LESSON 3: Visualizing Ocean Currents

Teacher's Guide

Objective: In this lesson, students will use a rheoscopic fluid to simulate ocean currents. They will observe convection, density-driven flow, and wind-driven flow. In observing the fluid, students will see turbulence and eddies.

There is a short reading included at the end of the student guide.

Inquiry question:
What causes oceanic currents?

Time Required: One class period

Standards Addressed:
6th Grade: SC.6.E.7.1, SC.6.E.7.3, SC.6.E.7.4, SC.6.E.7.5, SC.6.N.3.4
7th Grade: SC.7.N.1.3, SC.7.N.3.2, SC.7.N.1.5, SC.7.P.11.4
8th Grade: SC.8.N.1.5, SC.8.N.3.1

Materials:
- Individual copies of Student Guide (on page 21)
- Straight-sided bottle with cap filled completely with rheoscopic fluid (no air space at the top)
- Small flashlight (optional)
- Shallow container larger than the bottle
- Hot water
- Shallow tray or dish (about 7" across)
- Drinking straw
- Food coloring (red, yellow)
- Salt
- Ice cube tray
- 2 plastic containers (at least 9"x9")
- Small funnel
- Clear flexible rubber tubing
- Air stone diffuser (used in aquariums)

PREPARATION

Convection. Rheoscopic fluid can be either purchased or made cheaply and easily, although the DIY version will settle more quickly. Cosmetic mica powder can be purchased online or at a craft store and is very safe. ¼ tsp in a liter of water yields a very nice flow visualization and suspension of particulate. After several minutes it will settle to the bottom, but any movement will maintain a swirling pattern. Food dye can be added to the water or it can be left undyed. As the bottle should be filled to the top with no air pocket, it is advisable to glue the top onto the bottle to prevent leaks.

Wind-Driven Flow. The rheoscopic fluid can be used in a shallow tray to show wind-driven flow.

Density-Driven Flow. Mix the red food dye with water and freeze it in the ice cube tray to produce red ice cubes. Mix the salt with water and yellow dye. 35 grams of salt in 1 liter of water will produce a 35ppt salinity, which is the global average for seawater. Fill one container all the way with fresh water and fill the other container 1/3 with fresh water.

PROCEDURES

Students will work through each of the items and record their observations in the data table on the student guide.

Step 1: Convection

A smooth-walled bottle containing rheoscopic fluid (with no air space) is placed in a larger dish of warm water. Students observe the flow of the fluid at the edge of the bottle. Students will see the fluid submerged in the warm water is rising and the fluid at the top that is not submerged sinking.

Step 2: Wind-driven flow

Using a shallow tray of fluid and a drinking straw, students blow gently parallel to the fluid surface to observe changes in flow of the rheoscopic fluid.

Step 3: Density-driven flow

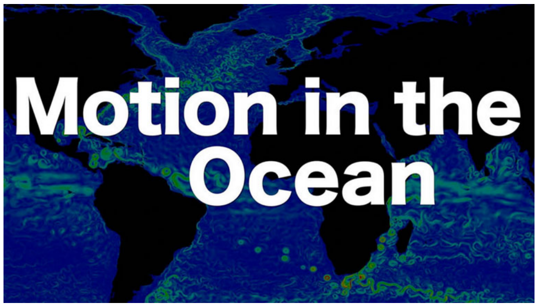
1. Connect the tubing to the air stone diffuser and place the diffuser in the bottom of the partially filled container (below the fresh water). Connect the funnel to the other end and slowly pour the salt-dye-water mixture into the container. It should layer below the fresh water layer with minimal mixing. Fill it to the same level as the first container.
2. Put the red ice cubes in both containers and watch where the melt water goes. This melt water represents the cold/salty dense water in the poles. The top layer of fresh water is the surrounding surface waters; the bottom salty layer represents the deep dense ocean layers.

Step 4: Coriolis Effect

Students will read “Motion in the Ocean” (on page 23) and watch the video “Why Do Hurricanes Spin?” to learn more about the Coriolis Effect (see URL link to the video below left).

After the data collection, students will read about and watch a video on the NOAA website showing the ocean conveyor belt and, specifically, the Gulf Stream current (see URL link to “Motion in the Ocean” at right).

https://www.youtube.com/watch?v=6L5UD240mCQ



https://oceanservice.noaa.gov/podcast/apr14/mw123-currents.html

Finally, students will watch the video “Science in a Time of Crisis: Tracking the Currents” to learn more about how scientists reacted to the BP oil spill on the Gulf of Mexico.

https://ocean.si.edu/planet-ocean/tides-currents/science-time-crisis-tracking-currents

NAME______________________________Class______________________ Period______________

QUESTION: What causes oceanic currents?

These activities will help you understand the phenomena that drive ocean currents. Rheoscopic fluids will be used. The prefix ***rheo-*** means flow and the root ***-scopic*** means see. The fluids we will use will help us see the movement of water.

Each group needs to follow teacher instructions for obtaining: safety goggles, one smooth-walled bottle of rheoscopic fluid, several straws, a stirring rod or metal utensil, one ice cube, dishes of saltwater and freshwater, a shallow dish with room temperature water

Wear safety goggles for all of these procedures.

First pass the bottle of rheoscopic fluid to all of your lab partners to examine. Discuss with your partners what you observe. For the remainder of these procedures, try to make sure you keep the fluid as still as possible as you begin each activity.

Activity 1

Warm water bath. Leave the rheoscopic fluid bottle on the table for 1 minute to allow the movement of particles to slow. Carefully place the bottle containing room temperature rheoscopic fluid into a larger dish of very warm water. Observe the flow of the fluid in the bottle (use a flashlight, if available).

Activity 2

Blowing across surface. Once you and your lab partners have recorded observations for procedure 1, pour rheoscopic fluid into a shallow tray. The fluid should not fill more than half of the tray. Use a drinking straw (do not share a straw with your partners) to very gently blow a full breath of air parallel to the fluid surface. Describe what you observe in the data table. Repeat blowing and observing using a slightly stronger and then a stronger force. Observe how blowing affects movement of water in the dish.

Activity 3

Salt and freshwater mixing. Put the red ice cubes in both containers and watch where the melt water goes. This melt water represents the cold/salty dense water in the poles. The top layer of fresh water is the surrounding surface waters and the bottom salty layer represents the deep dense layers in the ocean.

Step/Procedure	Treatment	Process we are modelling?	Observations
1. In a warm water bath	Initially placed in water		
	After 2 minutes		
2. Blowing across surface	Gentle blowing		
	Medium blowing		
	Strong blowing		

Step/Procedure	Treatment	Process we are modelling?	Observations
3. Salt and freshwater mixing	As colors start to flow		
	After 3 minutes		

Activity 4

Coriolis Effect. Watch the video "Why Do Hurricanes Spin?" and discuss. How does the Coriolis Effect influence the movement of water in the ocean?

https://www.youtube.com/watch?v=6L5UD240mCQ

Activity 5 - Coriolis Effect

Now read about ocean currents and watch the "Motion in the Ocean" video from NOAA.

1. What is an eddy?
2. What is the Loop Current?
3. Name three factors that put the motion in the ocean.

https://oceanservice.noaa.gov/podcast/apr14/mw123-currents.html
How much do you know about ocean currents? Watch our three-minute video podcast to learn what puts the motion in the ocean.

Next, go to https://earth.nullschool.net/#current/ocean/surface/currents/orthographic to see current wind, weather, ocean, and pollution conditions as forecast by supercomputers on an interactive animated map. The Earth Nullschool maps are updated every three hours.

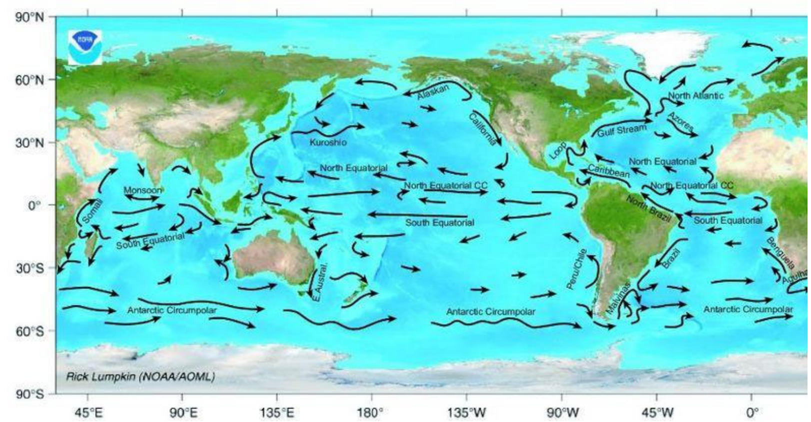
Zoom in to the Gulf of Mexico and answer these two questions.

1. What was happening in the Gulf of Mexico? How is it connected to the rest of the Atlantic Ocean?
2. How do you think understanding currents can help us when oil spills happen?

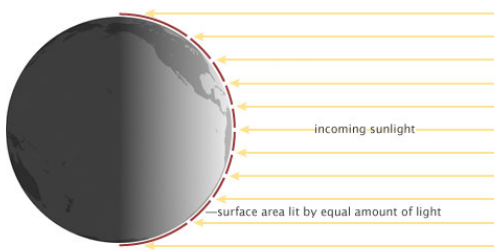
Reading: Motion in the Ocean

By Karolyn Burns, MS, Yana Bebieva, PhD, and Cathrine Hancock, PhD.

Although it can take thousands of years, the world's oceans are interconnected and communicate with each other. They do this through water movement, from one ocean basin to another. Energy is what makes the water move. There are different types of energy that affect the ocean in different ways, but the two most important forces are the wind, which provides kinetic energy, or the energy of motion. The other is the sun, which provides heat. Ultimately, the air movement that creates wind is also powered by the sun, and the sun is the source of energy for the Earth. Surface currents are driven by the wind, as the friction between air and water pushes the surface water around.



https://commons.wikimedia.org/wiki/File:Ocean_surface_currents.jpg

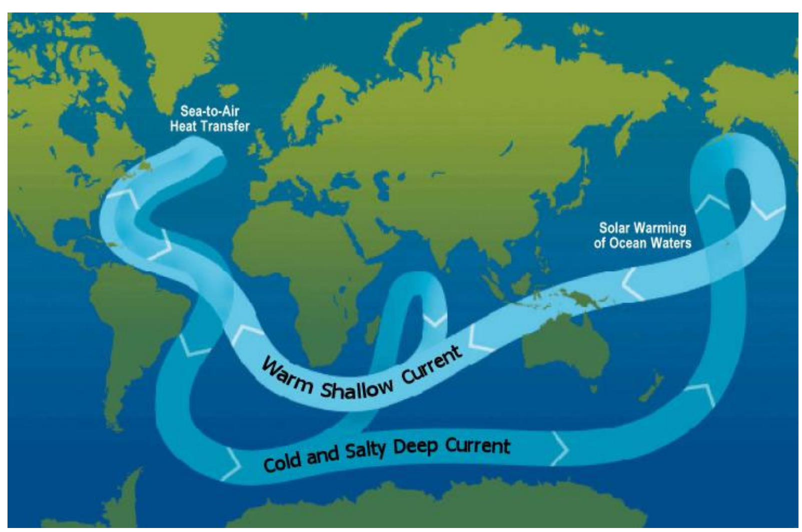


https://earthobservatory.nasa.gov/features/EnergyBalance/page2.php

There are also currents that move under the ocean's surface, and these are driven by heat. The earth is round, and the axis is at an angle. The sun shines directly on the equator, and less light and heat make it to the poles.

This creates a temperature difference between these surface waters. Think of a cold room, with a fire place on one side. If you start a fire in the fireplace, right by the fireplace it is hot. As you move away from the fire it gradually gets colder and colder. The heat travels from the fireplace to the other side of the room, but it takes time.

Surface water at the equator can move in two directions, downward (towards the ocean floor) and poleward. For water to sink, it needs to be denser than its surroundings. Water density is affected by heat and salt. Warm/fresh water is less dense than cold/salty water. So, warming the waters at the equator will decrease their density, forcing them to stay at the surface. Therefore, the only place this warm surface water can move is poleward.



https://commons.wikimedia.org/wiki/File:Ocean_circulation_conveyor_belt.jpg

Surface waters move poleward to redistribute the heat energy from the equator to areas that are colder. On their way to the poles this water encounters colder air above it, removing heat and increasing the density of the surface water. At the poles the air is freezing, which forces even more heat out of the surface waters. Eventually sea ice will form. When sea ice forms out of salt water, most of the salt is expelled into the remaining water. Now the remaining water is cold and salty, which means it is denser than the surrounding water. This dense water will sink until it reaches a water mass with the same density as itself. At this point, the water will spread out moving toward the equator. The equatorward flow will mix with surrounding water masses, decreasing its density. Thus, the equatorward flow will slowly rise in the water column until it reaches the surface once more. Then the cycle will start all over again.

The sinking of dense waters at the poles is called convection; and the entire circulation is commonly referred to as that thermohaline circulation. (***thermo*** – heat, ***haline*** – salt).