

## PHYSICAL PROPERTIES OF SEA WATER

### Physical properties of sea water

Many of the processes that occur in the oceans depend on the physical [properties of sea water](#). The conduction of heat, absorption of light, transmission of sound, formation of [waves](#), [tides](#), ice, currents and water masses are some of the important physical features of ocean water. Sea water contains pure water as well as salts, dissolved gases, organic substances and undissolved suspended particles. The presence of salts and other substances in sea water greatly influence the various characteristics of sea water. Hence, an understanding of the [physical properties of sea water](#) is necessary to study the various processes that occur in the ocean. The forces that cause circulation of water in the ocean arise from changes in the physical properties of that water.

Physical properties like temperature and salinity directly affect the density, buoyancy and stability of seawater and consequently the motion of water in the ocean basins. The physical properties of seawater also strongly influences the behaviour of heat and light in the ocean.

The unit of physical oceanography deals with the following chapters

1. [Salinity and chlorinity](#)
2. Temperature of seawater
3. thermal properties of seawater
4. Colligative and other properties of seawater
5. Residence time of constituents in seawater
6. Properties of sea ice
7. Transmission of sound
8. absorption of radiation
9. Eddy conductivity
9. Diffusivity and viscosity
10. General distribution of temperature, salinity and density
11. salinity and temperature of surface layer and sub surface layer (SST)
12. [Distribution of temperature and salinity](#), TS diagram
13. [water mass of indian ocean salinity and chlorinity](#)

### **Salinity and Chlorinity**

#### **Salinity**

Salt content of water is the total quantity dissolved salts in 1.0Kg. of seawater. Most of the major constituents of sea water are not affected by biological and chemical reactions they are called "conservative elements". Sea water maintains "[Constancy of composition](#) of sea water". Salinity of water varies with evaporation and fresh water precipitation.

Table 1- Range of salt contents in different water bodies

Marine Environments	Ranges of salts
Open ocean	32-38% average 35%
Shallow coastal water	27-30
Estuaries	0-30
Semi enclosed sea	

Baltic Sea	<25
Hyper saline bodies (Red sea, Tropical coastal Lagoon)	>40

### Chlorinity

Chlorinity is a measure of the chloride content, by mass, of seawater (grams per kilogram of seawater, or per cubic meter). Initially, chlorinity was defined as the weight of chlorine in grams per kilogram of seawater after the bromides and iodides had been replaced by chlorides. To make the definition independent of atomic weights, chlorinity is now defined as 0.3285233 times the weight of silver equivalent to all the halides present.

### Temperature and Thermal properties of sea water

The mean temperature of seawater is low, roughly 75% of the ocean's volume has a temperature from 0° – 5°C (Pinet 1996). The same percentage falls in a salinity range between 34–35 ppt (3.4–3.5%) (Pinet 1996). There is still quite a bit of variation, however. Surface temperatures can range from below freezing near the poles to 35°C in tropical seas. The vertical structure of the temperature can be divided into three basic layers, a surface mixed layer, where gradients are low, a [thermocline](#) where gradients are high, and a poorly stratified abyssal layer which are poorly stratified.

Temperature, in the ocean's layers are highly latitude dependent. The thermocline is pronounced in the tropics and the, but nonexistent in polar waters (Marshak 2001). The Thermocline usually lies near the surface, where evaporation raises salinity in the tropics, or meltwater dilutes it in polar regions. These variations of salinity and temperature with respect to depth change the density of the seawater, creating the [pycnocline](#).

Surface water temperature of the ocean as a whole ranges from -2°C to 35°C. Temperature is highest along the equator because of the warming of the [earth](#) in the tropics and the sea generally becomes cooler along the poles. At the sea surface the temperature changes with latitude.

Potential temperature  $\theta$  is calculated by correlating the adiabatic compression at a given depth and is more important than in situation temperature. The temperature of deep sample when brought to surface reduces to range at about 0.1 to 0.2°C and this called **potential temperature** and it will be slightly cooler than the temperature at depth called the **in situation temperature**.

The distribution of temperature in the ocean controls the distribution of marine organisms and density of seawater. Because of the greater heat capacity of water the surface temperature of the sea varies far less than land temperature. Consequently the sea provides a better stable environment for marine life and a moderating influence on the coastal climate.

### Thermal properties of seawater

Ocean can absorb great amount of solar heat during the day without undergoing drastic change in temperature. Oceans can supply enormous quantity of thermal energy to the atmosphere in the form of vapour and rain is formed due to condensation of water vapour on cooling.

Seawater never freeze due to high latent energy of fusion. The Ocean acts as a reservoir of heat energy that becomes neither hot in the summer nor cold in winter. A thermal gradient exists between the ocean and atmosphere. The ocean exchange heat energy with the atmosphere rapidly, and as a result heat in the ocean and the air temperature are thermostatically controlled.

## Colligative and Other [properties of sea water](#)

### Colligative properties

Colligative properties are those properties of solutions that depend on the number of dissolved particles in solution, but not on the densities of the solutes. For example, the freezing point of salt water is lower than that of pure water, due to the presence of the salt dissolved in the water. To a good approximation, it does not matter whether the salt dissolved in water is sodium chloride or potassium nitrate; if the molar amounts of solute are the same and the number of ions are the same, the freezing points will be the same. For example,  $\text{AlCl}_3$  and  $\text{K}_3\text{PO}_4$  would exhibit essentially the same colligative properties, since each compound dissolved to produce four ions per formula unit. The four commonly studied colligative properties are a) freezing point depression, b) boiling point elevation, c) vapor pressure lowering, and d) osmotic pressure. Since these properties yield information on the number of solute particles in solution, one can use them to obtain the molecular weight of the solute.

### Colligative Properties of Seawater:

The dissolved salts in seawater accounts for some of the properties of seawater that distinguishes it from freshwater:

- Salts lower the freezing point of seawater from  $0^\circ\text{C}$  to  $-2^\circ\text{C}$ .
- Salt increases the boiling point of seawater and seawater evaporates more slowly.
- The heat capacity of seawater decreases with increasing salt content.
- Osmotic pressure increases with increasing salt content.
- The greater the salinity, the greater the electrical conductivity of water.

## Residence time of constituents in sea water

A useful concept for characterizing substances in seawater is residence time. It is the time required to replace the amount of a given substance in the ocean completely. This concept can work in two ways, using either the rate of addition of elements or the rate of removal of elements incorporated in sediments deposited on the ocean bottom. Using the second option, we can define residence time as follows

Residence time = Amount of element present / Removal rate (in years)

Sodium's calculated residence time in the ocean of 68 million years is one of the longest residence times for an element.

An element's residence time in the sea is related to its chemical behavior. Elements like sodium are little affected by sedimentary or biological processes. They have residence times of millions of years. Elements used by organisms or readily incorporated in sediments, such as aluminium or iron, have much shorter residence times, ranging from a few hundred to a few thousand years.

We can also calculate residence times for water. There is a net removal, due to evaporation (which does not fall back on the ocean surface as rain) of a layer of water about 10 centimeters thick from the ocean surface each year. This water falls on the land and returns to the ocean through river discharge. Recall that the ocean has an average depth of about 4000 meters. From these figures we find the residence time of 40,000 years for water.

## Chapter 2: Sea ice

### Properties of sea ice

The physical properties of sea ice depend upon the a) [salinity of sea water](#) from which it forms, b) temperature, c) air-content or porosity, d) pressure, e) speed of ice formation, and f) age

and history of the ice. As soon as the temperature of the sea surface reaches the freezing point, pure ice begins to form. At this stage, sea water is trapped among the ice crystals. On further cooling, the various salts present in the sea water crystallize gradually depending upon the temperature. For example, sodium sulphate ( $\text{Na}_2\text{SO}_4 \cdot 10 \text{H}_2\text{O}$ ) crystallizes at  $-36.0^\circ\text{C}$  and calcium chloride ( $\text{CaCl}_2$ ) crystallizes at  $-55.0^\circ\text{C}$  (Ringer, 1928).

### Salinity of sea ice

The salinity of sea ice depends on the salinity of the original sea water, the speed of ice formation and the age of the ice. The salinity of sea ice is less than the salinity of the original sea water from which ice is formed, because some portion of the brine between the ice crystals seeps out. The salinity values usually vary between two for very old ice, 3-5 for ice after the first winter, 10 for new ice that is just formed and 20 for ice that is formed from sea water which is flooding.

### Density of sea ice

The density of sea ice depends mainly on its air-content or porosity, the amount of enclosed brine and the freezing temperature. According to Schwerdtfeger (1963), the density of sea ice is related to the air-content, and brine enclosed. Density of ice can be given by equation

$$r_t = (1 - a) (1 + 4.56 S / T) 0.917$$

Where,  $r_t$  is the density of the sea ice in  $\text{g/cm}^3$ ,  $a$  is the air content in volume per cent,  $S$  is the salinity in parts per thousand and  $T$  is the temperature in  $^\circ\text{C}$ . Pure fresh water ice has a density of 0.91676 at  $0^\circ\text{C}$ , while pure water in the liquid state has a density of 0.999867 at  $0^\circ\text{C}$ . The density of sea ice varies both above and below that of pure ice, i.e., above and below 0.91676 depending upon brine content in the ice and air-content.

### Specific heat of ice

The specific heat of sea ice varies over a wide range and depends upon the brine or salt content and on the temperature of the ice. However, the specific heat of pure ice varies very little and depends upon its temperature. The specific heat of sea ice is higher than the specific heat of pure ice, especially just below the freezing point, since more amount of heat is required for melting or freezing of additional brine content. According to Malmgren (1927), the specific heat of pure fresh water ice (when the salinity is zero) varies between 0.48  $\text{cal}/^\circ\text{C-g}$  at a temperature of  $-2^\circ\text{C}$  and 0.46  $\text{cal}/^\circ\text{C-g}$  at a temperature of  $-22^\circ\text{C}$  and when salinity is two, the specific heat of sea ice varies between 2.47  $\text{cal}/^\circ\text{C-g}$ , at a temperature of  $-2^\circ\text{C}$  and 0.52  $\text{cal}/^\circ\text{C-g}$  at a temperature of  $-22^\circ\text{C}$ .

### Latent heat of fusion and latent heat of freezing

The latent heat of fusion of pure ice i.e., the heat required to melt pure ice at  $0^\circ\text{C}$  and at atmospheric pressure is 79.67  $\text{cal/g}$ . Since the melting of sea ice does not occur at a fixed temperature due to the presence of salts, the usual definition of latent heat of fusion is not applicable to sea ice. Malmgren defined the latent heat of fusion of sea ice as the amount of heat required to melt 1g of sea ice of given salinity that was initially at the indicated temperature.

### Sea ice formation

The formation of sea ice depends mainly on sea water temperature, surface salinity, vertical distribution of salinity and water depth. Sea ice forms at higher latitudes due to extremely low

water temperature. As soon as the temperature of the sea surface reaches the freezing point, the formation of ice begins. The freezing point of water with a salinity of 35 is  $-1.91^{\circ}\text{C}$ . as water freezes at the surface of the ocean, the dissolved solids are left out of the crystalline structure of the ice. Hence, the salinity of the surrounding water increases. This higher salinity causes the lowering of the freezing point of the remaining water. Thus, surface salinity influences the freezing point. The vertical distribution of salinity as well as the depth of the water determine the thickness of the water layer that is involved in the vertical convection during the cooling processes.

Different types of ice are formed depending on the wind, current and sea state condition. when the winds are very weak and sea state is calm, clear crystalline “new ice” or “young ice” forms, while with the strong winds and rough seas, “grease ice” or “slush ice” forms, which looks turbid due to the enclosure of air bubbles within the ice crystals. If the winds continue to be weak during the freezing process, a primary thin ice called “nilas” forms from the new ice. When the grease ice begins to grow into disk’s, primary “pack ice” develops. The “pan cake” ice represents the transition from grease ice to pack ice. Sometimes, “hummocked ice” and “pressure ridges” form over depths of 8 – 10 m or even in 20m depth in the sea.

### Ice in the Oceans

There are two types of ice that cover the oceans. One is the sea ice which is formed by the freezing of sea water and the other is the fresh water ice such as the iceberg which is formed on the continent or on the ice itself and then carried into the ocean. The presence of ice in the ocean is important in many respects. [Sea ice formation](#) in high latitudes during winter season causes freezing up of harbours in these latitudes. Thus, sea ice creates navigational problems for ships and limits the usage of many ports in these areas. The floating icebergs in the oceans are dangerous to shipping particularly during fog conditions. Icebergs reach even low latitude areas due to favourable wind and current conditions and hence are the major problem for shipping activity in the oceans.

The transportation of sedimentary debris by ice is very important in high latitude ocean areas. Icebergs carry with them large amounts of material from the land. This material modifies the general topography of the [sea floor](#) and contributes significantly to the deep sea deposits. Sea ice also plays an important role in the transportation of sedimentary material. Sea ice tends to carry unsorted material including shells and other remains of organisms, from shallow water into deeper water and hence will give rise to accumulations of remains of organisms and organic material. The change of reflectivity that occurs when the sea freezes over, makes sea ice an important factor in the heat budget of the ocean. Sea ice damps surface [waves](#) in the ocean. Sea ice also changes the temperature and salinity in the upper layers of the ocean by the processes of melting and freezing.

## Chapter 3: Sound velocity and radiation

### Sound transmission in sea water

Sound is a form of mechanical energy which can be described as a periodic variation in pressure, particle velocity or displacement in an elastic medium. In general, sound propagates very well in liquids. Water transmits sound more efficiently than the atmosphere. Sound travels at a faster rate and with less absorption of energy through water than through the air.

#### Application of sound transmission in sea water

The propagation of sound in the ocean is of special importance since it has many applications. Sound is useful to find depths in the ocean. The echo sounder measures the

depth of the water under a ship's hull by estimating the time required for a sound pulse to travel to the [sea floor](#) and back to the ship. Sound can be used to locate objects, sense their shape and determine their distance away from the sound's source. The properties of the [sea floor](#) can be detected by studying the echo charts obtained by means of an echo sounder, since some [sea floor](#) materials. Sometimes, a special type of underwater phenomenon is detected on the depth chart of the echo sounder. Several marine organisms including fish move up towards the surface during night time and sink down to deeper waters during day time. These organisms form a layer known as the "deep scattering layer". A portion of the sound beam is scattered and reflected by the deep scattering layer creating the image of a false bottom on the echo sounder chart. Thus, sound transmission is useful to find the depth of availability of fish in the sea. Underwater sound propagation has important military applications also, particularly in submarine detection and echo ranging. In the sea, sounds are produced very frequently by three groups of animals, namely; fish, crustaceans and mammals including whales. Hydrophones are used to listen to the sounds of these animals. Analysis of these sounds will help in identifying their sources.

### Velocity of sound [waves](#)

The most important acoustical parameter in the ocean is the velocity of sound. Sound is a form of wave motion.

The velocity of sound [waves](#),  $V$  in a liquid is determined by the **Laplace equation**.

However, in practice it is more convenient to use the following expression --1

Where  $g$  is the ratio of [specific heat](#) at constant pressure ( $C_p$ ) to [specific heat](#) at constant volume ( $C_v$ ), i.e.,  $C_p/C_v$ ,

$K$  is the compressibility of the transmitting medium, i.e., liquid and  $\rho$  is the density of the liquid.

Since sound pulse is a wave of compression, and therefore, heats the liquid as it passes through, the ratio  $C_p/C_v$  i.e.,  $g$  is introduced in the expression.

The three variables ( $g$ ,  $\rho$  and  $K$ ) in the above expression depend on temperature, salinity and pressure. Hence, the velocity of sound [waves](#) in the ocean depends on temperature, salinity and pressure i.e., depth. A simplified form of the dependence of sound velocity on temperature, salinity, and pressure is given in the following equation (Medwin, 1975):

$$V = 1449.2 + 4.6 T - 0.055 T^2 + 0.00029T^3 + (1.34 - 0.010T) (S - 35) + 0.016Z \quad (3)$$

Where  $V$  is the velocity of sound in m/s,  $T$  is the temperature in  $^{\circ}\text{C}$ ,  $S$  is the salinity in parts per thousand,  $Z$  is the depth below the surface in metres. As the temperature of sea water increases, its density decreases and so from expression (1), the velocity of sound should increase with an increase in sea water temperature. Normally, an increase in salinity leads to an increase in density and therefore from expression (1), the velocity of sound should decrease with increase in salinity. But, an increase in salinity also decreases the compressibility of sea water, i.e.,  $K$  in expression (1) and this overtakes the effect of increase in density due to increase in salinity. Generally, the velocity of sound [waves](#) increases with increase in depth of the ocean.

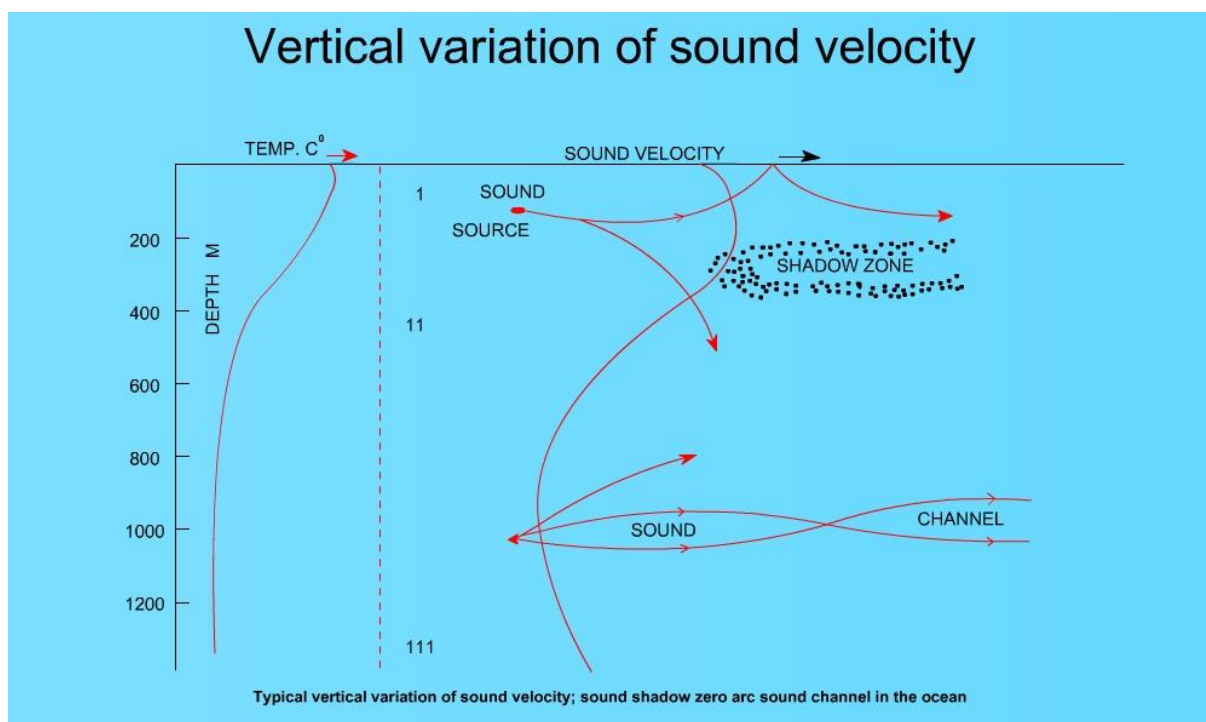
### Variation of sound velocity in the ocean

Sound velocity in the ocean ranges from about 1,400 to 1,570 m/sec. it increases with increasing temperature, salinity and pressure or depth in the ocean. The increase in sound velocity is about 4.5m/sec for  $1^{\circ}\text{C}$  increase in temperature; about 1.3 m/sec for one-

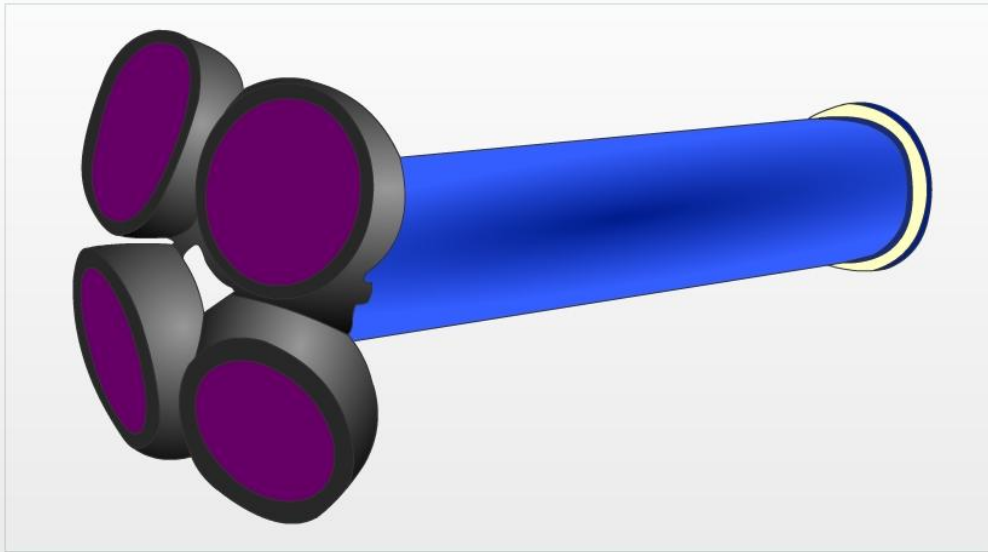
thousandth part increase in salinity and about 1.7 m/sec for 100m increase in depth. In the oceans, horizontal variations of sound velocity are smaller compared to vertical variations of sound velocity, because horizontal variations of temperature and salinity are smaller than the vertical variations.

The vertical variation of sound velocity in the deep waters of the ocean can be divided into three layer. In the upper layer of the ocean, which extends from surface to 100-150m depth, temperature and salinity variations are negligible as a result of mixing of waters due to wind and waves. The sound velocity increases as depth increases in this layer due to the pressure effect. In the middle layer or the thermocline layer, which extends from 100-150m depth to 1500m depth in the ocean, temperature decreases very rapidly. Sound velocity decreases very rapidly in this layer due to temperature effect. In the bottom layer i.e., below the thermocline layer and extending to the bottom of the ocean, temperature and salinity variations are again very negligible. In this layer, sound velocity increases with depth due to the effect of pressure.

In the shallow waters of coastal regions and on the continental shelves, the sound velocity profile tends to be irregular and unpredictable. It is greatly influenced by surface heating and cooling, changes in salinity and water currents in these regions. The shallow water sound velocity profile is complicated by the effect of salinity variations caused by nearby sources of fresh water and contains several layers of different sound velocity gradients which have little temporal or spatial stability. the transmission of sound in the ocean is dependent on several environmental factors, the most important of which are the sound velocity distribution in the ocean, the depth and configuration of the bottom and the sediment characteristics of the bottom. In addition to temperature, salinity and pressure, the characteristics of the bottom also influence the propagation of sound in shallow water through absorption, reflection, etc. It is produced in the upper parts of the ocean. The positive gradient is due to the isothermal layer with the velocity of sound increasing with depth because of increasing pressure.



## Acoustic doppler current profilers



### Absorption of radiation, eddy conductivity, diffusivity and viscosity

#### Viscosity of sea water

The viscosity of seawater has an important influence on the motions of the [world ocean](#) and upon the nature of the forms of life that float or swim in the sea.

Viscosity arises from the internal friction of a fluid and may be defined as internal resistance to flow. It represents the ease with which molecules in the fluid move past one another or, alternatively, it also represents the ease with which mechanical energy can be exchanged between adjacent molecules. It is fluid viscosity that causes a motorboat to stop when the engine has been stopped. The viscosity of a fluid depends upon the chemical nature of its molecules. Viscosity is greatly affected by the temperature of the fluid; the viscosity of a fluid doubles if the temperature is decreased by 20<sup>0</sup>c. Salinity has only a minor effect on viscosity. In fact, the viscosity of seawater is about the same as that of fresh water at the same temperature.

#### Diffusion or diffusivity

It refers to transfer of material (eg. Salt) and temperature by eddies. Diffusion causes spreading or scattering of matter under the influence of a concentration gradient with movement from the stronger to weaker solution.