The Education Program at the
New Jersey Sea Grant Consortium

22 Magruder Road, Fort Hancock, NJ 07732 (732) 872-1300
www.njseagrant.org

UNDERSTANDING STORM SURGE

Activity #3 - Density Driven Currents

OVERVIEW

Air moves the same way liquids do. By using cold and warm water, students will be able to observe how cold air masses with high pressure and warm air masses with low pressure travel through our atmosphere, creating convection currents, wind, and storms.

MATERIALS

- Clear plastic or glass container rectangular in shape, about the size of a shoebox or a 5- gallon aquarium
- Red and blue food coloring
- Three measuring cups
- Three separate cups of water: 1000 ml of clear water at room temperature; 250 ml of warm water colored red, and 250 ml of very cold water colored blue.
- 2-4 pieces of white copy paper

PROCEDURE

1. Place a sheet of copy paper beneath the clear rectangular container and another piece of copy paper lengthwise across the side of the container.
2. Pour 1000 ml of clear room temperature water into the clear container.
3. Very slowly and carefully pour the cups with the 250ml of warm and cold water **simultaneously** into the clear container at opposite ends. Make observations of the colored waters while pouring.
4. Continue to make observations of the colored water and answer questions 1 – 8.

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Student Questions:

1. Where on Earth would you find very cold air?

2. Where on Earth would you find very warm air?

3. When first starting to pour in the cold water, what part of the container did it initially move towards? How does this relate to the movement of a mass of cold air in our atmosphere?

4. When first starting to pour in the warm water, what part of the container did it initially move towards? How does this relate to the movement of a mass of warm air in our atmosphere?

5. Viewing the container from the side, explain the direction and movement of the cold blue water.

6. Viewing the container from the side, explain the direction and movement of the warm red water.

7. What color water was displaced and moved up in the water column?

8. After about 2 minutes, what happened to the blue and red colored water? Why?

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Student Answers:

1. The North and South Poles of the Earth.

2. Near the Equator.

3. Students should observe the cold blue water sinking to the bottom of the container. Cold air is dense and sinks causing high pressure.

4. Students should observe the warm red water remaining near the surface on top of the room temperature water and/or rising after it is poured.

5. Students should observe the blue water sinking and travelling slowly across the container to the opposite side from where it was poured.

6. The warm red water will slowly float and travel across the top of the container to the opposite side from where it was poured. As the warm water cools it may start to sink but will be displaced by the cold water and rise again.

7. Students should observe a thermocline with a clear delineation: the warm red water on top, possibly a small purple mix in the middle, and the cold blue water at the bottom.
   This layering happens because as the cold water (air) molecules move close together, the water becomes denser and sinks to the bottom of the container. In contrast, as the warm water (air) molecules spread apart, the red water becomes less dense and floats on top of the cold water (air). When the two masses of water meet in the middle, they start to mix and equalize in temperature.

8. Eventually the different water temperatures will mix and equalize in temperature, and the water will turn all purple. However, this is not what happens on Earth because there is constant uneven heating from the sun. The round shape of the Earth, the Earth's tilt on its axis

and its orbit around the sun (creating seasons) cause the sun's rays to reach different areas of the Earth at different angles; In addition, the spin of the Earth (Corioles effect) and the differences in land and ocean heat absorption rates all create constant temperature changes around the earth. This constant change in temperature creates pressure differences which drive air around the world.

Further Explanation:

In this experiment, the cold blue water represents cold air near the North or South Pole of Earth. Cold temperatures cause air (and water) to become denser as molecules pack closely together and take up less volume. The cold water is denser, so it will sink and move to the bottom of the container. This is similar to what happens to cold air in Earth's atmosphere. The warm red water represents warm air from near the Equator. Warm temperatures cause air (and water) molecules to increase their movement and spread apart, taking up more space and becoming less dense. The warm water used in this experiment is less dense than the room temperature and cold water so the warm water rises to the top of the container. In the atmosphere, warm air acts similarly.

Students should be able to observe a thermocline or temperature gradient inside the container. This gradient should appear with the warm red water on top, possibly some mixed water in the middle (appears purple), and the cold blue water on the bottom. Students will also observe the masses of colored water moving to opposite ends of the container because the water strives to equalize its temperature. The cold blue water will travel down and towards the side where the warm red water was poured. As the cold blue water moves, it will displace some of the warm red water, pushing it up and over towards the side of the container opposite from where it was poured. These are convection currents. Because we cannot possibly keep adding warm and cold water to our small container, the waters will start to mix and turn purple as they start to equalize in temperature. Earth strives toward equilibrium with equal pressure and temperatures; however, this equilibrium is prevented from happening on Earth due to constant unequal heating from the sun.

The motion of the water in the container is similar to what happens to air in the Earth's atmosphere. In Earth's atmosphere, cool air masses with high pressure sink down and displace the warm air closer to Earth's surface; the warm air is pushed up and its displacement creates a low pressure system. Then warm air rises and travels to the upper part of the atmosphere where cool air prevails. This cools the warm air again, which then moves back down towards the surface of the earth. This downward flow of warm air creates a high pressure system.

As the cold and warm water begin to mix, students may also observe some swirling water, which is similar to strong winds in our atmosphere. This motion can be observed when the two different colored water masses meet. It happens because of the extreme difference of temperature and density of the colored waters.

The movement of the water in the container is similar to what happens in Earth's atmosphere when a cold air mass with high pressure meets a warm air mass with lower pressure. The meeting of these two extremes of temperature and pressure forms storms—and even hurricanes! Low pressure systems are found on the boundary between warm and cold air masses. As warm air rises up, cold air rushes into the area of low pressure and causes strong winds. The more warm air rises, the stronger the winds. However, because Earth is rotating, air does not just go straight up and down or back in forth in our atmosphere. Ask students to think about how the spinning of the Earth moves air in the atmosphere and never allows it to still. How could the rotation of the Earth affect weather patterns around the Earth? (This will be explored in the next activity).