we must be very careful to define salinity in ways that are accurate and practical. The range of salinity for most of the ocean's water is from 34.60 to 34.80 parts per thousand, which is 200 parts per million. The variability in the deep North Pacific is even smaller, about 20 parts per million. If we want to classify water with different salinity, we need definitions and instruments accurate to about one part per million. Notice that the range of temperature is much larger, about 1°C, and temperature is easier to measure.

Originally salinity was defined to be the "Total amount of dissolved material in grams in one kilogram of sea water." This is not useful because the dissolved material is almost impossible to measure in practice. For example, how do we measure volatile material like gasses? Nor can we evaporate sea-water to dryness because chlorides are lost in the last stages of drying.To avoid these difficulties, the International Council for the Exploration of the Sea set up a commission in 1889 which recommended that salinity be defined as the "Total amount of solid materials in grams dissolved in one kilogram of sea water when all the carbonate has been converted to oxide, the bromine and iodine replaced by chlorine and all organic matter completely oxidized." The definition was published in 1902. *This is useful but difficult to use routinely.* Many physical processes depend on temperature; and a few can be used to define absolute temperature . The unit of T is the kelvin, which has the symbol K. The fundamental processes used for defining an absolute temperature scale over the range of temperatures found in the ocean include

Controlling Factors of Salinity:

Among the major constituents of the sea water, several minerals approximately 47 is perceived to be present. The most common among them is sodium chloride, magnesium chloride, magnesium sulphate and calcium sulphate. The source of salt present in the ocean water have been explained in various forms. Generally continents are considered to be the main source of salinity which has been transported by means of river, wind and sea waves. The point of contradiction added with this notion have been explained in the following ways:

- The different mineral constituent deposited by the agents of gradation was eventually consumed by the various submarine organism and was then by converted into sodium chloride or the chemical reactions in the oceanic stretch itself would have resulted in the formation of Na Cl.
- This concept is associated with the formation of earth. It is perceived that surface give earth was marked with the prominent cover of sodium chloride in the forms of wrinkles, which was eroded and deposited in oceanic stretches by the agents of gradation. Therefore in due course of time oceans developed high concentration of Na Cl where as continent were made deprived of it.

Factors affecting the salinity:

The distribution of salinity presents a complex pattern both in terms of horizontal as well as vertical distribution. A varying set of factors ranging between the physical characteristics of ocean itself as well as external causes determines the variability of salinity. Among the important factors are:-

- **Temperature:** Salinity and temperature presents the direct relationship as the higher temperature facilitates higher rate of evaporation. Thus in the tropical beltcomparatively higher temperature facilitates higher concentration of salinity which decreases with increase in latitude.
- **Rainfall:** Being the source of fresh water the amount of rainfall plays a significant role in determining the concentration of salinity. Thus in the areas where rainfall is more than

evaporation, amount of salinity will be less. It is because of this reason that equatorial areas inspite of having high temperature enjoys moderate to less salinity.

- **Glaciers:** In the higher latitudes with the variation in the temperature the melting of glaciers provide fresh water. It is because of these phenomena that predominantly in sub polar areas the concentration of salinity is less.

  Low latitudes - Enclosed water body –high salinity

  High latitudes - Enclosed water body – less salinity.

- **Oceanic currents:** The surface flow of the ocean water in the form of narrow stream has been identified as a powerful factor deciding the amount of salinity. The impact of ocean current is seen throughout the year. Thus the areas in contact with warm current experiences rise in temperature, evaporation and thus salinity. The best example is the Eastern Coast of USA where gulf stream facilitates higher concentration of salt irrespective of latitude. On the other hand, the cold current reduces the temperature, evaporation and salinity as the current of Labrador facilitates lesser concentration of salt along the North Eastern Canadian Coast. The currents moving in the middle latitude results in increasing the temperature. Even though their origination is from the lower latitude on the other hand the current originating from higher latitudes facilitates reduction in salinity. It is because of this reason that along the mid latitude the areas affected by cold current develops dry condition facilitating the prominence of clear sky evaporation and higher salinity. Such impacts are developed by the cold California current and the Benguela current.
- **Prevailing winds:** The three permanent wind flowing in a particular direction plays a significant role in determining the flow direction of the surface water. It is under the impact of these winds that increase in salinity is experienced in the higher latitudes (Westerlies) where as it facilitates lowering down of salinity in lower latitudes (polar & trade winds).The flow of wind towards the coast and away from it also facilitates the variation in the concentration of salinity. In most general terms, the movement of onshore winds facilitates decrease in salinity along the coast where as offshore winds increases the salinity along the coast. In the overview of wind flow winds moving from ocean to land facilitates increase of salinity where as land to sea decreases salinity.

- **Rivers:** Designated as the source of fresh water, the mouths of the rivers results in lesser concentration of salinity. It is particularly true for the rivers which are draining larger amount of water into the Bay Gulf like Amazon, Mississippi, Hwang Ho, Ganges etc.
- **Continentality:** means the closeness of water body with the continents. The enclosed water bodies develop a typical trait of aping the characteristics of the land or continents. In this profile the lower latitude continental water bodies develops high temperature, evaporation and high salinity. On the other hand, the high latitude continental water bodies develops low temperature, low evaporation and low salinity. Along with it the melting glaciers further adds the clause for reduction in the salinity.
- **Climate:** Which is marked as the most important external cause influencing the salinity? Alike in tropical climate, higher evaporation facilitates higher concentration of salinity. Cold climatic conditions reduce the salinity. Humid climatic conditions further reduce the salinity. With the cumulative impact of these factor variations in the distribution of salinity is seen predominantly in the horizontal profile.

Horizontal distribution of salinity:

In accordance to the factor like temperature, rainfall, winds and oceanic current, the horizontal distribution of salinity is identified in Equatorial areas owing to higher rate of rainfall, the amount of salinity remains less than average. In the subtropical areas on the other hand increasing dryness and higher rate of evaporation facilitates maximum concentration of salinity. The polar areas with the reduced temperature and influx of fresh water by the melting glaciers facilitate lesser concentration of salinity. Thus the salinity profile varies in accordance to the variations in the latitude. But a different profile is seen when the horizontal distribution is studies in terms of regional analysis. As every latitude shows variability in the amount of salinity due to variable functional factors.

In most general terms the salinity is less in Equatorial areas and high in subtropical regions but along both these latitudes the concentration of salinity is varying in open and enclosed water bodies be enclosed water bodies have comparatively higher concentration of salinity. For eg. In the Atlantic Ocean, the open stretch of the ocean in the tropical belt registers average salinity but with the movement from west to east massive increase in the concentration of salinity is seen.

Caribbean Sea on the west and Mediterranean to the east shows higher concentration because of their continental location. Apart from this the Mediterranean Sea is surrounded by the arid and semiarid areas. Thus the deposition of the minerals from these regions into Mediterranean facilitates salinity rise. In addition to this, the areas with Mediterranean climate or the areas where big rivers has their mouths, Mediterranean sea develops lesser concentration of salinity like Gulf of Lion, Black Sea, Adriatic Sea, etc. At the arid periphery of Mediterranean sea the concentration of salinity is quite high. For example the coastal areas of Israel, Libya (Gulf of Sidra and Gabes). Moving towards the west the impact of continents eventually reduces beyond Strait of Gibraltar.

Gulf of Mexico also shows higher concentration of salinity but is always less than that of Mediterranean. In the open seas the concentration of salinity is generally less. But the exceptional case is the Sargasso Sea. This central stretch of North Atlantic is marked with the Quito stretch of water which has developed anti . In Gulf of Guinea, high amount of rainfall and influx of rainfall facilitates lesser concentration of salinity but towards south west coast of Africa, dry conditions facilitates increase in the amount of salinity.

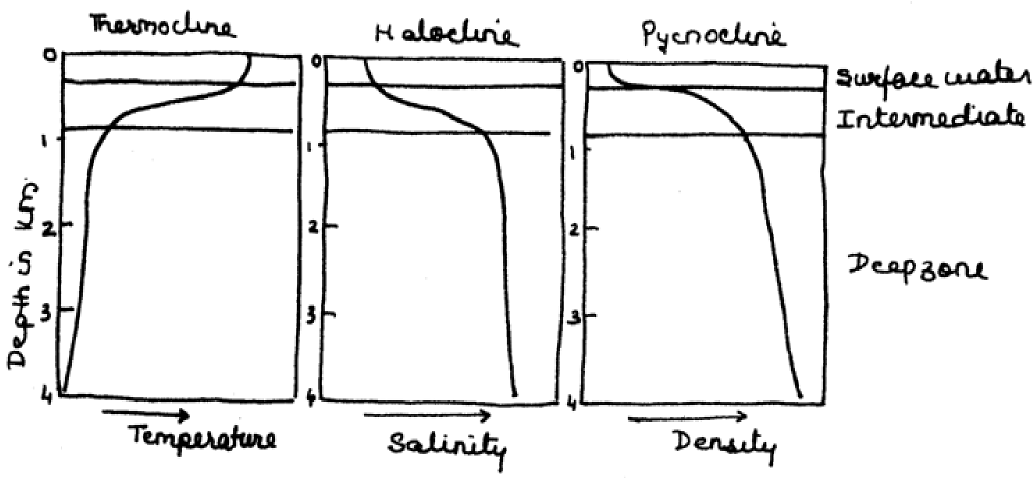
Almost same profile is seen in Indian Ocean. The Red Sea, Persian Gulf, Gulf of Oman, Gulf of Aden, Gulf of Khambhat, Kutch, Mannar are the water bodies which presents higher concentration of salinity in comparison to the open ocean. In the southern Indian Ocean, the warm oceanic current facilitates moist climates (less salinity) whereas along West Australia, cold current facilitates dry conditions and higher concentration of salinity.

In the Pacific Ocean, the enclosed water bodies like, East China Sea, Yellow Sea, South China, Gulf of Thailand, Tongking, the concentration of salinity is more.

Similarly in South Pacific Coral Sea, Arafura Sea, Gulf of Carpenteria and in the Eastern Coast, Gulf of California and Panama shows higher concentration of salinity than open sea Along the mid and high latitudes, the continentality develops very distinctive profile, that is, higher the degree of continentality lower will be concentration of salinity. It is because, the lesser temperature conditions and influx of fresh water by melting glaciers reduces the concentration. On the other hand the open oceans lacks the influence of continents and has the impact of warm oceanic currents. Therefore the concentration of salinity is more. For eg. Hudson Bay, Baffin

Bay, Baltic Sea, Beaufort Sea, White sea shows lesser concentration of salts whereas English Channel, North Sea and Bay of Biscay have higher concentration of salt.In the Pacific ocean, Sea of Okhostok and Berring, the concentration of salinity is less.In the higher latitudes, the lakes associated with the coastal areas in relative term shows lesser concentration of salinity. It is because of influx of rivers and melting ice. On other hand, the enclosed lakes of lower latitudes, Lake Van Dead Sea, Aral Sea, Caspian Sea, etc.

Vertical Distribution of salinity:



The vertical distribution of salinity is predominantly the outcome of the salinity profile on the surface, i.e. if the factors affecting the salinity facilitates the higher concentration on the surface salinity goes on decreasing with increasing depth and vice versa. Therefore in the equatorial areas, the lesser concentration of salinity facilitates decrease with increase in depth where as in the sub tropical areas the excessive concentration on the surface results in decreasing salinity with depth. At the approximate, depth of 2500m, the salinity is perceived to be uniformly balanced.

Significance of salinity:

The amount of salinity present in the ocean water determines both physical and economic characteristics of the ocean. As it is the prominent factor which determines the density of water, which has a significant role to play in determining the role of current. The amount of salinity also decides the origination and development of various sub marine organism predominantly fishes.

The salinity profile of ocean also has the indirect influence on the climatic profile of the particular latitude.

HEAT BUDGET

About half the solar energy reaching Earth is absorbed by the ocean and land, where it is temporarily stored near the surface. Only about a fifth of the available solar energy is directly absorbed by the atmosphere. Of the energy absorbed by the ocean, most is released locally to the atmosphere, mostly by evaporation and infrared radiation. The remainder is transported by currents to other areas especially mid latitudes. Note that "heat is the amount of thermal energy transferred from one body to another because of the temperature difference between those bodies". Heat lost by the tropical ocean is the major source of energy needed to drive the atmospheric circulation. And, solar energy stored in the ocean from summer to winter helps ameliorate Earth's climate. The thermal energy transported by ocean currents is not steady, and significant changes in the transport, particularly in the Atlantic, may have been important for the development of the ice ages. For these reasons, oceanic heat budgets and transports are important for understanding Earth's climate and its short and long term variability.

Changes in energy stored in the upper layers of the ocean result from a local imbalance between input and output of heat through the sea surface. This transfer of heat through the surface is called a *heat flux*. The flux of heat and water also changes the density of surface waters, and hence their buoyancy. As a result, the sum of the heat and water fluxes is often called the *buoyancy flux*.

The flux of energy to deeper layers is usually much smaller than the flux through the surface. And, the total flux of energy into and out of the ocean must be zero, otherwise the ocean as a whole would heat up or cool down. The sum of the heat fluxes into or out of a volume of water is the *heat budget*.

The major terms in the budget at the sea surface are:

- ***Insolation*** **the flux of sunlight into the sea;**
- ***Net Infrared Radiation*** **net flux of infrared radiation from the sea;**
- ***Sensible Heat Flux*** **the flux of heat out of the sea due to conduction;**

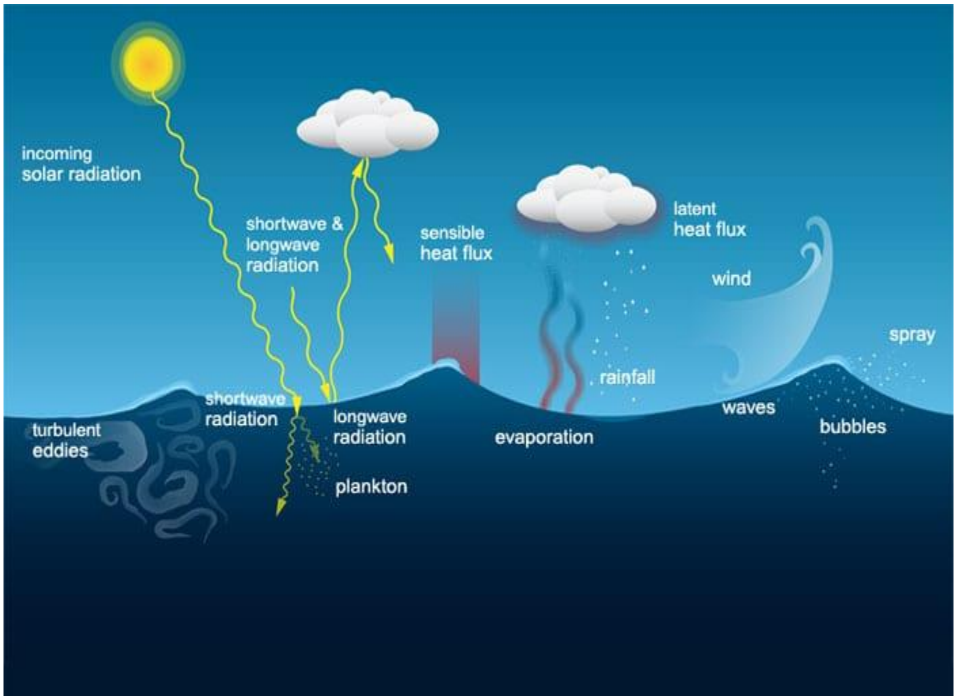
- ***Latent Heat Flux*** **the flux of heat carried by evaporated water; and**
- ***Advection*** **heat carried away by currents.**

Importance of the Ocean in Earth's Heat Budget

To understand the importance of the ocean in Earth's heat budget, let's make a simple comparison of the heat stored in the ocean with heat stored on land during an annual cycle. During the cycle, heat is stored in summer and released in the winter. The point is to show that the oceans store and release much more heat than the land.

The volume of water which exchanges heat with the atmosphere on a seasonal cycle is 100 m3 per square meter of surface, *i.e.* that mass from the surface to a depth of 100m. The density of water is 1000 kg/m3, and the mass in contact with the atmosphere is *density* × *volume* = *mwater* = 100,000 kg. The volume of land which exchanges heat with the atmosphere on a seasonal cycle is 1 m3. Because the density of rock is 3,000 kg/m3, the mass of the soil and rock in contact with the atmosphere is 3,000 kg.

. The large storage of heat in the ocean compared with the land has important consequences. The seasonal range of air temperatures on land increases with distance from the ocean, and it can exceed 40°C in the center of continents, reaching 60°C in Siberia. Typical range of temperature over the ocean and along coasts is less than 10°C.



The variability of water temperatures is still smaller.

Factors Influencing Insolation Incoming solar radiation is primarily determined by latitude, season, time of day, and cloudiness. The polar regions are heated less than the tropics, areas in winter are heated less than the same area in summer, areas in early morning are heated less than the same area at noon, and cloudy days have less sun than sunny days.

The following factors are important:

- The height of the sun above the horizon, which depends on latitude, sea-son, and time of day.
- The length of day, which depends on latitude and season.
- The cross-sectional area of the surface absorbing sunlight, which depends on height of the sun above the horizon.
- Attenuation, which depends on:
  - Clouds, which absorb and scatter radiation.
  - Path length through the atmosphere.
  - Gas molecules which absorb radiation in some bands. H2O, O3, and CO2 are all important.
  - Aerosols which scatter and absorb radiation. Both volcanic and marine aerosols are important.
  - Dust, which scatters radiation, especially Saharan dust over the Atlantic.
- Reflectivity of the surface, which depends on solar elevation angle and roughness of sea surface. Solar inclination and cloudiness dominate. Absorption by ozone, water vapor, aerosols, and dust are much weaker

Factors influencing Infrared Flux

The sea surface radiates as a blackbody having the same temperature as the water, which is roughly 290K. The distribution of radiation as a function of wavelength is given by Planck s equation. Sea water at 290K radiates most strongly at wavelengths near 10 µm. These wavelengths are strongly absorbed by clouds, and somewhat by water vapor. A plot of atmospheric transmittance as a function of wavelength for a clear atmosphere but with varying amounts of water vapor shows the atmosphere is nearly transparent in some wavelength bands called windows.

The transmittance on a cloud-free day through the window from 8 μm to 13 μm is determined mostly by water vapor. Absorption in other bands, such as those at 3.5 μm to 4.0 μm depends on CO2 concentration in the atmosphere. As the concentration of CO2 increases, these windows close and more radiation is trapped by the atmosphere.

Because the atmosphere is mostly transparent to incoming sunlight, and somewhat opaque to outgoing infrared radiation, the atmosphere traps radiation. The effect is known as the *greenhouse effect*. If the earth were in radiative equilibrium, with an atmosphere, the surface temperature would be 77°C. This does not happen because water evaporates from the surface, mostly from tropical seas, cooling the surface.

The net infrared flux depends on:

- Clouds thickness. The thicker the cloud deck, the less heat escapes to space.
- Cloud height, which determines the temperature at which the cloud radiates heat back to the ocean. The rate is proportional to *t*4, where *t* is the temperature of the radiating body in Kelvin. High clouds are colder than low clouds.
- Atmospheric water-vapor content. The more humid the atmosphere the less heat escapes to space.
- Water Temperature. The hotter the water the more heat is radiated. Again, radiation depends of *t*4.
- Ice and snow cover. Ice emits as a black body, but it cools much faster than open water. Ice-covered seas are insulated from the atmosphere.

Water vapor and clouds are more important for determining the net loss of infrared radiation than are changes in surface temperature. Hot tropical regions lose less heat than cold polar regions.

Factors influencing Latent-Heat Flux Latent heat flux is influenced primarily by wind speed and relative humidity. High winds and dry air evaporate much more water than weak winds with relative humidity near 100%. In polar regions, evaporation from ice covered oceans is much less than from open water. In the arctic, most of the heat lost from the sea is through leads (ice-free areas). Hence the percent open water is very important for the arctic heat budget.

Factors influencing Sensible-Heat Flux

Sensible heat flux is influenced primarily by wind speed and air-sea temperature difference. High winds and large temperature differences cause high fluxes. Think of this as a wind-chill factor for the oceans.

Meridional Heat Transport

Overall, Earth gains heat at the top of the tropical atmosphere, and it loses heat at the top of the polar atmosphere. The atmospheric and oceanic circulation together must transport heat from low to high latitudes to balance the gains and losses. This north-south transport is called the *meridional transport*.

How much heat is carried by the ocean and how much by the atmosphere? The sum of the meridional heat transport by the ocean and atmosphere together is calculated accurately from the divergence of the zonal average of the heat budget measured at the top of the atmosphere by satellites. To make the calculation, we assume steady state transports over many years so that any long-term net heat gain or loss through the top of the atmosphere must be balanced by a meridional transport and not by heat storage in the ocean or atmosphere. So let's start at the top of the atmosphere.

Heat Budget at the top of the Atmosphere

Heat flux through the top of the atmosphere is measured by radiometers on satellites.

- Insolation is calculated from the solar constant and observations of reflected sunlight made by meteorological satellites and by special satellites such as the Earth Radiation Budget Experiment Satellite.
- Back radiation is measured by infrared radiometers on the satellites.
- The difference between insolation and net infrared radiation is the net heat flux across the top of the atmosphere.

Errors arise from calibration of instruments, and from inaccurate information about the angular distribution of reflected and emitted radiation. Satellite instruments tend to measure radiation propagating vertically upward, not radiation at large angles from vertical, and radiation at these angles is usually calculated not measured.

The sum of the meridional heat transported by the atmosphere and the oceans is calculated from the top of the atmosphere budget. First average the satellite observations in the zonal direction, to obtain a zonal average of the heat flux at the top of the atmosphere. Then calculate the meridional derivative of the zonal mean flux to calculate the north-south flux divergence. The divergence must be balanced by the heat transport by the atmosphere and the ocean across each latitude band.

Oceanic Heat Transport

Oceanic heat transport are calculated three ways:

- *Surface Flux Method* calculates the heat flux through the sea surface from measurements of wind, insolation, air, and sea temperature, and cloudiness using bulk formulas. The fluxes are integrated to obtain the zonal average of the heat flux .Finally, the meridional derivative of the net flux gives the flux divergence, which must be balanced by heat transport in the ocean.
- *Direct Method* calculates the heat transport from values of current velocity and temperature measured from top to bottom along a zonal section spanning an ocean basin. The flux is the product of northward velocity and heat content derived from the temperature measurement.
- *Residual Method* first calculates the atmospheric heat transport from atmospheric measurements or the output of numerical weather models. This is the direct method applied to the atmosphere. The atmospheric trans-port is subtracted from the total meridional transport calculated from the top-of-the-atmosphere heat flux to obtain the oceanic contribution as a residual .

Meridional Fresh Water Transport

The Earth's water budget is dominated by evaporation and precipitation over the ocean. Baumgartner and Reichel report that 86% of global evaporation and 78% of global precipitation occur over the ocean. A map of the net evaporation shows that evaporation exceeds a meter per year in the trade-wind regimes in the eastern parts of the oceans. The transport of fresh water by the ocean can be calculated in the same ways heat transports are calculated, with similar uncertainties . Knowledge of water fluxes and transports is important for understanding the global hydrological cycle, ocean dynamics, and global climate. For example, the variability of fresh water fluxes may have played an important role in the ice ages .

Temperature

The oceanic temperature is defined as the amount of heat present in ocean water. The sources of this heat are designated to be insolation and volcanic activities. As the constituent of ocean water, its extent depth varies from one place to other and similarly prevailing winds, oceanic currents and climate also shows variability. The oceanic temperature develops a complex profile of distribution. The various factors are as follows:

- **Latitudes:** The temperature profile of the ocean varies with variation in latitudes. The tropical areas owing to attainment of direct sun rays has higher temperature thus moving from zero degrees to 90° varying inclination of suns rays results in declining temperature. Therefore Bay of Bengal has higher temperature than Bering Sea.
- **Salinity:** The salinity profile of ocean water has direct relationship with temperature. It is because of this season that with increasing latitude both temperature and salinity decreases. In terms of enclosed water bodies along low latitudes, both salinity and temperature are high whereas in higher latitude both are low when compared with the open water stretches of the same latitude.
- **Oceanic currents:** The warm currents increases the temperature of the coastal areas of higher latitudes thereby increasing salinity where as cold currents reduces the temperature and salinity.
- **Planetary winds:** The influence of oceanic currents is carried to the larger extent by the prevailing winds. The prevailing winds moving from lower to higher latitude facilitates temperature rise as westerlies whereas movement from high to low latitudes results in reduction of temperature as trade and polar winds.

In accordance to the factors mentioned, the variability in distribution of oceanic temperature is seen. In most general terms the mid of high latitude, water registers lesser temperature in comparison to the lower latitudes. This is because of variation in the angle of inclination of sun's rays and melting glacier. On the other hand, the lesser temperature in Hudson Bay, Baltic Sea, Baffin Bay, Labrador Sea, Sea of Okhostok in comparison to the Pacific, Atlantic Ocean is due to the continentality. Moreover the open water bodies are under the influence of prevailing winds and warm oceanic currents. The water bodies like Aral Sea, Persian Gulf, Red Sea registers higher temperature owing to the continentality of the lower latitudes.

Vertical distribution of ocean temperature:

In most general terms temperature decreases with increasing depth, but this trend is not seen in the areas marked with the presence of volcanism in the oceanic flow and also in the areas where melting ice and rain reduces temperature. It is because of this reason that along the Equatorial belt the surface temperature of the water is less which increases with increasing depth and ultimately starts decreasing. Elsewhere in tropical belt the temperature reduces steadily with rise in depth. The polar areas have lesser temperature on the surface and thus initial increase with depth lasts along the mid oceanic ridges. The volcanic activities facilitates rising temperature with increasing depth irrespective of the latitude.

Significance of Oceanic Temperature:

Various physical attributes of the ocean water like density evaporation, salinity, ocean currents, etc. are determined by the temperature. In the subtropical areas owing to high temperature, evaporation and comparatively less rainfall, the water level is less. Similarly the areas affected by warm oceanic currents develop instable profile. Among the economic significance, the confluence of warm and cold current provides one of the important clauses for fishery development, like the confluence of Oyashio (cold) and Kuroshio (warm) currents. Similarly the confluence zone of the current facilitates the formation of advection fog as in New Found Land which hinders the most of oceanic vessels. In the lower latitude, high temperature facilitates the development of salt industries especially along enclosed water bodies. The lower temperature condition in the higher latitude restricts the trade movements during winters.