23.3 Winds

Section Objectives

- **Describe the global patterns of wind.**
- **Describe some factors that create local wind patterns.**

Because the earth receives more solar energy at the equator than at the poles, there is a belt of low air pressure at the equator. The heated air in the region of the equator is constantly rising. At the poles, the colder air is heavier and tends to sink. This sinking of cold air creates regions of high atmospheric pressure.

Pressure differences in the atmosphere at the equator and at the poles create a general movement of air worldwide. Air moves from high-pressure belts toward low-pressure belts. In very general terms, air near the earth's surface generally flows from the poles toward the equator, as shown in Figure 23–12. At higher altitudes, the rising warm air cools, and there is a general return flow of air from the equator toward the poles.

Global Winds

The circulation of the atmosphere as well as the oceans is affected by the rotation of the earth on its axis. The rotation causes surface winds in the Northern Hemisphere to be deflected to the right and those in the Southern Hemisphere to be deflected to the left. This motion is called the *Coriolis effect,* after the nineteenth-century French mathematician who first described it. A ball thrown on the earth's surface will curve only slightly due to the Coriolis effect. The ball travels far too short a distance to be affected. The ocean currents and winds of the world, however, are strongly deflected. Winds that would otherwise blow directly from a high-pressure area toward a lower-pressure area are deflected by the Coriolis effect.

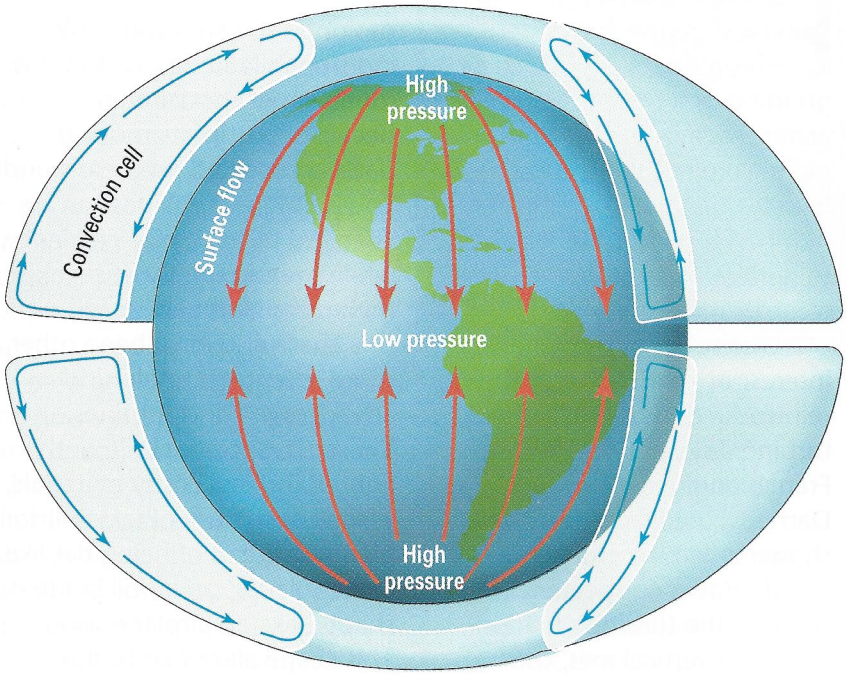
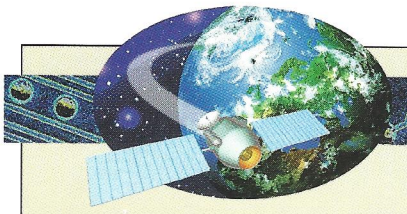


Figure 23–12. The blue arrows around the perimeter of the globe show the general circulation of air. Surface winds blow from polar high-pressure areas to equatorial low-pressure areas as shown by the red arrows. Wind movements are shown as if on a non-rotating earth, without the Coriolis effect.

A low-pressure belt exists at the equator because the heated air there tends to rise. As the warm air rises, it begins to move toward the poles. Around 30° latitude, some of this air sinks toward the earth's surface. At the surface, the descending air forms a high-pressure area from which air flows both north and south. At about 60° latitude, air flowing along the surface from the polar high and the high at 30° converges. This converging air rises, forming a low-pressure area at 60° latitude. The air flowing from the equator completes three looping patterns of flow called **convection cells.** The Northern and Southern hemispheres each have three convection cells.

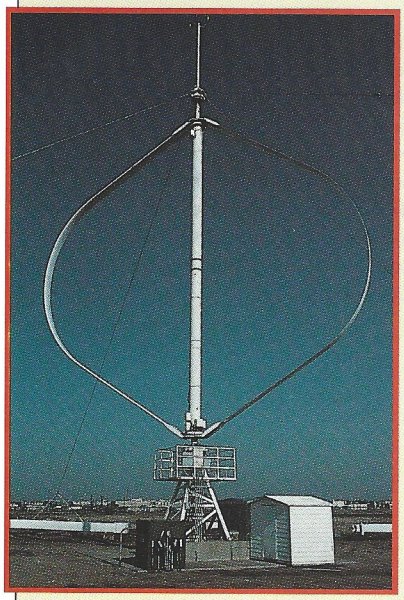
Trade Winds

The winds in both hemispheres flowing toward the equator between 30° and 0° latitude are called **trade winds.** Like all winds, they are named according to the direction from which they flow. In the Northern Hemisphere, the trade winds flow from the northeast and are therefore called the *northeast trades*. The northeast trades are deflected to the right by the Coriolis effect. In the Southern Hemisphere, the trade winds are called the *southeast trades* and are deflected to the left.



SCIENCE & TECHNOLOGY

Energy from the Wind



For more than a thousand years, people have used windmills for tasks such as grinding grain or pumping water. Today, more and more people are rediscovering the benefits of wind power as the number of wind turbines used to generate electricity continues to grow.

One result of the renewed interest in wind power is the reintroduction of the Darrieus turbine. Invented in 1920 by French engineer Georges Darrieus, the Darrieus turbine, shown at left, resembles an upside-down eggbeater. Because the turbine's blades spin on a vertical axis, the Darrieus turbine is mechanically simpler than propeller-type turbines, which spin on horizontal axes. The Darrieus turbine is designed to catch winds blowing from all directions, and it is much easier to maintain because most of its moving parts are located on the ground. The bend in the blades can be changed to maximize efficiency, while the turbine's vertical axis minimizes land use.

There also have been other, more recent, technological advances in wind turbines. These advances include both lighter and less costly materials, as well as the use of faster airfoil blades. Instead of being flat like earlier blades, an airfoil blade is shaped like an airplane wing. This shape allows air to flow

The trade wind systems of the Northern and Southern hemispheres meet at the equator in a narrow zone called the **doldrums.** The air in this warm zone moves mainly upward, and near the earth's surface the winds are weak and undependable. What problems might sailing ships have in the doldrums?

A belt of high pressure in the vicinity of 30° latitude is created by the descending air. This subtropical high-pressure belt is called the **horse latitudes.** The surface winds here are weak and changeable. The name *horse latitudes* was given to this region in the days when many sailing ships carried horses from Europe to the New World. Horses were often thrown overboard to save water for the sailors when the ships were becalmed and trapped in this zone because of the lack of wind.

Westerlies

In the subtropical highs, some of the descending air moving toward the poles is deflected by the Coriolis effect. This flow creates another wind belt in both the Northern Hemisphere and the Southern Hemisphere. These winds are known as the **westerlies.** In the Northern Hemisphere, the westerlies are southwest winds. In the Southern

smoothly over the blades, enabling the airfoil to use the lifting force of the wind more effectively.

The advantages to using the wind to generate electricity are that it consumes no fossil or nuclear fuel and produces no waste. Also, the wind itself costs nothing and is available in limitless supply. A disadvantage of wind power is the unpredictability of wind speed and direction. In addition, large wind farms can be noisy, visually unattractive, and deadly to migrating birds.

The photograph above shows some of the 13,000 wind turbines that have been installed in the Diablo Mountains of California. Home to some of the world's largest wind farms, California is now seeing its leadership in the multibillion-dollar market for wind-generated electricity being challenged. With steady growth in European countries such as the Netherlands, Denmark, Germany, and England, wind generation is quickly becoming the sustainable energy source of choice for utility companies worldwide.

What problems would there be in using wind turbines in areas along the equator and at 30° latitude?

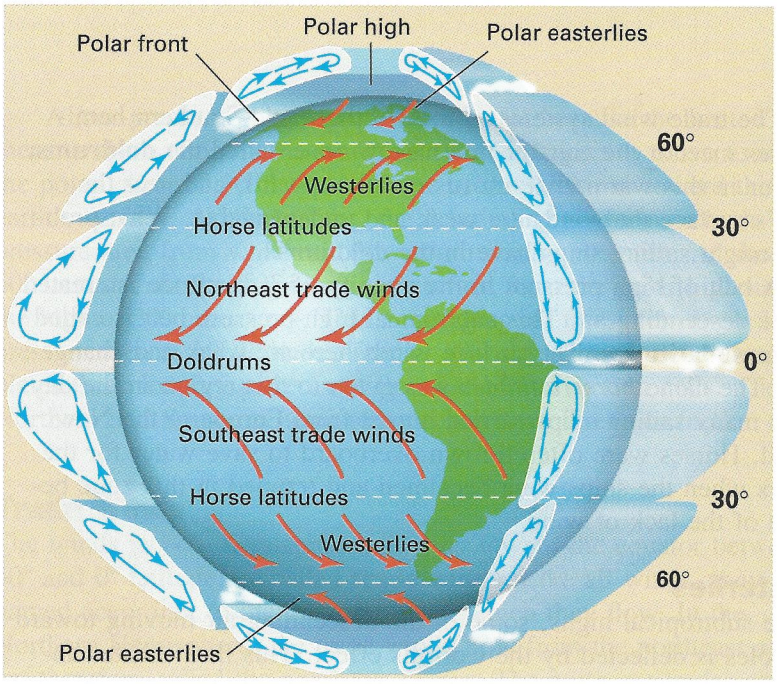


Figure 23–13. Both the Northern Hemisphere and the Southern Hemisphere have three wind belts. Wind belts are the result of pressure differences at the equator, the subtropics, the sub-polar regions, and the poles. The arrows are curved because of the Coriolis effect.

Hemisphere, they are northwest winds. The westerlies are located in a belt between 40° and 60° latitude. The contiguous United States is located within the westerlies, while Hawaii is located in the northeast trade winds, and parts of Alaska are in the polar easterlies.

Polar Easterlies

A third wind belt exists near each of the earth's poles, as shown in Figure 23–13. Poleward of the belt of westerlies, at about 60° latitude, is a belt of low pressure. These **subpolar lows** result when warm air moving poleward from the subtropical high is lifted by cold polar air moving toward the equator. Over the polar regions themselves, descending cold air creates areas of high pressure. The general surface movements of the cold polar air masses is toward the equator. Surface winds created by the polar high pressure are deflected by the Coriolis effect, becoming the **polar easterlies.** The polar easterlies are strongest where they flow off Antarctica. Where the polar easterlies meet warm air from the westerlies, a stormy region known as a polar front forms.

Wind and Pressure Shifts

As the sun's vertical rays shift northward and southward during the year, the positions of the pressure belts and wind belts also shift. Although the sun's rays move 47° in latitude, the average shift for the pressure and wind belts is only about 10° of latitude. However, even this small change means that some areas are in different wind belts during the year. In southern Florida, for example, westerlies prevail in the winter, but trade winds are dominant in the summer.

Jet Streams

Bands of high-speed winds exist in the upper troposphere and lower stratosphere over both the Northern and Southern hemispheres. These upper westerly winds are the **jet streams.** Because the temperature of polar air and middle-latitude air differs so greatly, the pressure

also differs greatly. The cold polar air is much denser than the warmer air of the middle latitudes. The resulting pressure differences produce the polar jet streams. These bands of winds, found at an altitude of 10–15 km, are about 100 km wide and 2–3 km thick. The polar jet streams may reach maximum speeds of almost 500 km/hr. These winds do not blow steadily but instead change speed and position. The polar jet streams are important because they control the path of storms and have an effect on airline routes.

In the subtropical regions, very warm equatorial air meets the cooler air of the middle latitudes, creating the subtropical jet streams. Unlike the polar jet streams, the subtropical jet streams do not change much in speed or position.

Local Winds

The movements of air are also influenced by local conditions. A local feature that produces temperature differences often causes a local wind. Local winds are not part of the global wind belts. Gentle winds that extend over distances of less than 100 km are called *breezes*.

Land and Sea Breezes

Equal surface areas of land and water may receive the same total amount of energy from the sun. However, the land surfaces heat up faster than the water does. During daylight hours, therefore, a sharp temperature difference develops between a body of water and the land along its shore. This temperature difference is apparent in the air above the land and water. The warmer air above the land rises, and the cool air from above the water moves in to replace it. A cool wind moving from water to land, called a *sea breeze,* generally begins in the afternoon. Overnight the land cools more rapidly than the water does, and the sea breeze is replaced by a *land breeze*. A land breeze flows from the cooler land to the warmer water.

Mountain and Valley Breezes

In mountainous regions during the daylight hours, a gentle *valley breeze* blows up the slopes. The valley breeze is caused by warm air from the valleys moving up slope. At night the mountains cool more quickly than the valleys do. Then, cooler air descends from the mountain peaks, creating a *mountain breeze*. Campers in mountain areas may experience a warm afternoon quickly turn to a cold evening soon after the sun sets, as the cold air flows down slope and settles in the valleys.

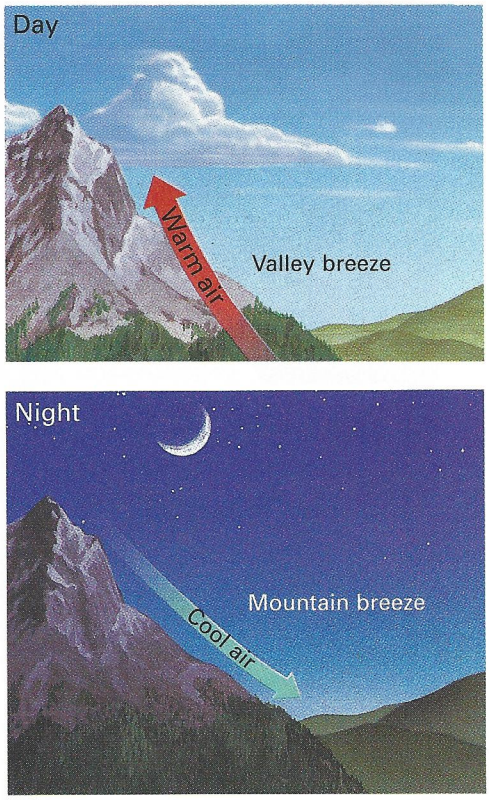


Figure 23–14. In the daytime, air heats rapidly in valleys. The warm air rises up the slope as a valley breeze. At night, air at the mountaintop cools quickly. The heavy, cool air moves down the mountain slope as a mountain breeze.

Section 23.3 Review

1. What are the results of the Coriolis effect on wind flow?
2. What surface wind belt flows in the middle latitudes?
3. On a camping trip on the Oregon coast, you decide to hike to the ocean, but you are not sure of the direction. The time is 4:00 P.M. How might the breeze help you find the ocean? Why?

Chapter 23 Review

Key Terms

- albedo (466)
- atmospheric pressure (457)
- barometer (458)
- climate (455)
- conduction (468)
- convection cell (470)
- doldrums (471)
- electromagnetic spectrum (463)
- exosphere (461)
- greenhouse effect (467)
- horse latitudes (471)
- ionosphere (461)
- jet streams (472)
- mesopause (461)
- mesosphere (461)
- nitrogen cycle (457)
- ozone (455)
- polar easterlies (472)
- standard atmospheric pressure (459)
- stratopause (460)
- stratosphere (460)
- subpolar low (472)
- temperature inversion (462)
- thermosphere (461)
- trade winds (470)
- tropopause (460)
- troposphere (460)
- weather (455)
- westerlies (471)

Key Concepts

The earth's atmosphere is a mixture of gaseous elements and compounds and tiny suspended particles. **See page 455.**

Atmospheric pressure is measured by a barometer. **See page 458.**

The atmosphere is divided into four major layers that vary in temperature. **See page 459.**

Certain substances, when released into the air, can be harmful to people, animals, plants, and property. **See page 462.**

Most of the energy that reaches the earth from the sun comes in the form of electromagnetic waves. **See page 464.**

Visible light and some infrared rays from the sun penetrate the earth's atmosphere and heat materials such as rocks, soil, and water on the surface. **See page 466.**

Heat is transferred within the atmosphere by three processes—radiation, conduction, and convection. **See page 468.**

Air-pressure differences and the earth's rotation cause the various global wind belts. **See page 469.**

A surface feature, such as a body of water, a mountain, or a valley, can influence local wind patterns. **See page 473.**

Review

On your own paper, write the letter of the term that best completes each of the following statements.

1. During one part of the nitrogen cycle, nitrogen is removed from the air mainly by nitrogen-fixing
   a. bacteria. b. waves. c. minerals. d. crystals.
2. Atmospheric pressure measured at sea level is
   a. 99 percent. b. 1.03 kg. c. 32 km. d. 1.03 kg/cm^2.
3. A barometer measures
   a. atmospheric pressure. b. wind speed.
   c. ozone concentration. d. wavelengths.
4. Almost all of the water and carbon dioxide in the atmosphere is in the
   a. exosphere. b. ionosphere.
   c. troposphere. d. stratopause.
5. Radio stations can increase the distances they reach by bouncing radio waves off the
   a. stratosphere. b. tropopause.
   c. ionosphere. d. troposphere.

6. Around Los Angeles, frequent temperature inversions are the result of cool, polluted air being trapped by
   a. acid rain. b. a layer of colder air.
   c. mountains. d. the ocean.
7. Almost all of the energy reaching the earth from the sun is in the form of
   a. atomic particles. b. electromagnetic waves.
   c. ultraviolet rays. d. gamma rays.
8. Raindrops may separate sunlight into a range of colors, thereby causing
   a. a mirage. b. an inferior mirage.
   c. acid precipiation. d. a rainbow.
9. The process in which the atmosphere traps warming solar rays at the earth's surface is called the
   a. greenhouse effect. b. Coriolis effect.
   c. doldrums. d. convection cell.
10. Heat can be transferred within the atmosphere in three ways—radiation, conduction, and
   a. scattering. b. temperature inversion.
   c. weathering. d. convection.
11. A vertical looping pattern of air flow is known as
   a. the Coriolis effect. b. a convection cell.
   c. a trade wind. d. a westerly.
12. A gentle wind covering less than 100 km is called
   a. a jet stream. b. the doldrums. c. a breeze. d. a trade wind.

Critical Thinking

On your own paper, write answers to the following questions.

1. Explain how houseplants can increase the amount of oxygen in your home.
2. During a jet flight over the North Pole and toward a region in the middle latitudes, the pilot adjusts the altimeter. Why is this adjustment necessary?
3. Most aerosol sprays are banned in the United States. Which of the four layers of the atmosphere does this ban help protect? Explain your answer.
4. You hear a lecture about the earth's weather. The speaker says, "Infrared rays coming from the earth's surface heat the atmosphere much like a greenhouse is heated." Explain why that statement is incorrect.
5. What effect might jet streams have on airplane travel?
6. If there is a breeze blowing from the ocean to the land on the coast of Maine, about what time of day is it? How do you know?

Application

1. In a certain area of the country, many of the fish in a local lake have died. In addition, soils were found to be highly acidic, and nearby trees were losing their leaves. What kind of pollution may have caused these problems? What is the source of this pollution?
2. In a drive across the desert with your family, you see a distant sand dune that appears to be floating on air. How can you explain what you see?
3. In what ways would a knowledge of the global wind belts have helped a sixteenth-century explorer sailing between Spain and the northern part of South America?

Extension

1. Use encyclopedias or the Internet to find out more about rainbows. Draw diagrams showing how rainbows form and why a rainbow forms an arc. Present both diagrams to the class.
2. Do research on the Beaufort wind scale. Assign a Beaufort number to the morning and evening winds in your area each day for a week. Plot the results on a graph with the time and day on one axis, and the Beaufort number on the other axis. Share your graph with the class, and lead a discussion about any trends you notice.