Pacific Battleship Center

USS IOWA

Educational Resource

Thermohaline Circulation Activity

Objective: Students will understand how temperature and salinity affect water density and drive deep ocean currents.

Grade Levels: 3-8

NGSS Standards: ESS2.C, PS1.A, PS2.A.

Vocabulary Words:
Density
Mass
Volume
Temperature
Thermal Energy
Salinity
Current
Thermohaline Circulation
Global Conveyor Belt

Materials:

- Food coloring
- Hot water
- Cold water
- Room temperature water
- Salt
- 5 paper or styrofoam cups
- 5 toothpicks or push pins
- Large container capable of holding water.
    - Cups selected must fit within the container. The container should be deep enough to allow water to cover ¾ of the selected cups, when submerged.

Alternative Materials/Activity: If materials listed above are scarce, you can discuss and observe the same phenomena using this simulation by MARE.

Background Information:

Water in the ocean is constantly moving. Shallow surface water currents are mostly driven by convective wind patterns. However, the majority of our oceans' waters are too deep to be driven by wind currents. On average, wind has been shown to only affect the upper 100m of the water column. So what drives water movement deeper in the ocean? Differences in water density! Density is how tightly matter is packed in a given space and can be described as the formula:

$$\text{Density} = \frac{\text{Mass}}{\text{Volume}}$$

Factors affecting water density are:

1. Temperature: When you add heat to a substance, you're adding thermal energy. When you heat up water, you're adding energy to the water molecules. This causes the molecules to start moving faster and faster. While moving fast, they tend to collide and bounce off of each other and spread out. Due to the water molecules spreading out, you find less molecules per unit volume of water, or a decrease in density, when compared to room temperature water. When you cool water down and remove that thermal energy, the water molecules start to slow down. The number of collisions greatly drops and they can pack more closely together. This results in more molecules per unit volume, or an increase in density, when compared to room temperature water. This phenomena can be viewed virtually in these demonstrations: MARE demonstration, PBS demonstration.

2. Salinity: When you add salt to water, it dissolves, adding its own mass to the water. This increased mass in a given volume of water leads to a larger density when comparing saltwater to freshwater.

Video of experiments demonstrating temperature and salinity effects on water density by Battleship IOWA Education.

Thermohaline currents are deep water currents driven by differences in density due to varying water temperature (thermo) and salinity (haline) around the globe. When water crystallizes into ice in the salty ocean, it actually pushes the salt molecules out. So under the polar ice caps, there is very cold, high saline water. The combination of cold temperature and high salt makes this water very dense, and it sinks away from the surface forming a current as it moves. As this current travels the globe, it will warm and

cool in the varying climates it encounters. Thermohaline circulation forms what is referred to as the Global Conveyor Belt of ocean currents.

Activity Instructions:

1. Fill a large tub with room temperature water. It should be full enough that water covers ¾ of the paper or styrofoam cups selected for use.
2. Prepare five water samples, one in each of the paper or styrofoam cups. Color each sample a different color with food coloring.
    a. 1 cup of room temperature water and 4 tablespoons of salt
    b. 1 cup of cold water
    c. 1 cup of hot water
    d. 1 cup of cold water and 4 tablespoons of salt
    e. 1 cup of hot water and 4 tablespoons of salt
3. Hold the cup containing water sample “a.” Halfway up the cup wall, poke push pin or toothpick through the wall of the cup. Leave the push pin or toothpick in the hole, blocking it so no water spills out.
4. Place sample “a.”, with its push pin or toothpick still in place, into the tub of room temperature water.
5. Remove the push pin/toothpick and allow the water inside the cup to leak out into the tub.
6. Observes how the water moves/disperses into the room temperature water of the tub.
7. Once finished observing sample “a”, drain water from the tub and refill, so all food coloring is removed.
8. Repeat all steps with each of the water samples, renewing the room temperature water in the tub for each trial.

Conclusion:

How did each water sample disperse into the tub of room temperature water? Discuss how the density of each water sample compares to the density of room temperature freshwater in the tub. Based on density, did each sample dispersed the way you thought it would?

Further Investigations:

Play with the temperature dial in this Global Conveyor Belt simulation by MARE and observe how the current changes with temperature. How could climate change affect thermohaline circulation and the Global Conveyor Belt?

Sources:

NOAA: National Ocean and Atmospheric Administration
https://oceanservice.noaa.gov/education/tutorial_currents/05conveyor1.html
https://oceanservice.noaa.gov/education/tutorial_currents/05conveyor2.html
https://oceanservice.noaa.gov/education/tutorial_currents/05conveyor3.html

MARE: Marine Activities, Resources, and Education. Lawrence Science Hall
http://static.lawrencehallofscience.org/mare-sims/1-8-model-ocean-animation.html
http://static.lawrencehallofscience.org/mare-sims/3-7-great-ocean-conveyor-belt.html