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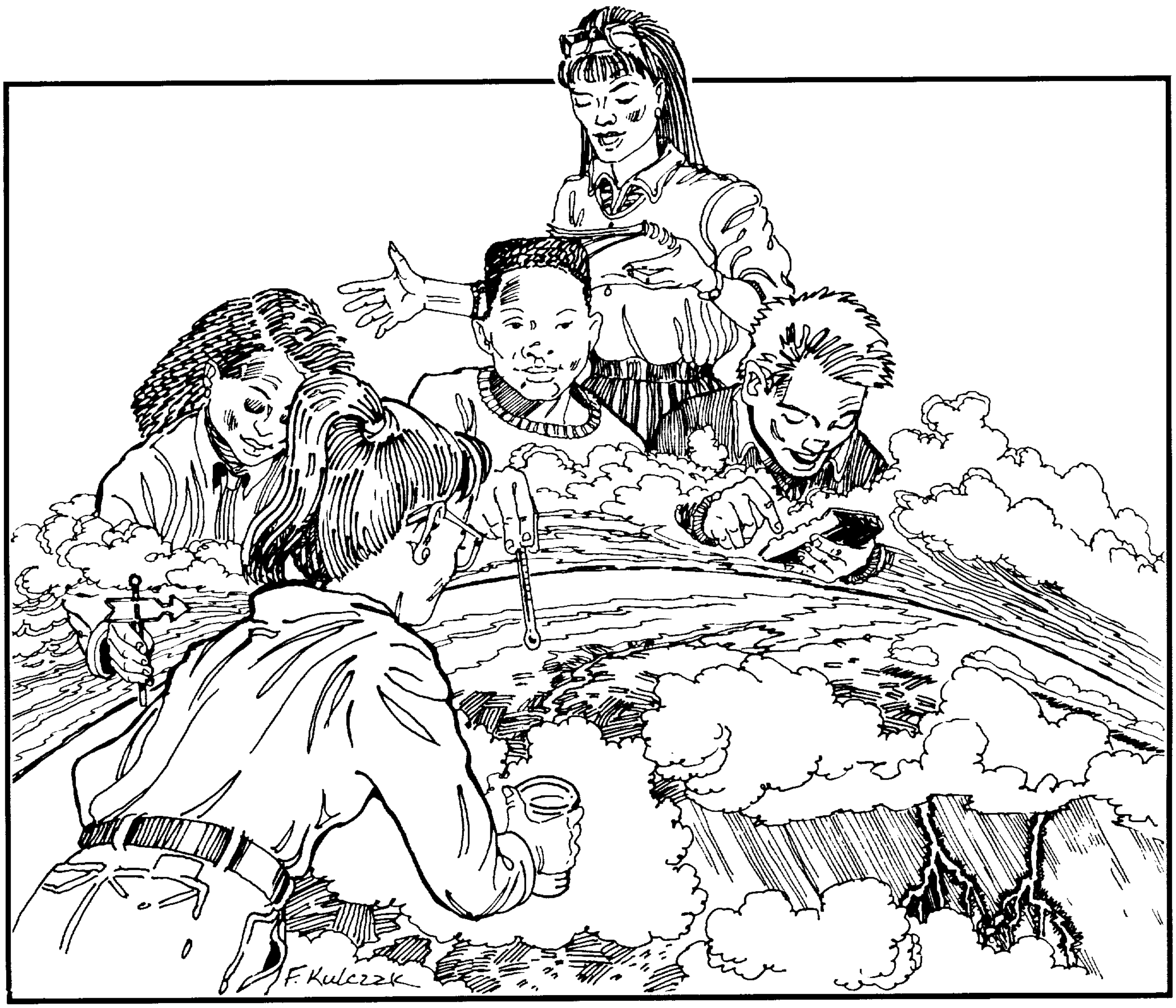
Atmospheric Detectives

ATLAS 2 Teacher's Guide with Activities



FOR USE WITH MIDDLE-SCHOOL STUDENTS

(NASA-EP-285) ATMOSPHERIC DETECTIVES: ATLAS 2 TEACHER'S GUIDE WITH ACTIVITIES. FOR USE WITH MIDDLE-SCHOOL STUDENTS (NASA) 26 p

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Atmospheric Detectives

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For use with middle-school students

Contents

Preface

Can you imagine doing a science project in space? This is the challenging and exciting situation that researchers experience in Spacelab, the laboratory carried inside the Shuttle. Here, hundreds of kilometers above Earth's surface, the crews of the ATLAS missions scan, probe, and measure concentrations of chemicals and water vapor in Earth's protective bubble. So far, one ATLAS crew has rocketed into the atmosphere, watching many sunrises and sunsets come and go while activating delicate instruments and conducting experiments that monitor the complicated interactions between the Sun, the atmosphere, and Earth.

We, the crew of ATLAS 2, will continue this important work aboard the Space Shuttle. Together, we will gather data that will be compared with information from satellites, balloons, and instruments on the ground. As part of the National Aeronautics and Space Administration's (NASA's) contribution to Mission to Planet Earth, ATLAS 2 will help develop a thorough picture of the Sun's output, its interaction with the atmosphere, and the well-being of Earth's middle atmosphere.

Because the health of the atmosphere is of vital importance to all Earth's inhabitants, everyone should be part of this investigation. You can be active participants in exciting and vital activities: recycling and practicing other conservation methods and gathering information to learn more about how you can keep our atmosphere healthy now, as students, and in the future as informed citizens, scientists, technicians, and mathematicians.

ATLAS 2 Crew

Ken Cameron

Flying the Space Shuttle on orbit offers the crew a unique vantage point that reinforces the idea that our planet is really a spacecraft itself, with a crew of 5 billion people. Just as the astronauts study the Shuttle's systems to learn to fly it safely, we on Earth all need to learn more about our planet, its atmosphere, and our Sun's influence on it in order to pilot it safely and successfully for a long voyage. I am very pleased and honored to be a part of this mission to study spacecraft Earth.

Stephen Oswald

Any opportunity to fly aboard the Space Shuttle is an extraordinary privilege, but it is especially gratifying to be participating in the ATLAS 2 mission, which promises to benefit all of humanity. Gathering data on the interrelationship between the Sun and our fragile atmosphere is precisely the kind of job that NASA should be doing and to which the Shuttle is best suited. ATLAS 2 could prove to be of tremendous importance to the long-term health of our planet, and I'm glad to be a part of the team.

Mike Foale

As a child, I was always intrigued by flying and spaceflight. The possibility of exploring other planets is one of the most exciting opportunities our generation could have. Science and mathematics were natural subjects for me to study at school, especially physics at Cambridge University. With that background, my dreams were realized when I was lucky enough to fly on ATLAS 1. The sunrises and sunsets, the Earth's terminator [the dividing line between the sunlit and dark portions of Earth], and the aurora were some of the most beautiful views I have ever seen. Flying on ATLAS 2 gives me a wonderful chance to see such beautiful sights all over again and to add yet another piece to the scientific puzzle of our planet's climate.

Ellen Ochoa

I remember watching Apollo 11 land on the Moon the summer before I started junior high school. While I was fascinated by the event, it never occurred to me that I could grow up to be an astronaut. I guess I just assumed that exploring space was limited to a special group of people very different from me. But space exploration is a field that is open to anyone who is interested in learning new subjects, investigating mysteries, and working hard to achieve goals. In my case, my interest in math led me to study physics in college, and my interest in solving problems led me to graduate school and a career in research. It wasn't until I was in graduate school that I found out about the astronaut selection process and realized that NASA was looking for people like me. That was a wonderful surprise — and a challenge to try to do my best in school and at work in order to achieve such an exciting goal. I feel very lucky to have been chosen as an astronaut and to have been selected for the ATLAS 2 mission. This flight is an incredible opportunity for me to be involved in an important scientific research effort to understand how both the Sun and human activities affect our atmosphere.

Ken Cockrell

I have always wanted to fly. One of my first childhood memories is of an airplane flying over my backyard. That little event sparked a desire in me to fly that has never gone away. In school, I chose courses in math and science and an engineering degree to prepare for a flying career. After college, I joined the Navy and flew jet fighters from aircraft carriers for 15 years. It was tremendous fun to fly each new type of airplane that came along during those years. Now the new "airplane" is the Space Shuttle, and I'm more excited about flying it than I've ever been before. To me, the Shuttle is the greatest flying machine ever built. On ATLAS 2, the Shuttle enables us to study the changes in our atmosphere and to better understand the changes in the Sun's energy. This knowledge may help us protect the Earth's fragile environment in the future, and I'm proud to be a part of the effort.

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INSTRUCTIONS FOR USING THE TEACHER'S GUIDE

The ATLAS 2 Teacher's Guide

- ✓ blends lessons in mathematics, chemistry, physics, and Earth science
- ✓ nurtures students' natural curiosity and excitement about science and technology
- ✓ encourages students to see their questions as the seeds of careers in science, mathematics, and technology
- ✓ fosters creative and critical thinking and problem-solving skills
- ✓ supplements the ATLAS 1 Teacher's Guide, *Earth's Mysterious Atmosphere* (NASA publication EP-282).

The ATLAS 2 Teacher's Guide probes the connection between the activities of scientists and researchers and the observable world of weather and climate. To do this, the guide has been divided into four sections:

I. Case History: What ATLAS 1 Discovered briefly summarizes the findings of the ATLAS 1 Spacelab/Shuttle flight of March 1992. It links that mission with the science goals of ATLAS 2 and future flights.

II. The Search: What ATLAS 2 Scientists Investigate delves into the invisible world of protons, neutrons, and electrons to explain the fundamental mechanisms of absorption of ultraviolet (UV) radiation by ozone and the destruction of ozone by chlorofluorocarbons (CFCs). It also explains why ATLAS scientists study the Sun's energy.

III. The Motive: How Solar and Atmospheric Changes Might Affect Climate explores the relationship between solar activity and weather and climate. Specifically, this section looks at solar output, wind patterns, and water vapor.

IV. The Method: How ATLAS 2 Investigators Make These Measurements studies the remote-sensing techniques of spectrometry and limb sounding. It also involves students in ground-truth studies and exercises that emphasize the importance of mathematics and precise measurement.

The guide may be taught in its entirety, or you may choose to teach particular sections. You may even want to choose among the cases in each section. Cases and sections are designed to stand alone; the ideas contained in them do not depend on the rest of the guide.

The science concepts in the ATLAS 2 Teacher's Guide have been designed to complement the middle-school (grades 6, 7, and 8) curriculum; however, many activities may be used with younger and older students. You may adapt the guide to your students' needs and interests.

All sections follow the format of a detective case.

Cases: Several cases appear in each major section. These are in the form of questions that student detectives might ask about the atmosphere — its functions, possible damage or changes, and causes and solutions.

Clues: These precede investigations and contain important background information for teachers and students.

Investigation: These hands-on activities focus and extend information in the **Clues** section. There are two investigations per case. You may use one or both as teaching activities or reproduce them and assign as tasks to small groups.

Materials: This section lists the materials needed to perform the investigation. Household items are used whenever possible.

Procedure: This provides detailed instructions and cautions. Before beginning any procedure, encourage students to formulate hypotheses about what they think will happen.

Questions: Answers to most questions are found at the end of each of the four major sections. Some are open ended to stimulate creative thinking. Encourage students to support creative answers with what has been observed in the **Investigation** or learned in the **Clues** sections.

Relating Science to . . . These sections provide suggestions for group or individual activities in other areas of study, such as art, literature, math, music, and social studies.

Helping Mother Earth: These facts and classroom discussion ideas extend the guide's scope beyond ATLAS' atmospheric research to include other areas of concern in the environment. Students may work on these activities in school or at home.

Case History: What ATLAS 1 Discovered

Have you ever put together a model — a small copy of an airplane, a car, ship, or spacecraft? Toy manufacturers try to make their models as much like the original object as possible. Model cars have the same tires, the same color paint, and the same decorations as real cars. In a similar way, scientists studying the atmosphere create models. Using mathematics instead of wood, plastic, and rubber parts, they try to show how wind currents, the oceans, the Sun, and elements and compounds in the atmosphere interact, and how they are affected by humans. If you make a model car, you may be able to compare it with a real car to check its accuracy. Researchers check the accuracy of their mathematical models by comparing predictions with actual observations. To do this, they measure natural and manufactured chemicals in the atmosphere, wind currents, sunlight, and many other factors to determine if what they thought should be there is actually there. Using models in this way, researchers can understand past and present events and possibly predict future occurrences.

The ATLAS 1 Spacelab mission, which flew in March 1992, acquired some of the important information needed to check existing models and develop new ones. The huge amount of data collected includes the measurement of many trace gases in the middle atmosphere. One very interesting result was the observation of a layer of tiny droplets of sulfuric acid and water in the atmosphere. These small, floating particles called **aerosols** resulted from the eruption of Mount Pinatubo in the Philippines in 1991. The aerosol layer was so thick that some of the ATLAS instruments could barely measure through it. Observers on future missions will be studying this layer to see how much it has diminished and if it still has any effect on the ozone that exists at about the same altitude. Other researchers have also been checking surface temperatures and sunlight measurements from the ground. They will use these data in mathematical models to determine whether this aerosol layer has shielded Earth from some of the Sun's heat.

ATLAS 1 scientists found that amounts of some chlorofluorocarbons in the atmosphere had doubled since 1985. These atmospheric detectives also measured amounts of a substance called **hydroxyl.** This chemical "eats" ozone in the mesosphere in much the same way that chlorine compounds destroy ozone in the stratosphere. The scientists also measured water vapor, which acts as a greenhouse gas. ATLAS 1 instruments also recorded important information on ozone that will help researchers understand how ozone behaves in the stratosphere. ATLAS 1 measurements were made primarily in the Southern Hemisphere. If it is launched in the spring, ATLAS 2 will concentrate on measurements in the Northern Hemisphere.

Another goal of ATLAS 1 scientists was to study the total radiation traveling from the Sun to Earth's atmosphere. They accomplished this goal and at the same time analyzed particular wavelengths of sunlight that could affect our atmosphere, such as ultraviolet, visible, and infrared. Light measurements will be carefully compared with past and future information to decide whether the total solar radiation is changing.

It will take many years to analyze the ATLAS 1 data. In the meantime, data from ATLAS missions, the Upper Atmosphere Research Satellite and other spaceborne instruments, and ground measurements will be collected and studied. Atmospheric detectives all over the world will be working to learn more about our planet, our star, and the enormous, complicated system that connects them. You can be an important part of that team. Let's join them!

The Search:

What ATLAS 2 Scientists Investigate

Case No. 1 — Why study the atmosphere?

CLUES:

What things are most valuable? Diamonds? Gold? Air? Although we can't measure its value in dollars, Earth's atmosphere is also precious, for without it, life on Earth would not exist. Our bubble in space provides air to breathe, regulates the Sun's energy to heat and cool our planet, and filters the Sun's rays, allowing those that provide heat and light to reach Earth's surface while blocking those that are deadly.

Scientists are concerned because the amounts of some chemicals in our atmosphere are changing. Gases released by industry and agriculture are building up in the lower atmosphere and could enhance the atmosphere's warming influence, perhaps leading to temperature changes with long-range effects. Ozone, a part of the stratosphere that acts as a natural screen for dangerous ultraviolet (UV) radiation, is being destroyed by other human-made compounds. In 1992, concentrations of this gas over the Antarctic reached their lowest levels since measuring began in the 1960s. Scientists estimated an area of depleted ozone in the Antarctic that is larger than the United States and deep enough to hold Mount Everest. If the depletion of the ozone layer in the stratosphere continues, increases in UV radiation reaching Earth's surface would be a serious concern. Plants and animals would be affected. Even the tiny ocean organisms that remove carbon dioxide from the atmosphere might be destroyed, possibly increasing concentrations of this greenhouse gas in the atmosphere and raising temperatures. Also, these organisms serve as the base of oceanic food chains, and changes in their populations could have serious environmental consequences.

Researchers have also wondered if the Sun's output is changing, leading to temperature or other atmosphere changes on Earth. What will be the outcome of all these changes? Scientists form theories but cannot be sure. These are mysteries; there are many clues but no definite answers yet.

To investigate these mysteries, ATLAS 2 scientists will continue to measure the gases in the middle atmosphere (stratosphere and mesosphere) and monitor the output of the Sun.

Investigation A: Building Gases

Scientists working on ATLAS 2 measure many familiar gases in the atmosphere, such as ozone, carbon monoxide, carbon dioxide, water vapor, and methane. They also measure less well-known gases such as chlorine monoxide and nitrogen compounds.

To understand the importance of these gases in the atmosphere, you must first know something about the structure of the molecules and atoms that make up these gases. Atoms, originally thought to be the smallest particles making up an element, are actually composed of **protons**, **neutrons**, and **electrons**. Protons are particles carrying a positive electric charge (+), and neutrons have no electric charge. Protons and neutrons form the **nucleus**, or center, of the atom. Electrons, which carry a negative charge (–), revolve around the nucleus in a kind of **electron cloud**. Low- energy electrons move around close to the nucleus, while high-energy electrons speed around the outside levels of the cloud. These levels are sometimes called **shells**.

Atoms can gain, lose, or share electrons. When atoms share electrons, **bonds** form between them, and they become molecules. Molecules may be composed of atoms from the same element or atoms from different elements. For example, oxygen molecules (O_2) are made of 2 atoms of oxygen, but water molecules (H_2O) are made of 2 atoms of hydrogen and 1 atom of oxygen. The small number to the right of the chemical symbol tells how many atoms of each element are in the molecule.

Atoms of oxygen (O) tend to gain electrons. They may also share electrons with other oxygen atoms, forming molecules of oxygen (O_2) or ozone (O_3). In the stratosphere, ozone protects plant and animal life by absorbing harmful ultraviolet (UV) rays. In the troposphere, ozone is not so helpful. It is a major ingredient in smog, which damages plants and endangers humans and other animals. Try making this model to help you visualize the formation of ozone, this gas that can be helpful or harmful.

Materials Needed:

- ✓ **4 white marshmallows**
- ✓ **toothpicks**

Procedure

The marshmallows represent atoms of oxygen, and the toothpicks represent the bonds between them. Use one toothpick to join two marshmallows. Repeat the process with the other two marshmallows. You now have a model of two molecules of O_2 as it usually exists in the lower atmosphere.

In the stratosphere, UV radiation is absorbed by O_2 molecules. This extra energy breaks the bond between the two atoms. Pull apart one pair of atoms to show the breaking of the bond. These oxygen atoms are now free to join with other O_2 molecules, forming O_3, or ozone. If you join one free marshmallow to a pair, you will have a model of O_3 and can see that there is still another oxygen atom ready to create more ozone.

Questions

❶ What do you think happens to the amount of UV radiation reaching Earth when ozone is destroyed?

Helping Mother Earth

Trees take in carbon dioxide, one of the major greenhouse gases, and use it and water to make food (a form of sugar). In return, they give us the oxygen we breathe. To help reduce greenhouse gases, it is important that we cut down fewer trees. To accomplish that, we must use less paper. Help your family start a "rag bag." In it, collect old clothes that can be used to clean up around the house, washed, and used again. This will save paper towels for "throw away" messes only.

Investigation B: Out Goes the Ozone

Chlorofluorocarbons (CFCs) are compounds used mainly as coolants in refrigerators and air conditioners. When CFCs escape, they are mixed by air motions in the atmosphere and transported into the stratosphere. There, they absorb UV radiation. This extra energy breaks the bonds holding these compounds together, releasing an atom of chlorine. The chlorine atom then pulls away the third oxygen atom in ozone, breaking the weak bond that joins it to the rest of the molecule. This destroys an ozone molecule and forms a molecule containing one atom each of chlorine and oxygen that also has weak bonds, making it **unstable**.

Because the chlorine-oxygen molecule is unstable, it is easy for free atoms of oxygen (O) to pull away the oxygen atom, forming O_2 and releasing the chlorine to destroy more ozone. This process and slightly more complicated ones are what is depleting the protective "ozone umbrella" in the stratosphere. The chlorine is not used up, and it can continue to destroy ozone.

Make these models for a "bite-size" view of the reactions between CFCs and ozone.

Materials Needed:

✓ **bag of jellybeans, gumdrops, or other soft, multicolored candy**
✓ **box of toothpicks**

Procedure

One of the simplest CFC molecules is $CFCl_3$. It has one atom of carbon, one atom of fluorine, and three atoms of chlorine. To make a model of a molecule of $CFCl_3$, use three pieces of green candy to represent chlorine, one black piece to represent carbon, and one red piece to represent fluorine. Because the fluorine and carbon atoms are smaller than the chlorines, cut the black and red candies in half, and keep only half of each. Toothpicks will represent the bonds between the molecules.

Stick three toothpicks into the piece of black candy, forming a three-legged stool with the legs evenly spread. Attach a green candy to the free end of each toothpick. Stand the stool on the desk and gently push down on the piece of black candy until the green pieces have slid apart enough that the black candy is suspended about 2 inches above the table. With your stool sitting on the table, insert a toothpick vertically in the top of the black candy and attach the red piece to the free end of the toothpick. This is a rough model of a $CFCl_3$ molecule. Lay it aside until later.

Use three pieces of white candy (representing atoms of oxygen) to create a model of ozone. Use two toothpicks to connect them, forming a triangle. Get an extra white piece and keep it handy for use later.

Lay your model of $CFCl_3$ and your model of ozone on a sheet of clean paper. When UV radiation hits a CFC molecule, the molecule releases chlorine. Pull off one green piece of candy from the $CFCl_3$ model to show this process.

The free chlorine atom destroys an ozone molecule by attracting one of the oxygen atoms away from the ozone molecule. Remove one of the white pieces of candy and its toothpick, and attach it to the free chlorine. This newly formed molecule containing chlorine and oxygen is unstable. Use the extra white candy to represent a free atom of oxygen. This can attract the other oxygen atom away from the chlorine. Remove the white candy and its toothpick from the green piece of candy and connect it to the "free" white piece.

Questions

1. At the end of this process, is the chlorine atom attached to anything?
2. If this chlorine atom gets near more ozone, what will happen?
3. What good things can you do now with all these candies?

Relating Science to . . .

Math: In 1991, the size of the Antarctic ozone hole was estimated at 17.58 million square km at its largest. This was 13 times its size 10 years ago. How large was it 10 years ago?

Case No. 2 Why study the Sun?

CLUES:

Another possible source of climate change is our star — the Sun itself. The Sun's energy varies and could be modifying the chemistry and makeup of Earth's atmosphere.

The power of the Sun's energy is particularly visible when there are **prominences**, huge bright loops or arches of gas that are evidence of violent solar storms. **Solar flares** are another kind of storm, but they are much briefer. Although short, they are accompanied by increases in X-ray, gamma ray, and UV emissions by the Sun. Variations in the strength of the **solar wind** also reflect changes in the Sun's output of energy. The solar wind is a stream of high-energy particles released into space from the outermost layer of the Sun's atmosphere, the **corona**. The solar wind is capable of interfering with radio and telephone communications on Earth. **Sunspots**, which can be larger in area than Earth itself, are huge storms in the Sun's lower atmosphere, the **photosphere**. The Sun's atmosphere above sunspots emits strong streams of X-rays, but the Sun's total brightness decreases when large groups of sunspots appear on its surface.

All of these solar activities may affect Earth's climate, but we cannot know unless we study the Sun's energy over a long period of time. The best place to study the energy beaming from the Sun is in space, beyond the absorbing and reflecting effects of Earth's atmosphere. Scientists made some of their major discoveries about the Sun while occupying America's first space station, Skylab, in the 1970s. Researchers have continued this important work over the years and now pursue it with ATLAS 2 and the Upper Atmosphere Research Satellite, measuring the Sun's total energy output and comparing it with past measurements and future calculations. ATLAS 2 scientists also evaluate changes in the intensity of individual parts of the solar spectrum — particularly infrared, visible, and UV radiation — during this mission and others. (The solar spectrum is the range of energy emitted by the Sun.)

Investigation A: Here, Spot.

While it is never safe to look directly at the Sun, sunspots can be viewed indirectly. Consult an almanac or other science reference book to find out when sunspots are most likely to occur. During times of sunspot activity, try this experiment.

Materials Needed:

✓ **paper plate**

✓ **straight pin**

✓ **sheet of white typing paper**

Procedure

Use the straight pin to make a hole in the center of the paper plate. With your back to the Sun, hold the plate so that the sunlight can travel through the center hole. Focus the light onto the white paper, creating a small image of the Sun. It may be necessary to slowly move the plate toward and then away from the white paper until you obtain a clear image. The spots on the Sun should be visible as small, dark areas on the focused image.

Questions

❶ What other solar event might be visible using this method?

Investigation B: Hot, Hotter, Hottest

Although it has never been measured, scientists believe that the Sun's core is its hottest region, where hydrogen atoms are fused into helium atoms — a **fusion reaction** — releasing enormous amounts of energy and creating temperatures up to 15,000,000 °C. Above the core, our star's atmosphere is made up of three layers: the photosphere, the first layer; the **chromosphere**, the middle layer; and the corona, the outermost layer. Temperatures in the photosphere reach only about 0.0004 of the temperature in the core. The chromosphere is actually warmer than the photosphere, with a temperature of about 27,800 °C. The corona is the warmest of the three layers. Gas particles there are hot, but they are still about 14,000,000 °C below temperatures at the Sun's core.

To give you an idea of some of the relative temperatures inside the Sun and in its layers, try this exercise.

Materials Needed:

✓ **illustration on this page**

✓ **pencil**

✓ **crayons or colored pencils**

Procedure

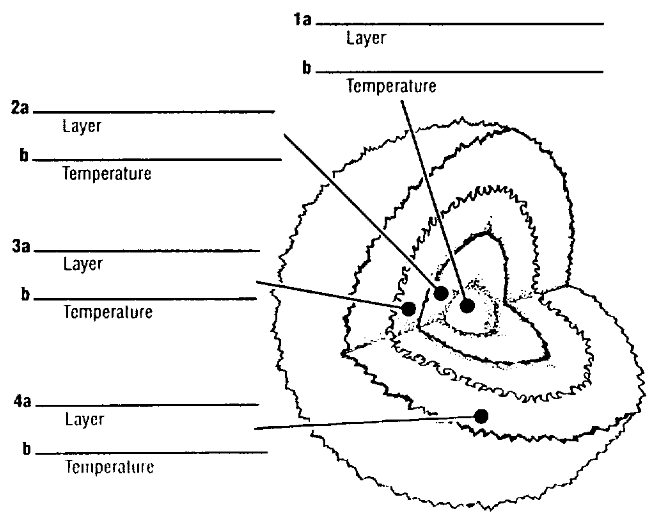
Using the information above, label the Sun's core and layers in the blanks provided. Calculate the temperatures at each location, and write those in below the name of the layer. Then color the core and layers according to the following key:

0 - 10,000 °C = red

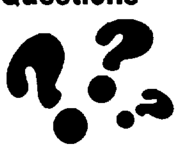
11,000 - 30,000 °C = orange

31,000 - 2,000,000 °C = blue

more than 2,000,000 °C = white



Questions



❶ What is the temperature of the photosphere?

❷ What is the temperature of the corona?

❸ What color is the core?

Relating Science to . . .

Art: In the 1700s, an English scientist named William Herschel made many important discoveries about telescopes and the Sun. He also believed that there were "solar inhabitants" who lived inside the Sun. Use your imagination to draw several of these creatures. Be sure to show how they have adapted to their fiery environment.

Helping Mother Earth

When you get your tennis shoes or some other small item of clothing wet, hang them outside and dry them with Sun power. This way you save the gas or electricity that would have been used to run an almost-empty dryer.

The Motive:

How Solar and Atmospheric Changes Might Affect Climate

☛Case No. 1 How could changes in the Sun affect climate?

CLUES:

Science researchers are investigating the possibility that changes in the Sun's energy output over long periods are altering Earth's climate. Amounts of visible light have been shown to vary somewhat, and emissions of UV radiation are even more unpredictable than visible wavelengths. Since changes in UV emissions can affect the chemistry of the ozone layer, scientists must measure both the Sun's UV output and the ozone in the atmosphere. By doing this, they can determine if thinning of the protective ozone layer is caused by the Sun, by human activities and natural events, or by all of these.

Increases in UV radiation coming from the Sun could also cause more chemical reactions that heat the middle atmosphere. On the other hand, a decrease in the amount of ozone in the stratosphere could reduce temperatures in the middle atmosphere because there would be less ozone to absorb the radiation. These changes in chemical composition and temperature in the stratosphere could lead to changes in temperature and weather on Earth.

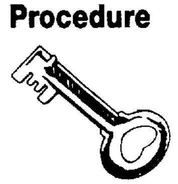
Investigation A: Watt Power!

For a long time, scientists believed that the amount of energy streaming across the millions of miles of space from the Sun never changed. In fact, the power of sunlight reaching the top of Earth's atmosphere is called the **solar constant**. The solar constant is figured to be about 1,300 **watts** per square meter at the top of the atmosphere. This is a great deal of power when you think about the light given off by only a 100-watt light bulb. But what if the Sun's radiance is not "constant" at all? Are even small changes in that power enough to change Earth's climate? ATLAS 2 scientists and those who come after them will continue to search for an answer to this mystery. To get some idea of the Sun's power in light bulb terms, complete this investigation.

Materials Needed:

✓ **pencil**
✓ **meter stick**
✓ **paper**

Procedure



Measure the length and width of a large section of the school playground or parking lot (about the area that would be occupied by three cars) with a meter stick. Multiply these two figures to find the number of square meters in this area. Now multiply that area by 1,300 to find the approximate number of watts received by that area on a sunny day. Finally, divide the number of watts by 100 to find out the equivalent number of 100-watt light bulbs that would be required to equal the amount of power arriving from the Sun at the top of the atmosphere. Note: This is only an approximate calculation. Exact figures would depend on the time of year, the exact time of day, and the geographical location of the area being measured.

Questions

❶ How many light bulbs are required?

❷ What does this tell you about the power coming from the Sun?

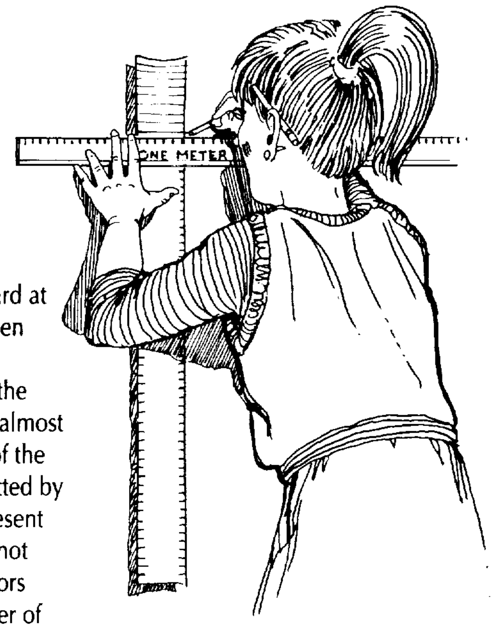
❸ How would your latitude affect the amount of the Sun's energy reaching the top of the atmosphere above you? What does this tell you about the power coming from the Sun?

Investigation B: All Kinds of Energy

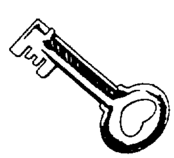
The Sun emits energy in different wavelengths, but that energy is not equally divided among the parts of the spectrum. Forty-one percent of the Sun's energy is emitted in the visible range. Fifty-two percent is emitted in the infrared range, and seven percent in what is called the "near" UV — those wavelengths that are closer in length to visible light. X-rays and the shorter UV wavelengths are only 0.001 percent of the total energy emitted. At the other end of the spectrum, radio waves and microwaves are only about 0.0000000001 percent. Scientists are particularly interested in UV emissions, for some frequencies of this wavelength are dangerous to humans, other animals, and plant life. Variations in UV emissions can also cause changes in the atmosphere. If there is more UV, chemical reactions speed up, increasing the heat in the atmosphere. If the Sun's output is changing in any way, it is important for us to know about it. To get a picture of the Sun's output by wavelength, try this activity.

Materials Needed:

- ✓ **1 piece of rectangular tagboard (sentence board), about 1 m long**
- ✓ **pencil**
- ✓ **meter stick**
- ✓ **colored pencils or markers**



Procedure



Using the meter stick, draw a vertical line across the tagboard at every 1-cm mark as shown. You should have 100 boxes when finished. Think of each box as a percent [0.01 (1/100th)]. Designate the left of the tagboard as the radio wave end of the spectrum. Energy emissions in this part of the spectrum are almost too small to mark, so draw a thin brown line at the far left of the tagboard to represent the radio waves and microwaves emitted by the Sun. Counting from the left, color 52 blocks red to represent the infrared emissions. (Remember that these emissions do not have "color"; they are invisible to the naked eye. These colors symbolize the wavelength differences.) Calculate the number of blocks that will represent visible light. Color these yellow. Figure the number left for the near UV, and color these pink. Because this leaves almost no space for remaining shorter wavelengths of UV and X-ray, draw only a thin purple line across the far right end of the tagboard to represent these wavelengths.

Questions

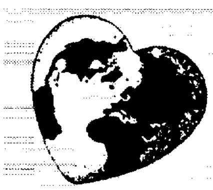
1. How many blocks will represent visible light?
2. How many will represent the near UV?
3. What wavelength range enables us to see?
4. What wavelength ranges provide most of Earth's heat?
5. Which wavelengths are beneficial to human, animal, and plant life?

Relating Science to . . .

Math: Scientists often measure temperatures in Kelvin (K). The zero point on the Kelvin scale is called **absolute zero**, which is believed to have no heat at all. The temperature 273 K is 0 degrees on the Centigrade (Celsius) scale. Because 0 on the Celsius scale is the point at which water freezes and 100 °C is the point at which water boils (at sea level), then the boiling point of water (at sea level) in Kelvin would be 373 K. To convert degrees Celsius to Kelvin, add 273. What would your normal body temperature be in Kelvin?

Draw thermometers showing the freezing and boiling points of water at sea level on the Celsius and Kelvin scales. Begin by drawing a horizontal line across a sheet of paper. Use this to mark the freezing point of water for both thermometers. From these points, construct two vertical lines to represent the Celsius and Kelvin scales. Be sure to show zero and the boiling and freezing points of water on both scales.

Helping Mother Earth



Did you know that it takes 180 kg of coal to produce the electricity needed to power a single 100-watt bulb that burns half a day, every day for a year? Burning this much coal would release 450 kg of greenhouse gases. Turn off the lights when you are not using them!

☛ Case No. 2

What does wind have to do with weather?

CLUES:

Like all other matter, air is made up of molecules. As air molecules are warmed, they absorb energy and move more quickly, causing the air to expand and its density to decrease. Density differences create pressure differences. Pressure variations from place to place force air to move, somewhat like air is pushed out of an inflated balloon. The force caused by pressure differences is called the **pressure gradient force**. Air motion is also affected by gravity and by Earth's rotation. The effect of Earth's rotation is called the **Coriolis effect**.

The complicated balance of pressure gradient forces, gravity, the Coriolis effect, and the wind's own energy work together to determine the motion of the atmosphere. The result can be calm, sunny weather. Or it can be a demonstration of nature's enormous power, such as a tornado or a hurricane.

Weather includes water, which is also affected by these forces. When water evaporates from the oceans and is carried over land, it condenses and falls as precipitation: rain, snow, or sleet. Weather varies greatly from place to place, but different regions of Earth have fairly stable **climates**, or normal weather patterns. Scientists are concerned that if changes in the heating or cooling of Earth's atmosphere occur, entire climates could change, affecting sea levels, natural ecosystems (such as forest, grasslands, etc.) and agriculture — the world's food supply.

Investigation A: Blow, Wind, Blow!

Wind direction is also an important component in determining weather patterns. If pressure differences were the only thing acting on winds, they would simply blow from high- to low- pressure areas. However, the Coriolis effect causes winds to appear to curve as they blow. The Coriolis effect is an apparent curve in the direction of anything moving over Earth's surface. To understand the effect, try this demonstration.

Materials Needed:

- ✓ **lazy susan or microwave turntable**
- ✓ **piece of cardboard, about 15 cm square**
- ✓ **scissors**
- ✓ **ruler**
- ✓ **marker**

Procedure

Cut a circle out of the cardboard the size of the turntable you use. Make a dot in the center of the circle to represent the North Pole. Place the cardboard "record" on the turntable. Using the ruler and the marker, draw a straight line from the center of the cardboard to one edge. This represents wind direction unaffected by Earth's rotation.

Slowly start the turntable rotating counterclockwise.
Again, using the ruler and marker, try to draw a straight line from the center of the cardboard to the edge. This represents winds moving from the North Pole toward the equator. Stop the turntable. Examine the line you have drawn.

Questions

❶ Is the first line straight?

❷ Is the second line straight?

❸ Since you drew both lines with a ruler, what can you say about the wind's path?

❹ Does the wind's path really change, or does it just seem to change?

❺ Would air moving from the South Pole into the Southern Hemisphere move in the same direction?

Investigation B: Global Wind Patterns

The region of Earth receiving the Sun's most direct rays is the equator. Here, air is heated and rises, leaving low-pressure areas behind. Moving to about 30 degrees north and south of the equator, the warm air from the equator finally begins to cool and sink. Between 30 degrees latitude and the equator, most of the cooling, sinking air moves back to the equator. The rest of the air flows toward the poles. The air movements toward the equator are called **trade winds** — warm, steady breezes that blow almost continuously. The Coriolis effect makes the trade winds appear to be curving to the west, whether they are traveling toward the equator from the south or the north.

The trade winds coming from the south and the north meet near the equator. These converging trade winds produce general upward winds as they are heated, so there are no steady surface winds. This area of calm is called the **doldrums**.

Between 30 and 60 degrees latitude, the winds that move toward the poles appear to curve to the east. Because winds are named for the direction from which they originate, these winds are called **prevailing westerlies.** Prevailing westerlies in the Northern Hemisphere are responsible for many of the weather movements across the United States and Canada.

At about 60 degrees latitude in both hemispheres, the prevailing westerlies join with **polar easterlies** to produce upward motion. The polar easterlies are formed when the atmosphere over the poles cools. This cold air then sinks and spreads out over the surface. As the air flows away from the poles, it is turned to the west by the Coriolis force. Again, because these winds begin in the east, they are called the easterlies. Many of these changes in wind direction are hard to visualize. Complete this exercise to see the patterns of the winds.

Materials Needed:

✓ **illustration below**

✓ **pencil**

✓ **colored pencils or markers**

Procedure

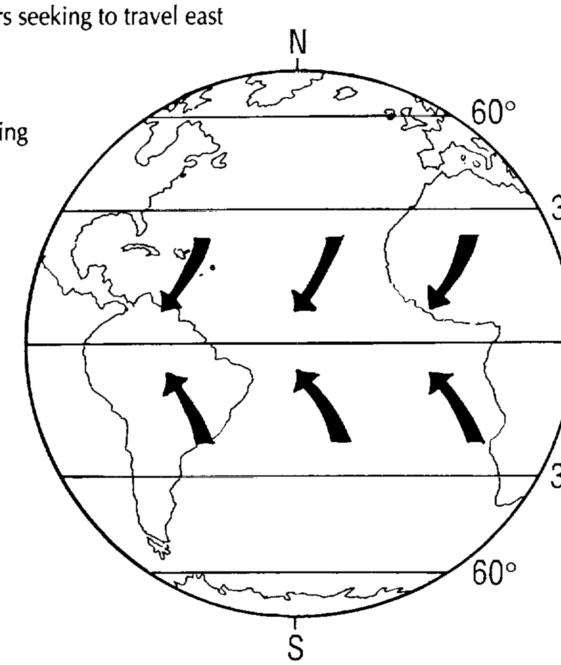
Carefully read the paragraphs above. Draw arrows to represent wind movement, being sure to show how the winds change direction at certain latitudes, which are labeled for you. Arrows representing the trade winds have already been drawn. Use orange to color the trade winds, green for the prevailing westerlies, and blue for the polar easterlies. You may need to look back at the results of Investigation A to be able to show the Coriolis effect.

Questions

❶ What winds would Columbus have used to travel from Spain to the Caribbean?

❷ Which winds would he have needed to return to Europe?

❸ Would winds have favored European explorers seeking to travel east around the tip of Africa?



Relating Science to . . .

Mythology: In your library, read about the following characters associated with the wind in Greek mythology: Aeolius, Zephyrus, Notus, Eurus, and Boreas. Report your findings to your class.

Helping Mother Earth

Clothing can be recycled, too. Donate old clothes to a charity organization or sell them at a yard sale. When you do this, you are helping to preserve natural resources, such as cotton, wool, and silk. You are also reusing human-made materials, such as rayon, polyester, and dacron, which are made from oil.

Case No. 3 What are the roles of water vapor?

CLUES:

When you were small, did you like to play in the rain, feeling the cool drops on your face? Have you ever played in snow, tossing snowballs and building snowpeople? It provides fun, but water in its many forms is also a vital part of Earth's survival. Water vapor creates clouds that reflect sunlight and keep our planet from overheating. Water vapor also supplies water that makes up fog and rain. When the tiny water droplets that form clouds collide and join, they become heavier until they are pulled to Earth by gravity as rain. When temperatures are low enough that water vapor changes to a solid, snow is formed. All of these conditions are part of our weather. Water vapor plays many other roles too. In the troposphere, it acts as a greenhouse gas, absorbing heat and warming the atmosphere. Water vapor is carried into the stratosphere by convection currents. Here and even higher in the mesosphere, it is involved in chemical reactions. ATLAS 2 scientists are measuring concentrations of water vapor to better understand its many functions.

Investigation A: Slinging Things Around

While ATLAS 2 scientists measure water vapor in the middle atmosphere, you can measure it in the troposphere. An instrument called a **sling psychrometer** uses evaporation to measure to amount of water vapor in the air.

Materials Needed:

- ✓ **2 outdoor thermometers, securely mounted on cardboard or plastic**
- ✓ **length of twine, about 1 m**
- ✓ **gauze pad**
- ✓ **thread, about 5 cm long**
- ✓ **glass of water, allowed to reach room or outdoor temperature**

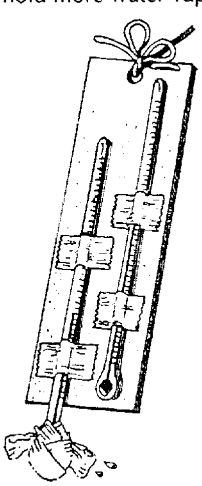
RELATIVE HUMIDITY

Dry Bulb Thermometer Readings (°C)	Difference Between Wet and Dry Bulb Thermometer Readings (°C)				
	1°	2°	3°	4°	5°
10°	88%	77%	66%	55%	44%
11°	89%	78%	67%	56%	46%
12°	89%	78%	68%	58%	48%
13°	89%	79%	69%	59%	50%
14°	90%	79%	70%	60%	51%
15°	90%	80%	71%	61%	53%
16°	90%	81%	71%	63%	54%
17°	90%	81%	72%	64%	54%
18°	91%	82%	73%	65%	57%
19°	91%	82%	74%	65%	58%
20°	91%	83%	74%	66%	59%
21°	91%	83%	75%	67%	60%
22°	92%	83%	76%	68%	61%
23°	92%	84%	76%	69%	62%
24°	92%	84%	77%	69%	62%
25°	92%	84%	77%	70%	63%
26°	92%	85%	78%	71%	64%
27°	92%	85%	78%	71%	65%
28°	93%	85%	78%	72%	65%
29°	93%	86%	79%	72%	66%
30°	93%	86%	79%	73%	67%
31°	93%	86%	79%	73%	67%
32°	93%	86%	80%	74%	68%
33°	93%	86%	80%	75%	68%
34°	94%	86%	81%	75%	69%
35°	94%	87%	81%	76%	69%

Procedure

Wrap the gauze around the bulb of one thermometer and secure with the thread. Punch a hole at the top of the cardboard or plastic thermometer mounting. Tie and knot the twine through this hole. Wet the gauze with water from the glass. Whirl or "sling" the thermometers around to speed up the evaporation process. Have you ever stood in a breeze while wearing wet clothes? If you have, you know that you are cooled as the water evaporates from your clothes. Because evaporation requires heat energy, the temperature recorded on the thermometer with the wet gauze will fall.

About every 20 seconds, check and record the temperatures. Repeat the whirling and checking until the temperature of the gauze-wrapped thermometer stops falling, which occurs when the evaporation of water from the gauze has cooled the thermometer as much as possible. This final reading is called a **wet bulb thermometer** reading. Then record the temperature on the other thermometer. Use the chart on this page to determine the **relative humidity**, the percentage of moisture the air holds "relative" to the amount it is capable of holding. (To use the chart, locate the row for your dry bulb reading and the column for the difference in your wet and dry bulb readings. The number in the box where this row and column meet is the relative humidity.) Relative humidity is easy to understand if you know that the amount of water vapor that air can hold depends on air temperature. Warm air can hold more water vapor than cool air. At 30 °C, 1 cubic meter of air can hold 30 grams (g) of water. If that amount of air at 30 °C holds only 20 g, the relative humidity is 66%. This percentage is the actual amount of water vapor held (20 g) divided by the amount it is capable of holding (30 g). The answer will be a percentage, because it is the relationship between actual humidity and possible humidity, based on temperature.



20 g / 30 g x 100 (because this is a percentage) = $66\frac{2}{3}$%

Air that is holding the maximum amount of water vapor possible at a given temperature is **saturated**. The temperature at which air becomes saturated is called the **dew point**. When air temperature drops below the dew point, water vapor begins to change back into a solid or liquid in a process called **condensation**.

Questions

1. What relative humidity reading did you get outdoors?
2. Repeat the experiment inside. What is the relative humidity indoors?
3. The wet thermometer reading is lower than the dry. What do you think caused the drop in temperature?
4. What would the relative humidity be if the wet and dry bulb temperatures were the same?
5. Calculate the relative humidity of 1 cubic meter of air at 30 °C if it holds only 10 g of water.

Investigation B: Clouds in a Bottle

Clouds are created when water vapor in air cools and **condenses**, or changes from a gas to a liquid. As it moves upward, the air cools until it reaches the dew point, the point at which air is saturated with water vapor. The shapes of the clouds that form depend on the stability of the surrounding air.

To get an idea of how clouds form, do the following.

Materials Needed:

✓ **several cans of carbonated soft drinks at room temperature**

Procedure

Open a can of carbonated soft drink, being careful not to shake it up. Watch carefully to spot the fog that comes from the opening. Pressure on gas causes its temperature to rise. When pressure is released, the gas cools. When the can is opened, pressure inside the can is released, and you see the water vapor condense as the gas (air, carbon dioxide, and water vapor) cools. There are other ways to see a process somewhat similar to cloud formation. Watch dry ice (frozen carbon dioxide) when it is exposed to the air, or watch the "clouds" that are released when you open the door to the ice section of a refrigerator.

Questions

❶ Try the same procedure with a very cold can of soft drink. Do you see as much of a cloud? Why?

❷ A weather event called fog is actually a cloud on the ground.
a. What time of day do you usually see fog?
b. What causes fog to form?

Relating Science to . . .

Geometry: You may not realize it, but if you have ever cut out paper snowflakes, you were illustrating a scientific fact. To discover what that fact is, divide into teams and make snowflake patterns. Each team will need a compass, several pieces of white paper, a protractor, a pencil, and a pair of scissors.

1. Using a compass, draw a circle about 15 cm in diameter.
2. Cut out the circle.
3. Fold the circle in half.
4. Place the half-circle on the table (or desk) with the fold toward you.
5. Measure the folded edge to find the middle point.
6. Place the center of a protractor on this middle point.
7. Measuring up from the left corner, place a dot at the 60° point at the outer edge of the half-circle.
8. Fold the right corner of the half-circle up to your left, placing the corner on the 60° mark.
9. Fold the bottom corner on the left up and across to the right, forming a cone. Keep the right edges of the cone even.
10. Using your scissors, cut straight across the open end of the cone from corner to corner so all the edges will be straight and a triangle will be formed.
11. Cut decorative notches in the three sides and the middle of the triangle. Be creative!
12. Repeat this procedure with 2 more pieces of paper.
13. Cut each triangle a little differently. Cut only the outside edges of the last triangle you make.
14. Now unfold each snowflake you have made.
15. Answer the following questions:
    a. Each team should display its work. What do all of the snowflakes have in common?
    b. Ice crystals always assume the same shape. What is that shape called? The last shape, the plainest, is the basic shape of an ice crystal. The fancier shapes grow if there is a large amount of water vapor in the air, and temperatures are low.

Helping Mother Earth

Some greenhouse gases occur naturally. Others are produced by industries making things for us to use. If we plan carefully to reuse everyday objects, we are helping to reduce greenhouse gases and garbage. Make sure that all the items used in experiments in this activity guide are reused or recycled.

The Method:

How ATLAS 2 Investigators Make These Measurements

Case No. 1 How can we measure from a distance?

CLUES:

Is it possible to measure the energy coming from the Sun? We certainly can't go to the Sun and leave a thermometer, and measurements on Earth's surface are affected by the absorption and reflection of our atmosphere. How can we measure ozone and other gases in the atmosphere? Going into space and "taking a sample" of ozone or other gases would give only a tiny specimen from one point in space at one particular time. Scientists who study the Sun and the atmosphere cannot use ordinary means of measurement. They cannot come in contact with those things they need to measure. Instead, they must use **remote sensing**, the process of obtaining information from a distance. Science detectives aboard ATLAS 2 operate seven remote-sensing instruments: two **radiometers** and five spectrometers. The radiometers measure the amount of the Sun's energy showering into Earth's atmosphere. The spectrometers sample sunlight interacting with the atmosphere or radiation emitted by the atmosphere.

Investigation A: Fingerprints!

As you know, visible light is only part of the solar spectrum. All energy particles in the spectrum move in waves at the same speed. Over the same distance, more energetic particles have more waves than particles with less energy. Another way of saying this is that particles with more energy move at greater frequencies than particles with less energy. Scientists label the parts of the spectrum according to the frequency of the wave particles of energy. Radio waves are long, low-frequency waves. As we move up through the microwave, infrared, visible, UV, X-ray, and gamma-ray parts of the spectrum, the waves have much higher frequencies. Gamma-ray waves have the highest frequencies.

All elements absorb or reflect different wave frequencies. This is why the objects we look at have different colors. Grass, for example, reflects more green light in the visible spectrum than any other part. When light emitted from or reflected by an object is passed through a **spectroscope**, the pattern of lines that emerges is called a **spectral signature**. This resulting "fingerprint" enables scientists to identify elements.

To see how objects reflect or absorb light, try this experiment.

Materials Needed:

- ✓ **paint chips from one paint manufacturer (to make results as uniform as possible): red, blue, green, and yellow. (All students' paint chips should be identical.)**
- ✓ **different light sources: Sun, incandescent, neon, high-pressure sodium, low-pressure sodium, halogen, etc.**
- ✓ **different colored incandescent bulbs**
- ✓ **chart printed on this page**

LIGHT SOURCE				
Sun	Neon	Incandescent	Halogen	
Blue				
Red				
Green				
Yellow				

Procedure

Expose identical paint color chips to different light sources. Write down the color of the chip as it appears under different lights. Compare your results.

Questions

1. Do the colors seem to change under different light sources?
2. Can the colors actually change? Why?
3. What else could be causing the colors to appear to change?
4. What does this tell you about the frequencies of the light sources?

Investigation B: Out on a Limb

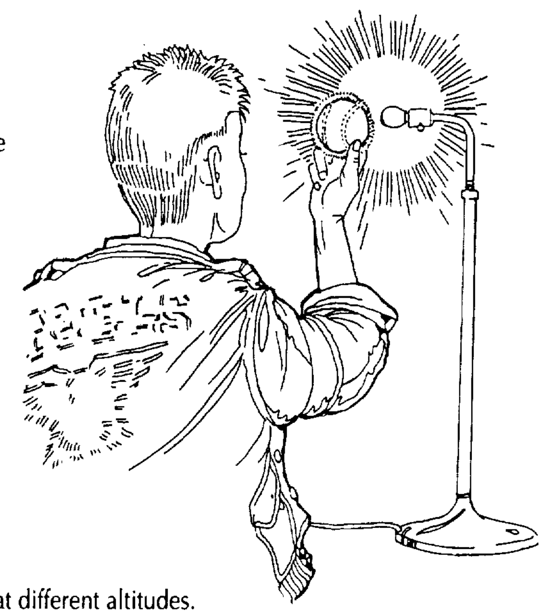
One remote sensing technique is called **limb sounding**. Earth's limb is the very edge of the planet's horizon as it appears from space. When observers "sound," they scan the atmospheric layers above the horizon. They may examine the Sun's light as it passes through the atmosphere or measure emissions from Earth's atmosphere.

In the first method, researchers compare the Sun's unfiltered light to sunlight that has passed though the atmosphere. Certain frequencies of light moving through the atmosphere may be absorbed by different chemicals. Also, the same chemical might absorb several different frequencies of light. Comparing the unfiltered and filtered sunlight can reveal much about elements and compounds in the atmosphere, such as what chemicals are there, how much of the chemicals are present, and where they are densest.

It is not necessary for the scientists to use sunlight for the second method. In this form of limb sounding, they scan Earth's limb, looking for the spectral signatures of chemicals which may be emitting energy into the atmosphere.

Materials Needed:

- ✓ **light source, such as a light bulb in a lamp**
- ✓ **new tennis ball**



Procedure

Facing the light, hold the tennis ball at eye level, blocking the light as much as possible. Look through the fuzz at the very edge of the ball. If the light bulb were the Sun and if your eye were an ATLAS instrument on the Shuttle, it would be looking at the Sun through the *lower* part of Earth's atmosphere. Now, move your head slightly so you can see more of the light bulb, but still be looking through the tennis ball fuzz. At this point, if the light bulb were the Sun and your eye were an ATLAS instrument on the Shuttle, it would be measuring the sunlight coming through Earth's *upper* atmosphere. This is similar to the method of limb sounding in which researchers examine sunlight through Earth's atmosphere. The tennis ball represents Earth and the fuzz represents Earth's atmosphere. As the Shuttle passes from the dark area on Earth's night side, scientists are able to look through the atmosphere, examining and measuring the Sun's radiation and the atmosphere's contents at different altitudes.

Questions

❶ As the Shuttle approaches the sunlight, what part of the atmosphere will researchers observe first?

❷ As the Shuttle continues through its orbit, do the ATLAS instruments observe sunlight through different layers of the atmosphere?

❸ Why is this important?

Relating Science to . . .

Art: Try to mix paints or colored pencils to achieve the strange colors that resulted when you held the paint chips under different kinds of light. Paint an outdoor scene substituting these new colors for green, blue, and other naturally occurring colors.

Creative Writing: Write a story entitled, "Looking Through Colored Glasses." Use your imagination to describe the world as it might look in different colors.

Helping Mother Earth

When you go to the supermarket for a few small items, carry your own reusable grocery bag. Members of the school's sewing classes may want to make canvas bags as a class project.

☛ Case No. 2

How can scientists be sure their measurements are accurate?

CLUES:

The sunspot cycle lasts about 11 years. Other changes in the Sun's emission of energy take place even more slowly, and they are extremely small changes. The Sun's brightness varies only from 0.1 to 0.5 percent, but when you think of the Sun's energy output, even these seemingly small changes might create noticeable variations in our climate. Scientists must measure carefully to detect these tiny changes and over long periods of time to discover cycles of change. Instruments must also be extremely accurate and must be **calibrated** (checked against a known standard) frequently.

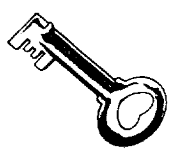
Investigation A: Millions of Measurements

This activity will help you see how difficult it can be to measure small amounts accurately.

Materials Needed:

- ✓ **one 1-m stick per group**
- ✓ **pieces of tagboard (sentence board), about 1 m long (two for each student group participating)**
- ✓ **pencils**

Procedure



Work in pairs, and create two measuring instruments out of tagboard, using a standard meter stick to mark centimeters on one instrument and decimeters (1/10 meter) on the other. Make the tagboard instruments approximately 1 meter long. Measure the items listed on the chart AS CAREFULLY AS POSSIBLE. Measurements should be made first in decimeters and then in centimeters. Estimate each fractional part as a decimal, and convert each measurement to millimeters. When all measurements are complete, check the accuracy of your tagboard instruments by using the meter stick to make the same measurements in millimeters.

	LENGTH					WIDTH					HEIGHT				
	tagboard				meter stick	tagboard				meter stick	tagboard				meter stick
	dm	= mm	cm	= mm	mm	dm	= mm	cm	= mm	mm	dm	= mm	cm	= mm	mm
New pencil															
Science textbook															
Notebook paper															
Desktop															
Penny															
Shoelace aglet															
*															
*															
*															

* *The students may pick additional objects to be measured.*

Questions

1. How did your measurements made with the tagboard instruments compare with the measurements made with the meter stick? Why?
2. Which things were most difficult to measure accurately with the tagboard instruments? Why?
3. Which scale (decimeter or centimeter) on the tagboard instruments gave you the most exact measurement? Why?
4. How can scientists be sure that their measurements of small changes are accurate?
5. What does this suggest about the difficulty of making small measurements accurately?

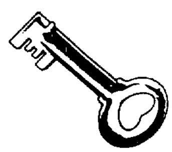
Investigation B: Nothing but the Truth

All the mysteries that ATLAS 2 scientists are investigating involve possible causes of atmospheric changes. To obtain the most accurate information, researchers must measure chemicals at different altitudes in the atmosphere in sunlight and in darkness, and during all seasons for many years. Even then, scientists have more questions: Are the instruments measuring accurately? What were conditions nearer the ground when measurements were made from space? How are conditions in the middle atmosphere related to events in the troposphere? To help answer these questions, researchers use airplanes, balloons, rockets, and ground measurements to double check and add to data obtained from space. These efforts are called **ground-truth studies** and they make remotely sensed data even more accurate and important. You, too, can perform ground-truth studies.

Materials Needed:

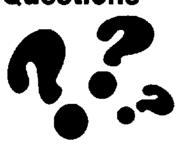
✓ **daily newspapers**
✓ **pencils or pens**

Procedure



Check the newspaper daily and record information on temperature highs and lows, amount of precipitation, and humidity. Keep these charts, and as the year goes on, figure weekly and monthly averages for your area. You may want to compare these with figures from previous years, using an almanac or examining old newspapers in the microfiche section of your library. You might also want to make your own measurements of rainfall, snowfall, and high and low temperatures. Different groups may want to select forecasters on several radio or TV stations to determine which predicted results are closest to those actually measured.

Questions



❶ What do you notice about temperature highs and lows, precipitation, and humidity throughout the year?

❷ Do these seasonal variations mean that the climate is changing?

❸ If you investigate measurements from past years, do changes necessarily mean that the climate is changing?

❹ How accurate are the weather forecasts in your area?

Date	High Temp	Low Temp	Precip-itation	Humidity
1.				
2.				
3.				
4.				
5.				
6.				
7.				
8.				
9.				
10.				
11.				
12.				
13.				
14.				
15.				
16.				
17.				
18.				
19.				
20.				
21.				
22.				
23.				
24.				
25.				
26.				
27.				
28.				
29.				
30.				
31.				
Daily Average				

Relating Science to . . .

Math: Calculate weekly, monthly, and yearly averages of temperature and rainfall in your area. Make a bar chart showing average temperatures for each time span. Another important statistic is how much temperature and rainfall changes differ from the average. This difference is called the "standard deviation" because it measures how much something "deviates" or differs from the average.

Helping Mother Earth

We often take water for granted, but it is one of our most precious resources. Leaks waste water, and even a small leak that fills up a coffee cup in 10 minutes will waste over 11,370 liters of water in a year. To check your house for a leak, read the water meter before the family leaves to go on vacation. Make sure you turn off all appliances that use water, such as ice makers, automatic sprinklers, and humidifiers. Read the meter again when you get back. If it has moved and no one has been at home, you have a leak.

ANSWERS

The Search: What ATLAS 2 Scientists Investigate

Case No. 1 - Why study the atmosphere?

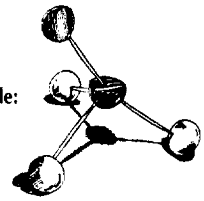
Investigation A: Building Gases

① The amount of UV radiation reaching Earth increases.

Investigation B: Out Goes the Ozone

① No.
② It will destroy the ozone.
③ Eat them.

Correct model of $CFCl_3$ molecule:



Relating Science To . . .

Math: Ten years ago, the ozone hole was estimated to be 1.35 million sq km.

Case No. 2 - Why study the Sun?

Investigation A: Here, Spot.

① Solar eclipse

Investigation B: Hot, Hotter, Hottest

Labels for the drawing of the Sun:
1a. Core
b. 15,000,000
2a. Photosphere
b. 6,000
3a. Chromosphere
b. 27,800
4a. Corona
b. 1,000,000

Answers to questions:
① 6,000 °C
② 1,000,000 °C
③ White

The Motive: How Solar and Atmospheric Changes Might Affect Climate

Case No. 1 - How could changes in the Sun affect climate?

Investigation A: Watt Power!

① Answers will vary. For a space measuring 9.5 m x 4.5 m, the answer is approximately 556 bulbs.
② The amount of power or energy coming from the Sun is enormous.
③ Sunlight arrives at the equator at the most direct angle, so areas near the equator receive the most energy.

Investigation B: All Kinds of Energy

① 41 blocks
② 7 blocks
③ Visible light
④ Infrared and visible
⑤ Infrared, visible, and some UV wavelengths

Relating Science to . . .

Math: A normal body temperature of approximately 37 °C would be 310 K.

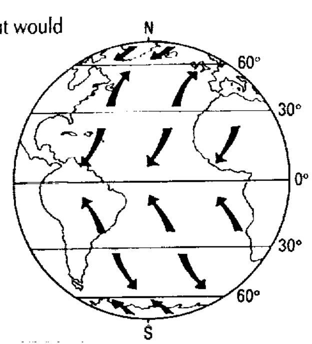
Case No. 2 - What does wind have to do with weather?

Investigation A: Blow, Wind, Blow!

① Yes.
② No, it is curved to the left.
③ The wind's path is straight, but the Earth rotates beneath the wind.
④ It just seems to change.
⑤ They would still curve to the left but would be blowing from the opposite pole.

Investigation B: Global Wind Patterns

① Trade winds
② Prevailing westerlies
③ No.



Case No. 3 - What are the roles of water vapor?

Investigation A: Slinging Things Around

① Depends on conditions
② Depends on conditions
③ Cooling effect or evaporation
④ 100%
⑤ 33 1/3%

Investigation B: Clouds in a Bottle

① No. The gas inside a very cold can is not under much pressure because there is little heat. Since there is not much change in pressure when the can is opened, the gas does not condense.
② **a.** In the morning
b. At night, the ground surface cools by radiating heat to space. Air near the ground cools to the dew point temperature, causing water in the air to condense.

Relating Science To . . .

Geometry:
15a. They all have six sides.
b. A hexagon

The Method: How ATLAS 2 Investigators Make These Measurements

Case No. 1 - How can we measure from a distance?

Investigation A: Fingerprints!

① Yes, the colors look different under different lights.
② Yes and no. The colors appear different under different light sources, but when viewed in regular sunlight, they return to the color as we usually see it.
③ The frequencies emitted by different lights are causing the colors to appear to change.
④ The various light sources emit frequencies of light that are not the same as regular sunlight. The colors absorb these frequencies differently than regular sunlight, and our perception of the colors changes.

Investigation B: Out on a Limb

① In this demonstration, their first view of sunlight will take place in the lower part of the atmosphere, the troposphere.
② Yes. As the Shuttle moves around Earth, scientists are able to view sunlight as it moves through the upper layers of the atmosphere.
③ Different wavelengths of the sunlight are absorbed at varying heights in the atmosphere. This allows the researchers to determine the concentrations of specific chemicals at various atmospheric heights.

Case No. 2 - How can scientists be sure their measurements are accurate?

Investigation A: Millions of Measurements

① Answers will vary. If the tagboard measurements were very close to the meter stick measurements, it was because students were very careful in making the measurement and instrument, and gradations were precise. If tagboard measurements varied significantly, it was because the group did not make a precise instrument and/or they did not measure carefully.
② The small items were most difficult to measure accurately.
③ The centimeter scale should give the most exact measurement.
④ Scientists should measure very carefully and use instruments that can indicate very small changes.
NOTE: Conversion factors for the chart —
1 centimeter = 10 millimeters *1 decimeter = 10 centimeters*

Investigation B: Nothing but the Truth

① Temperature, precipitation, and humidity vary regularly with the seasons.
② No. Seasonal changes by themselves do not necessarily indicate a change in climate.
③ Investigations covering many hundreds of years would be able to indicate whether climate is changing. Observations of changes occurring over a few years may or may not have enough information.
④ Answers will vary.

NOTE: For a good source of climatological data, write for a monthly summary from:

Local Climatological Data
National Climatic Data Center
Federal Building
Ashville, NC 28301
Attn: Publications

They provide summaries published each month of the year, which are available for past years at a reasonable fee. There is also a yearly summary of temperature and precipitation. These data sheets are available for many cities throughout the U.S.

Glossary

absolute zero: the zero point on the Kelvin temperature scale at which a substance has absolutely no heat

aerosol: fine solid or liquid particles suspended in air

bonds: forces that hold compounds together; formed when atoms share electrons

calibrate: to check or adjust a measuring instrument against a known standard

chromosphere: the middle gaseous layer of the Sun's atmosphere

climate: the average of local temperature, precipitation, and wind conditions, etc., over a period of years

condense: to change from a gas to a liquid or solid

condensation: the process of changing from a gas to a liquid or solid

corona: the outer layer of the Sun's atmosphere

Coriolis effect: a force created by Earth's rotation; strongly influences global wind patterns

dew point: the air temperature at which moisture in the air begins to condense and form dew drops

doldrums: an area near the equator where the air is generally calm

electron: a negatively charged particle in an atom

electron cloud: a "cloud" formed by electrons revolving around a nucleus of an atom

fusion reaction: a reaction in which the nuclei of atoms combine to form more massive nuclei with a simultaneous release of huge amounts of energy

ground-truth studies: measurements of atmospheric conditions made from Earth to verify the accuracy and precision of measurements of the same area made from space

hydroxyl: a compound made of one atom each of oxygen and hydrogen

limb sounding: a technique used from space to measure Earth's atmospheric elements by scanning the atmosphere from the horizon upwards or from the top of the atmosphere downwards

nucleus: the center of an atom consisting of protons and neutrons

neutron: a small, uncharged particle in the center of an atom

photosphere: the Sun's lower atmosphere

proton: a small, positively charged particle in the center of an atom

prominence: a huge arc of gas emitted from the Sun's surface during a solar storm

polar easterly: cold wind flowing away from Earth's poles toward the west

pressure gradient force: pressure variations that force air to move from place to place

prevailing westerly: wind in the 30° - 60° latitude belts that travels from the west to the east

radiometer: an instrument that measures radiant energy; for example, the amount of solar energy received by Earth

relative humidity: the amount of water vapor in the air at a specific temperature compared to the maximum amount it could hold at that temperature

remote sensing: a process of obtaining information from a distance

saturated: unable to hold or contain more

shell: the outside area of an electron cloud

sling psychrometer: an instrument consisting of a dry and a wet thermometer whose readings are compared to measure relative humidity

solar constant: the amount of solar energy received per unit time (e.g. second) by the upper layer of Earth's atmosphere

solar flare: a temporary outburst of solar gases from a small area of the Sun's surface

solar wind: electrified gases ejected at high speeds from the surface of the Sun

spectroscope: an instrument that separates light into specific wavelengths

spectral signature: a distinctive array of wavelengths of light emitted or reflected by a particular substance

sunspot: dark spots that appear on the Sun during times of increased solar activity

trade winds: steady winds in the tropics that blow from east to west

unstable: likely to change

watt: a unit of measurement of power; how fast energy is expended or received

wet bulb thermometer: a thermometer used to measure relative humidity

Resources

Organizations

This list of independent organizations represents possible sources of educational materials and information not available from the National Aeronautics and Space Administration and is offered without recommendation or endorsement by NASA.

American Geophysical Union
2000 Florida Avenue, N.W.
Washington, DC 20009
Phone: 202-462-6903

American Meteorological Society
45 Beacon Street
Boston, MA 02108
Phone: 617-227-2425

Aspen Global Change Institute
100 East Francis
Aspen, CO 81611
Phone: 303-925-7376

Environmental Action Foundation
6930 Carroll Avenue
Suite 600
Takoma Park, MD 20912
Phone: 301-891-1100

Environmental Research Institute of Michigan
Satellite Technology Education Program
Box 139001
Ann Arbor, MI 48113-4001
Phone: 313-994-1200

Friends of the Earth
Public Information Office
218 D Street, SE
Washington, DC 20003
Phone: 202-544-2600

National Center for Atmospheric Research
P.O. Box 3000
Boulder, CO 80307-3000
Phone: 303-497-8600 or 8606

National Geographic Society
17th and M Street, NW
Washington, DC 20036
Phone: 202-857-7000

U.S. Department of Commerce
National Oceanic and Atmospheric Administration
Education Programs Branch/EA31
11400 Rockville Pike, Rm 105
Rockville MD 20852
Phone: 301-443-8031

U.S. Environmental Protection Agency
Public Information Center
401 M Street, SW
Washington, DC 20460
Phone: 202-260-7751

Publications

Asimov, Isaac. *How Did We Find Out About the Atmosphere?* New York: Walker and Co., 1985.

Earth Book for Kids. The Learning Works. P.O. Box 6187, Santa Barbara, CA 93160

Williams, Jack. *USA Today: The Weather Book.* New York: Vintage Books, 1992.

NASA, (1989), *The Upper Atmosphere, A Program to Study Global Ozone Change,* 3/89:20K.

NASA, (1992), *ATLAS 1: Encountering Planet Earth,* NASA Marshall Space Flight Center.

NASA, (1991), NASA Fact Sheets, NASA Goddard Space Flight Center.

1. *What Is Ozone?, What Are Chlorofluorocarbons?, What is the Connection?*
2. *What is the Greenhouse Effect?*
3. *TOMS (Total Ozone Mapping Spectrometer)... Monitoring and Measuring Ozone*

NASA, HQL-207, UARS Lithograph

NASA, MH-007/10-91, Mission Highlights, STS-48 [Upper Atmosphere Research Satellite], Space Shuttle *Discovery*

NASA, MH-010/5-92, Mission Highlights, STS-45 [Atmospheric Laboratory for Applications and Science 1], Space Shuttle *Atlantis*

NASA, EP-274/1-90, *Seeing in a New Light,* Astro-1 Teacher's Guide with Activities

NASA, EP-280, July 1992, *Microgravity,* A Teacher's Guide with Activities, Secondary Level

NASA, EP-282/11-91, *Earth's Mysterious Atmosphere,* ATLAS 1 Teacher's Guide with Activities

Videotapes

NASA, *Beyond the Clouds: The Upper Atmosphere* (length 12:10)

NASA, *Beyond the Clouds,* Video Resource Guide, VRG-002 8/91

NASA, *Liftoff to Learning: Space Basics* (length 20:55)

NASA, *Liftoff to Learning: Space Basics,* Video Resource Guide, VRG-001 1/91

NASA, *Liftoff to Learning: Atmosphere (length 16:00)*

NASA, *Liftoff to Learning: Atmosphere,* Video Resource Guide, VRG-006-1292

Videotapes are available through NASA Teacher Resource Centers or Central Operation of Resources for Education (CORE). See pp. 19 and 20 for current addresses and phone numbers.

NASA Educational Resources

NASA Spacelink: An Electronic Information System

NASA Spacelink is a computer information service that allows individuals to receive news about current NASA programs, activities, and other space-related information, including historical and astronaut data, lesson plans, classroom activities, and even entire publications. Although primarily intended as a resource for teachers, anyone with a personal computer and modem can access the network.

The Spacelink computer access number is 205-895-0028. Users need a computer, modem, communications software, and a long-distance telephone line to access Spacelink. The data word format is 8 bits, no parity, and 1 stop bit. For more information, contact:

Spacelink System Administrator
NASA Marshall Space Flight Center
Mail Code CA21S
Marshall Space Flight Center, AL 35812
Phone: 205-544-6360

NASA Spacelink is also available through the Internet, a worldwide computer network connecting a large number of educational institutions and research facilities. Callers with Internet access may reach NASA Spacelink at any of the following addresses:

spacelink.msfc.nasa.gov
xsl.msfc.nasa.gov
128.158.13.250

NASA Select Television

NASA Select Television is the Agency's distribution system for live and taped educational programs. The educational and historical programming is aimed at inspiring students to achieve, especially in mathematics, science, and technology.

If your school's cable TV system carries NASA Select or if your school has access to a satellite antenna, the programs may be down-linked and videotaped. NASA Select is transmitted on SatCom F2R, transponder 13, C-band, 72 degrees west longitude, frequency 3954.5 MHz, vertical polarization, audio on 6.8 MHz. A schedule for NASA Select is published daily on NASA Spacelink. For more information, contact:

NASA Select
c/o Associate Administrator for Public Affairs
NASA Headquarters, Code P
Washington, DC 20546

NASA Education Satellite Videoconferences

During the school year, a series of educational programs is delivered by satellite to teachers across the country. The content of each video conference varies, but all cover aeronautics or space science topics of interest to the educational community. The broadcasts are interactive; a number is flashed across the bottom of the screen, and viewers can call collect to ask questions or take part in a discussion. For further information, contact:

Video Conference Coordinator
NASA Aerospace Education Services Program
300 North Cordell
Oklahoma State University
Stillwater, OK 74078-0422
Phone: 405-744-7015

Dr. Malcom V. Phelps
Educational Technology Branch
Education Division
Code FET
NASA Headquarters
Washington, DC 20546
Phone: 202-358-1540

NASA Central Operation of Resources for Educators (CORE)

CORE was established for the national and international distribution of NASA- produced educational materials in audiovisual format. Submit a written request on your school letterhead for a catalogue and order forms. Orders are processed for a small fee that includes the cost of the media. For more information, contact:

NASA CORE
Lorain County Joint Vocational School
15181 Route 58 South
Oberlin, OH 44074
Phone: 216-774-1051, Ext. 293 or 294

Teacher Resource Center Network

To make information available to the educational community, the Education Division has created the NASA Teacher Resource Center Network. Teacher Resource Centers (TRCs) contain a wealth of information for educators: publications, reference books, slides, audio cassettes, videocassettes, telelecture programs, computer programs, lesson plans and activities, and lists of publications available from government and nongovernment sources. Because each NASA field center has its own areas of expertise, no two TRCs are exactly alike. Phone calls are welcome if you are unable to visit the TRC that serves your geographic area. The chart that follows delineates the geographic regions and provides addresses.

National Aeronautics and Space Administration
General Information for Teachers and Students

If you live in:		Center Education Program Officer	Teacher Resource Center
Alaska Arizona California Hawaii Idaho Montana	Nevada Oregon Utah Washington Wyoming	Mr. Garth A. Hull Chief, Educational Programs Branch Mail Stop TO-25 **NASA Ames Research Center** Moffett Field, CA 94035 Phone: 415-604-5543	NASA Teacher Research Center Mail Stop TO-25 NASA Ames Research Center Moffett Field, CA 94035 Phone: 415-604-3574
Connecticut Delaware District of Columbia Maine Maryland Massachusetts	New Hampshire New Jersey New York Pennsylvania Rhode Island Vermont	Mr. Elva Bailey Chief, Educational Programs Public Affairs Office (130) **NASA Goddard Space Flight Center** Greenbelt, MD 20771 Phone: 301-286-7207	NASA Teacher Resource Laboratory Mail Code 130.3 NASA Goddard Space Flight Center Greenbelt, MD 20771 Phone: 301-286-8570
Colorado Kansas Nebraska New Mexico	North Dakota Oklahoma South Dakota Texas	Dr. Robert W. Fitzmaurice Center Education Program Officer Public Affairs Office (AP-4) **NASA Johnson Space Center** Houston, TX 77058 Phone: 713-483-1257	NASA Teacher Resource Room Mail Code AP-4 NASA Johnson Space Center Houston, TX 77058 Phone: 713-483-8696
Florida Georgia	Puerto Rico Virgin Islands	Mr. Raymond R. Corey Chief, Education and Awareness Branch Mail Code PA-EAB **NASA Kennedy Space Center** Kennedy Space Center, FL 32899 Phone: 407-867-4444	NASA Educators Resources Laboratory Mail Code ERL NASA Kennedy Space Center Kennedy Space Center, FL 32899 Phone: 407-867-4090
Kentucky North Carolina South Carolina	Virginia West Virginia	Mr. Roger Hathaway Acting Head, Office of Public Services Mail Stop 154 **NASA Langley Research Center** Hampton, VA 23665-5225 Phone: 804-864-3307	NASA Teacher Resource Center Mail Stop 146 NASA Langley Research Center Hampton, VA 23665-5225 Phone: 804-864-3293
Illinois Indiana Michigan	Minnesota Ohio Wisconsin	Dr. Lynn Bondurant Chief, Office of Educational Programs Mail Stop 7-4 **NASA Lewis Research Center** 21000 Brookpark Road Cleveland, OH 44135 Phone: 216-433-5583	NASA Teacher Resource Center Mail Stop 8-1 NASA Lewis Research Center 21000 Brookpark Road Cleveland, OH 44135 Phone: 216-433-2017
Alabama Arkansas Iowa	Louisiana Missouri Tennessee	Mr. William E. Anderson Chief, Education Services Branch Public Affairs Office (CA21) **NASA Marshall Space Flight Center** Marshall Space Flight Center, AL 35812 Phone: 205-544-7391	NASA Teacher Resource Center Alabama Space and Rocket Center Huntsville, AL 35807 Phone: 205-544-5812
Mississippi		Mr. Marco Giardino Center Education Program Officer Mail Stop AA00 **NASA John C. Stennis Space Center** Stennis Space Center, MS 39529 Phone: 601-688-2739	NASA Teacher Resource Center Building 1200 NASA John C. Stennis Space Center Stennis Space Center, MS 39529 Phone: 601-688-3338
The Jet Propulsion Laboratory (JPL) serves inquiries related to space and planetary exploration and other JPL activites.		Mr. Richard Alvidrez Manager, Public Education Mail Code 180-205 **Jet Propulsion Laboratory** 4800 Oak Grove Drive Pasadena, CA 91109 Phone: 818-354-8592	NASA Teacher Resource Center JPL Educational Outreach Mail Stop CS-530 Jet Propulsion Laboratory 4800 Oak Grove Drive Pasadena, CA 91109 Phone: 818-354-6916
California (mainly cities near Dryden Flight Research Facility)			NASA Dryden Flight Research Center Public Affairs Office (Trl. 42) NASA Teacher Resource Center Edwards AFB, CA 93523 Phone: 805-258-3456
Virginia's and Maryland's Eastern Shores			Wallops Flight Facility Education Complex – Visitor Center Building J-17 Wallops Island, VA 23337 Phone: 804-824-1176