INTRODUCTION
What causes the wind to blow? Mostly, it has to do with the uneven heating of the earth. Breezes occur because land and water heat and cool at different rates.

When the sun’s energy heats the earth, the temperature of the air above the earth’s surface changes. Air, warmed by the surface below it, starts to rise, and cool air moves in to take its place. This circulation of air causes changes in the weather, including the formation of winds.

In this lesson, you will connect two of the Convection Tubes you used in Lesson 4. What happens when two masses of air with the same temperature and humidity meet? What happens when air masses of different temperature and humidity conditions meet? After observing the movement of air in the convection model you set up, you will apply what you have learned to two real-world situations. You will analyze how land breezes and sea breezes form and how tornadoes develop in the United States.

OBJECTIVES FOR THIS LESSON

Set up an investigation that demonstrates what happens to two air masses when they meet.

Analyze the movement of two air masses with different temperature and humidity conditions.

Devise working definitions for the terms “convection current” and “weather front.”

Relate the movement of air within the convection model to the formation of land and sea breezes and the development of tornadoes.

Explain how winds form.
Getting Started

1. Think back to Lesson 4. What did you discover about how the temperature of air affects the way air moves? Discuss this with your class.

2. Look back to the reading selection, “Air Masses,” on page 49 in Lesson 4. Where do you think air masses with different temperature and humidity conditions are most likely to meet in the United States?

MATERIALS FOR LESSON 5

For you
- 1 copy of Student Sheet 5.1a: When Air Masses Meet
- 1 copy of Student Sheet 5.1b: Convection on the Earth

For your group
- 1 tote tray
- 2 Convection Tubes
- 1 piece of plastic tubing
- 1 flashlight
- 1 120-mL plastic container of hot water (with screw-top lid)
- 1 120-mL plastic container of crushed ice (with screw-top lid)
- 1 candle
- 1 punk stick
- 1 small aluminum pan
- Scissors
Inquiry 5.1: Investigating the Effects of Colliding Air Masses

PROCEDURE

1. Collect one copy of Student Sheet 5.1: When Air Masses Meet. Read the question at the top of the student sheet: What happens when two of the same—and then different—air masses meet? You will investigate this question during the inquiry.

2. Look at one set of connected Convection Tubes and the materials for each group. Then look at Table 1 on Student Sheet 5.1a. What are some ways you might set up this equipment to investigate the question in this inquiry? Discuss this with your class. One suggested setup is shown in Figure 5.1.

3. On your student sheet, make a list of the materials you will use and the procedures you will follow to test each setup. Be prepared to share your ideas with the class.

4. What will you keep the same in each setup? What will you change during each test? Write down your ideas on Student Sheet 5.1a.

5. What do you think will happen when cold moist air meets cold moist air? What do you think will happen when warm moist air meets warm moist air? What will happen when cold moist air meets hot dry air? Discuss your predictions with your group. Record what you think will happen in the Predictions column in Table 1 on your student sheet.

Figure 5.1

Connected Convection Tubes

Candle
Crushed ice
6. Review with your teacher the following points, which you should keep in mind while you work:

A. Keep the Convection Tubes connected at all times.

B. Do not record any temperature changes in this lesson.

C. Introduce smoke into the top of the cylinder, as shown in Figure 5.2.

7. Before you begin, review Safety Tips with your teacher.

8. Collect and set up your materials. Begin the investigation. Discuss your observations with your group as you work, and record them on your student sheet. For each setup, remember the procedures your group developed. Use your flashlight to see the smoke.

9. When you have finished testing all three conditions, clean up. Put out the burning punk by dipping just the tip of it in a cup of water. Cut off the wet tip with the scissors. Refill your container with crushed ice for the next class.

![Figure 5.2](image) *Use the punk stick to introduce smoke into the top of the tube.*
REFLECTING ON WHAT YOU’VE DONE

1. Answer the following questions. Discuss your observations with the class.

   A. What did you observe when both tubes contained air with the same temperature and humidity conditions? Why do you think this happened?

   B. What did you observe when the tubes contained air with different temperature and humidity conditions? Why do you think this happened?

   C. On the basis of your results from Lessons 4 and 5, under what conditions do you think winds and rotating storms might form?

2. Look again at the illustration in “Air Masses” (Lesson 4). Where in the United States do you think air masses with different temperature and humidity conditions might meet? The boundary that forms when this happens is called a weather front. What type of weather do you think might occur along a front?

3. A convection current formed when you set up the Convection Tubes so that a hot air mass collided with a cold one. Use your experiences to write your own definitions for the terms “convection current” and “weather front.” Discuss your definitions with the class.


5. Your teacher will ask you to complete Student Sheet 5.1b: Convection on the Earth to find out what you know about how air moves. On this sheet you will do these steps:

   • Illustrate how air moved in your group’s Convection Tube.
   • Relate the movement of air within your convection model to the formation of land and sea breezes.
   • Apply the movement of air within your convection model to the development of tornadoes.
Why Does the Wind Blow?

What causes the wind to blow? From light breezes to strong gusts, winds are the result of uneven heating of the earth’s surfaces.

The process begins as the sun warms the earth. As the layer of air above a warmed surface heats, it expands, becomes lighter, and rises. Meteorologists use the word “convection” to describe the movement of heat through air or water. This movement results from temperature differences. As the warm air rises, it expands and cools. Cold air moves in to replace the rising warm air. The earth warms this layer of incoming cool air and it, too, rises, and then is replaced by another layer of cooler air. This cycle goes on and on. The circulating flow of air resulting from temperature differences is called a convection current. Convection currents can form in liquids, too.

Land Breezes and Sea Breezes

Land breezes and sea breezes are caused by convection. These breezes occur where large bodies of land and water meet. The different rates at which land and water heat and cool cause these winds. This happens more often in early summer than at other times of the year.

During the day, land warms up faster than the water in lakes or oceans does. Warm air rises above the land, forming an area of low pressure. In low-pressure areas, the air is warm and light, which means it is not dense. Cool air over the water moves toward the land and replaces the rising warmed air. This flow of air is called a sea breeze.

At night, the land cools faster than the water does, so the air over the land becomes cooler than the air over the water. As the warm air over the water rises, cool air from the land moves toward the water to replace it. The flow of air from land to water is called a land breeze.
What Are Monsoons?

Monsoons are very powerful land and sea breezes that change direction with the seasons. They occur mostly in southern Asia and are an important part of daily life there.

During the summer, the air over the land heats up. As the hot air rises, it is replaced by warm, moist air from the Indian Ocean. The water vapor in the rising air condenses, forms clouds, and produces rain. The heat in the area helps drive the monsoons, bringing long periods of rain to the region. During the summer, people grow rice and other crops that need much moisture.

In the winter, the land cools faster than the water does. Cool air over the land sinks and moves out to sea. During this time of year, southern Asia receives little rain.

Global Winds

Winds don’t just blow locally. They are continually forming around the earth, moving in a particular direction and traveling over long distances. These winds, which form between the equator and the poles, are called global winds.

The equator and the poles are not heated evenly. Near the equator, the sun’s rays are more intense. (See the illustration.) This makes the areas nearby, called the tropics, very warm. Near the poles, sunlight that reaches the earth’s surface has to pass through more atmosphere than at the equator. Because the atmosphere both absorbs and reflects the sun’s heat, the poles are not as warm.
Circling the Globe

Global winds are the result of giant convection currents that circulate within the Northern and Southern Hemispheres of the earth. As warm air is heated at the equator, it rises and flows both north and south toward the poles. If the earth didn’t rotate, the hot air at the equator would rise to the poles, cool, sink, and flow back to the equator again. (See the illustration, right.) But the earth does rotate, which means that air and water currents on the earth are deflected.

Trade winds, westerlies, and easterlies are names of different kinds of global winds that form because of the earth’s rotation and the sun’s energy. Trade winds flow toward the equator, turning west as they go. Westerlies flow from west to east. These winds are called westerlies because they flow from the west. For example, polar westerlies are winds that flow toward the poles, turning east as they go. Easterlies flow from east to west. These winds are called easterlies because they flow from the east. For example, polar easterlies are winds that sink at the poles, spread outward, and turn west as they go.

What happens when these global winds meet? Where the westerlies and easterlies meet, weather changes occur. The meeting of the westerlies and easterlies has a major effect on the weather that occurs in North America.
Jet Stream

Strong winds in what is called a jet stream are long, relatively narrow “tubes” of air in the upper troposphere. Located about 10 km above the ground, the jet streams are only a few hundred kilometers wide, but they sometimes stretch halfway around the earth.

Jet stream winds usually travel at about 200 kilometers per hour, but sometimes they can move twice that fast. American pilots during World War II discovered them. Jet streams and their paths vary from day to day and season to season. These powerful winds play a large part in moving air masses around the earth. This means that they also play a big part in determining the earth’s weather. Forecasters can use the path of a jet stream to predict how weather will move across the country.

Clouds in the jet stream over the Middle East. Today, the jet streams help high-flying airplanes travel east. Planes going west try to avoid the jet stream. Can you figure out why?

The jet stream affects where fronts form, and it moves weather in the United States from west to east.
WEATHER FRONTS

Have you ever heard your local weather forecaster talk about “weather fronts”? Fronts bring changes in the weather. They occur when air masses of different temperature, pressure, and humidity conditions collide. A weather front forms along this boundary between different air masses.

There are several different types of fronts. A cold front is the leading edge of a moving mass of cold air. When a cold air mass pushes a warm air mass ahead of it, the dense, cold air slides under the light, warm air. The warm air gets pushed upward, which causes thunderstorms. If there is a lot of water vapor in the rising warm air, dense clouds form, and rain or snow may fall. If there is little water vapor, only clouds form. Cold fronts frequently move fast and cause abrupt changes in weather, including violent thunderstorms or tornadoes. After a cold front passes, cool, dry air moves in.

At a warm front, a moving, warm air mass overrides a cold air mass ahead of it. The warm air is less dense, so it rises above the cold air. If the warm air is dry, scattered clouds form. If the warm air is humid, rain (or light rain or snow in the winter) normally falls along the front. Warm fronts typically move slowly, so rainy weather usually stays around for days.

If two air masses move close to one another but neither has enough force to move the other, they both remain fixed in place. The boundary between them is called a stationary front. At the point where the warm air and cold air meet, water vapor in the warm air condenses into rain, snow, fog, or clouds. If the stationary front remains in place for a long time, it may bring days of clouds and precipitation.

In a more complex frontal system—an occluded front—both a cold and a cool air mass collide with a warm air mass, which becomes trapped in the center. The warm air mass is lifted upward. It is cut off, or occluded, from the ground. As the warm air cools, its water vapor condenses. Then the weather may bring clouds and rain or snow.

When you listen to weather forecasts from now on, pay close attention to what the forecaster says about fronts. Do you notice that one type of front tends to form in your area more than others? What type of weather and cloud cover does each front bring? The appearance of clouds will often tell you a lot about the way air is circulating in each frontal system.
People who live in Tornado Alley, which includes the Central Plains states of Kansas, Oklahoma, Texas, and Missouri, pride themselves on being able to cope with anything. But in May 1999, even they were overwhelmed by the devastating tornadoes that ripped through their area. The tornadoes roared across Oklahoma and Kansas, destroying homes, businesses, schools, and churches, and killing 44 people.

One monstrous tornado skipped across the ground for 4 hours. Meteorologists classified it an F-5, the most powerful tornado there is. Its winds were more than 419 kilometers per hour (260 miles per hour). It cut a path about 2 kilometers wide and tore up 100 kilometers of flat countryside. The destruction was massive: entire neighborhoods were transformed into piles of bricks and stones.

This neighborhood in Moore, Oklahoma, was in ruins after a tornado flattened many houses and buildings.
Tornado Alley usually experiences the highest number of tornadoes per year. In Tornado Alley, cool, dry air from the Rocky Mountains and Canada meets warm moist air from the Gulf of Mexico.

cars were crushed beyond recognition and tossed down the street, natural gas poured from broken lines, and fires erupted from the gas.

Although the tornado was worse than expected, it had, in fact, been predicted. Using helicopters and radar, weather forecasters gathered storm data and warned people that a severe storm was about to hit. Warning sirens went off, and the media gave people the most up-to-date information. Even so, many people were caught off guard, especially visitors to Tornado Alley.

Damage in Moore, Oklahoma, from the tornado on May 3, 1999
Rebuilding—The Next Step

After surviving a catastrophic event such as the Oklahoma tornadoes, people turn their attention to rebuilding their lives. The outpouring of supplies and support from neighboring areas heartened people in Kansas and Oklahoma. Food, diapers and other essential supplies, money, and clothing found their way to emergency shelters. Neighbors took to the streets with chain saws and other tools, trying to help each other salvage what they could from the debris.

Nonetheless, it will be a long time before the people of Oklahoma and Kansas forget the devastating tornadoes of 1999.

Waterspouts

A waterspout is a rotating column of air over a large body of water. Some waterspouts begin as tornadoes and then move over water. These are called tornado waterspouts. They are the most dangerous kind.

Other waterspouts form over a large body of warm water. These are called fair-weather waterspouts. They do not start from a thunderstorm, and they are much smaller than tornado waterspouts. Some scientists think this type of waterspout forms when sea breezes meet, especially in the Florida Keys. Many fair-weather waterspouts also form over the Great Lakes in the summer.
Staying Safe
Where should a person go if a tornado strikes? A storm shelter or basement is the safest place to be, but even in Tornado Alley, many people don’t have access to them. Some families find shelter in a closet, while others climb into their bathtubs. Other options are to crouch under a piece of heavy furniture or to go to an inside room with no windows.

To help people stay safe in weather emergencies such as tornadoes, relief workers from agencies such as the Federal Emergency Management Agency and the American Red Cross recommend that people stock their homes with the following supplies:

- Flashlights and extra batteries
- Portable, battery-operated radio with extra batteries
- First-aid kit
- Emergency food and water
- Essential medicines

Using a bridge or highway overpass as shelter from a tornado may not be a good idea. Although overpasses and bridges are solid structures, you are still above ground and can be swept away by the tornado’s intense winds. Instead, seek shelter in a ditch or low-lying area below ground level and away from vehicles.