IMAX

A collection of information, activities and resources on environmental and Earth science topics for teachers of students in grades 3-12

BLUE PLANET

TEACHER'S RESOURCE GUIDE

BLUE PLANET®

A collection of information, activities and resources
on environmental and Earth science topics
for teachers of students in grades 3–12

Office of Education•National Air and Space Museum
Smithsonian Institution•Washington, D.C. 20560
November 1990

Printed on recycled paper in the United States of America

Blue Planet, released November 1990, is presented as a public service by the Smithsonian Institution's National Air and Space Museum and the Lockheed Corporation. Filmed in cooperation with the National Aeronautics and Space Administration, it was produced by Imax Space Technology Inc. and distributed by Imax Systems Corporation.

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Comments Welcome

The National Air and Space Museum periodically updates its curriculum materials to incorporate teacher comments and current information from the constantly changing field of aerospace. Any comments, criticisms, or ideas that you can recommend are welcomed. Suggestions are reviewed before updating curriculum materials. Please send your comments to Materials Development Revisions, Office of Education, Room 211, The National Air and Space Museum, Washington, DC 20560.

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Special thanks to Brian Duff, Jo Dugi, Bobbe Dyke, Andrew Johnston, Sue Mander, Karen Mannes, Anita Mitchell, Patricia Floyd Nagel, Sandra Narva, Mary Jane Taylor

SUBJECTS AND GRADE LEVELS

ACTIVITY	Art	Biology	Environmental Science	Geography	Geology	Literature	Math	Meteorology/Weather	Social Studies	3–4	5–6	7–8	9–10	11–12
	Subjects									**Grade Levels**				
Changing Environments	•		•						•	•	•	•		
Craters: Making an Impact					•			•		•	•	•	•	
Dynamic Equilibrium		•	•										•	•
Earth Views	•									•	•	•		
Earthquakes: Whose Fault Is It?					•					•	•	•		
Getting Earth Down to Size							•					•	•	
Groundwater Filtration Model			•							•	•	•	•	
Monitoring Ozone from Your Classroom			•				•						•	•
Night Lights				•					•	•	•	•	•	•
Our Changing Earth			•	•	•			•				•	•	•
Responsive Systems		•	•									•	•	
Solar Heating			•					•		•	•	•	•	
Thunderclouds: Convection Connections			•		•			•				•	•	
Tropical Rain Forests: Where Are They?				•				•				•	•	
Who Wins When the World Changes?						•			•				•	•

INTRODUCTION

We shall not cease from exploration.
And the end of our exploring
Will be to arrive where we started
And know the place for the first time.
—*T. S. Eliot**

Of the billions of people who have lived on planet Earth, only a few hundred have seen it from space. According to those few, it was an unforgettable and eye-opening experience. From such a vantage point, it is easier to put global issues in perspective. Knowing this, the National Air and Space Museum and the Lockheed Corporation, in cooperation with the National Aeronautics and Space Administration, contracted with Imax Space Technology Inc., a subsidiary of Imax Systems Corporation to produce the film, *Blue Planet*. This goal of this film is to offer millions of people a view of their home from space.

This educational booklet focuses on the environmental and Earth science concepts that are addressed in the film. The activities presented here are intended to be a collection of resources from which teachers can pick and choose. We have tried to introduce some innovative ideas as well as to include some old favorites. These activities are designed to enhance your students' educational experience and to give them a new perspective of the "blue planet" on which we live.

The majority of the space footage seen in *Blue Planet* was taken during three Shuttle flights, STS-29, STS-32, STS-34.** Taking pictures of Earth from orbit, using the IMAX® camera, was only one of a number of mission objectives for the crew.

Space Shuttle *Discovery*, STS-29, March 13–18, 1989. STS-29 deployed the third Tracking and Data Relay Satellite. In addition to this satellite, the Shuttle carried other cargo, referred to as payload, which included two student experiments—one on protein crystal growth, and another on chromosome and plant cell division. Commander Michael L. Coats, pilot John E. Blaha, and mission specialists James P. Bagian, James F. Buchli, and Robert C. Springer flew on this Shuttle mission.

Space Shuttle *Atlantis*, STS-34, October 18–23, 1989. The *Galileo* planetary exploration spacecraft was deployed on STS-34. This spacecraft will not reach Jupiter, its main destination, until December, 1995. *Galileo's* instruments will collect data on the atmosphere, satellites and powerful magnetic field of Jupiter while orbiting the planet, as well as

* *Four Quartets*

** STS numbers designate Space Shuttle missions; STS stands for Space Transportation System.

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send an entry probe into its atmosphere. This mission also carried the Shuttle Solar Backscatter Ultraviolet instrument; its ozone measurements assist in calibrating other ozone-monitoring instruments on satellites. Secondary payloads involved radiation measurements, lightning research, and a student experiment on ice crystal growth in space. Commander Donald E. Williams, pilot Michael J. McCulley, and mission specialists Ellen S. Baker, Franklin R. Chang-Diaz, and Shannon W. Lucid, made up the flight crew.

Space Shuttle *Columbia*, STS-32, January 9–20, 1990. Highlights of the STS-32 mission included deployment of the Navy satellite Syncom IV and retrieval of the Long Duration Exposure Facility (LDEF), previously launched on Shuttle mission 41-C in April 1984. LDEF carried experiments which covered diverse research—from astrophysics to space environment effects on tomato seeds. After the flight, the seeds were distributed to school teachers for experiments in the classroom. Secondary STS-32 payloads included experiments on the effects of microgravity and light on daily rhythms and metabolic rates. Members of the flight crew were commander Daniel C. Brandenstein, pilot James D. Wetherbee, and mission specialists Bonnie J. Dunbar, Marsha S. Ivins, and G. David Low.

With only 25 hours of intensive training from the film production team, astronauts must become expert filmmakers. They use four lenses for filming—30 mm fish-eye lens, 40 mm normal lens, and 60 mm and 100 mm telephoto lenses.* Manual focusing requires the astronauts to work quickly in setting up each shot; the ground is moving beneath them and each roll of film runs only three minutes. Astronauts cannot film during takeoff or reentry since the 41 kg (90 lb) IMAX camera and film magazines must be safely stowed at these times.

Prior to flight, the film production team briefs the Shuttle crew on the film's goal and script. After a mission, the film editors review the footage and plan for filming on future missions. The large IMAX film size and the giant theater screens—up to eight stories tall and 34 m (110 ft wide)—produce a unique film experience. When astronauts see this space footage, they often remark that it is the next best thing to being there.

* The focal length of camera lenses is measured in millimeters, abbreviated mm.

DISCUSSION QUESTIONS

Let us shake off this close-clinging dew
From our members eternally new
And sail upwards the wide world to view
*—Aristophanes**

The questions in this section are intended to promote discussion, not anxiety, among your students. Talk about some of these ideas with your students before seeing the film. Afterward, discuss them again and see how perceptions have changed. Did the film answer any of your students' questions? We recommend not making this section into an evaluative activity; students might miss important observations while they are busily filling out question sheets.

Is it day or night?

What does the sky look like above the atmosphere? How can you tell day from night? What separates day from night? If you could orbit Earth right now, would you be in darkness or daylight? Why does the Sun rise and set? What would you see if you could hover in space directly above your town for 24 hours?

Where is the blue sky?

What is sky made of? Imagine being on a space shuttle that is launched in the morning; how would your sky change as you rocket into space? Does the atmosphere have an end? What does a sunset look like from orbit? What does Earth's atmosphere look like from orbit?

Where are the stars?

Can you see stars from space? In the film *Blue Planet*, there are many scenes of Earth from orbit and the blackness of space beyond. Can you see stars in this blackness? Can the orbiting astronauts see stars?

Which way is up?

How do we define North? In the film, is North always at the top of the screen? What is North to someone in Australia? Are Australians standing upside-down compared to someone in the United States? How can this be right? Imagine hovering above the North Pole; describe the spinning motion of Earth. Which direction does the Shuttle orbit? Why?

Can you see waves?

Can you see waves in the sand? In the water? In the clouds? What causes waves? What do clouds look like from orbit? Do they look different when seen from above? As you view clouds in the film, imagine

* *The Clouds*

what they would look like from the ground. Can you see any storm systems? What do these remind you of? Can you see clouds everywhere, or do they tend to be in groups? Notice how clouds form differently over land than they do over oceans. Do the clouds cast shadows?

How big is Earth?

How big does Earth look from orbit? Does the entire globe fit into one picture? What kinds of things can you see from space? What do rivers look like? Do all rivers look the same? What do cities look like from space? Can you see mountains? Snow? Craters? What was the most surprising thing you saw?

Can you see people from space?

What is the smallest thing you can see from orbit? Are very straight features manmade or natural? What manmade objects can you see from space? What colors do you notice most?

TO THE TEACHER

Don't let the previous open-ended questions make you uncomfortable. This next section is designed to help you address some of the issues that these questions may have raised. You may want to encourage your students to seek out the answers elsewhere; library, parents, a neighbor who happens to be an aerospace engineer, and so on. Most of these questions are rather complex and deserve to be explored more fully than space here will allow. We hope that you will find them thought provoking.

Is it day or night?—The sky appears black above the atmosphere even during the day. When you look at Earth from space, the part which is in shadow is experiencing night and the part which is in sunlight is experiencing day. The ground is dark during the night and bright during the day. The edge of blackness, which separates day from night, is called the terminator; look for it in the film.

Since the Shuttle orbits Earth about every 1½ hours, the astronauts on board experience 16 sunrises and 16 sunsets every 24 hours ($24 \div 1\frac{1}{2} = 16$). If you could hover above your town for 24 hours you would experience day and night in the same way as someone on the ground.

Where is the blue sky?—Earth's sky or atmosphere is made up of air molecules. Gravity holds most of the air molecules near Earth's surface. If you flew on a morning Shuttle launch, you would see many color changes in the sky—as your craft gains altitude, the sky changes from light blue to dark blue and finally to black. The atmosphere doesn't end abruptly; it tapers off and gradually becomes the near vacuum of interplanetary space. At sunset, gold-red clouds and their immense shadows look even more dramatic from space. In orbit, sunsets happen quickly—you can see one every 90 minutes! From orbit, the atmosphere looks like a thin blue line around the curve of Earth.

Where are the stars?—Space is the best place to see stars because it is beyond Earth's atmosphere, which interferes with starlight. However, stars are easy to see from an orbiting spacecraft only when it is over the dark half of Earth (night). Stars appear dim when compared to either the Sun or the bright half of Earth and are therefore difficult to see if these are also in view. (Note: Theoretically, astronauts should be able to see stars in space when the Shuttle is above the bright half of Earth. However, even when astronomer-astronaut Karl Henize tried this by adapting his eyes to the dark for 30 minutes before looking out through a hooded window, he could see very few stars.) Unfortunately you can't photograph stars with movie cameras running at normal speed even above the side of Earth where it is night.

Which way is up?—North is always on the spin axis of a planet. In the film, north is rarely at the top of the screen because the camera can be turned in any direction while taking pictures. North, to someone in Australia is the same as it is for someone in America; the direction toward the North Pole. Australians are standing upside down when compared to people in the United States because the immense gravity of Earth pulls everything toward its center. Looking down on Earth's North Pole, our planet spins counterclockwise. The Shuttle orbits to the east, which takes advantage of Earth's rotational speed. A westward launch, though feasible, would require far more power as well as another launch site (probably in California) since for safety reasons launches must occur over water.

Can you see waves?—Many of the wave-like forms that are visible from space are actually huge structures on the ground. What from orbit look like ridges of sand in the Namib desert are actually dunes, hundreds of meters high. Clouds tend to accumulate into visible bands that look like waves. Internal waves in the oceans can be seen when the Sun angle is just right. Storm systems look like cloud pinwheels or spirals and may conjure up visions of tornadoes or of water going down a drain.

How big is Earth?—Apollo astronauts took the familiar whole Earth picture on their way to the Moon, a thousand times farther from Earth than the Space Shuttle orbits. Compared to that view, Earth seems relatively close in the film *Blue Planet*. The activity "Bringing Earth Down to Size" should help put things in perspective. Rivers often look like twisting, brown threads; sometimes you can see the Sun glinting off their surfaces.

Can you see people from space?—Most of the questions in this section are subjective and will depend on student's observational skills. Keep in mind that cameras that use film, such as the IMAX camera, take very different pictures from cameras that use electronic sensors, such as the cameras aboard satellites. Compare the few satellite images in the film *Blue Planet* with the rest of the orbital photography. Cameras that use film more closely approximate what our eye sees from orbit. When you are in orbit, you will be much too far away to see people and will probably not even be able to distinguish large structures such as buildings or city blocks. From space, cities look like gray patches. We hope you will be surprised at what you can see from space; the more you look, the more you will see.

Our Changing Earth

The ground seemed cut up from the fellowship
Of verdure, field from field, as man from man,
The skies themselves looked low and positive
As almost you could touch them with a hand.
*—Elizabeth Barrett Browning**

Goal

To develop observational skills and to gain a greater appreciation of the processes that are continually changing our planet.

Key Concepts

- Earth environments are constantly changing.
- Many of these changes can be observed from Earth orbit.

Overview

Earth is a dynamic planet. Its land, oceans, and atmosphere are always changing. Though many of the changes on Earth are too small to be viewed from space, some changes are more easily seen from orbit than from the surface. In this activity, students can identify many examples of change in various Earth environments as they observe Earth from "orbit" while watching the film *Blue Planet*.

Materials

- IMAX film: *Blue Planet*
- Student Worksheet: Evidence of a Changing Earth (page 10)
- Reference materials (encyclopedias, books on Earth science, etc.)

Preparation

Review the overview section and discuss with your class what is meant by environmental or geological change. Events such as volcanoes erupting or the bulldozing of large tracks of land could cause both environmental and geological changes. No doubt you will think of many others. Talk about seeing the film and discuss the type of changes you might expect to see in the film. Review the section titled Discussion Questions in the beginning of this booklet. Before beginning, you will probably want to duplicate the Student Worksheet: Evidence of a Changing Earth on page 10 for your students.

Procedure

a. Look for changes that are occurring on the surface of Earth, in its water, and in its atmosphere while viewing *Blue Planet*.

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* *Aurora Leigh*

b. Record your observations as soon as possible after seeing the film. (It will be too dark to do this in the theater.)
c. Divide into small student groups and share your observations.
d. Select one change from each of the three categories on the student worksheet for further research.
e. Use reference materials to discover possible effects of this change on the future of the planet and its life.
f. Present your research to other members of the class.

TO THE STUDENT

Observe

1. Record your observations on the student worksheet provided.
2. Which category had the greatest number of changes?

Interpret

3. Which of the examples that you researched would have a positive effect on the planet and on the plant and animal life on Earth?
4. Which would have a negative effect?
5. Which would have a neutral effect?
6. Which of your observed changes are naturally reversible?
7. Which might be reversed through people's efforts?
8. Which of your observed changes might be irreversible?

Apply

9. Choose one of the changes you identified as negative and predict what would happen if this change were not reversed for 100 years. What would happen if it were not reversed for 1000 years.
10. Identify the causes of five of the changes you listed in your observations.
11. Of the five changes whose causes you just identified, describe something that you personally could do to reverse or prevent one of them.
12. Was your solution aimed at the cause of the change or at its effect? Discuss.

Glossary

Atmosphere—The air that surrounds Earth and is held near its surface by gravity.

Topics for Further Research

- Sakurajima Volcano, Japan

- Hurricanes, monitoring from space
- Lake Chad in Africa

TO THE TEACHER

Review this activity with your class before seeing the film, *Blue Planet.* It should work well as a cooperative learning experience as well as to provide research experience. The number of valid responses is practically limitless.

Students should be able to hypothesize about or to research the causes of the changes they have noted. Throughout this activity, make students aware that many scientists do not agree on the causes or the "cures" of many environmental changes. Problems are usually easier to prevent than to fix; thus, for question 12, most students will probably aim their solutions at causes rather than effects.

Student Worksheet

Evidence of a Changing Earth

Land

Example of Change | Effect on Planet/Life

Water

Example of Change | Effect on Planet/Life

Air

Example of Change | Effect on Planet/Life

Dynamic Equilibrium

When we try to pick out anything by itself,
We find it hitched to everything else in the universe.
—John Muir, American Naturalist

Goal

To build a model which shows the state of dynamic equilibrium and to relate it to Earth systems.*

Key Concepts

- Many global processes are in a state of dynamic equilibrium.
- The equilibrium point can be shifted by outside pressures.

Overview

This model is used to explore the concept of dynamic equilibrium and to relate it to the global systems of Earth that are in a state of dynamic equilibrium. Some of these are discussed in the film *Blue Planet*. In this experiment, the flow of water through a perforated container illustrates the concept of dynamic equilibrium. The water level remains constant (in equilibrium) even though there is continuous change (dynamic) as water flows through the system.

Materials

- Clear plastic bottle
- Water faucet and drain
- Flexible tubing (optional)

Preparation

Drill a vertical series of holes in the plastic bottle using a sharp 5 mm (1/4 in) drill bit. You may want to start each hole with a compass point or an awl. Place the holes at regular vertical intervals, but not directly over one another. A spiral arrangement works very well. This will allow better observation, permitting each stream of water to flow without interruption.

* This activity is based on an idea published in the *Greenhouse Gas-ette*, a newsletter of the Climate Protection Institute. Used with permission.

Procedure

a. Read and answer the questions in the "hypothesize" section below before beginning.
b. Place the bottle under the faucet so that everyone in the group can see it. You may need to use tubing to direct the flow of water into the bottle.
c. Slowly turn on the faucet until you have a steady, moderate flow of water.
d. Watch what happens and record your observations.
e. Repeat steps *c* and *d* using a different rate of flow.
f. Try repeating steps *c* and *d* while blocking some of the holes or after increasing the size of one of the holes below the water line.

TO THE STUDENT

Hypothesize

1. Will the bottle ever become full during the experiment?
2. Will all the streams look exactly the same?
3. What will happen if you block one of the holes during the experiment?
4. What will happen if you stop the incoming flow of water during the experiment?

Observe

5. Revise your hypotheses to reflect what you learned by investigating.

Interpret

6. List the variables that you can control directly.
7. Which variable can you control only indirectly?
8. How are the incoming and outgoing rates of water flow related?
9. How are the incoming rates of water flow and the water level related?
10. How does the size of the hole influence the result?

Apply

11. How could this model be analogous to the level of greenhouse gases in the atmosphere? What would the incoming flow of water represent? What would the outgoing flow of water represent? What would the water level represent? Which variable can people affect the most? How is this shown in the model?
12. How could this model relate to the level of atmospheric ozone?

What would the incoming flow of water represent? What would the outgoing flow of water represent? What would the water level represent? Which variable can people affect the most? How is this shown in the model?

13. How could this model relate to a loss of habitat for a species in a particular area? What would the incoming flow of water represent? What would the outgoing flow of water represent? What would the water level represent? Which variable can people affect the most? How is this shown in the model?

Glossary

Dynamic Equilibrium—A condition in which several processes act simultaneously to maintain an overall steady state in a system.

Habitat—The place where a plant or animal lives or grows.

Topics for Further Research

- Ecosystem
- Ozone, its natural production and destruction
- Earth's oceans as a reservoir for carbon dioxide

TO THE TEACHER

The bottle will fill only if inflow exceeds outflow, which may happen if you block some of the holes or use a very fast rate of inflow. The streams at the bottom of the bottle are under the greatest water pressure and will therefore produce faster, straighter streams. If you block one of the holes during the experiment, the water level will rise (all other factors being equal) and reach a new level of equilibrium. If you stop the incoming flow during the experiment, the water level will go down as the bottle empties through the holes. If students increase the incoming rate of flow during the experiment, the water level will rise.

Experimenters can directly control inflow and outflow by varying water pressure or hole size respectively, but can control the water level only indirectly, by varying inflow or outflow. The incoming water flow equals the outgoing flow when the water level is steady. A faster rate of incoming water flow will produce a higher water level than a slower one. Larger holes will increase the outflow and lower the water level, and vice versa, providing the inflow does not change.

In the "apply" section (page 12), the student relates each variable to current situations. If the rate of production of greenhouse gases increases, the total amount of these gases will also increase, as shown by a higher water level, provided the rate of their destruction remains fixed. Scientists hypothesize that the long-term effect of such a situation will lead to an increase in global temperature. If the rate of ozone destruction is increased while its rate of production remains fixed, the total concentration of ozone will drop as shown by a lower water level. A decreased ozone level allows more ultraviolet radiation to reach Earth's surface. Excessive ultraviolet radiation is harmful to life forms. If the rate of habitat destruction is increased while other variables remain unchanged, the number of species in a particular area will likely decrease from death or migration.

The following chart should help to organize these thoughts:

INFLOW (regulated at water faucet)	OUTFLOW (regulated by hole size)	WATER LEVEL (depends on in- and outflow)
Production of greenhouse gases*	Destruction of greenhouse gases	Level of greenhouse gases
Production of ozone	Destruction of ozone*	Ozone concentration
Creation of habitats	Loss of habitats*	Number of habitats

*Variable under investigation

This activity focuses on the idea that equilibrium points can be shifted by natural and manmade causes. Once students understand this concept, they may want to research and debate such questions as *How do people interfere in global processes? Should people interfere? Can people help interfering?*

Bringing Earth Down to Size

Then let me have the higher post;
Suppose it but an inch at most.
*—Jonathan Swift**

Goal

To compare various large heights to the diameter of Earth.

Key Concepts

- Few structures, natural or manmade, provide much contrast in height on a small-scale model of Earth.
- Drawing things to scale helps to develop accurate mental pic-

Overview

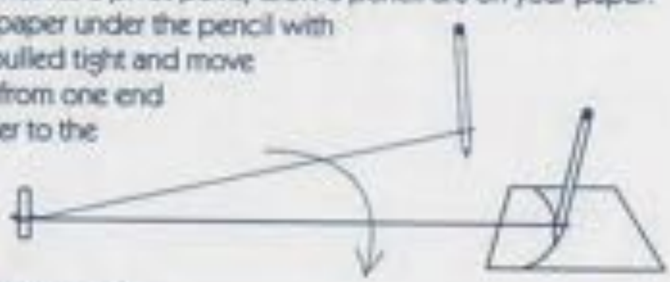
When you observe Earth from orbit in the film *Blue Planet*, you will probably be surprised by what you see. Earth may look nearer than you expected, or you may have thought you would see more detail. This activity should help you to better visualize how Earth's larger structures compare with Earth's size.

Materials

- Plain paper
- Pencils
- String (1½ m per group)
- Meter sticks
- Centimeter rulers
- Standard globe (12 in diameter)

Procedure

a. Tie one end of the string around a pencil. Make a small loop in the string 1 meter from the pencil and secure a piece of chalk in the loop. Using the pencil as a pivot point, draw a chalk circle on the floor.
b. Label this circle as Earth. Label the radius as 1 meter.
c. Using the chalk as a pivot point, draw a pencil arc on your paper. (Place the paper under the pencil with the string pulled tight and move the pencil from one end of the paper to the other.)



* *Verses on the Death of Dr. Swift*

d. This arc represents part of Earth's surface.
e. Use the values from the SCALE HEIGHT column in the following table to illustrate each item listed.

ITEM	ACTUAL HEIGHT	SCALE HEIGHT
Earth's radius	6,380 km (3,965 mi)	1.00 m
Average altitude of Space Shuttle	300 km (186 mi)	47.02 mm
Altitude of cruising jet liner	12.2 km (7.6 mi)	1.91 mm
Deepest ocean trench	11.0 km (6.9 mi)	1.72 mm
Mount Everest	8.8 km (5.5 mi)	1.38 mm
110 story skyscraper	0.3 km (0.2 mi)	0.05 mm

TO THE STUDENT

1. What is the diameter of the Earth model you drew?
2. If you could run your hand over a model of Earth this size (a radius of 1 m) how would it feel?
3. Use a globe to show the approximate height of an orbiting space shuttle.
4. How big would the Moon be on the scale of your model?
5. Determine the scale used in your drawing.

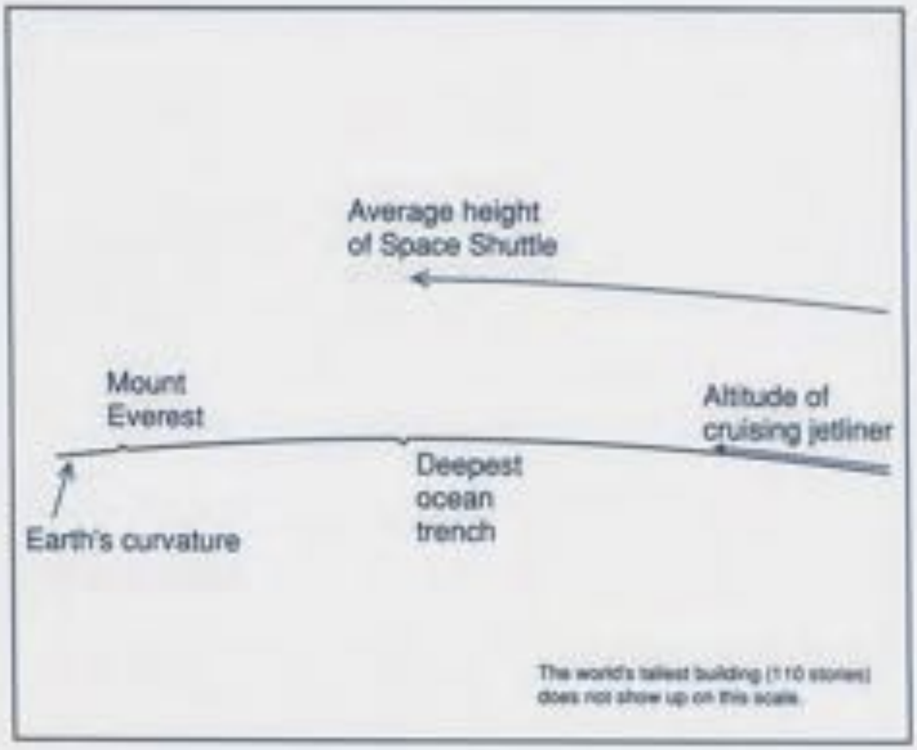
Topics for Further Research

- Radar mapping
- Topography
- Surveying

TO THE TEACHER

The diameter of your model should measure 2 m. Even a model this large would feel remarkably smooth; Mount Everest would be only a tiny bump. On our model the Space Shuttle orbits 47.02 mm above the surface; a 12 in globe is only about one-sixth as big, so the altitude would be about 8 mm, or about a quarter inch. The Moon is about one-fourth the size of Earth and could be represented by a circle with a radius of about 25 cm. The Moon is about 30 Earth-diameters away which translates to 60 meters on this scale.

The scale used in this exercise is 1:6,380,000. Young students will probably need some instruction in estimating fractions of millimeters. Enlarging the scale to avoid this doesn't work satisfactorily since it flattens out Earth's curvature. You may want to have the students research the heights of other things and incorporate them in their drawings (such as: weather balloons, high altitude aircraft, Earth's atmosphere, Earth's crust, deepest oil well, distance to the Sun, size of Sun, and distance to nearest star). Using the metric system keeps the math simple. For this reason, we have not included the comparable English measurements.



Earth Views

Once a photograph of Earth,
taken from outside, is available,
an idea as powerful as any in history
will be let loose.
—Fred Hoyle, British astronomer, 1948

Goal

To visualize Earth on several scales

Key Concepts

- Earth looks different when seen from far away.
- Our imaginations have been influenced by the space program.

Overview

The film *Blue Planet* shows Earth from three vantage points—the Moon, Earth orbit, and ground level. Seeing IMAX footage of Earth from orbit inspired the making of this film, which focuses on Earth and its environment. This activity encourages students to take a journey of the imagination.

Materials

- Sheets of plain paper
- Crayons or marking pens
- Other art materials for collage (optional)

Procedure

a. Read the following out loud:

Imagine that you are returning to Earth from a trip to a nearby star. (Although physical laws and present technology make such a trip impossible, yours can be an imaginary flight.) Our Sun is a star, and from far away it would look just like one of the stars in the night sky.

As you approach the Solar System, the Sun will become bigger and brighter, and you might be able to see tiny, dot-like planets. As you come closer still, you will see Earth and its moon. Earth may look something like the famous picture of Earth, taken by the Apollo astronauts on their way to the Moon. As you approach Earth, you will be able to see more detail. Imagine seeing North America, then your region, then your town, and finally your own house. (To help you visualize what happens, try this: look across the room at a globe while walking toward it.)

b. Using the art materials provided, draw three or four pictures to show what you would see from your spaceship on your trip home. The pictures will be like snapshots taken at the beginning, the middle, and near the end of your trip.

c. Choose a descriptive title for each of your drawings; for example, *How Earth Looked as We Flew by the Moon.*

TO THE STUDENT

1. Suppose you are at a nearby star and you look back toward the Sun. Would it hurt your eyes?
2. As you fly by the planets would you notice phases (crescent planet, half planet, etc.) similar to those we see in our moon?
3. Would you see all nine planets on your journey?

Glossary

Phase—The appearance of the illuminated surface of a planet or moon. Phases recur at regular intervals.

Topics for Further Research

- *Pioneer 10*
- *Voyager 1* and *Voyager 2* spacecraft
- Telemetry

TO THE TEACHER

From another star, the Sun would look like any other star in the night sky and thus would not hurt your eyes. Planets shine by reflecting light from the Sun. Sunlight falls only on that half of the planet facing the Sun. Using binoculars or telescopes, we can observe phases for Mercury, Venus, and the Moon from Earth. Phases of the planets would be seen easily on this trip.

The planets move in almost circular orbits in nearly the same plane; Pluto is the exception, having a noticeably elliptical orbit that is out of the plane of the rest of the planets. The planets are usually spread out in many different directions from the Sun. You could see any of the planets, provided that the Sun did not block your view. You would need a telescope to see those farthest away. The cameras aboard the spacecraft *Voyager 1* took a picture of our solar system from a vantage point far above the plane of the orbits. The resulting composite image captured seven of our nine known planets; Mercury and Mars were obscured by the Sun.

Earthquakes: Whose Fault Is It?

It interpenetrates my granite mass,
Through tangled roots and trodden clay doth pass
*—Percy Bysshe Shelley**

Goal

To create a dynamic earthquake model with which to better understand the mechanism that causes earthquakes.

- Earth is a dynamic planet.
- Most earthquakes correspond to shifting tectonic plates.

Overview

Long linear fault lines are easily seen from orbit, as recorded in the film *Blue Planet*. These are especially noticeable in the footage taken of the Andes, and along the coast of California. In this activity, students create a simple but authentic model of plate tectonics, similar to those used by geological researchers today. Using clay soil and wood, students generate a series of fissures not unlike those created during some earthquakes.

Materials

- Pieces of wood**
- Clay soil
- Mixing containers
- Stirring utensils

Procedure

a. Read the following out loud:

   Beneath our feet, Earth has an interesting and complex structure. The outermost layer, called the crust, is about 30 kilometers, or 20 miles, thick. The crust floats on the layer below, the semi-solid mantle. The mantle flows slowly, and sometimes the crust moves in response. Scientists use the technique in this experiment to understand what happens during earthquakes.

b. Put a large handful of clay soil in a container and slowly add water, stirring continuously, until the clay has the consistency of peanut butter.

c. Butt the two pieces of wood together and spread the clay over the area where the edges meet.

---

* *Prometheus Unbound*, Act 4

** Each setup requires a pair of boards of the same thickness, each having at least one straight side about 15 cm (6 in) long. Heavy cardboard will work too.

d. Set the model aside overnight so that it will partially dry.
e. The next day, *slowly* slide the pieces of wood past each other (see arrows on illustration) and carefully observe the surface of the clay.

TO THE STUDENT

Observe

1. Describe the clay's appearance before the pieces of wood were moved.
2. If you looked only at the clay, could you tell that there were two boards beneath it before you moved the boards?
3. Describe the change in the clay's appearance during the experiment.

Interpret

4. What do the pieces of wood represent?
5. What does the movement of the pieces of wood represent?
6. List some shortcomings of this model?

Apply

7. Name some places that experience earthquakes and compare their topographies with the model you created in this activity.
8. Why are earthquakes more prevalent in some areas?
9. Where does the energy in earthquakes come from?
10. Why do some earthquakes cause more damage than others?
11. What evidence of earthquakes can be seen from orbit?

Glossary

Earth's Crust—The solid outer layer of Earth.

Fault—A break in Earth's crust with the mass of rock on one side of the break pushed up, down, or sideways.

Mantle—The part of Earth beneath the crust and above the outer core.

Tectonic Plates—Large, crustal blocks composed of Earth's crust and upper mantle which move horizontally across Earth's surface relative to one another. Plates are about 100 km (60 miles) thick.

Topics for Further Research

- Plate Tectonics
- San Andreas Fault
- Strike-slip fault

TO THE TEACHER

Although students' descriptions of the clay's appearance will vary, they should be able to describe an overall change from a smooth, flat surface before the boards are moved to a rough, cracked surface afterward. Students should not be able to tell that there are two boards directly beneath the clay's surface until they move them.

The boards represent tectonic plates that are part of Earth's crust. The movement represents an earthquake. Small models can rarely show the complexity apparent on a larger scale. The surface crack is showing the result of activity of the two boards below. Seldom does an earthquake create a crack on Earth's surface; more typically, it deforms the surface.

There are many locations that experience earthquakes. California, for example, is an earthquake-prone area. Photographs showing the topography of an area before and after an earthquake would help to illustrate this point. Look for such pictures in the library if your Earth science textbook lacks good photographs. Earthquakes usually originate at the boundaries between moving tectonic plates. Because the plates are so large, land areas located far from their boundaries are less likely to experience earthquakes. Heat from inside Earth makes the fluid mantle layer move by convection. The movement in the mantle causes the crust to move. Earthquakes release large amounts of energy, creating tremors in the surrounding terrain. When they occur under large land masses, their effects often reach the surface, shaking—and sometimes destroying—structures and noticeably changing the landscape. An earthquake can produce a tidal wave when it occurs under the ocean floor. Generally, large earthquakes cause more damage than small ones. The degree of damage also depends on location. Heavily populated areas, those with poorly constructed buildings, or ones with an unstable terrain tend to sustain far more damage than do unpopulated areas, cities with well-constructed buildings, or areas with a stable terrain. Earthquakes can deform the surface of Earth by forming long, linear structures called faults. The largest of these are seen easily from orbiting spacecraft. Look for them on the west coasts of North and South America in the film *Blue Planet*.

Craters: Making an Impact

The rude sea grew civil at her song,
and certain stars shot madly from their spheres,
to hear the sea-maid's music.
*—William Shakespeare**

Goal

To investigate how impact craters are formed.

Key Concepts

- Impact craters are formed when meteoroids collide with a planetary body.
- The energy of meteoroids depends on their mass and speed.
- High-energy meteoroids form larger craters than low-energy meteoroids.

Overview

Experience the thrill of a helicopter ride through Meteor Crater in Arizona while watching the film, *Blue Planet*. This crater was formed when a meteoroid collided with Earth. This lab exercise investigates some of the processes which are involved in forming impact craters and then looks at how weather might affect such craters.

Materials

- Plastic tray
- Sand
- Flour
- Strainer or sifter
- Meter sticks and centimeter rulers
- Spheres of three different weights**
- Empty spray bottles/plant misters
- Water
- Student worksheets: Craters: Data Tables I and II (page 27)

Procedure

a. Fill tray with sand to a depth of 5 cm (2 in) and smooth the surface.
b. Put flour in the strainer and shake it over the sand until the sand is covered with a thin layer of flour.
c. Drop the smallest sphere onto the tray of sand from a height of about two meters (six feet).

* Midsummer Night's Dream
** Marbles, ball bearings, and small balls work well.

d. Record the diameter and appearance of the crater on Craters: Data Table I (page 27).
e. With the two heavier spheres, repeat steps *c* and *d*.
f. Choose one of the spheres and drop it in turn from three different heights.
g. Record your observations on your data sheet.
h. Using an empty spray bottle, pump air across the rim of a crater.
i. Fill a spray bottle with water and spray some water onto the surface of the sand at another crater.

TO THE STUDENT

Observe

1. Complete the data charts.
2. Describe any changes in the appearances of the craters after adding wind or water.

Interpret

3. If the sand represents Earth's surface, what do the spheres represent?
4. What is the relationship between crater size and sphere weight?
5. When there is no wind resistance, a sphere dropped from a great height is moving faster at the time of impact than a sphere dropped from a lower height. What is the relationship between the crater size and the height from which a sphere is dropped?
6. What kinds of weather did you simulate in this lab exercise?

Apply

7. Research some pictures of impact craters on Earth and other planetary bodies. (Our moon, Mercury, and Mars are good choices.) Are all craters the same size? Relate your answer to what you discovered in this lab exercise.
8. What effect does weather have on the appearance of a crater on Earth?
9. The number of meteoroids that hit a planetary body depends mainly on the gravity of that body. Thus we can assume that Earth has intercepted as many meteoroids as any planetary body its size. Why then, are craters far more evident on Mercury and our moon than on Earth?

Glossary

Meteor—Bright streak in the sky that is seen when a meteoroid burns up in Earth's atmosphere (sometimes called a shooting star).

Meteorite—The stony material that has reached Earth's surface from outer space without burning up.
Meteoroid—Any one of the many small bodies that become a meteor or shooting star when it enters Earth's atmosphere.

Topics for Further Research

- Ejecta
- Crater
- Meteor

TO THE TEACHER

Students should be able to measure the diameters of craters accurately enough to clearly distinguish the different sizes. The depth of craters may be described qualitatively since this is harder to measure, and it is often difficult to remove a partially buried ball without destroying the crater.

The spheres represent meteoroids. When dropped from the same height, the lighter spheres produce smaller craters than do the heavier spheres. Heavier spheres make larger craters than do lighter ones because their larger mass gives them more energy. Chances are that lighter spheres will be smaller, but it is interesting to compare a lighter, larger ball with a heavier, smaller ball to demonstrate that the heavier ball makes the larger crater, regardless of size, when dropped from the same height as the lighter ball.

Any sphere produces larger craters when dropped from greater heights. All objects near Earth are accelerated equally by Earth's gravity. Therefore, when there is no wind resistance, spheres dropped from a greater height are moving faster at the time of impact than those dropped from a lower height. Faster spheres make larger craters than slower ones because their greater speed gives them greater energy.

Different-sized craters are easily seen on our moon—refer to a photograph, or use binoculars to see lunar craters on a clear night. Students should be able to conclude that size differences seen in lunar craters are the result of meteoroids with different weights and speeds of impact.

Craters should look weathered after the addition of simulated "wind" and "rain" and some may be completely obliterated. (On this small scale, using spray bottles more accurately portrays the effects of wind and rain than would using a fan or a watering can, but check this beforehand to see that the force of the spray is appropriate for the materials you are using.) Earth's weather tends to erase the features of a crater in a way similar to the processes in this experiment. Erosion due to weathering is a major reason that large craters are far less obvious on Earth than they are on the Moon and Mercury, which have no atmosphere and thus no weather. Also, Earth lacks impact craters because most meteoroids burn up in Earth's atmosphere before reaching its surface.

This activity models reality for the most part, but does have a few differences. The layer of flour shows how buried soil is exposed on impact. You may try using several thin layers of different colored materials, such as powdered tempera paint, to show more clearly how deep soil is ejected up and out on impact. Also, your students could make oblong craters if they threw their "meteoroids" to hit the sand at an angle. In reality, however, while low-angle meteoroids are common, oblong craters are rare. When meteoroids hit, they vaporize and the resulting explosion forms circular craters for most angles of entry. This can be demonstrated in a laboratory setting but requires that the balls be thrown at high speeds, using a slingshot or other tool. At high speeds, only projectiles coming in at very low angles (less than 15°) make oblong craters. This is very similar to what happens in real impact craters. The violent force of impacts also makes it rare to find even small portions of meteorites left in craters.

CRATERS: DATA TABLE I

WEIGHT OF SPHERE	CRATER DIAMETER	APPEARANCE OF CRATER
Light		
Medium		
Heavy		

CRATERS: DATA TABLE II

DISTANCE DROPPED	CRATER DIAMETER	APPEARANCE OF CRATER

Thunderclouds: Convection Connections

I wield the flail of the lashing hail,
And whiten the green plains under,
And then again I dissolve it in rain,
And laugh as I pass in thunder
*—Percy Bysshe Shelley**

Goal

To investigate convection and relate it to the formation of cold fronts.**

Key Concepts

- When a colder, denser mass of fluid contacts a warmer, less dense one, the resulting movement is predictable.
- Cold and warm masses of fluid do not usually mix immediately upon contact, but first form an invisible boundary called a front.

Overview

In the film, *Blue Planet*, many thunderclouds are seen from space. Thunderclouds often form along a cold front, which is the boundary between a cold air mass and a warm air mass. This activity illustrates convection, showing how cold and warm masses of fluids move when near each other. Although this model cannot create a miniature thunderstorm, it does generate a front between the warm and cold areas.

Materials

- Glass aquarium or clear plastic shoe box
- Plastic bag
- 4 - 5 ice cubes
- Warm water
- Red and blue food coloring
- Clothes pin or large clip
- Student worksheet: Convection Connections (page 31)
- Red and blue pencils
- Straight pin

* *The Cloud*
** This activity is based on an idea published in the Earth Science Teacher Resource Guide published by Virginia's Fairfax Country Public Schools. Used with permission.

Procedure

a. Fill the container two-thirds full with warm water.
b. Put the ice cubes in the plastic bag. Use the straight pin to punch five small holes in the bottom of the bag.
c. Gently place the bag of ice at one end of the container as shown in the previous diagram and clip it to the side of the container.
d. Immediately add three drops of blue food coloring to the water directly over the front edge of the bag of ice.
e. Quickly add three drops of red food coloring to the water at the opposite end of the container. Do not shake the table as you watch the colors move through the water.
f. Using the student worksheet provided, record your observations.

TO THE STUDENT

Observe

1. Use the red and blue pencils to illustrate what you see (1) as the colors begin to move, (2) when the colors are midway across the container, and (3) when the colors are at their maximum movement before blending. In each diagram label the cold water, warm water, and cold front.

Interpret

2. Why does the blue color move in the way it does?
3. What type of air mass does the blue area represent?
4. What type of air mass does the red area represent?

Apply

5. If this model illustrates a weather front, where would thunderclouds form?
6. Compare the temperature and moisture of a Canadian air mass to one that formed over the Gulf of Mexico. Describe the temperature changes, cloud formation, and weather that could result when these air masses meet.
7. Describe a thundercloud you observed in the film *Blue Planet*.

Glossary

Cold Front—The advancing edge of a mass of cold air as it overtakes, passes under and replaces a warmer one.

Topics for Further Research

- Convection currents

- Cumulonimbus clouds
- Cold front

TO THE TEACHER

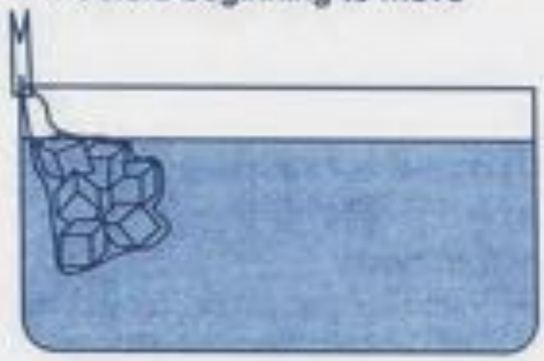
Your student's illustrations should look something like this:

The blue area moves along the bottom of the container because the cold water is denser and forces the warmer, less dense water to rise above it. If the blue area represents a cold air mass, the red area represents a warm air mass. Thunderclouds often form along the front or boundary between warm and cold air masses. An air mass from Canada is usually cold and dry; an air mass from the Gulf of Mexico is usually warm and moist. The cold air can wedge under warm air, forcing it upward. Often, as the warm, moist air rises, water vapor condenses and thunderclouds form. The weather is relatively warm ahead of the cold front. As the front passes, the weather often turns stormy and the temperatures drop. Occasionally, a line of active showers and thunderclouds, called a squall line, develops parallel to, and ahead of a fast-moving front. If the rising warm air is dry and stable, scattered clouds are all that form, and there is no resulting storm. Thunderclouds (cumulonimbus) have a big, puffy shape. They grow vertically, then spread out, forming their characteristic, flat-topped shape.

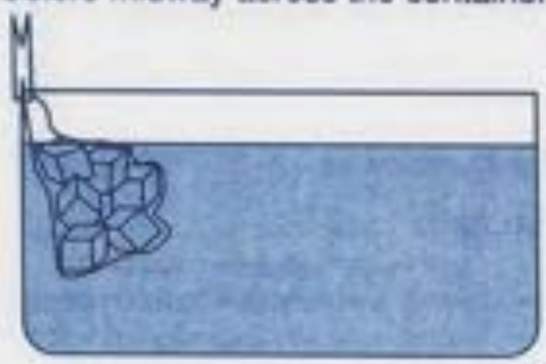
Student Worksheet

Convection Connections

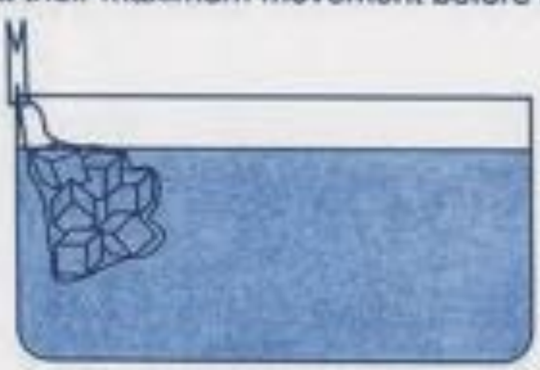
I. Colors beginning to move



II. Colors midway across the container



III. Colors at their maximum movement before blending



Tropical Rain Forests: Where Are They?

I should like to rise and go
Where the golden apples grow;
Where below another sky
Parrot islands anchored lie
*—Robert Louis Stevenson**

Goal

To understand the importance of the Sun in producing the warm climate needed for tropical rain forests.

Key Concepts

- Tropical rain forests grow only near the Equator.
- Earth's equatorial region is very warm.
- Direct rays from the Sun make Earth's equatorial region warmer than other regions.

Overview

Today, tropical forests cover about seven percent of Earth's land and form a green belt around the equator, ranging as far as 23° latitude to its north and south. Tropical rain forests have an average annual temperature of 27°C (80°F). This activity demonstrates visually how Earth's equatorial region receives more concentrated sunlight, which produces warmer temperatures.

Materials

- Light source from a slide projector
- Temperature-sensitive liquid crystal sheets
- Small ball—about 8 cm (3 in) diameter
- Globe of the world

Preparation

See the Resources section of this booklet (page 70) for ordering information for the temperature sensitive liquid crystal sheets. Sheets with a sensitivity range of 30°C to 36°C (86°F to 97°F) will work best and will need to be cut into strips about 2 cm by 30 cm (1 in by 12 in) by you or your students before starting. These are shiny plastic sheets, which together with a bright white ball, can produce undesirable glare. You may want to reduce this glare by painting the ball dull black and covering the liquid crystal sheet with non-glare, transparent adhesive tape.

* *Travel*

Procedure

a. Experiment with a piece of the liquid crystal sheet that you plan to use in this activity. What color indicates the warmest temperature? What color indicates the coolest temperature? What are the in-between colors?

b. Wrap the strip thermometer around the circumference of the ball and tape it in place.

c. Turn on the slide projector. (Do not look directly into the light source.)

d. Hold the ball, about 30 cm (12 in) from the lens, within the beam of light. Position the ball so that the temperature strip is vertical.

Nearly parallel rays of light from slide projector

e. Hold the ball in the light beam for 2 to 3 minutes.

TO THE STUDENT

Observe

1. Describe your observations, using diagrams if you wish.
2. Did the ball heat uniformly? Discuss.

Interpret

3. What do the ball and lamp represent in the real world?
4. Draw latitude and longitude lines on a diagram of the ball.

Apply

5. Which areas of Earth receive the most direct sunlight?
6. Which areas of Earth receive the most oblique sunlight?
7. Why do tropical rain forests grow near Earth's equator?

Glossary

Rain Forest—Large, very dense forest, usually in the tropics, where annual rainfall is 100 in or more.

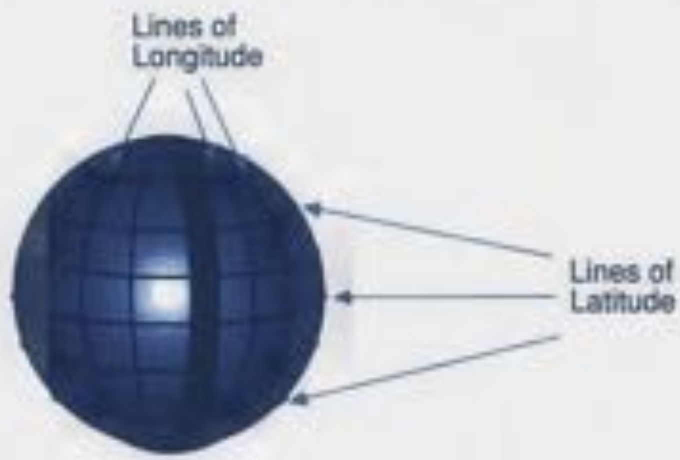
Tropical—Refers to region between the Tropic of Cancer and the Tropic of Capricorn (23.45° latitude north and south). The climate in this region is very warm except at high altitudes.

Topics for Further Research

- Threats to the rain forests: logging, farming, cattle ranching, development.
- Rain forest products: rubber, tubocurarine (a medicinal drug), mahogany, chocolate, nuts.
- Indigenous peoples of the rain forests: the Efe of Zaire; the Kayapo of Brazil, the Lua' of Thailand.

TO THE TEACHER

After about two minutes, the results of this experiment should be clearly visible; the strip of liquid crystal sheet should turn colors, forming a bright spot in the center of the ball where the light energy is most intense, surrounded by bands of other colors which indicate cooler temperatures. The ball, like Earth, does not heat uniformly. (Earth's rotation elongates this hot temperature spot into a band at the equator.) The lamp represents the Sun and the ball represents Earth. Latitude and longitude lines drawn on the ball would look something like this:



Equatorial regions of Earth receive the most direct sunlight, and polar regions receive the most oblique sunlight. Direct sunlight is more concentrated (i.e., more light energy per square centimeter) than oblique sunlight and produces warmer temperatures. Tropical rain forests require warm temperatures, thus they grow near the Equator where it is warm year-round.

Changing Environments

Peace! And the settlers flocked anew,
The farm lands spread, and the town lands grew;
But Daniel Boone was ill at ease
When he saw the smoke in his forest trees.
*—Arthur Guiterman**

Goal

To depict an environment that has changed over time.

Key Concepts

- Environments can change over time.
- These changes can occur over different time frames.
- These changes may result from natural or manmade causes.

Overview

Earth's environment is shaped and changed by many forces; some, such as earthquakes, volcanoes, and violent storms, change the landscape quickly, while others, such as erosion and ecological succession are more subtle. People have always changed their local environments, but now increasing evidence indicates that human activities are shaping Earth's environment on a global scale. In this activity students illustrate before and after views of environments that have changed, then identify and classify the particular agent of change.

Materials

- Plain paper
- Marking pens or crayons
- Materials for collage (yarn, felt, etc.)

Procedure

a. Read the following out loud:

Environments can change over time. Have you ever seen an area that used to be grassy or wooded but is now covered with houses or shopping centers? Do you know of an abandoned parking lot or apartment building overgrown with weeds? Have you ever visited a lake made by a dam that blocks a river? Imagine exploring a dried-up riverbed or finding a marine fossil far away from the ocean. These are all examples of environments that have changed.

b. Think of a local, national, or global environment that has changed.

c. Use art materials to create a before-and-after representation of this environment. Try to be as imaginative as possible, using a

* Daniel Boone

variety of materials to create drawings, collages or dioramas.

TO THE STUDENT

1. Was the environment you illustrated changed by nature, or by people?
2. Did the change happen quickly or slowly?
3. Do you think that the change will be permanent or temporary?
4. Did the change affect anything beyond the immediate environment?
5. Would you classify the change as a negative or a positive one? Who might disagree with you on this?
6. Earth is a group of many interacting environments. What environmental changes could affect life all over Earth?

Glossary

Ecological Succession—A progressive series of changes that slowly returns an area to its original state; for example, an abandoned farm can become a hardwood forest in a century or two.

Topics for Further Research

- Environmental Impact Statement
- Desertification
- American Painter, Thomas Moran (1837–1926)

TO THE TEACHER

No doubt, students will list a wide variety of environmental changes, but they should be able to classify them according to origin, natural or manmade; time frame, long or short; permanence, temporary or persistent. The question on permanence is quite subjective. Keep in mind that few changes really last forever but might be considered permanent by the student if they last for more than a generation. An example of a local change with wider implications is ...*waterfowl no longer migrate to nest and reproduce in an environment where the marsh has been filled in to build waterfront houses*, or ...*the apartment complex was no longer safe to live in due to the rat and termite infestation.* Discussing question 6 is a good way to bring out many current environmental issues such as oil spills, destruction of temperate and tropical forests, and dumping of trash in the oceans or in space. Try to compare these with long-term natural changes that are documented in Earth's geological record. Further information can be found in the library.

Responsive Systems

Man is a complex being:
he makes deserts bloom—
and lakes die.
—Gil Stern

Goal

To realize that living systems respond to stimuli.

Key Concepts

- Earth's environment is responsive.
- Responses depend upon time frame and magnitude of the disturbance.
- Short-term benefits often come with long-term consequences.

Overview

Earth's environment responds to and assimilates much of our organic waste. This activity focuses on that response and then asks whether all such responses are beneficial. Students set up an aquatic ecosystem which they then pollute using small amounts of household ammonia. Students collect data using chemical analysis for up to 5 weeks.

Please note: This activity only deals with organic pollutants which can be assimilated by the environment. Two other categories of pollutants are not investigated here. They are (1) harmful chemicals such as nuclear wastes, industrial wastes, and crude oil, and (2) so-called inert substances such as glass and many plastics which are considered undesirable because they tie up resources and, under certain circumstances, may leach toxic substances.

Materials

For each setup you will need:

- Ammonia, nitrite, and nitrate test kits.* Enough for 10 tests each.
- Container, approximately 1 liter (1 quart) capacity
- Clear household ammonia (not scented or sudsing)
- Aquatic plants
- Fish gravel/small stones
- Sunlight (or other light source)
- Distilled water**
- Responsive Systems Data Chart (page 41)

Procedure

a. Set up your aquatic system as shown in diagram.
b. Add 10 drops of household ammonia per liter (quart) of water

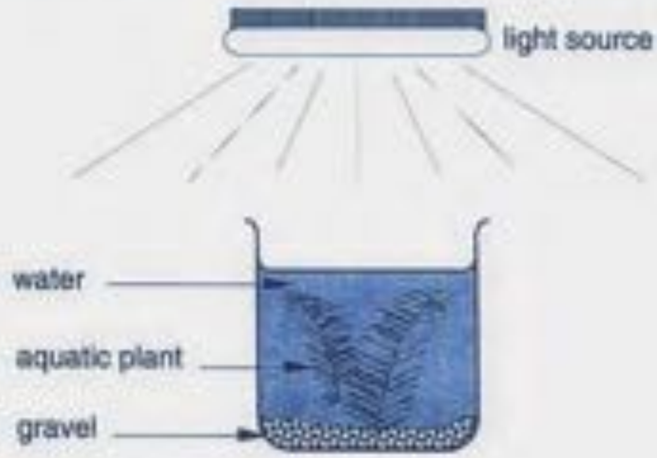
---

* These are available from most aquarium supply or pet shops.

** Tap water typically has a nitrate level of 2 to 5 parts per million which may be a problem depending on the sensitivity of your nitrate analysis kit.

and stir.*

c. Measure the ammonia, nitrite, and nitrate concentrations in the water using test kits.



d. Record all results using the data chart provided.

e. Test water regularly, about once every day for a week and then once a week for the next four weeks. (Keep the water level constant by adding more distilled water when necessary).

TO THE STUDENT

Observe

1. What changes in the ammonia level did you record?
2. What changes in the nitrite level did you record?
3. What changes in the nitrate level did you record?

Interpret

4. How much ammonia was used compared to the amount of water polluted?
5. Did this amount of pollution "ruin" the ecosystem?

Apply

6. What would happen if you added too much ammonia to this system?
7. What environmental pollutants are similar in composition to the

* This should produce an ammonia concentration of about 5 parts per million. If this ammonia concentration cannot be measured easily by your chemical test kit, you will need to adjust the number of drops of ammonia that you add.

ammonia in this experiment? Do they affect the environment in similar ways?

8. Probably the most visible result of this experiment is increased plant growth. Is this always a good thing? Discuss.
9. Polluting the water in this experiment is comparable to dumping sewage in a lake. Is this a logical way to dispose of wastes? Discuss.
10. You added a substance that, in reasonable amounts, plants and bacteria can break down. Name some pollutants that are not easily broken down. What happens when these kinds of pollutants are added?
11. Your experiment "recovered" from an ammonia level of 5 parts per million. Design an experiment to determine this system's tolerance level of ammonia.

Glossary

Ammonia—A strong smelling, colorless gas composed of nitrogen and hydrogen atoms. Ammonia dissolves easily in water and the resulting product, ammonia water or household ammonia, is used for cleaning.

Bacteria—Very tiny, simple plants which can usually be seen only through a microscope.

Ecosystem—A natural neighborhood consisting of living organisms, their physical environment, and the relationship between them.

Nitrate—A substance containing the chemical formula $-NO_3$; for example, potassium nitrate is used to fertilize crops.

Nitrite—A substance containing the chemical formula $-NO_2$; for example, sodium nitrite is used as a food preservative.

Topics for Further Research

- Eutrophication
- Limnology
- Sewage treatment facility

TO THE TEACHER

Initially, the ammonia concentration measures about 5 parts per million, with nitrite and nitrate levels at zero (sudsing ammonia may contain nitrates). In a few days, the nitrite level increases dramatically, followed by an increase in the nitrate concentration. Then, the ammonia concentration decreases, followed by a decrease in nitrites and finally in nitrates. If you run the experiment long enough (for three to five weeks), the levels of all chemicals should drop to zero, provided the plants remain healthy. Plants should grow noticeably and may look greener. The chemistry is as follows: (1) Plants can absorb some ammonia, but most is converted to nitrites by bacteria, (2) Bacteria convert the nitrites to nitrates, (3) Plants absorb the nitrates. The gravel dramatically increases the surface area, encouraging bacteria growth. The bacteria are the key players in this experiment (not the green plants).

In this experiment, the number of drops of household, ammonia compared to the number of drops of water to which it was added, is at least 1 to 10,000. (Note: 5 parts per million is a measure of the amount of pure ammonia in the water. Household ammonia is mainly water, which explains why the pollution ratio is only 1:10,000.) This small amount is enough to stimulate plant growth but not enough to ruin your ecosystem.

Like ammonia, commercial fertilizer, sewage and yard wastes are nitrogen-based pollutants. They affect the environment in similar ways, causing algae and green plants to grow in lakes and streams. As plants die, they decay. This uses oxygen and releases substances which again stimulate plant growth. As more and more plants die and decay, oxygen levels in the lake decrease, and the type of fish that is able to live there changes. This natural chain of events is greatly accelerated by organic pollution. Increased plant growth in aquatic systems can also choke waterways and pipes. Dumping pollution in open lakes is not a logical way to dispose of it. Even though lakes can recover from small amounts of organic pollution (similar to what happened in this experiment), they usually also undergo problematic changes associated with the increased plant growth. If pollution levels are too high for a system, plants and animals will die. See the "overview" section of this activity where question 10 is addressed. Students' experimental design will vary.

Recommendations: Do not make up the weak ammonia solution ahead of time as this will seriously affect your results. Elodea is a good choice of plants since it is hardy and easily obtained. Good lighting is *crucial*. Sunlight or fluorescent light is better than incandescent light, which does not emit enough blue light for these plants to photosynthesize efficiently. We recommend using chemical analysis kits designed for fresh water aquaria since kits for saltwater are too sensitive. Control setups don't work well because bacteria may start growing and produce similar results!

Allow the ability level of students to determine the method of data collection. Gather qualitative data by noting color changes during the chemical analysis; gather quantitative data by recording the numeric values that colors represent. Students can graph the results.

Responsive Systems Data Chart

Date of Sampling	Ammonia	Nitrite	Nitrate

Who Wins When the World Changes?

Ask for what end the heavenly bodies shine,
Earth for whose use? Pride answers, "'Tis for mine."
*—Alexander Pope**

Goal

To help create an awareness of cultural diversity.

Key Concepts

- Literature and language reflect attitudes and reveal cultural beliefs.
- Most global issues are extremely complex and involve many points of view.

Overview

The goal of the film *Blue Planet* is to increase peoples' awareness of current environmental issues. A great deal of debate surrounds most of these global issues. Even well-respected scientists and scholars do not agree as to the causes and solutions. This activity should help students appreciate the complexity involved as they grapple with current global issues after examining authentic text and historical evidence.

TO THE STUDENT

Observe

1. What does it mean to have a *point of view?*
2. How does our point of view affect our actions? List three historical or personal examples.
3. Read the following excerpt out loud.

   We did not think of the great open plains, the beautiful rolling hills and winding streams with tangled growth as wild. Only to the white men was nature a wilderness and only to him was the land infested with wild animals and savage people. To us it was tame. Earth was bountiful and we were surrounded with the blessings of the Great Mystery. Not until the hairy men of the East came and with brutal frenzy heaped injustices upon us and the families we loved was it wild for us. When the very animals of the forest began fleeing from his approach, it was then for us the wild west began.

   Chief Luther Standing Bear, Oglala Sioux

* *An Essay On Man*

4. Whose point of view is being discussed here? Whose point of view is left out? Refer to your previous discussion.

Interpret

5. What is meant by savage?
6. What is meant by civilized?
7. Who decides which is which?
8. Can civilization be mistaken for savagery? If that happens, are the results potentially destructive? Discuss.

Apply

9. Write or give a short oral presentation about a personal example of meeting someone with an opposing point of view. Can you put yourself in the other's place? How did this experience change your views?
10. Identify the various points of view involved in one of the following global topics: deforestation, production of hazardous wastes, use of land/water/air, waste disposal. Are there more than two points of view involved in any topic? Why can you identify with some points of view better than others?

Glossary

Deforestation—The removal of trees or forest from the land.

Hazardous Wastes—Any waste material perilous to health, producing permanent, damaging effects.

Topics for Further Research

- Deforestation
- Hazardous wastes
- Pelican Island, Florida (first U.S. wildlife sanctuary)

TO THE TEACHER

The global issues addressed in this activity are complex and involve many points of view. For instance, to seriously look at the issue of deforestation we must consider the points of view represented by farming, logging, cattle ranching, needs of a growing population, scientific research, and conservation. People involved in these areas will differ from each other in their points of view. Encourage your students to research each of these areas. Consider having a class debate on one global issue using various points of view.

Night Lights

And rise, O moon, from yonder down,
Till over down and over dale
All night the shining vapor sail
And pass the silent-lighted town.
*—Alfred, Lord Tennyson**

Goal

To develop observational and interpretive skills by using satellite imagery.

Key Concepts

- Fires and city lights can be seen from Earth orbit.
- Seeing Earth from orbit changes our perspective.
- Excessive city lights greatly limit what we can see in the night sky.

Overview

Students can gain a new appreciation for geography by examining night imagery from satellites. Movies cameras make pictures that are quite different from those made by satellite cameras. The satellite images in the film *Blue Planet*, including the image of Earth at night, were originally taken by satellite cameras and subsequently filmed by the IMAX camera. The pictures included for use in this activity are reproductions of satellite images.

Materials

- Satellite images of the United States and the World (pages 47, 48)
- World and U.S. reference maps

Procedure

Study the satellite images, and discuss the following questions. Use maps only as a last resort!

TO THE STUDENT

Observe

1. Look closely at the dots of light on the study prints. Describe their various shapes and sizes.
2. Locate large areas of blackness. What could they be?
3. Try to identify some of the largest dots of light.

* *Epilogue*

4. Is your hometown's location bright or dark? Discuss.

Interpret

5. Are all of the dots of light cities? Explain.
6. Why can't you see clouds in these pictures?
7. The pictures are actually photomosaics; that is, one picture made from many pictures that fit together like a puzzle. Why was this technique used to make these pictures?
8. Could all of the pictures have been taken during one orbit?
9. Identify dots of light that are probably fires. (Consider the time of year that fires are likely to be prevalent. These mosaics are made from pictures taken during November to February.)

Apply

10. Where would you choose to build an astronomical observatory? Why?
11. Which countries are well outlined by lights? Why?
12. How would either view have looked 100 years ago? What might it look like 100 years from now?
13. Could you use these data to estimate population density? Why or why not?

Glossary

Astronomical Observatory—A building equipped with telescopes and designed for observing celestial bodies.

Geostationary—Description of an Earth orbit in which a satellite is revolving at the same rate as Earth rotates and therefore appears to be stationary when observed from Earth. Only satellites in a circular, equatorial orbit and at an altitude of 35,784 km (22,222 mi) can be geostationary.

Photomosaic—A group of aerial photographs put together to form a continuous photograph of an area.

Topics for Further Research

- Light pollution
- Human geography
- Low-pressure sodium lamps

TO THE TEACHER

The dots of light on this print can be grouped into three main categories: city lights, vegetation fires, and gas burn-offs in oil fields. The brightness and proximity of lights to each other determines their shapes and sizes. Also, the camera that took these pictures is extremely sensitive, and overexposes the very bright lights. Rain forests and deserts are remarkable for their absence of lights. The lights seen in these areas are probably fires.

This picture is made from numerous images placed side by side like a jigsaw puzzle. Researchers use the best and discard any that are blurry or obscured by cloud cover; these mosaics are based on images taken over a ten-year period. This picture could not be made during one orbit because typical satellites (except for geostationary ones) orbit Earth more than once a day. This means that it is night on only part of Earth during one satellite orbit. Geostationary satellites orbit over a fixed position above the equator and therefore can image only the area directly below them. The camera's field of view presents another limitation: the weather satellite that took these images scans a pole-to-pole swath of Earth 3000 km (1860 mi) wide on each orbit.

Fires appear in this image as fine dot-like specks; note East Africa (images taken in September) and the highlands of Southeast Asia (images taken in February). The Amazon and Congo Basins are also ablaze during their dry seasons, but not in the image here. In general, however, slash-and-burn fires do not show up well in night satellite images since they tend to occur during the day and their smoke obscures them. This practice requires large amounts of land and is therefore rarely employed in densely populated areas.

Large, bright dots in oil-rich areas of the world are probably gas burn-offs; however, only some oil fields employ this practice so that not all oil fields are seen easily from space.

From a large city, you can see only the brightest meteors (shooting stars) and a few hundred stars. Compare that to the countryside where, with the naked eye, you can typically distinguish the Milky Way and see about 2000 stars. Ideally, you want to build astronomical observatories in areas with very little light pollution, though in reality this leads you to remote regions. Historically, civilizations settled near rivers and oceans since water was an important means of transportation. Thus many countries that have river or ocean borders are well outlined by lights. No doubt this phenomenon would have been even more obvious 100 years ago. At that time there would have been far less city lighting and probably more vegetation fires.

Is it possible to predict the next 100 years? Will we become more energy conscious? Will we lose major energy sources and be unable to light up the night? Your students should be able to explain their predictions. This image could not be used to accurately estimate population; some of the brightest lights occur from gas burn-offs and from the lights used by night fishing fleets. Some countries employ more efficient lighting practices than others (compare France with England), some are more energy conserving, and others have fewer resources (for example, the United States uses 75 times as much electricity per capita as does India).

Solar Heating

And now the sun had stretched out all the hills,
And now was dropped into the western bay;
At last he rose, and twitched his mantle blue:
Tomorrow to fresh woods, and pastures new.
—John Milton*

Goal

To observe heating due to solar energy.

Key Concepts

- The Sun heats Earth.
- Various surfaces and substances can affect the degree of solar heating.

Overview

Student groups investigate solar heating by putting several boxes in sunlight (or near light bulbs) with thermometers inside. Then they record the temperature inside the box over a period of several hours to investigate how effectively each box absorbs the Sun's energy. Experimental design is changed and investigated throughout this open-ended activity.

Materials

- Shoe boxes
- Clear plastic wrap
- Thermometers (small enough to fit into shoe boxes)
- Black construction paper, aluminum foil, and masking tape
- Lamps with incandescent bulbs, if sunlight is unavailable.

Procedure

Place a thermometer inside an empty shoe box and try one or more of the following:

- Cover the box with clear plastic wrap.
- Line the box with black construction paper or aluminum foil.
- Tilt the boxes toward or away from the light.
- Place the boxes in sunlight or near a light bulb.
- Place the boxes in a dark area (to simulate night).

Observe how the temperature changes during your different experiments. Investigate your own ideas. Try making comparisons by setting up the experiments in pairs: one in the Sun, one in the shade; one box covered with foil, one covered with clear plastic wrap, and so on.

* *Lycidas*

TO THE STUDENT

1. What happens if we wear dark clothing on a sunny day?
2. How could we use solar energy most effectively to heat homes?
3. How is Earth like a greenhouse?

Glossary

Greenhouse Effect—The absorption and retention of the Sun's radiation in Earth's atmosphere, resulting in higher temperatures.

Solar—Having to do with the Sun.

Topics for Further Research

- Radiant energy
- Passive solar heating
- Greenhouse effect

TO THE TEACHER

We recommend stressing the investigative processes in this open-ended activity, rather than trying to draw conclusions. Keep in mind that the concept of a controlled experiment is hard for most children to understand before the junior high years.

Dark clothing absorbs a lot of the Sun's radiation while white clothing reflects more, thus we generally feel warmer when we wear dark clothing. Houses are best warmed by the Sun when sunlight shines directly through the windows and is not blocked by overhanging eaves or nearby trees. Ideally the rays of the Sun will warm up stone or brick inside the house which will store heat and release it slowly at night. Keeping windows closed helps to trap the heat inside. It's hot inside a greenhouse on a sunny day because the heat is trapped inside. When sunlight streaming through the glass of a greenhouse strikes a surface, light energy changes to heat energy which is then trapped by the glass. The Sun heats Earth in a similar way. Earth's atmosphere, like glass, lets light through but holds heat in.

Groundwater Filtration Model

Water, water everywhere,
Nor any drop to drink.
*—Samuel Taylor Coleridge**

Goal

To demonstrate the natural water filtration properties of Earth's rock layers.**

Key Concepts

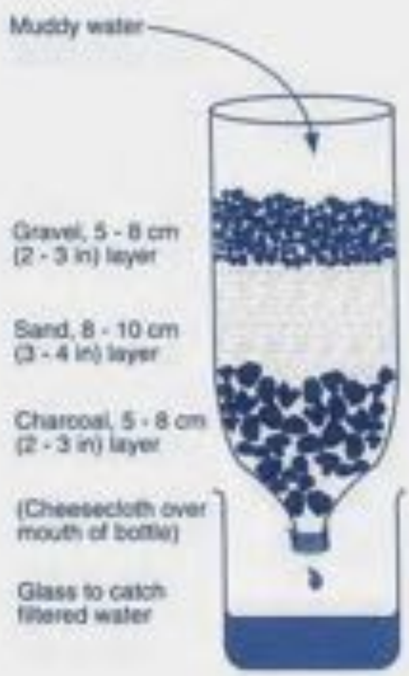
- Earth's rock layers filter water as it passes through them.
- Earth's filtration properties are limited.
- Earth's filtration processes can reach a saturation point.

Overview

Underground water is usually cleaner than water found on the surface of Earth. Only part of our rain stays on Earth's surface in rivers, lakes, and streams. Much of it percolates down through layers of soil and rock to become groundwater. Earth's different rock layers filter out pollutants as the water passes through. This activity demonstrates some of the filtering processes of Earth and, like Earth, it cannot filter out oil, petroleum products, or dissolved chemicals.

Materials

- Clear plastic bottle
- Gravel
- Sand
- Charcoal
- Cheesecloth
- Muddy water
- Food coloring (optional)



Preparation

Collect muddy water from a stream or make your own. Flour and clay soil make good pollutants.

* *The Rime Of The Ancient Mariner*
** This activity is based on an idea published in *The Waste Case*, a curriculum guide published by the Buhl Science Center. Used with permission.

Procedure

a. Cut the bottom out of a plastic bottle as shown in the diagram.
b. Place a piece of cheesecloth over the mouth of the bottle and secure it with a rubber band. This holds the charcoal in the bottle; it has no significant filtration properties.
c. Invert the bottle and fill according to the diagram.
d. Place a glass under the neck of the bottle to catch the water as it drains.
e. Pour muddy water into the bottle and wait for it to drain through the bottle.

   CAUTION: *This is only a model to help you visualize Earth's filtration process. The water may still contain invisible, but harmful, pollutants after filtering and will not be pure enough to drink. Complex processes are needed to purify water further.*

TO THE STUDENT

Observe

1. Write a brief paragraph describing your observations.

Interpret

2. How is your model similar to Earth?
3. How is your model different from Earth?
4. Where does the pollution go?
5. Does your model have a saturation point? Investigate this and discuss how this might relate to Earth?
6. Why is the order of layers important?

Apply

7. Are all water pollutants visible? Discuss.
8. Repeat procedure step *e* using water that has been "polluted" with food coloring. Compare the filtration of the muddy water and the colored water and relate your findings to the real world.
9. What factors affect Earth's water-purifying properties?
10. Do some research to find out where your town's water supply originates. Is it from a lake, a reservoir, groundwater, or another source.

Glossary

Groundwater—Water beneath Earth's surface, especially water that seeps downward and saturates the soil.

Topics for Further Research

- Water purification
- Waste disposal and city planning
- Groundwater

TO THE TEACHER

While student observations will vary, they should each note that the dirty water poured into the top of the apparatus comes out clear at the bottom. This model simulates Earth's various layers, but in actuality, these differ in structure from region to region. (This model takes only a few centimeters to simulate hundreds of meters of rock and soil, thus the use of charcoal, which is not a common rock layer.) Most visible pollutants stay in the rock layers. Organic pollutants tend to decay; inorganic chemicals may remain lodged in rock layers for long periods of time. The model reaches its saturation point when the water at the bottom comes out dirty. In this model, the coarse top layers filter out larger particles and the lower layers catch increasingly smaller pollutants. Many dissolved pollutants are invisible or transparent and, like the food coloring, cannot be removed by simple filtering. A number of factors affect Earth's capability to filter pollutants: three such factors are the amount, the concentration, and the toxicity of pollutants.

DO NOT DRINK *the water from this model; some of the most harmful pollutants dissolve in water and cannot be seen.*

Monitoring Ozone from Your Classroom

The machine does not isolate man
from the great problems of nature
but plunges him more deeply into them.
*—Antoine de Saint Exupery**

Section I

When Does the Ozone Hole Appear?

Goal

To determine the time of year that the ozone hole is most apparent, by using actual data.

Key Concepts

- The ozone hole is only apparent during certain months.
- Although the term ozone "hole" is widely used in popular and scientific literature, the phenomenon is more correctly described as a low concentration of ozone.

Overview

Students construct a graph using raw data obtained from orbiting satellites to determine the time of year that the ozone hole is most apparent. Students also gain experience with managing a large amount of data.

Materials

- Data table: Ozone Concentration For Latitudes 90°S to 30°S, 1987 (pages 61 and 62)
- Graph paper

Procedure

Referring to the data in the Ozone Concentration data table:

a. Determine scale for each axis; plot OZONE CONCENTRATION (Dobson Units/DU) on the vertical axis and TIME (days) along the horizontal axis.
b. Using these data and the graph paper, construct a graph showing the relationship between ozone concentration and day of the year.
c. Label the months on your graph, correlating numbers with dates. ***NOTE:*** *There are a lot of data here. You may want to treat them in one of the following ways: (1) plot only every tenth day, (2) average every 10 days' worth of data and plot this average value, (3) plot a small portion of data, then*

* *Wind, Sand And Stars*

combine your efforts with classmates' work to produce one large graph. Be sure to use a constant scale.

TO THE STUDENT

Observe

1. When is the ozone concentration lowest? Give month and season.
2. When is the ozone concentration highest? Give month and season.

Interpret

3. Do you need to plot each day's Dobson Units? Explain.
4. How is the ozone level related to the time of year?
5. Which is the best description of a low number of Dobson Units?
   a. An area of no ozone
   b. An area of low concentration of ozone molecules
   c. An area of high concentration of ozone molecules
6. Would you describe this phenomenon as a "hole"? Why or why not?

Apply

7. Why do you think the ozone level begins to decrease when it does?
8. What is the value of using an entire class to analyze these data?

Section II

Have Antarctic Ozone Levels Changed in Ten Years?

Goal

Students will generate and interpret false color plots of ozone depletion in Antarctica over a ten-year period.

Key Concepts

- Ozone concentrations over Antarctica have changed in the last ten years.
- Using color to represent data simplifies data interpretation.

Overview

Ozone plots published in newspapers and magazines may be familiar to you, but do you understand them? In this activity students generate and interpret such plots to gain a better understanding of ozone depletion in Antarctica. This exercise models current science by using color codes to facilitate data interpretation.

Materials

- Ozone plots: Total Ozone Monthly Mean, October 1980-1989 (pages 65–69)
- Ozone plot: Antarctica: South Polar Plot (page 63)
- Colored pencils - 16 different colors

Preparation

Line drawings may be enlarged on a copying machine—enlarging 150 percent will put one plot horizontally on a standard page. The line drawing, Antarctica: South Polar Plot, can be made into a transparency and superimposed over plots to provide geographical information. Divide your class and generate a few series of plots to save time.

Note: *Each series may have a different color key but the color key must be the same within a series.*

Procedure

Working in student groups:

a. Determine color values for the Dobson Unit ranges. (Technicians utilize computers to assign specific colors to specific ranges of Dobson Units. For example, values 100–124 may be yellow; 125–149 may be orange, and so on.)

b. Color the key on each of the ten plots, using your chosen colors.

c. Color each plot, using your color key to guide you.

Note: *Some plots may show only a few of the colors from their keys.*

TO THE STUDENT

Observe

1. List the value and year for the lowest ozone concentration in these data.
2. Describe the geographic location of the ozone hole.

Interpret

3. Describe the general trend of ozone values from 1980 to 1989.
4. Does the ozone always drop from year to year?
5. Why are ten years of data better than two?

Apply

6. Should we make hundred-year predictions using ten years of data? Discuss.
7. How would a plot for a specific day differ from a monthly mean plot? Why interpret monthly mean plots versus daily plots?
8. Collect pictures of ozone plots from magazines and newspapers. Compare these plots with ones you generated in this experiment.
9. If your class produced more than one series of plots with different color keys, compare these keys. Which are the easiest to understand? Which do the best job of depicting the data?

Glossary

Austral—Southern, or having to do with the southern hemisphere.

Chlorofluorocarbon (CFC)—A compound containing carbon, chlorine and fluorine atoms; an example is Freon™, used in air conditioners and refrigerators.

Dobson Unit—A measurement of the thickness of the ozone layer, by an equivalent layer of pure ozone gas at normal temperature and pressure at sea level. In other words, 100 DU = 1 mm of pure ozone gas at normal temperature and pressure at sea level.

Ozone—A form of oxygen produced by energy from ultraviolet radiation or electricity such as lightning. When present in the air in higher concentrations than normal, it can be detected by its sharp pungent odor, which resembles weak chlorine.

Polar Night—The period of total darkness during the winter months that occurs at both of Earth's polar regions.

Ultraviolet Rays—The invisible rays in the part of the spectrum beyond violet. The wavelength of ultraviolet rays is shorter than those of visible violet and longer than those of x-rays.

Topics for Further Research

- *Nimbus-7* satellite
- SSBUV (Shuttle Solar Backscatter Ultraviolet) instrument
- Chlorofluorocarbon

More Ideas:

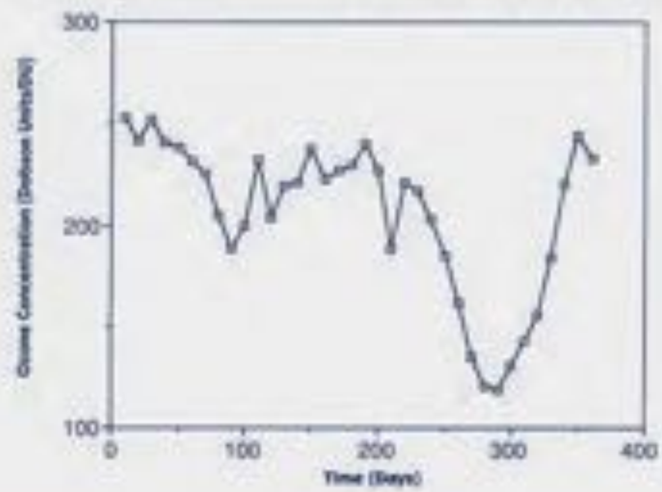
- Color code and interpret the seasonal plots provided (January, April, July, October 1987).
- Research ozone changes according to latitude.
- Research ozone measuring techniques prior to 1980.
- Compare Arctic and Antarctic ozone levels.
- Update these experiments by researching current ozone values.

TO THE TEACHER

Section I: According to these data, the ozone reaches its lowest values in October, which is spring in the Southern Hemisphere. The highest concentrations of ozone occur over Antarctica in January, mid-austral summer.

Student graphs should look something like the one below:

OZONE CONCENTRATION FOR LATITUDES 90°S to 30°S, 1987



Sometimes too much data confuse rather than clarify an issue. This activity focuses on trends, thus it is not necessary to plot each day's Dobson Units. The ozone levels are fairly consistent throughout the year, with a noticeable drop in September and October. Low readings of ozone mean there are fewer ozone molecules in that particular area. The ozone hole is more aptly described as a low concentration, since to date there have been no recorded readings of zero for ozone.

Ozone concentration is lowest in the spring, following the cold winter. Scientific studies link ozone level to atmospheric temperature. Students can benefit from each others' work, accomplishing more as a class than they could individually. Before scientists had wide access to super-computers, they often employed rooms full of people using calculators to manage large amounts of data.

Section II: The measurements for 1987 and 1989 are equally low at 125 DU. The greatest ozone depression is primarily over the Antarctic continent. Using ten years of data, the general downward trend of ozone levels is quite obvious, but would not be clear with only two years of data (note: 1987 and 1988).

We have not been collecting satellite data long enough to yield statistically accurate, long-term predictions, and must, therefore, incorporate data from ground-based ozone-monitoring equipment as well. More data are usually preferred and generally yield better (more reliable) results than less data. Data sets, both small and large, must be subjected to sophisticated statistical analysis to test their reliability. Daily plots are more complex and show far more detail. Monthly average plots are easier to interpret because the plots are simpler, without the extremes. Collected ozone plots should look similar to the ones your class generates. The color keys will differ since these are nonstandard and dependent upon individual scientists. Color keys are often based on the visible spectrum, or rainbow, and range from light to dark for high to low values. You will note larger differences if you collect a daily plot, which will look far more complex for reasons described previously. (Color keys are a matter of personal preference, though some communicate better than others.) Students should be able to support their conclusions.

What's the Science? The large, rapid, and unexpected decrease in the amount of springtime Antarctic ozone over the last decade cannot be attributed to known natural processes. Although there is increasing evidence that present-day pollution plays a major role in this, scientists do not, at this time, have a model that adequately simulates the chemistry or weather conditions that accompany ozone depletion. The following paragraphs outline our current understanding of ozone chemistry.

As sunlight strikes the upper atmosphere, oxygen molecules react to form ozone.* The resulting ozone concentration is rather small but it has a very important effect. The ozone gas absorbs much of the Sun's ultraviolet radiation,** which would harm life on Earth in excessive amounts. As ozone absorbs ultraviolet light energy, the temperature of the sur-

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* A molecule of ozone consists of three atoms of oxygen bonded together.

** A component of sunlight

rounding air increases. This warmer air does not mix with the cooler air beneath it, confining the majority of the ozone gas to the stratosphere (approximate altitude 25 km or 15 mi).

Ozone may remain in the atmosphere or decompose back to oxygen. Two things seem to speed up the natural process of ozone destruction: (1) the presence of pollutants such as oxides of nitrogen and chlorofluorocarbons (CFCs) which catalyze* the reaction, and (2) the presence of polar stratospheric clouds, which provide aerosol surfaces needed for the catalyzed reaction. Also, certain weather conditions, such as sunlight and extremely cold temperatures, are necessary for the accelerated ozone loss. Winds, high in the atmosphere above the South Pole, create a stable vortex** that concentrates the cold, and thus the ozone destruction. The resulting severe depletion of ozone is localized above Antarctica and is generally referred to as the ozone hole.

The ozone hole appears in the austral spring, following the continent's coldest season and polar night. Ozone depletion over the Arctic is not as well defined as in Antarctica. The relatively warmer northern climate, different distribution of landmasses, and lack of a stable windy vortex are thought to be reasons for this.

The ozone hole cannot be seen by the human eye, but must be measured by special instruments. Since 1978, the Total Ozone Mapping Spectrometer (TOMS), an instrument aboard the *Nimbus-7* satellite, has been observing ozone levels by measuring ultraviolet radiation that is backscattered by the atmosphere or reflected from Earth's surface.

TOMS measures the total ozone from the ground to an altitude of 50 km. Each section of the flat ozone plots, generated in this activity, represents a column of atmosphere thousands of meters thick. TOMS measures ozone values from above for the entire depth of the atmosphere. Since this type of ozone mapping requires sunlight, measurements cannot be made at night or in polar areas during their season of 24-hour darkness (polar night). Although TOMS collects ozone data for the entire planet, the data in these lab exercises are only from the Southern Hemisphere. The Shuttle Solar Backscatter Ultraviolet instrument, flown on various Shuttle missions, including STS-34, assists scientists in calibrating TOMS. Ozone levels are recorded in Dobson Units, a measurement of the thickness of ozone layer, by an equivalent layer of pure ozone gas at normal temperature and pressure at sea level. In other words, 100 DU = 1 mm of pure ozone gas at normal temperature and pressure at sea level. The average amount of ozone at mid latitude is 3 mm or 300 DU.

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* In this instance, the reaction is speeded up.

** A whirlpool of wind.

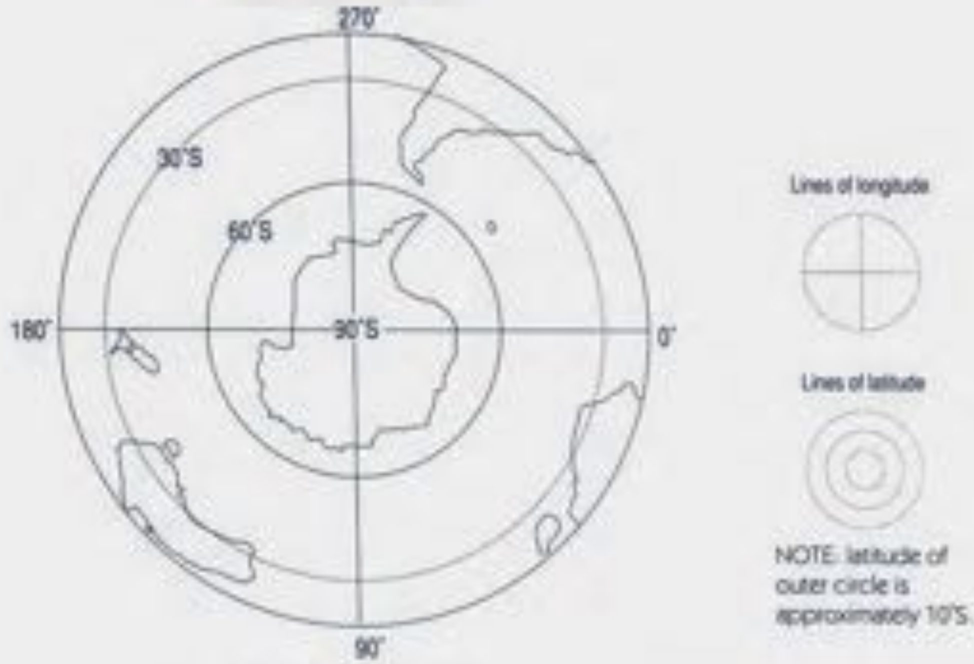
Ozone Concentration for Latitudes 90°S to 30°S, 1987

DAY	DU	DAY	DU	DAY	DU	DAY	DU
1	255	47	242	93	200	139	219
2	254	48	238	94	201	140	221
3	254	49	238	95	197	141	227
4	248	50	238	96	199	142	218
5	251	51	226	97	205	143	217
6	253	52	228	98	201	144	225
7	254	53	234	99	206	145	217
8	251	54	240	100	200	146	216
9	251	55	242	101	205	147	218
10	253	56	239	102	208	148	228
11	257	57	239	103	210	149	227
12	255	58	240	104	222	150	237
13	255	59	236	105	227	151	226
14	253	60	231	106	224	152	223
15	254	61	237	107	218	153	203
16	253	62	238	108	222	154	222
17	252	63	244	109	225	155	207
18	251	64	236	110	232	156	206
19	245	65	222	111	235	157	212
20	242	66	224	112	231	158	229
21	251	67	227	113	229	159	234
22	246	68	220	114	232	160	223
23	251	69	219	115	216	161	233
24	251	70	225	116	213	162	219
25	249	71	219	117	208	163	215
26	246	72	208	118	219	164	231
27	250	73	213	119	227	165	235
28	249	74	210	120	204	166	233
29	247	75	217	121	215	167	222
30	252	76	217	122	210	168	228
31	246	77	217	123	212	169	216
32	250	78	210	124	213	170	227
33	250	79	203	125	213	171	229
34	249	80	205	126	216	172	209
35	249	81	206	127	233	173	203
36	248	82	208	128	235	174	220
37	246	83	201	129	229	175	220
38	243	84	198	130	219	176	229
39	243	85	203	131	226	177	233
40	241	86	207	132	228	178	231
41	244	87	204	133	220	179	237
42	244	88	203	134	213	180	230
43	240	89	188	135	211	181	235
44	243	90	188	136	228	182	230
45	244	91	195	137	227	183	221
46	233	92	193	138	230	184	217

Ozone Concentration for Latitudes 90°S to 30°S, 1987 *(cont.)*

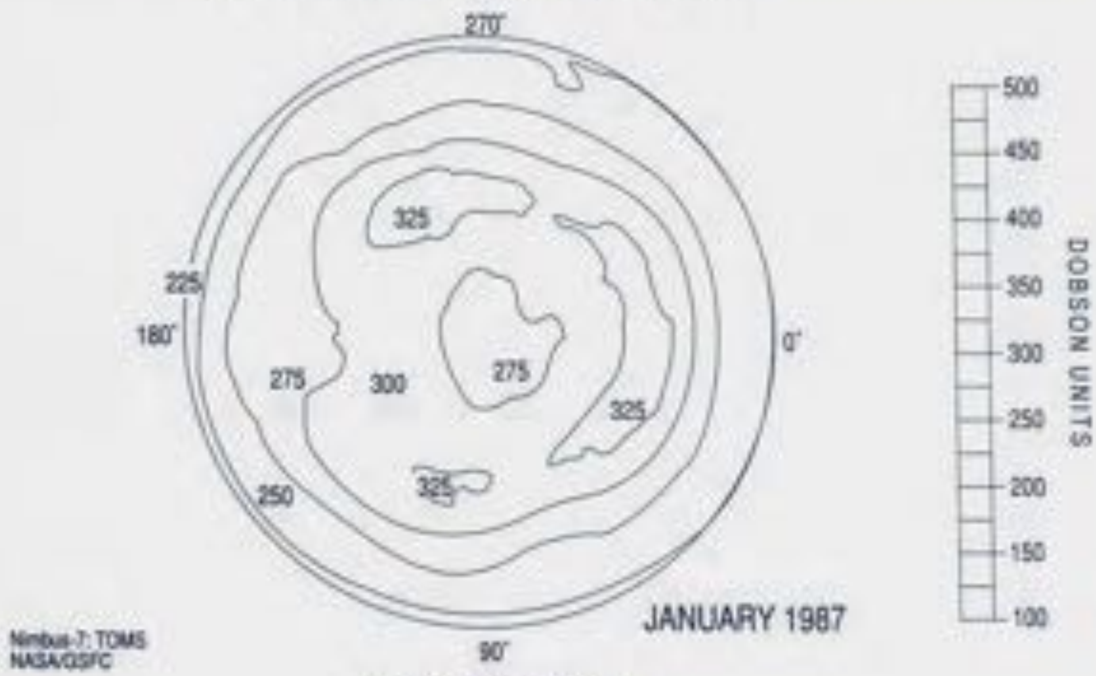
DAY	DU	DAY	DU	DAY	DU	DAY	DU
185	225	231	201	277	112	323	167
186	232	232	217	278	106	324	165
187	228	233	210	279	112	325	160
188	227	234	219	280	121	326	157
189	228	235	218	281	119	327	164
190	240	236	212	282	117	328	170
191	234	237	203	283	127	329	174
192	238	238	207	284	132	330	184
193	233	239	193	285	127	331	181
194	233	240	203	286	125	332	184
195	209	241	206	287	125	333	191
196	207	242	210	288	122	334	197
197	223	243	209	289	121	335	200
198	215	244	194	290	119	336	209
199	229	245	202	291	124	337	202
200	227	246	189	292	122	338	210
201	235	247	204	293	125	339	219
202	230	248	173	294	125	340	220
203	205	249	173	295	120	341	215
204	204	250	185	296	124	342	227
205	234	251	173	297	129	343	228
206	229	252	175	298	128	344	231
207	244	253	178	299	133	345	246
208	225	254	171	300	131	346	249
209	208	255	161	301	135	347	248
210	188	256	158	302	133	348	252
211	172	257	166	303	133	349	247
212	214	258	160	304	135	350	244
213	201	259	161	305	141	351	245
214	208	260	162	306	143	352	242
215	208	261	164	307	142	353	242
216	215	262	164	308	141	354	250
217	207	263	151	309	141	355	249
218	190	264	147	310	143	356	249
219	204	265	144	311	142	357	247
220	221	266	149	312	143	358	240
221	220	267	151	313	143	359	231
222	228	268	146	314	147	360	233
223	224	269	144	315	141	361	236
224	220	270	135	316	146	362	244
225	200	271	131	317	146	363	242
226	230	272	122	318	153	364	242
227	199	273	112	319	154	365	243
228	183	274	111	320	156		
229	172	275	119	321	155		
230	217	276	124	322	163		

ANTARCTICA

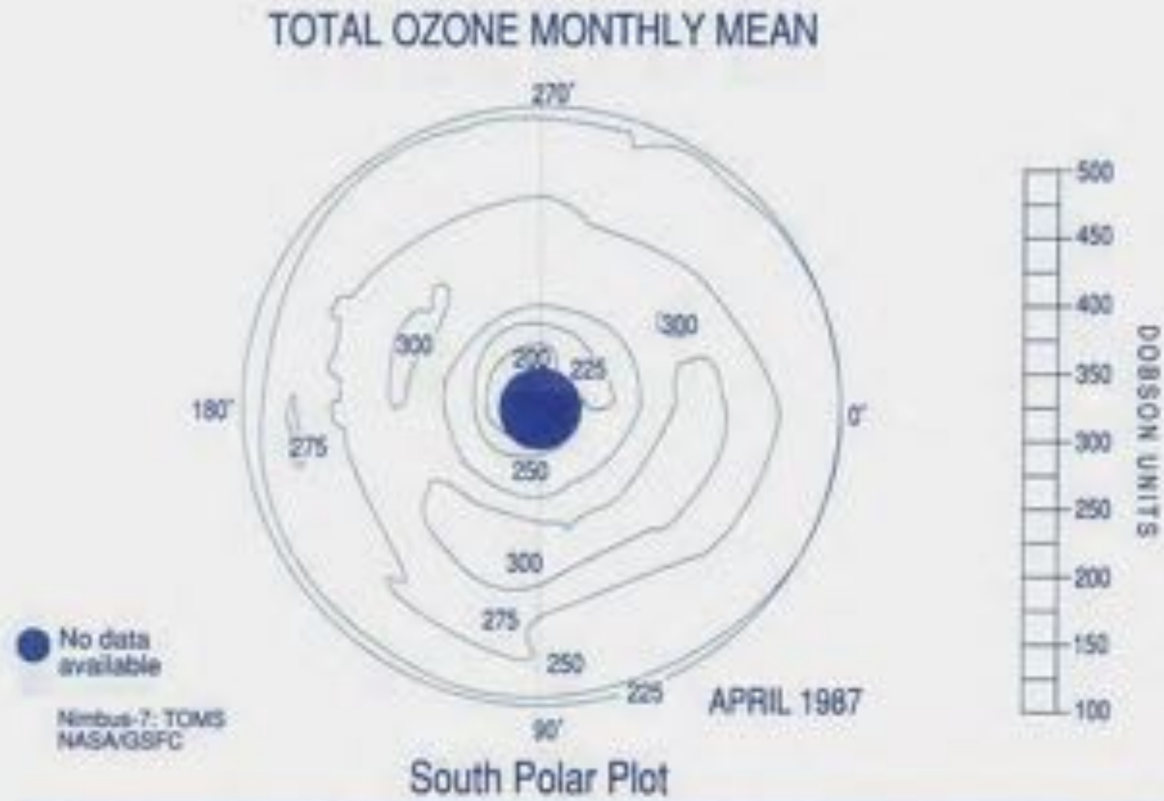


South Polar Plot

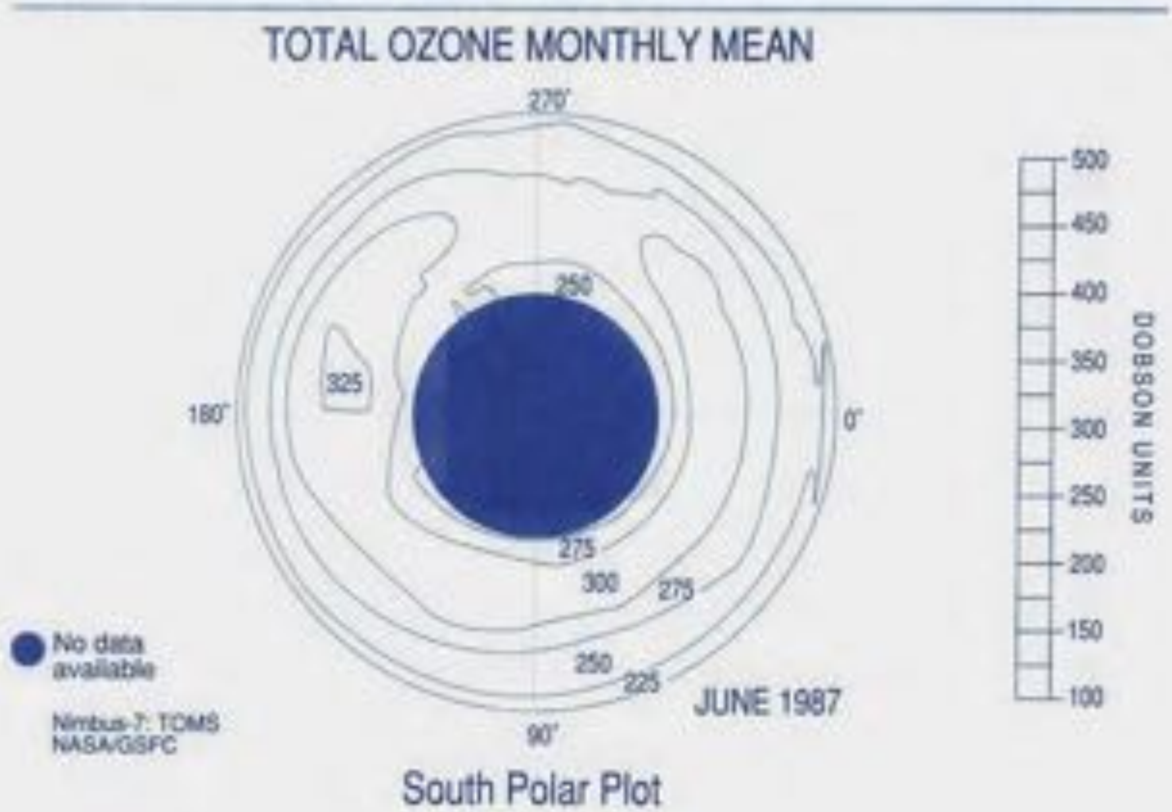
TOTAL OZONE MONTHLY MEAN



South Polar Plot

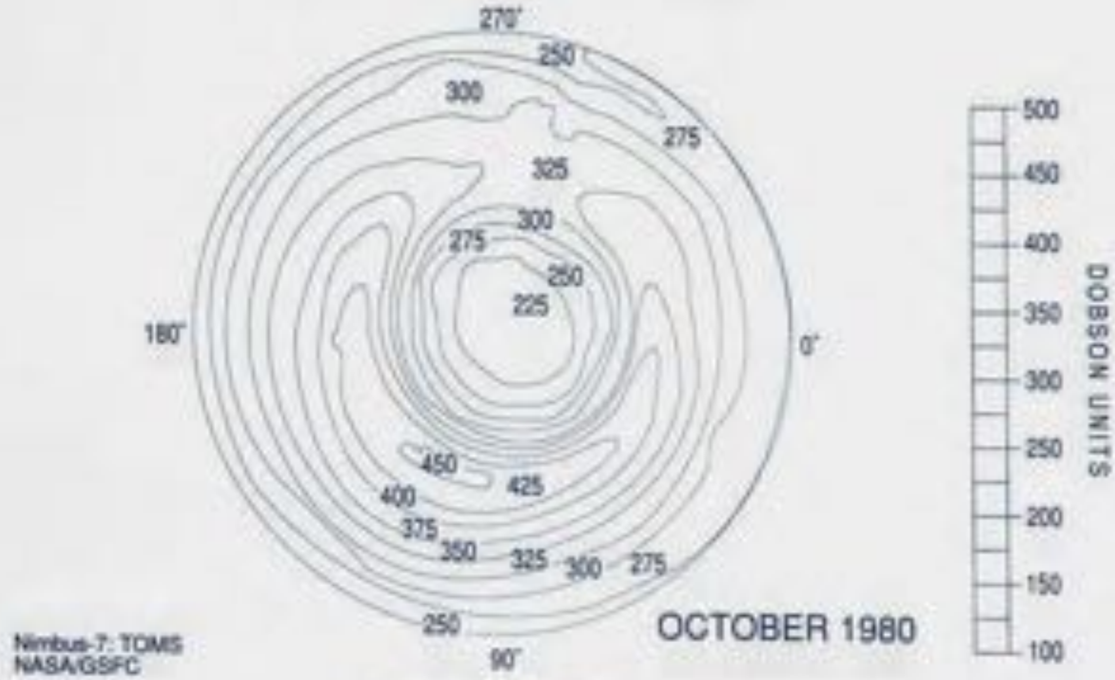


TOTAL OZONE MONTHLY MEAN
270°
180°
0°
90°
300
300
200
225
275
250
300
275
250
225
No data available
Nimbus-7: TOMS
NASA/GSFC
APRIL 1987
500
450
400
350
300
250
200
150
100
DOBSON UNITS
South Polar Plot



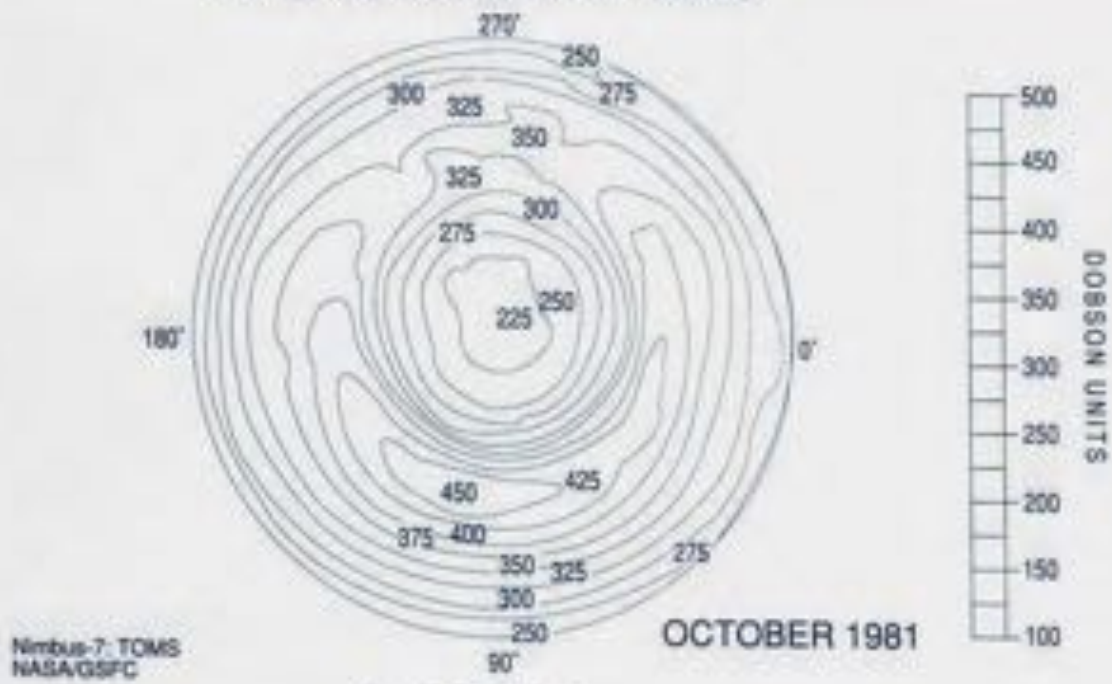
TOTAL OZONE MONTHLY MEAN
270°
180°
0°
90°
250
325
275
300
275
250
225
No data available
Nimbus-7: TOMS
NASA/GSFC
JUNE 1987
500
450
400
350
300
250
200
150
100
DOBSON UNITS
South Polar Plot

TOTAL OZONE MONTHLY MEAN



South Polar Plot

TOTAL OZONE MONTHLY MEAN



South Polar Plot

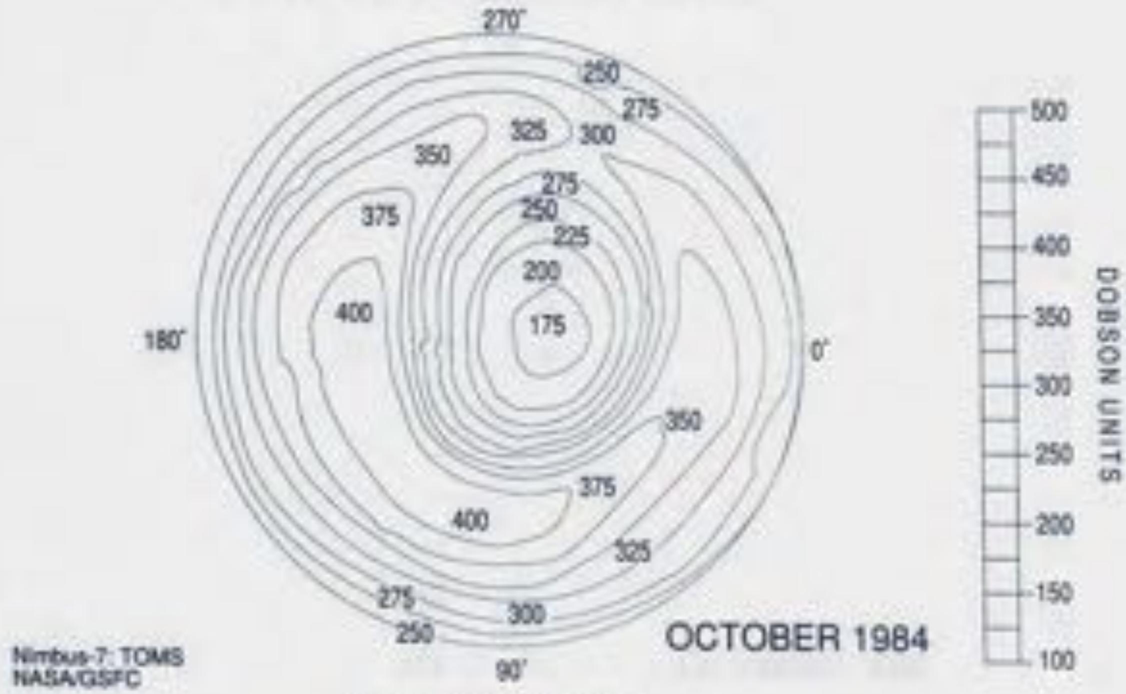
TOTAL OZONE MONTHLY MEAN

South Polar Plot

TOTAL OZONE MONTHLY MEAN

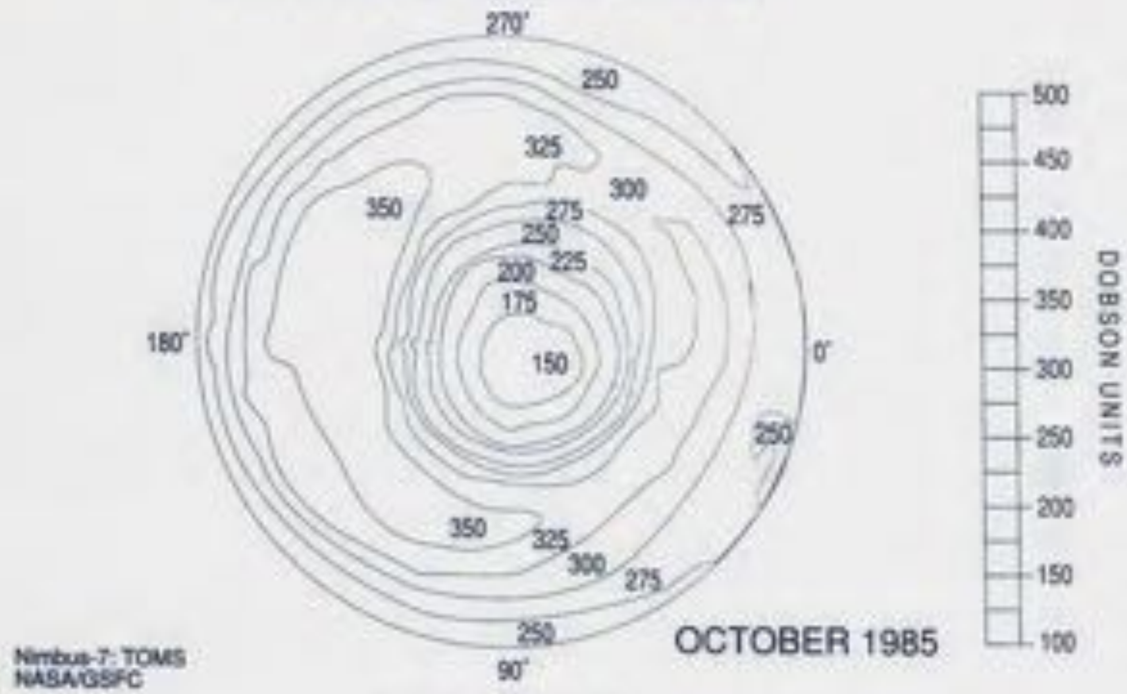
South Polar Plot

TOTAL OZONE MONTHLY MEAN



South Polar Plot

TOTAL OZONE MONTHLY MEAN

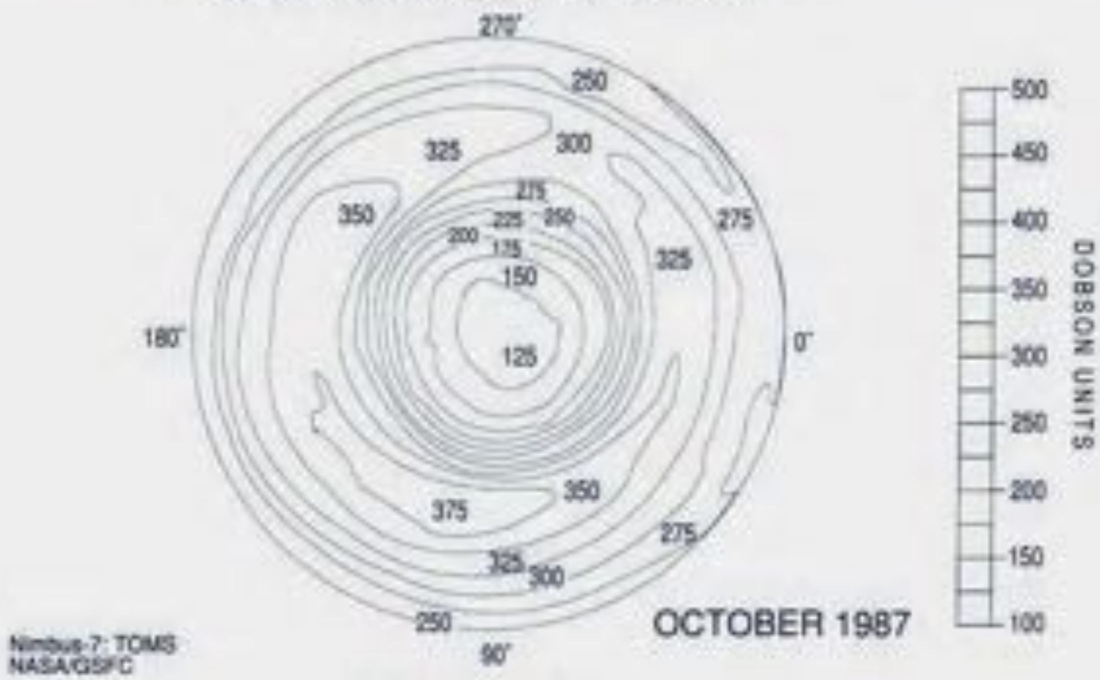


South Polar Plot

TOTAL OZONE MONTHLY MEAN

South Polar Plot

TOTAL OZONE MONTHLY MEAN

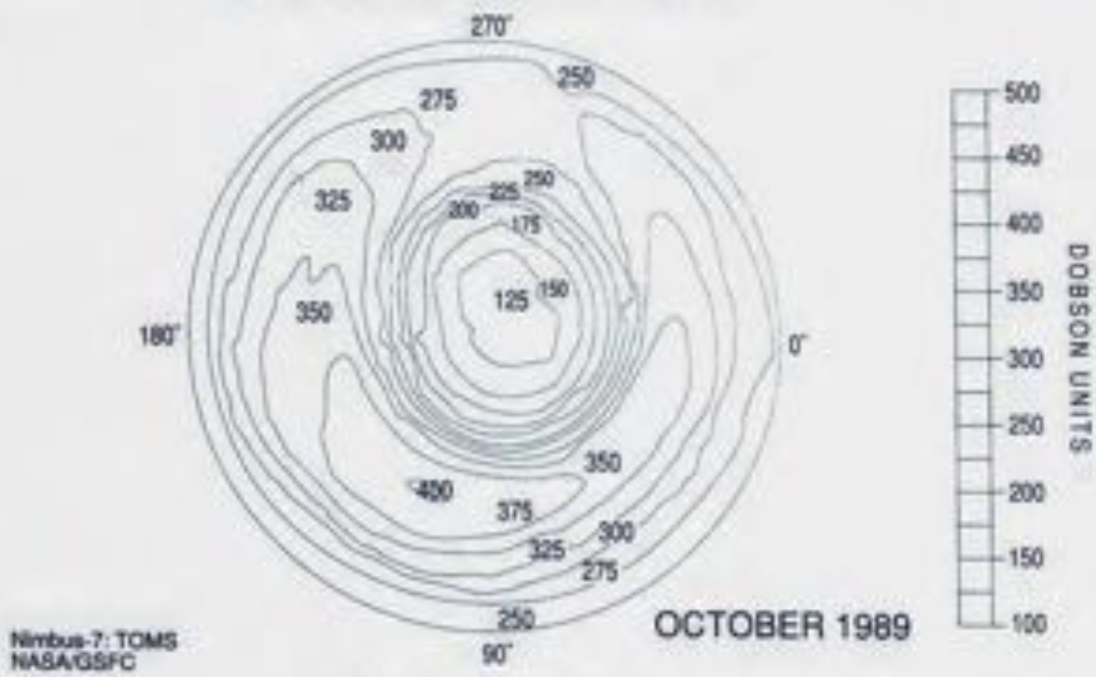


South Polar Plot

TOTAL OZONE MONTHLY MEAN

South Polar Plot

TOTAL OZONE MONTHLY MEAN



South Polar Plot

RESOURCES

Teaching Materials

- ***Geology: The Active Earth.*** Curriculum guide for grades K-7. Available from the National Wildlife Federation, 1400 16th Street NW, Washington, DC 20036-2266 [1-800-432-6564].
- **The Waste Case.** An activity-based teaching guide on trash and the environment. Contact Buhl Science Center, Allegheny Square, Pittsburgh, PA 15212-5363, Attn. Wayne LaBar [412-237-3363] for ordering information.
- ***Global Warming and the Greenhouse Effect, Acid Rain, Convection: A Current Event.*** These and other teachers guides are available from LHS GEMS, Lawrence Hall of Science, University of California, Berkeley, CA 94720 [415-642-7771].
- ***Temperature sensitive liquid crystal sheets.*** Thin plastic sheets that change colors when exposed to various temperatures. Available from Edmund Scientific Supply Co., 101 East Gloucester Pike, Barrington, NJ 08007-1380 [609-573-6250].
- ***Greenhouse Gas-ette Newsletter.*** Available to educators free of charge. Request on school letterhead from Climate Protection Institute, 5833 Balmoral Drive, Oakland, CA 94619.
- ***Earthquakes: A Teacher's Package for K-6.*** Activity-based earthquake curriculum. Available from The National Science Teachers Association, 1742 Connecticut Avenue, NW, Washington, DC 20009 [202-328-5800].
- ***Looking At Earth.*** Educational activity packet developed by the National Air and Space Museum staff to accompany school tours focused on Earth exploration. To request the current school tour brochure, write the Tour Scheduler Office, P-700, National Air and Space Museum, Washington, D.C. 20560.

Pictures and Posters

- ***Earth at Night.*** A detailed and informative poster of satellite images of Earth at night. Available from Hansen Planetarium, 1098 South 200 West, Salt Lake City, UT 84101 [1-800-321-2369].
- ***Nighttime images*** of individual continents from space. Available from International Dark-Sky Association, 3545 North Stewart, Tucson, AZ 85716.
- Photographs of ***Earth from orbit.*** Can be viewed on microfilm at the Library of Congress, Washington, DC. Can be ordered from the EROS Data Center, User Services Section, Sioux Falls, SD 57198 [605-594-6151].
- USGS ***satellite image maps.*** Contact the U.S. Geological Survey,

Earth Science Information Center, 507 National Center, Reston, VA 22092 [1-800-USA-MAPS] for a free listing.

- ***Maps*** of Antarctica, the Arctic and many other areas are available from the National Geographic Society, Washington, DC 20036. Write for a complete map list.

Articles and Pamphlets

- Sullivan, W.T. III "Our Endangered Night." ***Sky & Telescope***, Vol. 67, No. 5 (May 1984): 412-414. Informative article on light and radio wave leakage from Earth.
- ***EOS-A Mission to Earth.*** Beautifully illustrated article on many topics affecting change in our world. Write: EOS Program Office, NASA Headquarters (Code EE), Washington, DC 20546.
- Link, Terry. "Sources for a Small Planet." ***Library Journal*** (June 1, 1990): 81-88—A series of bibliographies on the environment, including pamphlets, organizations and computer databases.
- ***You Can Do It.*** Send a postcard requesting this 16 page booklet, which lists ways each person can help improve the environment, to, the National Wildlife Federation, 8925 Leesburg Pike, Vienna, VA 22184-0001.
- ***Think Globally, Act Locally 1990 Earth Day.*** Ideas about what we can do to address our environmental problem. Write the U.S. Environmental Protection Agency, Washington, DC 20460.
- ***Environmental Scorecard.*** Booklet that reports how members of Congress vote on various environmental issues. Write the League of Conservative Voters, P.O. Box 66500, Washington, DC 20077.
- ***Protecting the Ozone Layer: What You can Do.*** Available from the Environmental Defense Fund, 527 Park Avenue South, New York, NY 10010 [212-505-2100].
- ***free leaflets*** on global warming and the greenhouse effect. Available from The Union of Concerned Scientists, 26 Church St., Cambridge, MA 02238 [603-547-5552].

Films and Videos

- ***Post Flight Press Conference Tape 3.*** Video containing mission highlights from STS-29, -32, and -34; the three main Shuttle missions during which *Blue Planet* was filmed. This and many other reasonably priced audiovisual materials are available from NASA CORE, c/o Lorain County JVS, 15181 Route 58 South, Oberlin, OH 44074 [216-774-1051 ext 293].
- ***The Best of JPL.*** A video that includes a computer generated animation sequence similar to that seen in the film *Blue Planet*. Send $9.50 to Trieta, P.O. Box 12445, Glendale, CA 91214.
- ***The Miracle Planet.*** Television series which focuses on many of the environmental topics addressed in the film *Blue Planet*. Con-

tact Ambrose Video, 1290 Avenue of the Americas, Suite 2245, New York, NY 10104 [212-265-7272] for ordering information.

- ***Powers of Ten.*** Classic film on the relative size of things, from the universe to the microworld of cells. This nine minute film is available for purchase or rental from Pyramid Film and Video, Box 1048, Santa Monica, CA 90406 [1-800-421-2304].
- ***Atmospheric Science: Earth's Atmosphere.*** A thirteen minute film on Earth's atmosphere with accompanying teacher guide. Available for purchase from Coronet/MTI Film and Video, 108 Wilmont Road, Deerfield, IL 60015 [1-800-621-2131].

Books

- ***The Miracle Planet.*** New York: W.H. Smith Publishers, Inc., 1990. Based on the PBS television series that focuses on many of the environmental topics addressed in the film *Blue Planet.*
- Burton, Virginia Lee. ***The Little House.*** Boston: Houghton Mifflin Co., 1969. A classic childrens' story about the effects of urbanization and light pollution.
- Dillard, Annie. ***Pilgrim at Tinker Creek.*** New York: Harper-Row, 1988. An author's observations and reactions to the world around Tinker Creek.
- Carson, Rachel. ***Silent Spring.*** Boston: Houghton Mifflin Co., 1962. A classic on environmental pollution.
- Look for a poster book to be published in conjunction with the film *Blue Planet* in 1991 in New York by Harry N. Abrams, Inc.

Computer Software

- ***JEdI Project CD-ROM.*** Compact discs containing current scientific data, designed for use in the classroom. Accompanying lesson plans suggest uses for data bases. For more information contact the JEdI Teacher Coordinator, U.S. Geological Survey, 912 National Center, Reston, VA 22092-9998 [703-648-6636].
- ***Geological History.*** Use this software on an Apple II computer to print out a geological cross section to build a 3-D model. Order from Sunburst Communications, 39 Washington Avenue, Pleasantville, NY 10570-2898 [1-800-628-8897 ext. 2105].
- ***Earthquake Lab.*** Turns an Apple II computer into a seismograph, which students can use to measure their footsteps or passing trucks. Use with Science Toolkit Plus Master Module. Order from Brøderbund Software, PO Box 12947, San Rafael, CA 94913-2947 [1-800-521-6263].

WHERE CAN YOU SEE *BLUE PLANET*?

The IMAX film *Blue Planet*, premiers in Washington, DC in December 1990. Check with your local IMAX/OMNIMAX theater to find out when it will be showing in your area.

UNITED STATES

Alabama	Huntsville	Alabama Space and Rocket Center
Arizona	Tusayan	Grand Canyon IMAX Theater
California	Los Angeles	California Museum of Science and Industry
	San Diego	San Diego Hall of Science
	Santa Clara	Great American Lockheed Pictorium
Colorado	Denver	Denver Museum of Natural History
Connecticut	Norwalk	The Maritime Center
D.C.	Washington	The National Air and Space Museum, Smithsonian Institution
Florida	KSC	NASA Kennedy Space Center's Spaceport
Hawaii	Honolulu	Polynesian Cultural Center
Illinois	Chicago	Museum of Science and Industry
	Gurnee	Six Flags Great America
Kansas	Hutchinson	Kansas Cosmosphere and Discovery Center
Kentucky	Louisville	Museum of History and Science
Maryland	Baltimore	Maryland Academy of Sciences
Massachusetts	Boston	Boston Museum of Science
Michigan	Detroit	Detroit Science Center
Minnesota	Shakopee	Valleyfair Amusement Park
	St. Paul	The Science Museum of Minnesota
Nevada	Las Vegas	Caesar's Palace
New Mexico	Alamogordo	The International Space Hall of Fame
New York	New York	American Museum of Natural History
Ohio	Cincinnati	Museum Center at Union Terminal
	Sandusky	Cedar Point Amusement Park
Pennsylvania	Philadelphia	Franklin Institute
Texas	Fort Worth	Fort Worth Museum of Science and History
	Houston	Houston Museum of Natural Science
	San Antonio	Rivercenter Mall
Virginia	Richmond	The Science Museum of Virginia
Washington	Seattle	Pacific Science Center
	Spokane	Riverfront Park

CANADA

Alberta	Edmonton	Edmonton Space and Science Centre
British Columbia	Vancouver	Science World British Columbia
Manitoba	Winnipeg	Portage Place IMAX Theatre
Ontario	Niagara Falls	Niagara IMAX Theatre
	Toronto	Ontario Place
Quebec	Hull (Ottawa)	The Canadian Museum of Civilization
	Montreal	Le Vieux-Port de Montreal