



ARM

CLIMATE RESEARCH FACILITY

Education and Outreach Lesson Plan

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Grade levels 9–12
Monsoon Convection Cells

Approximate Time

One hour

Objective

The student will investigate how high and low pressure differences caused by temperature create monsoons as evidenced by the completion of the experiment.

Background Information

If you live near a large lake, then you may have heard of the term “lake breeze.” If, instead, you lived near the ocean, you would experience the “sea breeze.” These are relatively small-scale atmospheric circulations that are caused by the temperature difference between land and water. More specifically, during the daytime (especially in summer), land surfaces heat up more than water surfaces. The warm air over land rises because it is lighter than cool air. As the warm air rises, it displaces the air higher up, so this air seeks a way to go back towards the surface and fill the gap left by the rising air. The easiest place to go is over the water. The temperature is cooler, and air stays near the surface because cool air is heavier than warm air. In the morning, this process begins slowly, but through the day it can become quite strong. In the evening the process weakens again, and at night it often reverses, because the land surface cools faster than the water surface. In this nighttime case, the breeze is called a “land breeze,” because it blows from the land to the water.

“Monsoon” in India refers to the seasonal wind that blows from the ocean during part of the year and from the land during the rest of the year. The monsoon is a larger and seasonal version of the land and sea breeze. During winter, sea surface temperatures in the Indian Ocean are warmer than land surface temperatures. This leads to the dry season in India, because the wind blows from the land to the ocean, just as the land breeze does near a big lake on summer nights. Conversely, in summer, the land heats up more than the ocean and gives rise to the opposite circulation. A humid wind then blows from the ocean towards the land and produces significant amounts of rainfall. India and Southeast Asia are famous for the monsoon. However, the word monsoon is now used for similar seasonal winds in North Africa and Eastern North America, though the Indian monsoon is the most intense of them all.

In northeastern India, the fertile land around the Ganges River supports several hundred million people. This river, the largest in India, is fed by monsoon rains and runoff from the nearby Himalayan Mountains. In 2011 and 2012, scientists are studying how the characteristics of particles in the atmosphere—called aerosols— may be affecting the monsoons that feed the Ganges. Read more at: <http://www.arm.gov/sites/amf/pgh/>.

Key Points to Understand

- Wind results from pressure gradients, (i.e., pressure differences from place to place).
- Air generally moves from an area of high pressure to an area of low pressure. Over large distances, the Earth's rotation deflects these winds to their right in the northern hemisphere and to their left in the southern hemisphere. This is known as the Coriolis effect. This effect has zero value at the equator.

- Wind continues until air pressure is equalized.
- Monsoon circulation cells are continuous and reverse their direction seasonally.

Key Vocabulary

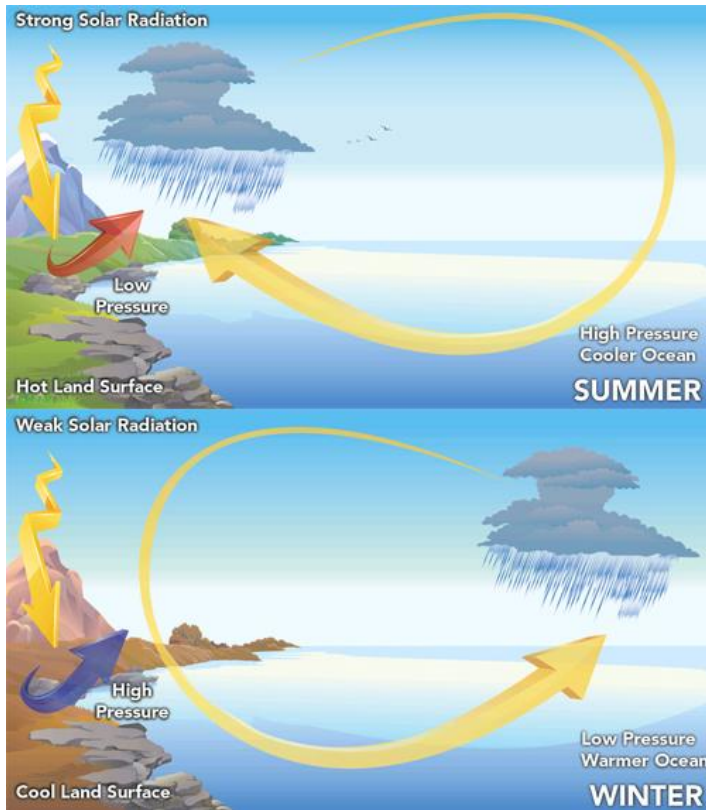
- **Aerosol:** Particles in the atmosphere. There are an abundance of naturally occurring aerosols in the Earth's atmosphere, i.e., dust and salt from sea spray. Pollution also contributes aerosols for cloud formation.
- **Atmosphere:** The air surrounding and bound to the Earth.
- **Convection:** Transport of heat and moisture by the movement of a fluid.
- **Jet Streams:** Relatively strong winds concentrated in a narrow stream in the atmosphere, normally referring to horizontal, high-altitude winds.
- **Monsoon:** A thermally driven wind arising from differential heating between a land mass and the adjacent ocean that reverses its direction seasonally.

Materials

- Glass pie plate
- Food coloring
- Eye dropper
- 4–5 Styrofoam cups
- 1 cup ice
- 1 cup hot water
- Student Recording Sheet

Preparation

Students often have misconceptions about wind and where it comes from. Before the lesson begins, discuss wind with your class. The main point of the discussion is to reveal students' ideas of wind and its origins. Additionally, discuss monsoons: What is a monsoon? In what regions/countries do monsoons occur? How do monsoons affect India? Explain that a monsoon cell is a thermally driven wind arising from differential heating between a land mass and the adjacent ocean that reverses its direction seasonally.



Monsoon winds (or monsoon circulation cells) are caused by the difference in temperature between the oceans and continents. In the summer, continental landmasses heat up more quickly than the surrounding ocean waters. The land heats the air above it, which causes the air to rise. The rising air, or **convection**, causes low pressure. Meanwhile, the cooler air over the ocean waters causes higher pressure because it is more humid and dense. Wind is formed as the **atmosphere** moves areas of high pressure into areas of low pressure to obtain balance. The result is a constant wind flowing from the ocean to land, driven by solar heating. As the cool ocean air is pulled upward onto land, it can no longer contain moisture, which causes the formation of rainclouds. Cloud formation and heavy rains are most likely to occur in areas with higher elevations, such as mountainous areas, thus causing the heavy

rains linked to monsoon season. In fall and winter, the circulation cell is reversed as the landmasses cool off more quickly than the ocean and the air moves from land to sea.

Procedure

1. Be sure that all materials are either centrally located or already distributed to the student groups. Pass out Student Recording Sheets. Students should begin by creating a hypothesis.
2. Place three Styrofoam cups upside down in a triangular shape.
3. Place the pie plate on top of the Styrofoam cups. Fill pie pan 3/4 full with water at room temperature.
4. Fill the fourth cup with hot water, then carefully slide it under the center of the pie plate. Try not to touch the pie plate so that the water inside remains still.
5. Put a few drops of food coloring inside the eyedropper.
6. Next, let the eyedropper touch the bottom of the pie plate right above the hot water. Squeeze out 1 or 2 drops of color, then carefully remove the eyedropper.

7. Watch the movement of the food color inside the plate. Look at it from above and also from the sides. Fill out Student Recording Sheet.
8. Now, place a cup of hot water near the side of the plate and a cup of ice under the center of the plate.
9. Squeeze 1–2 drops of color above the hot water. How does the food color move this time? Fill out the Student Recording Sheet.

Closure/Evaluation

The students have now created a convection cell. Convection is the movement of mass within a fluid. That fluid could be water (like the ocean), but air is also considered a fluid. In meteorology, convection means the upward movement of air. A convection cell is the circulation of air that includes both upward and downward motion. Did you notice how the drops of color move in the pie plate? Look from the side of the pan. You should see the color rising if it's near the cup with hot water and sink when it's near the cup with ice. In a monsoon convection cell there is constant wind flowing from the ocean to land, driven by solar heating.

Suggested Follow-Up Activities

- Collect current newspaper articles related to monsoons.
- Research the typical rainfall for your city each month. Then research the typical rainfall in the Ganges Valley of India, taking special note of monsoon season. Make a graph comparing the rainfall of both locations.
- Research the Monsoon season as it relates to the state of Arizona:
<http://phoenix.about.com/od/weather/a/monsoontrivia.htm>
- Write a report on the positive and negative effects of monsoons in India.
- Research the affects of aerosols and pollution on cloud formation and monsoons.
- Find and analyze poetry about monsoons.
- Wind Lesson plan found at <http://education.arm.gov/teacher-lounge/lessons/winds>.
- Learn more about the Ganges Valley Aerosol Experiment at <http://www.arm.gov/sites/amf/pgh/>.

Name _____
Date _____

Monsoons

Research Question: How are convection cells formed?

Hypothesis

Materials

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- 1 cup hot water
- Student Recording Sheet

Procedure

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2. Place three Styrofoam cups upside down in a triangular shape.
3. Place the pie plate on top of the Styrofoam cups. Fill pie pan 3/4 full with water at room temperature.
4. Using the fourth cup, fill it with hot water then carefully slide it under the center of the pie plate. Try not to touch the pie plate so that the water inside remains still.
5. Put a few drops of food coloring inside the eyedropper.
6. Next, let the eyedropper touch the bottom of the pie plate right above the hot water. Squeeze out 1 or 2 drops of coloring, then carefully remove the eyedropper.
7. Watch the movement of the food coloring inside the plate. Look at it from above and also from the sides. Record your observations on the Student Recording Sheet.
8. Now, place a cup of hot water under the plate near the side and a cup of ice under the center of the plate.
9. Squeeze 1–2 drops of coloring above the hot water. How does the food coloring move this time? Record your observations on the Student Recording Sheet.

Observations: Sketch or write.

How did the food coloring move with the cup of hot water in the middle of the pie plate?

How did the food coloring move with the cup of ice added?

Conclusion

Based on your hypothesis, recorded data, and findings from the experiment, write a conclusion.
