ARM
CLIMATE RESEARCH FACILITY

EDUCATION NEWS

In this issue:

Rainfall in Mountainous Areas

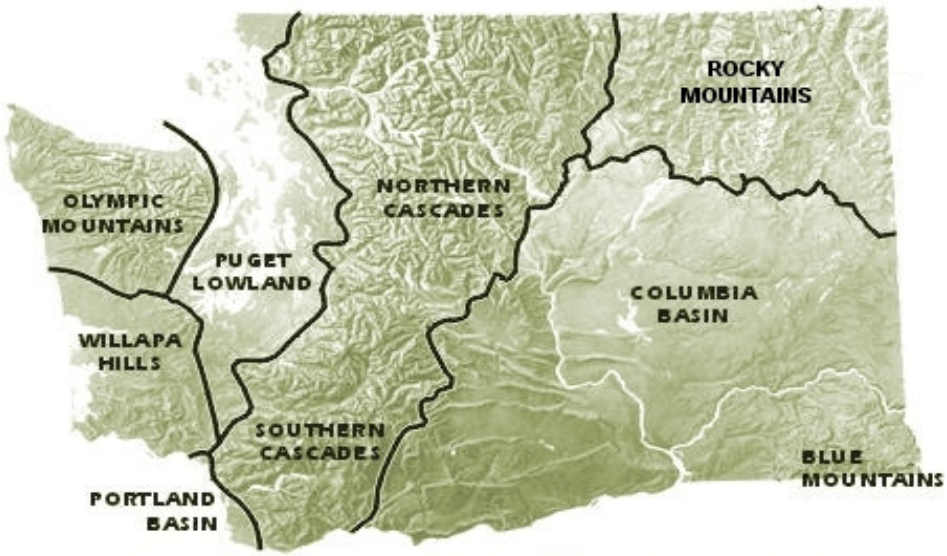
With contributions from Steve Linn, 4th grade teacher at Cottonwood Elementary, Kennewick, WA

"I've never heard of a Rain Shadow!"

It's an age-old question: So, where do you live?

My answer: "Washington—the STATE, that is." Inevitably, the next remark I hear is, "Oh, it rains a lot there. I bet you have webbed feet!" What transpires next is a mini-lesson in geography and weather, culminating with the term "rain shadow."

My new friend is amazed to learn that while Washington is home to a **rainforest** (yes, there are non-tropical rainforests), and plenty of rain on its western half, there is an area covering roughly half the state, on the eastern side of the Cascade Mountains, that receives very little rainfall.



Land Areas of Washington State
(Courtesy of Washington Department of Natural Resources)

On the eastern side of the Cascade Mountains, a **rain shadow effect** prevails, and much of the region is semi-arid, with less than 10 inches of rain per year. By definition, a rain shadow is a region of relatively low rainfall that occurs downwind of a mountainside or mountain range facing away from the direction of the wind. The mountains block the passage of rain-producing weather systems, casting a "shadow" of dryness behind them.

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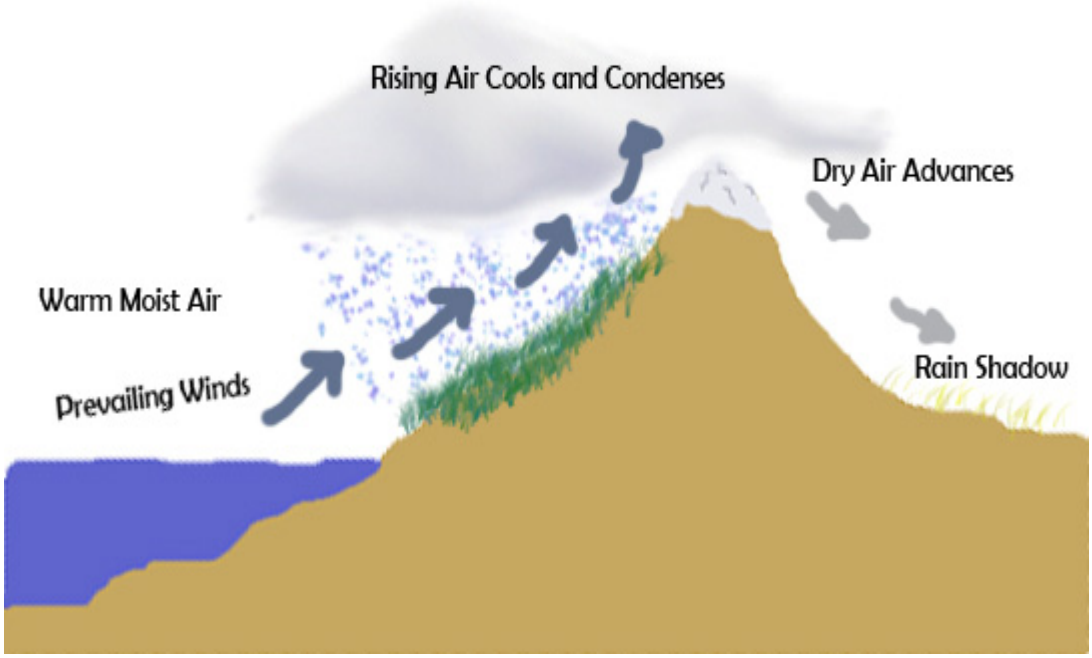
Anatomy of a Rain Shadow

There are two basic effects of precipitation caused by mountains. There is the **"orographic" effect** and the "rain shadow" effect. The diagram below illustrates how a rain shadow occurs.



The **orographic effect** happens on the windward side of a mountain. Rainfall amounts increase dramatically as you move farther up the mountain on the windward side. Winds carry air masses up and over the mountain range, and as the air is driven upward over the mountain, falling temperatures cause the air to lose much of its moisture as precipitation.

The other effect is the **rain shadow effect**. The rain shadow effect is where precipitation amounts drop significantly on the **leeward** side of a mountain. Upon reaching the leeward side of the mountain, the dry air descends and picks up any available moisture from the landscape below. The resulting profile of precipitation across the mountain is such that rainfall and moist air prevails on the windward side of a mountain range while arid, moisture-poor air prevails on the leeward side.

This explains why places like *Arica, Chile*, average only 0.5 millimeters of rain per year. The Andes Mountains, to the east, receive a lot of precipitation, but it dissipates by the time it gets to the *Atacama Desert*. The Tibetan Plateau is perhaps the best example of a rain shadow. Rain does not make it past the Himalayas, leading to arid weather on the leeward side of the mountain range. This same process occurs in the Columbia Basin of Washington on a smaller scale.

From Wet to Dry

The Atmospheric Radiation Measurement (ARM) Climate Research Facility is sponsored by the U.S. Department of Energy. ARM scientists study climate and weather around the world, including the amount and type of precipitation that different areas receive. In 2007, they spent several months in the Black Forest region of Germany, as part of the Convective and Orographically Induced Precipitation Study, or COPS. The purpose of COPS was to study the heavy rainfall and thick clouds that form due to complex terrain and nearby mountains. Measurements obtained during the COPS field campaign encompassed the entire life cycle of precipitation, including the development of clouds, followed by the onset, development, and organization of precipitation.

What's so important about orographic rain? Because it forms differently from "regular" rain, scientists have a difficult time predicting it, which can lead to unexpected storms and flooding. They will use the data gathered in Germany to improve the predictions of these kinds of cloud systems.

On the other side of the world, in 2009, ARM researchers visited Cerro Toco, a mountain located in Chile's Atacama Desert, for the Radiative Heating in Underexplored Bands Campaign (RHUBC-II). The Atacama lies in the rain shadow of the Andes and is one of the driest places on Earth. At an elevation of over 5,000 meters above sea level, climate instruments gathered information about the amount of infrared energy that reaches the Earth's surface.

RHUBC-II took place in this desert location because **water vapor** in the Earth's atmosphere can interfere with measurements of radiation. The arid conditions on Cerro Toco allowed the instruments to gather detailed measurements that will help scientists improve the mathematical formulas used to predict the way that energy behaves in climate models.

A State Cut in Two: A Second Rain Shadow

The most notable Washington rain shadow is influenced by a mountain range that originates in southern British Columbia, Canada, and terminates in California. Within Washington State, the Cascade Range extends approximately 93 miles (150 km) west to east and spans the state, running 250 miles (400 km) north to south.

The following locations are other examples of dry, rain shadow regions and the mountain ranges that shield them:

- The Gobi Desert lies in the rain shadow of the Himalayas.
- The Patagonia region lies in the rain shadow of the Andes.
- Death Valley lies in the rain shadow of the Pacific Coast Ranges of California and the Sierra Nevada Mountains.
- The city of Spokane in the state of Washington lies in the rain shadow of the Cascade Mountain Range (Spokane receives little rainfall- 17 inches/43 cm).

Other regions that receive orographic precipitation include the following:

- Oceanic islands, such as the Hawaiian Islands or New Zealand
- Areas around the Pennines, a mountain range in Northern England and Southern Scotland
- The eastern coasts of large islands like Australia and Madagascar
- Areas in the northwestern United States near the Great Lakes
- Seattle, Washington, which lies on the windward side of the Cascades and receives 36 inches (92 cm) of precipitation per year.

Definitions

- **Arid:** being without moisture; extremely dry; parched.
- **Desert:** a landscape or region that receives an extremely low amount of precipitation, less than enough to support growth of most plants. Deserts are defined as areas with an average annual precipitation of less than 10 inches (250 millimeters) per year, or as areas where more water is lost by evapotranspiration than falls as precipitation.
- **Leeward:** on the side sheltered from the wind.
- **Orographic effect:** precipitation will increase with elevation to the windward side of a mountain as topographic forcing squeezes out precipitation and dries out the cloud mass.
- **Precipitation:** the amounts of rain, snow, hail, etc., that have fallen at a given place within a given period, usually expressed in inches or centimeters of water.
- **Rainforest:** a dense evergreen forest with an annual rainfall of at least 160 inches (406 centimeters). Rainforests are often, but not always, located in tropical regions.
- **Rain shadow:** a region in the lee of mountains that receives less rainfall than the region windward of the mountains.
- **Water vapor:** water in its gaseous form, instead of liquid or ice.
- **Windward:** on the side exposed to the wind.

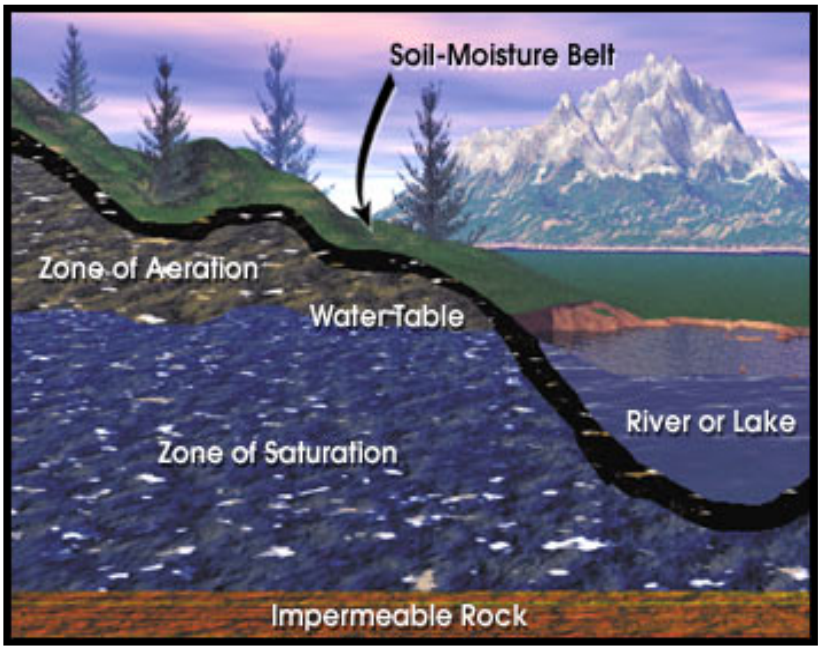
Related Activity: Rainfall and the Water Table

Grade Level: 3rd-5th

Approximate Time: Setup and initial experiment: 45 minutes, followed by several short time segments to observe, record, and add water to soil.

Objective

The student will be able to explain how an increase of rainfall influenced by climate change can affect the water table and soil salinity underground as evidenced by completion of the experiment and student recording sheet.



Background Information

Due to climate change processes, it is predicted that there may be a higher rainfall than normal in some areas and a lower rainfall than normal in others.

If rainfall increases, water flow in rivers will increase and so too will erosion by those rivers. Rivers that erode more than normal carry more silt. When the river runs into the nearby sea, that silt is deposited. An increase in rainfall may raise the water table nearer to the surface. A similar process can occur when deep-rooted trees are removed and the region is suddenly denied the water take-up evapotranspiration that the trees provided. Salt may then come to the surface as water evaporates.

For the full lesson plan, visit:

http://education.arm.gov/teacherslounge/lessons/Rainfall-and-the-Water-Table-Gr-3-5.pdf

ABOUT ARM

The ARM Climate Research Facility is a U.S. Department of Energy scientific user facility for the study of global climate change by the national and international research community. http://www.arm.gov/.