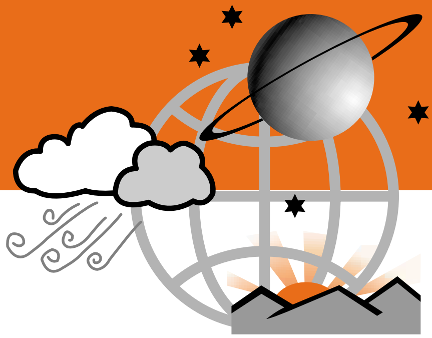


Chapter 21

Air Pressure and Winds

FAST AS THE WIND

Establishing a world's record for wind speed is not a simple matter. On April 12, 1934, an anemometer on the summit of Mount Washington in New Hampshire registered a sustained wind speed of 373 kilometers per hour (km/h) (231 miles per hour [mph]). At 1910 meters (6262 feet), Mount Washington is the highest summit in the northeastern United States. This record has stood for 70 years. Prevailing westerly winds are forced up the mountain. The mountaintop and the overlying layers of the atmosphere squeeze the winds, increasing their speed. The average wind speed at this location is 57 km/h (35 mph) making it the windiest surface location in the United States.

A slightly faster wind speed of 380 km/h (236 mph) was reported during a typhoon (hurricane) on the island of Guam in 1997. This report led to an investigation by the National Climate Extremes Committee. The committee found that the anemometer used in Guam was not properly calibrated for winds in excess of 274 km/hr (170 mph). The committee concluded that the combination of high wind and heavy rain caused the Guam instrument to malfunction and that the true wind speed was probably less than 322 km/h (200 mph).

Was the wind speed recorded on Mount Washington the fastest surface wind ever to occur? It is not likely. Winds in the strongest tornadoes are estimated to exceed 483 km/h (300 mph). Scientists have tried to measure tornado winds with ground-based instruments. However, the difficulty of placing instruments in the narrow path of a tornado, flying debris, and damage done by strong tornadoes makes this nearly impossible. Teams of "storm chasers" have tried to put instrument packages where a tornado would envelope them, but none have succeeded in obtaining anemometer measurements of the strongest tornado winds.

A new tool has become available for measuring extreme winds. Meteorologists can now use radar to measure wind speed and direction from a distance. **Radar**, a name taken from the terms "*ra*dio *d*etection *a*nd *r*anging," was developed during the Second World War primarily to observe enemy aircraft. It works by bouncing long-wave radio signals off distant objects. The distance is determined by how long the signals take to return as reflected energy. Advancing technology has enabled engineers to develop radar that can measure the speed with which objects or winds are moving toward or away from the radar station. This is called **Doppler radar**. Doppler radar was used to record a wind gust of 512 km/h (318 mph) in a tornado in Oklahoma in 1999. However, this wind speed does not have the accuracy of the 1934 measurement on Mount Washington.

WHAT CAUSES WINDS?

Surface winds blow in response to differences in air pressure. Winds always move from places of higher pressure to places of lower pressure. When you exhale, you do so by squeezing the air in your lungs, increasing the pressure. Air escapes from your body to equalize the pressure inside and outside your lungs. An air pump works in a similar way. By compressing the air inside the pump, air is forced out of the pump to where the pressure is lower.

You learned earlier that atmospheric pressure is caused by the weight of the atmosphere. Earth's atmosphere is not confined the way air is in your lungs or in an air pump. The atmosphere has a relatively uniform depth near Earth's surface. Differences in the density of air cause changes in the weight of the air. Primarily, temperature and humidity determine the density of air. (As temperature and humidity increase, air becomes less dense.) When air density increases, so does air pressure at Earth's surface, forcing the air to move to places with a lower surface pressure.

DEMONSTRATION #1

THE WEIGHT OF AIR

Use a sensitive balance to measure the weight of a deflated playground ball. Then pump up the ball and determine its weight again. The difference in weight is the weight of the air inside the ball.

DEMONSTRATION #2

THE FORCE OF AIR PRESSURE

This demonstration should be performed over a sink or a large container to catch spilled water. Fill a small glass with water and place an index card over the top. Carefully invert the glass while holding the index card to maintain an airtight seal. Remove your hand from the index card, air pressure will hold the card and the water in place until the wet card loses its stiffness.

DEMONSTRATION #3

AIR PRESSURE AND A SODA CAN

Materials: empty 12-oz soda can, hot plate or lab burner, ring stand, tongs, ice water

Pour about half a centimeter of water in the bottom of the empty soda can. Heat the can of water on a hot plate or over a burner flame until water vapor fills the can and drives out the air. Using the tongs, quickly invert the soda can and place it in the ice water. As the water vapor in the can suddenly condenses, atmospheric pressure will crush the can. Although the soda can has an opening, the change in air pressure inside the can is so rapid and so strong that the can suddenly collapses.

DEMONSTRATION #4

PRESSURE AND DEPTH

Differences in air pressure at different depths within the atmosphere can be modeled with a 2-liter plastic soda bottle or a similar tall plastic container. Three holes are pierced in the bottle at different heights. With the holes covered by plastic tape, fill the bottle with water. Hold the jar over a sink or a container to catch the water. Remove the tape from the holes; notice that the water emerging from each hole travels a different distance. This illustrates that pressure increases with depth in a fluid. Each hole represents a different level in the atmosphere.

Temperature, Air Pressure, and Winds

Heating increases the motion of air molecules and pushes them apart. If you have observed air rising over a campfire, you have observed convection currents in the atmosphere caused by density differences. The fire heats the air, causing it to expand. The low-density air floats higher into the atmosphere, and is replaced by cooler air that flows in from the surrounding area. This cooler air is then heated by the fire and expands to keep the air constantly flowing upward, carrying the heat of the fire into the atmosphere. Expansion by heating and contraction by cooling cause changes in atmospheric pressure.

Humidity, Air Pressure, and Winds

The role of humidity is not as obvious as that of temperature. Under the same conditions of temperature and pressure, the same number of molecules of any gas occupy the same volume. Therefore, if lighter gas molecules are substituted for heavier molecules, there is no change in volume, but the density of the gas decreases. The mass of the individual molecules determines the density of any gas.

You usually think of water as a substance that is more dense than air. Although it is true that liquid water is far more dense than air, this changes when water becomes water vapor. Dry air is 78% nitrogen. If you look at a periodic table of elements you will see that each atom of nitrogen has a mass of 14 atomic mass units (amu). Like many other gases, nitrogen exists in molecules of two atoms (N_2). Therefore, the mass of a molecule of nitrogen is 28 amu. Oxygen (O_2), which makes up most of the rest of dry air, has an atomic mass of 16 amu and a molecular mass of 32 amu. Oxygen is just a little more dense than nitrogen. Therefore air is composed mostly of molecules with a mass of about 28 amu, as shown in Figure 21-1.

Water vapor is a compound made of two atoms of hydrogen and one atom of oxygen (H_2O). The water molecule has three

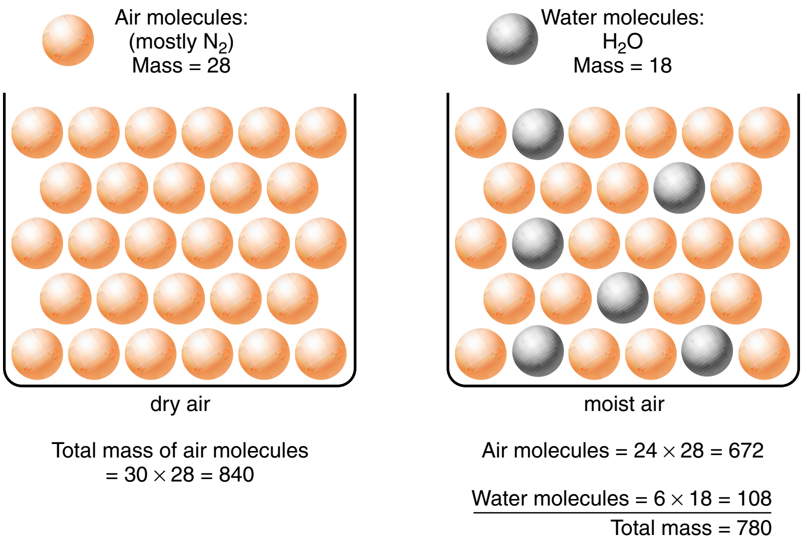


Figure 21-1 When water vapor is added to air, the air becomes less dense. Water molecules have less mass than molecules of nitrogen, which make up most of the atmosphere. Therefore, substituting water vapor for dry air makes the air less dense. (The units of mass in these diagrams are atomic mass units.)

atoms: one more than either nitrogen or oxygen. However, the hydrogen atoms are light. They have an atomic mass of just 1 amu. Recall that the oxygen atom has a mass of 16 amu. Therefore, the mass of the water molecule is 18 amu (1 + 1 + 16). This is considerably less than the molecular mass of nitrogen (28 amu) and oxygen (32 amu), which make up 99% of dry air. Therefore, if water vapor molecules replace dry air molecules, the air becomes less dense. Figure 21-1 models dry air as 30 molecules of nitrogen with a total mass of 840 amu. In the second part of this diagram, six water molecules have been substituted for the same number of nitrogen molecules. The total mass decreases to 780 amu. Therefore, adding water vapor to the atmosphere makes air less dense.

The effects of temperature and humidity are confirmed when you use a barometer to measure air pressure in different weather conditions. As temperature and humidity increase, the barometric pressure decreases. Conversely, a change to cooler and dryer weather results in increasing barometric pressure.

WHY DO LOCAL WINDS OCCUR?

There are two categories of wind currents. Regional winds extend over a large area, such as several states of the United States. Local winds are those that extend only for a few miles before they die out.

Convection Cells

Whenever air is heated in one place and cooled in another, circulation tends to occur. Consider a room with a heater on one side of the room and a cold window on the other. Air near the heater absorbs energy. This causes the air to expand and rise. At the far side of the room, air is cooled as it loses its energy. Heat is lost by contact with the cold window and the

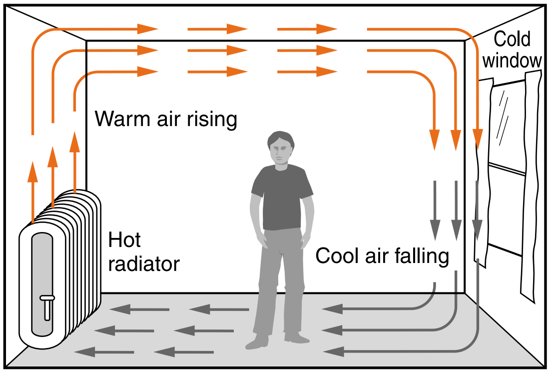


Figure 21-2 Air heated on one side of this room expands and rises. Cooling air on the opposite side contracts and sinks. This energy exchange maintains a flow of air and heat energy called a convection cell.

wall (conduction) as well as by radiating heat toward these surfaces. Air near this end of the room contracts and sinks to the floor where it flows toward the heater. As long as the air is heated in one place and cooled in another, circulation will continue. This pattern, shown in Figure 21-2, is called a **convection cell**. The air currents in the convection cell carry energy from the heater to the cold side of the room and the window.

Winds on Earth are not confined to a closed space the way air is in this diagram. Convection cells do occur within the atmosphere. Rising air in some locations must be balanced by sinking air in other places. Winds that blow in one direction at Earth's surface must be balanced by a return flow somewhere else. The return flow usually happens in the upper atmosphere.

ACTIVITY 21-1 OBSERVING CONVECTION

You can use smoke from an extinguished match or a stick of incense to show convection currents in a classroom. This works best in very cold weather when strong downdrafts overpower the heating effect of the match or incense. The smoke is used to locate places in the room where the air is moving in different directions. If people do not move around, you may be able to map complete convection cells with updrafts, downdrafts, and horizontal air flow.

Can you identify the net flow of energy within the classroom?

Land and Sea Breezes

The wind-producing effects of temperature changes can often be observed at the shore. During stable summer weather in coastal regions such as Long Island or along the Great Lakes, the wind direction can reverse on a daily cycle.

On a sunny day, the land heats up more than the water. To understand why it may help to look at Figure 21-3, from the *Earth Science Reference Tables*. This table shows the specific heat of seven common substances. *Specific heat* is the ability of a substance to absorb or release heat energy. Notice that water in liquid form has a specific heat of 1 calorie/gram · C°. In the form of ice or water vapor, its specific heat is only half as great. This means that a unit of heat energy absorbed by a given mass of ice or water vapor will cause twice the temperature rise it causes in liquid water.

The difference in specific heat is even greater for basalt and granite, which would heat up five times as much as liquid water. Since most beach sand is similar in mineral composition to these two igneous rocks, the sand on the beach heats relatively quickly. Metals, such as iron, copper, and lead, have even lower specific heats. Therefore, they heat up still faster when they absorb energy. The bottom line is, water heats more slowly than most other materials when it absorbs sunlight.

During the day, the land heats up more than the water. Radiation and conduction from the land's surface heat the air over the land. This heated air expands and becomes less

Specific Heats of Common Materials

MATERIAL		SPECIFIC HEAT (calories/gram · C°)
Water	solid	0.5
	liquid	1.0
	gas	0.5
Dry air		0.24
Basalt		0.20
Granite		0.19
Iron		0.11
Copper		0.09
Lead		0.03

Figure 21-3

dense, causing it to rise. The result is a breeze that comes from the water to replace the rising air over the land. **Sea breezes** are light winds that blow from the water to the land. They usually develop in the late morning or afternoon when the land becomes warm. These breezes continue into the evening until the land cools. (See Figure 21-4.)

Sea breezes provide relief in hot summer weather. There are two benefits: The breeze keeps people cool by replacing humid air that builds around the body, allowing sweat to evaporate, and it transports the cooler air over the ocean onto the beach, resulting in relief from summer heat at the hottest time of day.

The wind reverses direction at night and through the early morning, becoming a **land breeze**. Land not only warms faster than the ocean, but it also loses its heat more quickly. The lower specific heat for rock materials means that at night the same amount of energy lost has a greater cooling effect on the land than on water. When the land cools at night, so does the air over it. The air over the water is now warmer than the air over the land. Instead of the air rising over land, air begins to rise over the water during the evening. This causes the

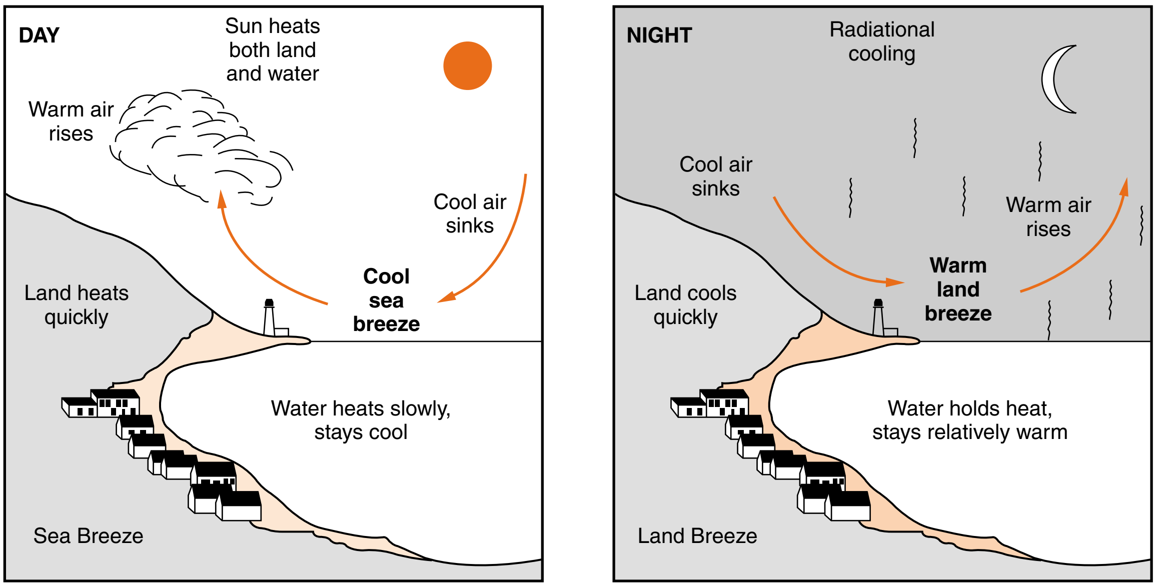


Figure 21-4 Rapid heating and rising air over land areas are responsible for sea breezes that occur during the day, blowing cool air from the ocean. At night, when the water is warmer than the land, the breeze blows from the land.

wind to change direction, blowing from the land to the water. The conditions that lead to a land breeze also are shown in Figure 21-4.

Land and sea breezes do not always occur along the shore. They require large areas of adjacent land and water. Therefore, these breezes do not occur at small lakes or ponds or on small islands. Nor do they develop when daily temperature changes are small, such as during cloudy weather. Strong regional weather events such as the passage of fronts can easily overpower land and sea breezes. However, when these breezes do occur, they can bring welcome relief from summer heat. People who live near the ocean sometimes talk about their "natural air conditioning" from these breezes.

WHAT CAUSES REGIONAL WINDS?

The fastest winds develop in larger and more powerful atmospheric events than land and sea breezes. If you have watched a television weather report you have probably seen maps of the United States with large areas marked "H" and "L." These are regional high- and low-pressure systems.

High- and Low-Pressure Systems

Low-pressure regions are areas where warm, moist air is rising. In the last chapter, you learned that rising air leads to cloud formation when the air is humid. Cloud formation, which occurs by condensation, releases latent energy and warms the air even more. This warming accelerates the updraft. Therefore, once a low-pressure system develops, it tends to strengthen and sustain itself as long as it can draw in moist air. In fact, some low-pressure systems build into major storm events that release great quantities of energy.

High-pressure regions are usually places where cool, dry air is sinking lower into the atmosphere. Although the air gets warmer as it descends, it may still be cooler than the surrounding air. The air spreads out at the surface and makes

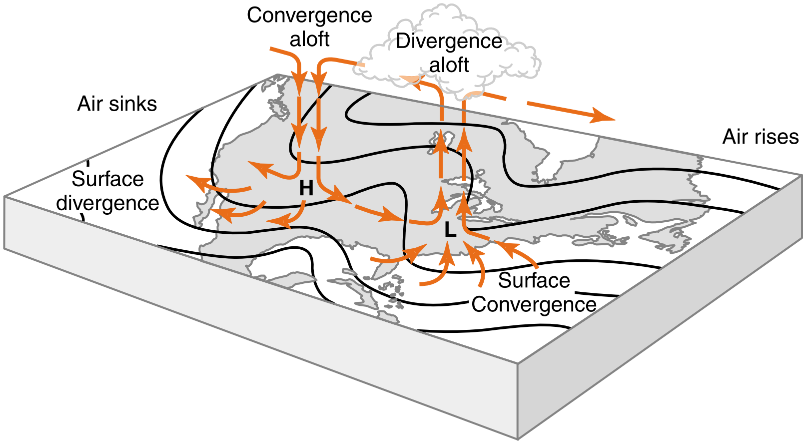


Figure 21-5 Regional high- and low-pressure systems often last for days as they move across the country and determine surface wind patterns.

room for more descending air. High-pressure regions can also remain strong for many days. Rising and falling air are characteristic of convection cells. Therefore, vertical air movements generate surface winds from regions of high pressure to places where the pressure is lower. Figure 21-5 is a diagram of North America that shows regional high- and low-pressure centers.

High-pressure systems are sometimes called zones of divergence. **Divergence** means moving apart. At Earth's surface, descending air spreads as it moves out of a high-pressure system as shown in Figure 21-5. Conversely, winds come together as they blow into regions of low pressure. Rising air at the center of the low sustains these winds. This is a pattern of **convergence**. It is like people converging on an arena where a concert will soon take place. Low-pressure centers are also called zones of convergence.

ACTIVITY 21-2 MOVEMENTS OF PRESSURE SYSTEMS

Use a daily weather map from a newspaper, televised weather report, or the Internet to locate high- and low-pressure centers on a map of the United States. Over the next three days, plot the movements of these pressure systems across the country. Is there a general direction in which they usually move?

The Coriolis Effect

The **Coriolis effect** produces the curved path that objects, including winds and ocean currents, appear to follow as they travel over Earth's surface. It was named after the French scientist who first described it. Consider the three people in Figure 21-6. To conduct an experiment, they are using a rotating platform similar to those often found in playgrounds. In part A, the boy on a rotating platform is about to throw a ball toward the two people opposite him. Part B shows the same people 1 or 2 seconds later. From the point of view of the boy on the ground, the ball travels straight toward him as the two people on the platform move. However, the people on the moving platform see the path of the ball curve to the right. If the platform in Figure 21-6 rotated in the opposite direction, the observers on the platform would see the ball curve left.

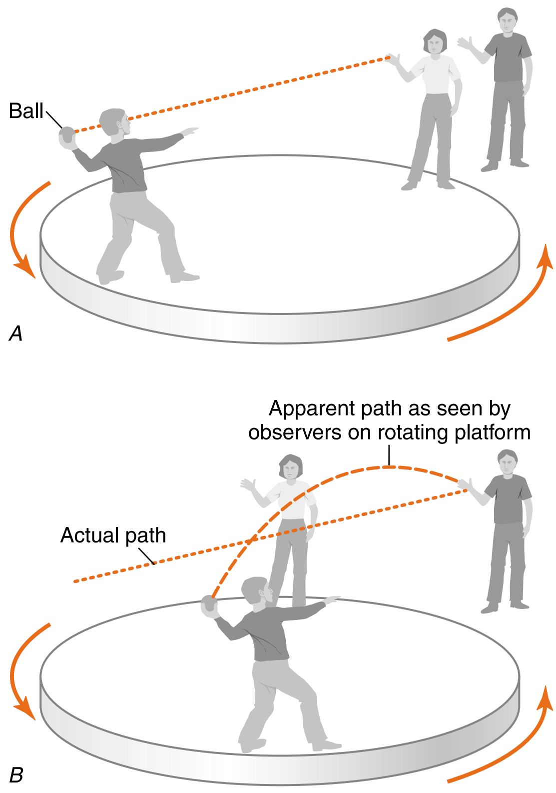


Figure 21-6 Whether the ball appears to curve or travel straight depends on whether you are on the rotating platform or standing still. This is why the Coriolis effect produces an apparent curvature.

The difference between a turn to the right and a turn to the left can be confusing. For example, if you stand facing another person, what you call the right side of the room will be to the other person's left. If each of you steps to the right, you will be going in opposite directions. Obviously, we need some kind of rule to distinguish which way is "to the right." This is not so different from the way winds are labeled. A wind is named according to the direction from which it comes, not to where it is going.

Right and left curves are determined according to the direction of movement as shown in Figure 21-7. One way to think of this is to imagine that you are walking in the direction of the arrow. A right curve would be to your right only if you are looking forward in that direction. Winds and ocean currents in the Northern Hemisphere appear to curve to the right as they move forward. In the Southern Hemisphere, winds and currents curve to the left.

If Earth did not rotate, patterns of convection on our planet would be relatively simple. Air would descend in high-pressure regions and blow directly toward low-pressure centers. However, the rotation of Earth on its axis causes wind patterns to be more complicated. The winds follow a straight path, but as they blow over long distances, the planet moves under them. The effect is not noticeable over small distances such as those covered by land and sea breezes.

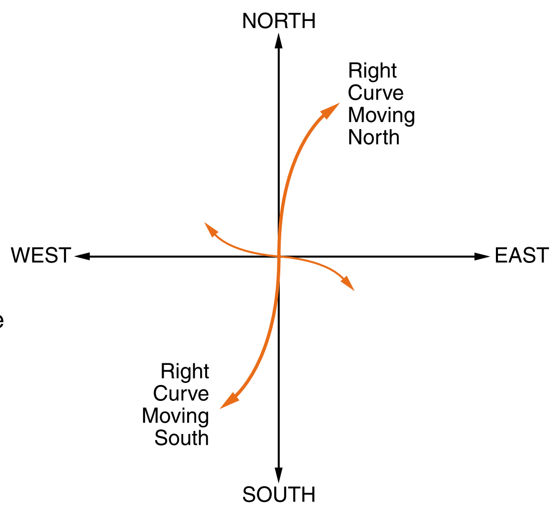


Figure 21-7 In addition to the four compass directions, this diagram shows four lines curving to the right. Left or right is defined according to movement in the direction of the arrow.

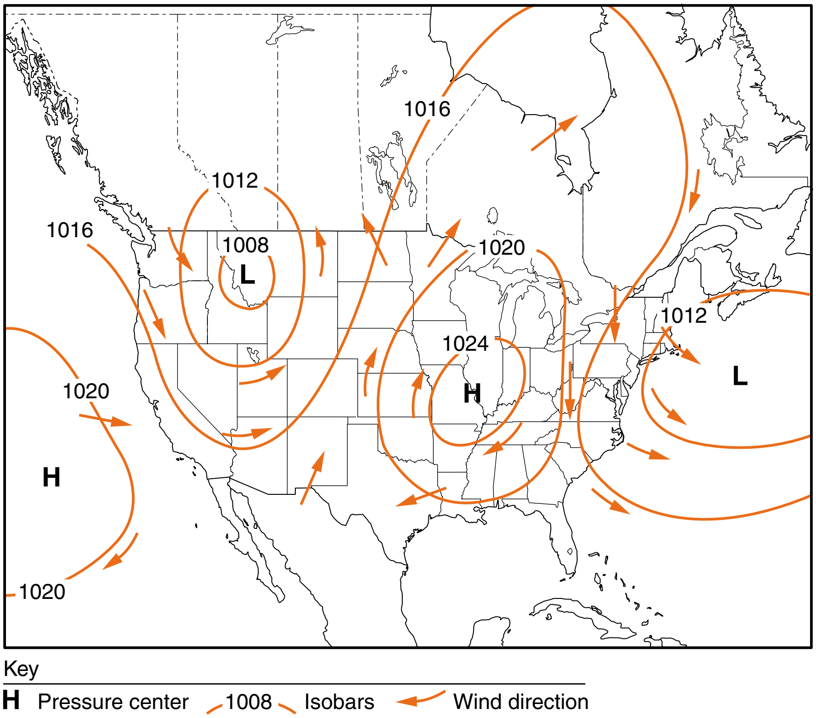


Figure 21-8 Due to the Coriolis effect, regional winds blowing from high-pressure centers to low-pressure regions curve to the right in the Northern Hemisphere. In the Southern Hemisphere, they curve to the left.

When you look at larger regional wind patterns, the apparent change in wind direction is very important. The apparent curvature of winds as they move along Earth's surface is the result of the Coriolis effect. Figure 21-8 is a simplified map of high- and low-pressure systems over North America. The isolines, called **isobars**, connect locations with the same atmospheric pressure. These lines highlight the high- and low-pressure centers. Arrows show wind directions. Although the winds do blow out of the high-pressure areas and into the low-pressure systems, the apparent curvature caused by the Coriolis effect swings them to the right of their path in the Northern Hemisphere. In the Southern Hemisphere, the Coriolis effect shifts the winds to the left of their path. In fact, over long distances, the Coriolis effect is so important that winds generally blow almost parallel to the isolines rather than following the pressure gradient from high pressure directly to lower pressure.

If you look at the ocean currents map in the *Earth Science Reference Tables*, you will notice that most or them circle clock-

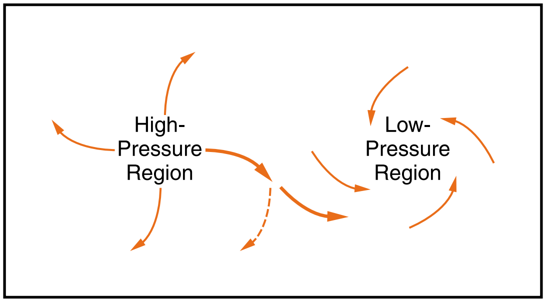


Figure 21-9 In the Northern Hemisphere, winds curve to the right as they exit a high-pressure system. To converge into a low-pressure area, they curve to the left. The dashed arrow shows that without this change the winds would not converge into the low.

wise (to the right) in the Northern Hemisphere and counterclockwise (to the left) south of the equator. The winds show a similar apparent curvature. In the Northern Hemisphere, winds that flow out of a high-pressure area turn clockwise while winds flowing into a low-pressure area turn counterclockwise. In the Southern Hemisphere the situation is reversed. Winds that flow out of a high-pressure area turn counterclockwise while the winds flowing into a low-pressure area turn clockwise. Notice that although the winds exiting a high-pressure center in Figure 21-8 curve right, they bend in the opposite direction as they approach low-pressure regions. What could cause them to curve in the "wrong direction" as they blow into a low? The easiest way to explain this change is to point out that if the winds continued to circle to the right, they would move away from the center of the low-pressure region. The dashed line in Figure 21-9 illustrates this. Therefore, to follow the pressure gradient, regional winds change their curvature as they converge into low-pressure systems.

Prevailing Winds

In New York State, winds blow from the west and southwest more often than they come from any other direction. Remember that winds are labeled according to the direction you face when you look into the wind. **Prevailing winds** refer to the most common wind direction and speed at a particular location and time of year. Figure 21-10 shows two diagrams of Earth. Part A shows how terrestrial winds might blow if

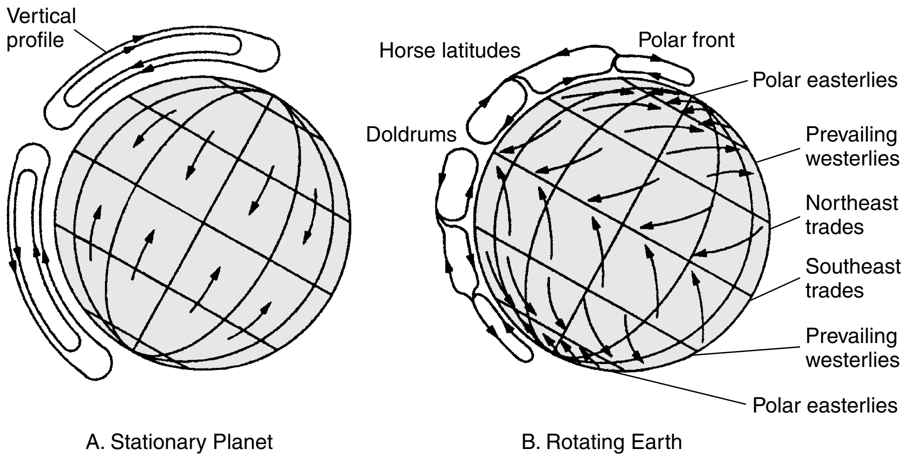


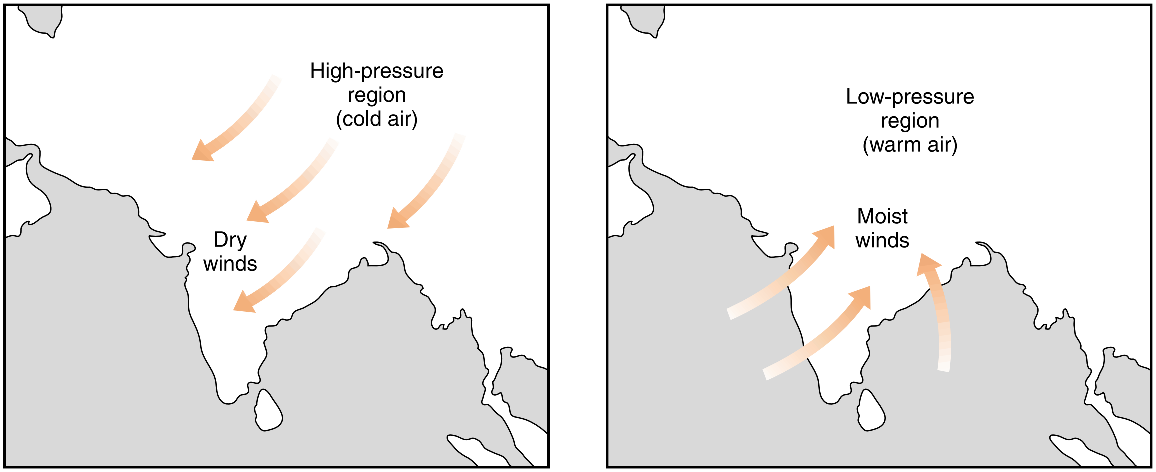
Figure 21-10 If Earth did not spin, wind patterns would be simpler. However, due to Earth's rotation and the Coriolis effect, winds appear to curve, creating prevailing winds from the west and the east and several convection cells in each hemisphere.

Earth were not spinning. Cold air would sink at the poles and travel along the surface toward the equator. Strong sunlight heating the air near the equator would cause the air to rise and move back toward the poles. Two large convection cells, as shown in the vertical profile, would dominate planetary winds.

Earth's rotation modifies this motion through the Coriolis effect as shown in part B. Winds curving to the right in the Northern Hemisphere and to the left in the Southern Hemisphere break the two convection cells shown in part A into six convection cells. Within each cell, winds curving to the right in the Northern Hemisphere and to the left in the Southern Hemisphere change the North and South winds into winds east and west winds. Regional weather systems (highs and lows) complicate the pattern even more. Winds can come from any direction depending on changes in the pressure gradient.

Monsoons

Large continents create seasonal changes in the direction of the prevailing winds. These seasonal wind directions are called **monsoons**. They are similar to land and sea breezes; but monsoon winds last for months and move over greater



Winter Monsoon

Summer Monsoon

Figure 21-11 Seasonal changes in temperature and atmospheric pressure over the continent of Asia result in seasonal winds called monsoons. Rainfall in India depends on these seasonal changes.

distances. The monsoons of India are a prime example. During the winter, when the sun is always low in the sky, the continent of Asia cools. Cooling of the air creates a long-lasting high-pressure zone over central Asia. Sinking air spreads southward over India, bringing in dry air from central Asia. Rain is very scarce in India during this part of the year. In fact, the dry air becomes warmer as it descends from the high plateaus; so the relative humidity actually decreases.

The monsoon climate is very different in summer. Central Asia becomes warmer as the sun moves higher in the sky. By midsummer, rising air over the continent draws in moist winds from the Indian Ocean. This brings much needed rain to the Indian subcontinent. The rains allow farmers to grow crops. Some years the summer monsoon winds are very weak and the rains come late, if at all. This causes food shortages for the millions of people who depend on the rain brought by the summer monsoon. Figure 21-11 is a simplified map of the seasonal changes in wind direction over India called monsoons.

New York State does not experience dramatic seasonal changes in wind direction and precipitation. However, the southwestern desert of the United States does experience monsoons. The dry conditions of spring and early summer are replaced by moist winds and occasional thunderstorms as summer winds bring moisture off the Pacific Ocean and into the deserts.

WHAT ARE JET STREAMS?

Jet streams were discovered during the Second World War when the pilots of high-altitude aircraft found themselves traveling much slower than their air speed indicated. Today, aircraft will sometimes change their flight paths to take advantage of fast tail winds, or to avoid fighting head winds. Wandering currents of air far above Earth's surface are known as **jet streams**. With wind speeds that can be greater than 160 km/h (100 mph), jet streams circle the globe, usually in the middle latitudes. Jet streams seldom follow surface winds and usually occur where cold polar air meets warmer air in the mid-latitudes. They circle the globe from west to east, usually in the upper part of the troposphere.

Meteorologists need to know the location and speed of these upper atmosphere winds because they influence the development and movements of storm systems. Figure 21-12

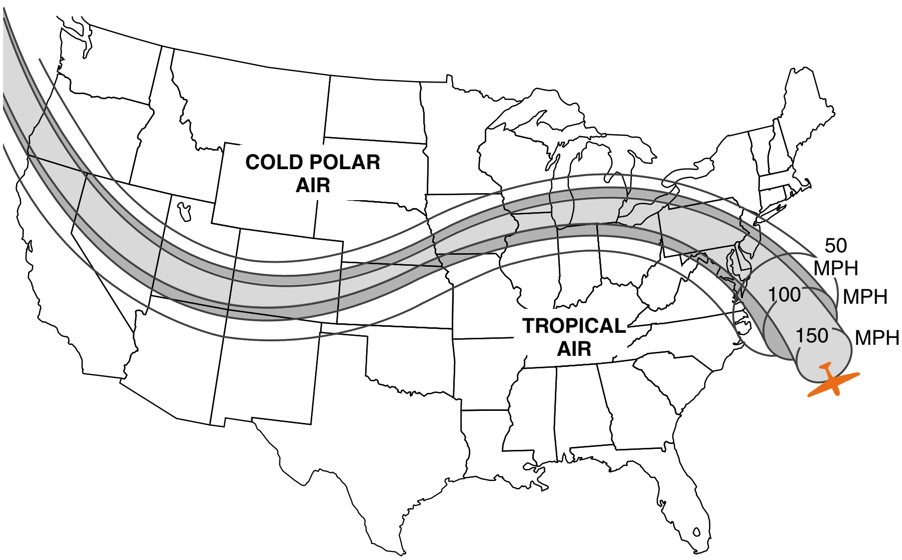


Figure 21-12 The jet stream is a narrow band of high-altitude wind that separates cold polar air from warmer air to the south. The jet stream gives rise to weather systems and steers their movements.

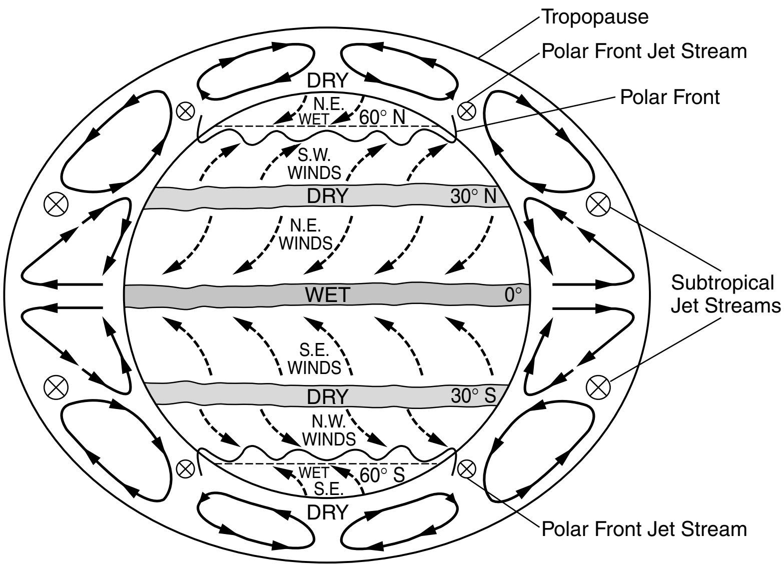


Figure 21-13 The combined effects of uneven heating by the sun and Earth's rotation (the Coriolis effect) set up patterns of atmospheric convection and prevailing surface winds. Zones of moist weather occur where rising air currents cause clouds and precipitation. Deserts are most common in the zones of sinking air.

shows a typical path of the jet stream crossing the United States from west to east.

The path of the jet stream is changeable as it meanders around the globe. In fact, two jet streams sometimes develop in the Northern Hemisphere. They tend to occur at the northern and southern limits of the zone of prevailing westerly winds. Figure 21-13, taken from the *Earth Science Reference Tables*, is a generalization of the pattern of winds on our planet. This diagram shows the large convection cells responsible for prevailing surface winds at various latitudes. Notice how the jet streams generally occur in the regions between the circular convection cells.

Notice in Figure 21-13 how rising and sinking air currents create wet and dry zones at particular latitudes. Where the air is often rising, such as along the equator, the cooling of warm, moist air creates clouds and precipitation. (Remember that air expands as it rises and air pressure is reduced. Expansion causes air to cool below the dew point.) Most of the world's deserts are located approximately 30° north and south of the equator in zones of high pressure. This is where sinking air currents become warmer as they fall through the atmosphere and the relative humidity at the surface tends to be low.

WHAT ARE ISOBARIC MAPS?

Meteorologists draw isoline maps of atmospheric pressure to help them identify weather patterns and predict weather. These maps are based on measurements of barometric pressure taken throughout a large geographic region, such as the 48 contiguous United States. Figure 21-14 is a simplified isobaric map.

Winds can be inferred from an isobaric map based on the following principles.

1. Winds blow out of high-pressure areas and into low-pressure areas.
2. Due to the Coriolis effect, in the Northern Hemisphere, winds circulate clockwise as they diverge from highs. They circulate counterclockwise as they converge into the lows.
3. Winds are the fastest where the pressure gradient is greatest. This is illustrated on the map in Figure 21-14. The fastest winds are in New England, and the far West is relatively calm.

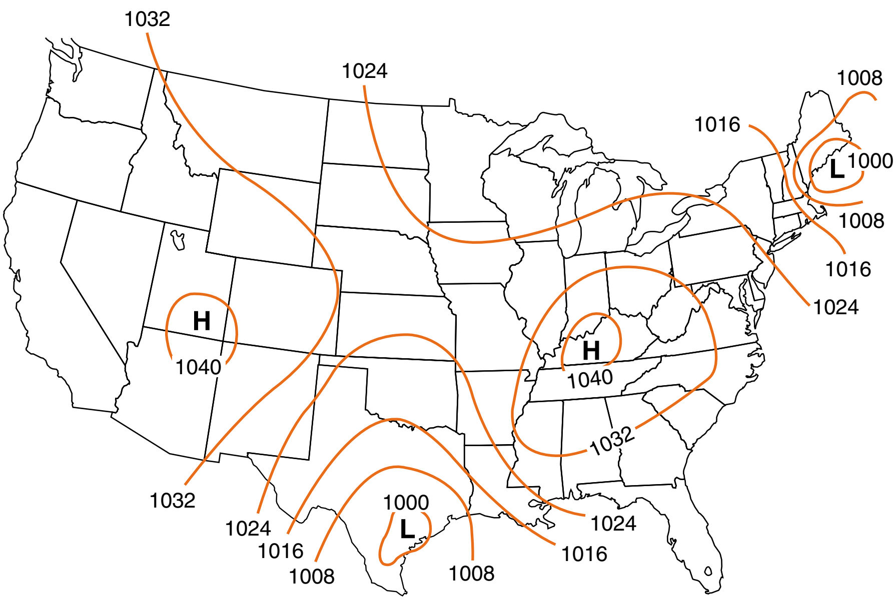


Figure 21-14 Isolines connect locations with the same atmospheric pressure and help to locate areas of high and low pressure. The numbers on the isolines represent barometric pressure in millibars.

ACTIVITY 21-3 SURFACE WIND PATTERNS

Using a copy of Figure 21-14, draw arrows to represent the surface winds at the time this map was drawn. The arrows should show wind directions throughout the map region. Also indicate relative wind speeds by the length of the arrows. (Please do not write in your book.)

TERMS TO KNOW

convection cell	**divergence**	**jet stream**	**prevailing winds**
convergence	**Doppler radar**	**land breeze**	**radar**
Coriolis effect	**isobar**	**monsoons**	**sea breeze**

CHAPTER REVIEW QUESTIONS

1. Which weather variable is a direct result of the force of gravity on Earth's atmosphere?

   (1) barometric pressure
   (2) cloud cover
   (3) relative humidity
   (4) atmospheric transparency

2. Winds always blow

   (1) from high-temperature locations to low-temperature locations.
   (2) from low-temperature locations to high-temperature locations.
   (3) from high pressure to low pressure.
   (4) from low pressure to high pressure.

3. As air on the surface of Earth warms, the density of the air

   (1) decreases.
   (2) increases.
   (3) remains the same.

4. During which process does heat transfer occur because of density differences in a fluid?

   (1) reflection
   (2) radiation
   (3) conduction
   (4) convection

5. Which atmospheric condition would cause smoke from a campfire on a beach to blow toward the ocean?

(1) warm air over the land and cool air over the ocean
(2) humid air over the land and dry air over the ocean
(3) low-density air over the land and high-density air over the ocean
(4) high pressure over the land and low pressure over the ocean

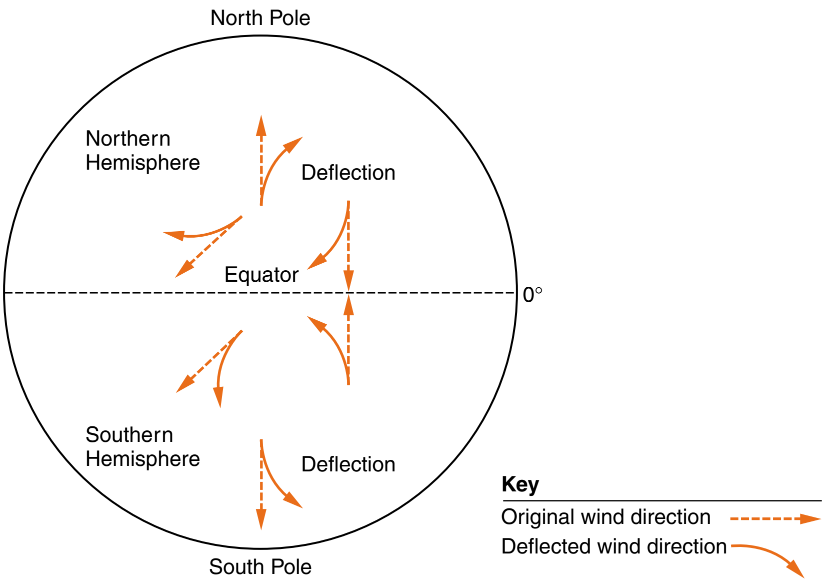
6. The air near the center of a low-pressure system usually will

(1) evaporate into a liquid.
(2) blow away from the center of the low.
(3) rise to form clouds.
(4) squeeze together to form a high-pressure system.

7. Which of the following has the greatest effect on regional wind patterns at Earth's surface?

(1) charged particles given off by the sun
(2) gravitational force from the moon
(3) Earth's yearly revolution around the sun
(4) rotation of Earth on its axis

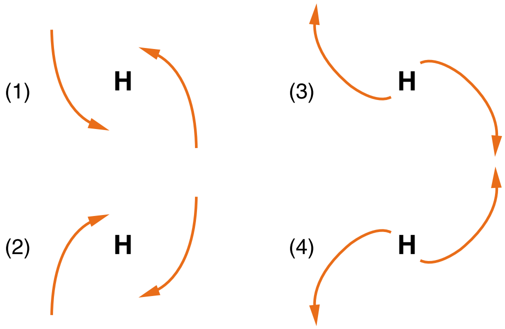
8. The diagram below shows some examples of how surface winds are deflected in the Northern and Southern hemispheres because of Earth's rotation.



Earth's rotation causes winds to be deflected to the

(1) right in both Northern and Southern hemispheres.
(2) right in the Northern Hemisphere and left in the Southern Hemisphere.
(3) left in the Northern Hemisphere and right in the Southern Hemisphere.
(4) left in both Northern and Southern hemispheres.

9. Which diagram below best shows the circulation of air around a Northern Hemisphere high-pressure center?



10. What is the most common wind direction 15° south of Earth's equator?

(1) northwest
(2) northeast
(3) southwest
(4) southeast

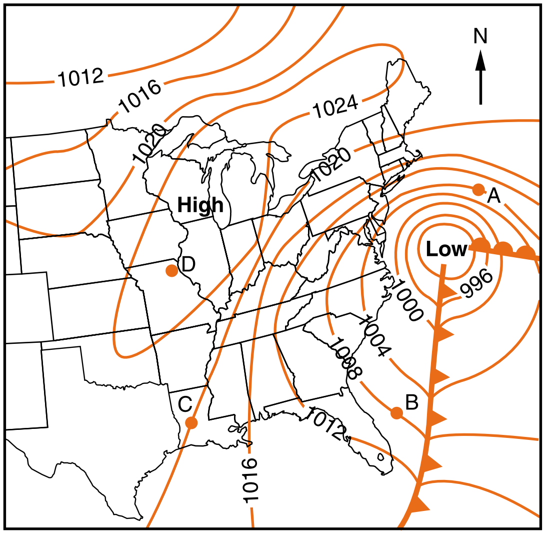
11. What is the general pattern of air movement on March 21 at Earth's equator?

(1) upward, due to low temperature and high pressure
(2) upward, due to high temperature and low pressure
(3) downward, due to low temperature and high pressure
(4) downward, due to high temperature and low pressure

12. Which kind of wind is best described as a strong west to east current of air high in the troposphere that guides weather systems across North America?

(1) prevailing winds
(2) the jet streams
(3) mid-latitude westerly winds
(4) polar east winds

Use the weather map below to answer the next two questions. Points A, B, C, and D are locations on Earth's surface.



13. The isolines on the map represent values of air

(1) density.
(2) humidity.
(3) pressure.
(4) temperature.

14. The strongest winds are closest to location

(1) A.
(2) B.
(3) C.
(4) D.

15. Which of the following changes is likely to cause an increase in wind velocity?

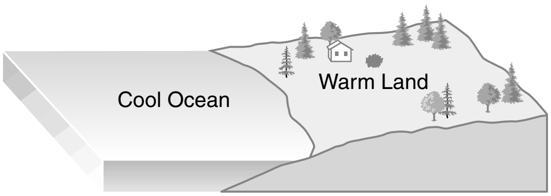
(1) an increase in cloud cover
(2) an increase in the pressure gradient
(3) a decrease in the rate of precipitation
(4) a decrease in the temperature gradient

Open-Ended Questions

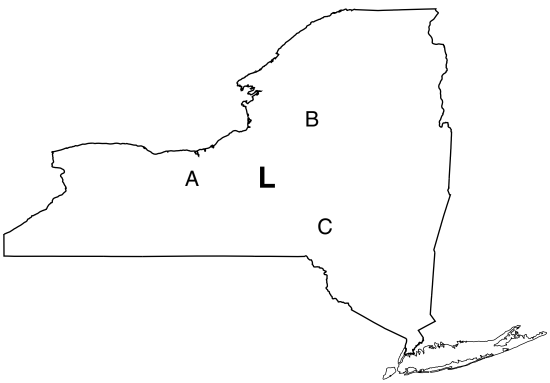
16. Why does the atmospheric pressure usually decrease when the air becomes more humid?

17. Name the instrument used by meteorologists to measure air pressure.

18. The diagram below represents summer afternoon conditions at an ocean shoreline location. Weather conditions are stable with no significant pressure gradient from regional high- or low-pressure systems. On a copy of this diagram draw arrows to show the most likely wind direction at the shoreline caused by the temperature conditions shown in the diagram. Show both horizontal and vertical motion of the air.



19. The diagram below shows the position of a strong low-pressure system located over central New York State. Make a copy of this diagram and draw three arrows at positions A, B, and C to show the direction of the movement of surface winds outside the center of the low.



20. What is meant by prevailing winds?