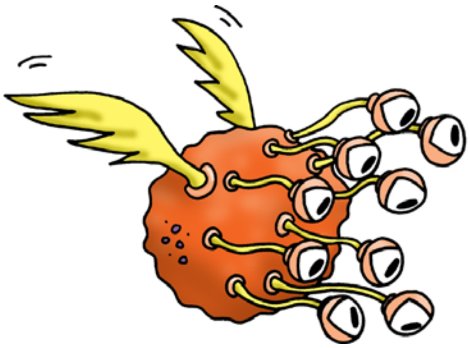
Originally published in The Technology Teacher*, October 2001, by the International Technology Education Association*



Keeping Nine Eyes on the Weather

You have probably heard the term "global warming" a lot in the news lately. What is it all about? Why do people disagree about how serious it is, whether humans are causing it, or, indeed, whether it even really exists?

Well, the reason they disagree is because the whole subject of climate and weather is so complex. There are so many different things going on—in the air, on Earth's surface, and in the oceans—that it is very difficult for scientists to figure out how these events and conditions interact so that they can predict how climate is changing and how fast.

Take clouds, for example. If they are very thick, they look gray or even black when we look at them from the ground, and they cast shadows because sunlight cannot penetrate them very well. But from above, clouds are brighter than the ocean (which is most of Earth's surface), as well as many types of land. They scatter some of the sun's energy back into space before it ever reaches Earth's surface. So, clouds have the effect of keeping Earth cooler.

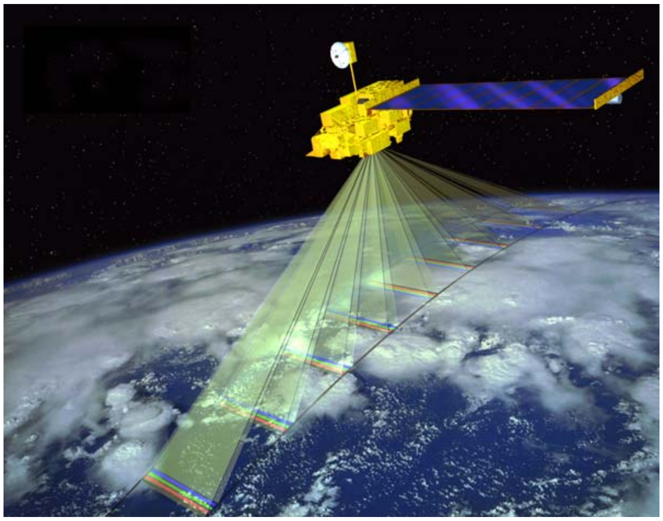
Some particles of pollution also scatter sunlight like clouds and add to the cooling effect. Other particles of pollution, such as soot, may absorb sunlight, causing the atmosphere to be warmer.

However, when humans burn gasoline in cars, jet fuel in planes, and coal or oil in power plants, gases such as carbon dioxide are produced, in addition to particles of pollution. Carbon dioxide is one of several "greenhouse gases." These gases act like the glass roof of a greenhouse, trapping radiant energy close to the Earth, and preventing some of the cooling off that normally occurs at night. So, extra amounts of these gases in the atmosphere could cause the Earth to get a tiny bit warmer each day.

The better scientists understand each part of this complex puzzle, the better they will understand the big picture. They and the rest of us can then be confident that their predictions of what the climate will be like in 10, 20, 50, or 100 years will be accurate.

One part of the puzzle, then, is how much of the sunlight reaching Earth is reflected and scattered back into space by clouds and particles of pollution in the atmosphere. *Terra* is an Earth observing satellite launched by NASA in 1999. Terra carries five very special instruments to study different aspects of the atmosphere, the land, and the oceans.

One of the instruments, called *MISR* (pronounced like "miser") has nine different cameras, each pointed in a different direction. MISR stands for Multi-angle Imaging SpectroRadiometer. As Terra passes over Earth, each of MISR's nine cameras takes an image of the same piece of Earth, each camera looking through the atmosphere from a different angle.



MISR is one of five instruments carried by the Terra satellite to study Earth.

So, for example, as the orbiting Terra satellite approaches Phoenix, Arizona, the forward looking MISR camera takes a picture at a shallow angle, looking through a lot of atmosphere to see the city ahead. As Terra gets closer, then the next camera, mounted at a slightly steeper angle, takes a picture of the same thing. As Terra passes directly above Phoenix, another camera takes a picture looking straight down, looking through the least atmosphere of all the cameras. As Terra gets farther away from Phoenix, the rear pointing cameras get their shots, also looking through a thicker layer of atmosphere, but with the sun shining at a different angle than seen with the forward looking cameras.

This model of MISR was built out of Lego bricks by the master model-builders at Legoland, California. On Terra, MISR is upside-down from this. MISR's nine cameras are represented with the blocks and wheels sticking out at odd angles. Light enters each camera through holes you can't see here.

MISR takes nine multi-angle pictures like this of every point on Earth's surface every nine days! And MISR will study Earth for six years. Imagine how many photo albums all those pictures would fill!

MISR's cameras are carefully calibrated to give extremely accurate information about the amounts and colors of light they are receiving. That is why MISR is called a "SpectroRadiometer": Spectro for spectrum (as in the colors of the spectrum) and radiometer being an instrument for measuring light.

But why are all these different angles necessary? There are three reasons:

(1) When the nine images are combined, they give a stereo view of the atmosphere and the clouds, so scientists can better study how clouds and particle pollutants are distributed throughout the atmosphere. The stereo views also give more information about formations on the ground.

(2) The different views show the effects of looking at the same scene through different amounts of air.

(3) Viewed from different angles, particles in the air scatter light differently, depending on their size, shape, and composition.

Activity 1: See Different Points of View

See for yourself how different the same thing looks, depending on your viewing angle.

You will need drawing paper, pencil, and something to draw.

Get everyone in the class to sit in a big circle. You can move your desks into a circle, or you can sit on the floor or outside in the grass in a circle.

First, put a simple object in the center of the circle, at about eye level. The object should be something that looks different depending on your viewpoint. A box is good. A ball or a can is not!

Second, everyone in the class study the object for a minute from where they are sitting, then carefully, but quickly, draw it. Be sure to really look at it and draw what you see.

Third, going clockwise, start anywhere in the circle and count off (person 1, person 2, person 3, and so on). Put your number in the lower right-hand corner of your drawing.

And last, line all the drawings up in order and see what it would look like to walk all the way around the object you drew.

Activity 2: Build a "MISR-lite" Model

You can build a very simple model (just one will do for the class) that will show how MISR views the world.

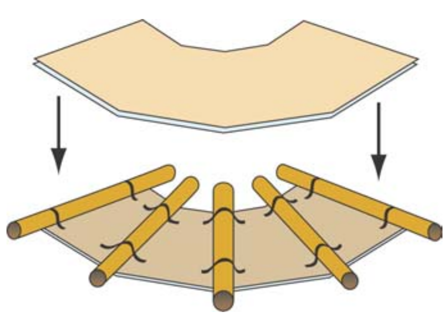
Materials:

- 5 cardboard tubes, with open ends. Good-sized mailing tubes are best, about 3 inches in diameter and about 3 feet long. Smaller tubes, such as come with wrapping paper, will work too.
- 2 large pieces of cardboard, about 2 x 3 feet.
- Tape--packaging, masking, or duct

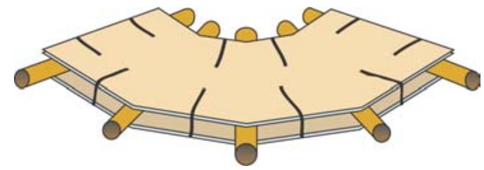
Construction:

Cut the large pieces of cardboard so they look more or less like the picture.

Tape the tubes to one of the cardboard pieces at different angles, as shown in the picture.

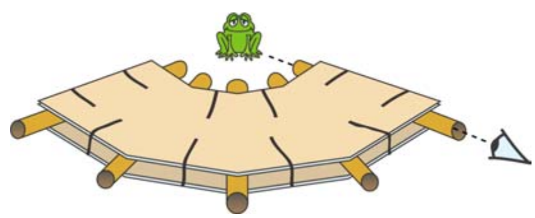


Top the tubes with the other piece of card-board, so you have a "tube sandwich." Tape the two pieces of together cardboard at a few places around the edges.



Activity 3: Viewing the World Narrowly

Place the MISR-lite flat on a table. Place a simple 3-D object (again, not a ball or cylinder shape!) in the center of the area where the tubes are close together. You can use an object similar to the one you drew in the first activity, or you can use something different.



Now, put a chair by each of the five tubes on the opposite side (where the ends of the tubes are far apart). A student sits in each chair and looks through his or her tube at the object. Then the student draws it, just as it appears through the tube. If you all agree to make your drawings of the object a certain height (which should appear the same for all viewing angles, although the width may appear different), you can make an animated flipbook of the drawings.

If all the tubes are pointed at the same object, why is the view different in each picture?

Do you have more information about the object from looking at it from different angles?

Activity 4: Taking to the Air

What if you took your MISR-lite with you on a hot-air balloon ride that passed over your house or the building where you live? If you turned the MISR-lite so the side with the flared out tubes pointed down, then looked through the other end of the different tubes, how would your house look as you passed over it?

To get an idea, place the small object that you drew, or another small object, on the floor. Stand-

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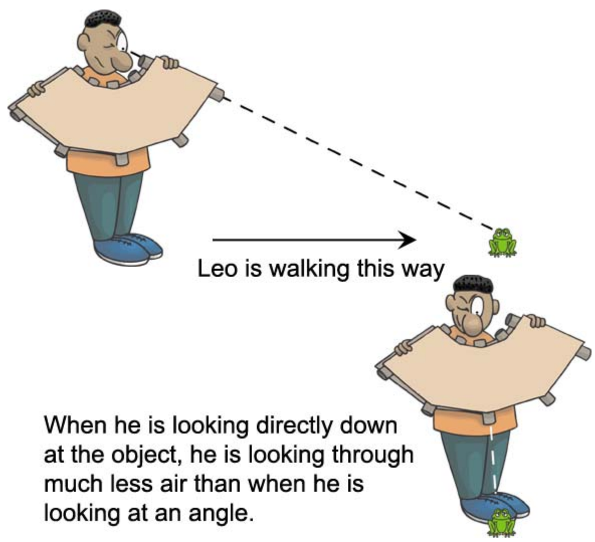
ing a few feet from the object, hold the MISR-lite model vertically and look through the tube that is pointing forward. Walk forward or backward until you see the object through the tube. Now walk forward until the object disappears, then look through the next tube and find the object. Continue walking forward, sighting the object through each tube in turn. Notice how the object looks different through each tube as the MISR-lite passes over it.

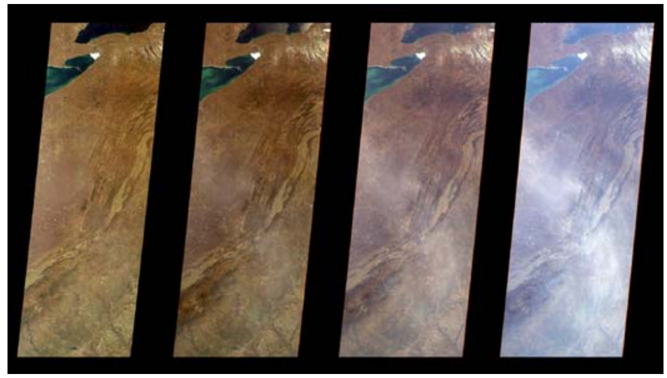


Notice that when you look through either of the topmost tubes (looking ahead or behind as you pass over the object), you are looking through more air than when you are looking straight down through the middle tube. Although in our demonstration there isn't enough of a difference in viewing pathlength to change the appearance of the object, if the air were foggy or smoky and you were a lot higher up in the sky, this angle would make quite a difference in how well you would see the ground.

You can also see how a flat shape changes, depending on your viewing angle. Draw a circle on a piece of paper and lay it flat on the floor. Look at the flat circle through the different tubes as you walk toward and away from it.

How MISR Sees the World

The following four pictures of the Appalachian Mountains in eastern United States were



taken by different MISR cameras. The picture at the left was taken with the MISR camera that points straight down. The three images to the right show exactly the same strip of land, taken by three of MISR's forward looking cameras, each pointed at a different angle (45.6 degrees, 60.0 degrees, and 70.5 degrees). As the slant angle increases, the camera looks through a thicker layer of atmosphere, and the whitish particles stand out more.

You can see how the angle makes the haze much more obvious. These images will help scientists understand how particles in the atmosphere interact with sunlight and how particle pollution affects Earth's climate.

Learn more about MISR at http://www-misr.jpl.nasa.gov/, and do an online crossword puzzle about MISR at The Space Place, http://spaceplace.jpl.nasa.gov/misr_xword/misr_xword1.htm.

This article was contributed by the Jet Propulsion Laboratory, California Institute of Technology, reflecting research carried out under a contract with the National Aeronautics and Space Administration. It was written by Diane Fisher, who is also the writer, designer, and developer of ***The Space Place****, a website with fun and educational space-related activities at http://spaceplace.jpl.nasa.gov. Thanks to Richard Shope, Space Science Education Outreach Liaison at JPL, for brainstorming help, and to Alex Novati for illustrations.*