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TEMPERATURE OF OCEAN WATER

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ABSTRACT
The ocean (also the sea or the world ocean) is the body of salt water that covers approximately 70.8% of the surface of Earth and contains 97% of Earth's water.Another definition is "any of the large bodies of water into which the great ocean is divided". Separate names are used to identify five different areas of the ocean: Pacific (the largest), Atlantic, Indian, Southern (Antarctic), and Arctic (the smallest). Seawater covers approximately 361,000,000 km2 (139,000,000 sq mi) of the planet. The ocean is the principal component of Earth's hydrosphere, and therefore integral to life on Earth. Acting as a huge heat reservoir, the ocean influences climate and weather patterns, the carbon cycle, and the water cycle.The top part of the ocean is called the surface layer. Then there is a boundary layer called the thermocline. The thermocline separates the surface layers and the deep water of the ocean. The deep ocean is the third part of the ocean. The Sun hits the surface layer of the ocean, heating the water up. Wind and waves mix this layer up from top to bottom, so the heat gets mixed downward too. The temperature of the surface waters varies mainly with latitude. The polar seas (high latitude) can be as cold as -2 degrees Celsius (28.4 degrees Fahrenheit) while the Persian Gulf (low latitude) can be as warm as 36 degrees Celsius (96.8 degrees Fahrenheit). Ocean water, with an average salinity of 35 psu, freezes at -1.94 degrees Celsius (28.5 degrees Fahrenheit). That means at high latitudes sea ice can form. The average temperature of the ocean surface waters is about 17 degrees Celsius (62.6 degrees Fahrenheit).90 % of the total volume of ocean is found below the thermocline in the deep ocean. The deep ocean is not well mixed. The deep ocean is made up of horizontal layers of equal density. Much of this deep ocean water is between 0-3 degrees Celsius (32-37.5 degrees Fahrenheit)! It's really, really cold down there!

There is a neat program that is measuring the temperature and salinity of ocean surface waters around the world. The Argo program deploys floats that measure salinity and temperature throughout the surface layer of the ocean. Over 3,000 free-drifting floats have been deployed all over the ocean and each float is programmed to sink 2,000 meters down, drifting at that depth for about 10 days. The float then makes its way to the surface measuring temperature and salinity the whole time. Data is transmitted to a satellite once the float reaches the surface, so that scientists and the public have access to the state of the ocean within hours of the data collection. At a greater depth in the water, measurements are often made with a CTD instrument (CTD = conductivity, temperature, depth), where the instrument is placed in the ocean water from a ship or a platform. These instruments are used by the Bermuda Institute of Ocean Sciences (BIOS), where they have been tracking ocean measurements like temperature, salinity and oxygen concentrations for over 55 years.

KEYWORDS: *ocean, water, temperature, deep, surface, thermocline, cold, heating, celcius, degree*

INTRODUCTION

Our planet is heated by solar radiation, incoming energy from the sun. Because the Earth is round, the angle of the surface relative to the incoming radiation differs with latitude. At low latitudes, near the equator, direct overhead sunlight received all year warms surface waters. At high latitudes, ocean waters receive less sunlight – the poles receive only 40 percent of the heat that the equator does. These variations in solar energy mean that the ocean surface can vary in temperature from a warm 30°C (86°F) in the tropics to a very cold -2°C (28°F) near the poles. In some areas, this surface temperature is relatively stable while in others, it fluctuates depending on the season (and thus the amount of sunlight received).[1,2]

World map of the five-ocean model with approximate boundaries

The temperature of ocean water also varies with depth. In the ocean, solar energy is reflected in the upper surface or rapidly absorbed with depth, meaning that the deeper into the ocean you descend, the less sunlight there is. This results in less warming of the water. Therefore, the deep ocean (below about 200 meters depth) is cold, with an average temperature of only 4°C (39°F). Cold water is also more dense, and as a result heavier, than warm water. Colder water sinks below the warm water at the surface, which contributes to the coldness of the deep ocean. The vertical structure in the ocean created by temperature differences has a large impact on how life is distributed in the ocean.[3,4]

The temperature decreases with increasing depth. The thermocline are layers of water where the temperature changes rapidly with depth. This temperature-depth profile is what you might expect to find in low to middle latitudes.

The study of the temperature of the oceans is important for determining the

1. movement of large volumes of water (vertical and horizontal ocean currents),
2. type and distribution of marine organisms at various depths of oceans,
3. climate of coastal lands, etc.

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.

Deep water organisms

- 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.

  Heating and cooling of ocean water
- 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).[5,6]

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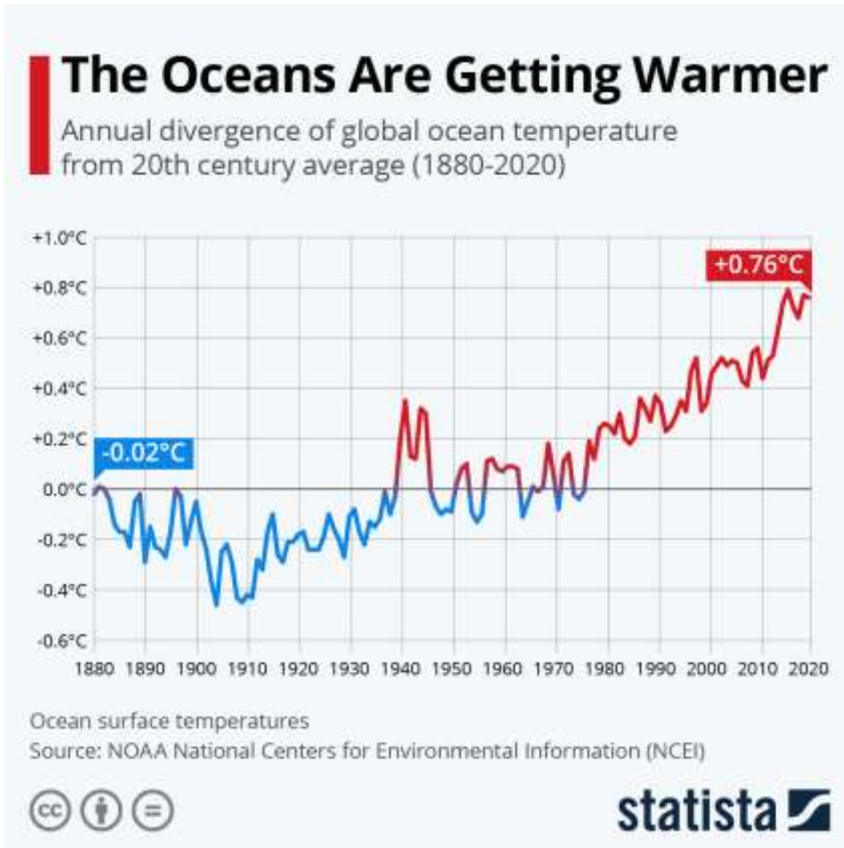

Ocean water is heated by 3 processes:

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.

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).[7,8]

Observations

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].

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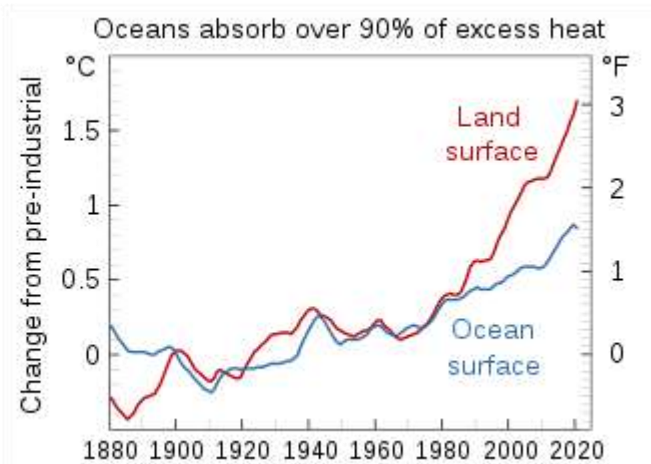
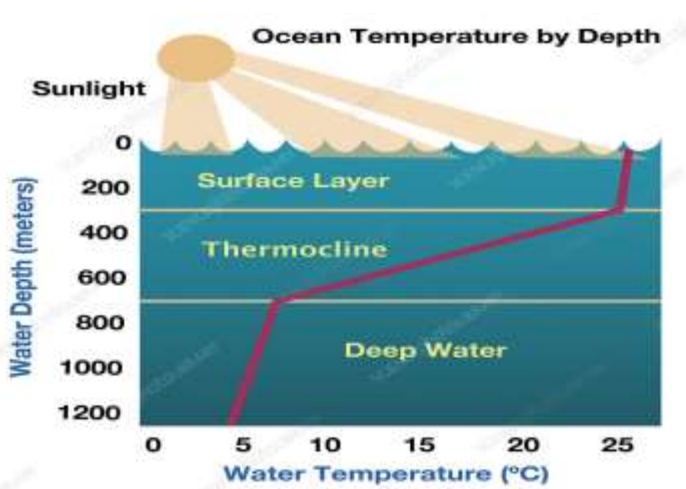


- The presence of submarine ridges and sills [Marginal Seas]: Temperature is affected due to lesser mixing of waters on the opposite sides of the ridges or sills.
- The shape of the ocean: The latitudinally extensive seas in low latitude regions have warmer surface water than longitudinally extensive 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.[9,10]



- 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).

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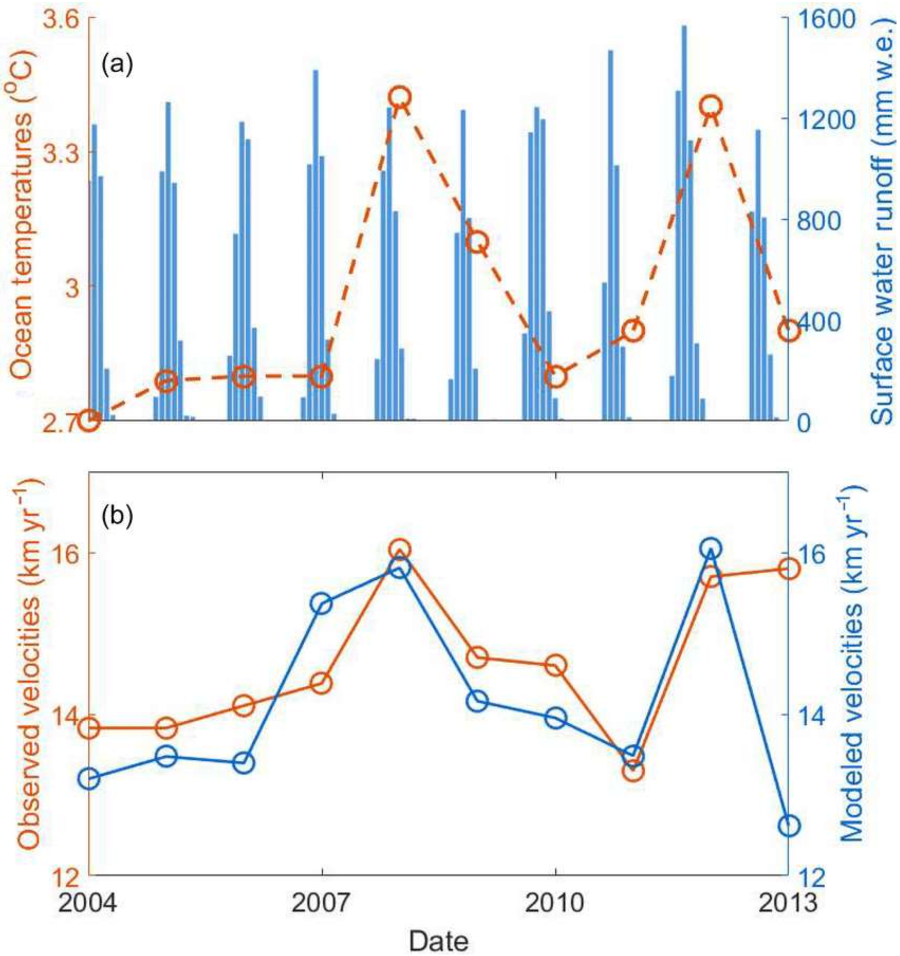

(a) Time series of observed ~ 300 m deep ocean temperature (red) from near the mouth of Ilulissat Fjord (see Fig. 1 for location). Blue bars are simulated monthly surface water runoff from the MAR regional surface mass and energy balance model (Alexander and Luthcke, 2016). (b) Measured ice front annual mean ice flow speeds (red) from Joughin et al. (2010), compared with our modeled speeds (blue).

- 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.

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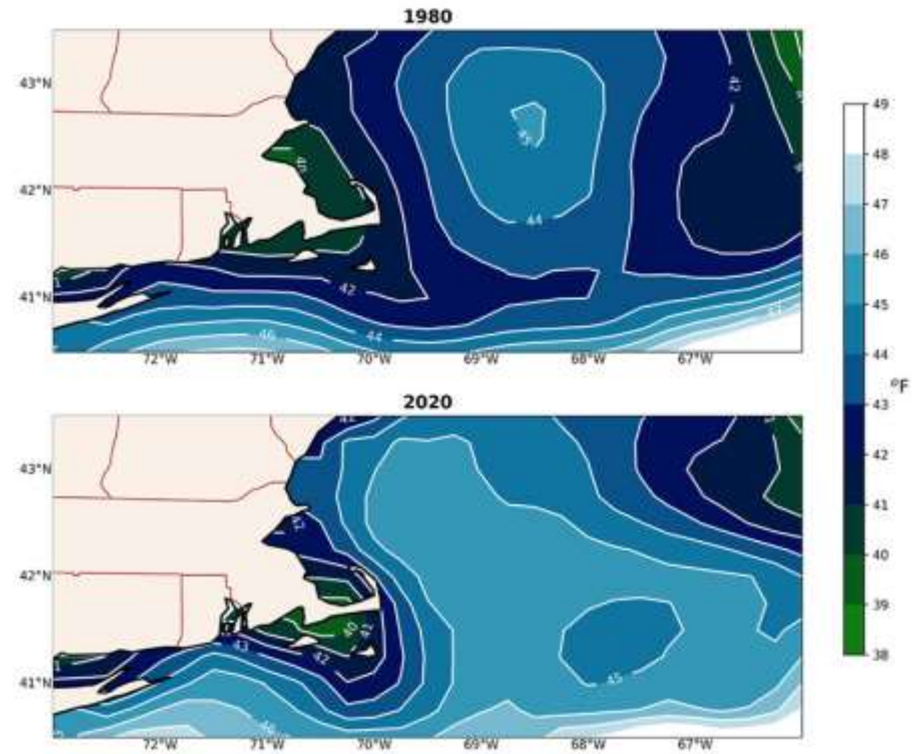

Rising sea temperature due to global warming

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.[11,12]
- 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.

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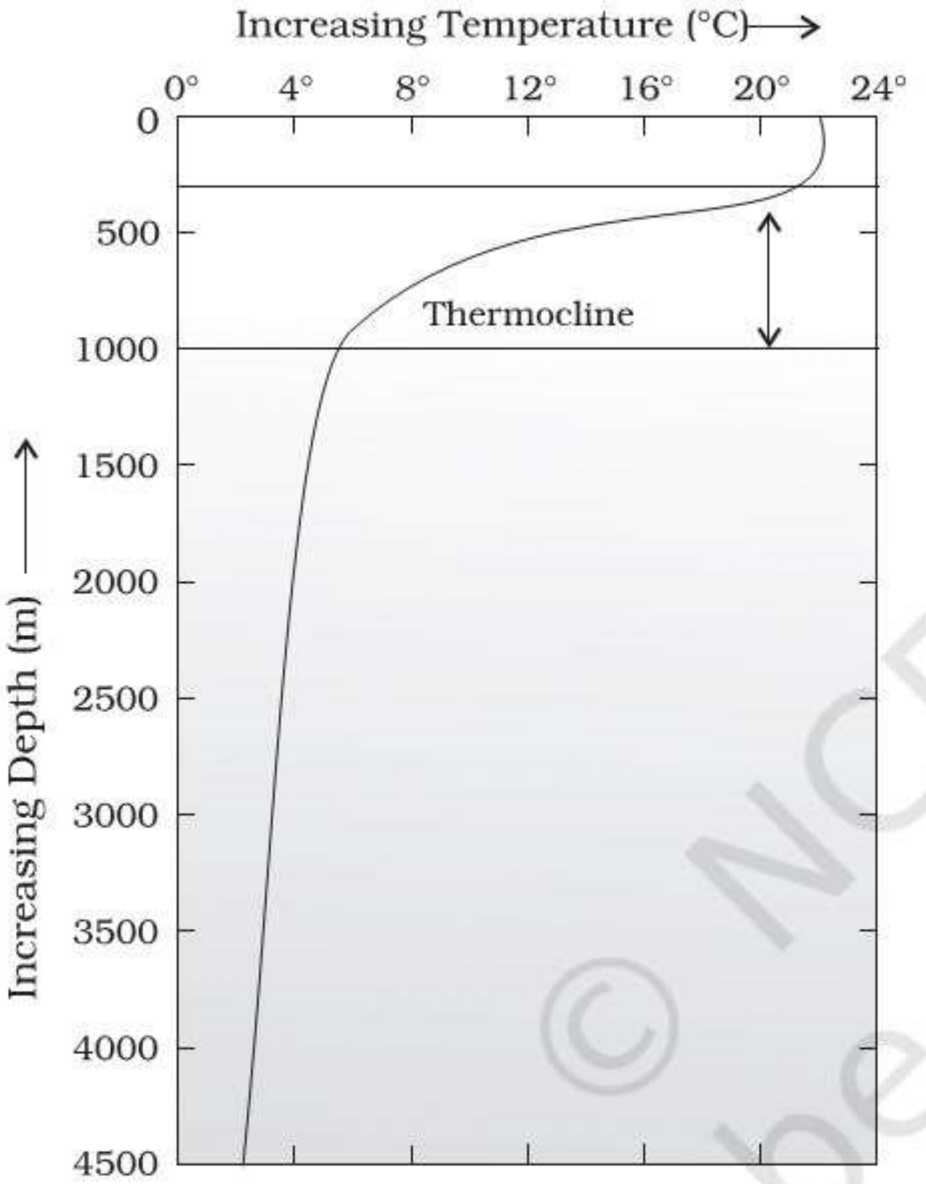


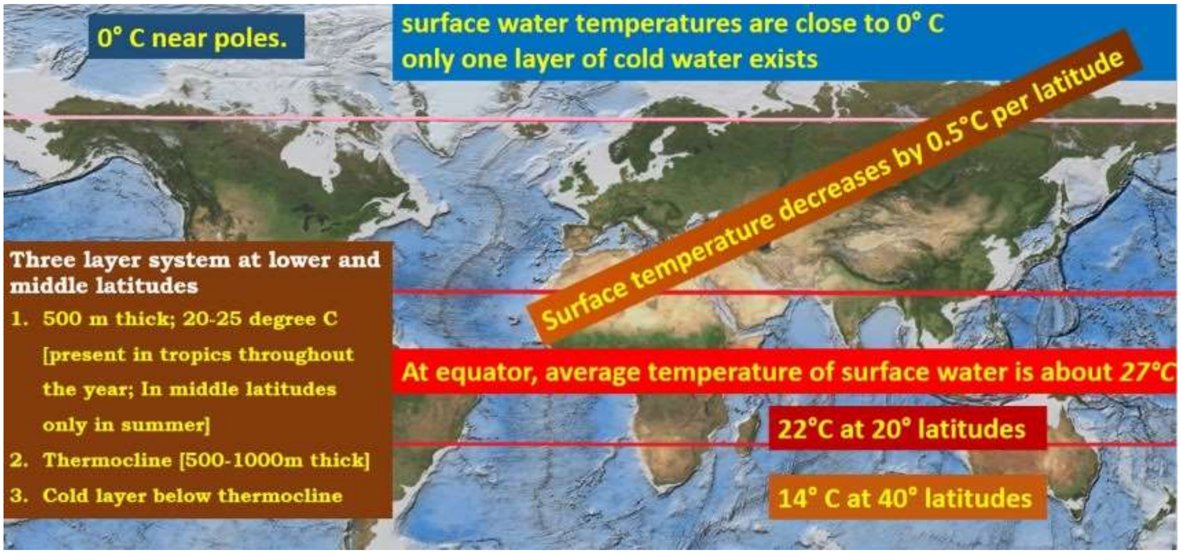
Figure 13.3 : Thermocline

DISCUSSION

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.[13,14]



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.[15]

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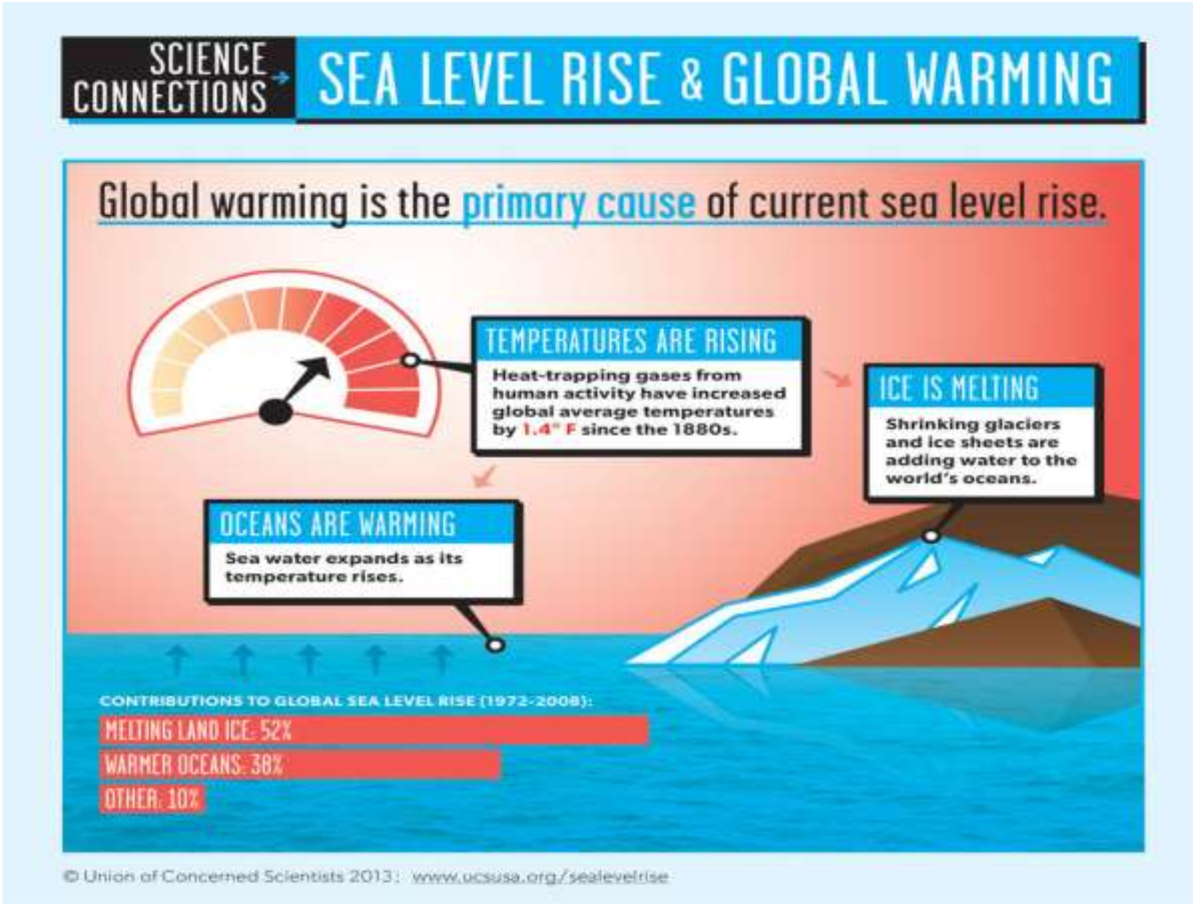

The rate of decrease of temperature with depths is greater at the equator than at the poles.

- 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.

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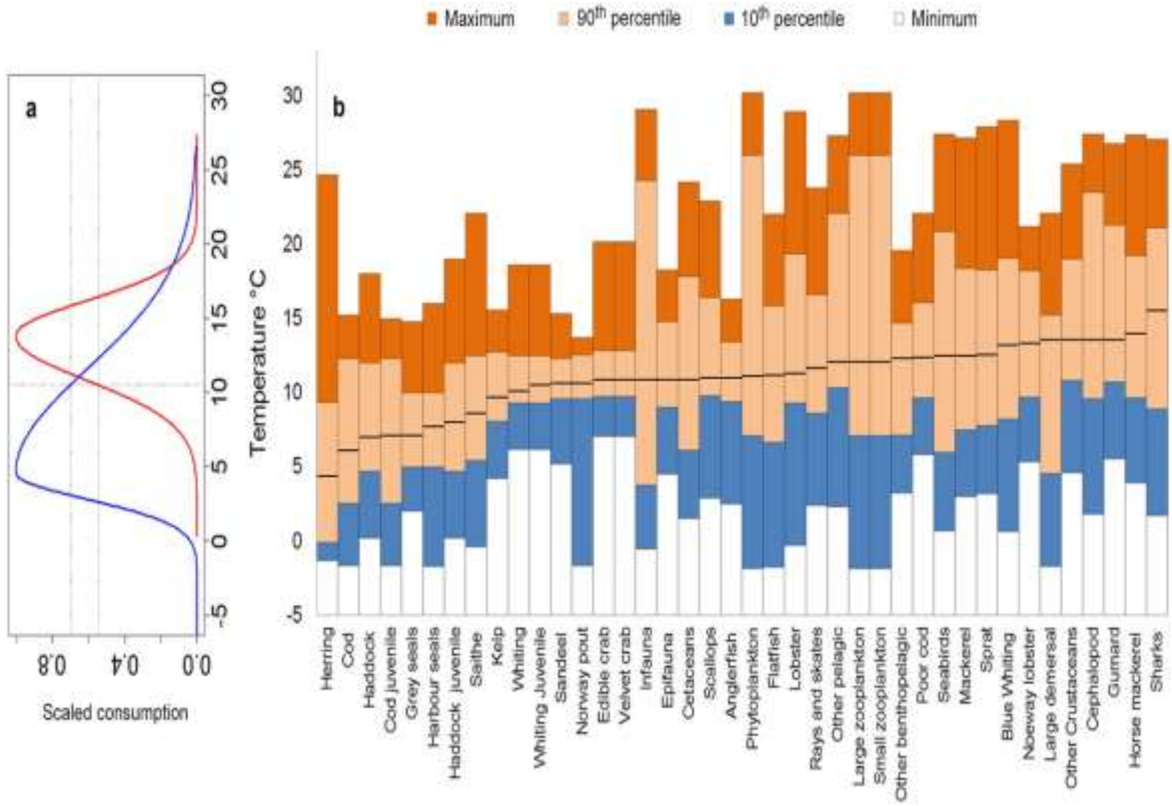

(a) Species thermal response functions (for Norway lobster, a eurythermal species (red, optimum temperature = 13.8 °C) and for herring, a boreal species (blue, optimum temperature = 4.6 °C)). The intercept between water temperature (e.g. 10.5 °C) and the species response functions determined the consumption rate scaling factor (i.e. 0.54 and 0.7 for Norway lobster and herring respectively). (b) Cumulative temperature tolerance graphs ranked by optimum temperature (bold black line) also showing maximum (upper limit of dark orange bar) and minimum (upper limit of white bar) temperatures and the 90th (upper limit of light orange bar) and 10th (upper limit of blue bar) percentiles for each functional group.

- 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.[16,17]

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.

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- 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.[18,19]

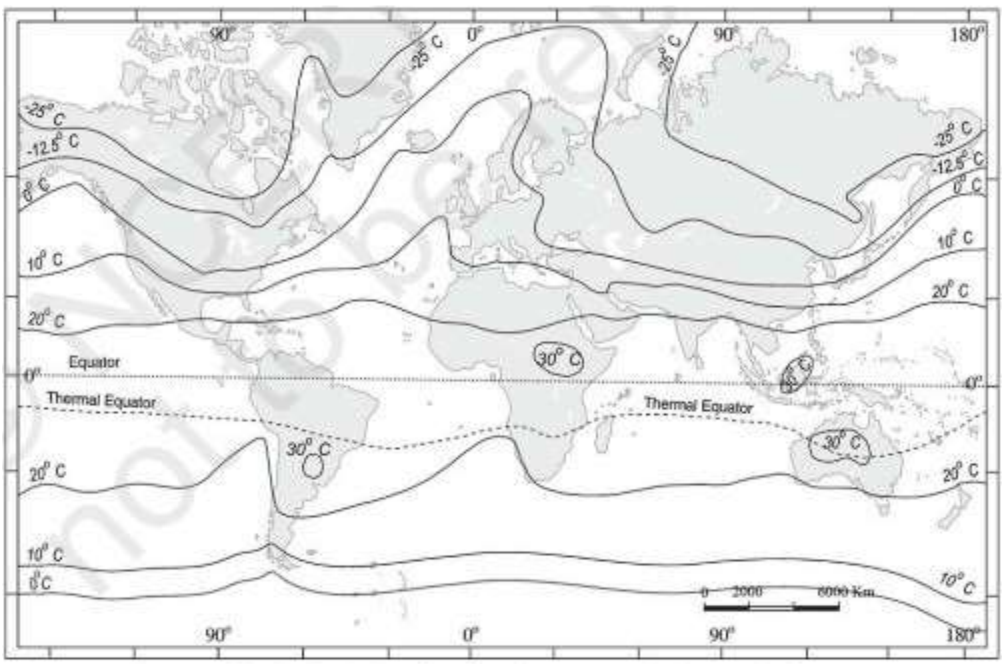


Figure 9.4 (a) : The distribution of surface air temperature in the month of January

RESULTS

Range of ocean temperature

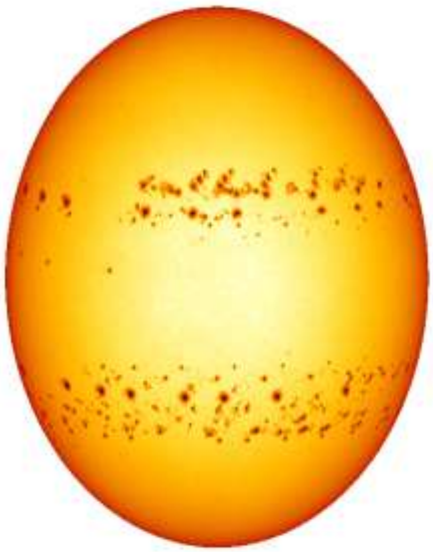
- The oceans and seas get heated and cooled slower than the land surfaces. Therefore, even if the solar insolation is maximum at noon, the ocean surface temperature is highest at 2 p.m.
- The average diurnal or daily range of temperature is barely 1 degree in oceans and seas.
- The highest temperature 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.

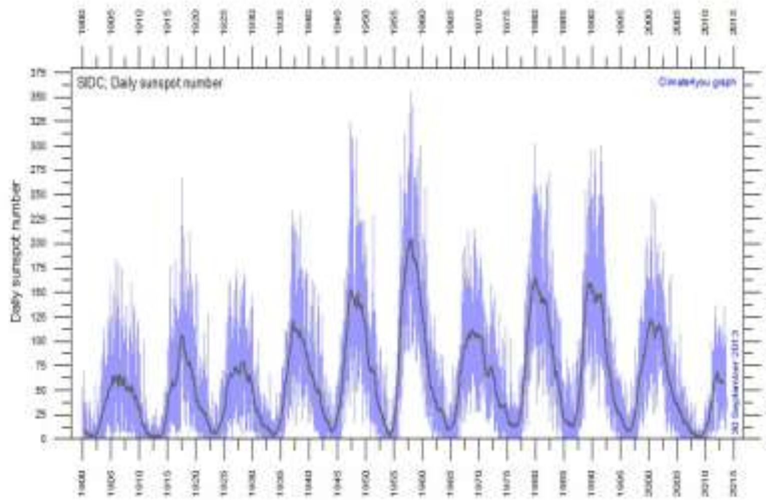
Climate crisis: Ocean temperatures hit record highs as rate of global warming accelerates

- 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]).[20,21]
- 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.[22,23]





CONCLUSION

The Ocean State Report is an annual publication of the Copernicus Marine Service and Mercator Ocean International providing a comprehensive, state-of-the-art report on the current state, natural variations, and ongoing changes in the global ocean and European regional seas. The goal of the Ocean State Report is to provide reliable and scientifically-assured information, drawing on data from the 1970s to present.[24] The report is written by over 150 scientific experts from more than 30 European institutions. There is particular emphasis on European seas, as the Ocean State Report is meant to act not only as a reference for a global audience, but more directly for the activities of the European Union. The full Ocean State Report (available here) is a supplement of the Journal of Operational Oceanography (JOO) , an official publication of the Institute of Marine Engineering, Science & Technology (IMarEST) , published by Taylor & Francis Group. [25,26]

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