ARM
CLIMATE RESEARCH FACILITY

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About ARM:

The Atmospheric Radiation Measurement (ARM) Climate Research Facility is a U.S. Department of Energy scientific user facility for the study of global climate change.

As part of its outreach program, ARM provides education resources for students, teachers, and communities.

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U.S. DEPARTMENT OF ENERGY | Office of Science

EDUCATION NEWS

Monsoons: Bring on the Rain

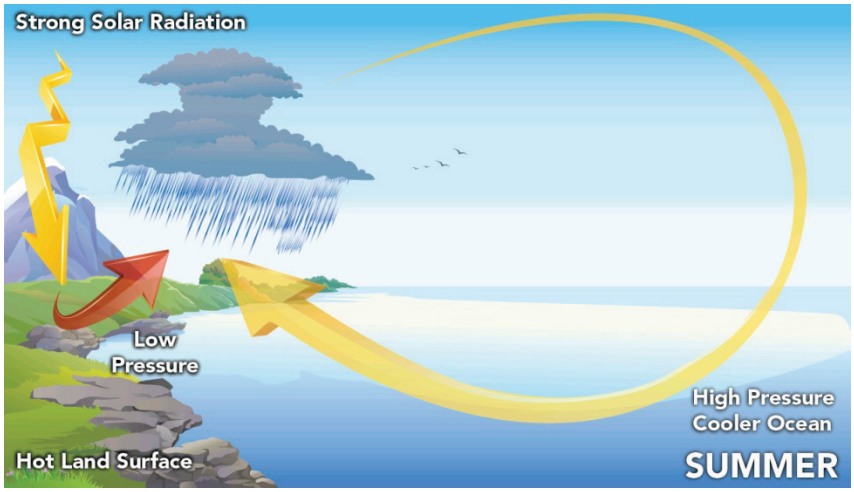
Imagine weeks of hot, dry heat, where it seems as if there will be no relief from the weather. Then suddenly, swift winds bring rushing rains and flooding. This rapid change in seasons, caused by a monsoon, is essential to life in the Ganges Valley, India.

What is a Monsoon?

A **monsoon** is the seasonal change in the direction of the prevailing wind, which brings about a shift in local weather. India's monsoon blows southwest from the Indian Ocean in the summer. Monsoon season is marked by heavy rains and dangerous flooding that can level communities and take thousands of lives. Conversely, a weak monsoon season may cause drought, crop failure, and various other hardships for humans and animals.

How are Monsoons Caused?

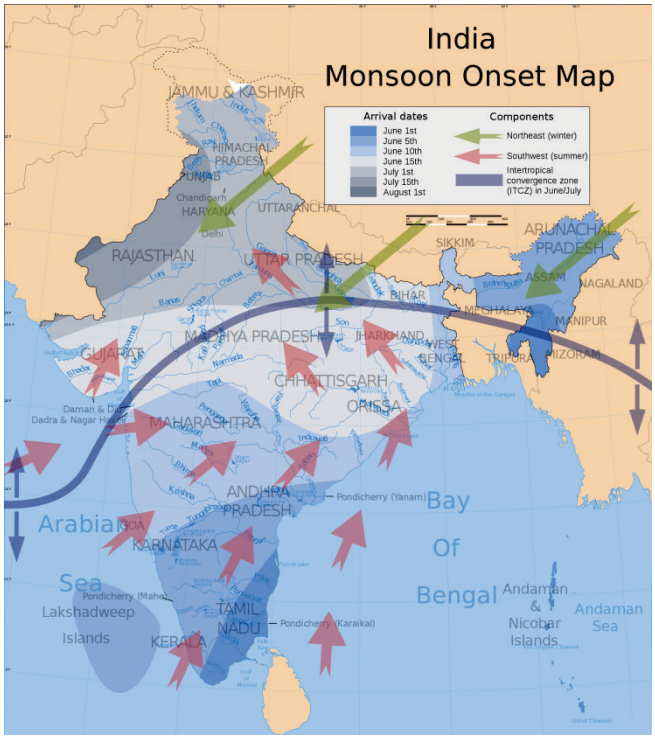
Monsoon winds (or monsoon circulation cells) are caused by temperature differences between oceans and continents. In the summer, continental land masses heat up more quickly than surrounding ocean waters. The land heats the air, which causes the air to rise. The rising air, or **convection**, causes low pressure. Meanwhile, cooler air over the ocean causes higher pressure because it is more humid and dense. Wind forms 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 cool ocean air is pulled upward onto warm land, it can no longer contain moisture, which causes the formation of rain clouds. Cloud formation and heavy rains are most likely to occur in regions with higher elevations, such as mountainous areas, causing the heavy rains linked to monsoon season. In fall and winter, the circulation cell is reversed as the land masses cool off more quickly than the ocean and the air moves from land to sea.

A Monsoon Example: India

The monsoon that occurs in India in the early summer months is caused by both the monsoon circulation cell between southern Asia and the Indian Ocean and the subtropical **jet stream**. In response to the seasons, this jet stream flows westerly and migrates to northern latitudes in the summer and to southern latitudes in the winter. As the subtropical jet stream moves north, it runs into the Himalayan mountain range, home to the world's highest peaks. As this jet stream moves over the Himalayas, the summer monsoon cell develops, causing torrential rain in the Himalayan foothills from June to September.



Courtesy of http://en.wikipedia.org/wiki/Monsoon

After six months of dry monsoon weather, India's summer monsoon brings about ninety percent of the annual rain. Rainfall is needed for animals and crops to survive. Without the monsoon rains, the nation's population would go hungry. While the rainfall is imperative for the survival of the region, it is also wildly destructive. The heavy monsoon rains have caused widespread flooding, mudslides, and the loss of lives.

Ganges Valley Aerosol Experiment (GVAX)

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. Some studies suggest that the growing haze over the Ganges Valley region will increase air temperature and pressure, which might draw moisture from the ocean and intensify the monsoon. Other studies indicate that the increased heat will cause clouds to dry up.

Through an intergovernmental agreement with India, the U.S. Department of Energy's ARM Climate Research Facility deployed a portable laboratory in Nainital, India, in June 2011 to measure the characteristics of **aerosols** (particles in the atmosphere such as smoke and dust), which may be affecting the monsoons that feed the Ganges River. For nine months, instruments included with this portable laboratory—known as the ARM Mobile Facility—will obtain various measurements of the aerosols, such as what they are made of, how big they are, and how they change over time. Combined with data from existing ground stations operated elsewhere in the region, the measurements from the mobile facility will be used by scientists to study how aerosols absorb or reflect sunlight and how clouds are affected by high concentrations of pollutants.

This study begins in the monsoon season and continues through the winter, when high pressure confines smoke from post-harvest field burning and increased fossil fuel use. It then extends into the dry, hot season, when winds bring dust from deserts to the west. Data gathered during GVAX will be used to build more accurate computer models of changes in regional weather patterns and assist in the development of mitigation measures in response to these changes.

Definitions

- **Aerosols:** 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.

Did you know?
Monsoons occur not just in India. Monsoons also happen in Africa, South America, and even in North America. In 2008, the National Weather Service established a monsoon season for Phoenix, Arizona, declaring it from June 15 to September 30. During this time frame, Phoenix can experience wind storms, dust storms, and heavy desert rains that result in flash floods.

Related Activity: Monsoon Convection Cells

Grade Level: 9th-12th

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.

Materials: Glass pie plate, food coloring, eye dropper, 4–5 Styrofoam cups, 1 cup ice, 1 cup hot water, Student Recording Sheet

Procedure:

1. Be sure that all materials are centrally located or already distributed to the student groups. Pass out Student Recording Sheets. Students 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.

For the full lesson plan, visit:

http://education.arm.gov/teacherslounge/lessons/Monsoon-Convection-Cells-Gr-9-12.pdf

ABOUT ARM EDUCATION AND OUTREACH

The goal of the ARM Education and Outreach Program is to develop basic science awareness and increase critical thinking skills focusing on environmental science and climate change for K-12 students.

Resources for students and teachers are available at: **education.arm.gov**

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