PART I: The Energy–Atmosphere System

Geosystems begins with the Sun and Solar System to launch the first of four parts. Our planet and our lives are powered by radiant energy from the star closest to Earth—the Sun. Each of us depends on many systems that are set into motion by energy from the Sun. These systems are the subjects of Part I.

Part I, The Energy–Atmosphere System, begins our study of Earth's physical and living systems. Radiant energy from the Sun provides the essential input that powers Earth systems. Because of Earth's curvature, the energy arriving from the Sun is unevenly distributed at the top of the atmosphere, creating energy imbalances over the surface. As a result, the equatorial region experiences surpluses, receiving more energy than it emits, and the polar regions experience deficits, emitting more energy than they receive. Seasonal change is another factor that affects the distribution of energy during the year.

Earth's atmosphere acts as an efficient filter, absorbing most harmful radiation and charged particles so that they do not reach Earth's surface. In the lower atmosphere the unevenness of daily energy receipt gives rise to global patterns of temperature and the circulation of wind and ocean currents, driving weather and climate. Humans and all other organisms depend on these interacting systems that are set into motion by energy from the Sun.

Solar Energy to Earth and the Seasons

2

Key Learning Concepts for Chapter 2

The following learning concepts help guide the student's reading and comprehension efforts. The operative words are in ***bold italics***. These are included in each chapter of *Geosystems*. The student is told: "After reading the chapter, you should be able to":

• ***Locate*** Earth in the Universe, ***describe*** the formation of our Solar System, and ***sketch*** Earth's orbital path around the Sun.

• ***Describe*** the Sun's operation, and ***explain*** the solar wind and the electromagnetic spectrum of radiant energy.

• ***Illustrate*** the interception of solar energy and its uneven distribution at the top of the atmosphere.

• ***Explain*** the concept of seasonality, and ***list*** the five reasons for Earth's seasons.

• ***Describe*** the Earth–Sun relationships during the annual march of the seasons.

Overview

Incoming solar energy arrives at the top of Earth's atmosphere, establishing the pattern of energy input that drives Earth's physical systems and influences our lives daily. This solar energy input to the atmosphere, combined with Earth's tilt and rotation, produces daily, seasonal, and annual patterns of changing daylength and Sun angle. The Sun is the ultimate energy source for most life processes in our biosphere.

The ultimate spatial inquiry is to know the location of Earth in the Universe. To properly set the stage for a course in the physical geography of Earth, internet videos, websites, and posters can be used to establish the location and place of our planetary home. Our immediate home is North America, a major continent on planet Earth, the third planet from a typical yellow star in a solar system. That star, our Sun, is only one of billions in the Milky Way Galaxy, which is one of billions of galaxies in the Universe.

This chapter examines the nature of the flow of energy and material from the Sun to the outer reaches of Earth's atmosphere. The top of the atmosphere is a measuring point to assess the arriving solar energy. Earth receives solar wind and electromagnetic radiation from the Sun.

Earth's orientation to the Sun varies seasonally. The chapter ends with a discussion of seasons and seasonal changes in insolation and daylength.

A list of key learning concepts begins the chapter and is used to organize the review section, with definitions, key terms and page numbers, and review questions grouped under each concept.

Outline Headings and Key Terms

The first-, second-, and third-order headings that divide Chapter 2 serve as an outline. The key terms and concepts that appear **boldface** in the text are listed here under their appropriate heading in ***bold italics***. All these highlighted terms appear in the text glossary. Note the check-off box (❑) so you can mark class progress.

The outline headings and terms for Chapter 2:

Geosystems Now: Searching for Earthlike Planets in the Goldilocks Zone

The Solar System

❑ ***Milky Way Galaxy***

Solar System Formation

❑ ***gravity***
❑ ***planetesimal hypothesis***

Measuring Distances in Space

❑ ***speed of light***
❑ ***perihelion***
❑ ***aphelion***

Solar Energy: From Sun to Earth

❑ ***fusion***

Solar Activity and Solar Wind

Sunspots

❑ ***sunspots***

Solar Wind Effects

❑ ***solar wind***
❑ ***magnetosphere***
❑ ***auroras***

Radiant Energy Flows

The Electromagnetic Spectrum

❑ ***electromagnetic spectrum***
❑ ***wavelength***
❑ ***electromagnetic spectrum***

Energy Emitted by Sun and Earth

❑ ***temperature***
❑ ***heat***

Incoming Energy at the Top of the Atmosphere

❑ ***thermopause***
❑ ***insolation***

Solar Constant

❑ ***solar constant***

Uneven Distribution of Insolation

❑ ***subsolar point***

Global Net Radiation

The Seasons

Seasonality

❑ ***Sun altitude***
❑ ***declination***
❑ ***daylength***

Reasons for Seasons

Revolution

❑ ***revolution***

Rotation

❑ ***rotation***
❑ ***axis***
❑ ***circle of illumination***

Tilt of Earth's Axis

❑ ***axial tilt***
❑ ***plane of the ecliptic***

Axial Parallelism

❑ ***axial parallelism***

Sphericity

Annual March of the Seasons

❑ ***Tropic of Cancer***
❑ ***Tropic of Capricorn***
❑ ***December solstice***
❑ ***Arctic Circle***
❑ ***March equinox***
❑ ***June solstice***
❑ ***Antarctic Circle***
❑ ***September equinox***

Seasonal Change in Sun Altitude
Seasonal Timing

The Human Denominator
Key Learning Concepts Review
Geospatial Analysis

GeoReports and Work It Out

GeoReport 2.1: The International Space Station in orbit above you
GeoReport 2.2: Why do we always see the same side of the Moon?

Work It Out 2.1: Daily Insolation Comparisons
Work It Out 2.2: Using a Solar Calculator
Work It Out 2.3: Consider Earth's Axial Tilt
Work It Out 2.4: Use the Analemma to Find the Subsolar Point

URLs Listed in Chapter 2

Kepler-186f:
www.nasa.gov/keplerbriefing0723

Solar System Simulator:
http://space.jpl.nasa.gov/

Sunspot Cycle and Auroral Activity:
www.solarscience.msfc.nasa.gov/SunspotCycle.shtml
www.gi.alaska.edu/auroraforecast

Chankillo Solar Observatory:
www.wmf.org/project/chankillo

Solar Calculator:
www.esrl.noaa.gov/gmd/grad/solcalc/

Analemma:
www.analemma.com

Annotated Chapter Review Questions

• ***Locate*** Earth in the Universe, ***describe*** the formation of our Solar System, and ***sketch*** Earth's orbital path around the Sun.

1. Other than planets, what are the components of our Solar System?
Our Solar System consists of our Sun, eight planets, over 100 moons, comets, asteroids, meteors, and four dwarf planets.

2. Briefly describe Earth's origin as part of the Solar System.
According to prevailing theory, our Solar System condensed from a large, slowly rotating, collapsing cloud of dust and gas called a nebula. As the nebular cloud organized and flattened into a disk shape, the early protosun grew in mass at the center, drawing more matter to it. Small eddies of accumulating material—the protoplanets—swirled at varying distances from the center of the solar nebula. The early protoplanets, or planetesimals, were located at approximately the same distances from the Sun that the planets are today. The beginnings of the Sun and the Solar System are estimated to have occurred more than 4.6 billion years ago. These processes are now observed as occurring elsewhere in the galaxy. Astronomers so far have observed almost two dozen stars with planets orbiting about them.

• ***Describe*** the Sun's operation, and ***explain*** the characteristics of the solar wind and the electromagnetic spectrum of radiant energy.

3. What is the sunspot cycle? At what stage was the cycle in the year 2014?
Over the last 300 years, sunspot occurrences have cycled fairly regularly, reaching a maximum every 11 years on average; however, the cycle may vary from 7 to 17 years. The current cycle, Sunspot Cycle 24, began with a minimum in 2008, followed by little activity until 2010, a maximum in 2013, and finally a second, slightly larger maximum in 2014.

4. Describe Earth's magnetosphere and its effects on the solar wind and the electromagnetic spectrum.
Earth's outer defense against the solar wind is the magnetosphere, which is a magnetic force field surrounding Earth, generated by dynamo-like motions within our planet. As the solar wind approaches Earth, the streams of charged particles are deflected by the magnetosphere and course along the magnetic field lines. The extreme northern and southern polar regions of the upper atmosphere are the points of entry for the solar wind stream.

5. Describe the various segments of the electromagnetic spectrum, from shortest to longest wavelength. What are the main wavelengths emitted by the Sun? Which wavelengths does Earth radiate to space?

See Figures 2.7 and 2.9. All the radiant energy produced by the Sun is in the form of electromagnetic energy and, when placed in an ordered range, forms part of the electromagnetic spectrum. The Sun emits radiant energy composed of 8% ultraviolet, X-ray, and gamma ray wavelengths; 47% visible light wavelengths; and 45% infrared wavelengths. Wavelengths emitted from the Earth back to the Sun are of lower intensity and composed mostly of infrared wavelengths.

• ***Illustrate*** the interception of solar energy and its uneven distribution at the top of the atmosphere.

6. If Earth were flat and oriented at right angles to incoming solar radiation (insolation), what would be the latitudinal distribution of solar energy at the top of the atmosphere?
The atmosphere is like a giant heat engine driven by differences in insolation from place to place (see Figure 2.13). If Earth were flat, there would be an even distribution of energy by latitude with no differences from place to place, and therefore little motion would be produced.

• ***Explain*** the concept of seasonality, and ***list*** the five reasons for Earth's seasons.

7. What phenomena define the concept of seasonality? How do these aspects of seasonality change during the year at 0° latitude? At 40°? At 90°?
Seasonality refers to both the seasonal variation in the Sun's position above the horizon and changing daylength during the year. Seasonal variations are a response to change in the Sun altitude, the angular difference between the horizon and the Sun. Seasonality also means a changing duration of exposure, or daylength, which varies during the year, depending on latitude. People living at the equator always receive equal hours of day and night, whereas people living along 40° N or S latitude experience about 6 hours of difference in daylight hours between winter and summer; those at 50° N or S latitude experience almost 8 hours of annual daylength variation. At the polar extremes, the range extends from a 6-month period of no insolation to a 6-month period of continuous 24-hour days.

8. Describe Earth's revolution and rotation and differentiate between them.
The structure of Earth's orbit and revolution about the Sun are described in Figures 2.3, 2.14, and GIA 2.1. Earth's *revolution* determines the length of the year and the seasons. Earth's *rotation*, or turning, is a complex motion that averages slightly less than 24 hours in duration. Rotation determines daylength, creates the apparent deflection of winds and ocean currents, and produces the twice-daily rise and fall of the ocean tides in relation to the gravitational pull of the Sun and the Moon. Earth's axis is an imaginary line extending through the planet from the geographic North Pole to the geographic South Pole.

• ***Describe*** the Earth–Sun relationships during the annual march of the seasons.

9. What are the solstices and equinoxes, and what is the Sun's declination at these times?
The solstices mark the dates when the Sun is over one of the tropics, the Tropic of Cancer on the June solstice and the Tropic of Capricorn on the December solstice. On the solstices, one pole receives 24 hours of light and the other pole receives 24 hours of darkness. The equinoxes mark the dates when the Sun crosses the equator and all locations on Earth receive 12 hours of daylight.

10. Describe seasonal conditions in the Northern Hemisphere on each solstice and equinox date.
See Figure GIA 2.1.
March Equinox
In the Northern Hemisphere, this is the vernal or spring equinox. The circle of illumination passes through both poles, so that all locations on Earth experience 12 hours of day and night. At the North Pole, the Sun rises for the first time since the previous September.
June Solstice
In the Northern Hemisphere, this is the summer solstice, marking the beginning of summer. Everything north of the Arctic Circle receives 24 hours of daylight.
September Equinox
In the Northern Hemisphere, this is the autumnal equinox, marking the beginning of autumn. As with the March equinox, days and nights are of equal length.
December Solstice
In the Northern Hemisphere, this is the winter solstice, marking the beginning of winter. Everything north of the Arctic Circle receives 24 hours of darkness.

GIA GEOquiz

1. Apply Concepts: Ushuaia, Argentina, is located at 55° S latitude near the southern tip of South America. Describe the march of the seasons for Ushuaia, explaining changes in daylength, Sun altitude, and the position of sunrise and sunset.
Day length would vary from 12 hours during the March equinox, to 16 hours during the June solstice, back to 12 hours during the September equinox, and finally down to 8 hours during the December solstice.

The angle of the Sun would vary from 35° above the horizon during the equinoxes, to 58.5° above the horizon during the June solstice, to 11.5° above the horizon during the December solstice.

The angle between the locations of sunrise and sunset would widen from the December solstice to the June solstice.

2. Explain: What happens to the amount of insolation an area on Earth's surface receives as you move away from the equator? What role does this play in producing the seasons?
While net radiation decreases as you move away from the equator, the seasonal difference in insolation also increases. This effect is more pronounced as you move closer to the Arctic and Antarctic Circles. The equator receives roughly the same amount of insolation year-round, while locations above the circles receive no insolation during their winters.

A large part of seasonality is daylength, which has a larger seasonal variation with increasing latitude. The equator has 12 hours of daylight each day, while the poles have a 24-hour difference between summer to winter.

Work It Out

Work It Out 2.1: Daily Insolation Comparisons

1. How much insolation arrives over the North Pole (90° N) in June?
Approximately 500 W/m^2.

2. How much insolation arrives over the equator in June?
Approximately 400 W/m^2.

3. Calculate the difference in energy receipt in June for the two locations.
Approximately 100 W/m^2.

4. In June, daylength at the North Pole is 24 hours and daylength at the equator is 12 hours. Given that the length of daylight in June is twice as long at the North Pole (24 hours) as at the equator (12 hours), explain why the insolation difference is only 100 W/m^2/day. (Use Figure 2.11 to help your thinking.)
Because of the curvature of Earth's surface, different locations receive sunlight at varying angles. The North Pole does receive 24 hours of light, which equals 21 W/m^2/hr, but that light is less concentrated than the energy received at the equator. The equator receives only 12 hours of light, but each hour equals 33 W/m^2/hr.

Work It Out 2.2: Using a Solar Calculator

1. What is the solar declination on your selected date? What does it mean if the declination has a negative value?
Personal answers. Negative declination numbers mean the Sun is below the horizon.

2. Try changing the date to 6 months ahead. How has the solar declination changed?
Personal answers.

Work It Out 2.3: Consider Earth's Axial Tilt

1. What do you think the effect on Earth's seasons would be
• If the tilt of the axis was decreased?
• If the tilt was increased a little?
• If Earth was lying on its side?
If the tilt of the axis was decreased, seasonality would decrease; if the tilt was increased a little, seasonality would increase a little. Hypothetically, if Earth were tilted on its side, with its axis parallel to the plane of the ecliptic, we would experience a maximum variation in seasons worldwide. In contrast, if Earth's axis were perpendicular to the plane of its orbit—that is, with no tilt—we would experience no seasonal changes, with something like a perpetual spring or fall season, and all latitudes would experience 12-hour days and nights.

2. What if Earth's orbit was more circular as opposed to its present elliptical shape?
If Earth's orbit was more circular, the slight difference in January and July insolation would decrease.

Work It Out 2.4: Use the Analemma to Find the Subsolar Point

1. What is the location of the subsolar point on your birthday?
Personal answer.

2. What is the location of the subsolar point today?
Personal answer.

Geospatial Analysis
Seasons in Tromsø, Norway

1. The University of Tromsø in Tromsø, Norway, is at a high latitude. What is the latitude for Tromsø, Norway, to the nearest degree?
69° N / 18° E.

2. Where is the Arctic Circle in relation to Tromsø?
Approximately 3° to the south of Tromsø.

3. For the most recent day, how many hours of daylight are there? You may need to view the video in full screen to see the date and time.
Personal answer.

4. How many hours of daylight are there in the most recent video for the vernal equinox? Summer solstice? Autumnal equinox? Winter solstice? Does the Sun ever rise above the horizon on the winter solstice?
Personal answer.