Seawater Properties that Control Density

Density is defined as the mass of water per unit volume and has units of grams per cubic centimeter (g/cm³), kilograms per liter (kg/L) or kilograms per cubic meter (kg/m³). The density of freshwater at 4°C is 1.0000 g/cm³ or 1.000 kg/liter or 1000 kg/m³.

Why do you think the mass of water is defined at a specific temperature?

The range of density in the oceans is from about 1.020 to 1.070 g/cm³. The changes in density are caused mainly by variations in pressure, salinity and temperature:

- colder water more dense
- saltier water more dense
- higher pressure causes density increase - pressure increases with depth due to the mass of water above

Temperature Effects on Density

Temperature changes effect seawater density: as water cools its density increases. As water cools, H₂O molecules pack more closely together (because the molecules are vibrating less at lower temperatures) and take up less volume. The same number of water molecules in smaller volume results in a higher density.

How much does the seawater density increase upon cooling from 20°C to 0°C? Seawater density increases from 1.0240 g/cm³ at 20°C to 1.0273 g/cm³ at 0°C at a constant salinity. Globally, there is an average of about a 20°C temperature decrease from the surface to bottom of ocean. The density increase with depth caused by the temperature decrease plays the greatest role in determining the density of a sample of water.

Thus the increase in density due to the decreasing temperature with depth dominates over the salinity decrease and makes the deeper water more dense than surface water. This means that in most regions the ocean is stable, that is, it will take energy to mix the ocean vertically. This is not necessarily the situation in the polar regions.

Depth vs Temperature

Globally, the entire temperature range for ocean water ranges from ~ -2°C to +40°C, which is much smaller than the temperature range for air, which varies from -60°C to +60°C.

Surface water temperatures vary much more than deep water temperatures. Most of the ocean is warm at the surface and colder at increasing depths. The region where temperature decrease is greatest with depth is called the thermocline. The rate of change of temperature with depth is called the temperature gradient. The steepness of the depth gradient in temperature depends on location. It is greatest in the warm tropical ocean (warm at the surface and colder with increasing depth) and least in the cold polar ocean (somewhat uniformly cold at the surface and at increasing depths).

Salinity Effects

Salt in seawater makes it denser than freshwater. How much salt is in seawater? Typically seawater contains between 33 to 37 grams of salt per liter of seawater, although the extremes of salinity can range from 28 to 40 g/L. Oceanographers measure salinity in parts per thousand (ppt), thus typical seawater is between 33 to 37 ppt.
To make seawater, start with freshwater and add 35 grams of salt to one liter (1 kg) of this freshwater (35 grams per 1000 grams). This resulting seawater is denser than freshwater because of added mass of dissolved salt.

Typically, the salinity decreases from the surface ocean to deep waters is very small, from about 36 g/L (ppt) at the surface to 35 g/L (ppt) in the deep water, thus there is a very small density decrease with depth given a constant temperature.

The salinity of seawater also affects its freezing point temperature. Freshwater has a freezing point at 0°C. Seawater’s freezing point is at ~ -2°C. The freezing point versus salinity explains why it is easier to form ice on a lake (freshwater) than on a bay (seawater).

**Density and Water Movement**

The density of seawater determines its tendency to move vertically. If density of water at surface is higher than below, the water will sink to a level of its own density. This situation the water column is ‘unstable’.

If density of water at surface is lower than below, the water will not sink. In this situation the water column is ‘stable’. In this situation it takes energy input (usually from the wind) to "push" water downward - e.g., like submerging a rubber duck in bathtub (you supply energy).

Sinking of surface water generally occurs where there is cold air to cool water at surface. This situation found at high latitudes near the poles. At these polar sites, surface waters cool and become dense enough to sink thousands of meters. Sinking of surface waters is a very important mechanism to replenish waters in the ’deep sea’.

In contrast, for most of the ocean (within ~50° of the equator) the surface waters are much warmer and less dense than the cold waters found at depth. Under these conditions surface waters do not sink and thus there is no direct contact with waters in the deep sea.

What controls surface salinity? Mainly the relative rates of evaporation versus precipitation. When the rate of evaporation is greater than the precipitation, then surface ocean salinity increases. When the rate of precipitation is greater than the rate of evaporation, then the surface ocean salinity decreases.

- Surface heating and precipitation promote water column stability by lowering the density of surface seawater.
- Cooling and evaporation diminish stability by increasing surface density.

**Pressure Effects**

As pressure increases, so does water density. The water molecules pack together tighter as pressure increases - the pressure increase with depth, due to the weight of the water above, and causes the greatest density changes in seawater with depth (greater than the density changes due to temperature and salinity changes).
**Seawater Profiles vs Depth**

**Thermocline** is a layer within a body of water or air where the temperature changes rapidly with depth. Because water is not perfectly transparent, almost all sunlight is absorbed in the surface layer, which heats up. Wind and waves circulate the water in the surface layer, distributing heat within it somewhat, and the temperature may be quite uniform for the first few hundred feet. Below this mixed layer, however, the temperature drops very rapidly—perhaps as much as 20 degrees Celsius with an additional 150 m (500 ft) of depth. This area of rapid transition is the thermocline. Below the thermocline, the temperature continues to drop with depth, but far more gradually. In the Earth's oceans, 90% of the water is below the thermocline. This deep ocean consists of layers of equal density, being poorly mixed.

**Pycnocline** is a layer where there is a rapid change in water density with depth. In freshwater environments such as lakes this density change is primarily caused by water temperature, while in seawater environments such as oceans the density change may be caused by changes in water temperature and/or salinity.

**Halocline** is a vertical salinity gradient. Because salinity (in concert with temperature) affects the density of seawater, it can play a role in its vertical stratification. Essentially, lower salinity water (= lower density) “floats” on top of higher salinity water (= higher density). The magnitude of the resulting density gradient plays an important role in determining the impact of vertical mixing. A strong salinity gradient will resist mixing, while a weak gradient can be mixed more easily. Typically, ocean vertical structure is dictated by temperature effects on density, but salinity and haloclines play a dominant role in certain regions of the world ocean. The sub-Arctic North Pacific is one such region.