Temperature and Salinity Distribution of Oceans

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.

Vertical Temperature Distribution of Oceans

- **Photic or euphotic zone** extends from the upper surface to ~200 m. 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

- 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.

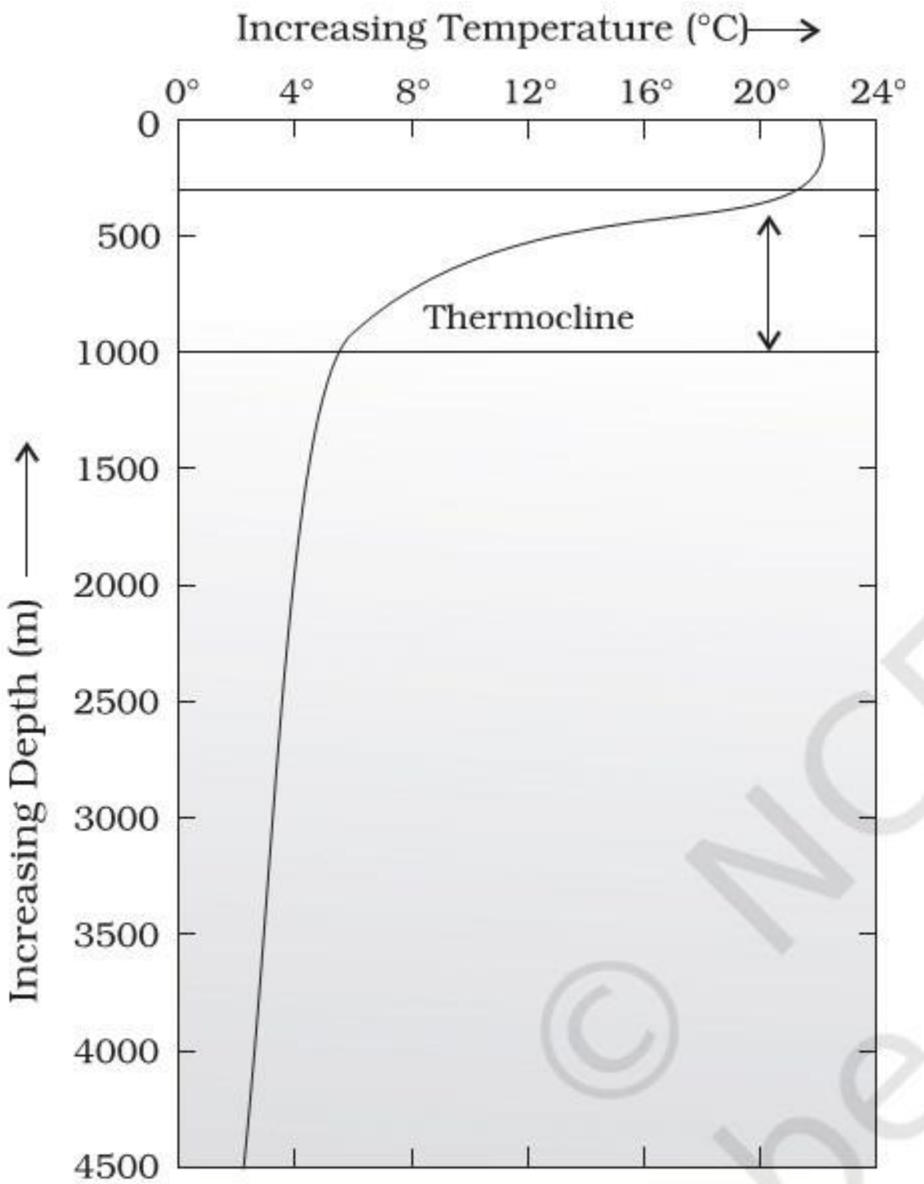
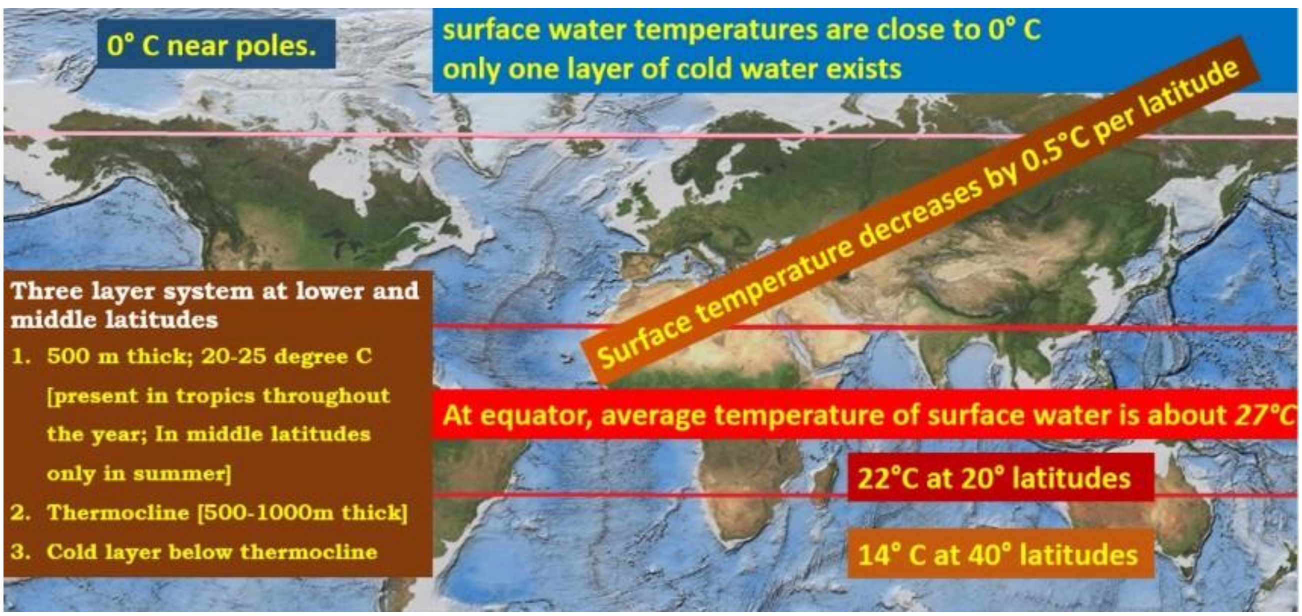


Figure 13.3 : Thermocline

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.

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.

Horizontal Temperature Distribution of Oceans

- 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.

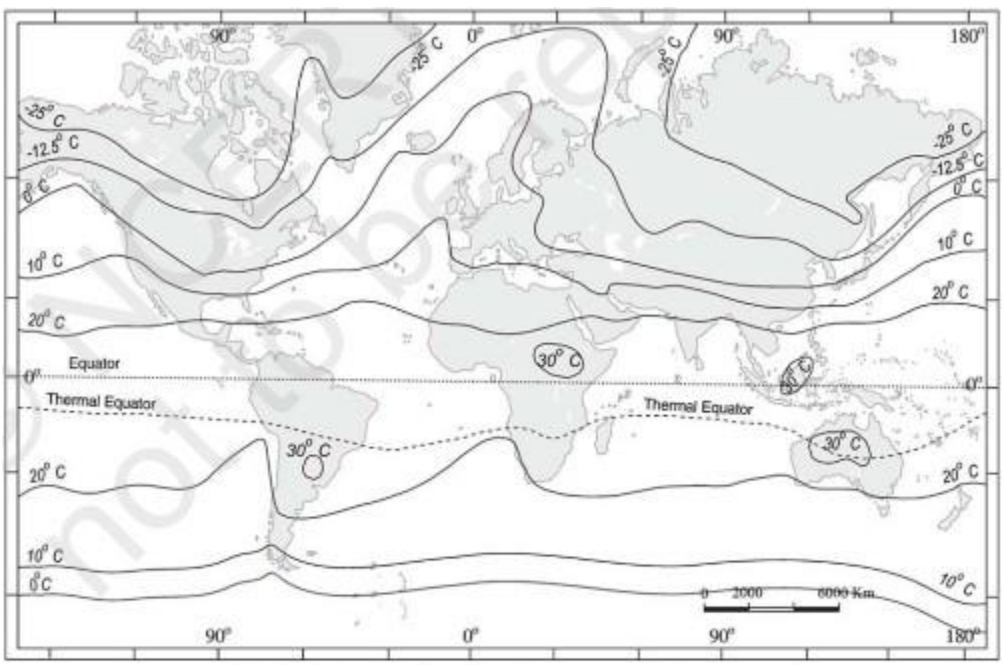


Figure 9.4 (a) : The distribution of surface air temperature in the month of January

Range of Ocean Temperature

- The oceans and seas get heated and cooled slower than the land surfaces. Therefore, even if the solar insolation is maximum at noon, the ocean surface temperature is **highest at 2 p.m.**

- The average diurnal or daily range of temperature is barely 1 degree in oceans and seas.
- The highest temperature in surface water is attained at 2 p.m. and the **lowest, at 5 a.m.**
- The diurnal range of temperature is highest in oceans if the sky is free of clouds and the atmosphere is calm.
- The annual range of temperature is influenced by the annual variation of insolation, the nature of ocean currents and the prevailing winds.
- The maximum and the minimum temperatures in oceans are slightly delayed than those of land areas (the **maximum being in August** and the minimum in February [Think why intense tropical cyclones occur mostly between August and October – case is slightly different in Indian Ocean due to its shape]).
- The northern Pacific and northern Atlantic oceans have a greater range of temperature than their southern parts due to a difference in the force of prevailing winds from the land and more extensive ocean currents in the southern parts of oceans.
- Besides annual and diurnal ranges of temperature, there are periodic fluctuations of sea temperature also. For example, the 11-year sunspot cycle causes sea temperatures to rise after a 11- year gap.

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.

Ocean Salinity

- Salinity is the term used to define the total content of dissolved salts in sea water.
- It is calculated as the amount of salt (in gm) dissolved in 1,000 gm (1 kg) of seawater.
- It is usually expressed as parts per thousand or ppt.
- Salinity of **24.7 (24.7 o/oo)** has been considered as the upper limit to demarcate '**brackish water'.**

Role of Ocean Salinity

- Salinity determines compressibility, thermal expansion, temperature, density, absorption of insolation, evaporation and humidity.
- It also influences the composition and movement of the sea: water and the distribution of fish and other marine resources.

Highest salinity in water bodies
Lake Van in Turkey (330 °/$_{oo}$),
Dead Sea (238 °/$_{oo}$),
Great Salt Lake (220 °/$_{oo}$)

Table 13.4 : Dissolved Salts in Sea Water (gm of Salt per kg of Water)

Chlorine	18.97
Sodium	10.47
Sulphate	2.65
Magnesium	1.28
Calcium	0.41
Potassium	0.38
Bicarbonate	0.14
Bromine	0.06
Borate	0.02
Strontium	0.01

Share of different salts is as shown below—

- **sodium chloride — 77.7%**
- **magnesium chloride—10.9%**
- **magnesium sulphate —.4.7%**
- **calcium sulphate — 3.6%**
- **potassium sulphate — 2.5%**

Factors Affecting Ocean Salinity

- The salinity of water in the surface layer of oceans depend mainly on **evaporation and precipitation.**

- Surface salinity is greatly influenced in coastal regions by the **fresh water flow** from rivers, and in polar regions by the processes of freezing and thawing of ice.
- Wind, also influences salinity of an area by transferring water to other areas.
- The ocean currents contribute to the salinity variations.
- Salinity, temperature and density of water are interrelated. Hence, any change in the temperature or density influences the salinity of an area.

Horizontal distribution of salinity

- The salinity for normal open ocean ranges between **33 and 37**.

High salinity regions

- In the land locked Red Sea (don't confuse this to Dead Sea which has much greater salinity), it is as high as 41.
- In hot and dry regions, where evaporation is high, the salinity sometimes reaches to 70.

Comparatively Low salinity regions

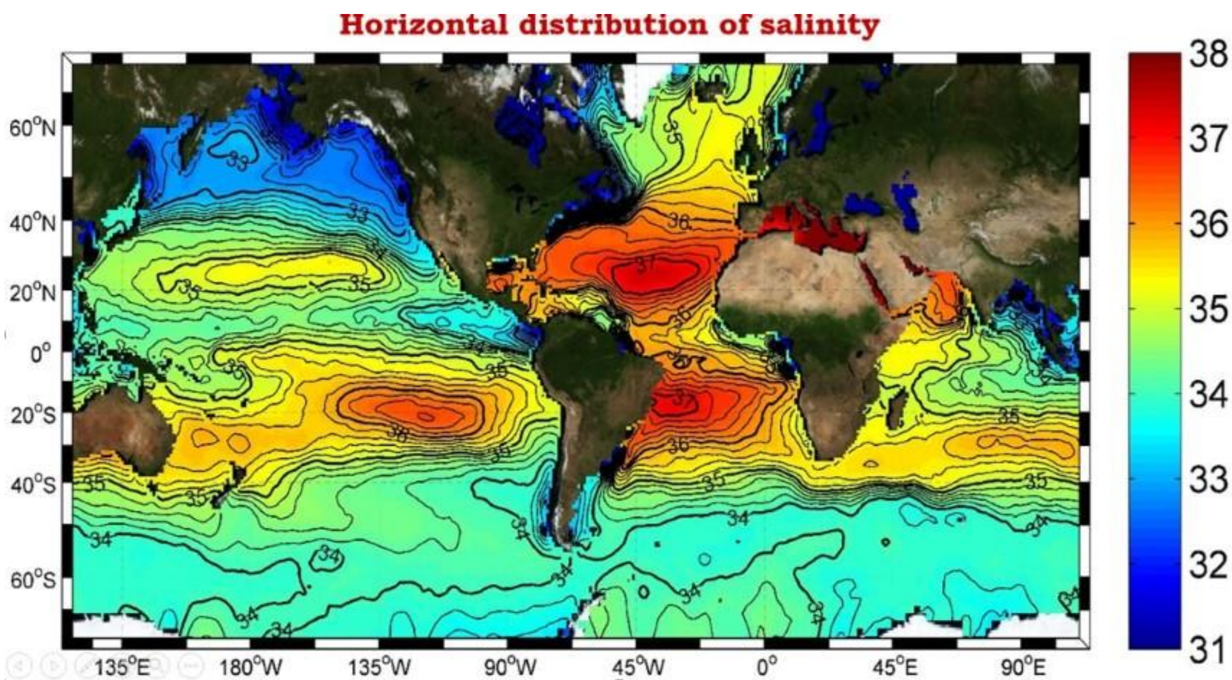
- In the estuaries (enclosed mouth of a river where fresh and saline water get mixed) and the Arctic, the salinity fluctuates from 0 – 35, seasonally (fresh water coming from ice caps).

Pacific

- The salinity variation in the Pacific Ocean is mainly due to its shape and larger areal extent.

Atlantic

- The average salinity of the Atlantic Ocean is around 36-37.
- The equatorial region of the Atlantic Ocean has a salinity of about 35.
- Near the equator, there is **heavy rainfall**, high relative humidity, cloudiness and calm air of the doldrums.
- The polar areas experience very little evaporation and receive large amounts of fresh water from the melting of ice. This leads to low levels of salinity, ranging between 20 and 32.
- Maximum salinity (37) is **observed between 20° N and 30° N and 20° W – 60° W**. It gradually decreases towards the north.



Indian Ocean

- The average salinity of the Indian Ocean is 35.
- The low salinity trend is observed in the Bay of Bengal due to influx of river water by the river Ganga.

- On the contrary, the Arabian Sea shows **higher salinity** due to high evaporation and low influx of fresh water.

Marginal seas

- **The North Sea**, in spite of its location in higher latitudes, records higher salinity due to more saline water brought by the North Atlantic Drift.
- **Baltic Sea** records low salinity due to influx of river waters in large quantity.
- The **Mediterranean Sea** records higher salinity due to high evaporation.
- Salinity is, however, very low in **Black Sea** due to enormous fresh water influx by rivers.

Inland seas and lakes

- The salinity of the inland Seas and lakes is very high because of the regular supply of salt by ' the rivers falling into them.
- Their water becomes progressively more saline due to evaporation.
- For instance, the salinity of the **Great Salt Lake** , (Utah, USA), the **Dead Sea** and the **Lake Van** in Turkey is 220, 240 and 330 respectively.
- The oceans and salt lakes are becoming more salty as time goes on because the rivers dump more salt into them, while fresh water is lost due to evaporation.

Cold and warm water mixing zones

- Salinity decreases from 35 – 31 on the western parts of the northern hemisphere because of the influx of melted water from the Arctic region.

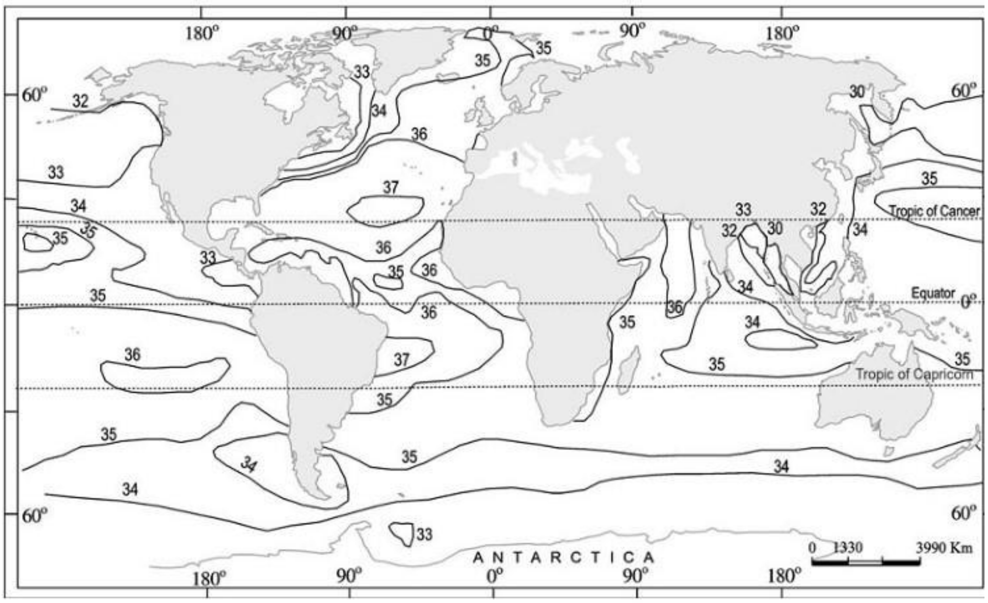


Figure13.5 : Surface salinity of the World's Oceans

Sub-Surface Salinity

- With depth, the salinity also varies, but this variation again is subject to latitudinal difference. The decrease is also influenced by cold and warm currents.
- In high latitudes, salinity increases with depth. In the middle latitudes, it increases up to 35 metres and then it decreases. At the equator, **surface salinity is lower.**

Vertical Distribution of Salinity

- Salinity changes with depth, but the way it changes depends upon the location of the sea.
- Salinity at the surface increases by the loss of water to ice or evaporation, or decreased by the input of fresh waters, such as from the rivers.
- Salinity at depth is very much fixed, because there is no way that water is 'lost', or the salt is 'added.' There is a marked difference in the salinity between the surface zones and the deep zones of the oceans.

- The lower salinity water rests above the higher salinity dense water.
- Salinity, generally, increases with depth and there is a distinct zone called the **halocline** (compare this with thermocline), where salinity increases sharply.
- Other factors being constant, increasing salinity of seawater causes its density to increase. High salinity seawater, generally, sinks below the lower salinity water. This leads to **stratification by salinity**.