

How does the earth cool itself off?

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



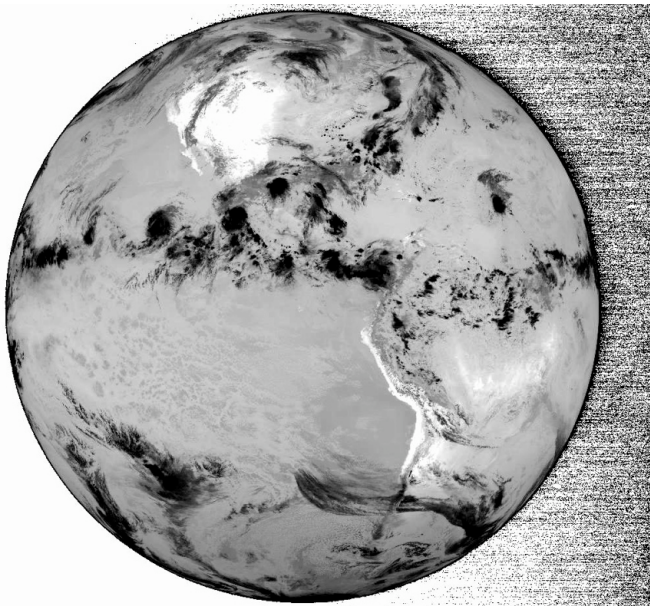
Overview

The earth gets energy from the sun. The sun shines on the earth's surface, warming it.

If the earth had no way of cooling off, it would simply keep getting hotter and hotter. So the earth must have some way of cooling off, some way of losing energy to space...

Theory

When light shines on the earth, different places heat up by different amounts. Snow reflects most of the incoming light, so snowy areas tend to stay cool. Dark areas, like black parking lots, absorb incoming light, and so will warm up.



GOES-9 11 July 1995, 1800 UTC 12 micron IR GOES Project, NASA-GSFC

An infrared view of the earth, at 12 microns. The atmosphere is transparent to infrared of this wavelength. White is bright, black is dim. Look for hot spots and cold spots. Deserts are hot, and emit a lot; clouds are cool, and emit very little.

Necessary materials:

- World map placemat
- Desk lamp
- IR thermometer
- 3 squares of standard transparency

The infrared thermometer is the key item; it measures temperature by measuring an object's emitted thermal radiation. The desk lamp is used to heat up the surface; any lamp will do, though an incandescent or halogen lamp is best.

In order to keep at a relatively constant temperature, the earth must get rid of energy too. And it does: As emitted thermal energy, infrared, that is transmitted to space.

The hotter something is, the more infrared emitted. So a picture of the infrared that the earth emits shows us the hot spots and the cold spots. Look at the satellite photo at left; the American west is clearly pretty hot, as is appears quite bright. Cloudy patches appear dark; clouds absorb or reflect the infrared from the surface, so we only see the infrared they emit. Clouds are cool, so clouds appear as dark spots. Deserts are hot during the day, because they absorb a lot of incoming radiation, but at night they radiate energy back to space, so they get quite cool.

The same principles work on a smaller scale as well, of course. And this lets us do a simulation of these principles on a tabletop scale.

Doing the Experiment

In this experiment, students will simulate the energy transfer between the earth and space by using the light from a desk lamp to warm up a placemat. The placemat will warm up, so it will emit infrared, which they can detect with an infrared thermometer. The hotter the surface, the more energy emitted, which the thermometer will show. Adding an “atmosphere” can reduce the transmission of infrared, holding heat in, another thing that the experiment can show.

SAFETY NOTE: The desk lamps get hot, and if they are too close to the placemat, they can melt it. Please be careful!

The experiment goes like this:

- Have students shine the light on the placemat for a few minutes, allowing it to warm. (Note: You can also do this experiment outside, letting the placemat warm up in the sun. That’s actually a better way to do it, if you can get your class outside!)
- Now have them use the infrared thermometer to probe the temperature of different places on the placemat. Different colors will absorb different fractions of incoming radiation, and so will be at different energies. Reds will be cool, blues will be warm. (That’s because reds tend to reflect infrared too; blues tend to absorb it, and so heat up more.)
- Now, add an atmosphere to a warm spot. While monitoring the temperature with the infrared thermometer, slip three taped-together sheets of transparency onto the placemat. This “atmosphere” will block the outgoing infrared, so the observed temperature will quickly drop. But as the “atmosphere” heats up the emitted infrared (from the transparencies) will come back.

We chose three sheets of transparency for this reason: Three sheets of standard transparency are about the same thickness, relative to the scale of the placemat, as the thickness of the earth’s atmosphere. This is another good point to make—just how thin the earth’s atmosphere is! (Three sheets of transparency corresponds to about 30 km on the scale of the placemat; 99% of the earth’s atmosphere is below this height.)

Summing Up

This is a good way to illustrate in a qualitative manner the radiational warming and cooling of the earth’s surface.

You could actually make this quantitative. If you measure the temperature vs. time, you can see that hot spots cool more quickly than cool spots—because they emit more infrared.

For More Information

CMMAP, the Center for Multi-Scale Modeling of Atmospheric Processes: <http://cmmmap.colostate.edu>

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