Why is it tropical in the tropics, but not at the poles?

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

Overview

Alaska, known as the land of the midnight sun, attracts tourists and adventurers alike. If you happen to be planning a summer getaway there, however, you might want to consider packing more jackets than sun tan lotion. In the city of Barrow, which is at 71˚ North, the sun does not set between the middle of May and the beginning of August but their average high temperature is only 45˚ F (7.2˚ C)! In July, the sun is up 24 hours a day in northern Alaska, but only 12 hours a day near the equator. So why is it hotter near the equator during this season? There are many different forces at work, but one—and the main one—is this: The hours that the sun is up isn't the only factor that determines the energy that the surface of the earth receives. Another factor is the angle at which the sun's radiation strikes the earth.

Necessary materials:

Per group of 3 or 4:

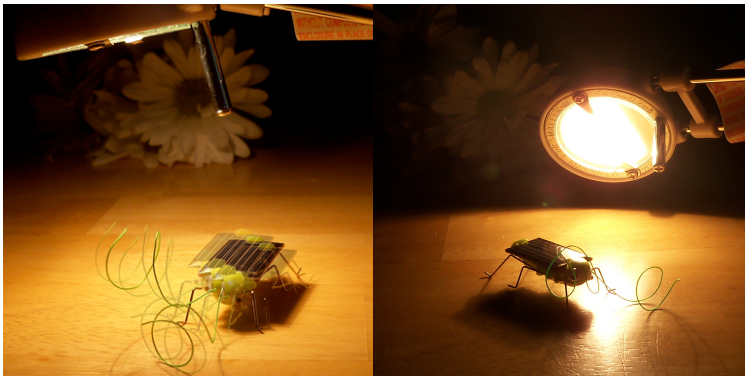
- One solar powered grasshopper
- One halogen or incandescent lamp

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.

Due to the tilt of the earth and the precession of the planet, the far North and South don't experience day and night as we do in the middle latitudes. During the summer in Barrow, the earth is tilted toward the sun. As it rotates the sun never sinks below the horizon—but the sun is always at a very low angle in the sky. The intensity is never very great.



The solar cell generates electricity that depends on the intensity of the light. So it generates more electricity when the lamp is directly overhead than when it is at an angle.

Doing the Experiment

Each group should set their lamp so that the light shines directly down on the solar powered grasshopper. This will be the highest intensity possible. The grasshopper will hop and shimmy as the solar cell runs the motor, a vibrating

motor from a cell phone.

Now, using the lamp's base as a pivot point, tilt it slowly back and fourth in an arc so that the light falls on the solar cell from directly horizontal on one side to the other side. Ask your students to note how the intensity changes given the change in behavior of the solar grasshopper. They should have observed a greatly reduced activity level of their insect when the light was coming in from a low angle across the "horizon" of the solar cell.

Most of us would associate a scene like this with dawn or dusk. This photograph, however, was taken at 10 am on a summer day in Barrow, Alaska

Summing Up

Equatorial areas do experience the sun directly overhead but the further north or south you are from the equator, the lower the sun sits in the sky. In Barrow, the sun never gets higher than approximately 30˚ above the horizon. There might be 24 hours a day of sunshine in the summer but they never the intense sunlight you'd experience at the equator.

A low intensity for 24 hours still does lead to a significant amount of incoming energy. In fact, the total energy from the summer sun in Barrow right at the summer solstice is more than that at the equator. But there are other climate factors at work. The cooling during the long winter night takes a long time to offset, particularly for a coastal city.

This experiment is a good way to introduce seasonal variability as well as reinforce the concept of intensity.

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