An exercise on: Physical Oceanography

Density Dynamics

Designed for: students in the 6th to 12th grade

Key words: density, stratification, turnover, water properties, ocean circulation, deep water formation, aquatic ecosystems

Aim: Familiarizing students with processes driven by changes in density (i.e. temperature and salinity), such as lake turnover and deep water masses formation.

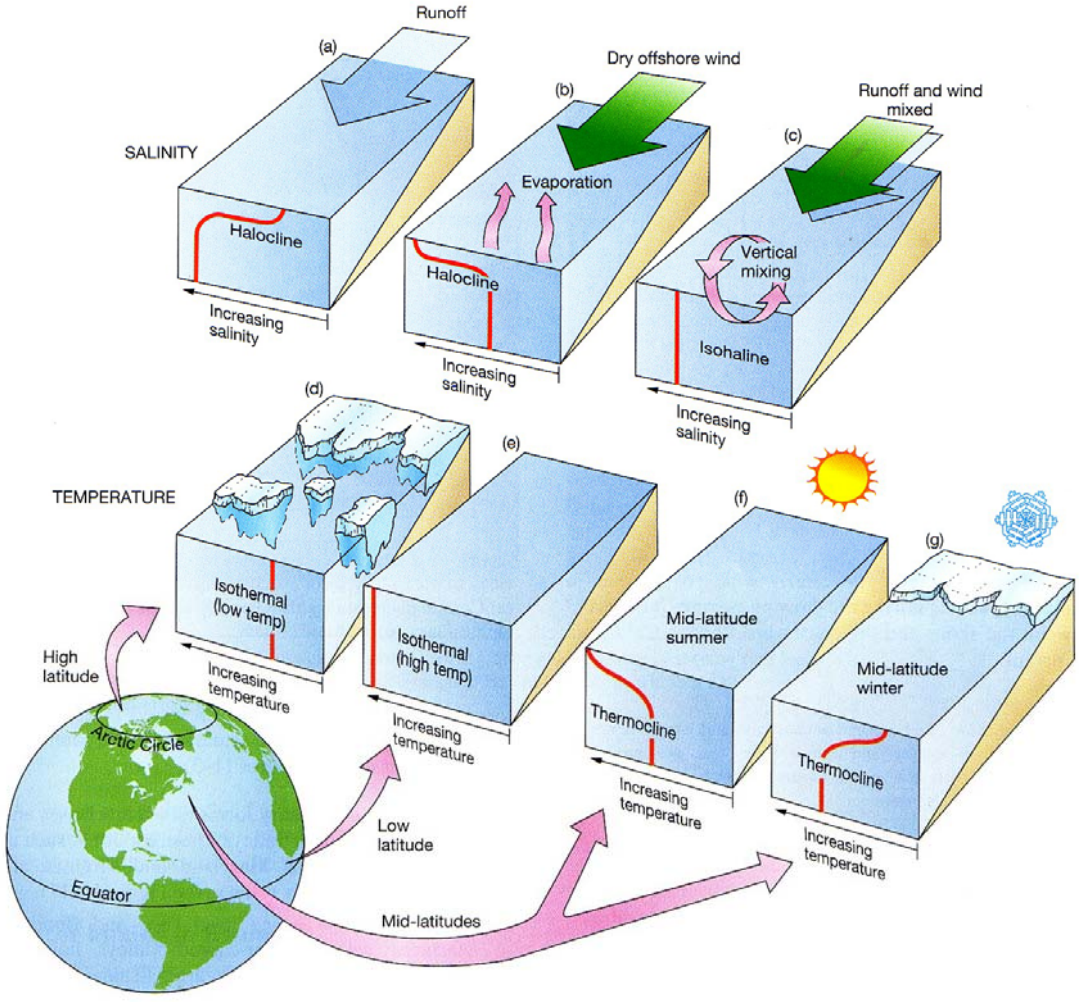

Figure 11–1 Salinity and temperature in the coastal ocean. Changes in coastal salinity (*top row*) can be caused by the input of freshwater runoff **(a)**, by dry offshore winds causing a high rate of evaporation **(b)**, or by both **(c)**. Changes in coastal temperature (*bottom row*) depend on latitude. In high latitudes **(d)**, the temperature of coastal water remains uniformly near freezing. In low latitudes **(e)**, coastal water may become uniformly warm. In the mid-latitudes, coastal surface water is significantly warmed during summer **(f)** and cooled during the winter **(g)**.

Reference for Diagram: "Essentials of Oceanography", Harold V. Thurman & Alan P. Trujillo, 7th edition, Prentice-Hall Inc., 2002

Short description: This exercise gives students an impression of how temperature and salinity affect the density of water and how water masses of different densities interact. The effects of density are visible in lakes as well as in oceans and hence density is an important parameter for HERMES research. For example, density dynamics is important in the ocean for vertical water movements, such as downwelling in the Gulf of Lions or sediment transport inside canyons. Density also plays a great role for the Mediterranean outflow – the Mediterranean outflow is intermediate water due to its high salinity, even though it has a much higher temperature than typical waters at 1000 meters depth.
You could either use this as a class demonstration, or ask students to work in small groups.

Materials:

- A transparent waterproof (e.g. glass or plastic) container of approximately 20 liters if you choose to make an interactive demonstration for the entire class, or one transparent waterproof container of approx. 4 liters per group of students.
- Two water samples, one at room temperature (approx. 20 degrees Celsius) and one warmer (approx. 35 degrees Celsius) plus two water samples of different salinities for the entire class, if you're making a demonstration, or per group of students. For the water samples with different salinities you could for example use a sample of fresh (tap) water and one of 32 ppt salinity (which can be easily prepared from tap water and sea salt) – this could illustrate a river water entering the sea. Or you could use smaller salinity differences, such as 28 ppt and 35 ppt for example, to illustrate different water masses in the ocean.
- Food coloring
- Thermometers
- Salinity meters or refractometers, if available
- Ice

Method:

- Tell students that densities of waters in nature are mostly controlled by temperature and salinity. Tell them also about the unique property of water that its density increases until it reaches 4 degrees Celsius, but then it decreases again as the water temperature drops further to 0 degrees Celsius. Ask students how does this property influence the life of aquatic organisms. In particular, ask them what effects do low temperatures in winter followed by warm temperatures in spring have on lakes and ponds and the organisms inhabiting them. Then ask them how ice formation on the polar seas in ocean influences the salinity of surface waters and the water and nutrients circulation patterns. Start a brainstorming on these topics, then propose students this exercise as a way to model the effects of these natural yearly processes on aquatic ecosystems.
- First prepare the two water samples of different temperatures and add a few drops of different food colorings in them. Ask students to measure their temperature and then pour a part of both water samples in the transparent container. The pouring procedure should be done carefully, either from one side of the container or through a floating sponge, in order to form two distinct layers of different colors.

If the water is poured too quickly, allowing a high degree of mixing, and the two layers are not observable, then the procedure should be started anew. You could either tell the students to first pour the coldest water in, or you can let them figure it out themselves through trial and error. After the two water layers are clearly visible, tell them that this stratification also happens in bodies of water in nature (both in lakes and in the ocean), when the upper layers of water are warmed by the sun.

- Continue by adding ice on the surface at one end of the container. Attract students' attention to the circulation patterns visible in the two differently colored layers as the ice melts and cold water flows from the surface to the bottom of the container. You can then cover the entire surface of the container with ice and ask students to compare what they observe with what happened when there was ice in only one corner of the container. Tell students that the processes that they observe are identical to those that happen in spring when ice melts in lakes and ponds due to the sun's warmth and as the surface water reach 4 degrees Celsius it sinks to the bottom, causing nutrient-rich bottom water to rise. This vertical movement of water in lakes and ponds in spring is called turnover. Turnover happens again in autumn when the surface waters cool again and sink.
- Students should write down or sketch the mixing and turnover processes they observe and measure the temperature at the surface, mid-depth and bottom of the water throughout the day to observe the changes in time of the degree of stratification of the water column.
- Next, tell students that, although usually temperature has the strongest effect on density, sometime salinity can play an important role. Give them the example of the Mediterranean outflow water which sinks to 1000 meters depth even though it is almost 10 degrees Celsius warmer than the water masses at that height, because its salinity is 5-6 ppt higher. Then you could repeat the entire procedure explained above by using the two samples of equal temperature but different salinities. Explain to students how the melting of ice in this case relates to the formation of deepwater in the high latitude oceans when (fresh-water) ice forms on the surface, leaving the salt behind, thus increasing the density of the surface water and causing it to sink. This happens for example in the North Atlantic in the Norwegian/Greenland, Labrador and Irminger Seas.
- Students should sketch the mixing processes they observe and to periodically measure the salinity at different depths.

Evaluation: The grading evaluation could be based on the students' sketches or written observations of the observed processes. You could also ask students to relate their personal experience of lakes, ponds or seas in different seasons to these processes.

Extend the exercise:

- You could investigate the effects of wind on these processes by using a small fan or you could use a hose to add water into the container and thus simulate the effects of a stream entering a lake.

- Freeze small rocks and sand into the ice you add to observe sedimentation processes as the ice melts.
- After this exercise you could take students on a field trip to a nearby lake or pond and observe these processes in nature.