CHAPTER 4

Seasonality

Seasonal variations represent the most extreme short-term changes in weather for a location. This is especially true in high latitude regions, which undergo dramatic shifts in temperature between winter and summer. In many locations, significant changes to the precipitation regime occur seasonally as well. Tropical locations are not as affected by seasonal temperature changes but may experience large transformations in precipitation patterns throughout the months of the year. In many locales, such modifications represent the only form of seasonality in the climate system. Because it is positioned between the high and tropical latitudes, moderate changes in temperature are felt throughout the year in Louisiana. Precipitation shows little seasonality compared to other locations.

What causes such widespread alterations in the state of the atmosphere? To answer this question, the relationship between the earth and the Sun must be explored, particularly the Earth's orbit and its axis of rotation.

Influences of Orbit and Earth's Shape

It may be surprising to hear that as the Earth orbits the Sun, its path does not form a circle nor is its elliptical path perfectly centered on the Sun. The Earth–Sun distance varies from about 91.4 million miles (147 million km) on or about 3 January (termed *perihelion*) to about 94.4 million miles (152 million km) on or about 4 July (termed *aphelion*), with an average distance throughout the year of 93 million miles (150 million km). Many people in the northern hemisphere are startled to learn that the Earth is closest to the Sun in January and farthest from the Sun in July. Those living in Louisiana can be thankful that the state is farthest from the Sun in July, because otherwise the summers would be even hotter than they are now! Indeed, because of the discrepancy between the timing of perihelion/aphelion and the observed temperatures throughout the year, distance from the Sun only has a small influence in creating seasonal temperature variations. If the Earth–Sun distance were the controlling influence, then January would be summer in both the northern and southern hemispheres, and July would be winter in both hemispheres. Obviously, other factors are more important in producing the pattern of seasons that exists on Earth.

Seasonality and Day Length

To understand why seasons and variations in day length occur throughout the course of a year, it's important to focus first on a few concepts about the Earth's rotation and tilt on its axis (**Figure 4.1**). Earth rotates on its axis from west to east (that is, counterclockwise when viewed from above the North Pole), making one complete rotation (360° of longitude) every 24 hours, or 15° of longitude every hour. The Earth is divided into 24 time zones that are approximately 15° of longitude in width, with the "official" time being set one hour apart

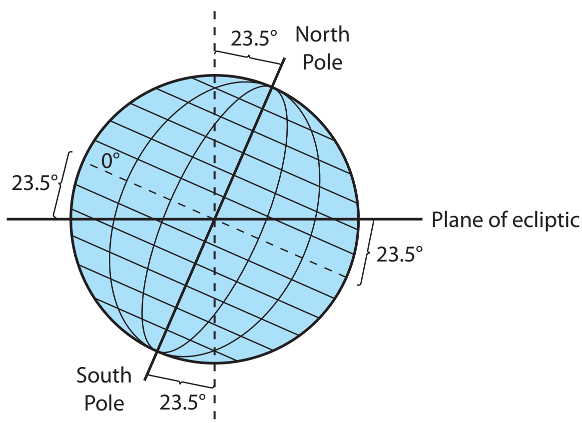

Figure 4.1. Earth' tilt is 23.5 degrees from a perpendicular ling through the plane of the ecliptic.

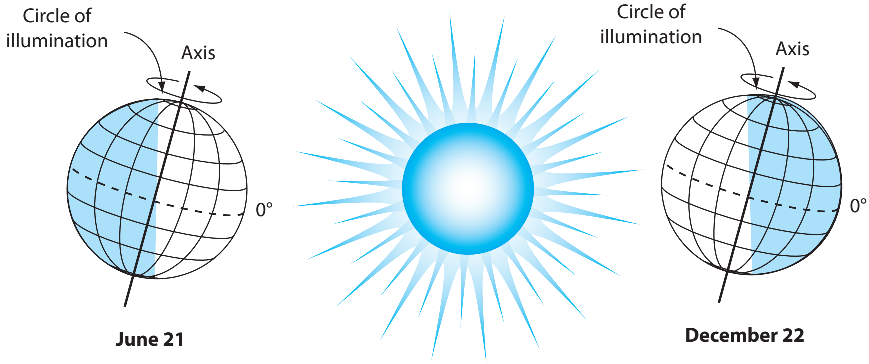

Figure 4.2. Unequal division of lines of latitude into day and night by the circle of illumination with change in orbital position.

in each adjacent time zone. At any given time in the day, one line of longitude is receiving its most direct rays of sunshine for that day, and the clocks at every location within that longitude's time zone are set to noon. All clocks at the n^{th} time zone away from the one with the longitude line receiving direct sunshine are set at n hours before or after noon. Some longitudes are so far from these direct rays that they are in darkness. Exactly one-half of Earth is illuminated at any given time. The circle of illumination is the boundary (as viewed from space) that separates the illuminated and dark halves of Earth. Because the Earth is constantly rotating, the circle of illumination passes through constantly changing parts of the Earth. Local sunrise and sunset occur when the circle of illumination passes through a location.

Figure 4.2 shows that the circle of illumination divides each line of latitude into "daylight sections" and "nighttime sections" through the course of a year. At any given time in June, more than half of any line of latitude in the northern hemisphere is in daylight, but in December, more than half of any line of latitude in the northern hemisphere is in darkness (**Figure 4.3**). The farther away from the North Pole the line of latitude is located, the greater the difference in day length from June to December. Notice also that in June, while more of the northern hemisphere at any line of latitude is in daylight than darkness, more of the southern hemisphere at any line

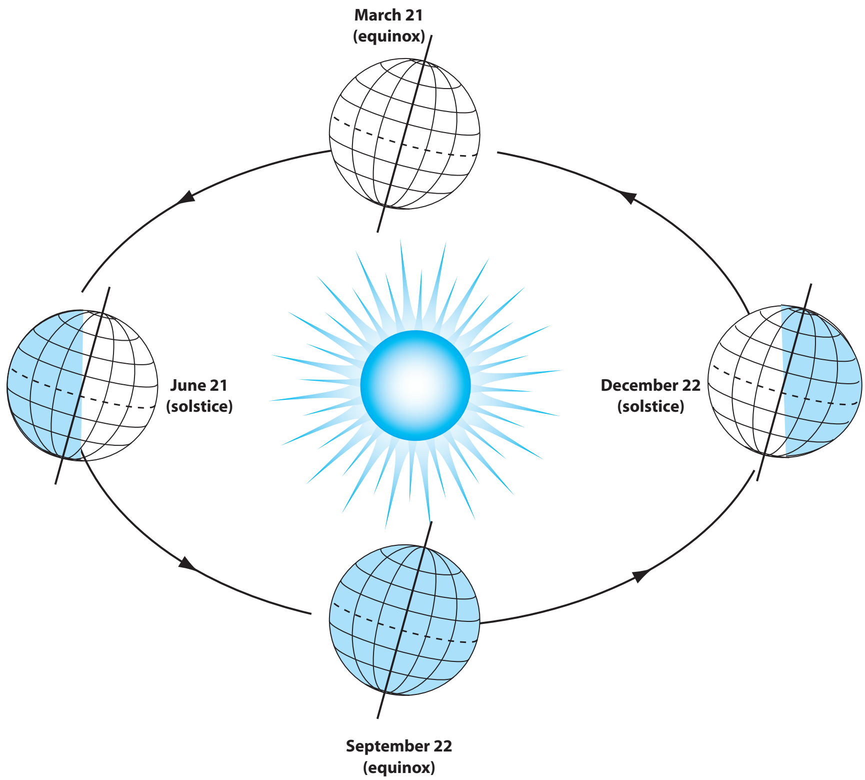

Figure 4.3. Relationships between Earth's axis and the circle of illumination during the equinoxes and solstice.

of latitude is in darkness than daylight. So summer in the northern hemisphere is winter in the southern hemisphere, and vice versa. To better understand why this is the case, look at Earth's rotational axis. The axis has a tilt of 23.5° from the vertical. But what is the definition of *vertical*?

To address this question, start with the *plane of the ecliptic*, which represents the imaginary geometric plane that cuts through both the Earth and Sun as the Earth revolves around the Sun. A line perpendicular to the plane of the ecliptic that cuts through the Earth's center would not pass through the poles. Instead, a 23.5° angle would be formed between such a perpendicular line—the Earth's center—and a line the passes through both of the Earth's poles (the axis). The Earth is tilted on its axis such that the axis of rotation lies 23.5° from the line perpendicular to the plane of the ecliptic. Likewise, the equator is tilted 23.5° from the plane of the ecliptic.

Regardless of the time of year (that is, no matter where the Earth is in its orbit around the Sun), the Earth's axis points in the same direction and remains tilted at 23.5°. In the northern hemisphere, the axis of rotation (the North Pole) is pointed toward the star Polaris (also known as the North Star). The Earth's orbit is so small in comparison to its distance to Polaris that it essentially points to Polaris year-round. At the North Pole at any time of the year, Polaris can be seen directly overhead. From any other point in the northern hemisphere, Polaris can be used to tell which direction is north, because it sits directly "over" the North Pole. But people in the southern hemisphere can't use Polaris to tell the direction of north because the star is blocked by the wide part of the Earth. Instead, the south polar axis points toward a series of stars known as the Southern Cross; those living in the southern hemisphere can identify the direction of south (but not north) by looking at the stars.

In truth, the shape of the Earth's orbit, the axial orientation, and angle of tilt all have varied through geologic time. This variance is believed to contribute to long-term global climatic changes on the order of tens of thousands of years. However, on time scales important in the context of contemporary weather and climate, the orbit and axis remain essentially constant.

Because of the consistency of the Earth's tilt as it orbits around the Sun, the proportion of each line of latitude inside the circle of illumination changes throughout the year. This means that any line of latitude in the northern hemisphere is in daylight for more hours than it is in darkness in the summer half of the year, and it is in darkness for a longer period of time than it is in daylight during the winter half of the year (Figure 4.3). This directly causes seasonality. With more daylight hours comes a longer period of time to heat up the surface. The only line of latitude that has unchanging day length throughout the year is the equator.

To better demonstrate the concepts of day length and Sun angle, consider four significant days of the year. The first is on or about June 21, which is known as the *summer solstice* in the northern hemisphere and the *winter solstice* in the southern hemisphere (more appropriately termed the *June solstice*; Figure 4.3). On that day, the position of the Earth in its orbit relative to the Sun is such that the northern hemisphere's axis is pointing maximally toward the Sun (Figure 4.3), even though the axis itself doesn't move through the course of the year. It is clear from Figure 4.3 that more than half of the 30°N line of latitude is the daylight sector of the planet while less than half of that parallel of latitude is in darkness. The farther north the line of latitude, the greater the percentage of that parallel is in daylight on June 21. The number of daylight hours thus exceeds the number of nighttime hours in the northern hemisphere during the summer half of the year (centered on June 21), because any line of latitude in the northern hemisphere is in daylight for a longer period of time than it would be in darkness as the Earth rotates on its axis. In the northern hemisphere, day length increases from the equator to the Arctic Circle (66.5°N) as more of each line of latitude resides within the illuminated half of Earth as latitude increases. So, length of daylight hours increases from 12 hours at the equator to 24 hours at the Arctic Circle. Every location within the Arctic Circle receives constant daylight through the 24-hour period on June 21.

Conversely, at any line of latitude in the southern hemisphere in the half of the year centered on June 21, nighttime hours exceed daytime hours (Figure 4.3). In the southern hemisphere, length of daylight hours during that time of year decreases from the equator to the Antarctic Circle (66.5°S) as the lines of latitude increasingly reside within the dark half of Earth as one increases in latitude. There, daylight decreases from 12 hours at the equator to zero at the Antarctic Circle. Because the equator is neither in the northern nor southern hemisphere, days and nights are of equal length on June 21 (as on every other day of the year).

Perhaps more importantly, because of the relationship between the Earth's axis and the position of the Sun on 21 June, the direct rays of the Sun fall on 23.5°N latitude—the most poleward extent throughout the year. This line of latitude is called the *Tropic of Cancer*. This means that on 21 June, the most intense rays of the Sun fall only slightly south of Louisiana.

A second important day of the year from an astronomical perspective is 22 September, again with slight variation in when the exact day occurs due to leap year. That day is termed the *autumnal equinox* in the northern hemisphere and the *spring* (or *vernal*) *equinox* in the southern hemisphere. On that date, the position of the Earth in its orbit is such that its axis is neither pointing toward nor away from the Sun, in either hemisphere (Figure 4.3). Every location on Earth thus has the same day length: 12 hours. In fact, the name *equinox* refers to "equal night." As on every other day of the year, however, not every location will receive the same intensity of radiation. The direct rays of the Sun shine along the equator on 22 September, and the solar angle decreases with increasing latitude, which causes greater atmospheric attenuation with increasing latitude. Local factors such as cloudiness also play a role. The only way to see the Sun directly overhead (90°) on 22 September is to be at the equator at noon local time (Figure 4.3).

By 22 December, the Earth is positioned in its orbit such that the axis is pointed maximally away from the Sun in the northern hemisphere and maximally toward the Sun in the southern hemisphere (Figure 4.3). That day is called the *winter solstice* in the northern hemisphere and the *summer solstice* in the southern hemisphere (generically, the *December solstice*). Conditions are exactly the same as those that occur on 21 June, but the hemispheres are reversed (Figure 4.3). Lines of latitude in the northern hemisphere have a decreasing length of daylight from equator to the Arctic Circle while in the southern hemisphere day length increases from equator to the Antarctic Circle.

On 22 December, the direct rays of the Sun fall on 23.5°S latitude, called the *Tropic of Capricorn*. Any location between the Tropic of Cancer and the Tropic of Capricorn receives the direct rays of the Sun at some point throughout the course of the year; these are said to lie in the *tropics*. Louisiana falls just outside the tropics but receives almost direct rays of sunshine on summer afternoons. Louisiana is said to have a *subtropical* climate.

A fourth important day through the year is 21 March, when exactly the same conditions occur as during the September equinox. Specifically, every location on Earth has virtually the same day length—12 hours—and the direct rays of the Sun fall on the equator. That day is referred to as the *spring* (or *vernal*) *equinox* in the northern hemisphere and the *autumnal equinox* in the southern hemisphere.

These relationships exist because of the changing relationship between Earth's axis of rotation and the position of the Sun as the Earth orbits the Sun. Because of these situations, significant differences in radiation are received at the surface during the course of a year, except near the equator. The differences in energy received in Louisiana are moderate; winter solar angles are much lower than those in summer, but they are still high enough to produce mild temperatures.