26.1 Factors That Affect Climate

Section Objectives

- **Explain how latitude determines the amount of solar energy received on earth.**
- **Describe how the different rates at which land and water are heated affect climate.**
- **Explain the effects of topography on climate.**

The average weather conditions of a region, or the weather patterns that occur over many years, are referred to as *climate*. Usually scientists describe climate in terms of the average monthly and yearly temperatures and the average amount of precipitation. Average temperatures are calculated by adding two or more temperature readings and dividing by the number of readings. For example, the average daily temperature is calculated by averaging the high and low temperatures of the day. The monthly average is determined by averaging the daily averages. The yearly average temperature can be calculated by averaging the monthly averages.

Another way scientists describe temperature is by indicating the **temperature range.** Temperature range is the difference between the highest and lowest temperatures of a day or month. The yearly temperature range is the difference between the highest and lowest monthly averages.

Using only average temperatures to describe climate can be misleading. For example, both St. Louis, Missouri, and San Francisco, California, have an average yearly temperature of about 13°C. However, St. Louis has a climate with cold winters and hot summers, while San Francisco has a generally mild climate all year.

Another major weather condition, precipitation, is described as the average precipitation a region receives in a year. However, average yearly precipitation alone does not accurately describe climate. For example, the average yearly precipitation for New York City and for Miami, Florida, is almost the same. In Miami, however, the rain falls mostly during the rainy season from May to October. In New York City, various forms of precipitation fall throughout the year. Clearly, the climates of these two cities differ.

An accurate description of climate cannot be given with only statistics; it must also include several factors that influence both temperature and precipitation. These factors include latitude, heat absorption and release, and topography.

Latitude

A major influence on the climate of a region is its latitude, or distance from the equator. Latitude determines the amount of solar energy received by, and the prevailing wind belts of, the region.

Solar Energy

The amount of solar energy that a location receives depends on two factors: the angle at which the rays of the sun strike the earth and the number of hours of daylight the location receives. The angle at which the sun's rays strike a region is determined by its latitude and by the tilt of the earth's axis. At the equator, the rays always strike the earth at a very high angle, nearly 90° for much of the year.

INVESTIGATE!

To learn more about climate, try the In-Depth Investigation on pages 538–539.

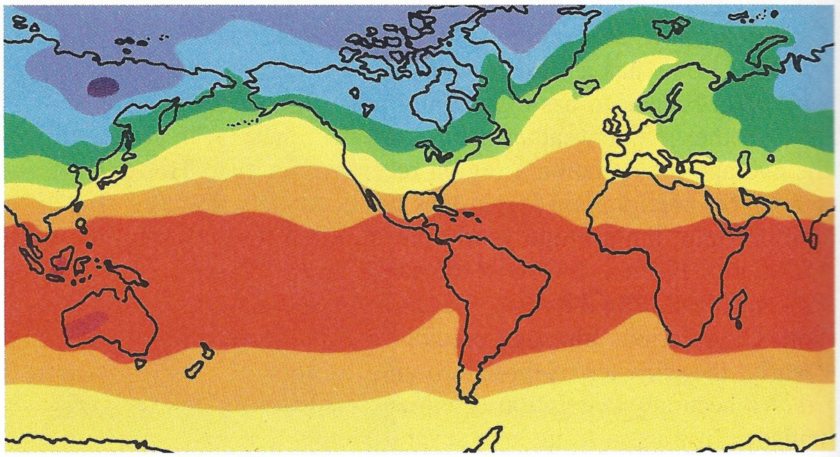
In equatorial regions, both day and night are about 12 hours long throughout the year. The result is steady high temperatures year-round and a yearly temperature range of only 3°C or 4°C in most areas. There are no summers or winters—only dry or rainy seasons.

At higher latitudes, the sun's rays strike the earth at an angle of less than 90°. The rays do not heat these areas as much because their energy is spread over a wider area. Thus, average yearly temperatures in these locations are lower than those at the equator. Also, the lengths of the days and the nights vary. For example, at 45° north or south of the equator, the hours of daylight vary from about 16 hours in the summer to about 8 hours in the winter. Therefore, the yearly temperature range is large—more than 30°C in some regions.

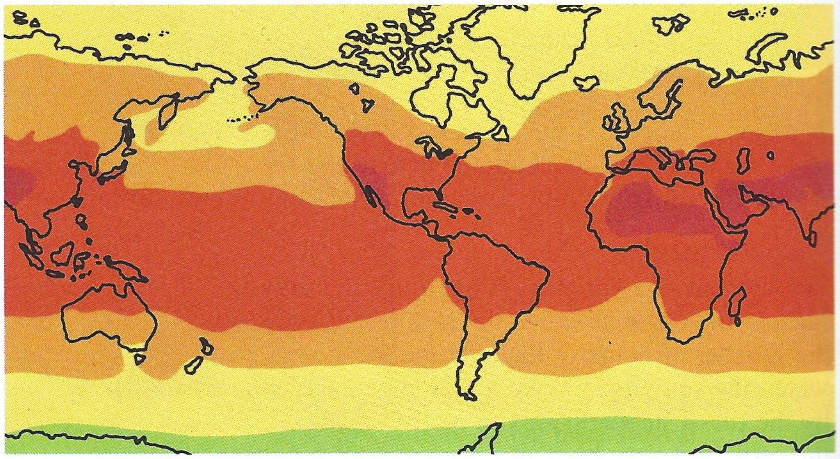
In the polar regions, the sun sets for only a few hours each day in the summer and rises for only a few hours each day in the winter. Thus, the annual temperature range is very large, but the daily temperature ranges are very small.

When the average daily temperatures in various parts of the world are plotted on a map, they form a series of temperature zones, as shown in Figure 26–1. The boundaries of these zones roughly follow the parallels of latitude. The average daily temperatures are

Figure 26–1. The zones of average daily sea-level temperature in January (top) and July (bottom) roughly follow the lines of latitude.



Average sea-level temperature in January



Average sea-level temperature in July

Degrees in Celsius (°C)

🟥	Over 32	🟩	−23 to −12
🟥	21 to 32	🟦	−34 to −23
🟧	10 to 21	🟦	−46 to −34
🟨	−1 to 10	🟪	Below −46
🟩	−12 to −1		

IMPACT ON SOCIETY

El Niño

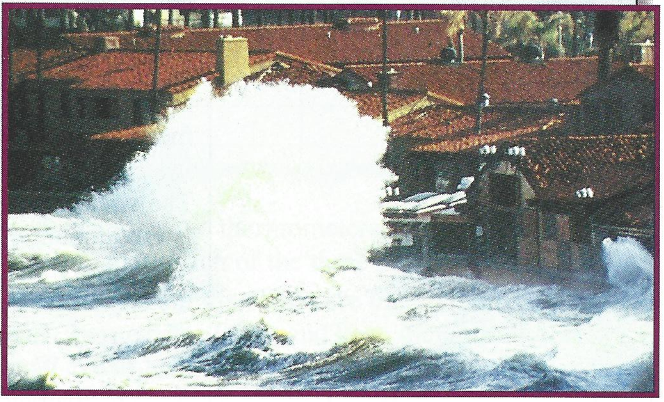
From late 1982 to mid-1983, unusually violent weather wreaked havoc around the world. Typhoons and cyclones battered the Pacific United States, Hawaii, and Tahiti. Floods ravaged the southeastern United States, Bolivia, Ecuador, and Peru. Droughts struck Australia, southern Africa, Central America, Indonesia, and the Philippines. More than 1,000 people died, and property and crop losses soared to billions of dollars.

The cause of this unusual weather was discovered to be a warm Pacific current known as *El Niño.* It appears around Christmas about every three to ten years and lasts for about a year. El Niño begins with a weakening of the trade winds that usually push warm water toward the western Pacific Ocean. The weakened trade winds allow the warm water to flow eastward instead. This warm current heats the cool waters of South America's west coast to more than 27°C, upsetting the local marine ecology.

El Niño's effects are not limited to the equatorial Pacific region, however. Sea surface temperatures strongly affect atmospheric pressure and, thus, overall weather patterns. For example, the warming of the Pacific Ocean near South America shifts the subtropical jet stream and can cause unexpected weather around the world.

The severe consequences of the 1982–1983 El Niño prompted scientists to study the relationship between the ocean and the atmosphere more intensively. Using historical data, satellite measurements of sea surface topography, computer-aided models, and a network of meteorological buoys, scientists can now predict El Niño a year in advance. Improved forecasting significantly reduced losses from a 1986 El Niño and from three El Niño events that occurred between 1991 and 1995.

How might El Niño change the marine ecology on the west coast of South America?



highest near the equator and decrease with distance from the equator. However, the irregular shape of the temperature zones indicates that the amount of solar energy is not the only factor affecting climate.

Wind Patterns

Latitude also determines global wind belts that affect a region and, thus, the general direction of the wind in any particular location. The latitude ranges of these global wind belts are described in Chapter 23. Winds affect many weather conditions, such as humidity, precipitation, temperature, and cloud cover. Hence, regions with different prevailing winds often have different climates. The global wind pattern is also influenced by ocean currents and major mountain ranges.

Within the different global wind belts are various regions of low and high pressure. In the equatorial belt of low pressure—the doldrums—the air rises and cools, and water vapor condenses. As a

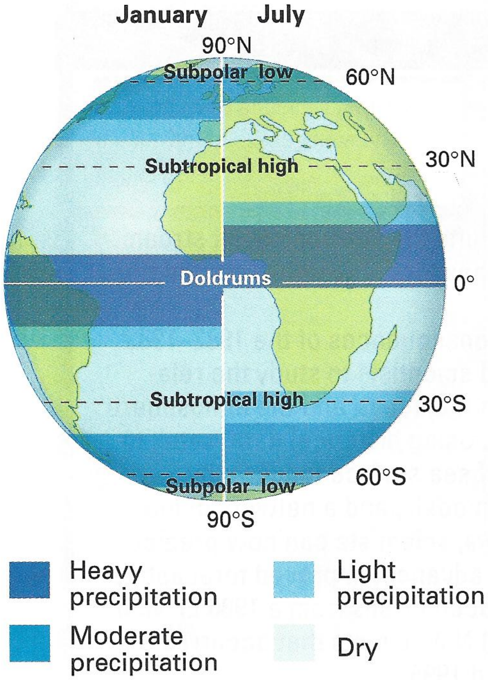


Figure 26–2. During winter in the Northern Hemisphere, global wind and precipitation belts shift to the south.

result, the equatorial regions of low pressure generally receive heavy precipitation. The amount of rainfall is most abundant in a belt around the equator and decreases steadily with increasing latitude. In the areas around 20° to 30° north and south latitude—the subtropical highs—the air is sinking, drying, and warming. Thus little precipitation occurs, causing most of the world's deserts to be located there.

Closer to the poles, at around 45° to 60° latitude, is a belt of higher precipitation. In these regions—the westerlies and subpolar lows—warm tropical air meets cold polar air, and *wave cyclones* frequently develop. At latitudes above 60°, average precipitation decreases in the cold, dry polar high-pressure air masses.

With the changing seasons, the global wind belts shift in a north-south direction, as shown in Figure 26–2. As the wind and pressure belts shift, the belts of precipitation associated with them also shift.

Heat Absorption and Release

The way solar energy strikes the earth and is absorbed or reflected also influences the surface temperature. Land heats faster and to a higher temperature than water does. One reason for this difference is that the land surface is solid and basically unmoving, while the water surface is liquid and continuously changing. Waves, currents, and other movements continuously replace warm surface water with cooler water from the ocean depths. This action prevents the surface temperature of the water from increasing rapidly. The surface temperature of the land, on the other hand, can continue to increase as more solar energy is received.

Land and water also absorb and release heat at different rates. The **specific heat** of water is higher than that of land. Specific heat is the amount of heat needed to raise the temperature of 1 g of a substance 1°C. A given mass of water requires more heat than does the same mass of land to increase its temperature the same number of degrees. Even if not in motion, water warms more slowly than land does. Water also releases heat more slowly than land does.

The average temperatures of land and water at the same latitude vary also because of differences in the loss of heat through evaporation. Evaporation affects water surfaces much more than it does land surfaces.

Ocean Currents

The amount of heat absorbed or released by the air is influenced by the temperature of ocean currents with which the air comes in contact. If winds consistently blow toward the shore, currents have a stronger effect on air masses. For example, the combination of a warm Atlantic current and steady westerly winds gives northwestern Europe an unusually high average temperature for its latitude. On the other hand, the warm Gulf Stream has less effect on the east coast of the United States because westerly winds usually blow the Gulf Stream and its warm maritime tropical air away from the coast.

Seasonal Winds

Heat differences between the land and the oceans sometimes cause winds to shift seasonally in certain regions. During the summer, the land heats more quickly than the ocean does. The warm air rises and is replaced by cool air from the ocean. Thus the wind moves landward. During the winter, the land loses heat more quickly than the ocean does, and the cool air flows away from the land. Thus the wind moves seaward. Such seasonal winds are called **monsoons.** They are strongest over the large landmass of Eurasia. For example, monsoons in southern Asia result from the heating and cooling of the northern Indian peninsula. In the summer, winds carry moisture to the land from the ocean, bringing heavy rainfall. In the winter, continental winds bring dry weather, sometimes even drought. Monsoon conditions also occur in eastern Asia and affect the tropical regions of Australia and East Africa.

SMALL-SCALE INVESTIGATION

Evaporation

Evaporation affects temperature. The converse is also true. You can demonstrate how temperature affects the rate of evaporation of water.

Materials

portable clamp lamp (or flexible-neck lamp) with an incandescent bulb; 3 small Petri dishes or watch glasses; 3 thermometers; 50-mL graduated cylinder; ring stand with 2 rings; clock or watch; meter stick; water

Procedure

1. On your own piece of paper, make a data table similar to the one shown here.
2. Assemble the ring stand on a table, with support rings at heights of 25 cm and 50 cm above the base. Position the lamp directly over the rings at a height of 75 cm.
3. Place a Petri dish or watch glass on the base of the stand, and place one on each of the two rings.
4. Lay a thermometer across each dish, and turn on the lamp. Wait 3 minutes, then read and record the temperature shown on each thermometer.

Dish	Temperature	Amount of water evaporated
1		
2		
3		

5. Remove the thermometers, and add 30 mL of water to each of the three dishes.
6. Make sure the dishes are lined up directly beneath the lamp, and keep the light on for 24 hours.
7. Turn off the lamp, and carefully pour the water from the first dish into the graduated cylinder and record any change in volume. Repeat this process for the other two dishes.

Analysis and Conclusions

1. At what distance from the lamp did the greatest amount of water evaporate? the least?
2. Explain the relationship between temperature and the rate of evaporation.
3. Explain why puddles of water dry out much more quickly in summer than they do in fall or winter.

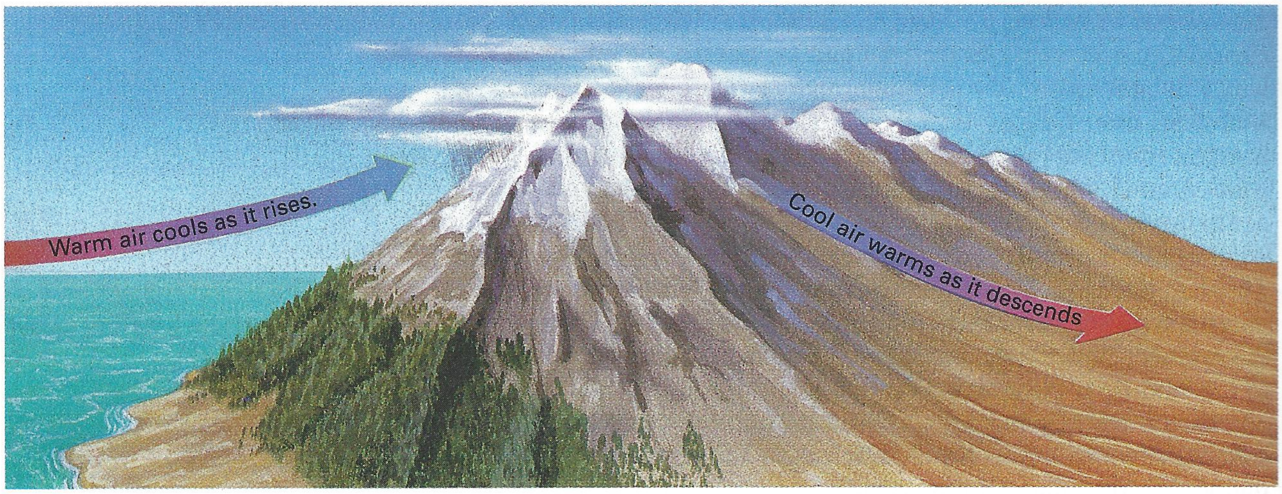


Figure 26–3. Air passing over a mountain range loses its moisture as it rises, expands, and cools. The dry air is compressed and warmed 1°C per 100 m as it descends on the other side of the mountain.

Topography

The topography, or shape of the land, also influences climate. The elevation, or height of landforms above sea level, produces distinct temperature changes. The average temperature decreases as altitude increases in the troposphere. For every 100 m increase in altitude, the average temperature decreases 0.7°C. Even along the equator, the peaks of high mountains are cold enough to be covered with snow.

Mountains influence the temperature and moisture content of passing air masses. When a moving air mass encounters a mountain range, it rises, adiabatically cools, and loses most of its moisture through precipitation. As the air descends on the other side of the range, it adiabatically warms (1°C every 100 m), compresses, and dries. Air flowing down mountain slopes, therefore, is usually warm and dry, as shown in Figure 26–3. One such wind is the **foehn** (FUHN)—a warm, dry wind that flows down the slopes of the Alps. Similar dry, warm winds that flow down the eastern slopes of the Rocky Mountains are called **chinooks.** A chinook wind can raise the air temperature very rapidly in a short period of time. In 1900, a chinook raised the temperature in a small town in Montana 17°C in three minutes. Would you expect to find more vegetation on the side of a mountain facing toward or away from the prevailing winds? Why?

Some winds that blow down mountain slopes are not warm. These winds have a source so high and cold that they remain cold even after heating. The **mistral,** which blows down from the snow-capped Alps to the Mediterranean Sea, is a strong, cold wind. Another cold mountain wind, the **bora,** blows from the mountains of Greece and the Balkan nations to the Adriatic Sea.

26.1 Section Review

1. List two factors that determine the amount of solar energy that an area receives. On what do these factors depend?
2. Does land or water heat more quickly? Why?
3. Compare monsoons and chinooks.