Session 1: How does the ocean move?

Introduction:

The ocean covers nearly 70% of the Earth's surface and this huge, connected, body of water is constantly moving. Water, plants, animals, pollutants and people are carried by ocean movements. Understanding how the ocean moves is thus very important. Physical oceanographers, just like a physicist who studies the motion of planets or objects falling, study the rising and falling movements of ocean water. While it might be intuitive to think that winds influence the movement of water on the surface of the ocean, we didn't know what was happening in the ocean interior and thus in the deep ocean until the 1960s. It was just in the early 60s that physical oceanographers proposed the mechanisms that drive ocean movement at the global scale and particularly in the deep ocean. This global circulation pattern is known as the Ocean Conveyor Belt, often also called thermohaline circulation, and is responsible for transferring heat throughout the ocean, helping to regulate the Earth's climate.

The Ocean Conveyor Belt is driven by deep water formation that arises due to differences in the water density. Water density is influenced by temperature and salinity. To understand it, let's from the poles. In the poles, seawater is cold and ice formation leads to more salty waters. Cold and salty waters are dense and therefore will sink. As the dense water sinks, it is replaced by less dense surface waters that are warmer and less salty. As a result of this movement, cold waters travel through the deep ocean from the poles towards the tropics. In turn, warm waters on the surface travel (also according to the wind belts) from the tropics transporting heat to the poles. That's why this circulation is so important to regulate the climate of the planet. However, the Ocean Conveyor Belt might be threatened by climate change, especially given that the ocean is getting warmer at an unprecedented rate. Ocean warming might decrease the formation of deep water in the poles which could potentially decrease the capacity of the Ocean Conveyor Belt to transfer heat throughout the ocean.

Now, you might be wondering, what about winds? Aren't winds important to control ocean movement? Well, winds don't have much of an influence on deep currents (as the name already tells us, it is too deep for winds to have an effect). However, winds will influence surface currents and can have an important role on causing coastal upwelling, in which deep, cold, nutrient-rich waters are driven to the ocean surface. Strong winds along the coasts of different regions in the planet can cause upwelling. Together with the Earth's rotation, these strong winds can push surface waters offshore. And this phenomenon is observed on the California Coast!

In this session, we will perform three fun experiments to understand how salinity, temperature and wind can affect water density and movement. We will then combine what we learned to understand how the ocean moves.

Goal: Students will get hands-on experience to observe different ocean physical processes and understand how seawater is circulated globally.

Learning objectives (LO):

1. By performing an experiment with **saltwater and freshwater**, students will be able to tell which kind of water is heavier/denser.
2. By performing an experiment with **cold and warm waters**, students will be able to tell which kind of water is heavier/denser.
3. Based on their experimental findings, students should be able to predict that colder and saltier waters tend to sink in the ocean while warmer and less salty waters tend to be on the surface.
4. Students should be able to perform a simple experiment to determine how winds can bring colder and deeper waters to the surface.
5. Distinguish the effects of temperature, salt and winds on ocean movement.
6. Students should be able to justify their thinking about the ocean movement in oral form.

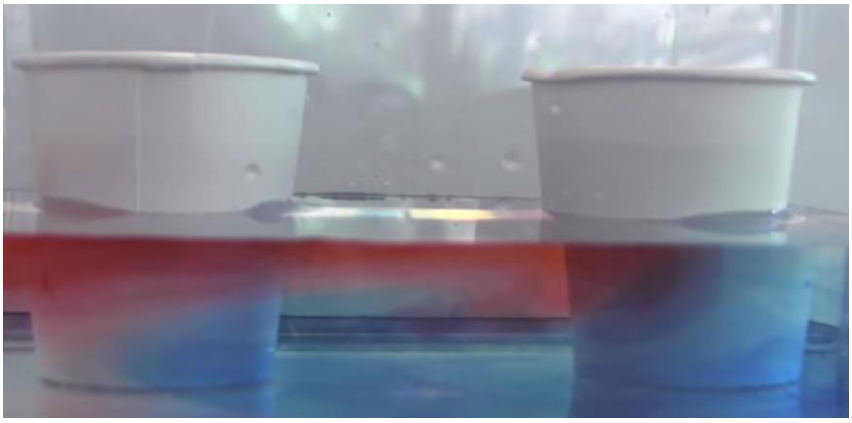
Session plan:

1. Present brief introduction slides.
    - Introduce the concept of a single connected ocean.
    - Discuss the relevance of ocean movement. What can be affected by it?
    - Ask: what drives ocean movement?
    - To understand that, we will perform three experiments. We can use the powerpoint slides that contain the student's handout to guide the students over the experiments while also performing the experiments with them.

Activities (detailed step-by-step can be found at the end of this document and in the hands-out)**:**

1. Activity 1: we will learn how salinity affects the density of the water by adding the same object to a glass with salt water and to a glass with freshwater. To start the discussion, we can ask: Have you ever tried floating in a river vs in the ocean? Where do you think it would be easier to float? Why? Let's think about what is the main difference between water in a river and in the ocean – you got it, salt! By the end of the experiment, we will relate this finding to the ocean, sharing that water in the poles is more salty due to sea ice formation.

2. Activity 2: we will learn how temperature affects water density by using dyes of different colors to identify cold and hot water. To start the discussion, we can ask: Have you ever noticed how temperature changes as you dive deeper in the ocean? What differences in temperature do you see in surface vs deeper waters? Why? By the end of the experiment, we will relate this finding back to the ocean, sharing that cold water in the poles sink and travels deep to the tropics while warm water in the tropics travels through the surface transporting heat to the poles.



3. Activity 3: we will learn how winds can drive coastal upwelling by blowing water with a straw in a tray with water that contains a colder blue liquid at the bottom. We can ask: how do you think winds might affect ocean movement? By the end of the experiment, we can give as an example the upwelling system on the California Coast, and explain its importance.

Experiment 1:

Material list:

- 2 small ducks
- 2 reusable plastic cups
- Table salt
- 1 spoon
- Water

Instructions:

1. Fill one cup with tap water.
2. Gently, place one of the ducks on top of the water surface and observe. What happens?
3. Fill the second cup with tap water.
4. Add the table salt to the second cup and stir it well.
5. Gently, place one of the ducks on top of the water surface and observe. What happens?

How it works:

As you place the ducks in cups with different waters (freshwater versus saltwater), you will learn that the saltwater is denser than the freshwater, since the ducks will float in one cup and sink in the other.

Experiment 2:

Material list:

- 2 different food coloring
- 2 small paper cups
- 1 plastic tray
- Cold water
- Warm water

Instructions:

1. Put the paper cups inside the tray side by side
2. Add cold water to one of the paper cups.
3. Add 6 drops of one of the food coloring to the paper cup containing cold water and stir it.
4. Add warm water to the other coffee cup.
5. Add 6 drops of the other food coloring to the coffee cup containing warm water and mix it.
6. Place both coffee cups inside the plastic tray, one on the left and one on the right, and make sure the tapes in the cups are facing each other.
7. Add tap water to the plastic tray until it is half full (make sure it does not surpass the level of water in the coffee cups).
8. Gently remove the adhesive tape of the cup containing warm water and then the adhesive tape of the cup containing cold water.
9. Observe for 2-3 minutes. What is happening over time?

How it works:

As you release the adhesive tapes, the colored waters from both cups will be released into the water of the plastic tray. Once the warm water meets the cold water, you will learn that cold waters are denser than warm waters, since the cold water will flow downwards and the warm water will flow upwards.

Experiment 3:

Material list:

- 2 reusable plastic cups
- 1 plastic funnel
- 1 food coloring
- 1 paper straw
- 1 spoon
- Cold water
- Warm water

Instructions:

1. Fill ¼ of the other cup with cold water.
2. Add 10 drops of the food coloring in the cold water and stir well.
3. Fill 2/3 of the other cup with warm water.
4. Place the funnel at the bottom of the plastic cup that contains warm water.
5. Gently add a little bit of the cold colored water through the funnel.
6. Gently remove the funnel and check what happens at the bottom of the cup.
7. Position the straw in a diagonal angle (but do not touch the water surface) and then blow through the straw! Now stop and look to the side of the cup to see the whirl you created!

How it works:

The differences in water temperature will make the colored water stay at the bottom of the cup, because it is denser than the warm water. The straw allows the simulation of winds which promotes mixing, bringing the colder and denser water to the surface. This phenomenon in the ocean is also known as upwelling!

References

Temperature experiment: https://www.youtube.com/watch?v=A2nEh0Zlqo8

Wind & upwelling experiment: https://www.youtube.com/watch?v=RC8CPfPPE0Y

Visuals (bath toys drifting away!): https://www.youtube.com/watch?v=p4pWafuvdrY&t=9s

For reference of circulation across the global oceans check also the movie “Perpetual Ocean” by NASA: https://www.youtube.com/watch?v=CCmTY0PKGDs&t=2s