

# Temperature, Pressure, and Cloud Formation

NASA/GODDARD SPACE FLIGHT CENTER/NOAA



*Hurricane Fran lashed communities in the southeastern United States, uprooting trees and bringing the threat of flash floods.*

## INTRODUCTION

Imagine a cloud taller than Mt. Everest—the tallest mountain in the world! Or think of a cloud so symmetrical that it looks like a perfect pinwheel in the sky. Hurricane Fran, pictured at left, was like that—tall and evenly shaped. How do clouds form? Why do they sometimes become hurricanes? Evaporation, warm rising air, dust particles, condensation of water, and the weight of air—called air pressure—are the ingredients for making clouds.

In Lessons 4 and 5, you modeled the movement of air caused by the uneven heating of the earth's surface. In this lesson, you will extend your observations to investigate how water evaporates and condenses into clouds. You will also investigate how air pressure affects cloud formation. Finally, you will relate this information to weather on the earth.

## OBJECTIVES FOR THIS LESSON

**Model and describe how water evaporates and condenses and how these processes play a part in cloud formation.**

**Model and describe the air pressure conditions under which clouds form.**

**Analyze weather maps.**

**Interpret data from tables in order to plot the path of a hurricane.**

## Getting Started

### MATERIALS FOR LESSON 6

#### For you

- 1 copy of Student Sheet 6.2: Tracking Hurricane Andrew
- 1 copy of Student Sheet 6.3: Reading Weather Maps
- 1 ruler
- 1 green pencil or pen
- 1 red pencil or pen

#### For your group

- 1 tote tray
- 2 clear bottles with caps
- 1 flashlight
- 2 digital thermometers
- 1 beaker of hot water
- 1 beaker of cold water
- 1 ice cube
- 3 consecutive daily weather maps

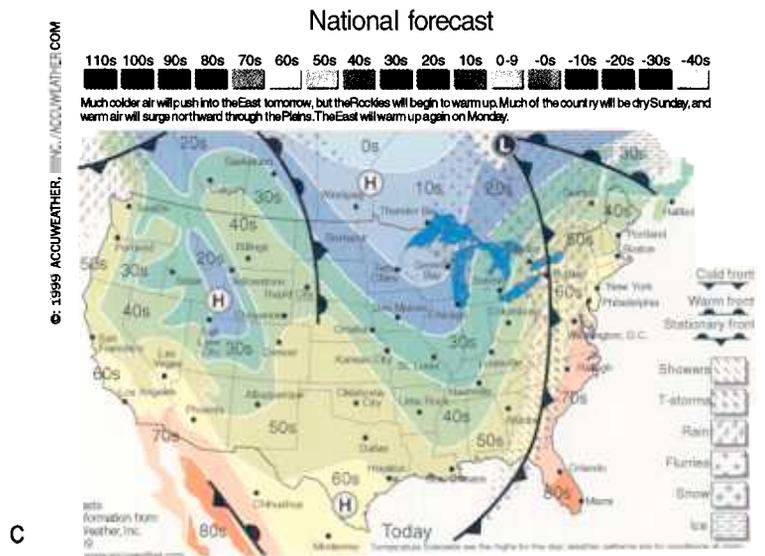
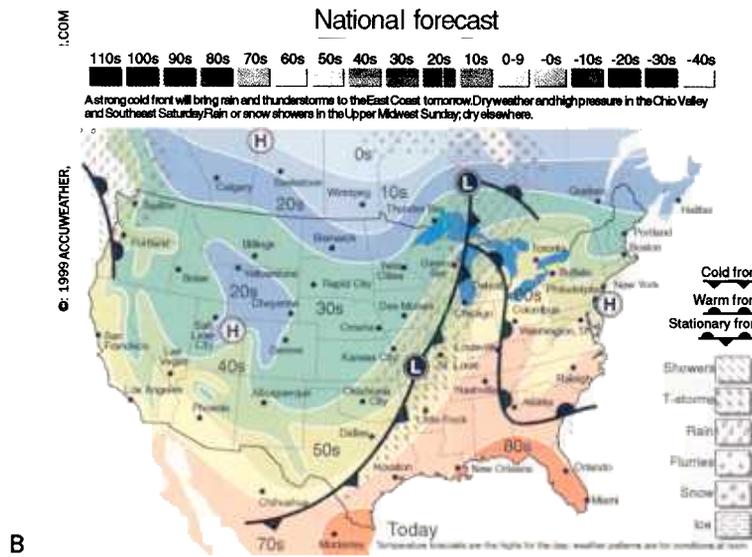
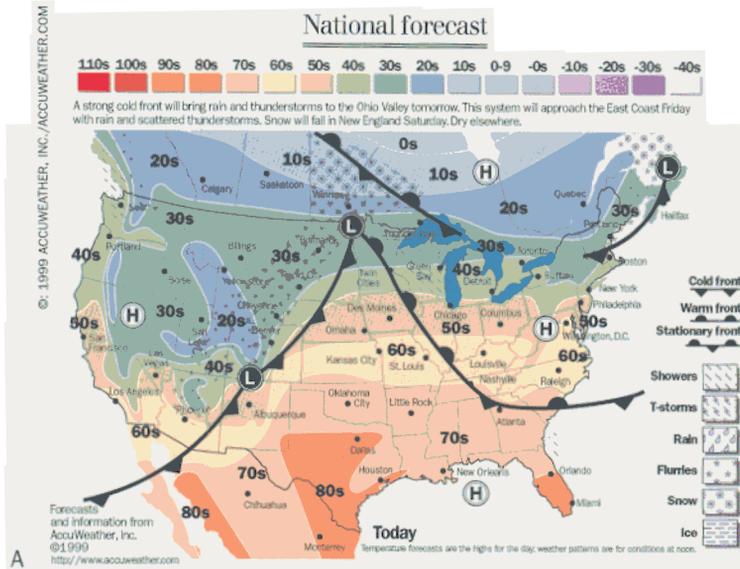
1. Look at the U.S. weather maps shown in Figure 6.1. Work with your group to make general observations of the maps. Discuss these questions:

*A. Where on each map do you think it is cloudy? How do you think clouds form?*

*B. What do you think “H” and “L” on the maps represent?*

*C. What type of weather would you expect in an area marked with an “H”? What type of weather would you expect in an area marked with an “L”?*

2. In this lesson, you will investigate some of the conditions under which clouds form. At the end of the lesson, you will look at weather maps again to relate what you observed in the lab to weather on the earth.



**Figure 6.1** Three consecutive daily weather maps

## Inquiry 6.1 Observing Evaporation and Condensation

### PROCEDURE

1. What do you already know about the water cycle and how clouds form? Discuss your ideas with the class.
2. Look at the equipment you will use for this lesson. Then try to answer the following question: How does the temperature of water affect evaporation and condensation?
3. Record the question from Step 2 in your notebook. Leave enough room to write your observations.
4. How would you use the materials to test this question? Share your ideas with the class.
5. Discuss with your teacher how you will record your predictions and observations in a table.



**Figure 6.2** Rub an ice cube or the palms of your hands on the outside of the bottle.

6. Collect your materials. Set them up as your group has planned. Then conduct your investigation.
7. How does the temperature of the air affect evaporation and condensation? Try this: Rub the ice cube on the outside of each bottle. (See Figure 6.2.) What happens? Rub your hands on the outside of the bottle. What happens? Discuss your observations with your group.
8. Clean up according to your teacher's instructions.

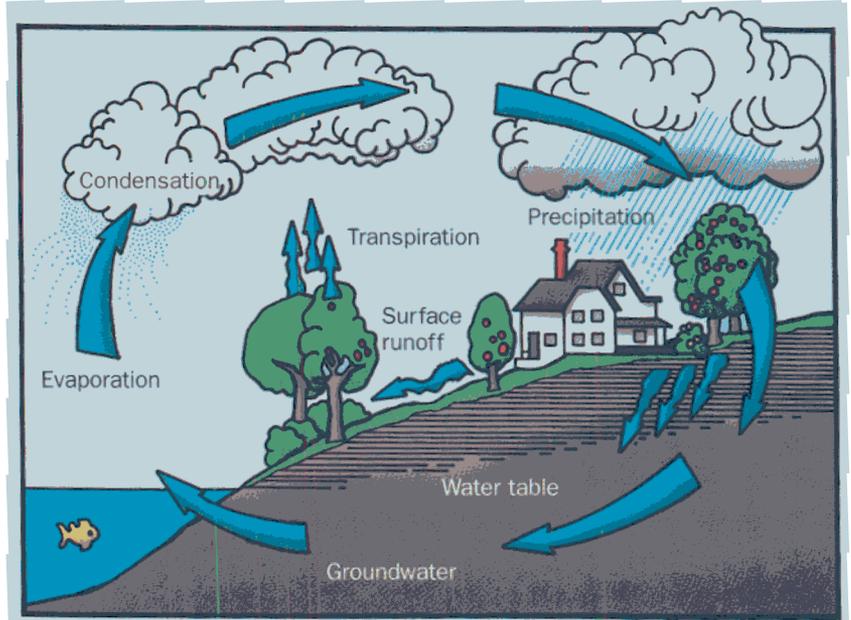
### REFLECTING ON WHAT YOU'VE DONE

1. Answer the following questions and then discuss them with your class.
  - A. What happened to the water in each bottle?
  - B. In which bottle did you observe the most evaporation and condensation? Why do you think this happened?
  - C. Were you able to change the amount of condensation that occurred inside your bottles? If so, how?
2. Read "Hurricane Formation and the Water Cycle" on page 72.
3. Relate what you observed in the lab to cloud formation on the earth. Record your ideas about the following:
  - A. Describe the water cycle and cloud formation.
  - B. If hurricanes get their energy from warm, evaporating water, where on the earth do you think hurricanes form most often?

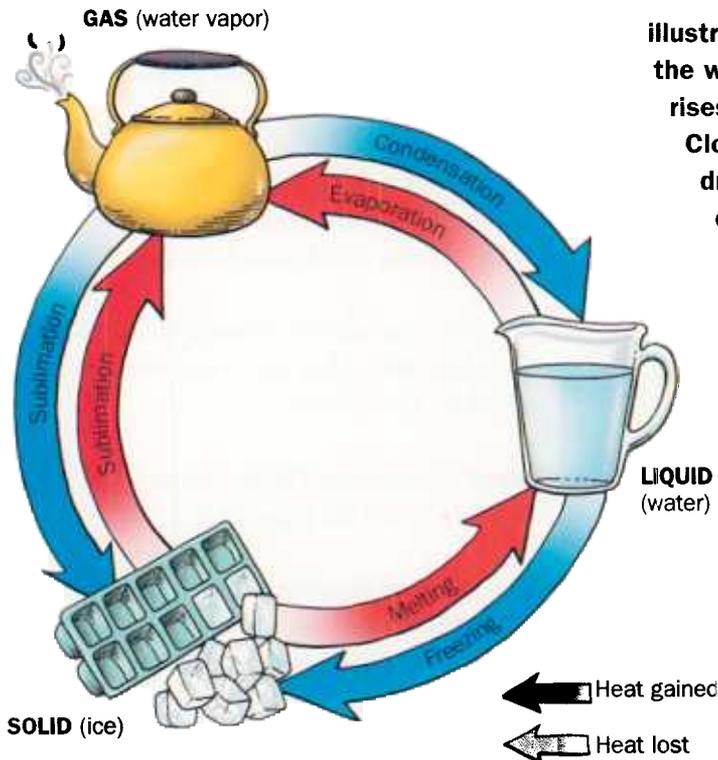
## HURRICANE FORMATION AND THE WATER CYCLE

Why do hurricanes develop over warm, tropical water near the equator? The warm water provides an almost endless supply of energy for these storms. Massive clouds form from the warm, evaporating water. Winds move the storm clouds along the hurricane's path. When the hurricane moves over land or cool northern water, it loses its energy and dies.

What process is at the heart of hurricane formation? It is the water cycle. As the



The water cycle on the earth



Condensation is the process by which water changes from a gas to a liquid. The heat given off during condensation "feeds" energy into a storm system.

illustration of the water cycle shows, during the water cycle, clouds form when warm air rises or when warm air and cold air meet. Clouds are made up of billions of tiny droplets of water or ice and dust particles. When water on the earth absorbs heat energy, it evaporates into a gas called water vapor. When air rises, it carries the water vapor with it. Air at higher altitudes within the troposphere is cool. Cool air cannot hold as much water vapor as warm air can. So some of the vapor turns into drops of liquid water. The process by which water changes from a gas to a liquid is called condensation. The process of condensation, shown in the illustration, releases heat, which feeds more energy into the system and evaporates the condensed water, causing the vapor to rise even higher. The liquid water collects on dust particles and forms clouds.

## Inquiry 6.2

### Modeling the Effects of Air Pressure on Cloud Formation

#### PROCEDURE

1. In this inquiry you will try to answer the following question: How does air pressure affect cloud formation?
2. Record the question in your notebook.
3. Discuss with the class how you will use the bottle of hot water to investigate this question.

A. What are the “ingredients” for cloud formation? (Think back to Inquiry 6.1 and the reader “Hurricane Formation and the Water Cycle.”)

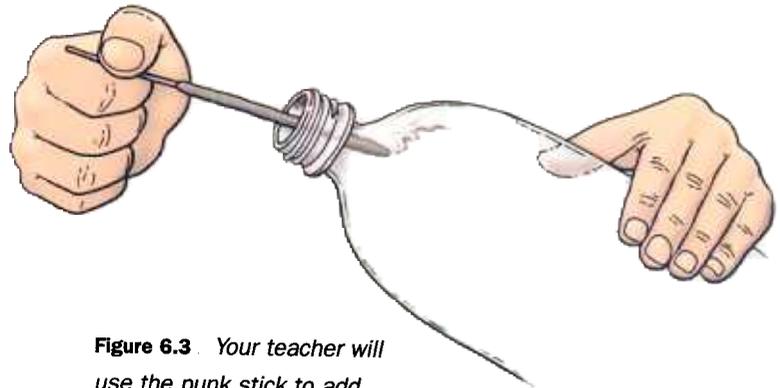
B. How could you create these conditions in your bottle?

C. If you want to test how air pressure affects cloud formation, how could you create high pressure in the capped bottle?

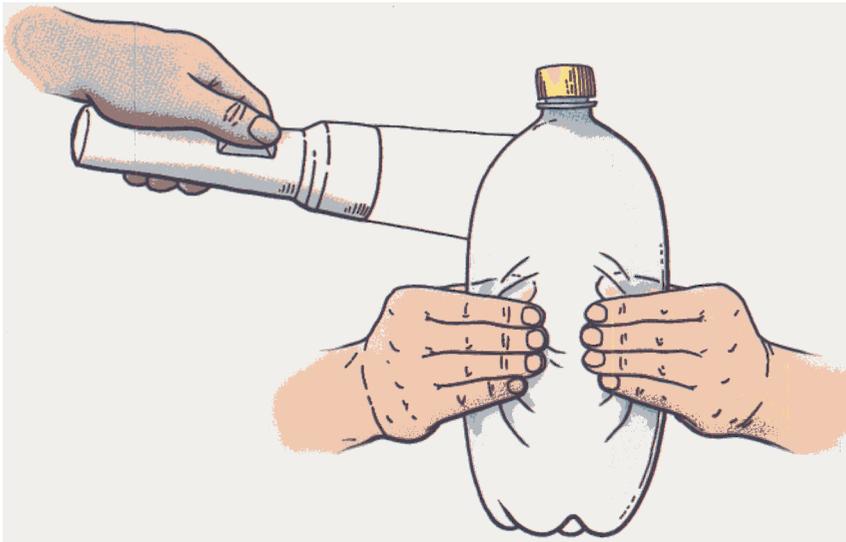
D. How could you create low pressure in the bottle?

E. How could you keep track of your predictions and observations?

4. Review Procedure Steps 5 and 6 with your teacher. Then collect your materials. Create a table to record your data and observations.
5. Your teacher will use a burning punk stick to add smoke to your bottle, as shown in Figure 6.3. Keep the lit punk inside the bottle for approximately 3 to 5 seconds. When your teacher removes the punk stick, quickly cap the bottle.



**Figure 6.3** Your teacher will use the punk stick to add smoke to each group's bottle.



**Figure 6.4** Squeeze and hold the capped bottle while someone else shines the light on it. Do clouds form under high or low pressure?

6. Before starting the investigation, swirl the water inside the bottle to reduce fog. Then shine the flashlight on the bottle, as shown in Figure 6.4, while squeezing and holding the bottle.
7. When your group is finished, clean up.

### REFLECTING ON WHAT YOU'VE DONE

1. Answer these questions and then discuss your answers with the class:
  - A. Why did you add smoke to the bottle?
  - B. What happened to the air when you squeezed the bottle?
  - C. When you released the bottle, you created a low-pressure system. Describe the air inside the bottle when this happened.
  - D. Use your own words to describe how air pressure and cloud formation are related.
2. Read "The Truth About Air," on pages 76–77.
3. You will be asked to complete Student Sheet 6.2: Tracking Hurricane Andrew for homework. As you do, consider these questions, which are listed on the student sheet:
  - A. Where did Tropical Storm Andrew start? Why do you think it started there?
  - B. At what point (longitude and latitude) did the tropical storm become a hurricane?
  - C. In what direction did the storm move?
  - D. Look back to the reading selection "Why Does the Wind Blow?" in Lesson 5. What do you think caused Hurricane Andrew to move along this path?
  - E. Where did Hurricane Andrew lose its energy and turn back into a tropical storm? Why do you think it happened in that location?
  - F. If you had been working at the National Hurricane Center when Hurricane Andrew struck, which cities or areas would you have evacuated? What day would you have requested the evacuation? Why?

## Inquiry 6.3

### Reading Weather Maps

#### PROCEDURE

1. Working with your group, make general observations of the weather maps that you brought to school. You can also use Figure 6.1 for this purpose.
2. Share your observations with your class.
3. Line up your maps in order by date. Identify one weather system (front, low-pressure system, or high-pressure system) on each map. In what direction is the system moving across the country? What do you think causes weather to move in this way? (The reading selection “Why Does the Wind Blow?” in Lesson 5 can help you answer this.)
4. Look over Student Sheet 6.3: Reading Weather Maps. Discuss it with your teacher. Work on it with your group. You may have to complete it for homework.

#### REFLECTING ON WHAT YOU’VE DONE

1. With the class, share your responses to these questions, which are also listed on Student Sheet 6.3:
  - A. *What kind of weather is associated with a high-pressure system?*
  - B. *What kind of weather is associated with a low-pressure system?*
  - C. *What symbol represents a cold front? What symbol represents a warm front?*
  - D. *Pick one weather front on a map. What weather is associated with it?*
  - E. *Why are the triangles and semicircles on the symbol for a cold and warm front facing in one direction? What do you think the direction of the symbol means?*
  - F. *How does weather move across the United States? Why is it important to know this information?*
2. Watch the video *Hurricane*. Relate the concept of pressure to how hurricanes form and move.

# The Truth About Air

## Air Pressure

Water pressure is caused by the weight of water, and air pressure is caused by the weight of air. The heavier the air, the more pressure it exerts on the earth.

Just as the leaves at the bottom of a pile are more squished than those at the top, air is more compressed (denser) at sea level than at higher altitudes. At the top of the atmosphere, air is less compressed and lighter. Close to the earth, air is more compressed and denser.

## Air Pressure and Weather

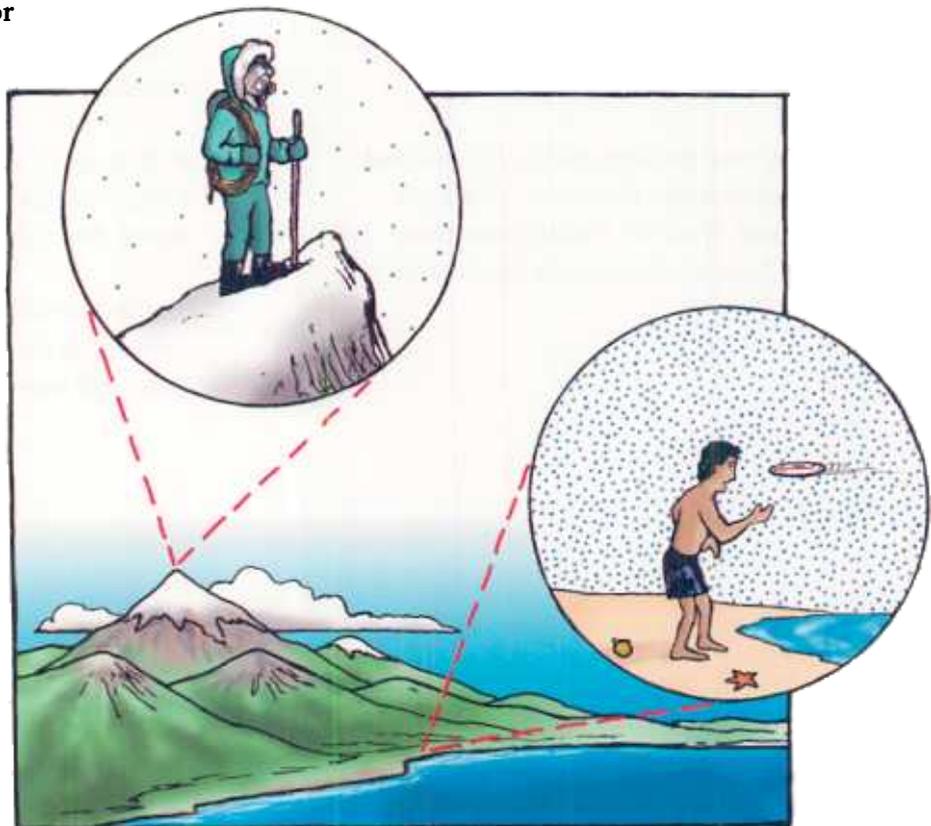
Air pressure is one factor that creates the constant changes in weather on the earth.

The formation of clouds, for example, is a direct result of air pressure. Look up into the sky. Low clouds, such as stratus clouds, are denser and thicker than clouds high in the sky. Clouds that are high in the sky, such as cirrus clouds, are wispy and thinner than clouds at low altitudes.

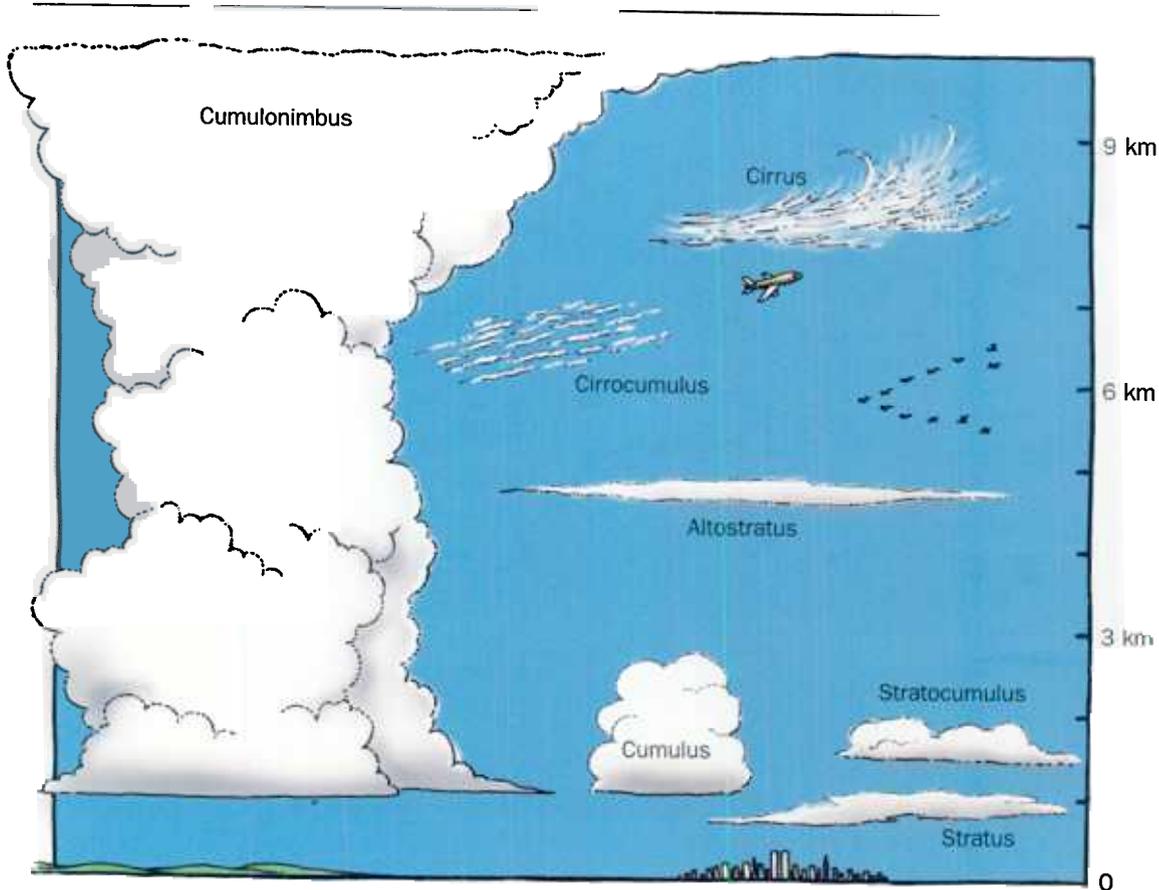
Air pressure differences also cause the air to move and create winds. Like all fluids, air flows from high-pressure regions to low-pressure regions. If you have ever walked into an air-conditioned building in the summer and felt a rush of wind against your body,

you know that air pressure affects the way air moves. The difference between the high air pressure in the building and the low air pressure outside causes the air inside to move rapidly toward the open door. (This same difference in air pressure created the movement of air in your connected Convection Tubes.)

Because air masses are in constant motion, air pressure in any location on the earth can vary from day to day, or even from hour to hour. Since pressure differences can help scientists predict how air might move, monitoring and predicting changes in air pressure is fundamental to weather forecasting. □



*Why does a mountain climber sometimes need an oxygen mask? It is because the higher a person goes, the lighter (less dense) the air becomes. That means there is less oxygen for the climber to inhale. In this picture, the particles of air are represented by dots. Where do you think the density of air (air pressure) is greater?*



*Air pressure affects the types of clouds that form at different altitudes.*

### **Torricelli: Inventor of the Mercury Barometer**

In 1643, Evangelista Torricelli, a student of Galileo, invented the mercury barometer. A barometer is an instrument that detects and measures air pressure changes. Torricelli's barometer was similar to those in use today. It had a long glass tube that was open at one end and closed at the other. Torricelli removed air from the tube; he covered the open end and submerged it in a dish of mercury. When he removed the cover from the open end of the tube, the mercury rose in the tube to nearly 76 centimeters above the dish. Torricelli correctly concluded that air outside of the tube was pressing on the mercury in the dish and that this pressure forced the liquid up in the tube. (The height of the liquid in the

tube was a measure of atmospheric pressure. The greater the atmospheric pressure, the higher the mercury moves up the tube.)

Why did Torricelli use mercury instead of water? First, water would evaporate in the tube. Second, water is less dense than mercury. This means that an atmospheric pressure of 76 centimeters of mercury would be equal to 1034 centimeters of water! Can you imagine a barometer that tall?

What do you think Torricelli's mercury barometer looked like? Draw a picture of it using information from this reader. Then look up Torricelli on the Internet and compare your drawing with the mercury barometer that Torricelli invented.

# HURRICANE MITCH



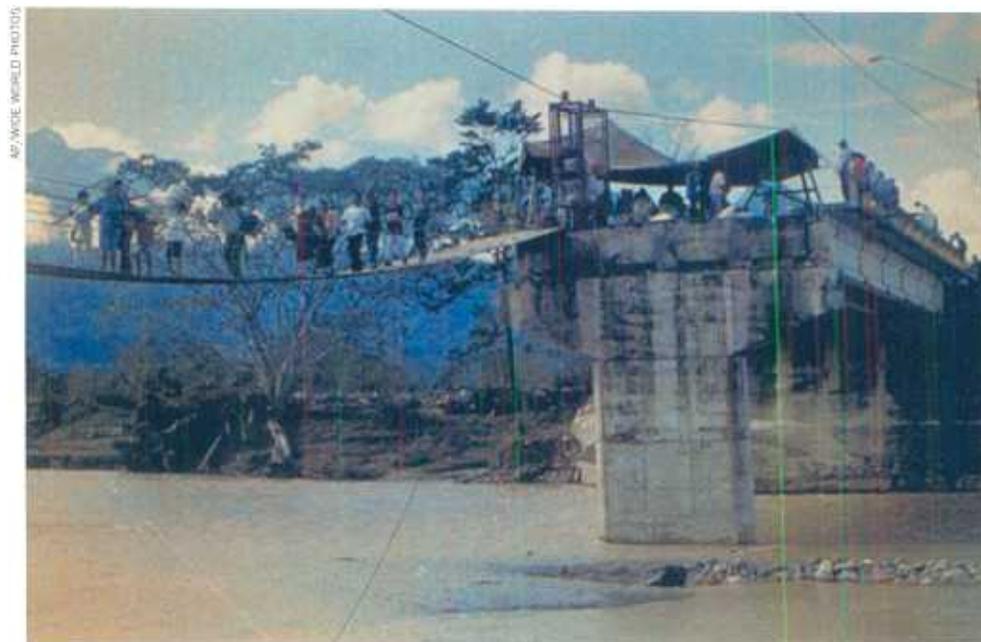
*Massive hurricane damage along a river in Honduras from Hurricane Mitch*

In late October 1998, Hurricane Mitch roared across Central America for several days. It affected areas from Nicaragua and Honduras through El Salvador, Guatemala, Belize, and southern Mexico. One of the strongest hurricanes in recorded history, it killed about 11,000 people. (Prior to Hurricane Mitch, only one other Atlantic hurricane had caused more deaths. The Great Hurricane of 1780 killed 22,000 people in the eastern Caribbean.) Mitch destroyed roads and bridges. It left more than 2 million people without homes, food, or drinking water. More than \$10 billion in damage occurred across the region.

In the aftermath of Hurricane Mitch, scientists wondered what had brought on such a monstrous storm and what could be done to prevent the resulting damage from happening again.



*Off the coast of La Ceiba, Honduras, children walk through sea foam caused by the churning water made rough by Hurricane Mitch.*



*People living near La Ceiba, Honduras, cross the Rio Bonito on a footbridge. Heavy rains from Hurricane Mitch damaged important roads and bridges, such as this one.*

### **Perfect Hurricane Conditions**

One of the key factors that created Mitch was very warm ocean water. During that hot October, the temperature of the Caribbean Sea reached almost 30 °C. The warm water quickly evaporated, creating huge amounts of water vapor in the atmosphere.

A second factor was a low-pressure area of thunderstorms over Honduras and Nicaragua that triggered the storm. These thunderstorms eventually dumped 127 to 190 centimeters of rainfall on Honduras and Nicaragua. According to the National Climatic Data Center, 64 centimeters of rain fell in just 6 hours.

### **A Region Unprepared**

Torrential rains would have devastated any country. But countries in Central America were particularly vulnerable. Many of the hillsides had been cleared for farming. Saturated with rain, they became unstable. Rocks and mud rumbled down the south side of Nicaragua's Casita Volcano. In all, nearly 2000 people lost their lives in mudslides. Towns and villages that were built next to rivers flooded. Water covered the ground that was already saturated from the rainy season. Most of the crops that had been

harvested and stored were destroyed by the hurricane. That year's second planting was completely washed away by the storm.

The people of Central America had been poorly prepared for a disaster of this magnitude. For one thing, the path of Mitch had not been predicted accurately. Meteorologists predicted a more northerly course, but Mitch turned south toward Honduras and then slowed to a tropical storm. As it crawled across Honduras, it dumped several meters of rain in just a few days. Runoff eroded mountainsides. Thousands of acres of land were swept away or were buried too deeply to be farmed. Flooding destroyed cash crops, such as coffee, melons, and bananas. Thousands of kilometers of roads and more than 100 bridges were left impassable.

Even if the people in Central America had been warned of the approaching hurricane, few communities had programs to help people prepare for an event like Hurricane Mitch. To prevent such devastation from occurring again, leaders decided that better warning systems were needed. In the meantime, people in Central America realized it would take years to recover from Hurricane Mitch. □