UNIT 1
THE ATMOSPHERIC FILTER

Introduction

Earth's atmosphere is essential to life. This ocean of fluids and suspended particles surrounds Earth and protects it from the hazards of outer space. It insulates the inhabitants of Earth from the extreme temperatures of space and stops all but the larger meteoroids from reaching the surface. Furthermore, it filters out most radiation dangerous to life. Without the atmosphere, life would not be possible on Earth. The atmosphere contains the oxygen we breathe. It also has enough pressure so that water remains liquid at moderate temperatures.

Yet the same atmosphere that makes life possible hinders our understanding of Earth's place in the universe. Our only means for investigating distant stars, nebulae, and galaxies is to collect and analyze the electromagnetic radiation these objects emit into space. However, most of this radiation is absorbed or distorted by the atmosphere before it can reach a ground-based telescope. Only visible light and some radio waves, infrared, and ultraviolet light survive the passage from space to the ground. That limited amount of radiation has provided astronomers enough information to estimate the general shape and size of the universe and categorize its basic components, but there is much left to learn. It is essential to study the entire spectrum rather than just limited regions of it. Relying only on the radiation that reaches Earth's surface is like listening to a piano recital on a piano that has just a few of its keys working.

Unit Goal

- To demonstrate how the components of Earth's atmosphere absorb or distort incoming electromagnetic radiation.

Teaching Strategy

The following demonstrations are designed to show how components of Earth's atmosphere filter or distort electromagnetic radiation. Since we cannot produce all of the different wavelengths of electromagnetic radiation in a classroom, the light from a slide or overhead projector in a darkened room will represent the complete electromagnetic spectrum. A projection screen will represent Earth's surface and objects placed between the projector and the screen will represent various components of Earth's atmosphere. All of the demonstrations can be conducted in a single class period. Place the projector in the back of the classroom and aim it towards the screen at the front. Try to get the room as dark as possible before doing the demonstrations.

ACTIVITY: Clear Air

Description:

Students observe some of the problems inherent in using astronomical telescopes on Earth's surface through a series of brief demonstrations given by the teacher.

Objectives:

To demonstrate how Earth's atmosphere interferes with the passage of electromagnetic radiation.

National Education Standards:

Science
- Evidence, models, & explanation
- Transfer of energy

Technology
- Understand troubleshooting, R & D, invention, innovation, & experimentation

Materials and Tools:

For all demonstrations
- Darkened room
- Overhead or slide projector
- Worksheet for each student

- Demonstration 1
  Small sheet of clear glass or Plexiglass™
  Emery paper (fine) to smooth sharp edges of glass or plastic

- Demonstration 2
  Shallow dish or pie tin
  Empty coffee can
  Ice
  Spray bottle and water
  Cloud cutout (cardboard or other material)

- Demonstration 3
  Stick matches
  Eye protection

- Demonstration 4
  Food warmer fuel (e.g. Sterno™) or electric hotplate
  Matches if using fuel
  Eye protection if using fuel
  Aluminum foil
  Sewing pin

- Demonstration 5
  150 to 200 watt light bulb
  Uncovered light fixture
  Star slide (see demonstration 4)

Background:

Earth's atmosphere appears to be clear to the naked eye. On a dark, cloud-free night far from city lights, thousands of stars are visible. It is hard to imagine a better view of the sky when the wisps of the Milky Way Galaxy are visible stretching from the northern to the southern sky. In spite of the apparent clarity, the view is flawed. Many wavelengths are blocked by the atmosphere and visible light is filtered and distorted.

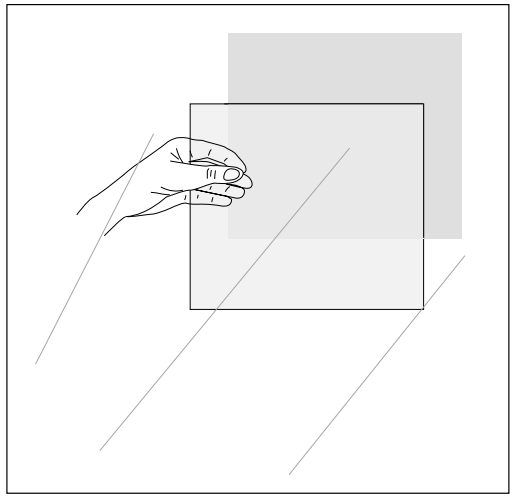
The demonstrations that follow are designed to show how Earth's atmosphere interferes with the passage of electromagnetic radiation. Visible light is used as an example of all wavelengths since most other wavelengths of electromagnetic radiation are difficult and even dangerous to produce in the classroom. Make sure students understand that the demonstrations are examples of what happens across the entire electromagnetic spectrum.

Management and Tips:
To make effective use of the demonstrations, it is necessary to have a room that can be darkened. A projection screen will represent Earth's surface and the light cast by an overhead or slide projector will represent all the wavelengths of electromagnetic radiation coming to Earth from space. The demonstrations are things that you do between the screen and the projector to represent phenomena occurring in Earth's atmosphere.

The actual demonstrations will take approximately 15 minutes to complete. Allow time to discuss the significance of each demonstration with your students. The most important thing to know is that Earth's atmosphere only allows a small portion of the electromagnetic spectrum to reach Earth's surface and astronomers' telescopes. The information astronomers can collect is incomplete and thus the story of the universe they are able to construct from this information is also incomplete. Conclude the discussion with the question "What can astronomers do about it?" The answer is to move observatories off the surface of Earth into outer space.

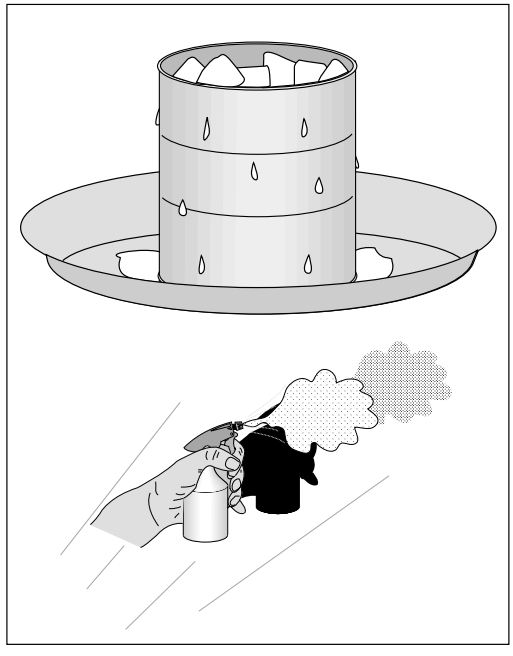
Procedures:
Demonstration 1 – The Air Is Not Clear
In this demonstration you will hold up a sheet of "clear" glass between the projector and screen. The glass represents the gases in Earth's atmosphere. Light from the projector is interrupted by the glass in its passage to the screen. Notice the faint shadow the "clear" glass casts on the screen. The shadow is evidence of a small amount of absorption of light by the glass. Also look for a reflection from the glass back in the direction of space. Photographs of Earth from space show a thin bluish layer of gas surrounding Earth. Being able to see the atmosphere from space indicates that some of the electromagnetic radiation falling on it from space is reflected back out into space.

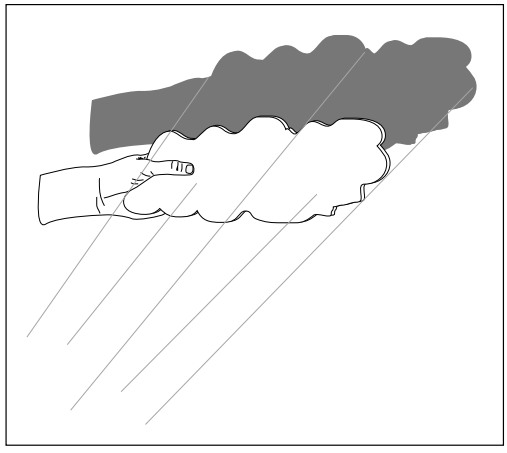
Demonstration 2 – Water in the Air
To begin this demonstration, fill a coffee can with ice cubes. The can is set in the middle of a dish or pie tin and left undisturbed. In a few minutes, the



outer surface of the can will begin "sweating." This is evidence that the air in the classroom holds moisture that condenses out when it comes in contact with a cold surface.

In the second part of the demonstration, spray a fine mist of water in the air between the projector and the screen. This illustrates how fine water droplets suspended in the air will block electromagnetic radiation. High humidity casts a haze in the sky that blocks incoming visible light.

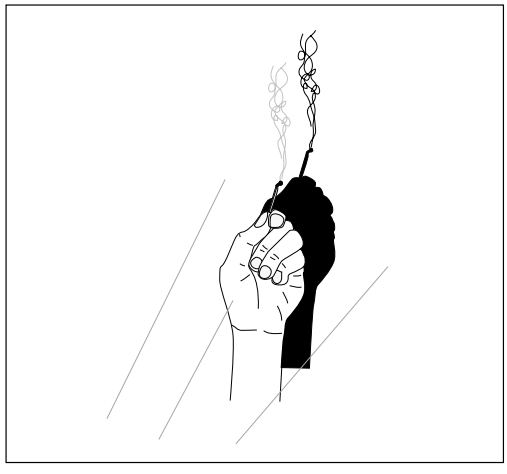




Finally, hold up the cloud cutout. The cloud shows what happens when moisture condenses in the air around small dust particles. The shadow cast by the cloud shows how clouds can substantially block visible light coming to Earth from space.

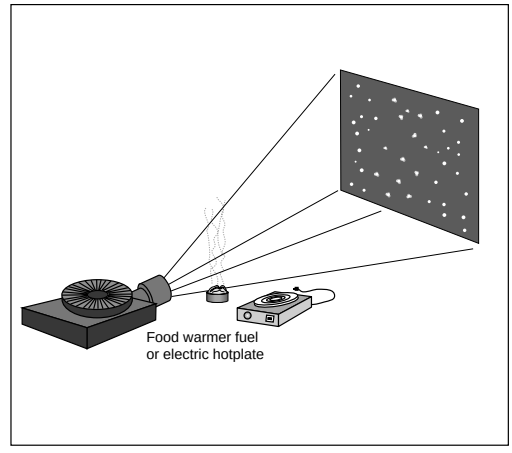
Demonstration 3 – Pollution

While wearing eye protection, strike a match and then blow it out right away. The smoke particles released from the match head will produce a noticeable shadow on the screen. Pollution from a variety of sources (human-made and natural) block some of the incoming visible light.



Demonstration 4 – Heat Currents

Prior to the demonstration, create a star slide. If you are using a slide projector, obtain a plastic slide mount in which the film can be removed. Slip a small square of aluminum foil into the

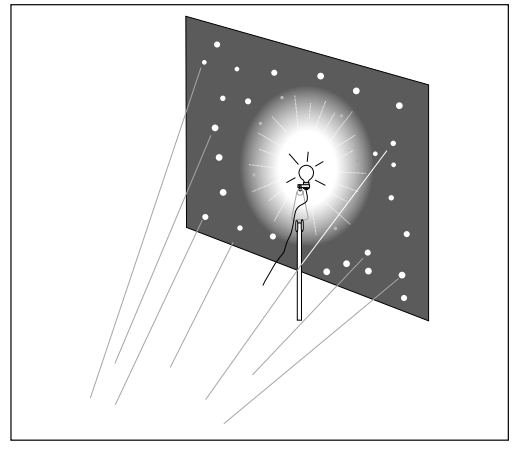


slide frame and use a pin to randomly prick about 30 holes into the foil. If you are using an overhead projector, prepare a star slide from a large square of aluminum foil. The square should cover the entire stage of the projector. Poke about 100 holes through the foil.

Project light through the slide you prepared. A small star field will be displayed on the screen. While wearing eye protection (not necessary if using an electric hot plate), place the warmer very near and just below the beam of the projector. Stars will show a twinkling effect on the screen. This demonstration shows how heat currents in Earth's atmosphere can distort the images of astronomical objects.

Demonstration 5 – Day/Night

Use the star slide you prepared in the previous activity. Hold up the lamp with the light bulb



near the screen. Turn on the bulb. Many of the stars on the screen near the bulb will disappear. This demonstration shows how the Sun's light overpowers the fainter stars. Sunlight brightens the gases, water, and particles in Earth's atmosphere so that the distant stars are not visible. If the Sun's light could be dimmed, other stars would be visible at the same time.

Assessment:

Collect student sheets. Compare the answers the students have given but focus on the last question in which students must propose solutions to the atmospheric problems associated with Earth-based observatories. Students may be aware of new strategies for improving the observations of Earth-based telescopes such as adaptive mirrors that change their shape slightly many times each second to compensate for air currents. However, no advanced telescope design technique will make up for electromagnetic radiation that does not reach Earth's surface.

Extensions:

- Have students research new Earth-based telescope designs on the Internet. Use search terms such as observatory, telescopes, and astronomy.

Student Work Sheet

Clear Air

Name: _____

1. Earth's atmosphere creates problems for astronomers. Identify and explain 3 ways Earth's atmosphere interferes with astronomical observations.

   A.

   B.

   C.

2. How might these problems affect the discoveries and conclusions astronomers reach through their observations?

3. Why are most astronomical observatories built on remote mountains?

4. What can astronomers do to capture the missing electromagnetic radiation for study?