

## VANDERBILT STUDENT VOLUNTEERS FOR SCIENCE

<http://studentorgs.vanderbilt.edu/vsvs>

# Deep Ocean Currents & Air Convection Currents

## 2018-2019– VINSE/VSVS

**Goal:** To teach students about deep ocean currents by allowing them to visualize and understand how and why the currents form. To introduce students to convection in liquids and gases.

Fits Tennessee standards

### Lesson Outline:

1. **Introduction to Ocean Currents**
2. **Density Background Information:**
  - a. Density Demonstration: VSVS volunteers will show students how salt packs around water molecules using a jar of marbles and salt.
  - b. VSVS team members will explain the concept of density.
  - c. VSVS members will use the Polydensity bottle to further explain density.
3. **Saltwater in the Ocean:**
  - a. The VSVS team will share some information about oceans with the students.
  - b. Saltwater demonstration: Students will add colored salt water to one side of a partitioned rectangular container and fresh water to the other side. Plugs in the partition are removed and students will watch the flow of water. Pepper is added to the surface of the water on both sides and students will observe the circulation.
4. **Where Are The Deep Ocean Currents?**
  - a. Students look at a map of deep ocean currents.
5. **Demonstration: Convection Currents in Gases.**

Students use a chimney apparatus and dry ice to investigate the flow of warm and cold air.
6. **Colliding Warm Air and Cold Air Masses.**

Students observe what happens when cold air meets warm air.
7. **Review**

### Materials

- water
- 1 6oz jar with marbles
- 1 6oz jar of salt
- 1 strainer
- 1 polydensity bottle
- 10 containers of salt
- 10 spoons
- 10 rectangular containers
- 20 16oz cups with marked water level [~250mL]
- 1 blue food coloring dropper bottle
- 1 pair plastic gloves (for VSVS members to wear when using food coloring)
- 1 pepper container
- 10 oval plates
- 1 wide mouth waste bottle for salt water
- 20 2 oz jars with holes in lids

- 10 plastic squares
- ice
- 32 Observation Sheets
- 10 Instruction Sheets
- 10 World Maps with Ocean Salinity
- 1 Chimney boxes
- 2 small Styrofoam cups
- 2 candles
- 1 box matches
- 1 lighter
- 4 Thermometer strips
- 1 binder containing powerpoint, lesson, instruction sheets, observation and answer sheet

**Teacher prep:**

**Fill 20 cups to 250 mL mark with tap water.**

**After salt has been added to marble jar, strain off salt, and keep for next class.**

**Pour out water from rectangular containers and rinse before using again.**

**Pack ice into 10 of the 2oz jars with holes in lids. Room Temp water will be added just before the experiment is done**

**Pack chimney into cardboard boxes and close lid on box to prevent glass cover from breaking.**

**During the Lesson:**

**Here are some Fun Facts**

- A well-known density-driven current occurs where the saltier Mediterranean Sea empties into the Atlantic Ocean. During World War II, submarines used this current to enter and leave the Mediterranean without even turning on their engines! (<http://science.howstuffworks.com/>)
- If the salt in all of the earth's seas could be removed and spread evenly over the Earth's surface, it would form a layer more than 500 feet thick – that's about as tall as 2.5 Batman Buildings!
- The oceans move 1.4 trillion cubic kilometers of water each day!
- Radioactive tritium is used to trace the world's currents because it is easily detected and it travels at the same speed as the water carrying it.
- It takes a minimum of 500 years and up to 1,000 years for the oceans' water to cycle itself globally.

**Unpacking the Kit– What you will need for each section:**

**Divide the class into 10 groups (of 3).**

**For Part II. Density Background Information and Demonstrations**

- 6oz container of salt, 1 6oz jar containing marbles , 32 Observation Sheets, 16 Instruction Sheets, 10 oil/salt water jars

**For Part III. Movement of Saltwater in the Ocean**

- 10 containers of salt, 10 spoons, 10 rectangular containers, 10 16oz/500 mL bottles water
- 20 16oz cups with marked water level [~250mL]
- 2 blue food coloring dropper bottle
- 1 pair plastic gloves (for VSVS members to wear when using food coloring)
- 2 pepper container
- 10 oval plates

**Your Notes:**

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## For Part IIIB. Cold Water in the Ocean

20 2oz jars with holes in lids  
2 16oz cups styrofoam Ice  
2 L water  
Food Coloring from Part III  
10 plastic plates  
10 Clear plastic squares

### **Set-up:**

**VSVSers will put 2 drops of blue food coloring in 10 of the jars and then pack with ice. (Just before the students do this experiment, VSVSers will pour room temperature water into all containers so they are FULL.)**

## For Part IV. Where Are The Deep Ocean Currents?

32 World Maps with Ocean Salinity  
33

### 1. Introduction to Ocean Currents

<b>Learning Goals: Students understand the two types of ocean currents</b>
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#### **Why is the science in this lesson important?**

The movement of deep ocean currents are partly responsible for global temperatures, as they cycle cold water to different areas of the globe. Changes in deep ocean currents due to climate change can alter ecosystems around the world.

#### **Ask students if they know the names of the 2 types of ocean currents?**

Ocean currents are divided into 2 types - **surface** and **deep**.

**Surface currents** are driven by the wind blowing over the ocean, the earth's rotation, and large land masses.

Surface currents occur at the surface of the ocean.

They are only about 400m (1300ft) deep (occur in the top 400m of the ocean).

**\*\*That's about that the height of two Batman Buildings (192m (630.5ft)\*\***

**Deep ocean currents** are driven by the temperature and density of the water.

Sometimes they are called submarine rivers.

90% of the ocean water is moved by the deep ocean currents.

Ocean water becomes denser when it is colder and when it has more salt dissolved in it.

Tell students they will investigate the behavior of dense salt water, which is similar to that found in the deep ocean waters.

### **Your Notes:**

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## 2. Density Background Information

**Learning Goals: Students observe how manipulations of mass and volume affect density.**

- Ask the students if they know what density is. Tell them that they can think of density as how much mass there is in a given volume. A good example would be the different densities of a golf ball and ping pong ball. They have the same volume but different mass.



### Demonstration

Materials:

- 1 6oz container of salt
- 1 6oz jar containing marbles
  - Show students the jar with marbles in it.
  - Tell the students that the marbles represent water molecules.
  - Pour the container of salt into the jar.
  - Explain to the students that the salt packs around the marbles in a similar way it does around water in salt water.
  - Ask students why they think saltwater is denser than regular water. *Saltwater has a higher mass because of the added salt, and hence is denser.*

### Tell students that a liquid with low density will float on top of a liquid with a high density.

- Have students observe the Polydensity bottle. Shake the bottle gently and let the students observe what happens (the 2 liquids gradually separate).
- Ask students what happened? *First the white beads moved to the top and the blue beads moved to the bottom of the liquid (refer to background information). Then the white beads floated down and the blue beads floated up and met in the middle.*
- Ask students why they think this happened?
  - *The two liquids have different densities.*
  - *One of the liquids is denser salt water (lies below the beads on the bottom).*
  - *The other liquid is less dense rubbing alcohol (lies above the beads on the top).*
  - *These 2 liquids do not mix, they form layers (salt water on the bottom & rubbing alcohol on the top)*
  - *The beads also have different densities:*
    - *The blue beads are more dense than the white beads and less dense than the salt water (they float on the salt water).*
    - *The white beads are less dense than the salt water and blue beads, but more dense than the rubbing alcohol (they float on the blue beads but not on the rubbing alcohol).*



**Your Notes:**

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**For VSVS background information only:** The bottle contains a mixture of isopropyl alcohol and saltwater. All of the liquids and beads have different densities. The rubbing alcohol is the least dense followed by the white beads, then the blue beads, with salt water being the densest. When the two liquids are forced to temporarily mix by shaking, the new liquid has a different density that falls between As the two liquids separate once more (due to their different densities), the initial layering reoccurs: the blue beads float to the top of the saltwater layer because they are less dense than saltwater, and the white beads float to the bottom of the isopropyl alcohol layer because they are more dense than the isopropyl alcohol.

### 3. Saltwater in the Ocean

#### How is Ocean Water Different from Fresh Water?

Ocean water is salty.

If the salt in all of the earth's seas could be removed and spread evenly over the Earth's surface, it would form a layer more than 500 feet thick – that's about as tall as 2.5 Batman Buildings!

- The average salinity of surface ocean water is 3.5%, which means for every liter of ocean water there are approximately 35 grams of salts dissolved in it.
- Fresh water (like that in lakes or rivers) has a very low salinity level, <0.05% (<0.5 grams per liter of fresh water).

#### Why the difference in Salinity?

- Ask students why they think the sea contains so much salt but lakes, streams, and rivers do not have much at all.
  - The salt in the ocean comes from the gradual process of weathering and erosion of the Earth's crust, as well as the wearing down of mountains.
  - Rain and streams then transport the salt to the sea.
- Some salts may have come from volcanic emissions when earth was being formed.
- Some salts also come from the magma at the mid-ocean ridges are located.
- As time has passed, the seas have actually gotten saltier. Water evaporation from the ocean leaves salts in the ocean while weathering continues to add salts.

#### What kind of salts are in the ocean?

- Seawater is actually really complex and contains salts made up of combinations of at least 72 elements, most in very small amounts. Salts of sodium, chloride, magnesium, sulfate and calcium are the most abundant.

#### Divide the class into 10 groups (of 3).

Tell students they will make their own salt water and observe what happens when it "meets" fresh water.

Pass out the following materials to each group:

2 16 oz cups water (filled to 250 mL line)

1 2 oz container of salt

1 spoon

1 plastic container with divider in middle and holes punched at bottom & top with plugs inserted

1 oval plate

#### Your Notes:

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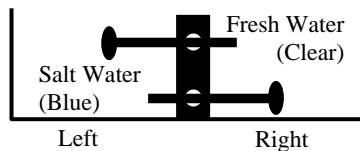
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1. Tell students to add 3 full spoons of salt to the water in **ONLY ONE** of the cups (labeled salt water).
2. A VSVS member will add 15 drops (or one squirt) of blue food coloring to the **SAME** cup until the solution is **dark blue**.

3. Make sure the students understand the differences between the 2 waters.

*The salt water (blue) is denser than the “fresh” water (clear).*

4. Draw a sketch of the container with the divider on the board. Tell students they will be adding the salt water to the **LEFT** side and fresh water to the right side **BUT NOT YET!** (point out that the sides of the container are labeled & make sure they have it turned the correct way)



5. Ask the students to predict what will happen when the 2 waters are added and plugs are removed.  
Accept all answers and write them on the board. Students may not have the correct answer at this time! **Do not correct them.**
6. Have one student per group be responsible for the salt water and another responsible for the fresh water. Tell these students to pour their water solutions into the correct sides **AT THE SAME TIME**

7. Tell the students that they are going to be removing the plugs and that they **ALL** need to be ready to observe the water from the sides of the container once the plugs have been removed.



- Have one student be in charge of the top plug on the salt water side and another student in charge of the bottom plug on the fresh water side. Tell them they will remove both plugs on the count of 3. **Count to 3 loudly, so everyone can hear.**
8. Have one VSVS member go to each group to sprinkle pepper on the top of the water on **BOTH** sides. Once this is done, the students should also observe the water from the top. The other VSVS members should be circulating the room helping students.
  9. Students should make their observations of the sides and top of the container over ~5 minutes and record their observations on their observation sheet.
  10. Ask students what happens to the salt water.  
*It moves through the bottom hole underneath the clear fresh water.*
  11. Ask the students what happens to the fresh water.  
*It moves through the upper hole and layers on top of the blue salt water.*

**Your Notes:**

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12. Ask the students what they noticed when the pepper was added.

*The pepper/water on the right (originally just clear water) seemed not to move much, but the pepper/water on the left side (originally blue salt water) is moving away from the hole and is circling around that side.*

**Explain to the students they have just created currents, similar to those in the ocean. The blue salt water is more dense than the fresh water, so it acts like the colder, saltier water of the ocean while the fresh water acts like the warmer less salty water of the ocean. Deep ocean currents are formed when denser water sinks/flows beneath less dense water, which in turn flows on top of the denser water, as they observed in their experiment.** You can also mention that when the pepper water hits the side of the container and circles around the left side, the effect is similar to that of water hitting large landmass – one of the causes of surface currents.

Set aside the model – the students will be referring back to it as they look at the map of ocean currents. They will observe the model again before the end of class to see that there are 2 distinct layers that do not seem to be mixing.

### 3B. Movement of Cold Water in the Ocean

Materials

20 2oz jars with holes in lids

Ice

Water

Food Coloring

Plates

Plastic squares

Set-up:

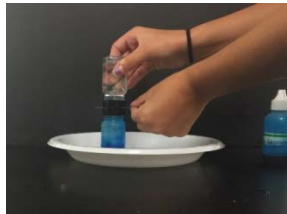
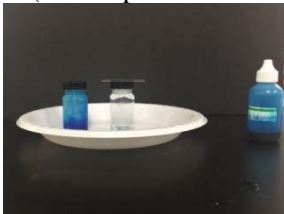
VSVSers will have already put 2 drops of blue food coloring in 10 of the jars packed with ice.

Now pour room temperature water into all containers so they are FULL.

Tell students that the blue water tells them that the water is COLD.

### **Students must do the following in this order:**

1. Take one bottle of cold and one of room temperature. Place the plastic square on top of the ROOM TEMPERATURE bottle. Hold the square securely to keep water from pouring out, turn it upside down and place on top of a bottle of blue cold water. Once in place, have one member of the group (or VSVSer) hold the 2 bottles securely and slide the plastic square out. Observe what happens. *Not much! There may be some initial movement of water due to the disturbance created when the plastic is removed.*
2. Separate the 2 bottles (a little water will spill, so keep on the plate. “Top” up the bottles with water if needed. (It is important to have both bottles full to the top.)



**Your Notes:**

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3. Place the plastic square on top of the COLD bottle, turn it upside down and place on top of the room temperature water bottle. Once in place, have one member of the group (or VSVSer if needed) hold the bottles securely and slide the plastic square out. Observe what happens. *The cold water will flow, and continue to flow, into the bottom warmer bottle.*

**Explanation:** Cold water is denser than warm water and so will sink to the bottom.

Warm water will rise up through cold water. Cold water will sink below warmer water.

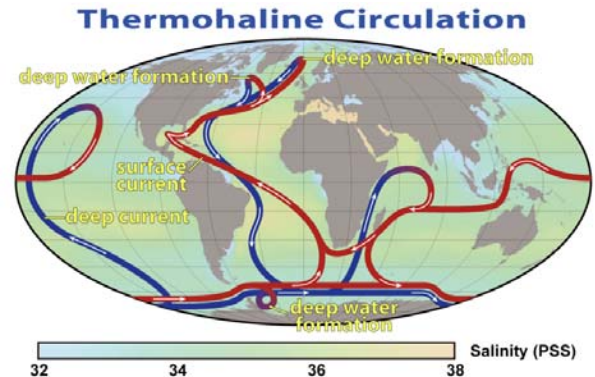
#### 4. Where Are The Deep Ocean Currents?

Tell students to look at the map of ocean currents (pass this out if you haven't already).

Have the students notice where **deep water formation** occurs (*3 areas in the Arctic & Antarctic*).

##### Background Information:

- The biggest source of deep water is highly saline surface water from the Gulf Stream in the North Atlantic. This water is cooled by the polar air and sinks to the bottom. It flows south to Antarctica.
- The densest water is in the Weddell Sea of



- Robert Simmon, NASA
- [http://earthobservatory.nasa.gov/Features/Paleoclimatology\\_Evidence/paleoclimatology\\_evidence\\_2.php](http://earthobservatory.nasa.gov/Features/Paleoclimatology_Evidence/paleoclimatology_evidence_2.php)

Antarctica. It forms in the southern winter when sea ice forms, leaving more salt in the water below the ice. This water sinks to the bottom of the ocean and flows north.

- The average temp of **surface** sea water is 17.5 °C (63.5 °F).  
75% of **all** ocean water has a temperature of between 0 °C (32 °F) and 5 °C (41 °F). So most of the water that fills the oceans is much colder than surface water.
- When ocean water freezes into icebergs and ice sheets, the ice is made of pure water with no salt. That salt is left in the water, so the ocean becomes saltier and denser. (This can be related to the marble demonstration - if all of the salt remained but a few marbles were removed (became ice), there would be more salt per marble).
- Have them trace the paths of the current with their fingers, following the arrows. Start at the northern-most point.
  - Tell students that the entire trip for the current to return to its starting point can take over 1000 years
- Have students look at where the water appears to warm up (blue changes to red).
  - *This happens in warm areas of the world, near Hawaii and off the coast of Africa.*
  - When the blue line turns red, the water has become less dense by warming up and/or becoming less salty, and hence rises above the denser water.

Have students look once more at their water experiment to notice the layering effect of the salt water and fresh water. Explain to them that these layers will remain separated for several hours

#### Your Notes:

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## 5. Experiment: Convection Currents in Gases.

Materials needed for each VSVS member:

- 1 Chimney apparatus
- 1 Styrofoam cup containing dry ice
- 1 Thermometer strip
- 1 small bottle of water (add water to the dry ice to create fog)
- 1 diagram of chimney apparatus

### Instructions to VSVS members:

1. VSVS members will take a chimney apparatus to each group and demonstrate the experiment. Students should write the temperature changes and air flow patterns on the diagram as the experiments are conducted.
2. Show students the dry ice and water and tell them that it is extremely cold and that they must not touch it with their hands. Hold the cup about 2-3 feet above the desk and tilt it sideways so that the group can see dry ice “fog” flowing out of the cup. This is just to see the direction the fog will naturally flow.
3. Explain that the “fog” is a very cold mixture of carbon dioxide gas, water vapor and air. The white color is from the condensed water vapor. (Carbon dioxide gas is colorless.)
4. The “fog” flows down towards the ground because it is colder and denser than the warm air surrounding it. Set the dry ice aside while steps 5-11 are completed.
5. Place metal box on level surface. Keep away from combustibles. Place the chimney in the center of the groups table.
6. Insert chimneys. **DO NOT LIGHT THE CANDLES UNTIL STEP 8.**
7. Use the thermometer strip to take the temperature of the air **2 inches** above each chimney. Read the thermometer by looking for the numbered region that is dark blue in color. Record these temperatures on the observation sheets. (The temperatures may not be the same for each measurement. Tell the students that these thermometers are not very accurate but can be used to record changes in temperatures.)
8. Light the candle and place it in metal box directly under the left-hand chimney.
9. Slide glass window in place to close box.
10. Hold the thermometer strip 2 inches above both the chimneys and record the temperature changes on the observation sheet. Remove the temperature strip as soon as it reaches the maximum temperature.

### Discuss results:

The temperature above the chimney above the candle increased dramatically. Why?

The temperature above the chimney without the candle did not change. Why?

## 6. Colliding Warm Air and Cold Air Masses.

1. Ask students what they think will happen when cold air meets warm air?
2. Hold the dry ice cup about 6 inches above the **left-hand chimney** (above the candle which is still going) and tilt the cup so that the fog can be seen flowing out. Ask what is the direction of the flow of the fog?
3. Move the cup lower to 2 inches above the chimney and ask them to observe what happens now. What happens to the cold air from the cup and the warm air from the chimney?  
*The rising warm air moves the cold air to the side.*
4. Ask students what they think will happen when cold air is introduced to the right-hand (RH) chimney, away from the rising hot air?

### Your Notes:

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*Cold air is denser than warm air and will sink to the bottom of the RH chimney.*

5. What will happen after the cold air reaches the bottom of the chimney? How will it move around in the box?
6. The VSVS members should “pour” cold “fog” out of their cup into the RH chimney.
  - a. Ask the students what do they observe. What path does the fog take?  
*The fog flows straight down the right hand chimney.*
  - b. What happens to the candle flame? Why?  
*It flickers, gets a little dimmer, and may go out.  
The denser cold fog sinks to the bottom of the RH chimney. The warm above the candle is rising and the cold air flows to replace it. The fog contains carbon dioxide which does not support combustion (burning).*

## 7. Review

- Ask students why saltwater is more dense than freshwater? *Saltwater has a higher mass but the same volume of freshwater.*
- Ask students: What can we say about cold air versus warm air?  
*Cold air sinks. Warm air rises.*

References: Educational Innovations Polydensity Bottle

Lesson written by: Patricia Tellinghuisen, Director of VSVS, Vanderbilt University  
Christina Luckabaugh, VSVS Lab Assistant, Undergraduate, Vanderbilt University

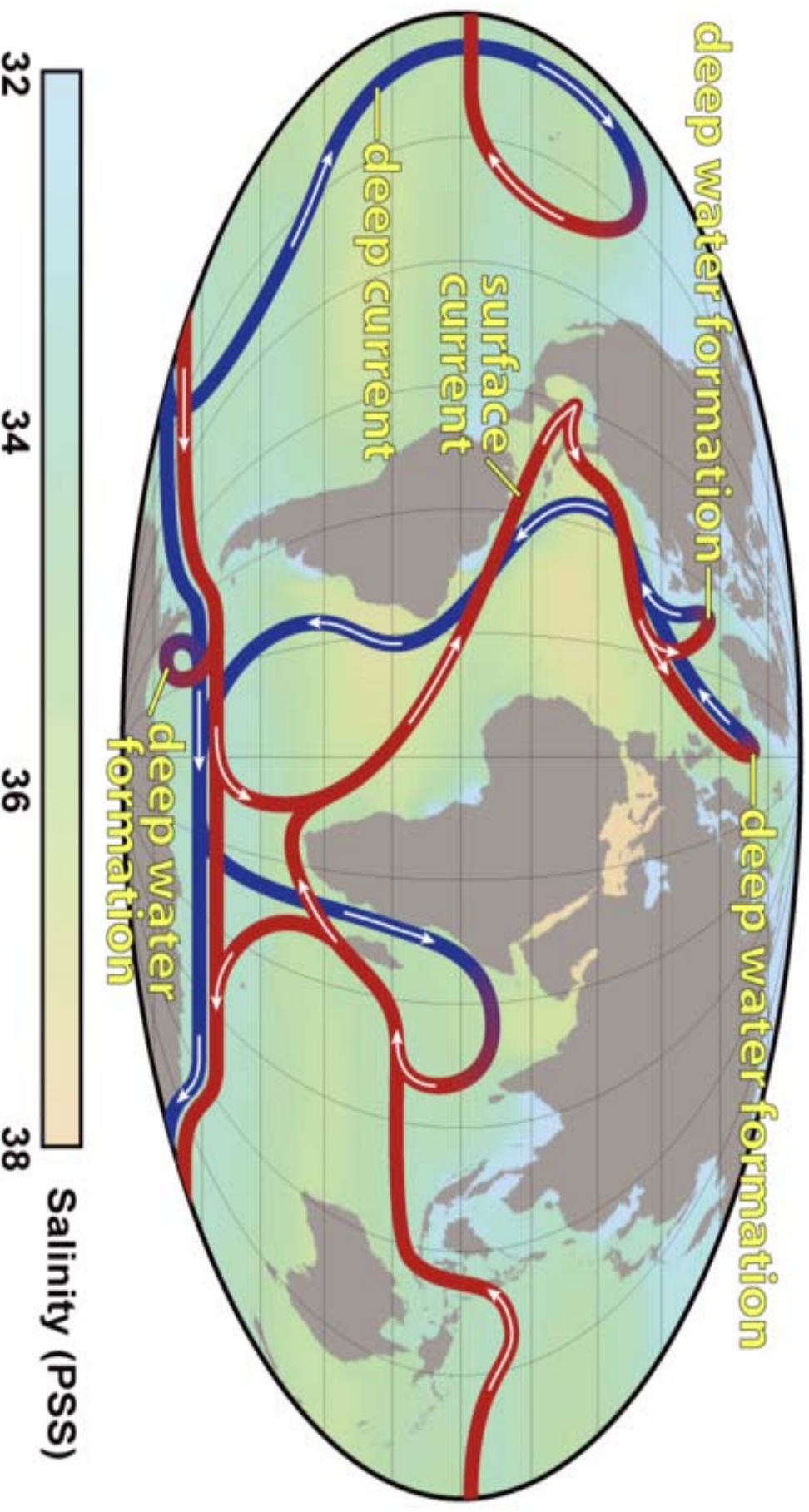
**Your Notes:**

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# Thermohaline Circulation



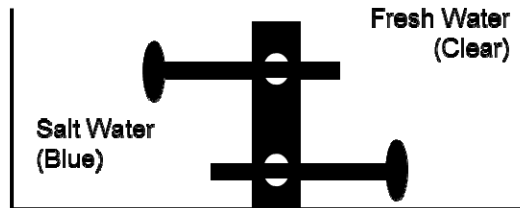
# Deep Ocean Currents – Instruction Sheets

## Demonstration

1. Observe the salt & marble demonstration.
2. Observe the Polydensity bottle demonstration.

## Making Currents Activities

1. Fill the cups with tap water to the 250 mL mark
2. Add 3 full spoons of salt to ONE of the cups of water.
3. A VSVS member will come around and add blue food coloring to that cup.
4. Predict what will happen when the two waters are added to the container.
5. At the same time (when told to do so), one person will add the blue salt water to one side and another will add the clear fresh water to the other side (as shown by this diagram).

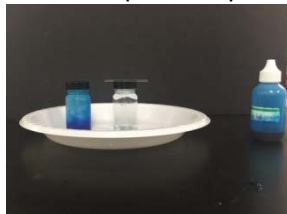


6. Be ready to make observation.
7. When the VSVS member counts to three, remove both plugs at the same time.
8. A VSVS member will come around and sprinkle black pepper on the water on both sides.
9. Observe the flow of water from the side and from the top of the container.
10. Record your observations on your observation sheet by drawing arrows on the diagram as directed and answering the three questions under it.

## Movement of Cold Water in the Ocean

### You must do the following in this order.

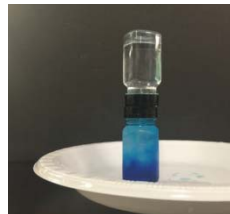
4. Take one bottle of blue ice water and one at room temperature (clear).
5. Place the plastic square on top of the **ROOM TEMPERATURE** bottle.
6. Hold the square securely to keep water from pouring out, turn it upside down and place on top of the bottle of blue cold water.
7. Once in place, have one member of the group (or a VSVSer) hold the 2 bottles securely and slide the plastic square out.



Step 2.



Step 3.



Steps 4 and 5



Steps 7, 8 and 9

8. Observe what happens.
9. Separate the 2 bottles and make sure both bottles are filled to the top with water (some may have leaked out – top up with water)
10. Place the plastic square on top of the **COLD** bottle, turn it upside down and place on top of the room temperature water bottle.

11. Once in place, have one member of the group (or a VSVSer) hold the bottles securely and slide the plastic square out.
12. Observe what happens

### **Analyzing the Map of Deep Ocean Currents**

1. Look at the map of ocean currents and answer the last three questions on your observation sheet. Use the information you learned in the previous examples and exercise to answer the next two questions.

### **Convection Currents in Gases Activity**

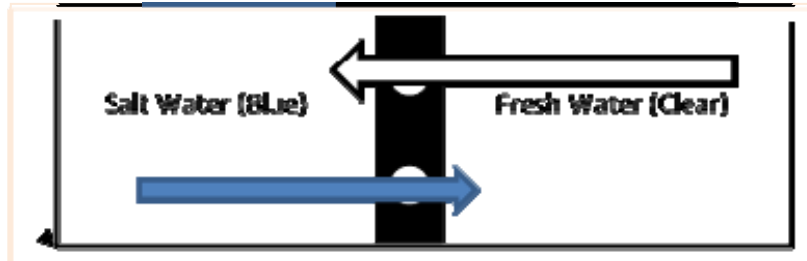
1. A VSVS member will come to each group to show the natural flow of cold fog.
2. When instructed to do so, record the initial temperature of the air **2 inches** above each chimney. Read the thermometer by looking for the numbered region that is dark blue in color. Record these temperatures on your observation sheet.
3. Once the candle is lit, record the temperature of the air **2 inches** above each chimney. **Remove the temperature strip as soon as it reaches its maximum temperature.** Record the temperatures on your observation sheet.
4. Observe the cold-fog demonstration.
5. Record your observations on your observation sheet by drawing arrows on the diagram to indicate the movement of hot and cold air.

# Deep Ocean Currents Answer Sheet

Name \_\_\_\_\_

2. Draw arrows on the diagram below showing the movement of the blue salt water and the clear fresh water.

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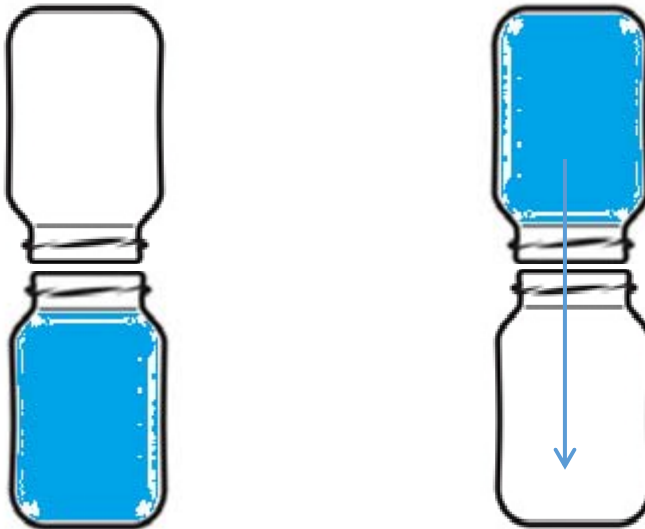


What happens to the salt water? *Moves through the bottom hole and stays below the fresh water*

What happens to the fresh water? *Moves through the top hole and stays above the salt water*

What happens to the pepper? *The pepper/water on the right (originally just clear water) does not move much, but the pepper/water on the left side (originally blue salt water) moves away from the hole and is circling around on that side.*

- 3B. Draw arrows on the diagram to show the movement of blue cold water and the clear room temperature water.



Look at the map of ocean currents to answer the following questions.

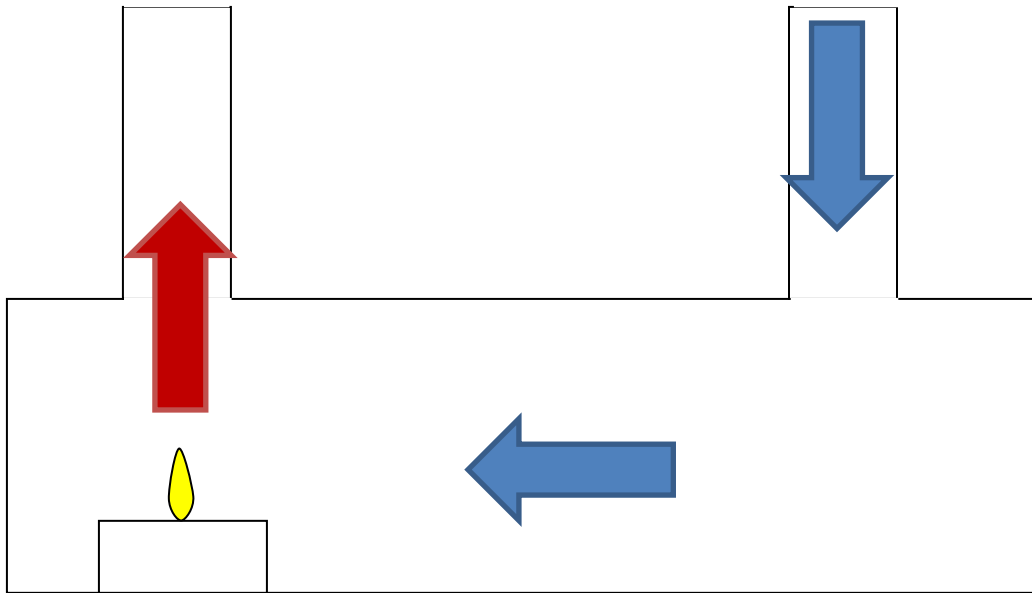
In what parts of the Earth does deep water formation occur? *3 areas in the Arctic & Antarctic*

Why does deep water formation occur in these regions? *Cold temperatures and salty water*

### Convection Currents in Gases

	<u>Above LEFT Chimney</u>	<u>Above RIGHT Chimney</u>
Initial Temperature		
Temperature After Candle is Lit		

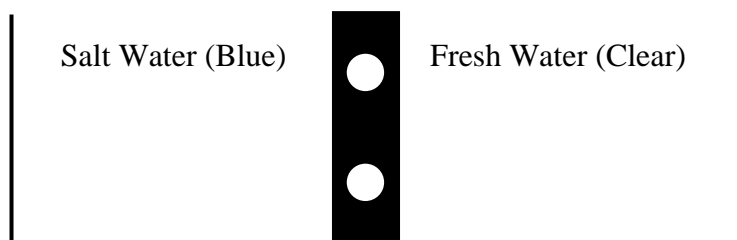
Draw arrows on the diagram below showing the movement of hot and cold air.



# Deep Ocean Currents Observation Sheet

Name \_\_\_\_\_

3. Draw arrows on the diagram below showing the movement of the blue salt water and the clear fresh water.



What happens to the salt water? \_\_\_\_\_

What happens to the fresh water? \_\_\_\_\_

What happens to the pepper? \_\_\_\_\_

- 3B. Draw arrows on the diagram to show the movement of blue cold water and the clear room temperature water.



4. Look at the map of ocean currents to answer the following questions.

In what parts of the Earth does deep water formation occur? \_\_\_\_\_

Why does deep water formation occur in these regions? \_\_\_\_\_

5. Convection Currents in Gases



	<u>Above LEFT Chimney</u>	<u>Above RIGHT Chimney</u>
<b>Initial Temperature</b>		
<b>Temperature After Candle is Lit</b>		

**Draw arrows on the diagram below showing the movement of hot and cold air.**

