Smoke and Mirrors:

Detecting the Amount of Gases in Wildland Fire Smoke

Glossary

ecosystem (**e** ko sis tem): Community of plant and animal species interacting with one another and with the non-living environment.

gaseous emissions (**gash** us **e mish** ens): Things discharged in the form of gas.

troposphere (**trop** uh sfer): The part of the atmosphere from Earth's surface up to about 6 miles.

vegetation (vej uh **ta** shun): Plant life.

molecules (**môl** uh kyools): Smallest particles of a substance. Consist of one or more atoms.

compounds (**käm** pownds): Chemical substances formed from two or more elements.

duct (dukt): A tube or a channel through which a gas or liquid moves.

plume (plum): Something that is shaped like a large, fluffy feather.

sample (**sam** pul): Part or piece that shows what the whole group or thing is like.

simulated (**sim** yoo lat ed): Created the appearance or effect of something for purposes of evaluation.

upwind (**up** wind): The direction from which the wind is blowing.

Pronunciation Guide

a	as in ape	ô	as in for
ä	as in car	u	as in use
e	as in me	ü	as in fur
i	as in ice	oo	as in tool
o	as in go	*ng*	as in sing

Accented syllables are in **bold**.

Dr. Yokelson

Dr. Ward

Dr. Griffith

Dr. Susott

Dr. Babbitt

Dr. Wade

Dr. Bertschi with African teens

Dr. Hao

Meet Dr. Yokelson:
I like being a scientist because in my job as a scientist at least one interesting thing happens almost every day.

Meet Dr. Ward:
I like being a scientist because every day brings something new. Being a fire scientist is important. I study questions about the danger of fire smoke to human health, whether forest fires contribute to global warming, and how to use small fires to protect society from big fires. The answer to one question often leads to many other questions.

Meet Dr. Griffith:
I like being a scientist because I am curious about what makes the world around me work the way it does. I enjoy developing instruments so that I can make careful measurements in our atmosphere. These measurements help me to solve problems. Being a scientist is a challenge, and it is very satisfying when you can help people solve problems.

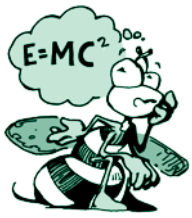
Meet Dr. Susott:
I like being a scientist because I get to work in interesting places with other scientists on problems of worldwide importance.

Meet Dr. Babbitt:
I like being a fire scientist because big fires are almost always exciting.

Meet Dr. Wade:
I like being a scientist because I get to investigate wildland fire. Wildland fire is one of nature's most awesome forces. Through research I learn how it can be harnessed to improve ecosystem health.

Meet Dr. Bertschi:
I like being a scientist because doing research is fun. Sometimes I get to go to interesting places to discover new things about the environment. I also like to tell others what I have discovered, and we get to share and discuss our ideas.

Meet Dr. Hao:
I like being a scientist because I want to understand the impact of human activities on the global environment.



Thinking About Science

Scientists often work with other scientists on their research projects. This is similar to what you do when you work with other students on a class project. In this study, scientists from the University of Montana, the USDA Forest Service, and the University of Wollongong in Australia worked together to study the *gaseous emissions* of forest fires. What are the advantages of working with others when you are trying to learn something new? What are the disadvantages?

Thinking About the Environment

You have probably heard a lot about global warming. Global warming is the gradual warming of the Earth. Some scientists believe that it will take decades or more to prove that global warming is or is not occurring. Other scientists believe that there is enough evidence now to claim that global warming exists. Global warming occurs when too much heat is trapped in the *troposphere* by certain kinds of gases. These gases are commonly called greenhouse gases. Some warming of the troposphere is necessary because the Earth would freeze without it. When greenhouse gases escape from Earth and are trapped in the troposphere, the heat is reflected back to Earth. One of the things that might cause greenhouse gases to escape into the troposphere is forest fires. The scientists in this study wanted to know the amount of greenhouse gases escaping to the troposphere during forest fires.

Introduction

Some kinds of forest fires can be beneficial to the natural environment and to people. Fire is a normal event in the natural environment. Some types of *vegetation* need fire to reproduce, and fire can help prepare the soil for new plant growth. Fires are sometimes purposely used by people to clear leftover trees and vegetation from an area after large trees have been cut for human use. Fires are also used to clear land of trees when the trees are not useful for lumber or other wood products. Forest fires also have some disadvantages. If they are not controlled, they might destroy homes and other buildings. Fire also produces gaseous emissions, some of which might contribute to global warming. The scientists in this study wanted to test the smoke that comes from forest fires to discover the amount of greenhouse gases going into the troposphere.

Reflection Section

- What is the question the scientists are trying to answer?
- If you were the scientist, how would you test the smoke coming from a forest fire?

Methods

The scientists built a special box to collect and measure the gases coming from forest fires. They put an instrument, called an infrared (**in** fruh red) spectrometer (spek **trôm** uh tür), into the box. An infrared spectrometer can identify what kind of *molecules* and *compounds* are in the smoke. It does this by shining infrared light into the smoke (figure 1). Different kinds of molecules react in different ways to the light. The spectrometer measures and records the reaction of the molecules and compounds, and from these measurements the scientists can identify the different kinds of molecules and compounds. They put the spectrometer in an airplane (figures 2 and 3).

To collect the smoke, they built a *duct* in the front of the plane, leading from the outside to the inside, and connected it to the spectrometer in the box. They also built a duct in the back of the plane, leading from the box to the outside. They put valves in the ducts so that they could control the air flow (figure 4). The scientists then flew the plane over three forest fires burning

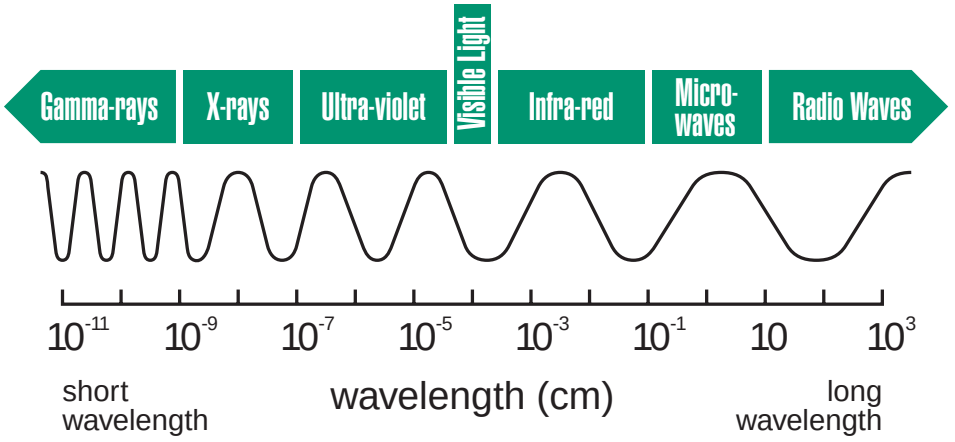


Figure 1. *Electromagnetic spectrum, showing the area of visible light and the light waves outside of the visible spectrum. Note the location of infrared light waves.*

in North Carolina (figure 5). The scientists collected smoke by opening the duct valves in both the front and back of the plane. Then they flew into the smoke *plume*. While they were in the smoke plume, they closed both of the valves (figure 6). In this way, the scientists collected *samples* of the smoke from the forest fire. The scientists flew the plane back and forth for many hours. They were able to collect many samples of the forest fire smoke.

Figure 2. *USDA Forest Service Air King 90. The smoke intake is visible in the side cockpit window. The pilot sat on the other side of the cockpit.*

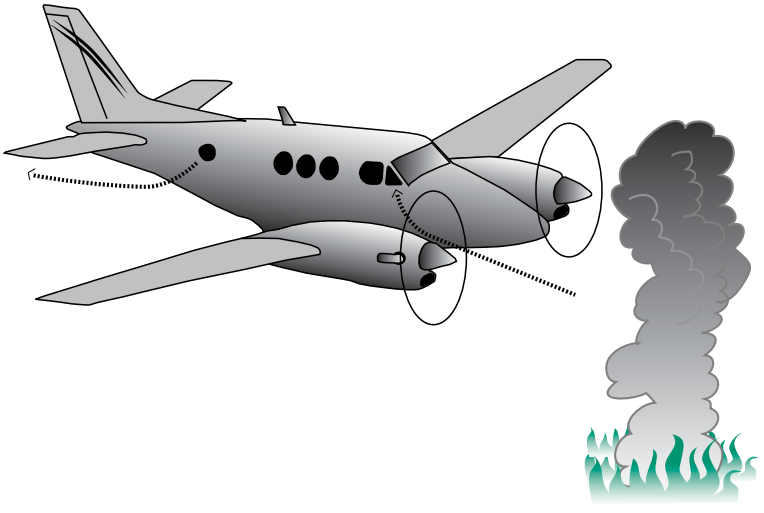


Figure 4. *Example of the duct system showing how forest fire smoke was moved through the spectrometer as the airplane flew through forest fire smoke.*

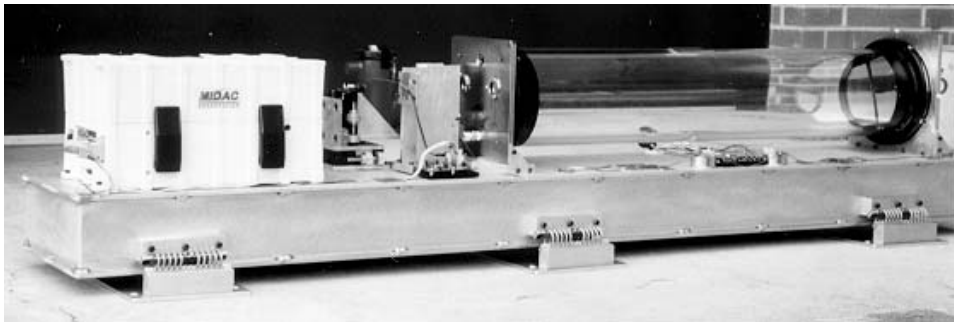


Figure 3. *The spectrometer before it was placed into the airplane.*

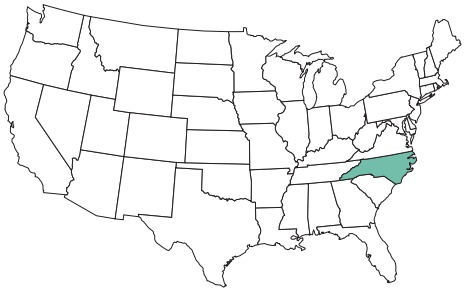


Figure 5. *North Carolina, on the east coast of the United States.*

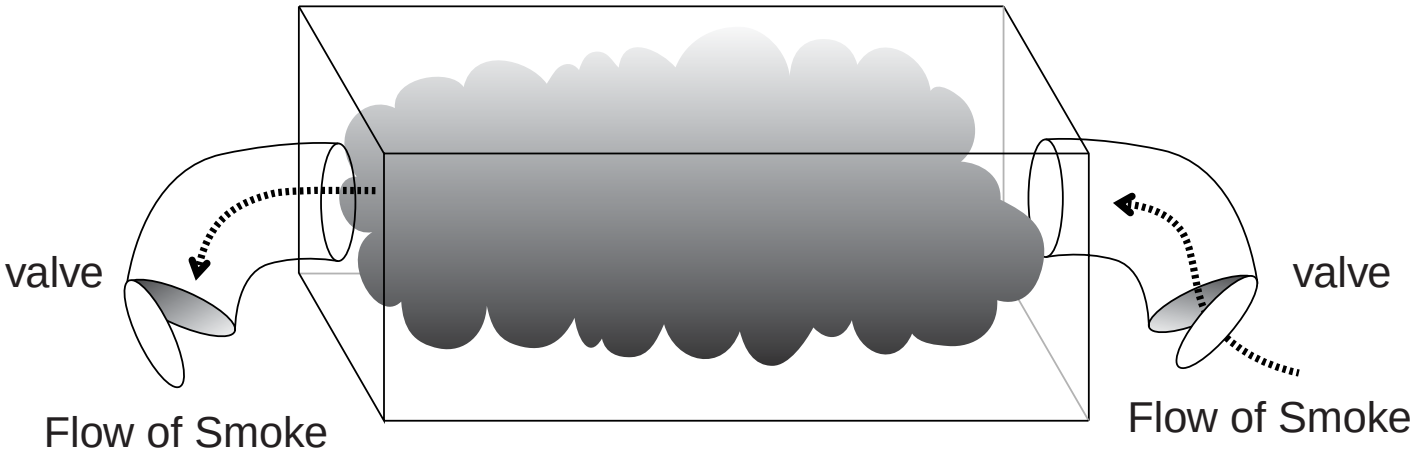


Figure 6. *The flow of the smoke was regulated by valves.*

The scientists used the spectrometer to measure the amount of certain greenhouse gases contained in the smoke. They measured formaldehyde (fôr **mowl** duh hid), acetic (uh **set** ik) acid, and methanol (**meh** than ôl). These three gases contribute to global warming by helping to create the greenhouse gas ozone (O_3). In the past, the scientists had *simulated* forest fire smoke in their laboratory. They had already measured the amount of these gases in the laboratory smoke as in the smoke from the actual forest fires. Then, they compared the amount of gases in both kinds of smoke.

Reflection Section

- Why do you think it is important to know how much greenhouse gases are contained in the smoke from forest fires? (Hint: Where does the smoke from these fires go?)
- Why do you think that the scientists compared the laboratory smoke with the actual smoke from forest fires?

Results

The scientists found that the amounts of formaldehyde, acetic acid, and methanol from the forest fires were similar to the amounts of these gases found in the laboratory smoke. Then, the scientists took all of their measurements and compared them with the amount of these gases other scientists had found in other research studies. The scientists in this study found greater amounts of the three types of gases than other scientists had found.

Fire Facts

Fires need fuel, heat, and oxygen to begin burning and continue burning. Although air usually contains about 21 percent oxygen, fire requires air with only 16 percent oxygen to burn. Wildland fire fuels are materials such as green plants, tree branches, and other burnable materials. When fuel burns, it reacts with the oxygen in the air, releasing heat and creating gases, smoke, and particles. This process is known as oxidation (ox uh **da** shun). Some of the gases created during oxidation may contribute to global warming. Close to Earth, the gases and particles in smoke can cause dangers to people's health.

Fire Safety Tips

Smoke from either wildland fires or uncontrolled home fires is very dangerous. The smoke from these fires poses a serious risk to human health and safety. If there is a fire in your home and smoke is surrounding you, stay as close to the floor as possible as you leave the house. Do not go toward the smoke, and use an escape route away from the smoke. Cover your nose and mouth with a damp cloth if possible. If you are outside near a wildfire or other fire, stay *upwind* of the fire, away from the smoke and the fire. Remember, smoke poses a serious danger to your health and safety – stay away from it!

Reflection Section

- Why do you think the scientists wanted to know how the actual forest fire smoke compared with the smoke they created in the laboratory? What would be the advantage of being able to create smoke in the laboratory that is similar to actual forest fire smoke?
- Why do you think it is important to compare current research results with earlier research results?

Implications

When formaldehyde, acetic acid, and methanol combine with other gases in the troposphere, ozone is formed. Ozone increases the possibility of global warming (See "Thinking About the Environment," above). Previous research had indicated that these three gases are not present in large amounts in forest fire smoke. However, the scientists in this study found that there are larger amounts of these gases in smoke than scientists had thought before. If the results from future studies agree with these results, forest fires may be become known as another source of gases that contribute to global warming.

Reflection Section

- Do you think that more studies should be done on this topic? Why or why not?

FACTivity

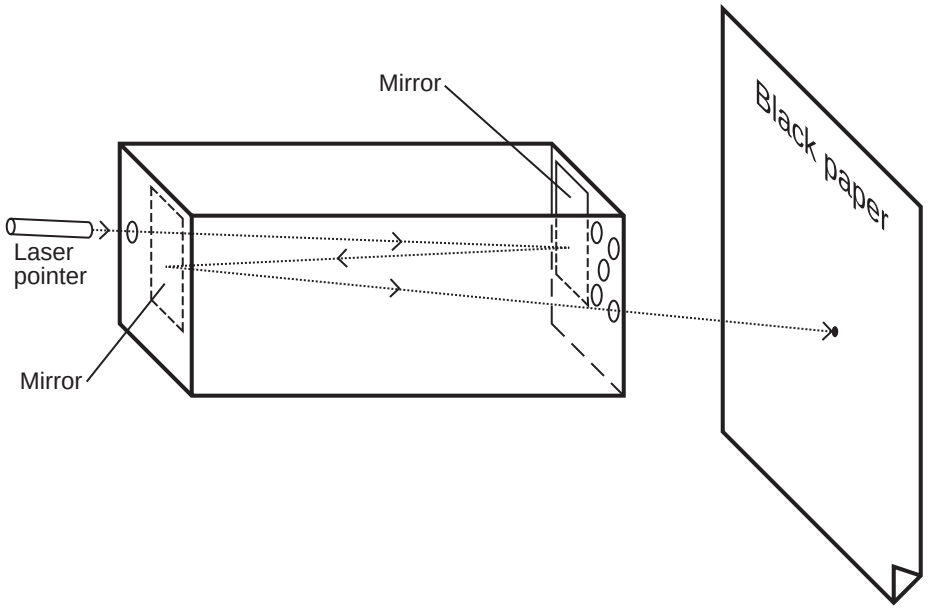
In this FACTivity, each student will answer the question: What barriers might you face if you had to quickly escape from a fire in your home? The method you will use to answer this question is: Each student will think about a fire occurring in the kitchen of their home. This is where many home fires start. When you learn about the fire, you are in your bedroom. What steps will you take to escape from your home? Get into groups of four students and discuss what you would do. Also discuss what you might do in advance of a fire, such as decide as a family where you will meet outside if a fire occurs, or where you should keep fire extinguishers in your home. As a class, make a list of the questions and barriers that you would face as you escape a fire in your home. Examples include whether to grab your favorite possession, or whether you would have to escape from a window. As a class, discuss the steps you would take. Develop five tips for escaping a fire and post them in your classroom.

Another FACTivity

The question you will answer with this FACTivity is: How do mirrors affect the distance light waves travel to reach an object? The method you will use to answer this question is: Get a shoe box, and two inexpensive mirrors, about 3.5 inches X 4 inches each. Tape the mirrors to one side of each end, as shown in the illustration below. Poke a small hole on one end where there is no mirror. On the other end, poke five holes. Turn the lights off so that the room is dark. Using a laser pointer (used for presentations), shine the pointer from the outside through the one hole. WARNING: Do NOT point the laser at any people! First, point the beam directly at one of the five holes, trying to get the beam to shine though the hole. One of your classmates can hold a piece of black paper about 1 foot from the outside of the opposite hole to make it easier to see the beam. Now using the mirrors, try to get the beam to come out of each of the five holes. If you can get dry ice (ask at your grocery store), line the shoe box with aluminum foil. Place the dry ice in the bottom of the box and cover the box with a piece of clear plastic or plexiglass. The dry ice will enable you to see the beam inside of the shoe box. WARNING: Have your teacher or an adult handle the dry ice.

Estimate how long the direct beam of light is between holes. You can use a ruler to measure the approximate distance. Now use the ruler to estimate how long the reflected beam is between holes. What happens to the length of the light beam when mirrors are used?

When using an infrared spectrometer, the infrared light causes molecules in the smoke to vibrate. The longer the beam of light, the better able scientists are to use the sample of smoke to identify chemicals. This is because a longer light beam will create more opportunity for vibration of the smoke molecules. This gives the scientists more information. The infrared spectrometer in this study caused the infrared light beam to travel back and forth 120 times! The spectrometer was only 0.8 meter long (to find out how many feet this is, multiply 0.8 X 3.28). How long was the light beam after it traveled back and forth 120 times? Now you know why the infrared spectrometer is built with mirrors.



From Yokelson, R. J., Goode, J. G., Ward, D. E., Susott, R. A., Babbitt, R. E., Wade, D. D., Bertschi, D. W. T., and Hao, W. M. (1999). Emissions of formaldehyde, acetic acid, methanol, and other trace gases from biomass fires in North Carolina measured by airborne Fourier transform infrared spectroscopy. *Journal of Geophysical Research, 104*(D23): 30,109-30,125.