

NATURE OF SEAWATER: SALINITY, TEMPERATURE, DENSITY, AND PRESSURE

- **surface salinities**
- **temperature profiles of the ocean; the thermocline**
- **seawater density dynamics**
- **deep ocean pressures**

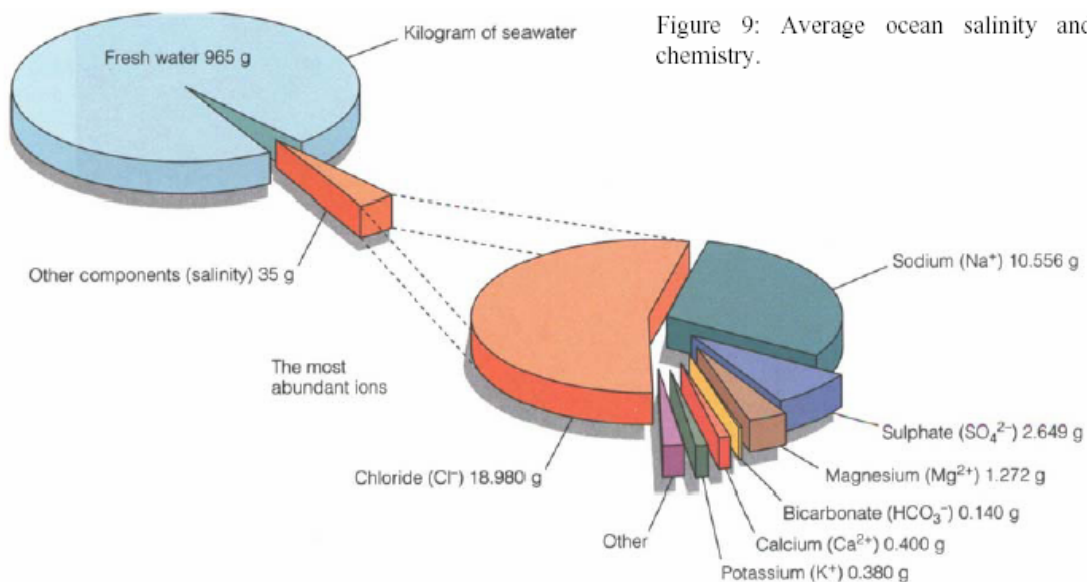
Part A. Surface Salinities

The total quantity of dissolved inorganic solids in water is its salinity. The ocean's salinity varies from about 3.3% to about 3.7% by mass, depending on evaporation, precipitation, and freshwater runoff from the continents. The overall average salinity is about 3.5% or

35 ‰ (parts per thousand). This means that for every 1,000 grams of seawater, the solids left behind would have a mass of 35 grams.

The oceans get salt from the weathering and dissolution of minerals on land and from volcanic emissions. Salinity is a conservative property; it remains constant for the ocean as a whole for long periods of time, although local salinities may vary: High salinity is found in partially enclosed areas where there is high evaporation rates and little mixing with other waters, as in the Red Sea and the Mediterranean Sea. Dilute seawater is found in coastal waters where there is excessive runoff from the land.

An analytical method of determining the salinity of a solution is to measure the solution's ability to conduct an electrical current. Conductivity increases with increasing salt content.



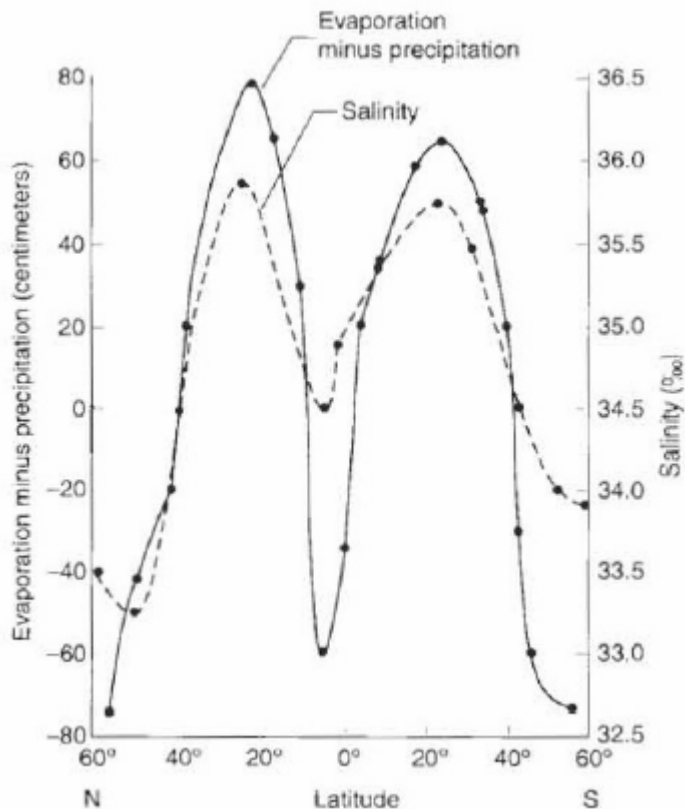
1a. In the above figure what is the most abundant dissolved ion? _____
 The 2nd most abundant ion? _____ 3rd? _____ 4th? _____
 5th? _____ 6th? _____ 7th? _____

b. The Gulf of Mexico has a higher salinity than the Atlantic Ocean, which means you can float in Florida's gulf coast waters noticeably easier. What holds you up?

Hint: Archimedes Principle: "An object partially or wholly immersed in a fluid, is buoyed up by a force equal to the weight of the fluid displaced by the object."

Lab 5

1c. Thirst-crazed shipwrecked sailors in the Atlantic Ocean 100 miles off Brazil's east coast drank Atlantic water. They suffered no kidney damage, little dehydration, and remained lucid and seizure free because they were actually drinking fresh water and not seawater. Why? Hint: look at a map of Brazil.



d. What latitudes have seawater with the highest salinities?

e. What latitude is Miami?

f. What latitudes have the lowest salinities?

g. Explain why equatorial seawater has lower salinity than mid-latitude seawater.

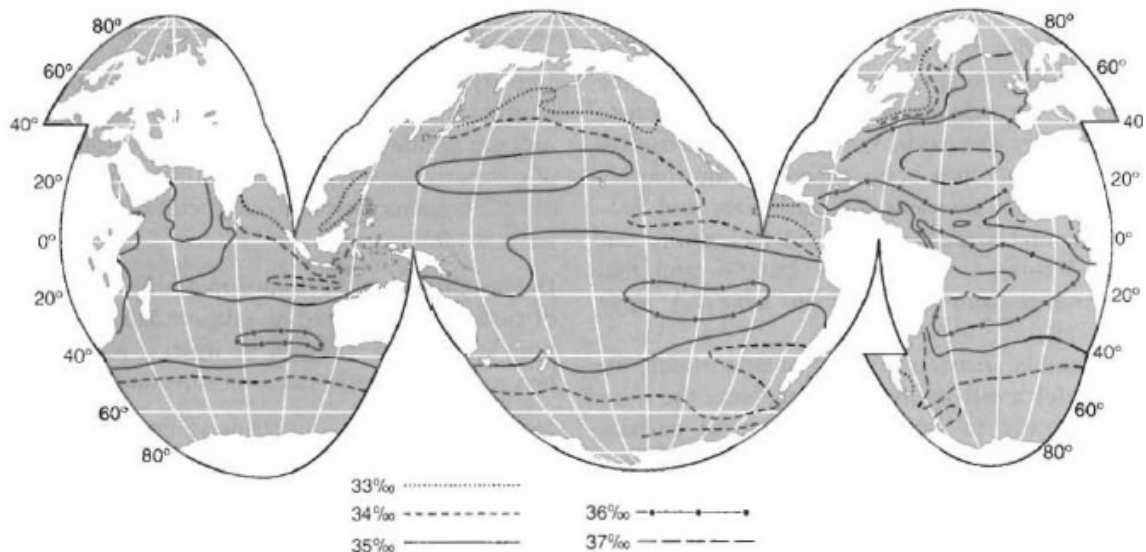


Figure 8: Salinity distribution in the surface waters of the oceans in August.

2 Study the isohalines (lines of equal salinity) above. Which ocean is saltiest? (circle)

Atlantic

Pacific

Part B. Taking the ocean's temperature: At most latitudes seawater has a layered temperature structure from the surface to the seafloor.

In our oceans seawater temperatures range from about **35 °C to -2 °C**.

3. Use the temperature profiles on Figure 1 (page 4) to answer the following:

a. Examine the seawater temperature profile for the low latitudes labeled "A". Is the warmer water found near the surface or the bottom?

b. Most of the sunlight entering the ocean is absorbed very near the surface. This sun-warmed surface water mixes with cooler, deeper waters as winds, breaking waves, and turbulent currents stir the water. One result of this mixing is a surface layer having nearly uniform temperature, or **isothermal**, conditions. On the low latitude profile, the mixed layer extends to a depth of

_____.

c. The temperature of seawater immediately below the mixed layer changes rapidly with depth. This layer of rapid temperature change extends down to about 1000 meters. It is called the **main thermocline**. As depth increases within the main thermocline does seawater temperature increase or decrease?

d. Examine the seawater temperature profile for the mid-latitudes labeled "B". This profile resembles the low latitude profile but with some important differences. Compared to the low-latitude profile, the mixed layer temperature is cooler or warmer?

And shows seasonal variation or no seasonal variation? _____

e. Examine the temperature profile for the high latitudes labeled "C". Compared to the low and mid-latitude profiles, the surface temperature is cooler or warmer? _____

f. Now examine the ocean temperature north-south cross-section extending from about 70 degrees south latitude to 70 degrees north latitude. At the bottom of each vertical dashed line in this diagram circle the letter A, B, or C indicating which of the three temperature profiles you would expect to find at that particular latitude.

g. The accumulation of ocean temperature measurements from a variety of locations reveals that there is a three-layered thermal structure in most of the ocean. At what latitudes is there a main thermocline layer with rapidly changing vertical temperatures separating the warmer surface mixed layer from the colder deeper layer?

Although this colder deep layer is found at all three latitudes, it extends essentially to the surface only at

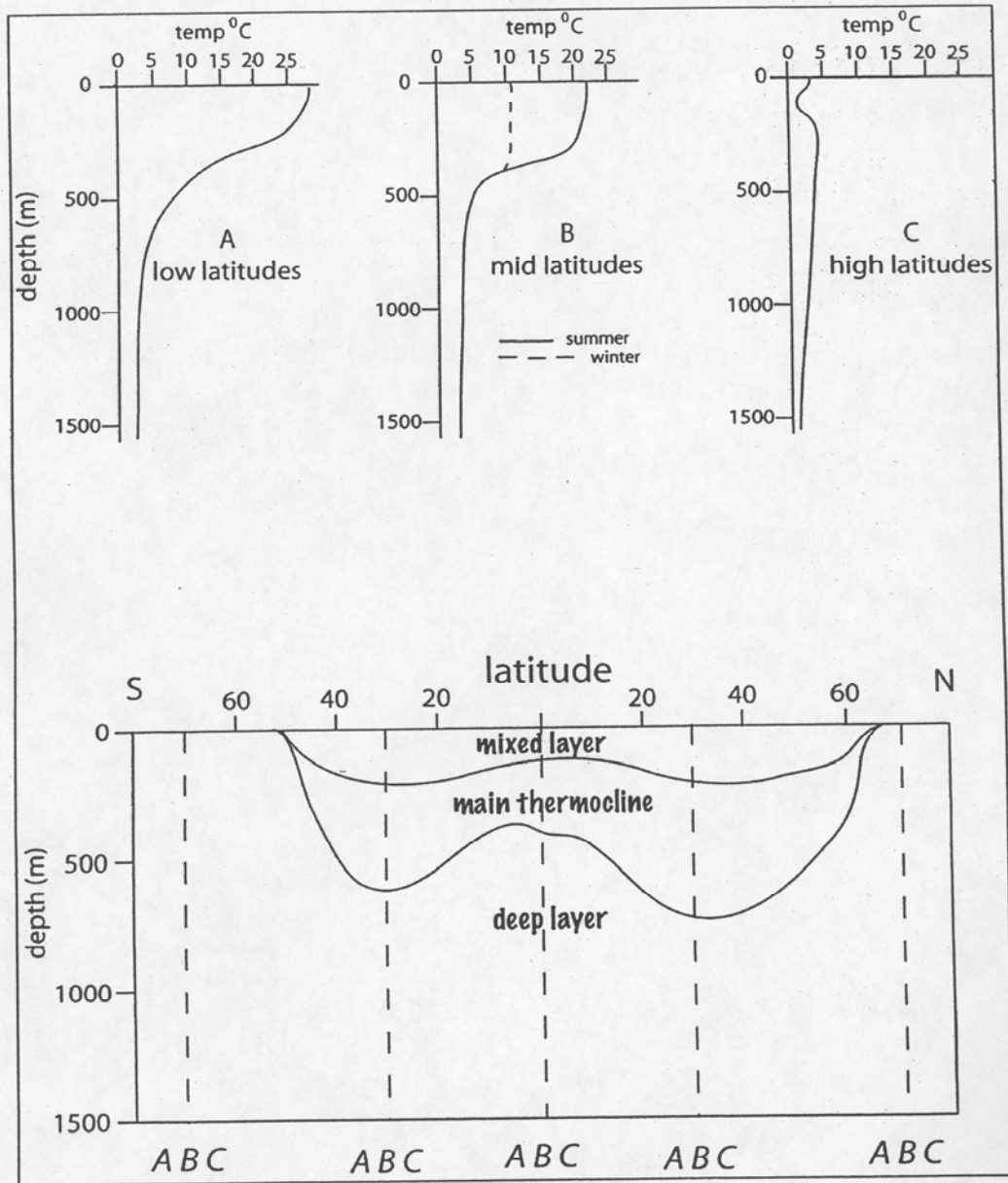
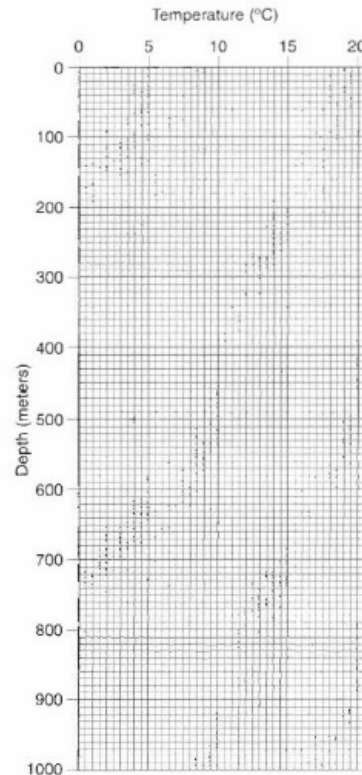


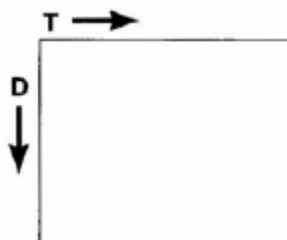
FIGURE 1. TEMPERATURE PROFILES
modified from: Visit to an Ocean Planet
<http://topex-www.jpl.nasa.gov/education>

The table below lists temperature and salinity data for an oceanographic station off Point Conception, Southern California.

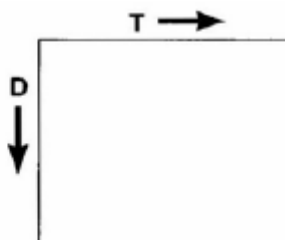
Depth (meters)	Temperature (°C)	Salinity (‰)	Depth (meters)	Temperature (°C)	Salinity (‰)
0	14.56	31.22	250	6.57	33.98
10	14.50	31.40	300	6.15	34.01
20	14.48	31.56	400	5.49	34.07
30	12.72	31.88	500	4.01	34.14
50	10.86	32.40	600	4.65	34.20
75	9.20	33.24	700	4.36	34.26
100	8.82	33.60	800	4.10	34.31
150	7.77	33.88	1000	3.51	34.41
200	7.10	33.94			



- 4 a. Using the tabulated data, plot temperature against depth on the above graph.
- b. Label the thermocline on your temperature plot.
- c. With depth does salinity increase or decrease? _____
- d. How would a depth-temperature curve from the Arctic differ from an Equatorial depth-temperature curve. Sketch each below.

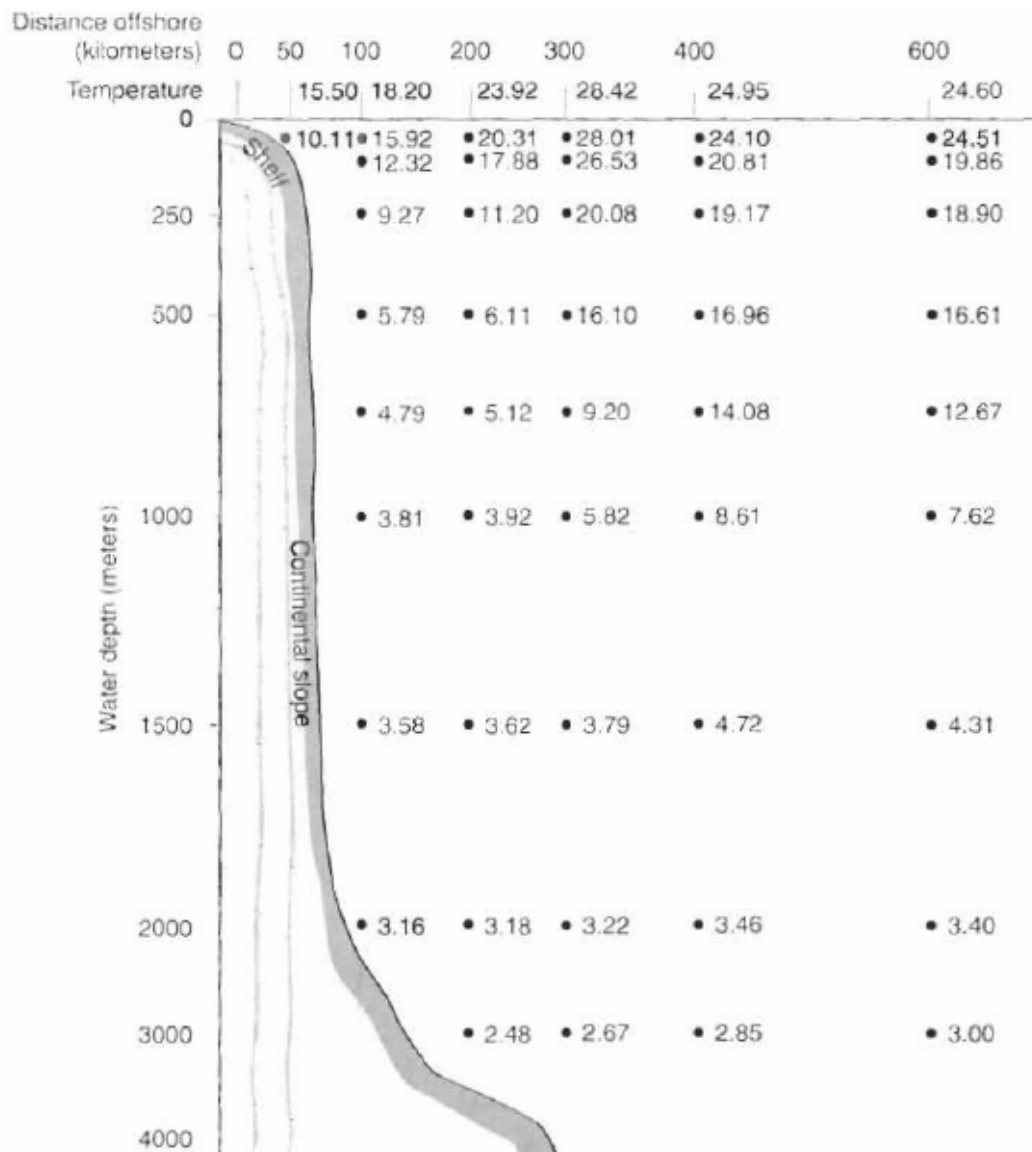


Arctic



Equatorial

5. The figure below contains oceanographic data for an east-west trending line in the western North Atlantic Ocean off North Carolina.



a. Contour the temperature data using a 2°C contour interval. Start with 16°C, then interpolate for values warmer and cooler than this.

b. Thermoclines may be identified by subsurface isotherms that are more closely spaced than the overall spacing pattern. There is a seasonal thermocline above the permanent thermocline in your contoured data.

Locate and label primary thermocline and seasonal thermocline.

Thermocline as a Density Barrier: The thermocline acts as a density barrier to vertical circulation; that is, we may view the thermocline as the floor of the low-density, warm surface water (the mixed layer) and the ceiling for the cold dense bottom waters. The thermocline inhibits large-scale vertical movements of water between the bottom and surface by the strong contrast in density between these two layers. However, in Polar

Regions, where there is no effective thermocline due to the colder surface waters, vertical circulation takes place as the surface waters sink to replenish deep waters in the major oceans.

A Global look at the temperature of the mixed layer:

The distribution of surface temperatures in the major oceans is shown in Figure 3. Points of equal temperature are connected by **isotherms**.

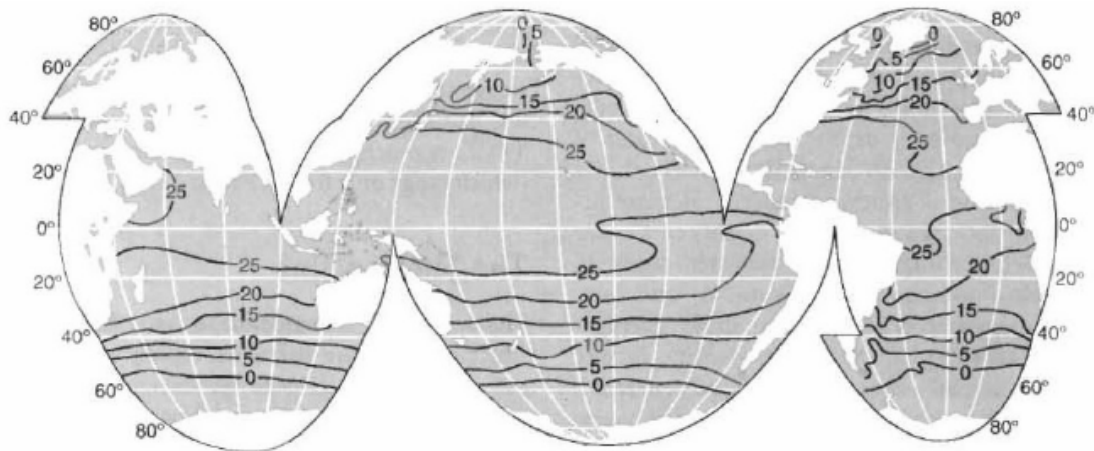


Figure 3: The distribution of surface ocean temperatures (in °C) for the month of August.

- 6 a. Look at the east and west coasts of the continental U.S. On which coast do warmer waters extend into higher latitudes? (circle)

East Coast

West Coast

- b. Look at the east and west coasts of South America. On which coast is the mixed layer warmer at higher latitudes?

East Coast

West Coast

- c. Look at the east and west coasts of Africa. On which coast is the mixed layer warmer at higher latitudes?

East Coast

West Coast

Part C. Density and Density Currents

Temperature, salinity, and pressure determine density.

⇒ Heating a substance usually causes it to expand lowering its density; when it cools, its density increases. **Temperature has the greatest effect on density.**

⇒ The addition of salts increases the density of seawater; the subtraction of salts decreases the density of seawater.

⇒ As pressure increases with depth (depths greater than 1000 meters), so does the density of seawater.

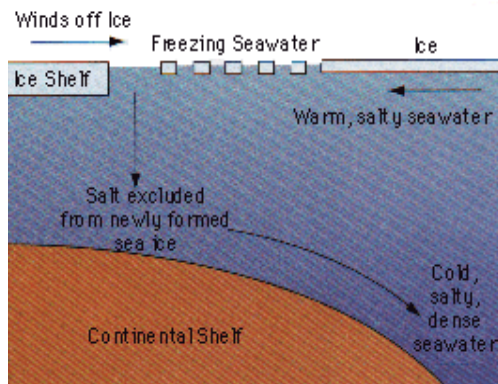
7. Water with the highest density is formed at 3.9 °C. Since Temperature has the greatest effect on density, at what regional latitudes (Figure 3. above) is water of highest density formed at the surface of the ocean?

Deep ocean currents are called density currents.

The movement of seawater by currents at great depth is called the **Thermohaline circulation** (*Thermo* = temperature; *haline* = salinity).

In other words, density currents are cold, very salty, and deep. The thermohaline circulation is a deep ocean conveyor where ~1000 years is needed for a density current to make a complete oceanic circuit. (Thermohaline circulation is faster in the Atlantic and slower in the Pacific).

↓ The sinking (downwelling) of cold, dense surface waters close to Antarctica and the Arctic



Polar winds chill the sea. Sea ice can only incorporate about 15% of the seawater's salt. The excluded salt makes the unfrozen seawater beneath the ice a dense brine which sinks to the bottom of polar seas, e.g.

- Labrador Sea
- Greenland Sea
- Weddell Sea

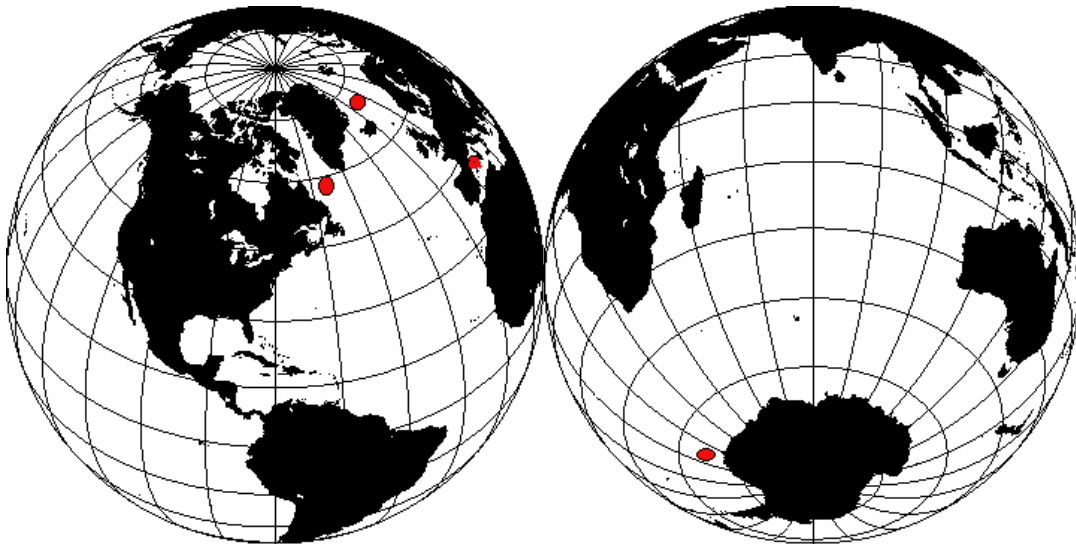


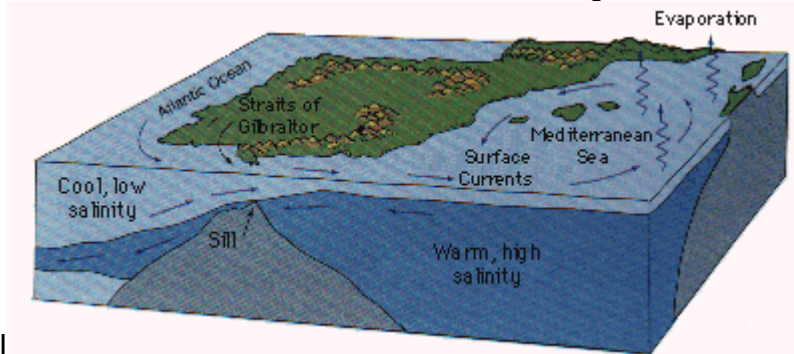
Figure 4: The principle locations for offshore downwelling feeds for density currents.

8. On Figure 4 locate the principal density current **downwelling sites** beside the corresponding dot:

- The **Weddell Sea** where Antarctic Bottom Water (ABW) forms
- The **Labrador Sea** and the **Greenland Sea** where North Atlantic Bottom Water (NABW) forms

9. The Mediterranean Sea is another downwelling site. It contributes to the global thermohaline equilibrium as its waters exchange salt and heat and other properties with the North Atlantic Ocean.

The water in the Mediterranean Sea has a higher salinity than the strong currents entering into it from the Atlantic Ocean or the Black Sea. Increased salinity due to evaporation causes its waters to sink beneath the incoming less saline entering waters.



- Locate the Mediterranean Sea beside the dot on Figure 4. (preceding page)
- For comparison tabulate those factors contributing to the density currents forming the NABW and ABW and the density current flowing from the Mediterranean Sea.

Principal Downwelling Sites	Identify Those Factors Contributing to Downwelling in each Sea	
	Surface water temperature Explain:	Increased salinity Due to:
North Atlantic Bottom Water (NABW): Labrador Sea Greenland Sea		
Atlantic Bottom Water (ABW): Weddell Sea		
Mediterranean Sea		

- Consider the density current leaving the Mediterranean Sea. Would you expect it to descend to greater depths in the North Atlantic Ocean? Why or why not?

- At what latitude is the Mediterranean Sea? _____
- Why don't density currents form at the Equator where high temperatures contribute to seawater evaporation?
Hint: you already answered this once. See 1g on page 2.

Part D. Pressure and the deep ocean

The pressure on your body as you walk around is 14.7 psi, that's pounds per square inch, or, in the metric system this is known as 1 ATM (one atmosphere). This represents the weight of our Earth's atmosphere – the weight of a one inch square column of air pushing on your body.

SCUBA divers and sea creatures are subjected to more than 1 atmosphere because water is many times denser than air. Ocean pressures increase by one additional atmosphere for every 10 meters of descent.

10. Calculate the pressure for each of the following depths:

Free dive record set by Francisco Ferreras,
1996, Cabo San Lucas, Mexico

Sperm whale descent

RMS Titanic's final resting place

Deepest spot on earth: Marianas Trench

DEPTH (m)	ATM	psi
127		
1,150		
3,810		
10,924		

Part E. Experiments**E.1**

Fill one 100 ml beaker with 80 ml de-ionized water, fill one beaker with 80 ml tap water, fill a third beaker with 80 ml sea water. Take a conductivity meter reading of each sample to compare the relative salinity of each sample. Conductivity is a measure of the ability of water to pass an electrical current and is affected by the presence of dissolved solids. As the level of the total dissolved solids (TDS) rises, the conductivity (electrolytic activity) will also increase.

Beaker Contents (100 ml water)	Conductivity
De-ionized water	
Room Temperature tap water	
Sea Water	

FYI

In the human body the main electrolytes are sodium (Na⁺), potassium (K⁺) and chlorine (Cl⁻). Table salt is the source of most of the body's Na⁺ and Cl⁻; our potassium comes from food. These ions control the electrical gradients maintained across cell membranes that enable nerves to conduct signals, muscles to receive signals to contract (including the heart), and gland function. Your kidneys and your thirst-response try to maintain the body's proper electrolytic soup.

If you drink seawater you will become dehydrated. The sodium concentration in sea water is several times higher than the concentration in blood. The body has to excrete the extra salt in the urine and more water is required to get rid of the salt than was in the sea water in the first place. Therefore, you will literally "dry up" drinking sea water as your neuron-muscular reactions become erratic. Some sea birds, like penguins, sea gulls and albatross, can drink sea water but they have special glands in their heads to excrete the excess salt. Think about your salty tears.

In Miami saltwater has intruded into the water supply of some coastal communities. Coconut Grove is an example of a community where the groundwater is unfit for human consumption due to elevated levels of dissolved solids from seawater intruding into the aquifer.

E. 2

Prepare a beaker with 100 ml seawater (salinity of 40‰) and one with 100 ml tap-water. Add red coloring to the seawater and blue coloring to the tap-water. Close the tap on the plastic tube provided (make sure it is tight). Fill the short side with seawater and the longer side with tap-water. Open the valve and watch what happens. Discuss the outcome. (This experiment simulates seawater intrusion, common e.g., in Florida.)