Atmosphere and Climate Change

CHAPTER 13

1 Climate and Climate Change
2 The Ozone Shield
3 Global Warming

READING WARM-UP

Before you read this chapter, take a few minutes to answer the following questions in your EcoLog.

1. What do you think are the main factors that determine the weather in the area where you live?

2. Why do you think the warming of the Earth by gases such as water vapor, carbon dioxide, methane, and nitrous oxide is called the greenhouse effect?

The climate on Earth can be very extreme. This satellite image of Hurricane Fran was taken before it struck the coastline of North Carolina in early September 1996.
Weather is the state of the atmosphere at a particular place at a particular moment. Climate is the long-term prevailing weather conditions at a particular place based upon records taken. To understand the difference between weather and climate, consider Seattle, Washington, and Phoenix, Arizona. These two cities may have the same weather on a particular day. For example, it may be raining, warm, or windy in both places. But their climates are quite different. Seattle’s climate is cool and moist, whereas Phoenix’s climate is hot and dry.

What Factors Determine Climate?
Climate is determined by a variety of factors. These factors include latitude, atmospheric circulation patterns, oceanic circulation patterns, the local geography of an area, solar activity, and volcanic activity. The most important of these factors is distance from the equator. For example, the two locations shown in Figure 1 have different climates mostly because they are at different distances from the equator.

Objectives
- Explain the difference between weather and climate.
- Identify four factors that determine climate.
- Explain why different parts of the Earth have different climates.
- Explain what causes the seasons.

Key Terms
- climate
- latitude
- El Niño
- La Niña

Figure 1 ▶ At left is Trunk Bay on the island of St. John in the U.S. Virgin Islands, which is located near the equator. Below is a photograph of the Antarctic Peninsula.
Latitude

The distance from the equator measured in degrees north or south of the equator is called latitude. The equator is located at 0° latitude. The most northerly latitude is the North Pole, at 90° north, whereas the most southerly latitude is the South Pole, at 90° south.

Low Latitudes  Latitude strongly influences climate because the amount of solar energy an area of Earth receives depends on its latitude. More solar energy falls on areas near the equator than on areas closer to the poles, as shown in Figure 2. The incoming solar energy is concentrated on a small surface area at the equator.

In regions near the equator, night and day are both about 12 hours long throughout the year. In addition, temperatures are high year-round, and there are no summers or winters.

High Latitudes  In regions closer to the poles, the sun is lower in the sky. This reduces the amount of energy arriving at the surface. In the northern and southern latitudes, sunlight hits the Earth at an oblique angle and spreads over a larger surface area than it does at the equator. Yearly average temperatures near the poles are therefore lower than they are at the equator. The hours of daylight also vary. At 45° north and south latitude, there is as much as 16 hours of daylight each day during the summer and as little as 8 hours of sunlight each day during the winter. Near the poles, the sun sets for only a few hours each day during the summer and rises for only a few hours each day during the winter. Thus the yearly temperature range near the poles is very large.

Figure 2  At the equator, sunlight hits the Earth vertically. The sunlight is concentrated on a smaller surface area at the equator. Away from the equator, sunlight hits the Earth at an oblique angle and spreads over a larger surface area.
Atmospheric Circulation

Three important properties of air illustrate how air circulation affects climate. First, cold air sinks because it is denser than warm air. As cold air sinks, it compresses and warms. Second, warm air rises. It expands and cools as it rises. Third, warm air can hold more water vapor than cold air can. Therefore, when warm air cools, the water vapor it contains may condense into liquid water to form rain, snow, or fog.

Solar energy heats the ground, which warms the air above it. This warm air rises, and cooler air moves in to replace it. This movement of air within the atmosphere is called wind. Because the Earth rotates, and because different latitudes receive different amounts of solar energy, the pattern of global atmospheric circulation shown in Figure 3 results. This circulation pattern determines Earth’s precipitation pattern. For example, the intense solar energy striking the Earth’s surface at the equator causes the surface as well as the air above the equator to become very warm. This warm air can hold large amounts of water that evaporate from the equatorial oceans and land. As this warm air rises, however, it cools, which reduces some of its ability to hold water. Thus, areas near the equator receive large amounts of rain.

Deserts

Air that is warmed at the equator rises and flows northward and southward to 30° north and south latitude, where it sinks. The sinking air is compressed and its temperature increases. As the temperature of the air increases, the air is able to hold a larger quantity of water vapor. Evaporation from the land surface is so great beneath these sinking warm air masses that little water returns to Earth in the form of precipitation. Thus, most of the Earth’s deserts lie at 30° north and south latitude.

Figure 3 ► Three belts of prevailing winds occur in each hemisphere.
**Global Circulation Patterns** Cool air normally sinks, but cool air over the equator cannot descend because hot air is rising below the cool air. This cool air rises and is forced away from the equator toward the North and South Poles. At about 30° north latitude and 30° south latitude, air begins to accumulate in the upper atmosphere. Some of this air sinks back to the Earth’s surface and becomes warmer as it descends. The warm, dry air moves across the surface and causes water to evaporate from the land below, creating dry conditions.

Air descending at 30° north latitude and 30° south latitude either moves toward the equator or flows toward the poles. Air moving toward the poles warms while it is near Earth’s surface. At about 60° north latitude and 60° south latitude, this air collides with cold air traveling from the poles. The warm air rises. When this rising air reaches the top of the troposphere, a small part of this air returns back to the circulation pattern between 60° and 30° north latitude and 60° and 30° south latitude. However, most of this uplifted air is forced toward the poles. Cold, dry air descends at the poles, which are essentially very cold deserts.

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**Ice Cores: Reconstructing Past Climates**

Imagine having at your fingertips a record of Earth’s climate that extends back several thousand years. Today, ice cores are providing scientists an indirect glimpse of Earth’s climate history. These ice cores have been drilled out of ice sheets thousands of meters thick in Canada, Greenland, and Antarctica. How do scientists reconstruct the climate history of our planet from ice cores? As snow falls to Earth, the snow carries substances that are in the air at the time. If snow falls in a cold climate where it does not melt, the snow turns to ice because of the weight of the snow above it. The substances contained in snow, such as soot, dust, volcanic ash, and chemical compounds, are buried year after year, one layer on top of another. Air between snowflakes and grains becomes trapped in bubbles when the snow is compacted. These bubbles of air can provide information about the composition of the atmosphere over time.

How do scientists date ice cores? Scientists have learned to recognize that differences exist between snow layers that are deposited in the winter and in the summer. Knowing these differences allows scientists to count and place dates with the annual layers of ice. Scientists can discover important events in Earth’s climate history by studying ice cores. For example, volcanoes produce large quantities of dust, so a history of volcanic
**Prevailing Winds** Winds that blow predominantly in one direction throughout the year are called *prevailing winds*. Because of the rotation of the Earth, these winds do not blow directly northward or southward. Instead these winds are deflected to the right in the Northern Hemisphere and to the left in the Southern Hemisphere.

Belts of prevailing winds are produced in both hemispheres between 30° north and south latitude and the equator. These belts of wind are called the *trade winds*. The trade winds blow from the northeast in the Northern Hemisphere and from the southeast in the Southern Hemisphere.

Prevailing winds known as the westerlies are produced between 30° and 60° north latitude and 30° and 60° south latitude. In the Northern Hemisphere, these westerlies are southwest winds, and in the Southern Hemisphere, these westerlies are northwest winds, as shown in **Figure 4**. The polar easterlies blow from the poles to 60° north and south latitude.

**Figure 4** The red areas indicate fires around Sydney, Australia, the smoke from which shows the direction the wind is blowing.

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**CRITICAL THINKING**

1. **Expressing Viewpoints** How might information about past carbon dioxide concentrations on Earth contribute to scientists’ understanding of present carbon dioxide concentrations?

2. **Applying Ideas** What information, besides what is mentioned in this Case Study, might scientists learn about Earth’s climatic history from ice cores?
Figure 5 ▶ The El Niño-Southern Oscillation (ENSO) is a periodic change in the location of warm and cold water masses in the Pacific Ocean. The phase of ENSO in which the eastern Pacific surface water is warm is called El Niño, and the phase where it is cool is called La Niña.

Figure 6 ▶ This satellite image shows the cool phase of the Pacific Decadal Oscillation. During this phase, cooler water (purple and blue) can be seen in the eastern Pacific Ocean. During the warm phase, the situation is reversed.

Oceanic Circulation Patterns

Ocean currents have a great effect on climate because water holds large amounts of heat. The movement of surface ocean currents is caused mostly by winds and the rotation of the Earth. These surface currents redistribute warm and cool masses of water around the planet. Some surface currents warm or cool coastal areas year-round.

Surface currents affect the climate in many parts of the world. Here, we will only discuss surface currents that change their pattern of circulation over time.

El Niño—Southern Oscillation  El Niño (el NEEN yoh) is the name given to the short-term (generally 6- to 18-month period), periodic change in the location of warm and cold water masses in the Pacific Ocean. During an El Niño, winds in the western Pacific Ocean, which are usually weak, strengthen and push warm water eastward. Rainfall follows this warm water eastward and produces increased rainfall in the southern half of the United States and in equatorial South America. El Niño causes drought in Indonesia and Australia. During La Niña (lah NEEN yah), on the other hand, the water in the eastern Pacific Ocean is cooler than usual. El Niño and La Niña are opposite phases of the El Niño–Southern Oscillation (ENSO) cycle. El Niño is the warm phase of the cycle, and La Niña is the cold phase, as illustrated in Figure 5.

Pacific Decadal Oscillation  The Pacific Decadal Oscillation (PDO), shown in Figure 6, is a long-term, 20- to 30-year change in the location of warm and cold water masses in the Pacific Ocean. PDO influences the climate in the northern Pacific Ocean and North America. It affects ocean surface temperatures, air temperatures, and precipitation patterns.
Topography
Mount Kilimanjaro, a 5,896 m extinct volcano in Tanzania, is located about 3° south of the equator, but snow covers its peak year-round. Kilimanjaro illustrates the important effect that height above sea level (elevation) has on climate. Temperatures fall by about 6°C (about 11°F) for every 1,000 m increase in elevation.

Mountains and mountain ranges also influence the distribution of precipitation. For example, consider the Sierra Nevada mountains of California. Warm air from the Pacific Ocean blows east, hits the mountains, and rises. As the air rises, it cools, which causes it to rain on the western side of the mountains. By the time the air reaches the eastern side of the mountains, it is dry. This effect is known as a rain shadow, as shown in Figure 7.

Other Influences on Earth’s Climate
Both the sun and volcanic eruptions influence Earth’s climate. At a solar maximum, shown in Figure 8, the sun emits an increased amount of ultraviolet (UV) radiation. UV radiation produces more ozone. This increase in ozone warms the stratosphere. The increased solar radiation can also warm the lower atmosphere and surface of the Earth a little.

In large-scale volcanic eruptions, sulfur dioxide gas can reach the upper atmosphere. The sulfur dioxide gas, which can remain in the atmosphere for up to three years, reacts with smaller amounts of water vapor and dust in the stratosphere. This reaction forms a bright layer of haze that reflects enough sunlight to cause the global temperature to decrease.
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Because of the Earth’s tilt, the angle at which the sun’s rays strike the Earth changes as the Earth orbits the sun. This change in angle accounts for seasonal climate differences around the world.

1. Explain the difference between weather and climate.
2. Name four factors that determine climate.
3. Explain why different parts of the Earth have different climates.
4. Explain what causes the seasons.

CRITICAL THINKING
5. Making Comparisons  At the equator, there are no summers or winters, only wet and dry seasons. Based on what you have learned about atmospheric circulation patterns, why do you think there are no seasons? Write a paragraph that explains your answer.

6. Analyzing Processes  If the Earth were not tilted in its orbit, how would the climates and seasons be affected at the equator and between 30° north and south latitude?