18.3 Cloud Types and Precipitation

Reading Focus

Key Concepts

- How are clouds classified?
- How are clouds and fogs similar and different?
- What must happen in order for precipitation to form?
- What controls the type of precipitation that reaches Earth's surface?

Vocabulary

- cirrus
- cumulus
- stratus
- Bergeron process
- supercooled water
- supersaturated air
- collision-coalescence process

Reading Strategy

Building Vocabulary Copy the table. As you read, add definitions.

Vocabulary Term	Definition
Cirrus	a. ?
Cumulus	b. ?
Stratus	c. ?
Coalescence	d. ?

Clouds are among the most striking and noticeable effects of the atmosphere and its weather. Clouds are a result of condensation best described as visible mixtures of tiny droplets of water or tiny crystals of ice. Clouds are of interest to meteorologists because clouds show what is going on in the atmosphere. If you try to recognize different types of clouds, you might find it hard to do. But, if you learn the basic classification scheme for clouds, recognizing cloud types will be easy.

Types of Clouds

Clouds are classified on the basis of their form and height. The three basic forms are: cirrus, cumulus, and stratus. All other clouds reflect one of these three basic forms or are combinations or modifications of them.

Cirrus (*cirrus* = a curl of hair) clouds are high, white, and thin. They can occur as patches or as delicate veil-like sheets or extended wispy fibers that often have a feathery appearance. An example of cirrus clouds is shown in Figure 11.

Cumulus (*cumulus* = a pile) clouds consist of rounded individual cloud masses. Refer to Figure 10 on page 515. Normally, they have a flat base and the appearance of rising domes or towers. These clouds are frequently described as having a cauliflower structure.

Figure 11 Cirrus Clouds

Section 18.3

1 FOCUS

Section Objectives

18.10 **Describe** how clouds are classified.
18.11 **Compare and contrast** clouds and fogs.
18.12 **Explain** what must happen for precipitation to form.
18.13 **Identify** what controls the type of precipitation that reaches Earth's surface.

Reading Focus

Build Vocabulary

L2

Concept Map Have students create concept maps of the types of clouds. Have them start with Clouds at the top and put the three families of clouds classified by height on the next level. Below that, they should put the types of clouds within each family, and on the last row, some details about each one.

Reading Strategy

L2

a. clouds that are high, white, and thin
b. clouds that consist of rounded individual cloud masses
c. clouds that occur as sheets or layers that cover much or all of the sky
d. the process in which larger drops fall through clouds, collide, and join together with smaller, slower droplets

2 INSTRUCT

Types of Clouds

Address Misconceptions

L2

Students may have many misconceptions about what clouds are made of and how they form. They may think that clouds are made of smoke or water vapor. They may think that clouds form when bodies of water boil. Have students make flowcharts with diagrams to show that clouds are made of tiny water droplets, and form when air containing water vapor is cooled.
Logical, Visual

Build Reading Literacy L1

Refer to **p. 278D** in **Chapter 10,** which provides the guidelines for identifying main ideas and details.

Identify Main Idea/Details Have students read Types of Clouds on pp. 517–520. Ask them to identify the main idea of each subheading. Point out that the main idea is usually in the first or second sentence of a subheading. Encourage students to use this exercise in the notes they use to study.
Verbal

Use Visuals L1

Figure 12 Use this diagram to explain the different types of clouds and their names. Ask: **To what does "stratus" refer?** *(clouds that cover much of the sky)* **What can you tell about altocumulus clouds from their name?** *(They are mid-level clouds made up of individual cloud masses.)* **What can you tell about cirrocumulus clouds from their name?** *(They are high-level clouds made up of individual cloud masses.)* **Are you likely to see all of these kinds of clouds in the sky at the same time? Explain your answer.** *(No, because many of the clouds form under different atmospheric conditions.)*
Visual, Verbal

Stratus (*stratum* = a layer) clouds are best described as sheets or layers that cover much or all of the sky. While there may be minor breaks, there are no distinct individual cloud units.

There are three levels of cloud heights: high, middle, and low, as shown in Figure 12. High clouds normally have bases above 6000 meters. Middle clouds generally occupy heights from 2000 to 6000 meters. Low clouds form below 2000 meters. The altitudes listed for each height category are not hard and fast. There is some seasonal and latitudinal variation. For example, at high latitudes or during cold winter months in the mid-latitudes, high clouds often are found at lower altitudes.

High Clouds

Three cloud types make up the family of high clouds: cirrus, cirrostratus, and cirrocumulus. Look at Figure 12. Cirrocumulus clouds consist of fluffy masses, while cirrostratus clouds are flat layers. All high clouds are thin and white and are often made up of ice crystals. This is because of the low temperatures and small quantities of water vapor present at high altitudes. These clouds are not considered precipitation makers. However, when cirrus clouds are followed by cirrocumulus or cirrostratus clouds and increased sky coverage, they may warn of approaching stormy weather.

Middle Clouds

Clouds that appear in the middle range, from about 2000 to 6000 meters, have the prefix *alto-* as part of their name. Altocumulus clouds are composed of rounded masses that differ from

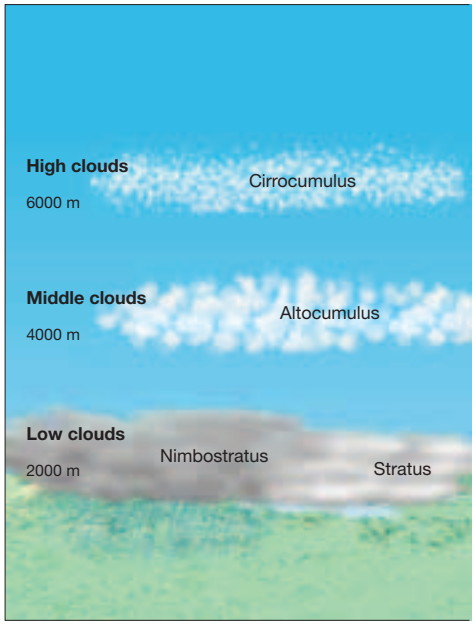


Figure 12 Cloud Classification Clouds are classified according to form and height.
Interpreting Diagrams ***Which cloud types are the chief precipitation makers?***

Customize for Inclusion Students

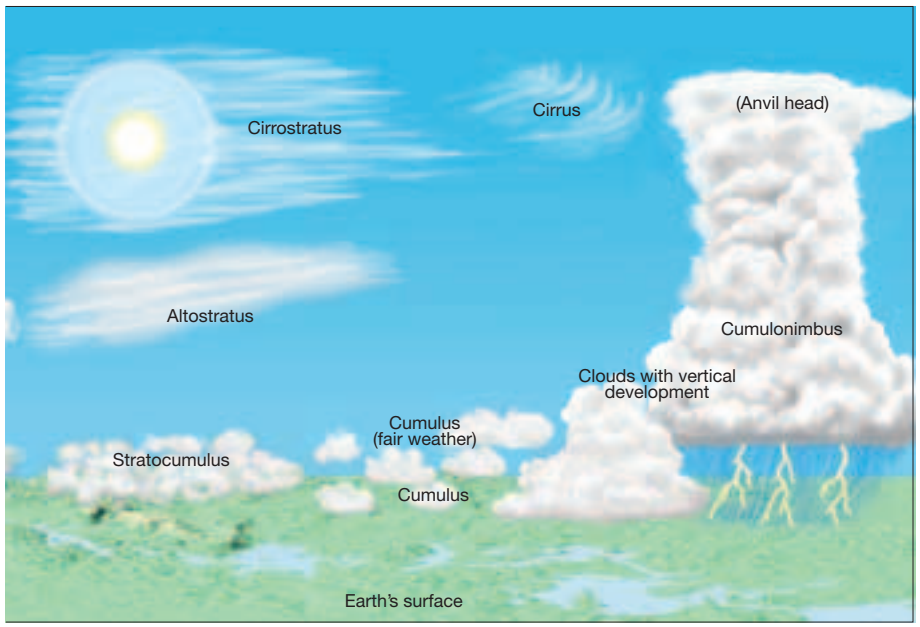
Behaviorally Disordered Have students work in groups to create a set of flashcards. Each card should contain information about a different type of cloud. One side of the card should have the name of the cloud (for example, altostratus) and three categories of color-keyed questions: Form of cloud, Height of cloud, Typical weather. Color key the answers on the other side of the card. *(flat layers, middle height, infrequent light snow or drizzle)* Students can use the cards to support one another in small study groups.

cirrocumulus clouds in that altocumulus clouds are larger and denser, as shown in Figure 12. Altostratus clouds create a uniform white to grayish sheet covering the sky with the sun or moon visible as a bright spot. Infrequent light snow or drizzle may accompany these clouds.

Low Clouds There are three members in the family of low clouds: stratus, stratocumulus, and nimbostratus. As illustrated in Figure 12, stratus clouds are a uniform, fog-like layer of clouds that frequently covers much of the sky. Occasionally, these clouds may produce light precipitation. When stratus clouds develop a scalloped bottom that appears as long parallel rolls or broken rounded patches, they are called stratocumulus clouds.

Nimbostratus clouds derive their name from the Latin word *nimbus,* which means "rainy cloud," and *stratus,* which means "to cover with a layer." As the name suggests, nimbostratus clouds are one of the main precipitation makers. Nimbostratus clouds form during stable conditions. You might not expect clouds to develop in stable air. But cloud growth of this type is common when air is forced upward, as occurs along a mountain range, a front, or where converging winds cause air to rise. Such a forced upward movement of stable air can result in a cloud layer that is largely horizontal compared to its depth.

Reading Checkpoint *What does the Latin word* **stratus** *mean?*



Build Science Skills

L2

Classifying Show students photographs of a variety of clouds. Have students classify the clouds according to Figure 12.
Visual

Build Science Skills

L2

Activity

Observing Ask students if they have ever wondered how some people can look out the window and predict the weather. Explain that learning to observe and identify clouds will help develop the ability to predict weather. Have students keep a log of cloud and weather observations for a least one month. For each page of their logs, have students record the date and time of observation; a description and drawing of the cloud cover, including the general altitude (high, middle, low), percent of sky coverage, and the thickness or relative height of clouds; a general description of any weather phenomena, such as wind or precipitation; and the temperature (either specific readings or general terms). After a period of time, students should analyze their observations and look for patterns between clouds and weather.
Visual, Logical

Answer to . . .

Figure 12 *The chief precipitation makers are nimbostratus and cumulonimbus clouds.*

Reading Checkpoint Stratus *means "to cover with a layer."*

Fog

Build Science Skills

L2

Comparing and Contrasting
Make sure that students understand the similarities and differences between fog and other types of clouds. Ask: **What is a fog?** *(It is a cloud with its base at or very near the ground.)* **How are fog and other clouds similar?** *(They are the same physically.)* **How are fog and other clouds different?** *(Clouds result from air rising and cooling adiabatically. Fogs form as a result of radiation cooling, movement of air over a cold surface, or evaporation of water vapor.)*
Logical

Go Online NSTA SCILINKS

For: Links on clouds and fog
Visit: www.SciLinks.org
Web Code: cjn-6183

Figure 13 This steam fog rose from upper St. Regis Lake, Adirondack Mountains, New York.

Clouds of Vertical Development

Some clouds do not fit into any one of the three height categories mentioned. Such clouds have their bases in the low height range but often extend upward into the middle or high altitudes. They all are related to one another and are associated with unstable air. Although cumulus clouds are often connected with fair weather, they may grow dramatically under the proper circumstances. Once upward movement is triggered, acceleration is powerful, and clouds with great vertical range form. The end result often is a cumulonimbus cloud that may produce rain showers or a thunderstorm.

Fog

Physically, there is no difference between a fog and a cloud. Their appearance and structure are the same. The difference is the method and place of formation. Clouds result when air rises and cools adiabatically. Most fogs are the result of radiation cooling or the movement of air over a cold surface. Fogs also can form when enough water vapor is added to the air to bring about saturation. **Fog is defined as a cloud with its base at or very near the ground.** When fog is dense, visibility may be only a few dozen meters or less, making travel not only difficult but often dangerous.

Fogs Caused by Cooling

A blanket of fog is produced in some West Coast locations when warm, moist air from the Pacific Ocean moves over the cold California Current and then is carried onshore by prevailing winds. Fogs also can form on cool, clear, calm nights when Earth's surface cools rapidly by radiation. As the night progresses, a thin layer of air in contact with the ground is cooled below its dew point. As the air cools, it becomes denser and drains into low areas such as river valleys, where thick fog accumulations may occur.

Fogs Caused by Evaporation

When cool air moves over warm water, enough moisture may evaporate from the water surface to produce saturation. As the rising water vapor meets the cold air, it immediately condenses and rises with the air that is being warmed from below. This type of fog over water has a steaming appearance, as shown in Figure 13. It is fairly common over lakes and rivers in the fall and early winter, when the water may still be relatively warm and the air is rather crisp.

How Precipitation Forms

Cloud droplets are very tiny, averaging less than 20 micrometers in diameter. Because of their small size, the rate at which cloud droplets fall is incredibly slow. Most cloud droplets would evaporate before falling a few meters into unsaturated air below. **For precipitation to form, cloud droplets must grow in volume by roughly one million times.**

Go Online NSTA SCILINKS

Download a worksheet on clouds and fog for students to complete, and find additional teacher support from NSTA SciLinks.

520 Chapter 18

Cold Cloud Precipitation

The **Bergeron process,** shown in Figure 14, relies on two physical processes: supercooling and supersaturation. Cloud droplets do not freeze at 0°C as expected. In fact, pure water suspended in air does not freeze until it reaches a temperature of nearly −40°C. Water in the liquid state below 0°C is said to be **supercooled.** Supercooled water will readily freeze if it touches a solid object. Freezing nuclei are materials that have a crystal form that closely matches that of ice. Freezing nuclei can cause supercooled water to freeze.

When air is saturated (100% relative humidity) with respect to water, it is **supersaturated** with respect to ice (greater than 100% humidity). Ice crystals cannot coexist with water droplets in the air because the air "appears" supersaturated to the ice crystals. Any excess water vapor becomes ice that lowers the relative humidity near the surrounding droplets. Water droplets then evaporate to provide a continual source of water vapor for the growth of ice crystals.

Because the level of supersaturation with respect to ice can be quite high, the growth of ice crystals is rapid enough to produce crystals that are large enough to fall. As they fall the ice crystals contact cloud drops causing them to freeze. A chain reaction can occur and large crystals, called snowflakes, form. When the surface temperature is above 4°C, snowflakes usually melt before they reach the ground. Even on a hot summer day, a heavy downpour may have started as a snowstorm high in the clouds.

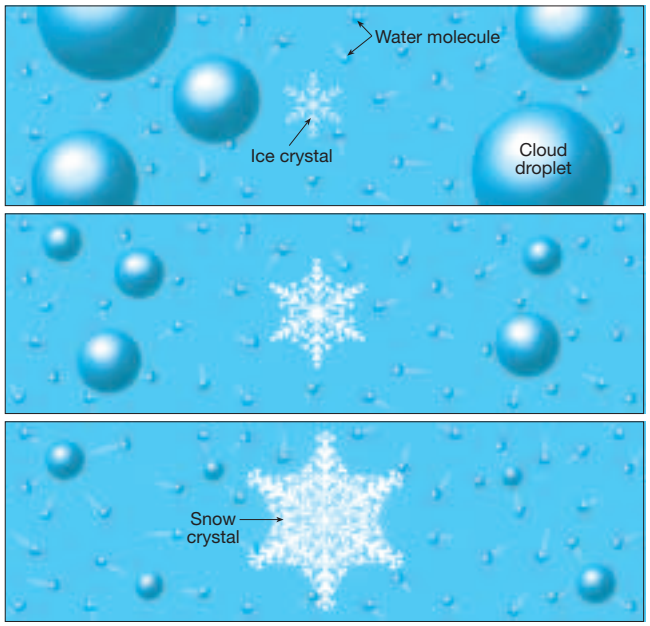


Figure 14 The Bergeron Process Ice crystals grow at the expense of cloud droplets until they are large enough to fall. The size of these particles has been greatly exaggerated.

Warm Cloud Precipitation

Much rainfall can be associated with clouds located well below the freezing level, especially in the tropics. In warm clouds, the mechanism that forms raindrops is the **collision-coalescence process.** Some water-absorbing particles, such as salt, can remove water vapor from the air at relative humidities less than 100 percent, forming drops that are quite large. As these large droplets move through the cloud, they collide and coalesce (join together) with smaller, slower droplets.

Go Online NSTA SciLinks

For: Links on precipitation
Visit: www.SciLinks.org
Web Code: cjn-6184

How Precipitation Forms

Use Visuals

L1

Figure 14 Use this diagram to explain one way ice crystals form. Ask: **How do ice crystals grow?** *(They use water vapor from the atmosphere.)* **How is the water vapor replenished?** *(It evaporates from water droplets.)* **What happens to the water droplets?** *(They get smaller and smaller.)*
Visual, Logical

Address Misconceptions

L2

Many students think that raindrops have a teardrop shape because that is how they are usually shown in artists' drawings. Explain that small water droplets, which are less than 1 millimeter in diameter, are shaped like spheres, as shown in Figure 14. Larger droplets form a shape more like that of a hamburger bun as they fall through the air. Very large droplets, which are more than 5 millimeters in diameter, will break up into smaller droplets.
Logical, Visual

Facts and Figures

The highest average annual rainfall on Earth was recorded at a station on Mount Waialeule, Hawaii. The station is on a windward mountain slope and gets an average of 1234 cm of rain a year. The record for most rainfall in a 12-month period occurred at Cherrapunji, India, where 2647 cm fell. Over one third of this rainfall—930 cm—fell in the month of July alone. This is 10 times more rain than Chicago receives in an average year.

Go Online NSTA SciLinks

Download a worksheet on precipitation for students to complete, and find additional teacher support from NSTA SciLinks.

Forms of Precipitation

Teacher Demo

Making Hail L2

Purpose Students will observe the process by which hailstones form.

Materials salt, water, 600-mL beaker, stirring rod, large test tube, ice chip

Procedure Put 15 g of salt and 50 mL of water into a 600-mL beaker. Stir the water until most of the salt dissolves. Clean a large test tube thoroughly and put 15 mL of cold water in it. Place the test tube in the beaker. Add crushed ice to the beaker until it is almost full. Tell students to watch the next step closely. Take the test tube out of the beaker and drop a small chip of ice into it. Ask students what they observed. *(A layer of ice formed on the ice chip.)* Tell students that hailstones form by a similar process.

Expected Outcome A layer of ice will quickly form around the ice chip.

Visual

3 ASSESS

Evaluate Understanding L2

Ask students to draw flowcharts showing the major steps in the Bergeron process of precipitation formation. Their charts should show at least three steps and be consistent with the text and Figure 14.

Reteach L1

Use Figure 12 to review different types of clouds. Ask students to explain the name of a cloud and describe the type of weather associated with it.

Writing in Science

Both processes are mechanisms that produce precipitation. The Bergeron process occurs in cold clouds and can result in any form of precipitation. The collision-coalescence process occurs in warm clouds and generally produces rain. Paragraphs should include a clear topic statement and several minor sentences that provide detail.

Forms of Precipitation

The type of precipitation that reaches Earth's surface depends on the temperature profile in the lowest few kilometers of the atmosphere. Temperature profile is the way the air temperature changes with altitude. Even on a hot summer day, a heavy downpour may have begun as a snowstorm high in the clouds overhead.

Rain and Snow In meteorology, the term *rain* means drops of water that fall from a cloud and have a diameter of at least 0.5 mm. Smaller drops are called *drizzle*. When the surface temperature is above 4°C, snowflakes usually melt and continue their descent as rain before they reach the ground. At very low temperatures (when the moisture content of air is small) light, fluffy snow made up of individual six-sided ice crystals forms. At temperatures warmer than −5°C, ice crystals join into larger clumps.

Figure 15 This largest recorded hailstone fell over Kansas in 1970 and weighed 766 grams.

Sleet, Glaze, and Hail Sleet is the fall of small particles of clear-to-translucent ice. For sleet to form, a layer of air with temperatures above freezing must overlie a subfreezing layer near the ground. Glaze, also known as freezing rain, results when raindrops become supercooled (below 0°C) as they fall through subfreezing air near the ground and turn to ice when they impact objects.

Hail is produced in cumulonimbus clouds. Hailstones begin as small ice pellets that grow by collecting supercooled water droplets as they fall through a cloud. If the ice pellets encounter a strong updraft, they may be carried upward and begin the downward journey once more. Each trip through the supercooled portion of the cloud may be represented by another layer of ice, as shown in Figure 15.

Section 18.3 Assessment

Reviewing Concepts

1. How are clouds classified?
2. Compare and contrast clouds and fogs.
3. What must happen in order for precipitation to form?
4. Describe how the temperature profile of air near Earth's surface controls the type of precipitation that falls to the ground.

Critical Thinking

5. **Predicting** What type of precipitation would fall to Earth's surface if a thick layer of air near the ground was −8°C?
6. **Classifying** Identify the following cloud types as producers of heavy, light, or generally no precipitation.
   a. cirrocumulus b. cumulonimbus
   c. stratus d. nimbostratus

Writing in Science

Compare-Contrast Paragraph Write a paragraph comparing the Bergeron and collision-coalescence processes. Relate each to the type(s) of precipitation that can result.

Section 18.3 Assessment

1. Clouds are classified according to form and height.
2. Clouds and fogs are physically the same. Fogs are clouds with their bases at or very near the ground.
3. Cloud droplets must increase in volume by about one million times.
4. Ice crystals formed at higher layers in the atmosphere become liquid and fall as rain if temperatures are warm enough near the ground. The thickness of layers at certain temperatures must also be thick enough to impart a change in the type of precipitation.
5. Light, fluffy snow would fall.
6. a. generally no precipitation **b.** heavy precipitation **c.** light or no precipitation **d.** light-to-heavy precipitation

people and the ENVIRONMENT

Atmospheric Stability and Air Pollution

Air quality is closely linked to the atmosphere's ability to scatter pollutants. Perhaps you've heard "Dilution is the solution to pollution." To a large degree, this is true. If the air into which pollution is released is not dispersed, the air will become more toxic. Two of the most important atmospheric conditions affecting the distribution of pollutants are wind strength and air stability.

When winds are weak or calm, the concentration of pollutants is higher than when winds are strong. High wind speeds mix polluted air into a larger volume of surrounding air, causing the pollution to be more diluted. When winds are light, there is less turbulence and mixing, so the concentration of pollutants is higher.

Atmospheric stability affects vertical movements of air. In general, the larger the extent of vertical mixing, the better the air quality is. During a temperature inversion, the atmosphere is very stable and it does not move much vertically. Warm air overlying cooler air acts as a lid and prevents upward movement, which leaves pollutants trapped near the ground, as shown in Figure 16.

Some inversions form near the ground, while others form higher above the ground. A surface inversion develops close to the ground on clear and relatively calm nights because the ground is a better radiator of heat than the air above it. Radiation from the ground to the clear night sky causes more rapid cooling at the surface than higher in the atmosphere. The result is that the air close to the ground is cooled more than the air above, yielding a temperature profile similar to the one shown in Figure 17. After sunrise, the ground is heated and the inversion disappears.

Although surface inversions usually are shallow, they may be thick in regions where the land surface is uneven. Because cold air is denser than warm air, the chilled air near the surface gradually drains from slopes into adjacent lowlands and valleys. As might be expected, these thicker surface inversions will not spread out as quickly after sunrise.

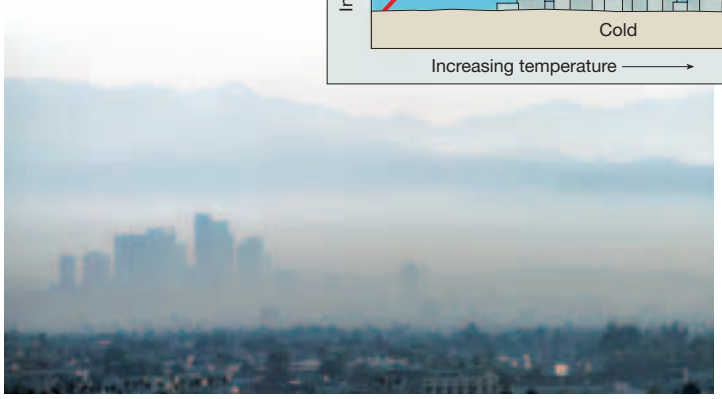


Figure 16 Air Pollution in Downtown Los Angeles
Temperatures inversions act as lids to trap pollutants below.

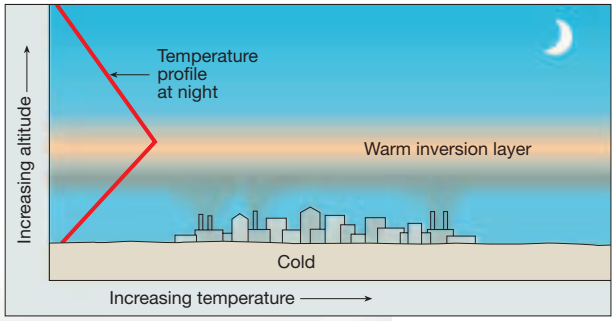


Figure 17 General Temperature Profile for a Surface Inversion

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Atmospheric Stability and Air Pollution

L2

Background

- The strength of the wind and the stability of the air are critical because they determine how rapidly pollutants are diluted by mixing with the surrounding air after leaving the source.
- The distance between Earth's surface and the height to which vertical air movements extend is termed the *mixing depth*. Generally, the greater the mixing depth, the better the air quality. When the mixing depth is several kilometers, pollutants are mixed through a large volume of cleaner air and dilute rapidly. When the mixing depth is shallow, pollutants are confined to a much smaller volume of air and concentrations can reach unhealthy levels.
- Because heating of Earth's surface by the sun enhances convectional movements, mixing depths are usually greater during the afternoon hours. For the same reason, mixing depths during the summer months are typically greater than during the winter months.
- Many extensive and long-lived air-pollution episodes are linked to temperature inversions that develop in association with the sinking air that characterizes slow-moving centers of high pressure. As the air sinks to lower altitudes, it is compressed and so its temperature rises. Because turbulence is almost always present near the ground, this lowermost portion of the atmosphere is generally prevented from participating in the general subsidence. Thus, an inversion develops aloft between the lower turbulent zone and the subsiding warmed layers above.

Teaching Tip

Ask students to research various methods that meteorologists use to define atmospheric stability. Have them explain each method and cite the pros and cons of each use.