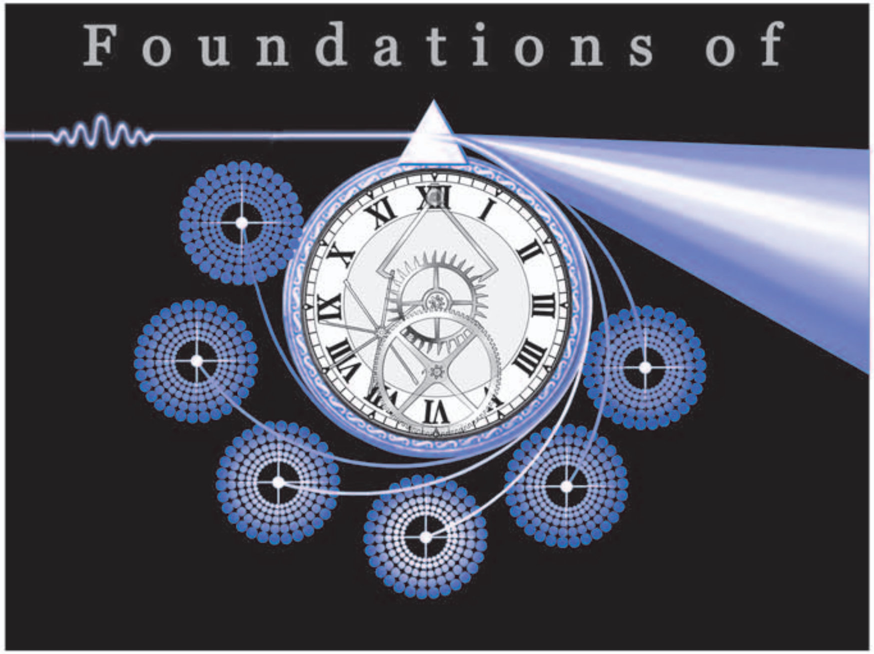

Physical Science

with Earth and Space Science

Tom Hsu, Ph.D.

FIRST EDITION
CPO Science
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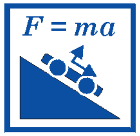
Unit 1: Forces and Motion



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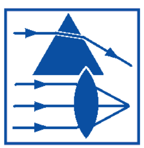
Unit 5: Light and Optics



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UNIT 9

Energy in the Earth System

Chapter 27

Weather and Climate

Why does the temperature on Earth vary from place to place? What causes wind and ocean currents? How do you read a weather map? In this chapter you will find answers to these and other questions about weather, storms, and climate.

Investigations for Chapter 27

27.1	Variations in Earth's Heating and Cooling	*How can we demonstrate the seasonal changes in incoming solar radiation?*

In this Investigation you will use a globe, solar cell, and flashlight to model the seasonal changes in intensity of solar radiation due to the tilt of Earth's axis.

27.2	Global Winds and Currents	*How are currents, temperature, and ocean salt related?*

In this Investigation you will model how water temperature and saltiness change the density of ocean currents. These changes cause currents to float, sink, plunge to the ocean bottom and jet to the surface.

27.3	Weather patterns	*How is relative humidity measured?*

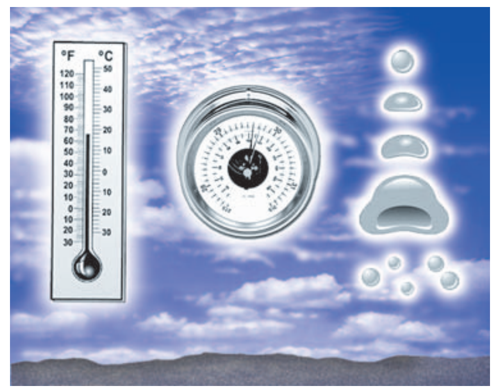
In this Investigation you will make and use a sling psychrometer to measure and graph water content in the atmosphere.

27.4	Storms	*How does Doppler radar work?*

In this Investigation you will learn how Doppler radar works and how it is used to track storms and other weather events.

27.5	Weather and Climate	*How do zoos model climates?*

In this Investigation you will research an animal living in a particular biome and design a suitable zoo habitat for the animal.



Learning Goals

In this chapter, you will:

- ✔ Learn how Earth's rotation, Earth's axial tilt, and distance from the equator cause variations in the heating and cooling of Earth.
- ✔ Learn how the heating of Earth's surface and atmosphere by the sun causes convection cycles in the atmosphere and oceans, producing winds and ocean currents.
- ✔ Learn about tools meteorologists use to predict weather, and how to read a weather map.
- ✔ Make and test your own weather instrument.
- ✔ Model a doppler radar system.
- ✔ Learn about the physical features that interact to form the climate of each of six important land biomes.

Vocabulary

air mass	El Niño-Southern Oscillation	longitude	temperate forest
biome	grassland	polar easterlies	temperature inversion
cold front	gyres	prevailing westerlies	trade winds
Coriolis effect	isobars	stratiform cloud	tropical rainforest
cumuliform cloud	jet stream	stratocumulus cloud	tundra
desert	latitude	taiga	warm front

27.1 Variations in the Heating and Cooling of Earth

Why isn't Earth evenly heated by the sun? In this section you will learn how the heating and cooling of Earth is affected by several factors. These include Earth's tilt and position in space, global wind patterns, ocean currents, and the high specific heat of water. To understand this complex system, you will build on what you know about radiation, conduction, convection, and specific heat.

Figure 27.1: *This image shows infrared radiation emitted by cloud tops, land, oceans, ice, or snow. The coldest areas (usually high clouds in the atmosphere) appear the brightest white. NOAA photo.*

Identifying locations on Earth

Satellite data is used to map patterns of heating and cooling

Much of the data that scientists collect about patterns of heating and cooling on Earth comes from satellite images (Figure 27.1). The National Oceanic and Atmospheric Administration (or NOAA) uses infrared photography to map how much heat is reflected or emitted from different areas of Earth each day. Scientists who analyze this data need a way to pinpoint locations on the infrared photographs of Earth. One common system is with a man-made grid of latitude and longitude lines (Figure 27.2).

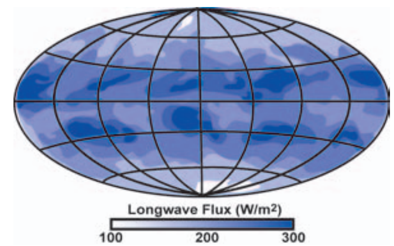
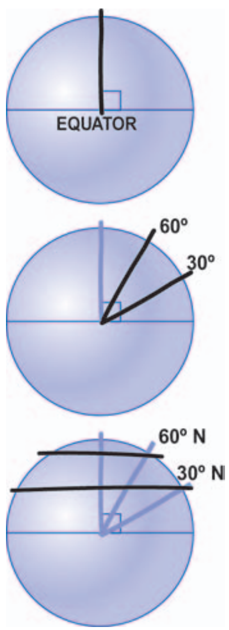


Figure 27.2: *Scientists use data from infrared photographs to map heat emitted from Earth's surface. NASA image.*

Latitude lines



Latitude lines measure distance from the equator. These lines run parallel to the equator and are labeled in degrees north or degrees south (Figure 27.3).

To figure out how the lines were originally labeled, draw a line on a globe from the north pole straight down to the equator. This line forms a 90-degree angle with the equator.

Next, draw 30- and 60-degree angles between the equator and the north pole.

Finally, draw lines parallel to the equator along these measured angles. These are the 30-degree north and 60-degree north latitude lines.

The same process is used to measure latitude in degrees south of the equator. You can find information about the latitude of a particular location by consulting an atlas or the Internet.

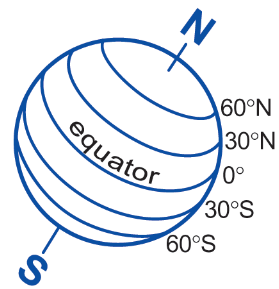


Figure 27.3: *Latitude lines.*

Longitude lines

Longitude lines run vertically from the north pole to the south pole. There are 360 equally-spaced longitude lines around the globe. The line that runs through Greenwich, England, is labeled 0 degrees longitude and is called the prime meridian. Lines *east* of the prime meridian are numbered from 1 to 179 degrees east, while lines *west* of the prime meridian are numbered from 1 to 179 degrees west. The 0- and 180-degree lines are not labeled east or west.

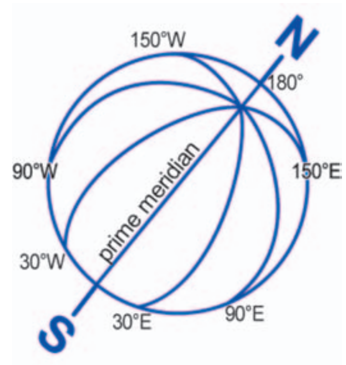
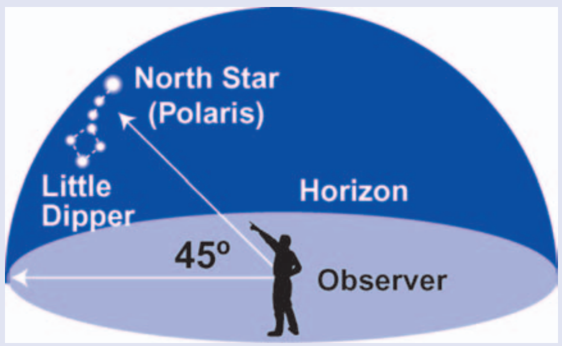


Figure 27.4: *Longitude lines.*

Latitude and longitude lines form a grid

Latitude and longitude lines form a grid that scientists use to locate various points on a satellite photo. This enables them to use the photos for climate research. For example, they can measure the spread of desert conditions across isolated parts of Africa, or compare the date each year when ice sheets melt in remote arctic locations.

Figure 27.5: *Latitude and longitude lines form a grid.*

> **Try this!**
>
> On a clear night, you can use the North Star to estimate your own latitude.
>
> The North Star is located at the end of the handle of the Little Dipper (the seven principal stars in the constellation Ursa Minor).
>
> Once you locate the North Star, point to it with one outstretched arm. Extend your other arm toward the horizon.
>
> 
>
>
> Have a friend use a protractor to estimate the angle formed by your two arms.
>
> The measure of the angle tells you your latitude. If the angle is 45 degrees, then you are located around 45° N latitude.

Temperature and latitude

Earth's temperature varies with latitude

In the northern hemisphere, we often associate "going south" with "getting warm." Birds, for example, fly south for the winter. States in the American South and Southwest are known as the Sunbelt. But in the southern hemisphere, the opposite is true. Birds fly north for the winter. The warmest part of Australia is the northern section. Generally, as latitude (or distance from the equator) increases, the amount of incoming solar radiation decreases.

At higher latitudes, solar radiation is less intense

The hottest part of Earth is near the equator, where the sun is closest to directly overhead year round. At the north and south poles, temperatures are much colder. To understand why, imagine shining a flashlight on a sheet of paper as in Figure 27.6. It makes a very bright, small spot. However, if the piece of paper is at an angle, the light is spread out over a larger spot and is less intense. The same thing happens to the sun's energy, which reaches the north and south poles at an angle. There, sunlight is spread out and thus less intense, while at the equator, the sunlight is direct and more intense (Figure 27.7). As a result, the average yearly temperature at the equator is 27°C (80°F), while at the north pole it is -18°C (0°F).

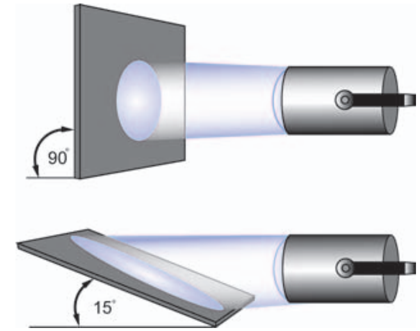


Figure 27.6: *If you hold a piece of paper at a 90-degree angle to a lamp and then at a 15-degree angle, where does the light have a larger area? Where is the light brightest and hottest?*

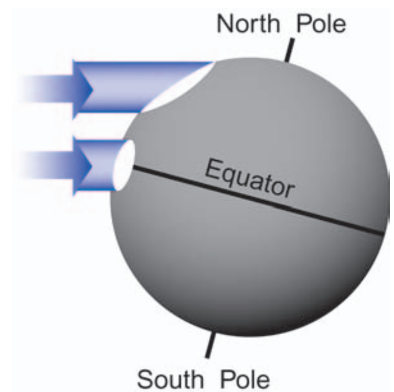
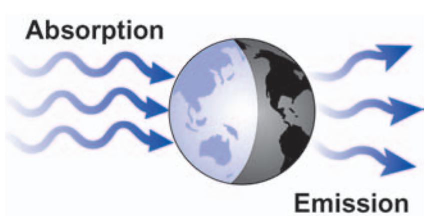


Figure 27.7: *This is how the sun's radiation reaches Earth. Sunlight is more intense at the equator.*

Temperature and Earth's rotation

Daytime heating and nighttime cooling



As Earth rotates, the portion of the globe facing the sun absorbs more solar radiation than it emits, and warms. Earth constantly emits some of the absorbed energy as infrared radiation. This emission of heat cools the dark side of the planet. Have you ever noticed that clear nights are often cooler than cloudy ones? That's because on a clear night, more of the emitted radiation escapes into space. Clouds absorb some of the radiation emitted by Earth's surface, keeping temperatures near the ground a little warmer.

Daytime heating in Arctic regions

You may know that in summer, the arctic regions experience daylight almost around the clock. With all that time to absorb heat, why don't they get very warm? There are two reasons. First, the sunlight is not intense, and second, snow reflects a great deal of the incoming radiation. Only a small percentage is absorbed.

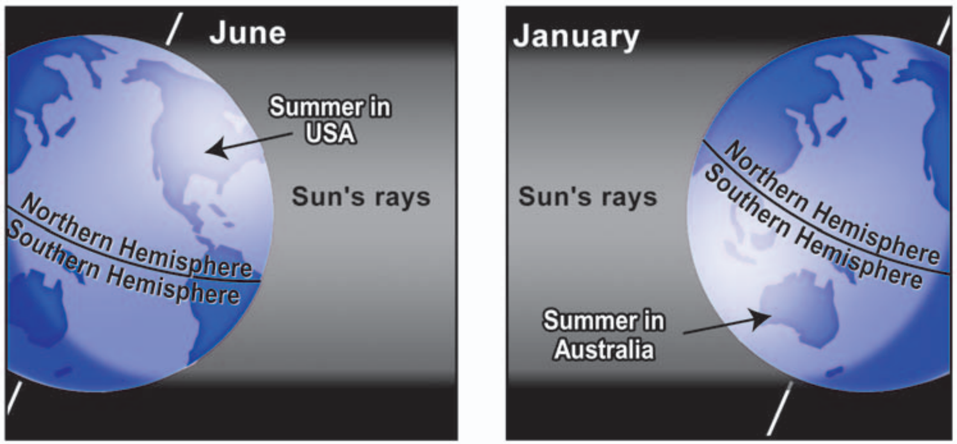
Why does Earth have seasons?

A common misunderstanding

Why is it cold in the winter and hot in the summer? Many people believe the answer is that Earth is closest to the sun in summer and farthest away in winter. In reality, distance from the sun has very little to do with seasons. Earth's orbit is almost circular. The difference between Earth's maximum and minimum distance from the sun is too small to cause changes in the seasons.

Earth's tilt causes seasons

The reason we have seasons is that Earth's axis is tilted at an angle. In January, the northern hemisphere is tilted away from the sun, and the southern hemisphere is tilted toward the sun. Rays of sunlight reaching the northern hemisphere are more spread out and less intense than those reaching the southern hemisphere. As a result, it is winter in the northern hemisphere and summer in the southern hemisphere.



As Figure 27.8 shows, in June, Earth has traveled halfway around its orbit and is on the opposite side of the sun. Now the northern hemisphere is tilted toward the sun. It receives more direct solar energy, and experiences summer conditions. The southern hemisphere is tilted away from the sun in June, and experiences winter.

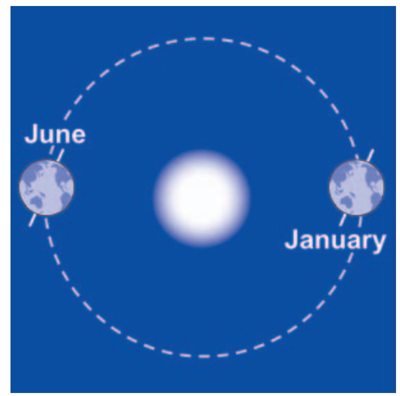


Figure 27.8: *Because of the tilt of Earth's axis, in June the northern hemisphere is tilted toward the sun. In January, the southern hemisphere is tilted toward the sun.*

The cover colorfully combines illustrations of the forces of nature studied in the various fields of the physical sciences. Here, the "evolving tapestry of conceptual thinking" begins with water. Water droplets dance with the planets including our own watery planet and Saturn with its icy rings. Water reappears in the combustion reaction of methane, as the substance on which plants depend, as pounding waves, and, on the back cover, as the darkening clouds of a coming storm. From this cycle of water, a modern bicycle rolls into a graphical interpretation of white light split into its rainbow of wavelengths and a fiber optic. You may lose yourself in many of these images which represent hundreds of years of scientific and technological innovation. Nevertheless, that our innovations are inextricably woven into and from the natural world is illustrated by the images of Earth and the spiral connection between the DNA helix and a bicyclist ever-moving forward. On the back cover, images from physics, chemistry, and earth and space science move around a chambered nautilus seen through the windows of the Golden Rectangle. We at CPO Science with Bruce Holloway, the spirited illustrator of the cover, hope these images will inspire your interest and excitement about the discovery of science.

The CPO Science Development Team

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