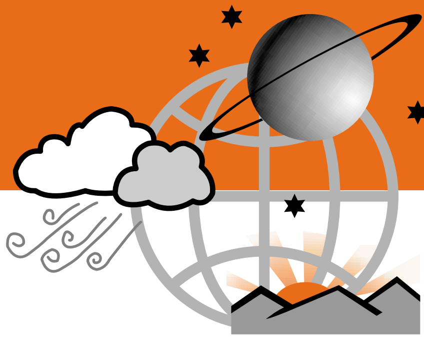


Chapter 24

Patterns of Climate

ARE CLIMATES CHANGING?

A century ago, 150 glaciers covered the mountains of Glacier National Park in Montana. Today, only 35 glaciers remain. Meanwhile, the remaining glaciers are melting back so rapidly that scientists estimate all of them could be gone in 30 years. From the Himalayas of Asia to the Andes of South America, the shrinkage in glacial ice is a worldwide event. Although a few glaciers are advancing, the great majority of them are clearly melting back.

Measurements of temperatures over the Earth have not been conclusive in showing a warming trend. Natural cycles of temperature change, our limited time frame of accurate temperature readings and the subtle nature of global climate change have made it difficult to measure global warming. Nevertheless, some scientists see the worldwide retreat of glaciers as a clear sign that Earth's climate is getting warmer. Figure 24-1 offers two views of Africa's highest mountain, Kilimanjaro, one taken in 1993 and the other in 2000. Notice the dramatic decrease in the glaciers and snow that occurred in this seven-year period.

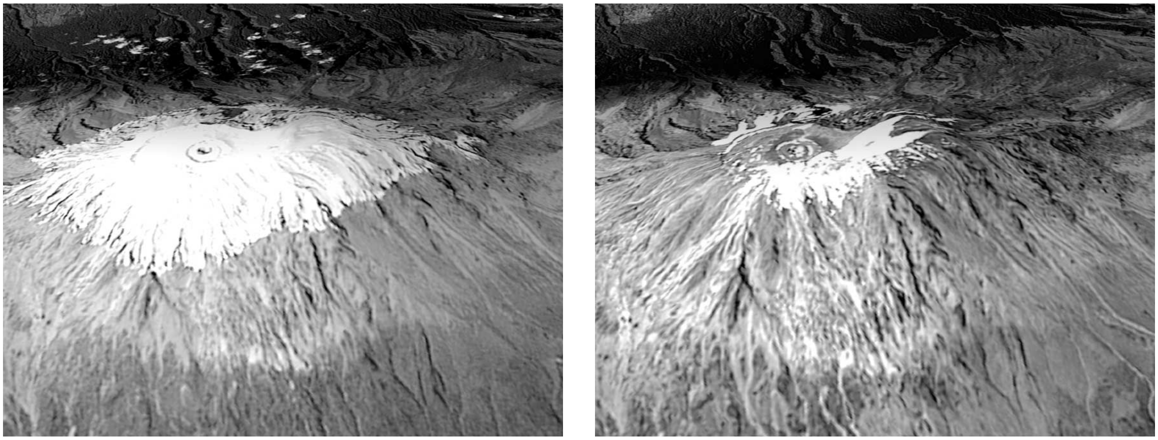


Figure 24-1 Photographs of Mt. Kilimanjaro taken in 1993 (left) and in 2000 (right). The snow and ice cover of Africa's tallest mountain decreased dramatically in the seven years between these images. Many scientists see this, and the worldwide recession of glaciers, as an indication of global warming.

In addition to indicating climatic change, glaciers also hold a record of past climates. The ice in glaciers can be thousands of years old. From the thickness of annual layers and the crystal structure of the ice, scientists can infer conditions of precipitation and temperature that occurred in the distant past. Glacial ice also preserves samples of the atmosphere trapped in the snow before it was buried within glaciers. Like layers of rock, glaciers preserve a record of prehistoric Earth that scientists can use to unravel the past.

WHAT IS CLIMATE?

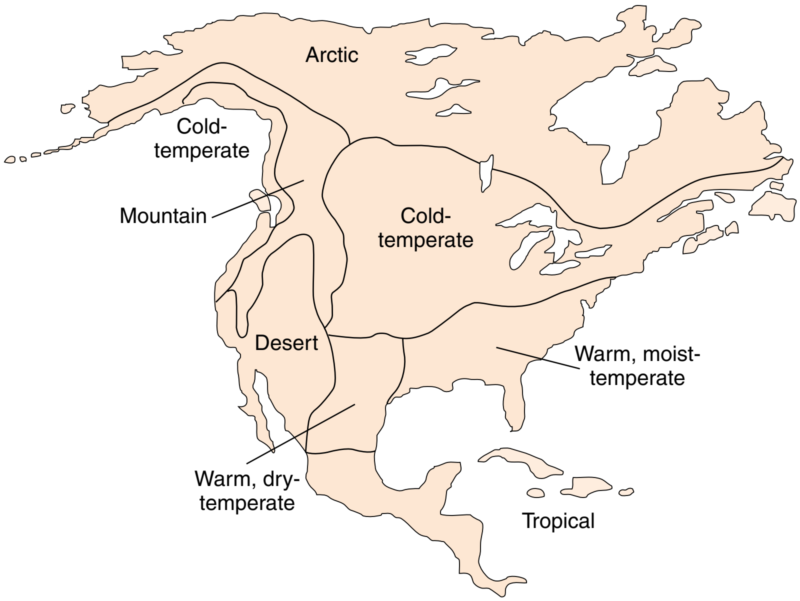
We usually think of the weather at a particular place and time, or perhaps over a period of hours or days. **Climate** is the average conditions of weather based upon measurements made over many years. Temperature and precipitation are the primary elements of climate, although humidity, winds, and the frequency of storms are also important aspects of climate. The normal seasonal changes in these factors are a part

Figure 24-2 Vegetation is an indicator of climate. These desert plants indicate that the local climate is usually dry with hot summers.

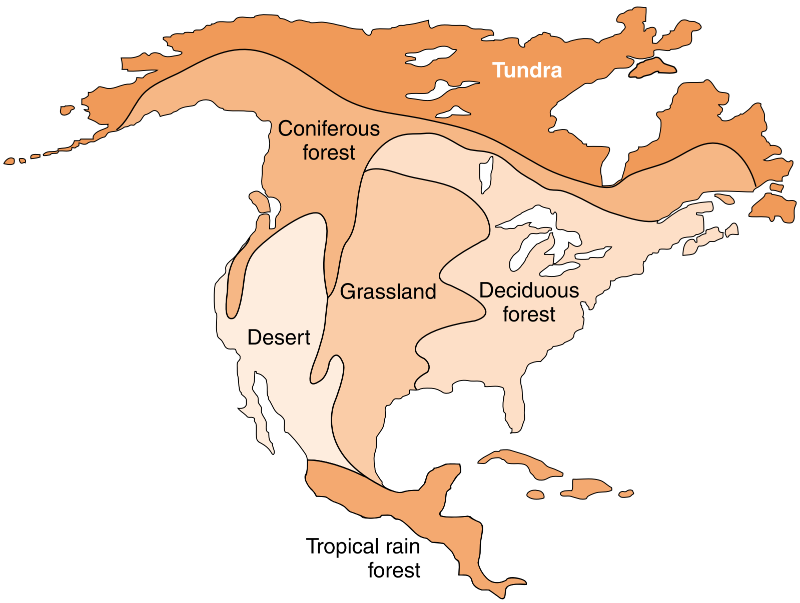
of climate as well. Scientists' understanding of the climate of an area is based primarily on historical records. The more observations that are available and the longer the period during which they have been kept, the more accurately scientists can describe the climate.

Climates can be classified according to temperature, such as tropical climates, which are usually warm; **temperate climates**, which include large seasonal changes; and polar climates, which are usually cold. Humidity and precipitation are often grouped when describing a humid climate or **arid** (dry) **climate**.

Vegetation is sensitive to climatic conditions. The plants found in an area are an indication of the climate, as you can see in Figure 24-2. If you travel through places where the natural vegetation changes you are probably observing the effects of changes in climate. Rain forests, deserts, grasslands, and tundra are terms that describe both vegetation and climate. Figure 24-3 includes two maps of North America. The first map shows zones of similar climate. The second map shows zones of similar vegetation. Notice how closely the zones of climate and vegetation match.



(a) Climate Zones



(b) Vegetation Zones

Figure 24-3 The similarity between the boundaries of the North American zones of climate and vegetation illustrates how the climate of a region determines its natural plant community.

HOW DOES LATITUDE AFFECT CLIMATE?

Variation in the intensity of insolation (sunlight) is the major cause of temperature differences over Earth's surface. In the tropics, where the noon sun is always high in the sky, solar energy is strongest. At the poles, where the sun is never high in the sky, solar energy is weakest.

Temperature

TROPICS The tropics are sometimes called the latitudes of seasonless climate. Although the noon sun is a little higher in the sky in some parts of the year than in others, the change is small. The seasonal change in the length of daylight is also very small—in fact, hardly noticeable at all. Therefore the strength of solar energy changes very little throughout the year. Except for mountain locations, the weather is always warm.

The tropics extend from the Tropic of Cancer 23.5° north of the equator to the Tropic of Capricorn 23.5° south of the equator. Here sunlight passes through the minimum thickness of Earth's atmosphere; so relatively little heat energy is lost within the atmosphere.

MID-LATITUDE Locations such as New York State have seasonal climates due to the annual cycle of changes in insolation. These are called temperate climates because the average temperature is neither hot nor cold. The largest seasonal changes actually occur in the mid-latitudes. The seasons in the Northern Hemisphere are the reverse of those in the Southern Hemisphere. When it is summer in the Northern Hemisphere, it is winter in the Southern Hemisphere.

POLAR REGIONS The polar regions are generally cool throughout the year, but they do experience seasonal changes. In the winter, the days are very short and the sun, if it is visible, is always low in the sky. Insolation is extremely weak and tem-

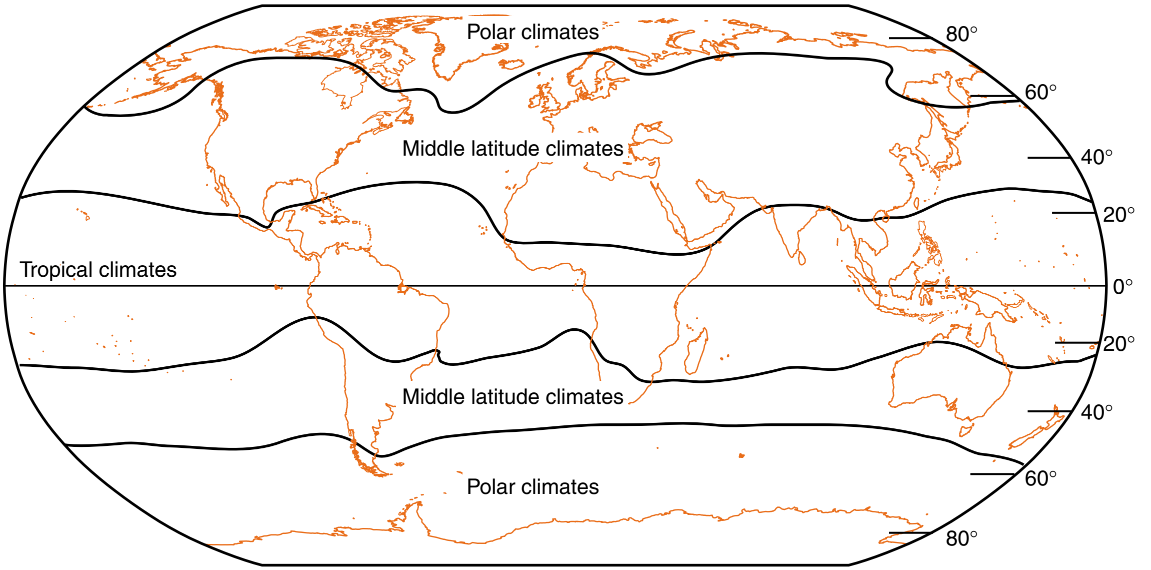


Figure 24-4 The annual cycle of insolation is the primary cause of seasonal temperature changes in climate and the global climate zones.

peratures may stay below freezing for months at a time. Even the summer sun is not very high in the sky, but daylight in the summer is very long. Because there is a large difference in the strength of insolation between winter and summer, polar locations are significantly warmer in the summer than they are in the winter. Figure 24-4 shows these world climate zones.

Precipitation

Latitude also affects patterns of precipitation. These patterns are a result of Earth's rotation acting on terrestrial winds. You learned earlier that instead of one big convection cell in each hemisphere, the Coriolis effect forms three convection cells in each hemisphere.

The three convection cells are shown on the Planetary Wind and Moisture Belts diagram in the *Earth Science Reference Tables*. Figure 24-5 on page 606 is a representation of part of that diagram. The left side of the diagram is a profile of Earth showing convection cells in the Northern Hemisphere. The diagram on the right shows Earth's surface as flat, the

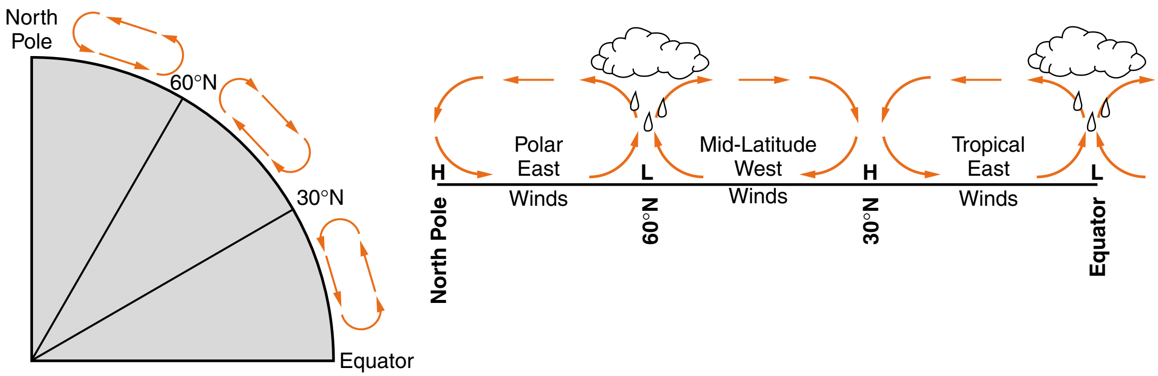


Figure 24-5

way it looks as you stand on it. Along the equator and at about 60°N latitude, air rises, forming low-pressure regions that circle Earth. The rising air causes cloud formation and generous precipitation at these latitudes. However, at a latitude of 30°N and at the North Pole (90°N) are regions of high pressure where sinking air warms and gets drier as it is compressed by atmospheric pressure. These latitudes have relatively little precipitation. The 90° segment shown in Figure 24-5 is one of four similar profiles that circle Earth.

The rotation of Earth and the position of the continents break convection in the Northern Hemisphere into three cells. Rising air near the equator and at about 60°N results in two low-pressure regions of plentiful precipitation that circle Earth. Sinking air at about 30°N and near the North Pole results in high-pressure zones dominated by low relative humidity and little precipitation. Six similar profile sections circle Earth, three in the Northern Hemisphere and three in the Southern Hemisphere.

These high- and low-pressure belts are not stationary. Seasonal changes cause them to shift toward the equator in the winter and toward the poles in the summer. Furthermore, the wandering jet streams move these regions of high- and low-pressure and interrupt them with the passage of storm systems. Other geographic features you will soon read about also influence patterns of precipitation. If you look at the location of the world's rain forests and deserts you will see that they generally occur in the latitude zones indicated in Figure 24-4.

ACTIVITY 24-1 LOCATING DESERTS AND RAIN FORESTS

On an outline map of the world's continents draw east-west lines at the equator, 30° north and south of the equator, and 60° north and south of the equator. On the same map label the major desert regions and rain forests of the world.

Do these features occur where you would expect them according to Figure 24-4 and the *Earth Science Reference Tables?*

WHAT OTHER GEOGRAPHIC FACTORS AFFECT CLIMATE?

Latitude plays a major role in determining the climate of an area. However, other factors, such as elevation, nearness of large bodies of water, winds, and ocean currents also affect climate.

Elevation

Elevation is indirectly related to the average temperature of a location. Recall that air expands as it rises within the atmosphere. As rising air expands, it becomes cooler. Perhaps you have noticed that high mountains are often snow covered, even in the summer, as shown in Figure 24-6 on page 608. Mount Kilimanjaro in Africa and Cotopaxi in South America are near the equator. However, both mountains have permanent snow cover near their summit. Nearby locations at lower elevation have a tropical climate where it never snows. Rising air cools at a rate of about 1°C per 100 meters (4°F per 1000 feet).

People who live in the low desert of Arizona often seek relief from the summer heat by traveling to nearby mountain locations. Within the state, travel north or south has little effect on temperatures. However, the large changes in elevation in that part of the country have major climatic consequences.

Figure 24-6 Due to differences in elevation, high mountains are often covered with snow while nearby lowlands are warmer and free of snow.

Mountain Barriers

Mountain ranges affect patterns of precipitation and temperature. For example, moist winds off the Pacific Ocean cross California and rise into the Sierra Nevada Mountains. Rising into the mountains, the air expands and cools below its dew point. Cloud formation and precipitation create a cool climate with abundant precipitation on the western side of the Sierra Nevada Mountains. When the winds descend on the opposite side of the mountains, the air is compressed by increasing barometric pressure and becomes warmer. As the descending air becomes warmer without picking up moisture, the relative humidity decreases.

The climate on the eastern side of the Sierra Nevada Mountains is very different from that on the western side. Rain forests that exist on the Pacific, or windward, side of the western mountains contrast sharply with inland deserts. Seattle and the coast of northern California have a temperate, moist climate. Inland cities such as Spokane, Las Vegas, and Phoenix are located in the desert climate zone. Climate on the downwind, or leeward, side of mountains is sometimes called a “rain shadow” climate because the mountain barriers rob

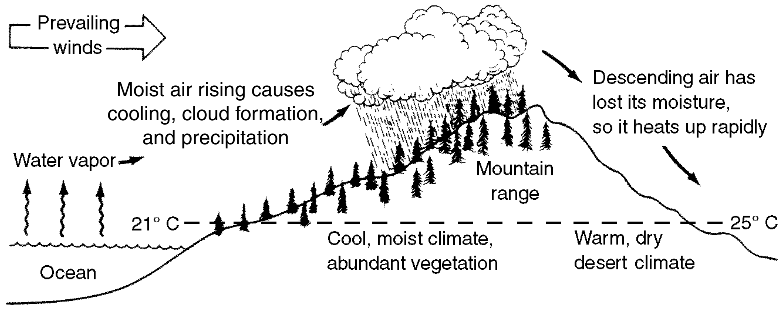


Figure 24-7 Cloud formation and precipitation usually occur on the windward side of a mountain range where moist air rises and cools. On the downwind side, descending air is warmed by compression, so the relative humidity quickly drops, generating an arid climate.

the air of its moisture before the air descends into the valleys. Figure 24-7 illustrates the difference between climates on the opposite sides of a mountain range.

Figure 24-7 shows another difference between climates on the opposite sides of a mountain range. Notice that the temperature near sea level on the left (ocean) side of the diagram is cooler than the temperature at the same elevation on the right (inland) side of the mountains. Why is the temperature warmer on the downwind side of the mountains?

As air rises into the mountains, condensation (cloud formation) releases energy, slowing the cooling. Instead of cooling at the dry air rate of 1 C° per 100 meters, the air cools at a lower rate of about 0.6 C° per 100 meters when clouds form. The descending air is not able to pick up moisture. Therefore, the air heats at the greater, dry air rate of 1°C per 100 meters. Figure 24-8 on page 610 illustrates this difference in the rate of temperature change between moist air moving up the mountain with cloud formation and the descending air, which is dry and heats more rapidly. Changes in climate caused by mountain barriers are called orographic effects.

Large Bodies of Water

The Atlantic Ocean and Long Island Sound moderate the climate of New York's Long Island. Therefore, winters are usually warmer on Long Island and summers cooler than in other

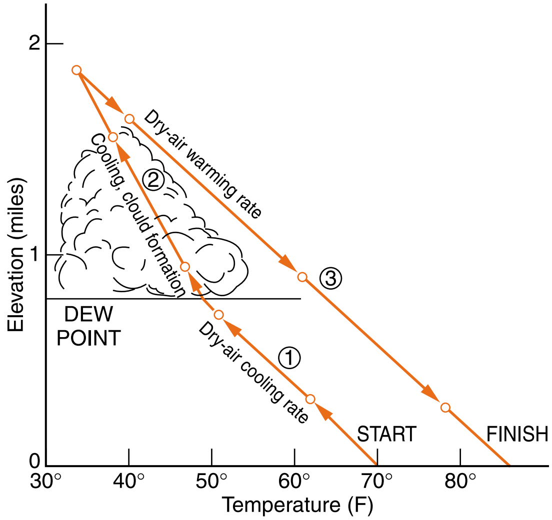


Figure 24-8 (1) As air rises, it expands and cools quickly. (2) When clouds form, condensation releases the energy stored in water vapor, slowing the rate of cooling. (3) When the air sinks to a lower elevation, there is no change in state to slow the rapid warming rate.

parts of the state. This is especially true for places along the coast when the winds are off the ocean. The inland regions of New York State experience the highest and lowest temperatures. The lowest temperature ever recorded in New York State was −52° F (−47°C) in the Adirondack Mountains. The record high temperature in New York State was measured in the capitol district: 108°F (42°C) at Troy. Both places are far from the moderating influence of the Atlantic Ocean and the Great Lakes.

Why do the oceans have such a great effect on climate? Table 24-1 is in the *Earth Science Reference Tables*. This table lists the specific heats of seven common substances. As you learned in Chapter 21, *specific heat* is a measure of the ability of a substance to warm as it absorbs energy or cool as it gives off energy. In general, metals have low specific heats. They heat up rapidly when they absorb energy. Rocks also have relatively low specific heat values. However, water has a very high specific heat.

This means that when the same amount of energy is absorbed by equal masses of water and these other substances, water has the least temperature change. It also means that when equal amounts of these substances cool, water releases the most energy. When water and land receive equal solar energy, the land heats more than the ocean. Large bodies of water change relatively little in temperature. Winds off the oceans or the Great Lakes, such as Lakes Erie and Ontario, moderate the temperature of nearby land areas.

TABLE 24-1 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

There are three other reasons that land areas experience greater changes in temperature than the oceans. First, because water is relatively transparent, sunlight penetrates deeper into water than it does on land. Rock and soil are opaque, so insolation energy is concentrated at the surface. Second, water is a fluid, so convection currents can distribute energy to the interior. Solids have no convective mixing. Finally, evaporation from the oceans uses some of the solar energy that would otherwise heat the oceans. Although there is some evaporation of water from soil, it is far less than evaporation from the oceans. Figure 24-9 on page 612 summarizes these factors.

Most terrestrial climates can be classified as maritime or continental. **Continental climate**, typical of inland areas, is characterized by large seasonal changes in temperature. In-

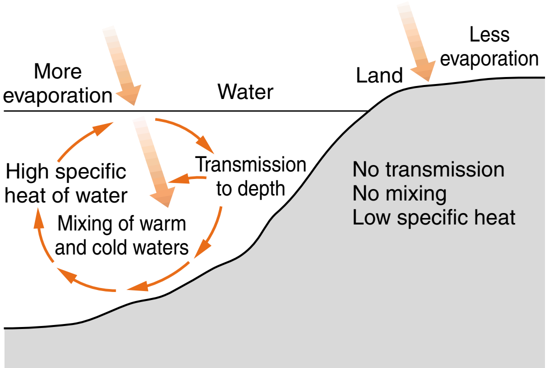


Figure 24-9 Four reasons that the oceans heat more slowly than land: (1) Sunlight can penetrate water but it is concentrated on the surface of the land. (2) Convection currents carry energy into the water. (3) Water has a higher specific heat than rock or soil. (4) Some solar energy is used in the evaporation of water.

land areas often do not experience the moderating influence of large bodies of water. Areas with a continental climate can be arid or moist, depending on the source region of the air masses that move into the area. The **maritime climate**, sometimes known as the marine climate, occurs over the oceans and in coastal locations where water moderates the extremes in temperature. Areas that have a maritime climate experience a consistently moderate to high humidity.

Prevailing Winds

New York State has greater extremes of climate than many other coastal states. California, for example, is known for its mild climate. Although inland areas of California experience greater ranges of temperature than the coastal locations, even these extremes are not as great as those are in New York State. The reason for this difference is the wind direction. Both states are in the global belt of prevailing west and southwest winds. However, those winds come off the Pacific Ocean in California. In most of New York State, the winds come from inland areas where temperatures are highly changeable. As a result, the nearby Atlantic Ocean has relatively little affect on the climate of most of New York State.

Monsoon climates include an annual cycle of change in weather patterns caused by shifting wind directions. In winter and spring, the wind comes from high-pressure centers over the continents. Spring weather is warm and dry with large changes in temperature on a daily cycle. When summer low pressure builds over the continents, the wind shifts direction. It brings moist air from the ocean. Summer weather generally is more humid with cooler days and warmer nights. The summer monsoons also bring clouds and precipitation, which reduce the temperature as well as the daily range of temperature.

Ocean Currents

Many tourists are surprised to see palm trees growing in the some parts of England and Ireland. Palm trees are not native to these countries, but these imported plants can survive the mild weather conditions found in some parts of the British Isles. The Gulf Stream and the North Atlantic Current transport warm ocean water from the South Atlantic Ocean to the area surrounding Great Britain. These islands experience more moderate temperatures than does New York State. The British Isles have damp and mild winters in which hard frosts are uncommon. This is true in spite of the fact that Great Britain is roughly 10° of latitude north of New York State. Along the East Coast of North America at the same latitude as Great Britain is the Labrador province of Canada, where the winters are even colder than in New York State.

Other locations are relatively cool because of nearby cold ocean currents. The California Current keeps the coastal city of San Francisco in "sweater weather" throughout the summer. Even in the summer, local residents who visit the ocean may wade in the surf, but the water is too cold for people to swim without a wet suit. People who live just a few miles inland often experience desert heat in the summer while the city of San Francisco is cool and temperate. The Surface Ocean Currents map in the *Earth Science Reference Tables* provides a useful way to tell where warm and cold ocean currents affect the climate of coastal locations.

ACTIVITY 24-2 CLIMATES AND OCEAN CURRENTS

Using a political map of the world and the Surface Ocean Currents map from the *Earth Science Reference Tables,* make a list of countries or regions that are affected by warm ocean currents. Make another list of places affected by cold currents. Alphabetizing your list will help you compare your locations with the lists of other students.

Ocean currents also affect patterns of precipitation. Cold air can hold far less water vapor than warm air. In addition, cool air blowing over warmer land surfaces causes the relative humidity to decrease. Decreasing relative humidity makes precipitation unlikely. Therefore, coastal regions affected by cold ocean currents are usually places where rainfall is scarce. A weather station in the Atacama Desert, along the west coast of South America, has been in place for decades without experiencing any measurable precipitation. On the other hand, the relatively warm Alaska current makes coastal Alaska one of the rainiest places in the United States.

Vegetation

The local climate and soil determine natural vegetation. Therefore, vegetation is a good indicator of the climate. For example, the temperate rain forests along the Pacific coast of the United States and Canada can thrive only in a cool, moist climate. However, vegetative cover also contributes to the climate. Thick vegetation, such as the trees and plants found in a forest, moderate temperature by holding in cool air during the day and preventing the rapid escape of warm air at night. Vegetation slows surface winds. In addition, plants contribute moisture to the air. During precipitation, the plant cover slows runoff and gives water at the surface time to soak into the ground. Groundwater is then absorbed by the roots of plants and rises into the leaves where, over an extended period, it is slowly lost by *transpiration*. Transpiration and photosynthesis also absorb solar energy, which would otherwise heat the land and air during daylight hours. So forest conditions are generally more moderate and consistently more humid than open land in the same area.

Human activities such as cutting wood, plowing fields, mining, or construction remove native plants and replace them with open ground, paved surfaces, or buildings. The human population of the planet has increased and our technology has become more advanced. **Deforestation**, cutting forests to clear land, and **urbanization**, the development of heavily populated areas, have replaced natural vegetation with farmlands and cities at an ever-increasing rate. Bare ground and paved surfaces do not allow evaporation of ground water, and they heat up quickly during the day and cool quickly at night. As a result of urbanization, the local climate becomes more arid and warmer with an increased daily range of temperatures.

Urban Heat Islands

Human activities release heat energy to the environment. Heating and air conditioning release heat to the outdoor environment. Cars, trucks, buses, and other forms or transportation consume fuel and release heat. Businesses and industries, which are concentrated around cities, produce heat in varying amounts. Many of the same activities that take place in rural regions also occur in urban areas, or cities. However, in a city, the high concentration of human activities produces an urban heat island. In general, urban areas warm up more quickly and stay warmer than rural locations.

The effects of urban heat islands are relatively easy to observe. Have you ever noticed how much longer winter snow lasts is the country than it does in nearby urban areas? Even undisturbed parkland in cities will be clear of snow before similar rural land is snow-free. On summer nights, city dwellers often need air conditioning all night while neighboring rural inhabitants can find relief by opening their windows to the cool evening air.

WHAT GEOGRAPHIC FEATURES OF NEW YORK STATE AFFECT THE LOCAL CLIMATE?

Differences in climate throughout New York State are not very large. Many climatologists would classify the whole state as a humid, continental, temperate climate with large seasonal variations in temperature. However, local geographic features do cause some significant differences in climate at various locations in the state.

As noted previously, the Atlantic Ocean and Long Island Sound make the climate on Long Island more moderate in temperature than inland areas of New York State. Winter temperatures do not get quite as cold and summer temperatures do not get as hot as those of inland areas. Winter precipitation that falls as snow upstate is more likely to be rain on Long Island. Breezes off the ocean keep the humidity higher than other parts of the state. Long Island is also more vulnerable to hurricanes and coastal storms.

Winter snow lasts longer in higher parts of the Adirondack Mountains and the Catskills for two reasons. First, the mountains, due to their elevation, are a little cooler than other areas of New York State. Second, mountains also influence patterns of precipitation. Air rising into these two mountain areas expands and cools, causing increased precipitation throughout the year. Mountains also influence the climate on their downwind side. The land around Lake Champlain and the central Hudson Valley are in the rain shadow of mountains and may have as little as half the annual precipitation of the nearby mountains.

You have previously read that the parts of New York State at the eastern end of Lakes Erie and Ontario are subject to increased precipitation from "lake-effect" storms. This is especially true in late autumn and early winter when the lake water is warmer than surrounding land areas. The lakes also moderate temperatures in nearby land areas. The first hard frost of autumn occurs later in these areas. The extended growing season makes land near the lakes valuable for agriculture.

HOW IS CLIMATE SHOWN ON GRAPHS?

Climate graphs are a visual way to show different kinds of climates. On the following graphs, a dark line shows the average monthly temperature and the average monthly precipitation is indicated by monthly bar graphs.

Figure 24-10 is a climate graph for Syracuse, New York. Notice the large seasonal changes in temperature and plen-

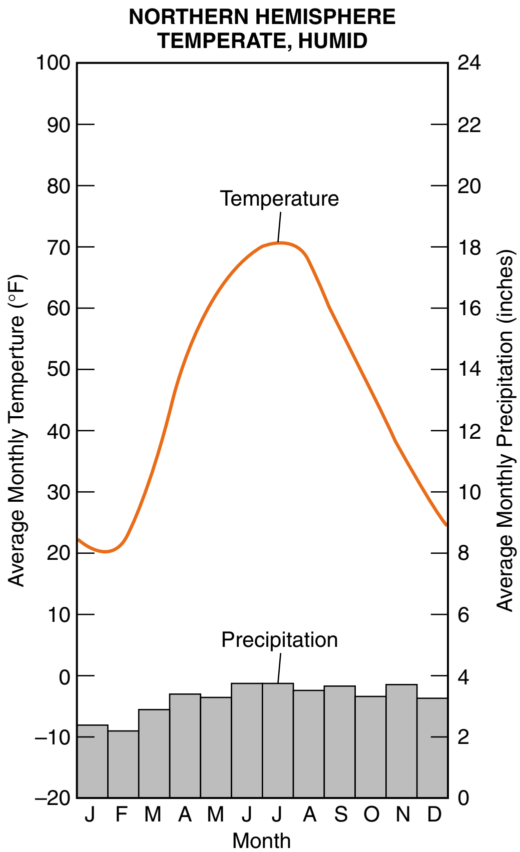


Figure 24-10 Climate graph for Syracuse, New York.

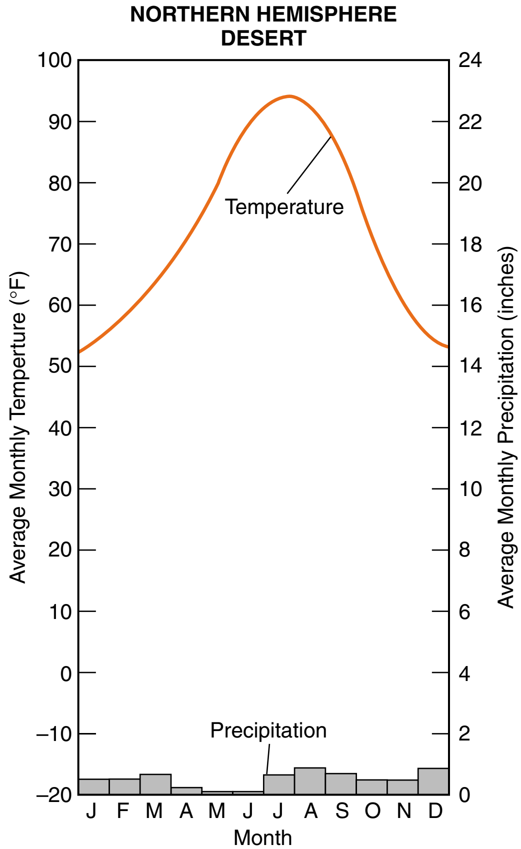


Figure 24-11 Climate graph for Phoenix, Arizona.

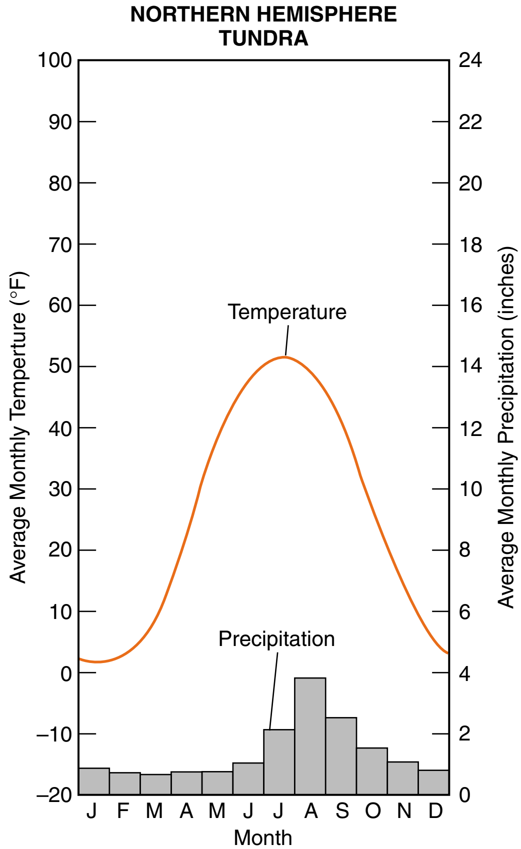


Figure 24-12 Climate graph for Nome, Alaska.

tiful precipitation throughout the year. Remember that these are average conditions over many years. Therefore, unusual events such as droughts do not show on these graphs.

Figure 24-11 is a climate graph for a desert location in the southwestern United States. Although it shows major seasonal changes in temperature like the Syracuse graph (Figure 24-10), this location is warmer in both the winter and the summer. Also notice the limited precipitation throughout the year, especially in the spring before the summer monsoon season.

Figure 24-12 is a tundra climate in arctic Alaska. Temperatures are significantly lower than Syracuse, New York, throughout the year. Although precipitation is low, so is evaporation in this cold climate.

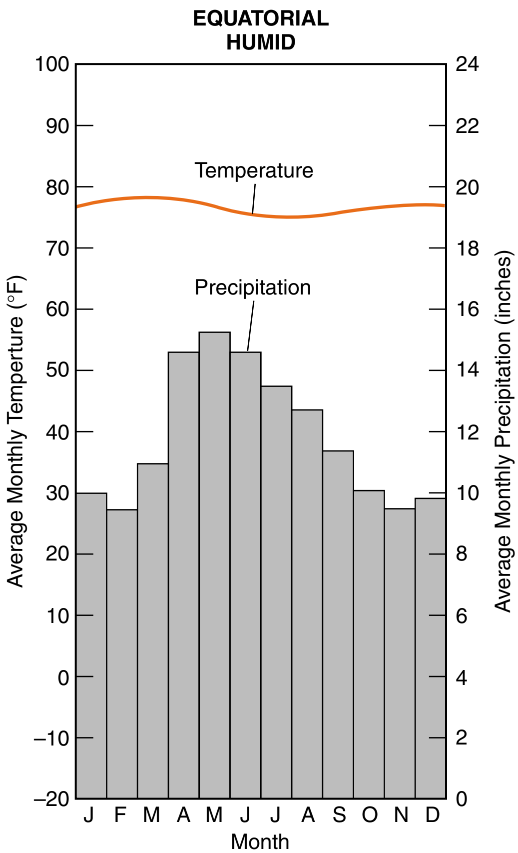


Figure 24-13 Climate graph for Fonte Boa, Brazil.

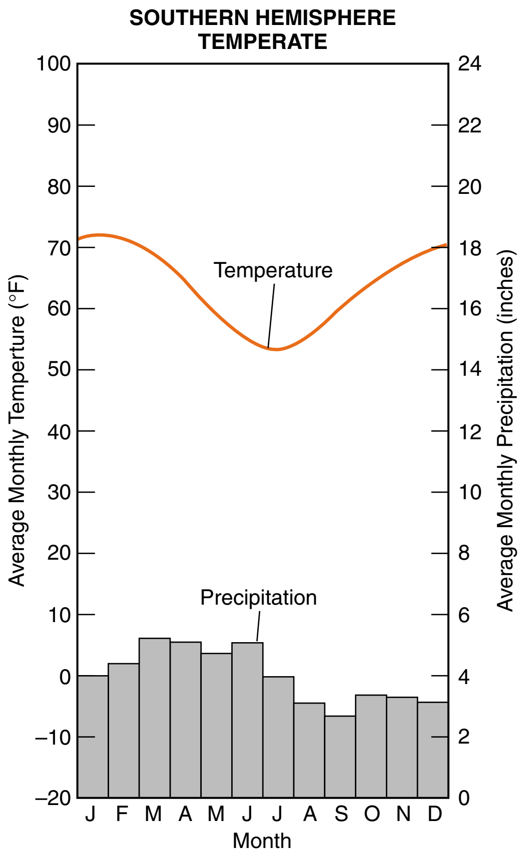


Figure 24-14 Climate graph for Sydney, Australia.

The rain forest of tropical Brazil provides the data for Figure 24-13. The average temperature changes very little throughout the year and precipitation is usually plentiful.

Notice that the highest and lowest temperatures in the Southern Hemisphere location illustrated in Figure 24-14 are off by 6 months from those of the Northern Hemisphere locations. This is also a coastal city so the annual temperature range is not as great as it is at the previous temperate locations.

The last climate graph is a monsoon location in India. (See Figure 24-15 on page 620.) Precipitation is very seasonal. Also notice how the temperatures fall off when the summer monsoons arrive in July.

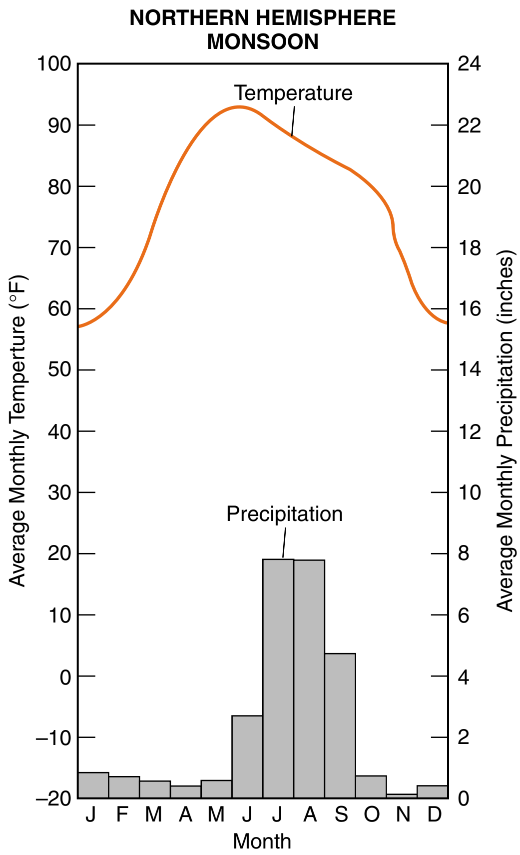


Figure 24-15 Climate graph for New Delhi, India.

TERMS TO KNOW

arid climate	**deforestation**	**temperate climate**
continental climate	**maritime climate**	**urbanization**

CHAPTER REVIEW QUESTIONS

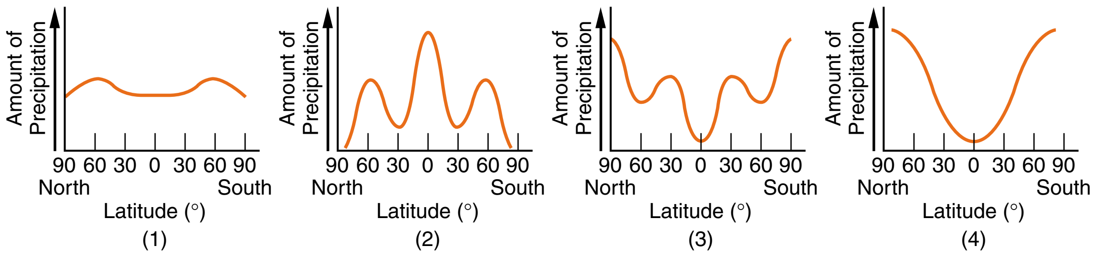
1. A high air pressure, dry climate belt is located at which Earth latitude?

   (1) 0°
   (2) 15°N
   (3) 30°N
   (4) 60°N

2. The average temperature at Earth's North Pole is colder than the average temperature at the Equator because the Equator

(1) receives less ultraviolet radiation.
(2) receives more intense insolation.
(3) has more cloud cover.
(4) has a thicker atmosphere.

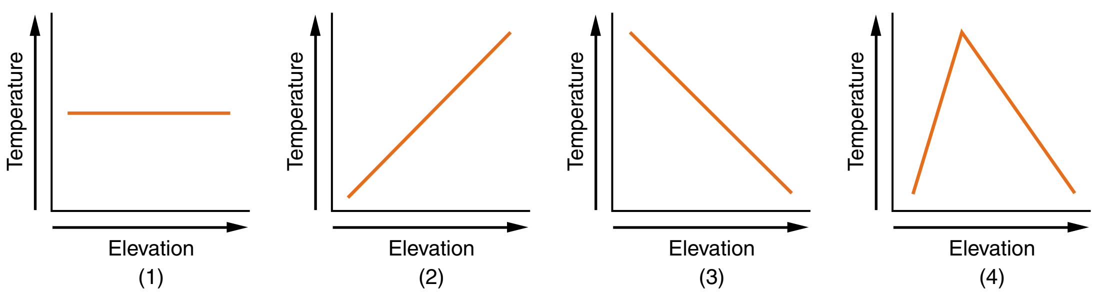
3. Which graph best shows the average annual amount of precipitation received at different latitudes on Earth?



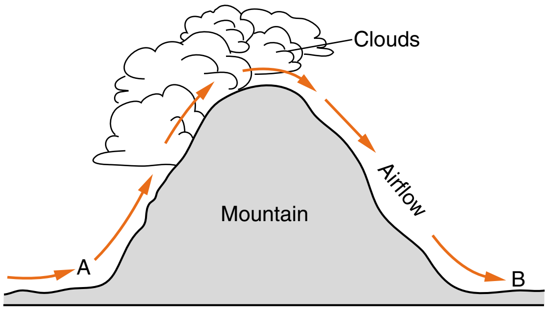
4. Which location probably receives the *least* average annual precipitation?

(1) Lake Placid in the central Adirondack Mountains of New York
(2) Buffalo, New York, at the eastern end of Lake Erie
(3) the South Pole research station in central Antarctica
(4) Belém, Brazil, along the equator in the Amazon tropical forest

5. Which graph below best shows the general effect that differences in elevation above sea level have on the average annual temperature?



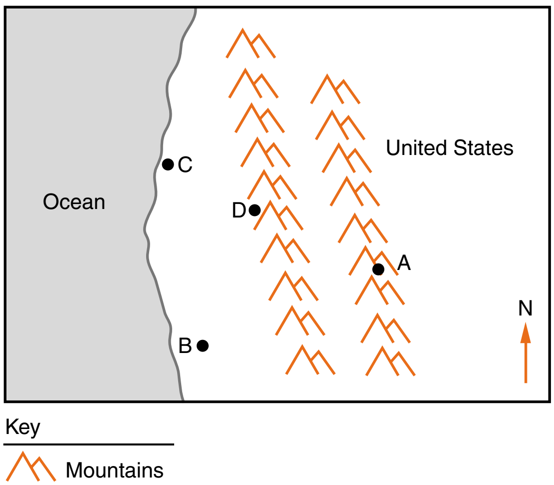
6. The diagram below shows prevailing winds that blow across a mountain range.



Compared to the temperature and humidity conditions at location A, the conditions at location B are

(1) warmer and less humid.
(2) warmer and more humid.
(3) cooler and less humid.
(4) cooler and more humid.

7. The map below shows the locations of four cities, A, B, C, and D, in the western United States where the prevailing winds are from the southwest.



Which city most likely receives the *least* amount of average yearly precipitation?

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

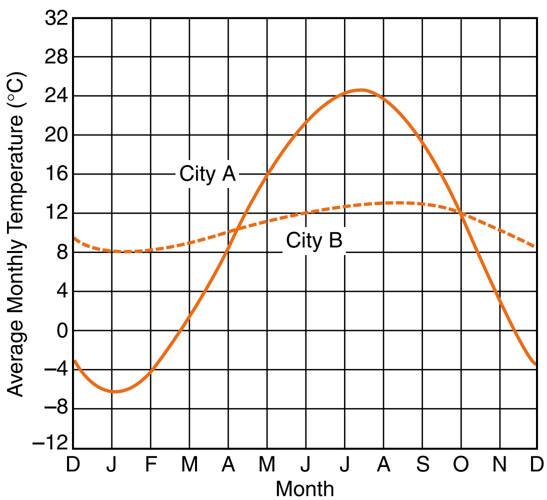
8. Liquid water can store more heat energy than an equal amount of almost any other naturally occurring substance because liquid water

(1) covers 71 percent of Earth's surface.
(2) has its greatest density at 4°C.
(3) has a high specific heat.
(4) can be changed into a solid or a gas.

9. On a clear summer day, the surface of the land is usually warmer than the surface of a nearby body of water because the water

(1) receives less insolation.
(2) reflects less insolation.
(3) has a higher density.
(4) has a higher specific heat.

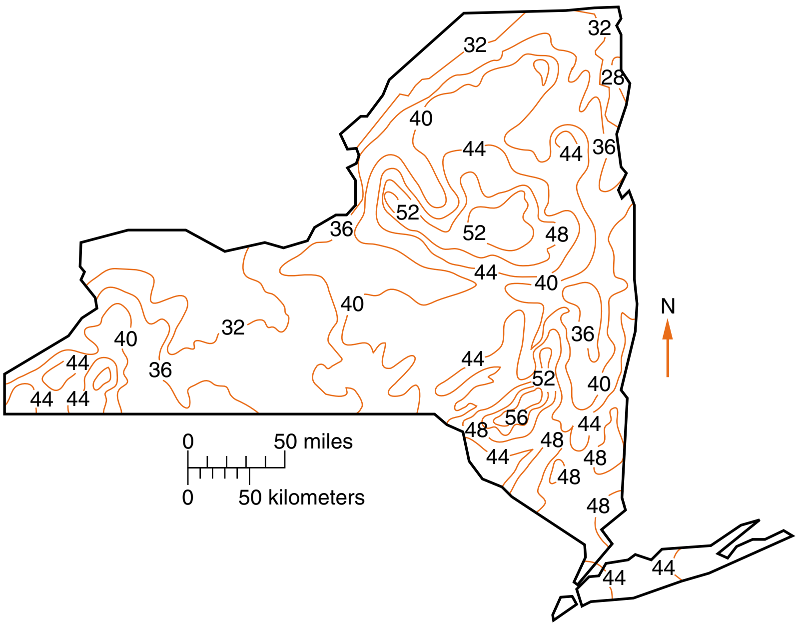
10. The graph below shows the average monthly temperature for two cities, A and B, that are both located at 41° north latitude.



Which statement best explains the difference in the average yearly temperature range for the two cities?

(1) City B is located in a different planetary wind belt.
(2) City B receives less yearly precipitation.
(3) City B has a greater yearly duration of insolation.
(4) City B is located near a large body of water.

The map below shows the average annual precipitation in New York State. Isoline values represent inches per year. Use this map to answer questions 11 and 12.



11. Jamestown, New York, receives more rainfall per year than Elmira. The primary reason for this difference is that Jamestown is located

(1) closer to a large body of water.
(2) at a higher latitude.
(3) at a lower elevation.
(4) in the prevailing southerly wind belt.

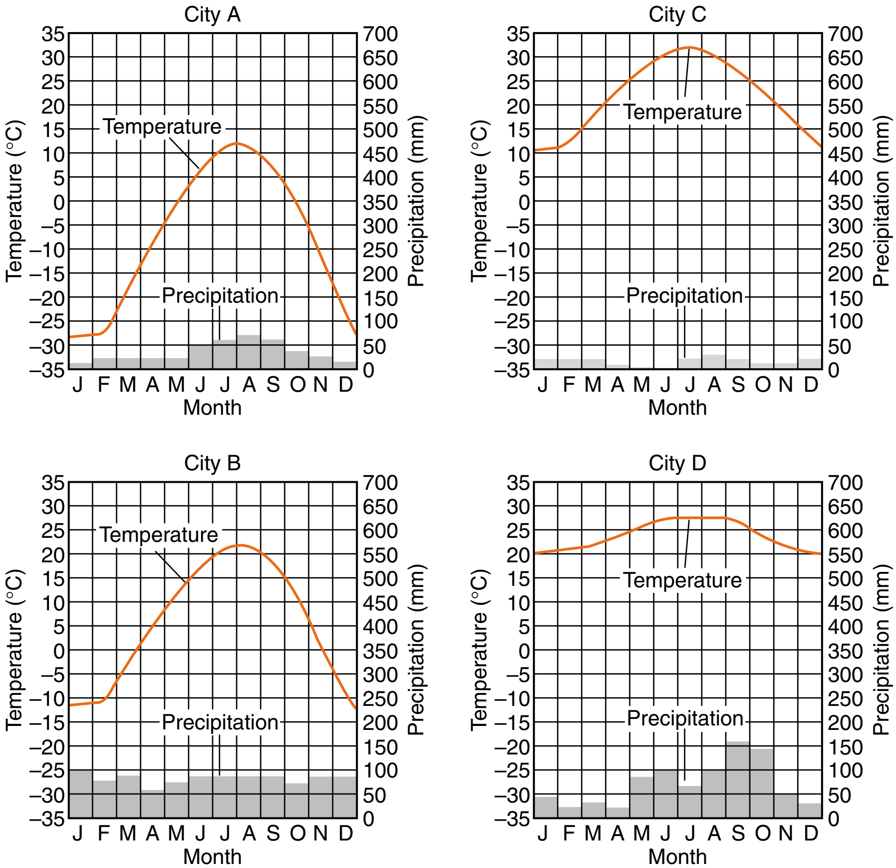
12. Which of these locations has the lowest average annual precipitation?

(1) Kingston
(2) New York City
(3) Old Forge
(4) Plattsburgh

13. Some housing developments in the barren southwestern deserts of the United States have included large irrigated areas of lawns and trees. As a result, the summer weather conditions within these developments have become more

(1) warm and moist.
(2) warm and dry.
(3) cool and moist.
(4) cool and dry.

Use these four graphs to answer the next two questions. Each graph below represents climate conditions for a different city in North America. The line graphs show the average monthly temperatures. The bar graphs show average monthly precipitation.



14. At which cities is the winter precipitation most likely to be snow?

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

15. In which sequence are the cities listed in order of decreasing average yearly precipitation?

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

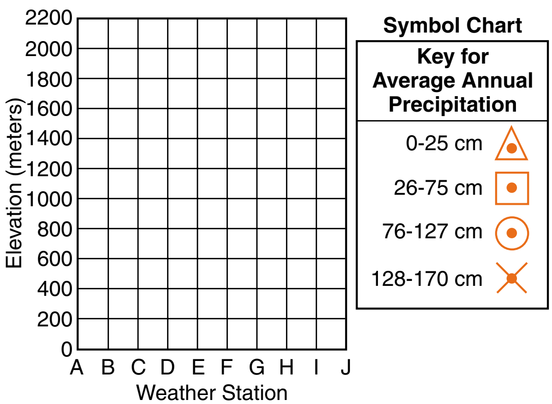
Open-Ended Questions

Use the data below to answer questions 16–18. The table shows the elevation and average annual precipitation at 10 weather stations, *A* through *J*, located along a highway that passes over a mountain.

Data Table

Weather Station	Elevation (m)	Average Annual Precipitation (cm)
A	1350	20
B	1400	24
C	1500	50
D	1740	90
E	2200	170
F	1500	140
G	800	122
H	420	60
I	300	40
J	0	65

16. On a copy of the grid below, graph the data from the data table according to the following directions. (Please, do not write in this book.)



a. Mark the grid with a point showing the elevation of each weather station above its corresponding letter, *A* through *J*.

b. Surround each point with the proper symbol from the chart to show the average annual precipitation for the weather station.

17. State the relationship between the elevations of weather stations *A* through *E* and the average annual precipitation at these weather stations.

18. Although stations *C* and *F* are at the same elevation, they have different amounts of average annual precipitation. Explain how the prevailing wind direction might cause this difference.

19. State why locations east of Lakes Erie and Ontario are more likely to receive lake-effect snowstorms than locations west of the these lakes?

20. Westerly winds blowing off Lake Ontario usually drop more precipitation on the Tug Hill Plateau landscape region than they do on the lowlands along the eastern shore of the lake. Why does the Tug Hill Plateau receive more precipitation than the nearby lowlands?