The Ocean's Effect on Climate, 2

Strands Matter

Topic Investigating the effects of oceans on climate

Primary SOL 6.5 The student will investigate and understand the unique properties and characteristics of water and its roles in the natural and human-made environment. Key concepts include

- d) the ability of large bodies of water to store thermal energy and moderate climate.

Related SOL 6.1 The student will demonstrate an understanding of scientific reasoning, logic, and the nature of science by planning and conducting investigations in which

- b) precise and approximate measurements are recorded;
- d) hypotheses are stated in ways that identify the independent and dependent variables;
- f) one variable is manipulated over time, using many repeated trials;
- g) data are collected, recorded, analyzed, and reported using metric measurements and tools;
- h) data are analyzed and communicated through graphical representation.

6.3 The student will investigate and understand the role of solar energy in driving most natural processes within the atmosphere, the hydrosphere, and on Earth's surface. Key concepts include

- b) the role of radiation and convection in the distribution of energy.

6.6 The student will investigate and understand the properties of air and the structure and dynamics of Earth's atmosphere. Key concepts include

- e) the relationship of atmospheric measures and weather conditions.

Background Information

Due to its high specific heat, water is able to absorb large amounts of thermal energy without showing a significant change in temperature. Therefore, large bodies of water act to moderate the climate of surrounding land areas by absorbing a large amount of the sun's thermal energy in summer and slowly releasing that thermal energy in the winter. For this reason, the climate of land areas near large bodies of water is generally slightly milder than it would be if there were no large bodies of water nearby.

The difference in heating and cooling rates of water and land also accounts for atmospheric convection currents, which produce landward and seaward wind patterns in coastal areas. During the day, the land and the air above it heat up much faster than any adjacent body of water and the air above it. As the air above the land gains thermal energy, it becomes less dense and begins to rise. By contrast, the water absorbs the incoming thermal energy from the sun more slowly, leaving the air above it cooler and, therefore, denser. As the air over the land rises, the cooler, denser air over the water flows along the surface to take its place over the land, causing a breeze. This explains why sea breezes are directed landward (toward the land) during the day.

At night, the land and the air above it cool much faster than the water and the air above it. As the water slowly radiates the thermal energy it has absorbed during the day, it causes the air above it to become warmer, which causes it to become less dense and to rise. The cooler, denser, air over the land flows along the surface away from the land to displace the rising air over the water, causing a breeze. This explains why sea breezes are directed seaward (toward the sea) at night.

Students must be able to define and distinguish among the terms *thermal energy, temperature,* and *heat*. Thermal energy can be transferred, but heat cannot be transferred because *heat* is the term that describes the transfer of thermal energy from one substance to another due to a difference in temperature. *Heat is a process, not a thing*. The expression "transfer of heat" harkens back to the days when heat was thought to be a thing (caloric) that could flow between objects.

Thermal energy is the energy of a substance, including both its average kinetic energy (temperature) and the number of molecules in the substance (mass). *Temperature* is a measure of the average kinetic energy of the molecules in a substance. Heat is the transfer of kinetic energy from molecules with more kinetic energy to molecules with less kinetic energy.

Materials

- Identical 1-liter containers with lids
- Celsius thermometers or temperature probes
- Water
- Dry soil or sand
- Paper towels
- Lamps
- Heat-producing light bulbs
- Graph paper
- Copies of the attached handouts

Vocabulary

heat, temperature, thermal energy

Student/Teacher Actions (what students and teachers should be doing to facilitate learning)

Before beginning the activity, review with students the components of an experiment and the process of completing an experimental design diagram to formulate a hypothesis and identify the independent and dependent variables and constants.

Introduction

1. Display a map of Virginia showing the cities of Norfolk, Virginia Beach, Lynchburg, and Staunton, and distribute copies of the attached Average Annual Temperatures in Virginia Cities handout.
2. Allow students time to analyze the data and note the general differences between the average winter temperatures in coastal areas and those in inland areas of Virginia.
3. Pose the following questions to check students' background knowledge and to engage them in the learning task:
   - What is the relationship between weather and climate?

- In addition to the difference in elevation, what factors might explain the differences between average winter temperatures in coastal areas and average winter temperatures in inland areas of Virginia?
- How does the heating of land and water produce wind patterns?

Procedure

1. Distribute copies of the attached Experimental Design Diagram, and lead students in reading over the steps for the investigation and identifying the experiment's components.
2. Have pairs of students conduct the experiment, one partner conducting the experiment to collect data on the heating and cooling rate of water, and the other conducting the same experiment on soil or sand.
3. Have the partners pool their data and graph the results. Then, direct each pair to compare their graphs to the graphs of another pair.
4. Instruct each group of four to use their graphs to formulate a conclusion and to infer the effect of large bodies of water, such as oceans or very large lakes, on the climate of neighboring land areas.

Observations and Conclusions

1. Lead students to conclude that from their data that while the temperature of land (soil or sand) increased rapidly while the light was on, it also decreased rapidly after the light was turned off. The temperature of the water was slower to increase, and the water retained the thermal energy much longer.
2. Use these results to discuss convection currents and resulting wind patterns and their effect on coastal climates.

Assessment

- **Questions**
  (Pose the same three questions used in the Introduction above.)
- **Journal/Writing Prompts**
  - Compare and contrast weather and climate.
  - Write a short personal narrative describing the temperature and wind during a 24-hour period spent at the beach and then a 24-hour period of time spent in Staunton, VA.
- **Other**
  (Use the Experimental Design Diagram.)

Extensions and Connections (for all students)

- Have students draw and label a diagram of an area where land and ocean meet, showing the temperature changes due to absorption of thermal energy during the day and radiation of thermal energy at night. Have students indicate the convection currents produced and the direction the wind will flow.
- Extend the concepts in this lab activity to explain the movement of cold fronts (dense air masses) and warm fronts (less dense air masses) or the movement of ocean currents across the Earth. These phenomena can be explained by connecting the heating and cooling of air and water masses and the convection currents that result.
- Have students explain how the tilt of the Earth on its axis and the consequent amount of solar radiation received (SOL 6.8g) affect global patterns of wind, weather, and ocean

currents. Ask them to explain why the climates of the North and South Poles are never warm even though they are covered or surrounded by oceans.

Strategies for Differentiation

- As a warm-up activity, have students complete a practice worksheet, accurately reading and recording temperatures on various thermometers in both Fahrenheit and Celsius.
- Have students color-code temperature regions on a map of Virginia.
- Invite an extension agent to discuss horticultural zones in Virginia and their various average temperatures.
- Have students identify the frost dates for their local area.
- Have students work with partners or assigned groups to complete the activity.
- Have students use a hands-on manipulative graphic organizer such as a foldable.
- Provide students with a pre drawn diagram to be labeled with concepts.

Experimental Design Diagram

Name: ____________________________ **Date:** ___________ **Class:** ____________________

Title:	
Hypothesis:	
Independent Variable (IV):	
Levels of the IV: (Label the level that will act as *control*, if there is one.)	
Repeated Trials:	
Dependent Variable (DV):	
Constants: (Be sure to include measurements where needed.)	

Materials

Two identical 1-liter containers with lids, two Celsius thermometers or temperature probes, water, dry soil or sand, paper towels, two lamps, heat-producing light bulbs, graph paper

Procedure

1. Pour about 250 ml of water into one of the containers—enough to cover the bulb of a thermometer. Pour soil or sand to the same height into the other container.
2. Put a hole in the lid of each container so that a thermometer will fit through. Place the lid on each container, gently put a thermometer through each hole, and position the thermometers so the bulbs are covered by the substances in the containers. *CAUTION! Be very careful! If a thermometer breaks, do not touch the glass. Tell your teacher immediately.*
3. After a few minutes, read the initial temperatures of the two substances (water and soil or sand) and record these temperatures on the data table on the next page.
4. Place the containers near the lights in such a way that when the lights are turned on, each container will receive light of the same intensity and direction (i.e., same angle). Turn on the lights.
5. Measure and record the temperatures every five minutes for 30 minutes.
6. Turn the lights off, and continue to measure and record temperature every five minutes for 30 more minutes.

Data Table

TIME (min.)	TEMPERATURE (°C)

	Water	**Water**	**Soil or Sand**	**Soil or Sand**
0				
5				
10				
15				
20				
25				
30				
35				
40				
45				
50				
55				
60				
Change between the initial and final temperatures				

Graph

1. Use graph paper and your data to construct a double-line graph of the heating and cooling rates of water and a similar graph of the heating and cooling rates of soil or sand.
2. Label the *x*-axis “Time (min.)” and the *y*-axis “Temperature (°C).” Note that the total time on the *x*-axis should be 60 minutes.
3. If you wish, use two colors for each substance—one to show the heating rate and one to show the cooling rate.
4. Make a key to indicate which colors represent the heating and cooling rates of water and which colors represent the heating and cooling rates of soil or sand.
5. Write a descriptive title for your graph.

Data Analysis and Conclusions

1. Both substances (water and soil or sand) received the same amount of thermal energy from the heat-producing light bulbs. Which substance showed the greatest temperature change while the light was on? Use data from your experiment to support your answer.
2. Which substance showed the greatest temperature change after the light was turned off? Use data from your experiment to support your answer.
3. Which substance retained the greatest amount of thermal energy? Use data from your experiment to support your answer.
4. As the water and soil or sand cooled, which would have made the air above its surface the warmest?

Applications

1. Use your data and analysis to help explain why there is a difference between the average winter temperatures in Lynchburg and Staunton (6–7 °C or 42–44°F) and the average winter temperatures in more moderate coastal Virginia areas (8–9 °C or 47–48°F).
2. Does the elevation of Lynchburg and Staunton play a part in temperature differences? Why, or why not?
3. How does the unequal heating and cooling of land and water produce convection currents (i.e., wind) in areas near bodies of water? Draw a simple diagram to accompany your answer.
4. How do the concepts you learned in this activity connect to what you have learned about the Earth's energy budget?

Average Annual Temperatures in Virginia Cities

Fahrenheit

Norfolk (°F)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Avg. High	47	48	57	66	75	82	86	85	78	68	61	52
Avg. Low	30	32	38	47	56	65	70	68	64	52	44	35
Mean	38	41	48	57	66	74	78	77	72	61	54	44

Virginia Beach (°F)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Avg. High	48	50	58	66	74	82	85	85	80	71	62	54
Avg. Low	32	34	40	47	56	65	70	68	65	55	45	36
Mean	41	42	48	57	65	74	78	78	74	64	54	45

Lynchburg (°F)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Avg. High	44	47	57	67	75	82	86	84	78	68	58	47
Avg. Low	24	27	35	44	52	60	65	64	57	45	37	28
Mean	34	37	46	56	64	72	76	75	68	57	48	38

Staunton (°F)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Avg. High	42	44	54	64	74	81	84	84	77	66	56	46
Avg. Low	18	21	30	38	48	56	60	58	51	38	31	24
Mean	31	34	44	52	61	68	74	71	64	54	44	35

Celsius

Norfolk (°C)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Avg. High	8	9	14	19	24	28	30	29	26	20	16	11
Avg. Low	−1	0	3	8	13	18	21	20	18	11	7	2
Mean	4	5	9	14	19	23	26	25	22	16	12	7

Virginia Beach (°C)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Avg. High	9	10	14	19	23	28	29	29	27	22	17	12
Avg. Low	0	1	4	8	13	18	21	20	18	13	7	2
Mean	5	6	9	14	18	23	25	25	23	18	12	7

Lynchburg (°C)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Avg. High	7	8	14	19	24	28	30	29	26	20	14	8
Avg. Low	−4	−3	2	7	11	16	18	18	14	7	3	−2
Mean	2	3	8	13	18	22	24	24	20	14	4	3

Staunton (°C)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Avg. High	6	7	12	18	23	27	29	29	25	19	13	8
Avg. Low	−7	−6	−1	3	9	13	16	14	11	3	−1	−4
Mean	−1	1	6	11	13	20	23	22	18	11	6	2