

## PHYSICAL PROPERTIES OF SEA WATER

### Salinity of Sea water

It is well known that sea water is salty. The reason for the oceans to be salty or saline is that all salts and other mineral elements have been washed away from the land to sea by rain over billions of years. All the rivers on the [earth](#) contribute to the oceans large quantities of dissolved solids every year. The total amount of salts in the oceans is estimated to be about  $5 \times 10^{19}$  kg.

Table 2. Different salts in seawater

| Constituent | g/kg of sea water | Percentage of dissolved material |
|-------------|-------------------|----------------------------------|
| Chloride    | 19.353            | 55.0                             |
| Sodium      | 10.760            | 30.6                             |
| Sulphate    | 2.712             | 7.7                              |
| Magnesium   | 1.294             | 3.7                              |
| Calcium     | 0.413             | 1.6                              |
| Potassium   | 0.387             | 1.1                              |
| Bicarbonate | 0.142             | 0.4                              |
| Bromide     | 0.067             | 0.189                            |
| Strontium   | 0.013             | 0.038                            |
| Boron       | 0.026             | 0.075                            |
| Fluoride    | 0.001             | 0.003                            |

### Factors Affecting Salinity

Factors that affect the salinity of the oceans can be broadly grouped into two categories, (a) factors that increase salinity and (b) factors that decrease salinity. The factors responsible for increase of salinity are : (i) evaporation (ii)Ice formation, (iii) advection of more saline water (iv) mixing with more saline deep water and (v) solution of salt deposits. The factors that are responsible decrease of salinity are: (i) Precipitation, (ii) melting of ice (iii) advection of less saline water, (iv) mixing with less saline deep water and (v) inflow of fresh water from land. Surface salinity changes are chiefly determined by three processes, namely, (a) decrease of salinity by precipitation, (b) increase of salinity by evaporation and (c) change of salinity by mixing processes. However, over large areas in the oceans, changes in surface salinity depend mainly upon changes in the difference between evaporation and precipitation.

## Surface Salinity Distribution in the Oceans

In the open ocean, surface salinity varies generally between 33ppt and 37ppt. The distribution of surface salinity in the oceans is primarily zonal. Lower salinity values are found in the coastal areas where large rivers enter the oceans. The salinity values are lower in the polar regions of the oceans because of melting of ice. Higher values of salinity are observed in the ocean regions where evaporation is high. A comparison of the average surface salinities of the North Atlantic, South Atlantic, North Pacific and South [Pacific oceans](#) reveals that the North Atlantic is most saline (35.5) and the North Pacific is least saline (34.2). Similarly, a comparison of the average salinities of the three non-polar oceans, namely, the Pacific, the Atlantic and the Indian Oceans shows that the [Pacific oceans](#) is the least saline (34.62), and the Atlantic oceans is the most saline (34.90), while the salinity of [the Indian Ocean](#) (34.76) lies between the salinities of the Atlantic and Pacific Oceans.

The average surface salinity of the oceans as a whole is more in the southern hemisphere (35ppt) than in the northern hemisphere (34ppt). In the northern hemisphere, the proportion of land to water is 2:3, while in the southern hemisphere it is 1.4:7. So there is less sea water in the northern hemisphere to receive the fresh water of rainfall upon land and sea. As a result, the surface salinity of the oceans in the southern hemisphere is high. There are other certain areas in the oceans where the surface salinity is relatively high. The most important among these is the Sargasso Sea in the central part of the North Atlantic Where the salinity reaches a high value of 38. In the Indian oceans, there are two areas of high surface salinity as high as 36ppt. In the South Pacific Ocean, there is an area off the coast of Peru with high surface salinity of 36.5.

## Latitudinal variation of surface salinity

Surface salinity value attains a primary maximum in the northern hemisphere between 20 and 25°N, a minimum just north of the equator at 5°N and a secondary maximum in the southern hemisphere between 20 and 25°S. From these sub-tropical maxima, the salinity value decreases rapidly towards higher latitudes in both the hemispheres. The highest surface salinity values in the oceans are found approximately in the regions of Tropic of Cancer and Tropic of Capricorn, which are at a distance of about 2,400km north and south of the equator, respectively. Similar trend of latitudinal variation of surface salinity is noticed for Atlantic and [pacific Oceans](#).

## Monthly and seasonal variations of surface salinity

Seasonal variations of surface salinity depend mainly upon the changes of evaporation and precipitation from season to season over the oceans. The seasonal variations of surface salinity in the open oceans are generally weak, not more than 0.5. These variations are important in regions where the climate is characterized by strong seasonal variations of precipitations. In the polar regions, the melting of ice in the summer and its movement by wind and current cause considerable seasonal variations. The seasonal variations of surface salinity are also more in coastal waters where there is lot of fresh water inflow through rivers. In Arabian Sea coastal waters near Mangalore, the surface salinity is found to vary from 29.6 in the south-west monsoon season (September) to 31.9 in the winter season.

## Diurnal variation of surface salinity

Diurnal variations of surface salinity are very small in the open ocean, since there are no significant diurnal variations in respect to precipitation and evaporation in the open oceans.

Even in the Arabian Sea coastal waters off Karwar, the diurnal variation of surface salinity is very small throughout the year. The maximum diurnal variation of surface salinity in these waters is found to be about (0.21 ppt).

## Chapter 4: Seawater Temperature

### Distribution of temperature and salinity

Temperature is one of the most important [physical properties of sea water](#). Salinity and temperature together control the sea water density. Sea water temperature controls the distribution of marine organisms and fish. Because of the influence heat has upon chemical reactions (metabolism) sea water temperature has profound effects on the life processes of fish. Sea water temperature has profound effects on the life processes of fish. Sea water temperature influences the properties of surface air over the ocean. The vertical temperature structure affects the propagation of sound in the sea and is therefore important for anti-submarine warfare. Sea water temperature is indicative of other changes and conditions in the sea such as [upwelling](#) intensities, current and [water mass](#) boundaries.

The sun provides 99.97% of the heat energy required for the various physical processes taking place in the [earth](#)-atmosphere system. The other energy sources, such as heat from the interior of the [earth](#), radiations from other Celestial bodies, energy from the gravitational attraction of the sun and moon are negligible compared with the radiant energy received from the sun. The sun, which is a luminous gaseous sphere, has a surface temperature of 6000°C and emits energy in electromagnetic [waves](#). The maximum emission occurs at relatively short wave lengths in the visible portion of the spectrum, between about 0.4 and 0.7µm (Trewartha and Horn, 1980). According to Sellers (196%), a breakdown of the spectral composition of solar radiation indicates that 9% is in the ultraviolet (less than 0.4µm), 45% is in the visible (between 0.4µm and 0.74µm), and the remaining 46% is in the infrared (more than 0.74µm). The amount of solar radiation incident at the top of the [earth](#)'s atmosphere depends upon the time of the year, the time of the day and the latitude (Ayoade, 1983). However, all of the radiation incident on the top of the atmosphere does not reach the surface of the [earth](#). The atmosphere absorbs, reflects, scatters and re-radiates solar energy. On a global basis of the above radiation, 6% is reflected and scattered by atmospheric constituents to space, 24% is reflected and scattered to space by clouds, 3% is absorbed by clouds, 14% is absorbed by atmospheric constituents, 22% reaches the surface of the [earth](#) as diffuse sky radiation, and 31% reaches as direct beam solar radiation on the surface of the [earth](#). Thus, the radiation reaching the surface of the [earth](#) is composed of direct beam solar radiation and the diffuse sky radiation.

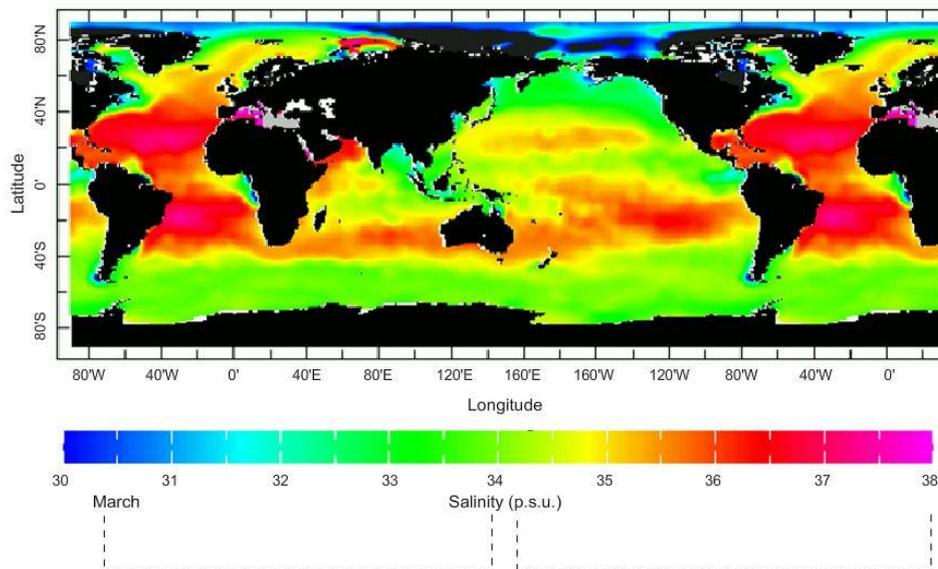
The radiation that actually reaches the surface of the [earth](#), i.e., the insolation is not all absorbed. Certain amount of insolation is reflected by the [earth](#)'s surface. The percentage of the insolation reflected by a surface is called the "albedo" of that surface. Fresh snow albedo is nearly 80%, from which it is clear that fresh snow absorbs only a comparatively small proportion of the insolation. The albedo of water is generally less than that of most surfaces on land. Due to several reasons, sea water and land surfaces behave differently to insolation. First, the albedo of sea water surface is generally smaller than that of land surface. Second, sea water surface is transparent and hence sun's rays can penetrate deeper than in the case of land surface which is comparatively opaque. Third, heat transfer in sea water is mainly by convection process, which is a quicker method for heat transfer than the slow conduction process through which heat is transmitted within land. Fourth, the [specific heat](#) of sea water is greater than that of land. Sea water required a greater quantity of heat per unit mass to change its temperature than that of land. Lastly, as water is always available for evaporation on the sea water surface, evaporation is continuous there, while on land evaporation takes place only

if the soil is moist. As evaporation is a cooling process, it must be considered while comparing the thermal properties of land and sea water surfaces.

### Factors Influencing Sea water Temperature

Sea water temperature varies with respect to space (horizontally and vertically) and time. Major variations in temperature are very common in the upper layers of the ocean because of the influence of external environmental factors. The factors which affects sea water temperature and its variation can be broadly classified into two groups: (1) energy transfer processes taking place below the sea surface and (2) advective transfer processes taking place below the sea surface. The first group is concerned with the factors associated with the transfer of solar radiation to the sea and with the factors associated with the removal of heat from the sea. The chief energy transfer processes that produce heating of the sea surface are the absorption of radiation from sun and sky, the convection of sensible heat from the atmosphere, and the condensation of water vapour. The energy transfer processes that produce cooling of the sea surface are the back radiation from the sea surface, the convection of sensible heat to the atmosphere, and the evaporation. The second group is concerned with the external and internal forces which cause movement of water without transfer of heat to or from the atmosphere (LaFond, 1954a). These forces produce tide, current and wind etc. which transport water from one place to another in the ocean. If the advected water differs in temperature from the adjacent water in its new region in the ocean, a temperature gradient horizontal or vertical, will be produced.

## Oceansalinity



### Sea Surface Temperature (SST)

#### Sea Surface Temperature (SST)

Knowledge of SST and its changes has been recognised as an important component of climate prediction models. Solar inputs, ocean mixed layer processes and wind at ocean surface have a direct bearing on SST variation. SST observations i different spatial and temporal scales are essential for the understanding of a variety of processes relating to the interaction between ocean and atmosphere. The have been very well correlated with thermal regimes in the ocean waters. The impact of monsoonal flow on the Indian oceanic waters causing extensive [upwelling](#) regions especially in the south west coasts has well documented. Climate studies have shown that the potential areas of cyclogenesis and

formation of weather systems is closely linked to temperature patterns of the upper oceanic layers. Information on SST is also crucial for understanding the ocean dynamics related to mixed layer depth and circulation.

### **T-S Diagram**

Water masses can be classified on the basis of their temperature-salinity characteristics, but density cannot be used for classification, because two water masses of different temperatures and salinities may have the same density. For the study of the water masses it is convenient to make use of the **temperature-salinity** diagram, which was introduced by Helland-Hansen (1916). Helland-Hansen points out that when in a given area the temperatures and corresponding salinities of the subsurface water are plotted against each other, the points generally fall on a well-defined curve, the T-S curve, showing the temperature-salinity relationship of the subsurface water of that region.

The corresponding temperature and salinity values in a water column are found to arrange themselves according to depth. The depths of the observed values can be entered along the T-S curves, which then will also give information on variation of temperature and salinity with depth.

Since the density of the water at atmospheric pressure, which is expressed by means of  $\sigma_t$ , depends only on temperature and salinity, curves of equal values of  $\sigma_t$  corresponding to any combination of temperature and salinity can be read off and, if a small scale is used, as is commonly the case, approximate values can be obtained. The slope of the observed T-S curve relative to the curves gives immediately an idea of the stability of the stratification.

A T-S diagram is shown in figure. In that the temperature and salinity values between 277 and 461m at stations 1638 agree with those between 590 to 790m at station 1640, indicating that at the two stations waters of similar characteristics was present, but at different depths.

## **Chapter 5: [Water mass](#)**

### **[Water mass of Indian Ocean](#)**

#### **Method of formation water masses:**

The water masses are formed in the oceans by two methods:

(a) by thermo haline alternation (2) by mixing of two or more water bodies.

Classification of water mass:

The water masses in oceans can be divided in to following general groups

1. The surface or near surface water masses (uppes 500m in the ocean depth)
2. Deep water masses (500-1200m depth) and
3. Bottom water masses (below 4000m depth)

### **[Water mass of Indian Ocean](#)**

The characteristics of water masses of Indian ocean are different from those of the other oceans because of its geographic position, climatic conditions, its separation from other regions and the nature of its current pattern.

The important factor which influences the water masses are the air temperature and the differences in precipitation from one region to another region.

There is a large difference in precipitation between the eastern and the western regions in the north. The annual mean precipitation in the North Indian Ocean is about 10cm/yr in the west on the Arabian coast and about 300cm/yr in the east near Sumatra. This is opposite to the situation usually seen on the eastern side and heavy precipitation on the western side occurs in the South Indian ocean. The southwestern Australia receives precipitation less than 50cm/yr

and Madagascar gets 200cm/yr. The influence of the Asian rivers in bringing fresh water into [the Indian Ocean](#) is magnified by the monsoonal climate. The summer monsoon freshwaters which the Ganges, the Brahmaputra, the Mahanadi, the Godavari and the Krishna rivers bring into the Bay of Bengal; the Indus, the Narmada and the Tapi rivers into the Arabian Sea and the Irrawady and the Salween rivers into the Andaman Sea greatly influence the salinity of the waters in the North Indian ocean.

[The Indian ocean](#) is closed on the northern side by the landmass of Asia at subtropical latitude. As a result, the ocean is separated from deep reaching vertical convection areas in the northern hemisphere and a unique atmospheric circulation known as monsoon circulation is developed, which influences the ocean southwards up to 10°S. The [surface current](#) pattern in the North Indian Ocean which changes with the seasonal reversal of monsoon winds influence its water masses. The waters from the Red Sea and Persian Gulf greatly influence the water masses of [the Indian Ocean](#).

In general, the water masses in the south Indian ocean between subtropical convergence (40°S) and 10°S are similar to those in the South Atlantic because of the similarity of the two regions with respect to latitudinal extent and climatic conditions.

### Water masses of South Indian Ocean

1. Indian ocean control [water mass](#)
2. Upper water masses in the south-east Indian ocean
3. Surface and near surface group of water masses in Southwest Indian Ocean
4. Antarctic intermediate [water mass](#)
5. Watermasses in intermediate depths of the Southeast Indian Ocean.
6. Intermediate watermasses in the Southwest Indian ocean
7. South Indian Deep [water mass](#)

### Water masses of the North Indian Ocean

1. Water masses in the equatorial area between 10°N and 10°S.
2. High salinity [water mass](#)
3. Persian gulf high salinity [water mass](#)
4. Red sea high salinity [water mass](#)

### Water masses in the Bay of Bengal

The Bay of Bengal is in the north-eastern corner of [the Indian Ocean](#) and is enclosed on the northern, western and eastern sides. The southern boundary extends from the south end of Sri Lanka to the north of Sumatra and is open to the Central Indian Ocean. The northern Indian Ocean wind system, together with the Himalaya Mountains causes the world's highest rainfall, which drains into the Bay of Bengal.

The surface [water mass](#) characteristics of the bay exhibit wide variations from one region to another due to differences in fresh water inflow and heat exchange. The Bay of Bengal surface water masses are broadly divided into: (1) the North Dilute [water mass](#) and (2) the Southern Bay of Bengal [water mass](#) (LaFond, 1958). The North Dilute [water mass](#) is formed during October-November in the northern end of the bay by the addition of fresh water.

Based on an analysis of the physical oceanographic data collected in the southern and central Bay of Bengal during the transition period between winters and summer seasons, two water masses in the upper 100m has been identified. The first [water mass](#) found in the upper 50m in the Eastern Bay of Bengal and the Andaman Sea which is characterized with salinity less

than 33.0 is named as the Eastern Dilute Water of Indo –Pacific origin. This water is considered to form by the admixture of the run of water from the Burmese coast with the (less saline) waters of Pacific origin entering the south eastern bay through the Straits of Malacca. The second [water mass](#) which is encountered in the upper 100 m of the Southern Bay and the western and middle parts of the Central Bay with the salinity range 33.0-34.0. Southern Bay of Bengal water reported by LaFond(1958). A high salinity [water mass](#) traced in a specified region in the central part of the bay below 300m depth is assumed to be the Persian Gulf Water, probably overlying the Red sea water. The major subsurface [water mass](#) with the temperature range 4-16°C and salinity range 34.8-35 is found to be present in all parts of the Southern and Central Bay below 100-150m depth.

Varadachari et.al.(1968) have identified two water masses in the upper 1000m of the Bay of Bengal with distinct salinity and characteristics. The upper [water mass](#) has the characteristics of Persian Gulf water and the lower one, that of Red Sea water. Both the water masses appear to enter the Bay south of 9°N latitude. Two isolated high salinity pockets have been identified as the remnants of the Arabian Sea High Salinity [Water mass](#). The salinity maxima found in the depth range of 200-900 m have been considered to be due to the penetration of the isohaline layer, which forms (at the boundary) when Persian Gulf [water mass](#) and Red Sea [water mass](#) come in contact in the Arabian sea. Varkey and Sastry (1992) utilizing the historical hydrographic data collected during several cruises, have confirmed the presence of the following tropospheric water masses in the Bay of Bengal: (i) Bay of Bengal Low Salinity Water around 20.8, (2) Arabian Sea High Salinity Water around 23.92 (3) [Water Mass](#) around 23.94 (4) Persian Gulf Water around 26.81 (5) Red Sea Water around 27.19 (6) Equatorial Surface Water around 22.5.

Deep water masses in the Bay of Bengal are characterized by temperatures as low as 1.1°C or even lower. As indicated by Sewel (1932), the main course of the Antarctic Bottom drift from the South Polar region through [the Indian ocean](#) to the north appear to be three main tongues of bottom water, of which the third can be traced into the Bay of Bengal. In the region of the Bay of Bengal, the major portion of the bottom drift is considered to undergo a further division into two subsidiary streams. One of these streams is likely to pass northwards between Carpenter's ridge on the west and the Andaman-Nicobar ridge on the east through a deep channel, where water of a temperature as low as 1.0°C can be traced on the bottom as far north as latitude 12°N. One portion of the other current branch is likely to flow northwards into the Bay of Bengal along the east coast of India, Where water of a temperature of only 1°C has been found at a depth of about 2000m as far north as latitude 9°N. Therefore the deep and bottom water masses present in the Bay of Bengal can be considered as the water masses that are derived from the south polar region, similar to those present in the Arabian Sea at deeper levels.