LESSON 6

Temperature, Pressure, and Cloud Formation

Inquiries 3
Periods 3–4

CONCEPTS

The movement and exchange of water between the earth, atmosphere, and oceans is called the water cycle.

Water vapor enters the air by evaporation from bodies of water.

Water vapor in the air changes to water by condensation.

Clouds form under low air pressure when water vapor from warm, rising air condenses (or when warm and cold air masses meet).

Precipitation, thunderstorms, tornadoes, and hurricanes often develop in low-pressure weather conditions (or when warm and cold air masses meet).

The path of a hurricane can be tracked, but it is not always easy to predict.

STUDENT OBJECTIVES

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, classify fronts, identify high- and low-pressure systems, and determine the weather conditions associated with each.

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

OVERVIEW

In Lessons 4 and 5, students observed air movement caused by the uneven heating of two surfaces. They then applied their observations to winds, fronts, and tornadoes on the earth. In this lesson, they investigate cloud formation and apply what they learn to hurricanes. In Inquiry 6.1, students use sealed bottles of water to investigate the conditions under which water evaporates and condenses. They relate these processes to the formation of clouds, and ultimately hurricanes, over warm water. During Inquiry 6.2, students manipulate the air pressure of a closed system to determine the effect of high and low pressure on cloud formation. During Inquiry 6.3, they apply their observations from the lab to weather maps and draw conclusions about the conditions under which clouds and storms form and move. The lesson ends as students watch a video on hurricanes and observe how scientists attempt to predict the path of a hurricane. This lesson prepares students for Lesson 7, in which they analyze the role of oceans in global weather.

BACKGROUND

Air Pressure

Atmospheric pressure, or **air pressure,** is the force that air exerts on everything on the earth. The amount of pressure that air exerts on water and land depends on the degree to which air is energized by the sun's heat.

The pressure at any point in the atmosphere can be measured in terms of the total weight of the air above that point. As an airplane climbs in altitude, fewer air molecules are above it. Therefore, atmospheric pressure always decreases with increasing altitude. Air pressure is greatest at lower levels in the atmosphere, where air is compressed under the weight of the air above. Like air density, air pressure decreases rapidly at first, then more slowly at higher altitudes.

A **bar** is a unit of pressure that describes a force over a given area. A **barometer** is an instrument that detects and measures pressure changes. Because scientists measure atmospheric pressure with a barometer, atmospheric pressure is often referred to as **barometric pressure.**

Meteorologists mark barometric pressure on a weather map with the letters "H" and "L." An "H" marks the center of an area of higher pressure than in the surroundings areas. An "L" marks the center of an area of lower pressure than in the surrounding areas. The terms "high" and "low" pressure are always relative to an area at a specific time. This means that there is no barometric reading that is always considered low. Whether a system is considered "high" or "low," therefore, depends on the pressure reading of surrounding air masses. In general, low air pressure usually leads to clouds and precipitation. High pressure usually brings clear skies.

Cloud Formation

Air pressure helps create the constant weather changes that people experience as wind, temperature, and clouds. The formation of clouds is complex. In simple terms, **clouds** are visible masses of billions of tiny droplets of water or ice crystals that have condensed around small particles in the atmosphere. Clouds form when water vapor from warm, rising air condenses as the air expands in low-pressure conditions, or when warm and cold air meet.

All air contains water in some form—liquid, solid, or gas. (TG Figure 4.1 in Lesson 4 shows how heat is taken in or given off during a change in state.) On the earth's surface, water molecules in oceans, lakes, and rivers absorb heat energy from the sun until they have enough energy to break away from the liquid surface and become individual molecules of **water vapor.** (Moist surfaces on the earth, and even water in plants, also contribute water vapor to the atmosphere.) When air heats up, the molecules gain energy and move farther apart. The water vapor molecules mix with the warm rising air and are carried up into the atmosphere.

As air rises, it expands to equal the surrounding lower air pressure conditions. As air expands, its temperature drops. Cool air cannot hold as much water vapor as warm air can, so some of the water vapor condenses on particles of dust, soil, salt, or other materials in the air. This condensed water forms droplets of liquid water, which people see from the ground as clouds or ice crystals. As the water condenses, it gives off latent heat energy. Because these condensed particles are so small, even weak air movements can keep them suspended. Typically, it takes close to a billion cloud droplets to provide enough water for each raindrop.

When air sinks, it compresses from the weight of the air above it, and its temperature increases. The warmth of the air keeps the water from condensing into clouds and precipitation. It also leads to the evaporation of any existing clouds. This is why high pressure often brings clear skies and fair weather.

Reading Selections

The first short reading selection in Lesson 6 in the Student Guide—"Hurricane Formation and the Water Cycle"—discusses the formation of clouds and the processes of evaporation and condensation. "The Truth About Air," the first extended reader of the lesson, discusses air pressure. A short historical reader entitled "Torricelli: Inventor of the Mercury Barometer," accompanies "The Truth About Air" and introduces students to an important weather forecasting instrument. A final reader, "Hurricane Mitch," describes the impact of a powerful storm that hit Central America in 1998.

MATERIALS FOR LESSON 6

For the teacher

1 sheet of newsprint or transparency
Markers
1 2-L bottle of room-temperature water
1 lighter
1 punk stick
2 hot pots (optional)
1 cooler (optional)
NOVA video: *Hurricane*
VHS cassette player and TV monitor

For each student

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
Blank Venn diagram (optional) (see Appendix C: Blackline Masters)

For each group of 4 students

1 tote tray
2 clear, 2-L bottles with caps
1 flashlight
2 digital thermometers
1 250-mL beaker of 50 °C–60 °C hot water
1 250-mL beaker of 20 °C–30 °C cold water
1 ice cube
3 consecutive days' weather maps

PREPARATION

1. Make a copy of Student Sheet 6.2: Tracking Hurricane Andrew for each student. (To conserve paper, you may want to copy it on back-to-back pages.) If your students are not familiar with how to use longitude or latitude, see Appendix D: Locating Areas on a Map Using Longitude and Latitude for an introductory lesson.
2. Make a copy of Student Sheet 6.3: Reading Weather Maps for each student.
3. If students are not familiar with how to use or create a Venn diagram, make a copy of the blank one in Appendix C: Blackline Masters for each student. Plan to review how to use the diagram before assigning homework for Period 1.
4. Students should have brought to class three consecutive U.S. weather maps from a local newspaper or the Internet. For students who have not done this, you may want to download current maps from the Internet, have old newspapers on hand, or have students refer to SG Figure 6.1 during the lesson.
5. If you do not have access to hot tap water, set up the hot pots. Heat the water to 50 °C to 60 °C and set the temperature on low. Fill one beaker with hot water and one beaker with cold water for each group.
6. Have ice cubes on hand for Inquiry 6.1. You may want to keep them in a cooler.
7. Set up the VHS player and TV monitor. Preview the video *Hurricane*. Decide which portion of this 60-minute video you will show during the last period of the lesson. Consider showing the 20-minute segment that starts about 20 minutes into the video.

Getting Started

1. Ask students to work in groups and look at the weather maps in SG Figure 6.1. Use the following questions to assess their current understanding of weather maps:

   A. Where on each map do you think it is cloudy? How do you think clouds form? (Frontal areas marked with rain or snow symbols are usually cloudy. Clouds form during the water cycle.)

B. What do you think "H" and "L" on the maps represent? ("H" means high pressure; "L" means low pressure.)

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"? (High-pressure weather is usually clear; low-pressure weather is usually cloudy.)

2. Let students know that in this lesson they will investigate some of the conditions under which clouds form. They will also closely examine weather maps, such as those shown in SG Figure 6.1.

Inquiry 6.1 Observing Evaporation and Condensation

PROCEDURE

1. Have students brainstorm what they already know about the water cycle and cloud formation. Record their ideas on a transparency or sheet of newsprint.

2. Show students one group's set of materials. Point out that one beaker of water is hot and one is cold. Inform them that in this inquiry, they will explore the following question: How does the temperature of water affect evaporation and condensation?

3. Have each student record the question in his or her science notebook. Students should plan to record observations under the question.

4. Invite groups to share ideas they might have about how to use the materials to investigate the question. If students need additional guidance in designing their investigation, review the following three points with them:

A. Students should measure and record the temperature of each beaker of water before they start the investigation.

B. Students should make and record their predictions. For example, what do they think will happen if they pour hot water in one bottle and cold water in the other and cap the bottles?

C. Students should control all variables. For example, they should make certain the volume of hot and cold water is the same in each bottle and make observations of each bottle for the same amount of time.

NOTE Set out a bottle of room-temperature water in front of the class for groups to use as a control.

5. Discuss with students how they will record their predictions and observations. Table 6.1 is an example.

6. Review Procedure Step 7. Then ask students to collect their materials and conduct the investigation. Remind them to record their predictions before they start.

7. Have students clean up. Save the bottles for Inquiry 6.2. If you teach another class, have students replenish the hot and cold water in the beakers.

Table 6.1 How Water Temperature Affects Evaporation and Condensation

Water in Capped Bottle	Water Temperature (°C)	Predictions (What I Think Will Happen)	Observations (What Happened)
Hot			
Cold			

REFLECTIONS

1. Ask students to answer these questions; then discuss them as a class.

A. What happened to the water in each bottle? (Students may say that nothing happened in the bottle with cold water. It remained clear. The bottle with hot water in it probably fogged up.)

B. In which bottle did you observe the most evaporation and condensation? Why do you think this happened? (More condensate [moisture] formed in the bottle with hot water because hot water evaporates faster than cool water does. Hot water evaporated into a gas—water vapor—and then condensed into water again when it touched the sides of the cool plastic bottle.)

C. Were you able to change the amount of condensation that occurred inside your bottle? If so, how? (Students may have rubbed an ice cube against the bottle to decrease the temperature of the plastic surface and create more condensate. Others may have held their warm hands against the bottle to increase the temperature of the plastic surface and evaporate the condensate on the sides of the bottle.)

2. Have students read "Hurricane Formation and the Water Cycle" (SG page 72).

3. Ask students to relate what happened in the lab to cloud formation on the earth. Have them record their answers to these questions and then discuss their responses:

A. Describe the water cycle and cloud formation. (Evaporation and condensation—together with precipitation and runoff—are part of the water cycle. The water cycle is the movement and exchange of water between the earth's surface and oceans—where water evaporates into a gas—and the atmosphere—where vapor condenses into water or ice and falls back to the earth as precipitation. See the illustrations in "Hurricane Formation and the Water Cycle" [SG page 72].)

B. If hurricanes get their energy from warm, evaporating water, where on the earth do you think hurricanes form most often? (Hurricanes form over warm water, usually near the equator where evaporation is abundant.)

NOTE If you are teaching in 45-minute periods, this is a good stopping point. Assign Homework for Period 1.

Inquiry 6.2 Modeling the Effects of Air Pressure on Cloud Formation

PROCEDURE

1. Inform students that in this inquiry, they will explore the following question: How does air pressure affect cloud formation?

2. Have each student record the question in his or her science notebook. Students should plan to record observations under the question.

3. Ask students to discuss with the class how they could use the bottle of hot water from Inquiry 6.1 to investigate the effects of air pressure on cloud formation. Guide students through the discussion by asking these questions:

   A. What are the "ingredients" for cloud formation? (Think back to Inquiry 6.1 and the reading selection "Hurricane Formation and the Water Cycle.") (Heat energy, water, and dust or other particles are ingredients for cloud formation.)

   B. How could you create these conditions in a bottle? (Hot water and smoke can provide the water vapor and dust particles.)

   C. If you want to test how air pressure affects cloud formation, how could you create high pressure in the capped bottle? (Squeeze the bottle and hold it for 5 to 10 seconds.)

   D. How could you create low pressure in the bottle? (Release your hands—which are applying the pressure—from the bottle.)

   E. How could you keep track of your predictions and observations? (A sample observation table is shown in Table 6.2. Remind students to record predictions before they start.)

4. Review Procedure Steps 5 and 6 in the Student Guide.

5. Have students collect their materials and begin Inquiry 6.2.

SAFETY TIP

Be careful with the burning punk stick. Do not let it touch the plastic bottle or the bottle will melt.

6. Have students clean up. You may want to keep a bottle and flashlight for demonstration purposes during the follow-up discussion.

Table 6.2 How Air Pressure in a Bottle Affects Cloud Formation

Air Pressure in Bottle	Predictions (What I Think Will Happen in the Bottle)	Observations (What Happened in the Bottle)
High		
Low		

REFLECTIONS

1. Ask students to answer these questions in writing and in a class discussion:

A. Why did you add smoke to the bottle? (Smoke provides the dust particles on which the evaporated water can condense.)

B. What happened to the air when you squeezed the bottle? (Squeezing the bottle compressed the air into a smaller area and increased its pressure. High pressure evaporated any clouds away.)

C. When you released the bottle, you created a low-pressure system. Describe the air inside the bottle when this happened. (The air expanded, and moisture within the air condensed into a cloud, which could be seen in the bottle.)

D. Use your own words to describe how air pressure and cloud formation are related. (Clouds usually form under low-pressure conditions.)

2. Have students read "The Truth About Air" (SG pages 76–77) and "Torricelli: Inventor of the Mercury Barometer." Help students understand that as air rises, air pressure decreases. Also point out that like a hot air balloon, air stops rising when it meets air of equal density and pressure.

3. Distribute, review, and assign Student Sheet 6.2.

NOTE This is a good stopping point for Period 2. You may want to assign Student Sheet 6.2 for homework. If necessary, review with students how to plot the path of a hurricane using longitude and latitude and how to predict its path given the pattern of its movement. Plan to review the completed homework assignment at the beginning of Lesson 7.

Inquiry 6.3 Reading Weather Maps

PROCEDURE

1. Ask each group to make general observations of the weather maps each group member collected and brought in. (As an option, use SG Figure 6.1 again.)

NOTE As an assessment, you may want students to record their observations of the maps in their notebooks individually before sharing their ideas with the group.

2. Invite groups to share their maps and observations with the class.

3. Have students line up their maps in chronological order. Ask them to identify one weather system on each map (for example, a front, a low-pressure system, or a high-pressure system). Have them determine in what direction each system is moving across the country. What do students think causes weather to move in this way? Help them understand that the earth's rotation (which is counterclockwise) and winds (in this case, the jet stream) are responsible for the movement of weather from west to east across the United States. (Refer students to the reading selection, "Why Does the Wind Blow?" in Lesson 5 for more information on the jet stream.)

4. Distribute Student Sheet 6.3 to each student. Review the directions and discuss how to complete the table. Then have students work on the student sheet in their groups. The following are points they should discover and that you may want to discuss with them as they work:

A. Symbols on the map indicate cold and warm fronts. Blue triangles represent cold fronts. Red semicircles represent warm fronts. Depending on the map, other symbols may also be present. Some students may know that the triangles and semicircles point in the direction that the cold or warm air is moving.

B. Rain and other precipitation usually happen along fronts.

C. An "H" indicates a high-pressure system. Rain does not usually occur there. An "L" indicates a low-pressure system. Cloud cover, precipitation, and unsettled weather usually occur there.

D. Symbols show what type of precipitation is falling.

E. Areas of the country that are the same color have the same temperature range.

F. Depending on the types of maps students examine, they may also observe that newspaper maps are simplified versions of National Weather Service maps, which have more elaborate symbols.

NOTE You may need an entire 45-minute class period to show and discuss the 20-minute segment of the *Hurricanes* video in Step 2 of the Reflections section. If necessary, ask students to finish Student Sheet 6.3 for homework for Period 3.

REFLECTIONS

1. Discuss the following questions, as outlined on Student Sheet 6.3, with students:

A. *What kind of weather is associated with a high-pressure system?* (Clear skies are often associated with a high-pressure system.)

B. *What kind of weather is associated with a low-pressure system?* (Low-pressure areas are often associated with cloudy skies, precipitation, and rising air currents.)

C. *What symbol represents a cold front?* (A blue triangle.) *What symbol represents a warm front?* (A red semicircle.)

D. *Pick one weather front on a map. What weather is associated with it?* (Students may recognize that storms or changing weather often results near the boundary between air masses [fronts] or in the center of low-pressure areas.)

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?* (The direction of the symbol faces the direction in which the front is moving.)

F. *How does weather move across the United States?* (Weather systems tend to move across the United States from west to east, often following the path of the jet stream.) *Why is it important to know this information?* (It can help meteorologists forecast the weather.)

2. Show the *Hurricanes* video. Help students relate the concept of air pressure to the formation and movement of hurricanes.

HOMEWORK

Period 1

1. Have students read "Hurricane Mitch" (SG pages 78–79).

2. Ask students to use a Venn diagram (see Appendix C) to compare thunderstorms, tornadoes, and hurricanes. To complete their diagram, they can refer to these reading selections: "That's a Fact!" (Lesson 2), "Trouble in Tornado Alley" (Lesson 5), and "Hurricane Mitch" (Lesson 6).

Period 2

Ask students to complete Student Sheet 6.2. It should be finished by Lesson 7.

Period 3

Have students finish Student Sheet 6.3.

EXTENSIONS

Science **Language Arts**

1. Invite students to keep a journal for a week, recording cloud types and weather conditions. They should record observations once a day.

Technological Design

2. Have students design and build an instrument that measures changes in air pressure. Two designs are shown in Figure 6.1. In Figure 6.1(A), exerting pressure on the stretched balloon over the large jar causes the air inside the jar to become compressed. This causes the toothpick on the small jar to move. The toothpick's movement indicates changing air pressure within the jar. In Figure 6.1(B), pressing on the balloon stretched over the small can causes the straw to move, just as increased air pressure inside the large jar caused the toothpick to move. Students can set this small can and an index card (marked with 0.5-cm increments) outdoors to measure relative changes in atmospheric pressure.

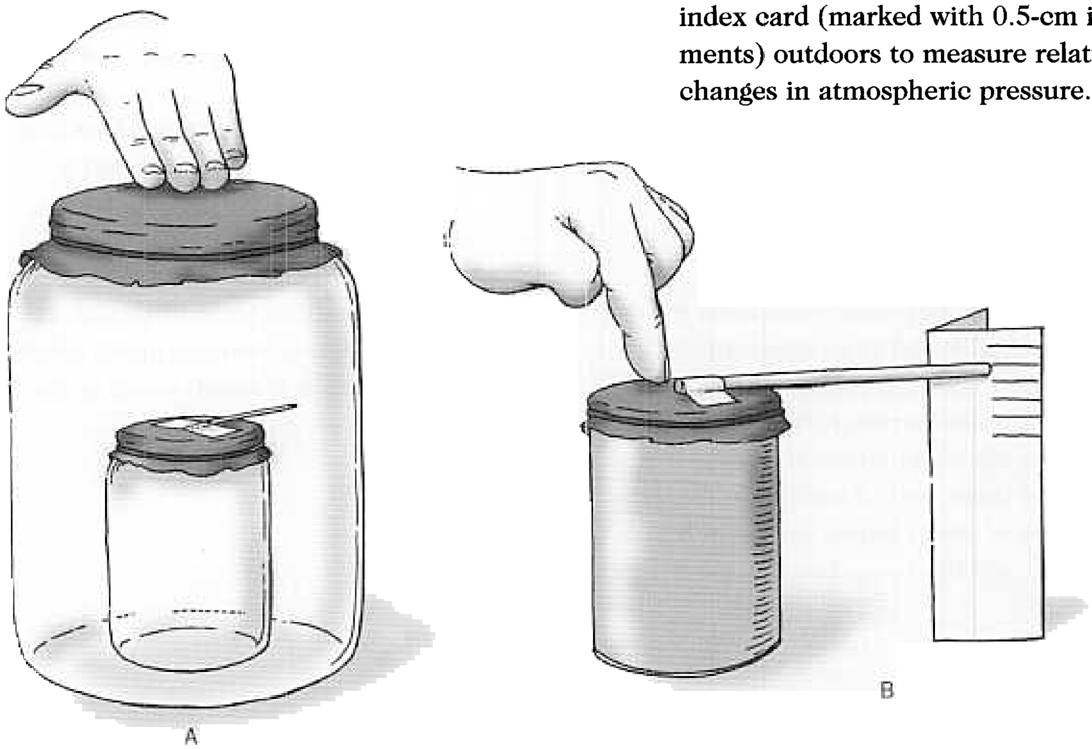


Figure 6.1 *Two designs for a home-made barometer*

■ **Science**

3. Display a scientific barometer in your room. Explain to students that this instrument detects changes in barometric (air) pressure, or the weight of the air. Ask students to keep track of the barometric pressure and the weather conditions.

■ **Mathematics** ■ **Technological Design**

4. Encourage students to start a weather club in your school. Ask students to design and build their own weather instruments. They can also set up a display of manufactured weather instruments. Students can use these instruments to record, map, graph, and analyze local weather data.

■ **Science** ■ **Language Arts**

5. Ask students to research the following: Think about the weight of the air above you. Does air pressure increase or decrease at higher altitudes? At what point might warm air stop rising and form clouds? (In other words, why doesn't rising air just keep rising all the way into space?)

ASSESSMENT

Comparing Storms

Use students' Venn diagrams (completed for homework during Period 1) to assess their understanding of how the causes, effects, and formation of thunderstorms, tornadoes, and hurricanes are alike and different. Look for students' grasp of these: size of each type of storm, how each type of storm forms, the path of each type of storm, and the respective speeds of their winds.

The Water Cycle

Students were first introduced to evaporation and condensation in Lesson 4, when they observed warm water evaporating and condensing in the Convection Tube. How have students' ideas grown over the past three lessons? Do they have a better understanding of how these processes fit into the water cycle and relate to cloud formation? Use their responses to the questions in "Reflecting on What You've Done" in Inquiries 6.1 and 6.2 to assess students' growth in understanding the water cycle.

Analyzing Weather Maps

Use students' general observations of maps during Inquiry 6.3, Procedure Step 2 to assess their grasp of the concepts addressed in this lesson. What associations do students make between air pressure systems and weather conditions? Use Student Sheet 6.3 and the anticipated responses in "Reflections" Step 1 to assess students' understanding of the following:

- The relationship between high- and low-pressure areas and their related weather
- The relationship between fronts and changing weather
- How weather systems move and how this information can be used in forecasting

PREPARATION FOR LESSON 7

Review the Preparation steps in Lesson 7. Prepare the potassium permanganate solution needed for Inquiry 7.1, which needs to be chilled or heated in vials.

Name:

Class: Date:

Student Sheet 6.2
Tracking Hurricane Andrew

Background When Hurricane Andrew struck, it was the most destructive hurricane ever to hit the continental United States. On August 24, 1992, Andrew moved toward the south Florida coast. Its maximum wind speed was 218 kilometers per hour. The hurricane was classified as Category 4. Andrew weakened somewhat as it moved over Florida and continued into the Gulf of Mexico, where it made final landfall west of New Orleans on August 26. The total damage from Hurricane Andrew exceeded $25 billion.

Directions

1. Use Table 1 and a red pencil to record the starting path of the hurricane on the hurricane tracking chart. Place a red dot at each position listed in Table 1. You may need to estimate. Use your ruler to connect the dots. (Each dot on the chart represents the location of the hurricane's eye.)

2. Use a green pencil to predict the path you think the hurricane will take next.

3. Use Table 2 and a red pencil to record the rest of the hurricane's path on the hurricane tracking chart.

4. Then answer questions A through F on loose-leaf paper.

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?

(continued)

Student Sheet 6.2 (continued)

Table 1 Path of Hurricane Andrew: Part 1

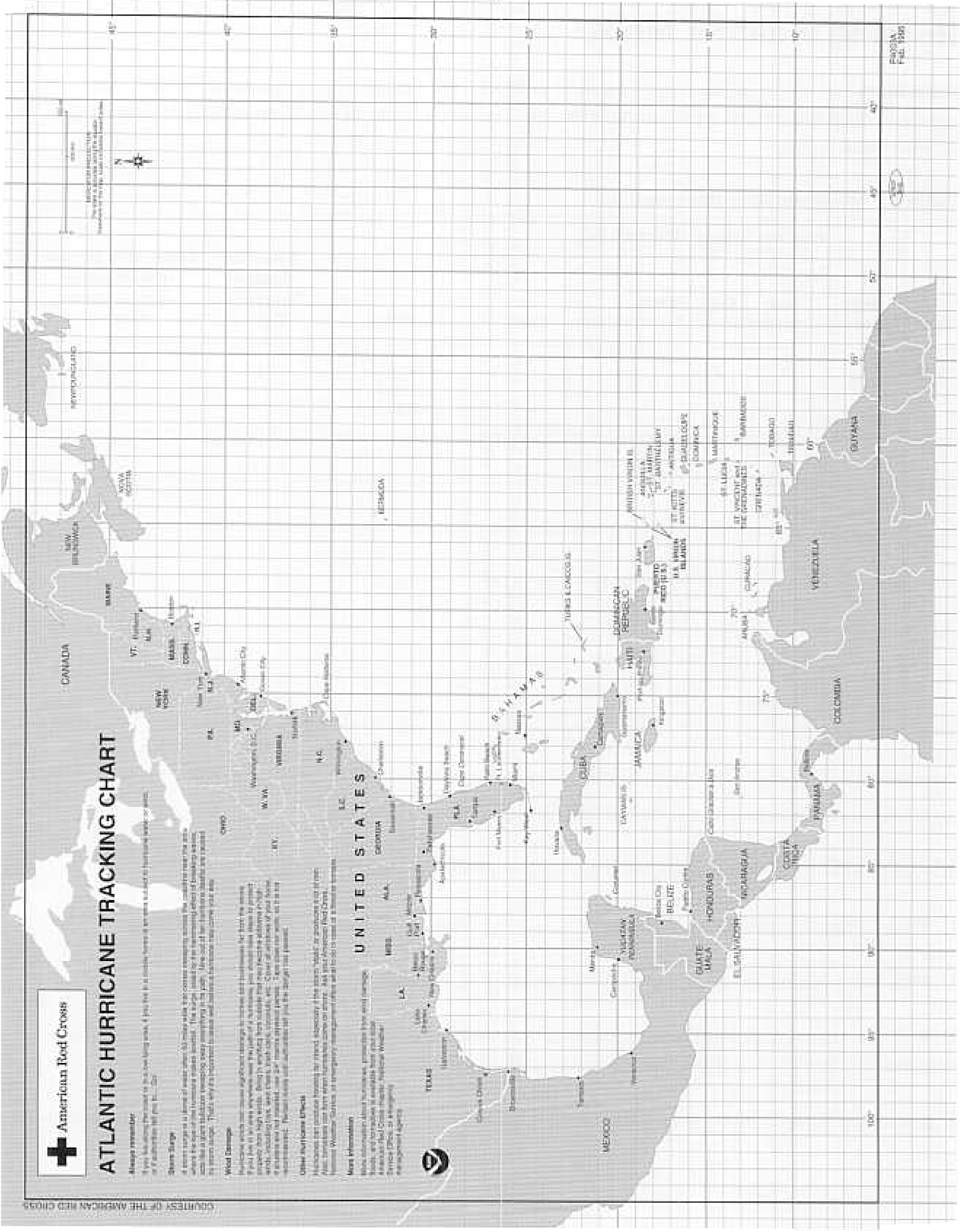
Date	Time	Latitude (° N)	Longitude (° W)	Wind Speed	Storm Status/ Hurricane Category
8-17-92	Noon	12.3	42.0	56 kph (35 mph)	Tropical storm
8-18-92	6:00 P.M.	15.4	51.8	73 kph (45 mph)	Tropical storm
8-20-92	6:00 A.M.	20.7	60.0	65 kph (40 mph)	Tropical storm
8-22-92	Noon	25.8	68.3	113 kph (70 mph)	Hurricane/1
8-23-92	Midnight	25.6	71.1	145 kph (90 mph)	Hurricane/2
8-23-92	Noon	25.4	74.2	194 kph (120 mph)	Hurricane/4
8-23-92	6:00 P.M.	25.4	75.8	218 kph (135 mph)	Hurricane/4

Table 2 Path of Hurricane Andrew: Part 2

Date	Time	Latitude (° N)	Longitude (° W)	Wind Speed	Storm Status/ Hurricane Category
8-24-92	Noon	25.6	81.2	177 kph (110 mph)	Hurricane/3
8-25-92	Midnight	26.2	85.0	185 kph (115 mph)	Hurricane/4
8-25-92	Noon	27.2	88.2	185 kph (115 mph)	Hurricane/4
8-26-92	Midnight	28.5	90.5	194 kph (120 mph)	Hurricane/4
8-26-92	Noon	30.1	91.7	129 kph (80 mph)	Hurricane/1
8-26-92	6:00 P.M.	30.9	91.6	80 kph (50 mph)	Tropical storm

(continued)

Student Sheet 6.2 (continued)



Name:

Class: | Date:

Student Sheet 6.3
Reading Weather Maps

Directions Use the weather maps you have collected (or Figure 6.1) to complete Table 1. One row has been done for you as an example, although your dates may differ. Then answer the questions on loose-leaf paper.

Table 1 Weather Map Observations

Date	Weather System Observed (✓)						Location	Direction Weather System is Moving	Associated Weather (Precipitation, Temperature Winds)
	High Pressure	Low Pressure	Cold Front	Warm Front	Storm	Other			
2-12		✓	✓				Phoenix, Denver, Rapid City	East	Flurries becoming heavier, 10 °C

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?