Why is it tropical in the tropics?

A laboratory experiment from the Little Shop of Physics at Colorado State University

Overview

We have all seen the proverbial "wish you were here..." postcard featuring white sand beaches and palm trees bordering sapphire blue water that stretches as far as the eye can see. Why is it that there are certain regions of the world that never seem to experience winter? Why do some areas of the world have dramatic seasonal variations in temperature and others tend to stay within a smaller range?

This activity will allow students to explore the relationship between angle of incidence, intensity of solar radiation, and how it relates to seasons as well as the general climate of different regions of our planet.

Necessary materials:

Per group of 3 or 4:

- One large inflatable Earth
- A solar grasshopper with leads
- Multimeter
- Alligator clip leads

We purchased the solar grasshoppers from Deal Extreme but you can use any device that acts similarly.

Theory

Our planet is warmed by the sun, but not every part of the planet is warmed equally. The amount of energy transferred depends on the angle that the sun's rays make with the surface. If you hold a flashlight above a table top and shine it straight down you see a circle of light. If you tilt the flashlight, however, the light will stretch out to form an oval, covering a larger area of the table. The amount of light is the same, but it's spread out over a larger area; we say that the **intensity** is less.

The Earth's spin axis is tipped 23.5° from the plane of its orbit around the sun. For folks in southern Florida, during the middle of the northern hemisphere summer, the noonday sun is nearly overhead, so the sunlight is quite intense. But 6 months later, the sun is never higher than a bit more than 40° above the horizon, so even at noon the intensity of sunlight never reaches the peak it does in the summer.

For locations on or near the equator, the intensity of sunlight experiences a much smaller seasonal variation. Equatorial locations are always warm, but they are also always about the same temperature. There's no winter in Mombasa, only a wet season and a dry season, both quite toasty.

Doing the Experiment

Your students will use the large inflatable Earth and the solar grasshopper to determine the intensity of the sun's radiation at a given point on the surface. Most students are familiar with the fact that solar cells use the sun's light to create electricity, but this is a good point to reiterate. The current that the cell produces is, more or less, directly proportional to the captured energy. Have your students do the following:

- Align the Earth so the sun shines directly on the equator, by the Galapagos Islands.

- Attach the clip leads to the solar grasshopper and to the multimeter.
- Set the meter to measure current and adjust the range so that the maximum current stays on scale.
- Place the solar grasshopper in the direct sunlight and measure the current
- Place the solar grasshopper where they live and measure the current. (Note: Fort Collins is about 40° N)

The amount of current you see will be proportional to the intensity of the sunlight. Have your student explore taking readings from different areas on the Earth at different latitudes. The current position of Earth, with the sun on the Galapagos Islands represents how it would be on either of the equinoxes. Think about how to tip the ball to represent northern hemisphere winter and summer; this takes some thought.

Look at the variation in current (and thus received power) over the course of one rotation (representing a day) for the northern hemisphere winter and summer. The key is to measure the seasonal variation. How much do things change between winter and summer. For latitudes of 40° N, a good deal. For the equator... Not so much.

Summing Up

When the solar grasshopper is at the equator, the angle between it and the sun isn't greatly affected by the precession of the planet and so students should see values that vary over a small range compared to the data from the higher latitude position. For the latter, students should be getting higher values when the solar grasshopper is tilted towards the sun and lower values when it is tilted away. This is not due to the fact that the grasshopper is closer or further from the sun, as per the common misconception, but due to the changing angle and therefore changing intensity of the solar radiation. This yields the vast seasonal variation experienced at the higher latitudes. The solar intensity at the equator stays high and relatively stable throughout the year making it a rather postcard-worthy region of the world.

For More Information

CMMAP, the Center for Multiscale Modeling of Atmospheric Processes: http://cmmap.colostate.edu

Little Shop of Physics: http://littleshop.physics.colostate.edu