TEMPERATURE CURRENTS

FOR THE TEACHER

Discipline
Earth and Physical Science

Theme
Energy

Key Concept
The force of the wind sets up the surface currents on the ocean. The deep oceans are set in motion by the interplay of salinity and temperature thus creating waters of different densities.

Synopsis
Students create currents with wind and by combining water of different temperatures and salinities. The relationship between temperature, salinity and density is examined.

Science Process Skills
observing, communicating, comparing, organizing, relating (identifying relationships, recognizing hypotheses, experimentation), interpreting

Social Skill
Checking for Understanding

Vocabulary
countercurrent, density, eddy, equator, gyres, photic zone, salinity, thermocline, upwelling

MATERIALS
Salt Solutions
Salt sold as table salt is often cloudy when dissolved in water so you might want to use kosher or canning salt. Ocean water is 35ppt (parts per thousand) salt and can be simulated by weighing 35 gm of salt, putting it in a 1 liter container and filling it with water to the 1 liter mark. You could also do this by

putting 2 scant tablespoons of salt in 1 quart of water or for one gallon of 35 ppt use 7 level tablespoons of salt. For 70 ppt, just double the salt.

"Ocean Current Worksheet" (see attached), one per student

Station 1: Current Bottles

- two identical bottles (use 250 ml Erlenmeyer flasks, 8 oz carbonated water bottles or baby food jars).
- 3x5 cards, two cut in half for each group
- salt, two Tablespoons for each group
- food coloring, blue and red for each group
- pie plate or dishpans in case of water spillage
- room temperature water
- colored pens or crayons

Station 2: Current Bottles

- two identical bottles (use 250 ml Erlenmeyer flasks, 8 oz carbonated water bottles or baby food jars).
- 3x5 cards, two cut in half for each group
- food coloring, blue and red for each group
- pie plate or dishpans in case of water spillage
- hot tap water for each group (enough to fill two bottles)
- very cold, icy or refrigerated water for each group (enough to fill two bottles)
- colored pens or crayons

Station 3: Ice Cubes (for each group)

- two quart jars (wide mouth mayonnaise work well)
- water (enough to fill jars)
- food coloring (two colors)
- 1/4 cup salt
- 6-8 ice cubes
- colored pens or crayons

Station 4: Arctic vs Tropical Water

- two paper cups per group
- two straight pins
- large clear container, such as plastic shoebox
- hot tap water, colored red for each group (enough to fill the paper cup)
- very cold, icy or refrigerated water, colored blue for each group (enough to fill the paper cup)
- room temperature water (enough to fill the large container)
- weights to hold cups upright in large container (use quarters, marbles or equivalent)

- colored pens or crayons

Station 5: Wind Driven Currents

- large round pan (drain pan for changing car oil works well)
- water to fill pan about half to 2/3rds full
- two hair dryers
- food coloring
- confetti
- large rock to act as island
- colored pens or crayons

Putting Students Knowledge to Work: The Unknown
For each student
large paper cup or sample jar of about one pint
two small clear plastic cups
plastic spoon

For each group or class to share:
measuring cups or graduated cylinders
scales or balances
food coloring
water samples of three different salinities: fresh water; slightly salty at 1/4 cup per quart and very salty at 1/2 cup per quart

INTRODUCTION
Currents are formed in the open ocean in two main ways: one, wind and the spinning Earth; and two, the interplay of salinity and temperature. Wind-driven ocean surface water and the spinning of the Earth create the great ocean gyres where the major currents rotate clockwise in the Northern Hemisphere and counterclockwise in the Southern Hemisphere. The interplay of salinity and temperature, the other major current maker, sets the deep oceans in motion vertically—from the surface to the depths. These deep up and down currents are formed by waters of different densities. Cold water is denser than warm and as a result, it tends to sink. The amount of dissolved substances, such as salt in the water also affects how fast and how deep the water sinks.

Temperature is one of the most important physical factors in the marine environment. It limits the distribution of ocean life by affecting the density, salinity, and even the concentration of dissolved oxygen in the oceans. Temperature also influences the metabolic rates and the reproductive cycles of marine organisms. The surface of the ocean is heated by the sun, but the depths remain cool—resulting in temperature layers with warmer surface waters floating on denser, colder, bottom water.

The area where cold and warm water meet is called the thermocline. It is the region at which the temperature changes rapidly. The thermocline is an important barrier to mixing because the warm surface water cannot displace the dense, colder, deep water. This layering means that one body of water has two totally different kinds of places for animals to live in terms of temperature. It may cause an unequal distribution of oxygen and essential minerals for plant growth, such as phosphates and nitrates. Oxygen diffuses in at the surface or comes from plants at the surface. Minerals, however, are released near the bottom as bacteria decompose dead plants and animals.

For much of the ocean, the sunlit photic zone is isolated from the nutrients of the deeper waters because of the difference in density. But in certain places, especially on west coasts, the phenomenon of upwelling changes all of this. Coastal upwelling replenishes nutrients when they otherwise would be depleted. Upwelling occurs off the California coast in spring and early summer as the prevailing northwest winds, in combination with the spinning earth, move surface water offshore, to be replaced by cold, nutrient-rich water from below. Wind and tides keep the water well mixed so that nutrients don't become lost in deep water. It is in these rich areas that kelp forests thrive.

The salinity of ocean water overall is on average 3.5% and has an average density of 1.025 g/ml. The densest water in the ocean is found on the bottom; but the physical processes that create this dense water (evaporation, freezing, or cooling) happen at the surface. Therefore, dense bottom water must have sunk from the surface. This sinking of surface water is the only way water circulates to the ocean depths.

Wind-driven currents have been a major force throughout history and have affected living things in many ways. The surface currents may hinder or help plants and animals to move around and even determine where they may live. Wind-driven currents have determined the course of ships and thus affected the migration and settling of people around the globe. Currents may affect the climate of the nearby land by moderating temperature extremes. Deep-ocean currents are also very important, especially when they upwell to the surface bringing with them the nutrients they have carried across ocean basins. For example, such an upwelling occurs off the Grand Banks in Nova Scotia as water, which sunk in Antarctica around the time of the Crusades, rises to the surface and supports a rich fishing ground.

INTO THE ACTIVITIES

Partner Parade

1. When and where was the last time you went swimming?
2. Have you ever been swimming in the ocean, lake or pool and noticed that the water felt warmer on the surface and colder below?
3. What do you suppose would cause this difference in temperature and why doesn't the deeper water warm up?
4. It has been said that you can read a newspaper without getting it wet while floating on your back in the Great Salt Lake. What might cause that to happen?
5. What do you think sets water in motion and causes currents to form?
6. Why are currents important to study? Who might use this information?

Have students sit with their last Tea Party partner and sketch a picture reflective of one of the questions and answers. Have students share their pictures with the class.

Read Aloud

Read about early sea explorers' journeys such as the Phoenicians, Columbus, and Magellan. Other possibilities include Two Years Before the Mast by Richard Henry Dana, Kon-Tiki by Thor Heyerdahl or the description of the Gulf Stream by Ben Franklin. Other good sources include The Old Man and the Sea by Ernest Hemingway or the Log From the Sea Of Cortez by John Steinbeck. Try to follow their routes along the ocean currents on a world map to learn how sailing people have made use of the currents in the ocean.

Overview of Currents

Examine a map of the Pacific Ocean and show how the wind drives currents in a clockwise fashion in the northern hemisphere. Show where the equatorial current deflects off Japan to the north. Point out the California Current and review how the water movement changes with the increase in wind in the spring and the resultant upwelling.

Anticipatory Chart

1. Have students sit with a partner and create a chart with two columns; one column labeled "What We Already Know About Currents" and the second labeled "What We Want to Find Out About Currents."
2. Lead a class discussion and record the group's ideas on a class chart. Refer back to the chart throughout the activity.

Portfolio Assessment

Tea Party Sketches
Anticipatory Chart
Observation of Checking for Understanding

THROUGH THE ACTIVITIES

1. Arrange materials into stations.

2. Have students work together in cooperative groups of five or six. Each student in the cooperative group can be given a role as follows: runner to get water and pour into appropriate container for experiment; reader of directions; recorder and/or illustrator of predictions and results; vote counter for consensus/agreement for questions, predictions and results; measurer of materials; performer of experiment.

3. Pass out the OCEAN CURRENTS Worksheet. Tell students that their group will rotate through each of the five stations. They will take their worksheet with them to each station. At each station they will find directions for their exploration. They will make predictions and collect as much information as possible in order to understand how currents are formed. They will also make hypotheses about the relationship between salinity, temperature and density and then design their own experiments.

4. Be sure to stress having the students make predictions for each part of this experiment. Have the students actually write down their predictions and tell them to include their reasons. As long as the reasons are "thoughtful", it doesn't really matter if they were "right or wrong". Making predictions requires making a commitment to anticipated results. Students having made a commitment are more observant, wondering and likely to explore.

5. Briefly demonstrate or describe the experimental set-up for the students for each station before they start the rotation as follows:

Current Bottles: Stations 1 and 2

a. Fill two bottles to the very top with water
b. Add food coloring to one of the bottles and mix thoroughly.
c. Place the 3x5 card over the mouth of one of the bottles. Turn the bottle over; the card will stay in place without holding it even with the bottle upside down.
d. Put the two bottles together with the card between. Do this over a container to catch any accidental spillage.
e. Pull out the card allowing the two liquids to come in contact with each other.

Ice Cubes: Station 3

Provide each group with a safe place to set up and leave their jar where it will not be disturbed by other groups working. Remind them to check on the progress of the ice melt periodically as they perform the other experiments and to add the food coloring after the ice has had a chance to melt some.

After completing all the stations, discuss the results of the Ice Cube Demonstration. Poll the class as to which jar the ice cubes actually did melt faster and possible explanations based on their results from all of the other stations. *(See below for the explanation.)*

ICE CUBES - Results and Explanations:
In the fresh water container, at first as the ice cubes are still melting, a current can be seen flowing towards the bottom as the icy water carries the food coloring down with it as it sinks. As the temperature equilibrates, the food coloring diffuses throughout the container.

In the salt water container, the food coloring remains trapped in the fresh water floating on top of the salt water. At first the density differences between the two layers is caused by a combination of both a thermocline and a salinity barrier which traps the food coloring in the surface fresh water layer. Even after the temperature equilibrates, the food coloring remains in the surface layer trapped by the differences in density between the fresh and salt water.

Ice cubes melt faster in fresh water for the following reasons:
a. Mixing of the fresh water and the water from the melting ice cubes is helped because the icy water is denser than the room temperature water and sinks rapidly to the bottom.
b. As the temperature equilizes, the thermocline disappears and there is no longer any barrier to mixing.
c. The ice cubes melt very slowly in the salt water because the salt water is more dense than the fresh water melting off of the ice cubes and so the ice cubes remain surrounded by the icy fresh water. Conclusion: very cold fresh water is less dense than very salty water.

Arctic vs Tropical: Station 4
Be sure that the students predict the outcome and make a drawing before performing the experiment. They should also draw the results after actually performing the experiment. Show the students how the set up should look and model the experiment for them. (See Student Directions for Station 4 for a diagram).
Results and Explanations: Three stratified layers will form in the large container based on the three different temperatures of the water masses. Cold blue colored water will form on the bottom, red hot water will form the surface layer and clear room temperature water form the middle layer. The layers remain until the temperature equilibrates. Conclusions: cold water is more dense than hot water. As the cold water reaches the opposite side of the container, it can be seen to rise to the surface along the edge. This phenomenon simulates cold deep water in the ocean upwelling to the surface as it reaches islands or continent edges.

Wind Driven Currents: Station 5

Be sure students are aware of the danger of using hair dryers around water. See the diagram for the experimental setup in the Student Directions of Station 5. This concept of wind driven currents can also be demonstrated for the students by using a drinking straw and food coloring and blowing across a glass pie plate placed on top of an overhead projector.

6. After each group has been to all stations, provide time for group members to compare their results and complete their worksheets. Some groups may want to repeat an experiment if their initial observations were not detailed enough to answer the questions on the worksheet.

Portfolio Assessment
Observation of Checking for Understanding
Observation of ability to conduct stations correctly
Completion of OCEAN CURRENT WORKSHEET

BEYOND THE ACTIVITIES

Putting Students Knowledge to Work: The Unknown
Do this activity after each group has had an opportunity to complete the stations and worksheets. This activity gives them the opportunity to put their newfound knowledge to work.
1. Give each member of a group a large paper cup or pint jar of unknown salinity water. Make one of the cups very salty (1/2 cup of salt per quart), one fresh.and the rest slightly salty (1/4 cup per quart). Put a number on each cup and keep a record of the salinity of each so that you will be able to tell them if they were correct. Vary the numbering of each group's cups.
2. Tell the students that they will be given a sample of water of unknown salinity and they need to determine which numbered cup has the very salty water, which has the fresh and which ones are only slightly salty.
3. Students can use any of the methods.practiced in the station experiments to determine the relative salinity or density. If you have a scale or balance available they could actually weigh their solutions to determine which one was heavier (denser). Remind them of the equipment available for their investigation. There is one thing that they cannot do. **Do not taste the solutions.** There are many kinds of salts that may be toxic and they should never taste an unknown solution.
4. Have the students detail their plan before carrying out their experiments and state their conclusions on the Ocean Current Worksheet.

Debriefing
Have students debrief their favorite/least favorite part of the activity. What did they learn the most from? What was a waste of time? How would they change the activity if they were the teacher?

Student Directions For Each Station

Station 1. Salinity Currents
In this experiment you will fill two bottles with a different salinity of water. After preparing the bottles, be sure to predict what will happen to the colored water before actually doing the experiment. Make your predictions by coloring the illustration on your Ocean CURRENT Worksheet.

1. Fill both bottles with room temperature tap water. Add approximately 1 Tbls. of salt and 8 drops of food coloring to the same bottle and shake well. The other bottle should just have the clear tap water. Make sure both bottles are completely filled to the top.

2. Place the 3x5 card over the mouth of the colored bottle and turn the bottle upside down. Do this over a dish in case of spillage. Be sure to hold the card in place as you turn the bottle over and then gently remove your hand from the card. The upward air pressure will hold the card in place. Center the upside down bottle directly over the mouth of the upright bottle with the clear water. Place the bottles in the pan on the table to catch spills and slowly slide the card from between the bottles. Show by coloring the illustrations on the OCEAN CURRENT WORKSHEET what actually happened to the colored water, and where it ended up.

3. Empty and rinse the bottles and do the experiment again, but this time turn the clear bottle upside down. Again record your predictions and then what actually happened.

Station 2: Temperature Currents
In this experiment you will fill two bottles with different temperatures of water. After preparing the bottles, be sure to predict what will happen to the colored water before actually doing the experiment. Make your predictions by coloring the illustration on your Ocean CURRENT Worksheet.

1. Fill one bottle with icy cold fresh water, add 8 drops of blue food coloring and shake well. Fill the second bottle with hot tap water. Make sure both bottles are completely filled to the top.

2. Place the 3x5 card over the mouth of the colored bottle and turn the bottle upside down. Be sure to hold the card in place as you turn the bottle over and then gently remove your hand from the card. The upward air pressure will

hold the card in place. Do this over a dish in case of spilling. Center the upside down bottle directly over the mouth of the upright bottle with the clear hot water. Place the bottles in the pan on the table to catch spills and slowly slide the card from between the bottles. Show by coloring the illustrations on the OCEAN CURRENT WORKSHEET what actually happened to the colored water and where it ended up.

3. Empty the bottles and do the experiment again, but this time turn the clear hot water bottle upside down. Again record your predictions and then what actually happened.

STATION 3: ICE CUBES
Will ice cubes melt faster in fresh or salt water?

1. Fill two quart jars with tap water. Be sure to allow space at the top for 3-4 ice cubes to be added without overflowing. Add approximately 1/4 cup of salt to one of the jars and mix thoroughly. Add 3-4 ice cubes to each jar and leave them undisturbed while the rest of the experiments are in progress.

2. Make a prediction as to which jar the ice cubes will melt the fastest. Write down your groups prediction and a possible explanation on your OCEAN CURRENT worksheet. It is OK if everyone doesn't agree, just note each prediction and a possible explanation.

3. Midway through the station rotations or after the ice cubes have had an opportunity to melt some, carefully add 3-4 drops of food coloring to each of the jars and watch what happens. Diagram the results on your OCEAN CURRENT worksheet. This part of the exploration may help to explain the results of the ice cube experiment. Can you now explain the results? Describe your possible explanation on your OCEAN CURRENT worksheet.

STATION 4: Arctic vs Tropical Water
1. Using the diagram below, predict the direction of water flow and the color pattern which will develop as the cold and hot water meet. Draw the predicted color pattern on your OCEAN CURRENT WORKSHEET using arrows and symbols (or colors) for each of the currents and layers which develop.

2. Obtain two paper cups and a clear plastic container. Place weights in the cups to keep them upright when placed in the large container. Fill the large container with tap water. Pour icy, cold blue colored water in one of the cups and hot tap water in the other.

3. Obtain two straight pins and stick one pin in each cup so they are just below the surface of the water in the large container. Leave the pins in the cups! Your setup should look something like this.

4. Carefully pull out the pin in each cup. Quickly record or draw the actual direction of water flow and the color pattern which develops on your OCEAN CURRENT WORKSHEET. Where did each of the differently colored waters end up? How long could you see this pattern? Why did the pattern finally disappear? What happened when the blue layer reached the opposite side of the container? Write or diagram your answers to these questions where you see them on the worksheet for Station 4.

STATION 5: WIND DRIVEN CURRENTS

1. Fill the pan about half to 2/3rds full of water. Use the hair dryer on the lowest setting to blow lightly over the surface of the water. Watch the surface of the water carefully and write down on your OCEAN CURRENT WORKSHEET any observations you can make.

2. Now use a higher setting on the hair dryer.and again write down any observations or comparisons on your worksheet. Answer the following questions where you see them for Station 5 on your worksheet:
a. What effect did blowing harder have on the surface of the water?
b. How did the water move in relation to the wind direction from the hair dryer?

3. Again use the hair dryer to create a current, but this time one person in your group will drop a few drops of food coloring and some confetti in the direction of the current. Then quickly a third person can draw on the OCEAN CURRENT WORKSHEET the direction in which the color travels, using arrows to illustrate the pattern.

4. <u>Equatorial Current with Continents</u>
In this experiment, pretend one side of the pan is North and South America and the opposite side of the pan is Japan, China, and Southeast Asia. Create an equatorial wind by directing one hair dryer to blow across the center of the pan. To form <u>countercurrents</u>, (adjacent currents moving in opposite directions), direct the second dryer from the opposite side of the pan and have the dryers blowing just past each other (see the diagram). Add confetti and food coloring to follow the path of the currents. Describe on your worksheet what happens when these currents hit the other side of the pan (continent).

5. <u>Eddies and Countercurrents with Islands</u>
Place an island (rock) sticking up in the path of the current. Before you begin, predict how the island will affect the current. Draw your predictions and then

try the experiment with the hair dryer. Answer the following questions where you see them for Station 5 on your worksheet:

a. Did the current slow down or change directions when it hit the island?

b. Did an eddy or countercurrent form?

c. Did the results agree or disagree with your prediction.

OCEAN CURRENTS WORKSHEET

STATION 1: SALINITY CURRENTS
Part 1. Colored salty water on top.
Predictions
1. Predict the final color on top and bottom for your exploration when the colored salty water started out on the top. Draw diagonal lines (////) or use colored pencils to show where the color will be after the card separating the different waters is removed.

2. What makes you think that this will happen?

Actual results

3. Now show what actually happened when you removed the card separating the waters. Draw diagonal lines (////) or use colored pencils to show where the color actually ended up.

4. Did your prediction actually happen?

5. If your prediction was different than what actually happened, what ideas do you have as to why you got these results?

Part 2. Clear, fresh water on top
Predictions
1. Predict the final color on top and bottom for your exploration when the clear, fresh water started out on the top. Draw diagonal lines (////) or use colored pencils to show where the color will be after the card separating the different waters is removed.

2. What makes you think that this will happen?

Actual results

3. Now show what actually happened when you removed the card separating the waters. Draw diagonal lines (////) or use colored pencils to show where the color actually ended up.

4. Did your prediction actually happen?

5. If your prediction was different than what actually happened, what ideas do you have as to why you got these results?

6. How did doing the experiment again with a different kind of water on top help you to understand the results?

7. In one sentence, describe what you learned from this experiment.

STATION 2: TEMPERATURE CURRENTS

Part 1. Colored cold water on top

Predictions

1. Predict the final color on top and bottom for your exploration when the colored cold water started out on the top. Draw diagonal lines (////) or use colored pencils to show where the color will be after the card separating the different waters is removed.

2. What makes you think that this will happen?

Actual results

3. Now show what actually happened when you removed the card separating the waters. Draw diagonal lines (////) or use colored pencils to show where the color actually ended up.

4. Did your prediction actually happen?

5. If your prediction was different than what actually happened, what ideas do you have as to why you got these results?

Part 2. Clear, hot water on top

Predictions

1. Predict the final color on top and bottom for your exploration when the clear, hot water started out on the top. Draw diagonal lines (////) or use colored pencils to show where the color will be after the card separating the different waters is removed.

2. What makes you think that this will happen?

Actual results

3. Now show what actually happened when you removed the card separating the waters. Draw diagonal lines (////) or use colored pencils to show where the color actually ended up.

4. Did your prediction actually happen?

5. If your prediction was different than what actually happened, what ideas do you have as to why you got these results?

6. How did doing the experiment again with a different kind of water on top help you to understand the results?

7. In one sentence, describe what you learned from this experiment.

STATION 3: ICE CUBES

1. Make a prediction as to which jar the ice cubes will melt the fastest, either the fresh water or the salt water. It is OK if everyone doesn't agree, just write down your prediction and a possible explanation.

2. Draw a picture of each of the jars when you start the experiment showing the size of the ice cubes. Check on the progress of your ice cube melt and draw a picture of the size of the ice cubes at least two more times during this period.

SIZE OF ICE CUBES
SALT WATER
START1st check2nd check

FRESH WATER
START1st check2nd check

3. What happened in the jars after the ice cubes melted some, and you added 3-4 drops of food coloring to each of the jars? Diagram what happened to the food coloring. This part of the exploration may help to explain the results of the ice cube experiment.
SALT WATERFRESH WATER

Can you now explain the results? Describe your possible explanation.

STATION 4: Arctic vs. Tropical Water
1. Using the diagram below, **predict** the direction of water flow and the color pattern which will develop as the cold and hot water meet. Draw the predicted color pattern using arrows and symbols (or colors) for each of the currents and layers which develop. Be sure to label the colors and temperatures for each of the layers of water or use a KEY like on the station directions.

2. As you pull out the pin in each cup, quickly record or draw the **actual** direction of water flow and the color pattern which develops.

3. Write or diagram your answers to the following questions:
a. Where did each of the differently colored waters end up?

b. How long could you see this pattern?

c. What happened when the blue layer reached the opposite side of the container?

d. If you were to go swimming after a winter rain when the ocean is calm, what sort of temperature and salinity layering would you expect?

STATION 5: WIND DRIVEN CURRENTS

1. Using the hair dryer on the lowest setting, watch the surface of the water carefully and write down any observations you can make.

2. Using a higher setting on the hair dryer, again write down any observations or comparisons you can make and answer the following questions:
a. What effect did blowing harder have on the surface of the water?

b. How did the water move in relation to the wind direction from the hair dryer?

3. Using the food coloring and confetti, draw the direction in which the color travels, using arrows to illustrate the pattern.

4. Equatorial Current with Continents
In this experiment, pretend that one side of the pan is North and South America and the opposite side of the pan is Japan, China, and Southeast Asia. Describe or diagram what happens when these currents hit the other side of the pan (continent). Also show what the countercurrents look like as they go past each other.

5. Eddies and Countercurrents with Islands
After placing an island (rock) sticking up in the path of the current, predict how the island will affect the current. Draw your predictions below and then try the experiment with the hair dryer. Answer the following questions:
a. Did the current slow down or change directions when it hit the island? Describe what happened.

b. Did an eddy or countercurrent form? What did it look like?

c. Did the results agree or disagree with your prediction.

PUTTING YOUR KNOWLEDGE TO WORK: THE UNKNOWN

For this activity, your teacher will give you a water sample of unknown salinity and you need to determine whether it is fresh water, slightly salty or very salty by comparing it with other samples in your group. You can use any of the methods you tried in the stations. **Remember to never taste unknown solutions.**

a. These are the steps I will take to determine whether I have fresh, slightly salty or very salty water

b. I think my sample is ________________________.

This is the evidence for my conclusion: