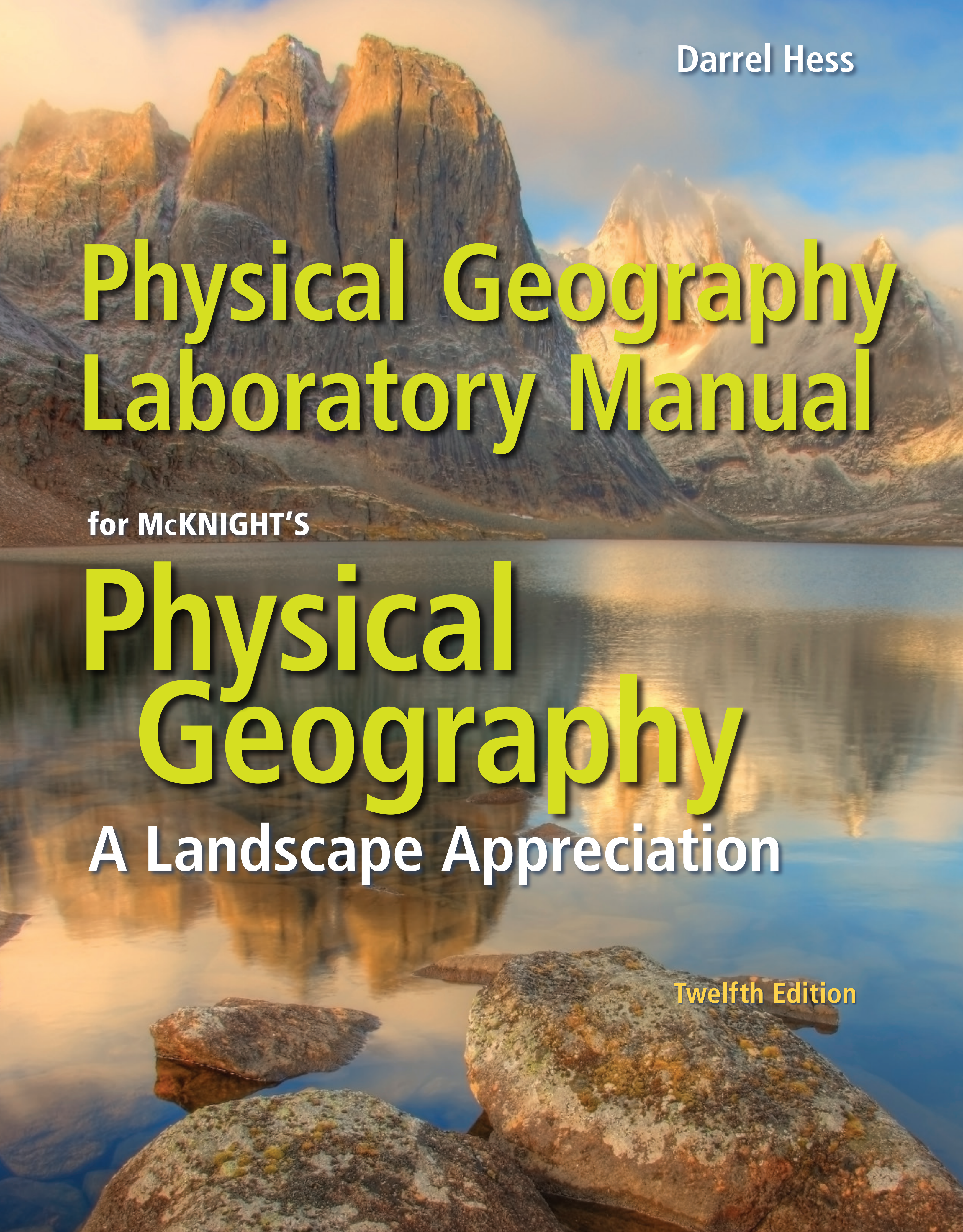

Darrel Hess

Physical Geography Laboratory Manual

for McKNIGHT'S

Physical Geography

A Landscape Appreciation

Twelfth Edition

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Physical Geography Laboratory Manual

TWELFTH EDITION

Darrel Hess

City College of San Francisco

for McKNIGHT'S

Physical Geography

A Landscape Appreciation

Twelfth Edition

Pearson

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CONTENTS

*Exercises with an asterisk * include Quick Response (QR) Codes that link print manual to online imagery or media. Exercises with a plus sign + include optional parts that make use of Google Earth™.*

INTRODUCTION

NEW TO THIS EDITION

All of the exercises found in the previous edition of this Lab Manual remain, along with one new exercise and many new features:

- A new exercise on *Groundwater* (Exercise 25) has been added.
- A new exercise on *Geographic Information Systems and Remote Sensing* (Exercise 8) replaces the last edition's GIS exercise. It has been written by Ryan Jensen of Brigham Young University, a recognized GIS expert.
- Sixteen new pages of color maps and images are included in the back of the Lab Manual, making a total of 32 pages of color maps. In previous editions of the Lab Manual, many of these new color maps appeared in grayscale.
- Many of the exercises underwent major revisions or expansions, including *Weather Variability and Climate Change* (Exercise 24), *Biomes and Ecological Land Units* (Exercise 26), *Aerial Photographs and Stereograms* (Exercise 32), and *Mass Wasting* (Exercise 38).
- The art has been improved and updated throughout the Lab Manual, including additional diagrams by illustrator Dennis Tasa from the twelfth edition of *McKnight's Physical Geography: A Landscape Appreciation*.
- The order of exercises has been rearranged slightly. At the suggestions of instructors, the exercises introducing contour line and topographic map skills now appear in the middle of the Lab Manual, just before the exercises on geomorphology that require these skills.
- Additional online resources, such as color maps, photographs, satellite images, and Google Earth™ "videos," have been added for some exercises. Students may immediately access nearly all of these materials by scanning QR (Quick Response) codes using a smartphone or other mobile device, or by visiting the MasteringGeography website.
- The new edition includes **MasteringGeography™ with Pearson eText**, specifically designed for this Lab Manual. The Mastering system helps teachers maximize lab time with media-rich, customizable, easy-to-assign, automatically graded assessments that motivate students to learn outside of class and arrive prepared for lab.

TO THE STUDENT

The exercises in this Lab Manual give you the opportunity to apply many of the concepts studied in your physical geography course.

Lab Manual Organization: The Lab Manual begins with some basics, such as metric conversions, latitude and longitude, and time zones. Next, you'll gain proficiency with mapping skills, such as using map scales, map projections, online mapping programs such as Google Earth™, and the fundamentals of GIS. The next section of the manual focuses on weather patterns and processes, the interpretation of weather maps, weather satellite images and climate data, as well as groundwater, biomes and soil. In the final section of the manual you will study the development of Earth's surface features, including the interpretation of topographic maps and aerial photographs, plate tectonics, volcanoes, faulting, the work of streams, underground water, wind, glaciers, and coastal waves.

Background Material: Each exercise begins with a brief introductory section that reviews key concepts and provides background information for the exercise problems. A reference to relevant pages in the textbook, *McKnight's Physical Geography: A Landscape Appreciation*, Twelfth Edition, by Darrel Hess, is provided at the beginning of most exercises. Key terms are marked in bold type, and a glossary is found at the back of the Lab Manual in Appendix I. It is likely that your instructor will assign several exercise problem sets to you each week. The length and relative difficulty of the problems vary from exercise to exercise.

Online Resources: Many of the exercises in the Lab Manual have problems using Google Earth™, or are based on photographs, satellite images or weather data you can access over the Internet. The Lab Manual website (**www.MasteringGeography.com**) provides easy links to all the Internet sites and images you'll need to complete these exercises, as well as various study tools and media to help you master course concepts.

Using Your Smartphone: You can access nearly all of the Internet content for the Lab Manual, including color maps, photographs, satellite images, and Google Earth™ "videos," by scanning the QR (Quick Response) code for an exercise with your smartphone or other mobile device. (You may need to download QR scanning software for your phone before using these codes.) This lets you view this enhanced Lab Manual content anywhere you can use your phone.

Color Topographic Maps: Thirty-two pages of topographic maps and aerial images are reproduced in color in the back of the Lab Manual. These maps are referred to in the exercises as "Map T-1," "Map T-2," and so on. A series of graphic map scales and a color map showing global precipitation is found inside the front cover of the Lab Manual. Charts showing standard symbols used on topographic maps and metric system conversion formulas are found on the inside of the back cover.

Stereo Aerial Photographs: Several of the exercises include stereo aerial photographs ("stereograms"). To view the aerial photographs in stereo, you will use a lens stereoscope supplied by your instructor. It is possible, however, to complete the exercises that include stereo aerial photographs even if you don't have a stereoscope or if you have difficulty using one.

Math Skills Practice Worksheet: You will find a "Math Skills Practice Worksheet" at the back of the Lab Manual in Appendix II. This ungraded worksheet will help you practice the kinds of math and charting skills you'll need to complete the exercises in the Lab Manual. Hints are provided to help you with the worksheet.

Supplies Needed: Few supplies are needed to complete the exercises. A ruler (about 6 inches long; graduated to at least 1/16 inch; scaled in both inches and centimeters), a 3-foot length of string, and blue, green, and red pencils will be useful. An inexpensive magnifying glass (about 5x) may be helpful in some map reading exercises. For a few of the exercises you will need access to a 25-centimeter (10-inch) diameter or larger globe and a small atlas with an index.

Unless otherwise directed by your instructor or the exercise problems, you should round off numbers in your answers to one decimal place (for example, round off 12.437 to 12.4).

MasteringGeography

The MasteringGeography website for the Lab Manual includes color maps, images, photographs, satellite movie loops, Google Earth™ KMZ files, and links needed to complete the Internet-based problem sets, along with various study tools and media to help you master course concepts. Go to **www.MasteringGeography.com**. The URLs of the recommended Internet sites needed to complete an exercise are also printed in the Lab Manual (instructors may recommend additional or different Internet sites for students).

TO THE TEACHER

This new edition of the Lab Manual retains all of the exercises found in the previous edition, along with a new exercise on *Groundwater* (Exercise 25) and a new exercise on *Geographic Information Systems and Remote Sensing* (Exercise 8), replacing the last edition's GIS exercise. The order of exercises has been adjusted slightly, grouping the topographic map interpretation skills in the middle of the Lab Manual before the exercises on geomorphology.

Short Exercises: For greater flexibility, some major topics are covered over several exercises, and the problems for most exercises are divided into two or more parts. The length and difficulty of the problem sets vary greatly from exercise to exercise. Although most exercises are designed to stand alone, in a few cases one exercise builds upon the previous one. For example, the exercise on the adiabatic processes assumes an understanding of relative humidity, and before assigning exercises using topographic maps or Google Earth™, those skills should be reviewed.

Students will be called upon to use several key skills repeatedly. For example, the interpretation of various kinds of isolines will be required throughout the weather and climate exercises, and the interpretation of topographic maps is needed throughout the geomorphology exercises. These skills should be emphasized early on.

QR Codes: The addition of QR (Quick Response) codes with many exercises gives students access to Lab Manual Internet content wherever they can use a smartphone or other mobile device. By scanning the QR codes, they can view color maps, satellite movie loops, color photographs, and Google Earth™ "videos" needed to complete nearly all of the Internet-based problems in the Lab Manual. The **www.MasteringGeography.com** website also provides all of the content accessed with the QR codes, along with KMZ files for the problems using Google Earth™.

S.I. and English Units: Although either English units or S.I. units may be used to complete many of the exercises, the emphasis in the weather and climate exercises is on S.I. units; because the topographic maps used in the geomorphology exercises are based on English units, most of the topographic map interpretation exercises retain their emphasis on English units.

Stereograms: All of the exercises that include stereo aerial photographs have matching topographic maps. If your school doesn't have lens stereoscopes for classroom use, you can visit online sites such as **www.forestry-suppliers.com** or **www.amazon.com** to purchase inexpensive "student model pocket stereoscopes." As in earlier editions of the Lab Manual, if students are unable to see the images in stereo, it is still possible to complete the exercise problems. Further, all topographic map- and stereogram-based problem sets also include the latitude and longitude of key features so that these areas may be studied with Google Earth™ or the USGS National Map.

Math Skills Practice Worksheet: A Math Skills Practice Worksheet is found in Appendix II. This ungraded worksheet helps students practice the kinds of math and charting skills they will need to complete exercises in the Lab Manual. Hints (but not the answers) are provided to help students with the worksheet.

Answer Key: An answer key for the exercises in the Lab Manual is available. The Answer Key also includes a sample course syllabus, and suggestions on supplementing Lab Manual exercises. Contact your local Pearson representative to receive a copy of the Answer Key.

MasteringGeography: The **Mastering** platform is the most widely used and effective online homework, tutorial, and assessment system for the sciences. It delivers self-paced coaching activities that provide individualized coaching, focus on course objectives, and are responsive to each student's progress. The Mastering system helps teachers maximize lab time with customizable, easy-to-assign, and automatically graded assessments that motivate students to learn outside of class and arrive prepared for lab.

MasteringGeography (**www.MasteringGeography.com**) is now available with this Lab Manual, as well as with *McKnight's Physical Geography: A Landscape Appreciation Twelfth Edition,* and offers:

- **Assignable activities** that include Pre- and Post-Lab assessments for each Lab Exercise, Geoscience Animation activities, *Encounter Physical Geography* Google Earth™ Explorations, Video activities, GIS-inspired MapMaster™ Interactive Map activities, Map Projection activities, GeoTutor coaching activities on the most challenging topics in geography, end-of-chapter questions and exercises, reading quizzes, Test Bank questions, and more.
- **Student Study Area** with Geoscience Animations, Videos, GIS-inspired MapMaster™ interactive maps, weblinks, glossary flashcards, *In the News* RSS feeds, chapter quizzes, an optional Pearson eText (including versions for iPad and Android devices), and more.

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The staff of the U.S. Geological Survey Earth Sciences Information Center in Menlo Park, California, provided valuable assistance in obtaining many of the maps and photographs used in this manual, as did the USGS/EROS Data Center in Sioux Falls, South Dakota. Thanks to Brendan Kelly and Greg Durocher of the USGS in Anchorage, Alaska, for their help selecting aerial photographs from that part of the country; to the staff at the Alaska Climate Research Center, University of Alaska, Fairbanks, for assistance obtaining climate data; and to Christopher Bailey and David Novak of NOAA for their help obtaining archived weather maps. Ed Shelden, Jr. provided much appreciated help with the processing of some of the digital images used in the Lab Manual.

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Most of all, I wish to thank my students who, often without knowing it, helped me develop and improve the exercises for this Lab Manual.

If students or instructors have any comments, please address them to:

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ABOUT OUR SUSTAINABILITY INITIATIVES

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EXERCISE 1

Metric Conversions

Objective:	To practice making unit conversions between the English system and the metric (S.I.) system of measurement.
Reference:	Hess, Darrel. *McKnight's Physical Geography,* 12th ed., pp. 6–8 and A1–A2.

METRIC CONVERSIONS

Although the general public in the United States still uses the so-called English system of measurement (e.g., feet, miles), most of the rest of the world—and the entire scientific community—uses the metric system (e.g., meters, kilometers). Today, the metric system has been incorporated into what is formally known as the ***Système International*** or ***S.I.*** system of measurement. In this Lab Manual you will encounter both English units and S.I. units of measure. It is useful for you to be comfortable using both systems, and for you to be able to convert units from one system into the other.

There are two levels of conversion precision that may be useful to you. First, it is helpful to have a rough idea of the equivalents—the kind of conversion you can do quickly in your head without a calculator. For example, it is useful to know that 1 kilometer is about two-thirds of a mile. The second kind of conversion is a precise equivalent—for example, 1 kilometer = 0.621 mile. These exact conversions are necessary if a precise measurement in one system must be duplicated in the other system. Some commonly used conversions are given in Figures 1-1 and 1-2 (to an accuracy of 3 decimal places). Additional conversions factors are found on the back cover of the Lab Manual.

Conversions: *S.I. to English*

	Exact Conversions	Approximate Conversions
Distance:	cm × 0.394 = inches	1 centimeter = a little less than $^1/_2$ inch
	m × 3.281 = feet	1 meter = a little more than 3 feet
	km × 0.621 = miles	1 kilometer = about $^2/_3$ mile
	1 cm (centimeter) = 10 mm (millimeters)	
	1 m (meter) = 100 cm	
	1 km (kilometer) = 1000 m	
Volume:	liters × 1.057 = quarts	1 liter = about 1 quart
Mass (Weight):	g × 0.035 = ounces	1 gram = about $^1/_{30}$ ounce
	kg × 2.205 = pounds	1 kilogram = about 2 pounds
	1 kg (kilogram) = 1000 g (grams)	
Temperature:	(°C × 1.8) + 32 = °F	1°C change = 1.8°F change

Figure 1-1: S.I. to English system conversions.

Conversions: *English to S.I.*

	Exact Conversions			Approximate Conversions		
Distance:	inches	× 2.540	= centimeters	1 inch	=	about $2\frac{1}{2}$ cm
	feet	× 0.305	= meters	1 foot	=	about $\frac{1}{3}$ m
	yards	× 0.914	= meters	1 yard	=	about 1 m
	miles	× 1.609	= kilometers	1 mile	=	about $1\frac{1}{2}$ km
	1′ (foot) = 12″ (inches)					
	1 yard = 3′					
	1 statute mile = 5280′					
Volume:	quarts	× 0.946	= liters	1 quart	=	about 1 liter
	gallons	× 3.785	= liters	1 gallon	=	about 4 liters
	1 gallon = 4 quarts					
Mass (Weight):	ounces	× 28.350	= g	1 ounce	=	about 30 g
	pounds	× 0.454	= kg	1 pound	=	about $\frac{1}{2}$ kg
	1 lb. (pound) = 16 oz (ounces)					
Temperature:	(°F − 32) ÷ 1.8		= °C	1°F change	=	about 0.6°C change

Figure 1-2: English system to S.I. conversions.

ROUNDING

In scientific work, many of the numbers used are measured quantities and so are not exact—they are limited by the precision of the instrument used in the measurement. Further, calculations based on measured quantities can be no more precise than the original measurements themselves. Therefore, measurements and the results of calculations should be recorded in a way that shows the degree of measurement precision. For example, if you use an electronic calculator to divide the following two measured quantities, you would get:

$$5.7 \text{ centimeters} \div 1.75 \text{ minutes} = 3.2571429 \text{ centimeters/minute}$$

But is 3.2571429 centimeters/minute a truly correct answer? Not really. In general, the greater the number of digits in a measurement or calculation answer, the greater the implied precision of measurement. A mathematical operation cannot make your measurements more precise. In the previous example, our distance measurement is only accurate to tenths of centimeters (perhaps limited by the measuring device we used), and our final answer can be no more precise than this. So:

$$5.7 \text{ centimeters} \div 1.75 \text{ minutes} = 3.3 \text{ centimeters/minute}$$

When rounding off numbers, if the first digit to be dropped is less than 5, leave the preceding digit unchanged; if the first digit to be dropped is 5 or greater, increase the preceding digit by one. So, 6.74 becomes 6.7, whereas 6.75 becomes 6.8.

Your instructor may introduce the concept of *significant digits* to you. This will further extend your understanding of the proper rounding of measured quantities.

Name ____ Section ____________________

EXERCISE 1 PROBLEMS/SOLUTIONS—PART

1. Complete the following conversions using exact conversion factors (round your answers to 1 decimal place).

	S.I. Units	English System Units
(a)	14 centimeters	__________ inches
(b)	29 meters	__________ feet
(c)	175 kilometers	__________ miles
(d)	42 liters	__________ quarts
(e)	57 grams	__________ ounces
(f)	65 kilograms	__________ pounds
(g)	37°C	__________°F

2. Complete the following conversions using exact conversion factors (round your answers to 1 decimal place).

	English System Units	S.I. Units
(a)	3 inches	__________ centimeters
(b)	4.3 feet	__________ meters
(c)	18 yards	__________ meters
(d)	73 miles	__________ kilometers
(e)	6.2 quarts	__________ liters
(f)	10 gallons	__________ liters
(g)	14 ounces	__________ grams
(h)	155 pounds	__________ kilograms
(i)	47°F	__________°C

Name ____ Section ____________________

EXERCISE 1 PROBLEMS—PART II

1. Complete the following conversions using exact conversion factors (round your answers to 1 decimal place).

	S.I. Units	English System Units
(a)	72 centimeters	__________ inches
(b)	24 meters	__________ feet
(c)	1300 kilometers	__________ miles
(d)	4.5 liters	__________ quarts
(e)	144 grams	__________ ounces
(f)	228 kilograms	__________ pounds
(g)	12°C	__________°F

2. Complete the following conversions using exact conversion factors (round your answers to 1 decimal place).

	English System Units	S.I. Units
(a)	55 inches	__________ centimeters
(b)	1774 feet	__________ meters
(c)	220 yards	__________ meters
(d)	23,900 miles	__________ kilometers
(e)	24 quarts	__________ liters
(f)	300 gallons	__________ liters
(g)	26 ounces	__________ grams
(h)	4500 pounds	__________ kilograms
(i)	88°F	__________°C

EXERCISE 2
Location

Objective:	To review the system of latitude and longitude and provide experience using atlases and globes.
Materials:	25 cm (10 inch) or larger diameter globe. World atlas (with index). Internet access (optional).
Reference:	Hess, Darrel. *McKnight's Physical Geography,* 12th ed., pp. 12–17.

LATITUDE AND LONGITUDE

Any location on Earth can be described using the grid system, or **graticule**, of **latitude** and **longitude**. Latitudes and longitudes are angular measures, with latitude describing north–south location, and longitude describing east–west location.

Lines of latitude on a map or globe are called **parallels** because they are all parallel to each other (Figure 2-1a). Latitude ranges from 0° at the equator to 90° north latitude at the North Pole and 90° south latitude at the South Pole.

Lines of longitude are known as **meridians** (Figure 2-1b). The meridians are farthest apart at the equator and converge at the poles.

The starting point for measuring longitude is the **prime meridian**, which runs through the Royal Observatory at Greenwich, England (just outside central London). Locations east of the prime meridian are described in degrees east longitude and locations west of the prime meridian in degrees west longitude. Longitude ranges from 0° at the prime meridian to 180° (on the opposite side of the Earth from the prime meridian). The complete grid system is shown in Figure 2-1c.

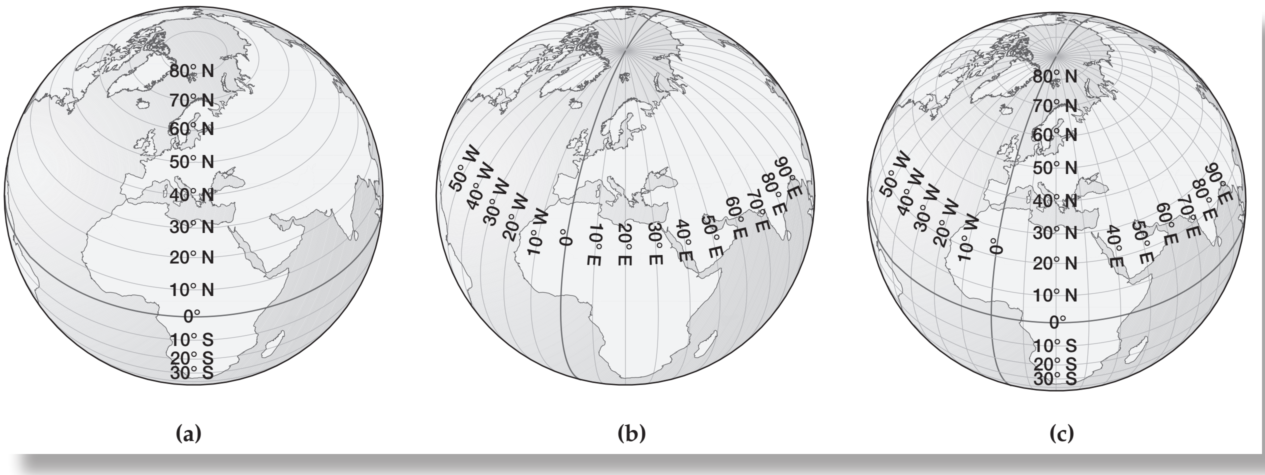


Figure 2-1: The geographic grid: (a) Parallels of latitude. (b) Meridians of longitude. (c) Complete grid system. (From McKnight and Hess, *Physical Geography*, 9th ed.)

When more exact descriptions of location are required (as when using detailed maps of a region), fractions of degrees of latitude and longitude are used. One degree is divided into 60 "minutes" (often written 60′) and each minute can be further divided into 60 "seconds" (60″). Therefore, $1° = 60'$, and $1' = 60''$. When describing angular measures such as latitude and longitude, minutes and seconds are *not* referring to time, but to fractions of degrees.

As an example, the precise location of the crater of Mount St. Helens in Washington is 46°11′55″ North, 122°11′15″ West.

Decimal Degrees: With the increasing use of **Global Positioning System (GPS)** satellite technology to determine location, it has become common in some circumstances to indicate fractions of degrees in decimal units. For example, 45°35′ N can be written 45.583° N, while 32°23′55″ N can be written 32°23.917′ N.

In some applications, north, south, east, and west can be omitted when specifying latitude and longitude. In these circumstances, north latitudes and east longitudes are shown with positive values, whereas south latitudes and west longitudes are shown with negative values. So, 38.5611° N, 110.0544° W would be designated 38.5611, −110.0544. *Note: With some applications, longitude is given before latitude.*

GLOBES AND ATLASES

Parallels and meridians are typically marked on globes in 10° or 15° increments. If the parallels and meridians are not marked on the globe, latitude and longitude are determined by using the degree markings on the arms or rings supporting the globe.

When searching for a location in an atlas, take advantage of the atlas index. The index will often comprise more than one-third of the pages in an atlas. In the index, cities, rivers, mountains, and other features are listed alphabetically. For each location, the index will typically provide the page number of the best map to use, the country, and often its latitude and longitude. Some atlases provide a pronunciation guide as well.

Some atlases do not refer to places in the index by latitude and longitude. Instead they provide a coordinate (such as "F7") that refers to a simplified grid system marked along the margins of each map in the atlas.

ONLINE GLOBE AND MAP PROGRAMS

In addition to printed atlases and physical globes, a number of online programs and mobile device apps allow you to access latitude and longitude information for the world. For example, a simple Google™ search will provide you with the precise latitude and longitude of any city in the world. You can also use Google Earth™ as a kind of electronic globe. When using Google Earth™ or Google Earth Pro™, go to "View" and check "Grid" to have the graticule appear around Earth—but don't zoom in so far that you lose a sense of the curvature of Earth.

Although it is easy to find latitude and longitude information online, the purpose of this lab exercise is to help you become familiar with the grid system as a whole—getting the correct numbers isn't as important as visualizing the grid and understanding how it works!

Name ______________________________ Section ______________

EXERCISE 2 PROBLEMS—PART I

1. Using a globe, determine the latitude and longitude of the following cities. Be sure to indicate if the location is north or south latitude, and east or west longitude. Indicate latitude and longitude to the nearest whole degree (round down if less than 30′; round up if 30′ or more).

	City	Latitude	Longitude
(a)	Chicago, Illinois	________	________
(b)	Tokyo, Japan	________	________
(c)	Sydney, Australia	________	________
(d)	Singapore	________	________
(e)	Buenos Aires, Argentina	________	________

2. Using a globe, determine which major city is located at the following coordinates:

	Latitude	Longitude	City
(a)	14° N	100° E	____________________
(b)	56° N	38° E	____________________
(c)	19° N	99° W	____________________
(d)	1° S	37° E	____________________
(e)	37° S	175° E	____________________

3. (a) What is the latitude and longitude of your school? (Estimate to the nearest minute of latitude and longitude; be sure to indicate if the location is north or south latitude, and east or west longitude.)

   (b) What resource did you use to determine this?

Name ____ Section ____________________

EXERCISE 2 PROBLEMS—PART II

1. On the diagram shown, plot the following coordinates with a dot. Then label each dot with its corresponding letter.

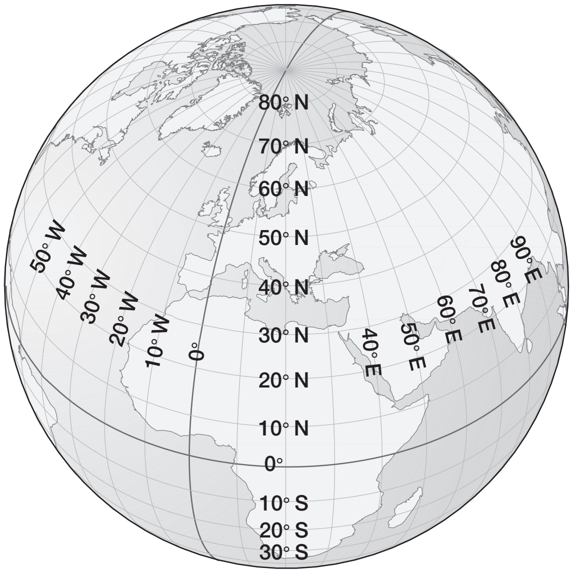
   (a) 10° N, 40° W

   (b) 50° N, 40° E

   (c) 40° N, 25° W

   (d) 5° S, 10° W

   (e) 65° N, 70° E



2. Use the index of an atlas to find the following places. Determine the latitude and longitude to the nearest degree.

	Place	Latitude	Longitude
(a)	Pusan (Busan)	________	________
(b)	Reykjavik (Reikjavik)	________	________
(c)	Walvis Bay	________	________
(d)	Tuvalu (Ellice Islands)	________	________

3. If you start at the equator and travel to 10° N, approximately how many kilometers (or miles) north of the equator will you be? Take the circumference of Earth to be 40,000 kilometers (24,900 miles). Show your calculations.

4. If you travel west through 10° of longitude along the equator, the distance traveled will be very different from the distance traveled through 10° of longitude at 60° N. Why?

EXERCISE 3
Time

Objective:	To learn to calculate time and day differences around the world.
Reference:	Hess, Darrel. *McKnight's Physical Geography*, 12th ed., pp. 22–25.

LOCAL SUN TIME

Although few people today are concerned with the local **Sun time**, it is a useful starting point for a discussion of time. Local Sun time is based on the position of the Sun in the sky. The local Sun time "noon" for a given location is the moment in the day when the Sun reaches its highest point in the sky. However, at the same moment that it is local Sun time noon at our location, at locations east or west of us the local Sun time is different.

Earth rotates from west to east (looking down at the North Pole on a globe, Earth would appear to be spinning counterclockwise). This means that at the same moment the Sun is low in the morning sky in Honolulu, it is high in the sky at noon in Denver, and low in the afternoon sky in New York. In other words, as we travel to the east, the time becomes progressively later.

STANDARD TIME

Rather than having people continually adjusting clocks to local Sun time when moving east or west, 24 **standard time zones** have been established by international agreement. Each time zone is a band of longitude, within which it is the same standard time (although, of course, the local Sun time varies slightly within the time zone). When moving from one time zone to the next, we adjust our watches by 1 hour.

The time zones are based on **central meridians** spaced 15° of longitude apart. Earth rotates through 360° of longitude in 24 hours, and so rotates through 15° of longitude in 1 hour ($360° \div 24 = 15°$). Although a standard time zone is 15° of longitude wide, the actual time zone boundaries have been adjusted over most inhabited areas of Earth (Figure 3-1).

TIME ZONE CALCULATIONS

The map in Figure 3-1 shows standard time zones around the world. If we remember that it is always later in New York than in San Francisco, it is easy to calculate time differences. It becomes 1 hour later for each time zone we cross moving from west to east (from San Francisco toward New York), and 1 hour earlier for each time zone we cross moving from east to west. New York is three time zones to the east of San Francisco, so New York time is 3 hours later than San Francisco time.

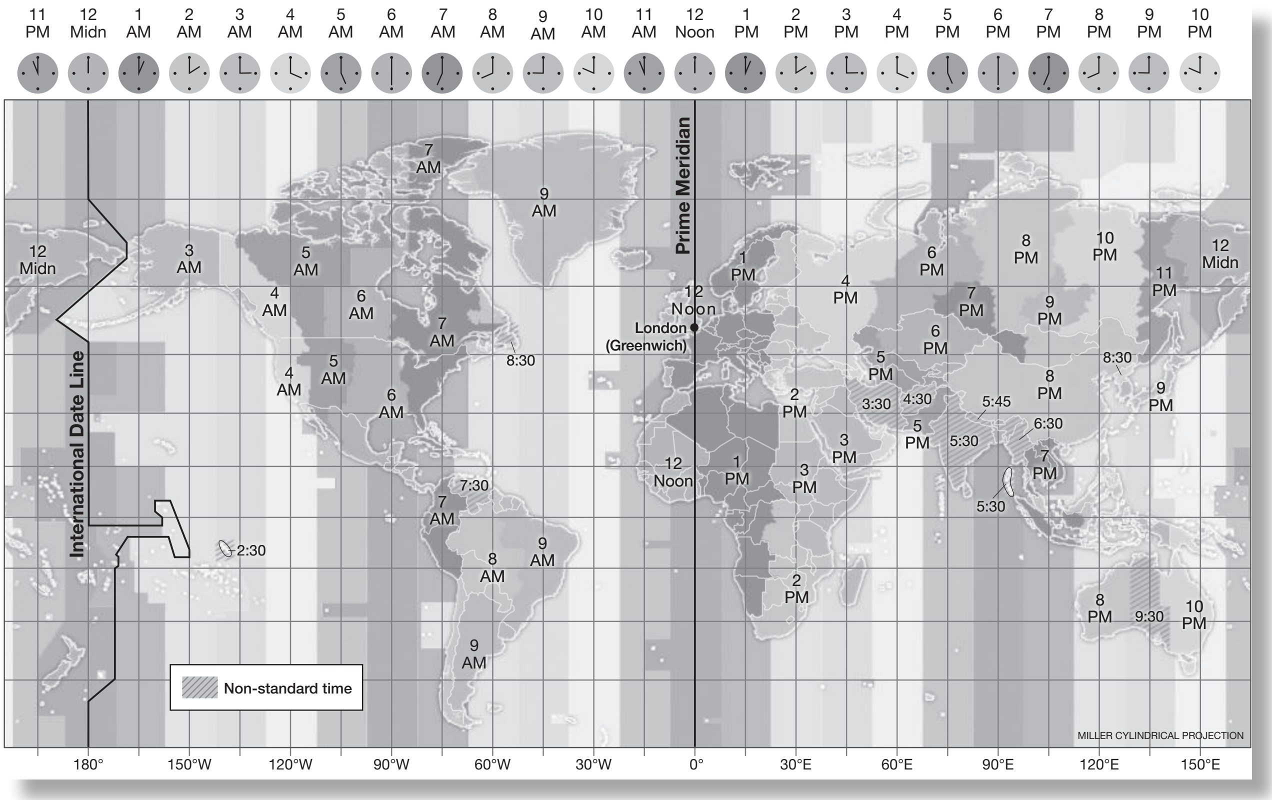


Figure 3-1: Standard time zones of the world. (From Hess, *McKnight's Physical Geography*, 12th ed.)

To avoid confusion, it is usually best to refer to "12:00 midnight" and "12:00 noon" rather than to 12:00 A.M. and 12:00 P.M., respectively.

Notice that a few time zones are based on the half-hour (such as for Newfoundland and India), but the same logic applies. For example, India is $5\frac{1}{2}$ hours later than Greenwich, England.

In 1884, **Greenwich Mean Time (GMT)** was established as the world reference for standard time (the Greenwich time zone is based on the prime meridian). Today, Greenwich time is known as **Universal Time Coordinated (UTC)** or **Zulu** time (Zulu time uses a 24-hour clock, so that "1530Z" would be 3:30 P.M. Greenwich time).

If you know the central meridian of a city's time zone, it is also possible to calculate time differences mathematically by determining the number of degrees of longitude between two locations. For example, Tokyo time is based on the 135° E central meridian and Rome is based on the 15° E meridian, a difference in longitude of 120°:

$$135° - 15° = 120° \text{ difference between Tokyo and Rome}$$

Fifteen degrees of longitude represents 1 hour of time, so:

$$120° \div 15° = 8 \text{ hours difference between Tokyo and Rome.}$$

Because Tokyo is east of Rome, the time will be 8 hours later in Tokyo than in Rome.

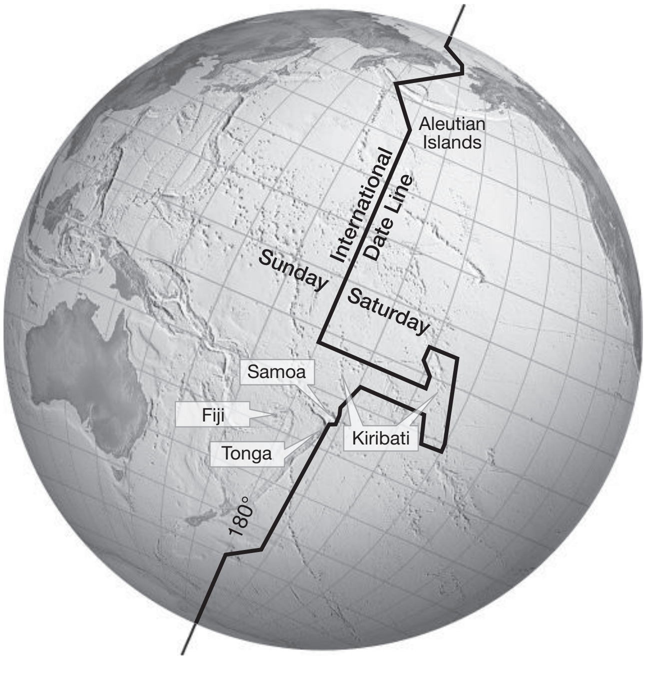


Figure 3-2: The International Date Line generally follows the 180° meridian, but deviates around various island groups, most notably Kiribati. (From Hess, *McKnight's Physical Geography*, 12th ed.)

INTERNATIONAL DATE LINE

When determining time differences between two places around the world, remember that the day may also be different. The day changes under two circumstances. First, the day changes at midnight. When traveling from west to east, when we cross into the time zone where it is midnight, it becomes the next day. Conversely, when traveling from east to west, when we cross into the 11 P.M. time zone, it becomes the previous day.

The day also changes at the **International Date Line** (IDL), which generally follows the 180° meridian down the middle of the Pacific Ocean (Figure 3-2). When crossing the IDL going from west to east (from China toward Hawai'i), it becomes the previous day. When crossing the IDL going from east to west (from Hawai'i toward China), it becomes the next day.

The International Date Line runs down the middle of a time zone. When first entering into this time zone, the hour changes, but the day remains the same until crossing the IDL (at which point only the day changes, not the time). Figure 3-3 shows the IDL and the bordering time zone boundaries. Sample times and days are shown in the diagram.

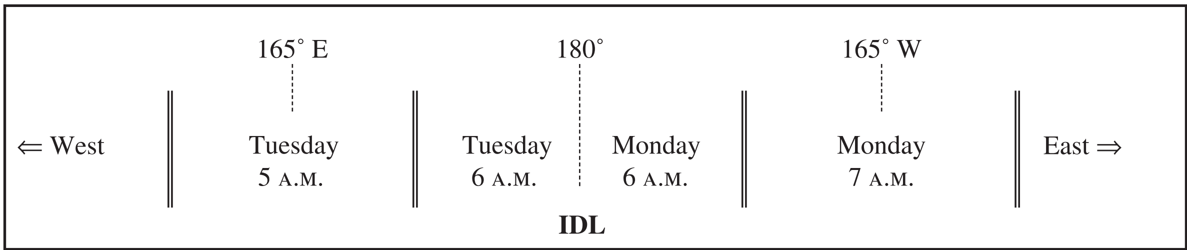


Figure 3-3: International Date Line (IDL) and bordering time zones, shown here with their central meridians along with sample days and times.

DAYLIGHT-SAVING TIME

A variation of standard time is **daylight-saving time**. Daylight-saving time is used throughout most of the United States during part of the year. In the summer, the days are longer than in the winter, and so there is a period of daylight that is "wasted" in the morning before people go to work. By shifting time ahead by 1 hour, there is, in effect, an "extra" hour of daylight in the afternoon after people come home from work. For most of the United States, daylight-saving time begins on the second Sunday in March and ends on the first Sunday in November.

Daylight-saving time calculations are easy. Simply remember the saying: "spring forward, and fall back." In other words, in the spring when going on daylight-saving time, we "spring forward" by adding 1 hour. When returning to standard time in the fall, we "fall back" by subtracting 1 hour.

When calculating time differences around the world, if both cities are observing daylight-saving time, you need not change your calculation procedure. However, if only one of the cities is observing daylight-saving time, convert that city back to standard time (by subtracting 1 hour), then proceed with your calculations as before.

SUNRISE AND SUNSET TIME CORRECTION

Local news media often provide us with the time of sunrise and sunset calculated specifically for our city. Because the local Sun time varies if we move east or west, the actual time of sunrise and sunset at locations east or west will vary slightly from that stated for our city. In locations to the east of our city, the exact time of sunrise and sunset will be earlier, while in locations to the west, the exact time will be later.

The sunrise/sunset time correction for different longitudes is easy to calculate. Earth rotates through 15° of longitude in 1 hour. Therefore, Earth rotates through 1° of longitude in 4 minutes ($60 \text{ minutes} \div 15° = 4 \text{ minutes per } 1°$). Locations to the east of us will experience sunrise/sunset 4 minutes earlier for each degree of longitude. Locations to the west will experience sunrise/sunset 4 minutes later for each degree of longitude. Note: This ignores differences in latitude that may also affect the sunrise/sunset time.

For example, if the stated sunset time for 75° W is 6:15 P.M., at 73° W, sunset will occur 8 minutes earlier (at 6:07 P.M.), while at 78° W, sunset will occur 12 minutes later (at 6:27 P.M.).

Name ____ Section ____________________

EXERCISE 3 PROBLEMS—PART I

Using the longitude of a time zone's central meridian (which has been provided for you), answer the following questions. Be sure to indicate if the time is A.M. or P.M.; however, refer to "noon" or "midnight" rather than to 12:00 P.M. or 12:00 A.M. It may be helpful to draw a simple diagram showing the central meridian of each time zone, such as Figure 3-3, when making your calculations.

1. If it is 10:00 A.M. Monday in Denver (based on 105° W), what time and day is it in New York City (75° W)?

2. If it is 11:00 A.M. Thursday in Seattle (120° W), what time and day is it in Seoul, South Korea (135° E)?

3. A satellite image of the United States was taken at "0900Z." What was the local standard time in Chicago (90° W)?

4. If it is Friday at 3:00 P.M. daylight-saving time in Kansas City (90° W), what is the day and time in Quito, Ecuador (75° W), where daylight-saving time is not being observed?

Name ____ Section ____________________

EXERCISE 3 PROBLEMS—PART II

1. (a) Your plane leaves Boston (75° W) at 7:00 A.M. on Saturday, bound for Los Angeles (120° W). The flight takes 5 hours. What is the time and day when you arrive in Los Angeles?

   (b) Your connecting flight to Taipei (120° E) leaves Los Angeles at 1:00 P.M. on that same day. The flight takes 11 hours. What is the time and day when you arrive in Taipei?

EXERCISE 3 PROBLEMS—PART III

1. For a given latitude, if the stated time of sunset is 6:45 P.M. at 90° W, what is the time of sunset at 91° W?

2. For a given latitude, if the stated time of sunrise is 6:10 A.M. at 120°00′ W, what is the time of sunrise at 117°30′ W?

EXERCISE 4
Map Scale

Objective:	To review the concept of map scale and to practice determining distances on a map using graphic and fractional scales.
Reference:	Hess, Darrel. *McKnight's Physical Geography*, 12th ed., pp. 30–32.

MAP SCALE

The **scale** of a map indicates how much Earth has been reduced for reproduction on that map. In practical terms, scale is the relationship between the distance shown on a map and the actual distance that this represents on Earth. There are three common ways to indicate the scale of a map.

Graphic Scales: The graphic scale for a map is a bar graph, graduated by distance. For example, Figure 4-1 shows the graphic map scales from a U.S. Geological Survey topographic map. To use a graphic scale, simply measure a distance on the map (or mark off the distance along the edge of a piece of paper), then compare the measured distance to the bar graph to determine the actual distance represented. On some graphic scales, "zero" is not at the far left. Graphic scales are useful because they remain accurate even if the map is enlarged or reduced in size.

In some cases, one graphic scale may not be accurate for all parts of the map. For example, some maps have several different graphic scales that are to be used for specified latitudes.

Fractional Scales: The fractional scale (also called the **representative fraction**) expresses the scale of a map as a fraction or ratio: 1/24,000 or 1:24,000.

This scale (read "one to twenty-four thousand") says that 1 unit of measurement on the map represents 24,000 units of measurement on Earth. At this scale, 1 centimeter on the map represents an actual distance of 24,000 centimeters on Earth, whereas 1 inch on the map represents an actual distance of 24,000 inches on Earth. Note that the units of measurement must be the same in both the numerator and the denominator.

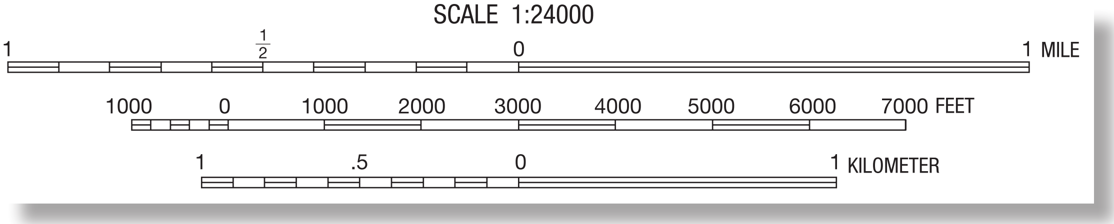


Figure 4-1: Graphic scales from a map with a fractional scale of 1:24,000. (From U.S. Geological Survey)

Verbal Scales: Map scale can also be expressed with words. Such **verbal map scales** are simply mathematical manipulations of the fractional scale. For example, there are 63,360 inches in 1 mile, so a map with a fractional scale of 1/63,360 can be expressed verbally as "one inch represents one mile."

COMPUTING DISTANCES WITH FRACTIONAL SCALES

In addition to using the graphic scale, it is possible to determine distances represented on a map by using the fractional scale:

1. Use a ruler to measure the distance on the map in centimeters (or inches). This is the *measured distance*.
2. Multiply the *measured distance* by the map's fractional scale denominator. This will give you the *actual distance* in centimeters (or inches).
3. To convert your *actual distances* in centimeters (or inches) to other units, use the following formulas:

To determine the distance in *meters*:	*Actual Distance* in centimeters ÷ 100
To determine the distance in *kilometers*:	*Actual Distance* in centimeters ÷ 100,000
To determine the distance in *feet*:	*Actual Distance* in inches ÷ 12
To determine the distance in *miles*:	*Actual Distance* in inches ÷ 63,360

For example, if we have a map with a scale of 1/50,000, a measured distance of 22 centimeters on the map represents an actual distance of 1,100,000 centimeters:

$$22 \text{ cm} \times 50{,}000 = 1{,}100{,}000 \text{ cm}$$

To calculate the actual distance in meters and kilometers:

$$1{,}100{,}000 \text{ cm} \div 100 = 11{,}000 \text{ meters}$$
$$1{,}100{,}000 \text{ cm} \div 100{,}000 = 11 \text{ kilometers}$$

If we have a map with a scale of 1/24,000, a measured distance of 8.25 inches on the map represents an actual distance of 198,000 inches (8.25 inches × 24,000 = 198,000 inches). So:

$$198{,}000 \text{ inches} \div 12 = 16{,}500 \text{ feet}$$
$$198{,}000 \text{ inches} \div 63{,}360 = 3.1 \text{ miles}$$

LARGE- VERSUS SMALL-SCALE MAPS

Large-scale maps refer to maps with a relatively large representative fraction (such as 1/10,000), whereas **small-scale maps** refer to maps with a relatively small representative fraction (such as 1/1,000,000). Large-scale maps show a small area of Earth in great detail, whereas small-scale maps show large areas in less detail.

Name ____ Section ___________________

EXERCISE 4 PROBLEMS—PART I

For questions 1 through 4, calculate the following distances using the fractional map scale. (Your instructor may ask you to show your work in the space provided.)

1. On a map with a scale of 1:24,000, a measured distance of 1 inch represents an actual distance of: ________ feet

2. On a map with a scale of 1:62,500, a measured distance of 4.5 inches represents an actual distance of: ________ miles

3. On a map with a scale of 1:250,000, a measured distance of 4.5 inches represents an actual distance of: ________ miles

4. On a map with a scale of 1:50,000, a measured distance of 7.5 centimeters represents an actual distance of: ________ kilometers

5. Map T-1 (in the back of the Lab Manual) shows part of the island of Hawai‘i at a scale of 1:250,000. Using the appropriate graphic scale on Map T-1, determine the distance from the “Patrol Cabin” (at the summit of Mauna Loa) to the “Rest House” (northeast of the summit of Mauna Loa):

   ________ miles (statute miles)

   ________ kilometers

6. Map T-9 shows an area near Park City, Kentucky, at a scale of 1:24,000. Using the appropriate graphic scale, determine the distance from the “Fairview Church” (in the southwest corner of the map) to the “X” marked “BM 585” along the Louisville and Nashville railway:

   ________ feet

   ________ miles

   ________ kilometers

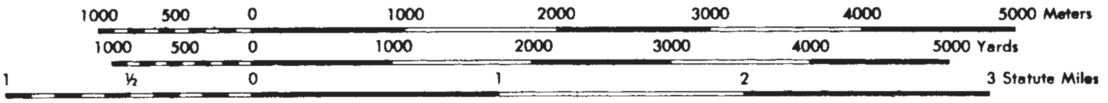
Name ____ Section ___________________

EXERCISE 4 PROBLEMS—PART II

1. If a measured distance of 10 inches on a map represents an actual distance of 5 miles, what is the fractional scale of the map?

2. Express a fractional scale of 1:100,000 as a verbal scale: One centimeter represents _____ kilometer(s).

Questions 3 through 4 are based on this set of graphic scales for a map with a fractional scale of 1:50,000:



3. Why isn't "0" at the far left of the scales?

4. If a map with these graphic scales is enlarged along with the scales (such as by using a photocopy machine):

   (a) Will the fractional scale of the map change? Why?

   (b) Will the graphic scales (as shown) still be usable? Why?

EXERCISE 5
Map Projections

Objective:	To examine the characteristics of different map projections.
Materials:	25 centimeter (10 inch) or larger diameter globe.
Reference:	Hess, Darrel. *McKnight's Physical Geography*, 12th ed., pp. 32–36.

CONFORMAL VERSUS EQUIVALENT MAPS

Only a globe can show the true area, shape, direction, and distance relationships of the spherical surface of Earth. It is impossible to show all of these relationships on a map without distortion.

Of the many different properties of maps, **equivalence** and **conformality** are perhaps the most important. An **equivalent map** (also called an **equal area map**) shows correct area relationships over the entire map. With an equivalent map, the area of one region on the map can be directly compared with the area of any other region. In contrast, a **conformal map** shows the correct angular relationships over the entire map. In practical terms, a conformal map shows the correct shapes of features in a limited area, although the true shapes of the continents can only be shown with a globe.

Figure 5-1 compares a conformal map (a) with an equivalent map (b). When compared with a globe, you will notice that the conformal map maintains the basic shapes of the continents, but the areas of the continents are severely distorted near the poles. On the other hand, the equivalent map shows the areas of the continents accurately, but the shapes are severely distorted in the high latitudes. It is

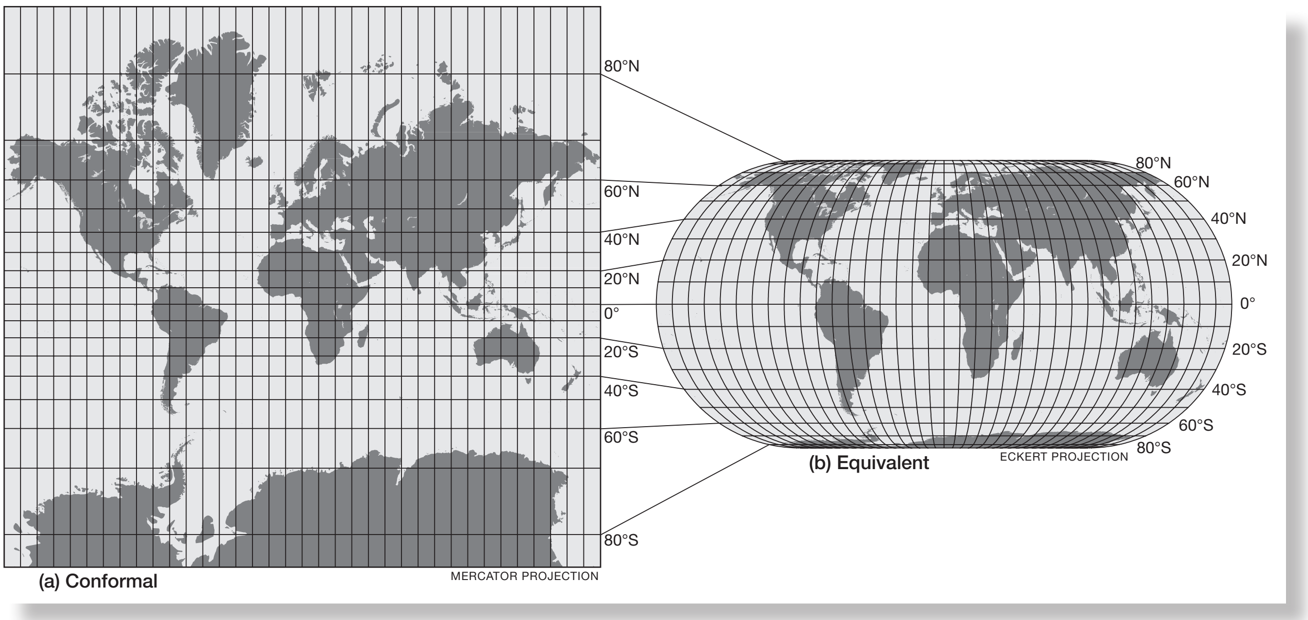


Figure 5-1: (a) Conformal projection—the Mercator. (b) Equivalent projection—the Eckert. (Adapted from McKnight and Hess, *Physical Geography*, 9th ed.)

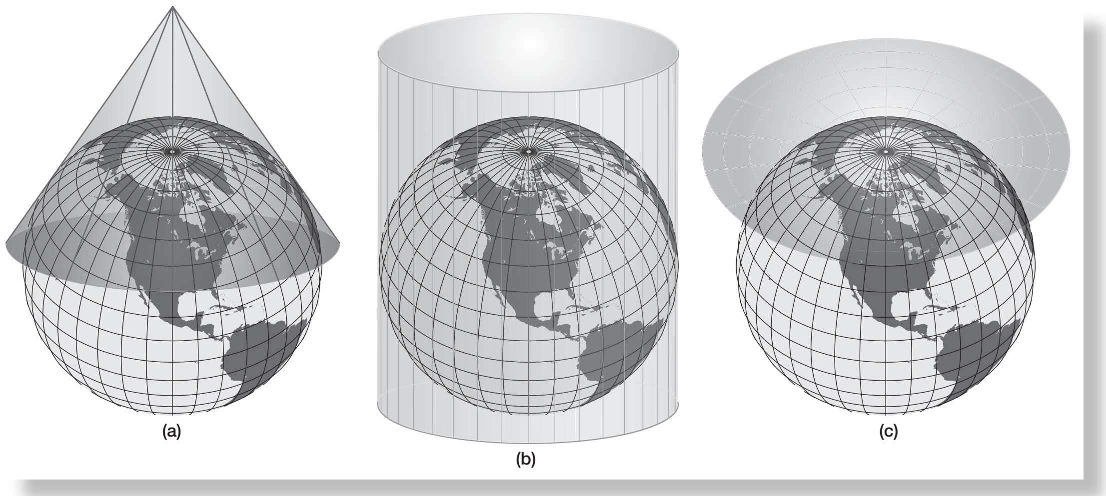


Figure 5-2: Three common families of map projections: (a) conic, (b) cylindrical, and (c) planar. (Adapted from McKnight and Hess, *Physical Geography*, 9th ed.)

impossible for a map to be both equivalent and conformal, and many maps are neither, but are instead a "compromise" map. (Note that these distortions are most pronounced on world maps—on large-scale maps showing limited areas, these distortions may not be a serious problem.)

Properties other than equivalence and conformality may also be maintained on a map. For example, true direction can be retained in some projections, and true distances can be shown on *equidistant maps,* but only from the center of the projection or along a specific set of lines.

MAP PROJECTIONS

Cartographers transfer the surface features of Earth to a map by mathematically "projecting" the **graticule** (the grid of latitude and longitude) out from the sphere onto a flat surface. Three common families of map projections are shown in Figure 5-2. In each case, there is one latitude or one point at which the map is tangent to ("touches") Earth. These latitudes are called *standard parallels* and represent the location of least distortion on the final map.

In the example shown, the **planar projection** (also called a *plane* or *azimuthal projection*) is tangent to the North Pole, and so would be suitable for maps of polar regions. The **cylindrical projection** is tangent to the equator, and would produce a map with low distortion in the equatorial regions. The **conic projection** is tangent to a parallel in the midlatitudes, making it a good choice for the midlatitude regions. Some cylindrical and conic projections are based on more than one standard parallel.

A fourth family of map projection is called **pseudocylindrical**. Pseudocylindrical projections are mathematically based on a cylinder, tangent to the equator, but the cylinder "curves back" down toward the poles so that the projection gives a sense of the curvature of Earth. The Eckert (Figure 5-1b) is based on a pseudocylindrical projection.

CHARACTERISTICS OF MAP PROJECTIONS

No single map projection is ideal for all purposes. Different kinds of projections produce maps that are suitable for different uses. For example, the conformal Mercator (Figure 5-1a) is based on a cylindrical projection. On the Mercator, any straight line is a **rhumb line** (a *loxodrome* or line of constant direction), making these maps useful for navigation.

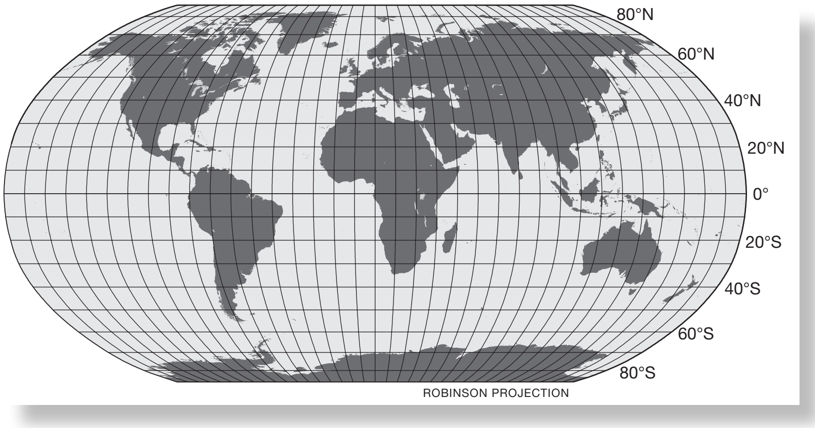


Figure 5-3: The Robinson is a compromise projection. (Adapted from U.S. Geological Survey *Map Projections* poster)

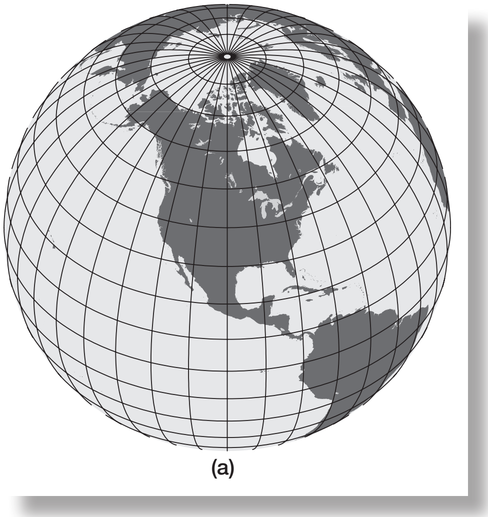
The Robinson (Figure 5-3) is a pseudocylindrical compromise projection that is widely used for maps of the world. It is neither conformal nor equivalent, but offers a good balance between correct shape and correct area.

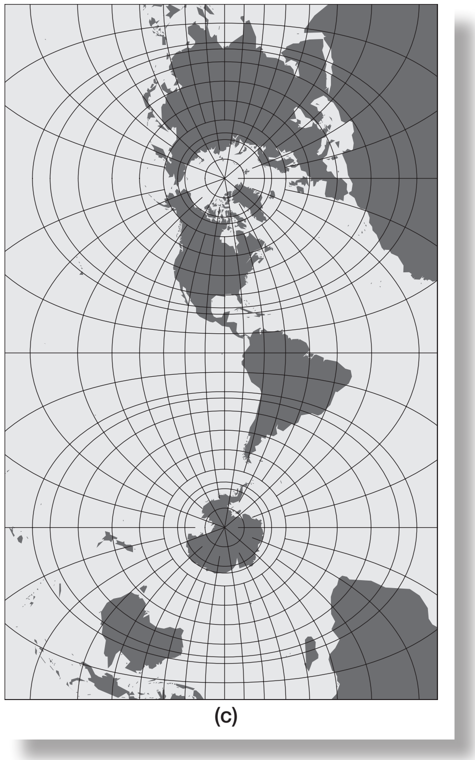
The Lambert Conformal Conic projection (Figure 5-4) uses two standard parallels, and is often used by the U.S. Geological Survey for large-scale topographic maps.

Orthographic projections (Figure 5-5a) are known as perspective maps. They make the Earth appear as it would from space. On **gnomonic maps** (Figure 5-5b), a straight line represents a path along a **great circle** (the largest circle that can be drawn on a sphere) and shows the shortest path between two points. Both orthographic and gnomonic maps are based on planar projections.

An interesting type of cylindrical projection is the "Transverse Mercator" (Figure 5-5c). Instead of being tangent to the equator, the Transverse Mercator is tangent to a standard meridian (the 90° W/90° E meridian in the example shown), but notice that unlike a normal Mercator, most parallels and meridians are shown as curved lines. The Transverse Mercator is conformal, and is used on many U.S. Geological Survey topographic maps.

Figure 5-4: Lambert Conformal Conic. (Adapted from U.S. Geological Survey *Map Projections* poster)





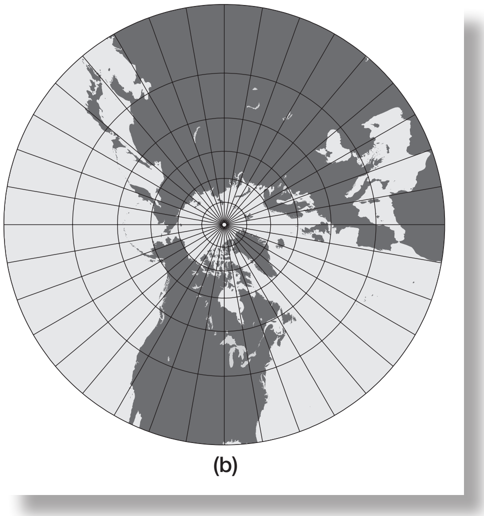


Figure 5-5: (a) Orthographic. (b) Gnomonic. (c) Transverse Mercator. (Adapted from U.S. Geological Survey *Map Projections* poster)

Goode's Interrupted Homolosine Equal Area projection (Figure 5-6) is widely used to show the distribution of phenomena on the continents. The Goode's Interrupted projection is equivalent, yet the shapes of the land masses are also very well maintained.

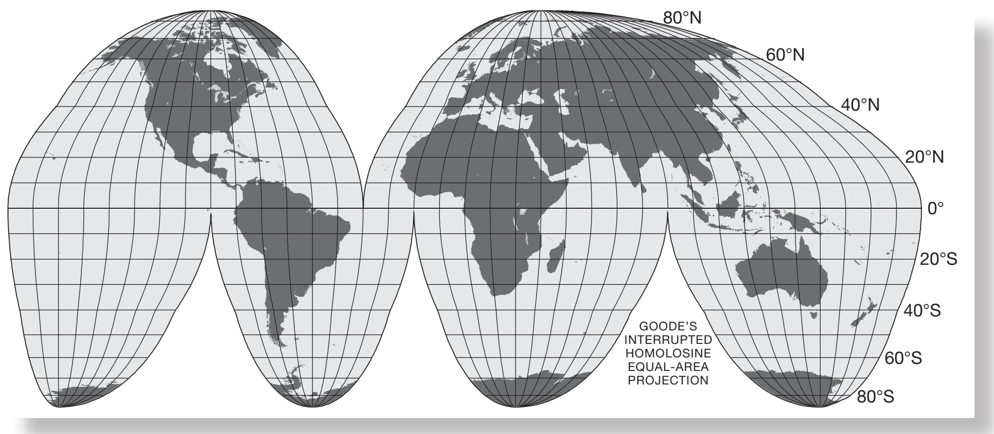


Figure 5-6: Goode's Interrupted Homolosine Equal Area Projection. (Adapted from McKnight, *Physical Geography*, 4th ed.)

Name ____ Section ____________________

EXERCISE 5 PROBLEMS—PART I

1. Compare the Mercator projection (Figure 5-1a) to a globe.

   (a) Are all of the lines of latitude parallel to each other on both the globe and the Mercator projection?

   (b) Do all of the parallels and meridians cross each other at right angles on both the globe and the Mercator? (Hint: Look carefully at just the immediate intersection of a parallel and a meridian on the globe.)

   (c) On a globe, the meridians converge toward the poles. Describe the pattern of meridians on the Mercator.

   (d) Is north always straight toward the top of the Mercator projection?

   (e) How would the North Pole be represented on the Mercator?

   (f) Could a single graphic scale be used to measure distances on a Mercator projection? Explain.

2. Study the Eckert projection (Figure 5-1b).

   (a) Do all of the parallels and meridians cross each other at right angles?

   (b) How does the Eckert maintain equivalence in the high latitudes (what happens to the meridians)?

   (c) What happens to the shape of Greenland?

   (d) Is north always straight toward the top of the Eckert? Explain.

Name ____ Section ____________________

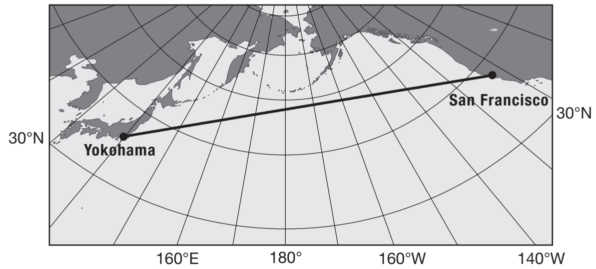
EXERCISE 5 PROBLEMS—PART II

1. Study the Goode's Interrupted projection (Figure 5-6):

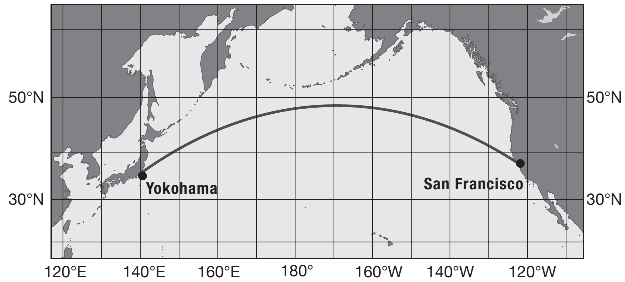
   (a) Are ocean areas "left off" this map? Explain.

   (b) The Goode's is based on two different projections, one for the low latitudes and one for the high latitudes. At approximately what latitude does the projection change? (Hint: Look for the change in the shape of the map margins in the North Pacific.)

2. On a globe, use a piece of string to find the shortest path between Yokohama, Japan (near Tokyo) and San Francisco. This path is a "great circle" path. Two maps are shown here, a Gnomonic (i) and a Mercator (ii).



(i)



(ii)

   (a) Is the path of the string on your globe the same as the heavy line shown on just one of these maps, or on both of these maps? (Hint: Look carefully at the string on the globe in relation to the Aleutian Islands of Alaska [at about 50° N, 175° W].)

   (b) In terms of a navigator trying to maintain a constant compass heading, why would the great circle path shown be difficult to follow exactly?

   (c) How would both a Mercator and a Gnomonic map be used together in navigation?

EXERCISE 6
Isolines

Objective:	To practice interpreting and drawing isolines.
Reference:	Hess, Darrel. *McKnight's Physical Geography*, 12th ed., pp. 37–39.

ISOLINES

Often in geography we are interested in mapping particular characteristics of an area, such as the elevation, the amount of rainfall, or the temperature. A common and very useful method of showing varying levels or concentrations of some phenomenon is with **isolines**. An isoline is a line on a map that connects points of equal value.

For example, **contour lines** on topographic maps are isolines that show elevation (contour lines are discussed in Exercise 28). In our study of weather and climate we will use several kinds of isolines, such as **isotherms**, to show temperature, and **isobars** to show atmospheric pressure.

There are just a few basic rules pertaining to all isolines:

(a) An isoline connects points on a map where the value of some phenomenon is the same.

(b) Isolines are drawn at regular intervals (e.g., for every 5° of temperature difference).

(c) Isolines are always closed lines, although they often close beyond the margins of a map.

(d) Isolines never cross each other.

(e) Where isolines are close together, they show an abrupt horizontal change in the phenomenon; where they are far apart, they show a gradual horizontal change.

(f) Values inside a closed isoline are either higher or lower than those outside the closed isoline (it is usually clear which is the case based on the pattern of adjacent isolines).

The following example will help illustrate how isotherms are drawn. Figure 6-1 shows a simple map with temperatures plotted for 17 different cities.

We will draw isotherms at 5° intervals (15°, 20°, 25°, etc.). An isotherm will pass through any point with the same value as the isotherm, but between higher and lower values. On one side of the line, the temperatures will be higher than the value of the isotherm, while on the other side, temperatures will be lower.

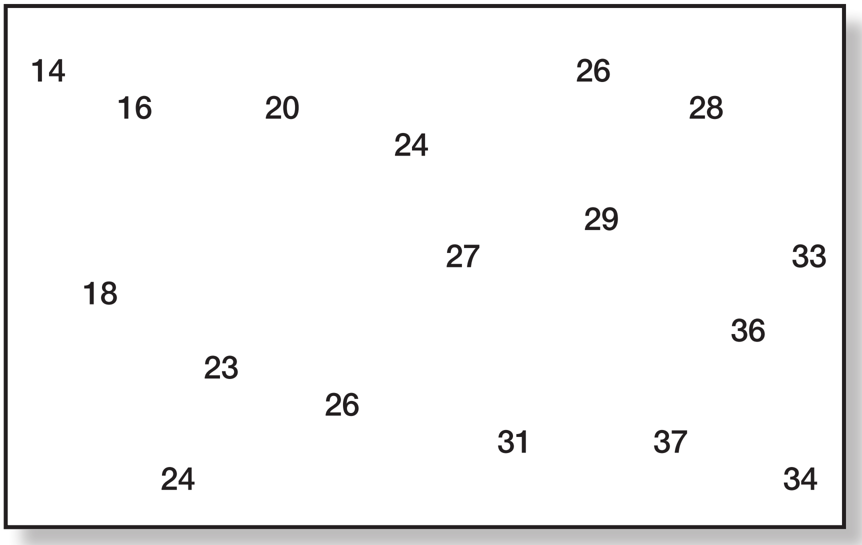


Figure 6-1: Map showing the temperatures in 17 cities.

Drawing isolines involves *interpolation*. For example, the 15° isotherm passes between the 14° and 16° locations, whereas the 27° location is about halfway between the 25° and 30° isotherms. Figure 6-2 shows the completed isotherm map. Notice that isotherms show the spatial pattern of temperature more clearly than the temperatures of the cities alone.

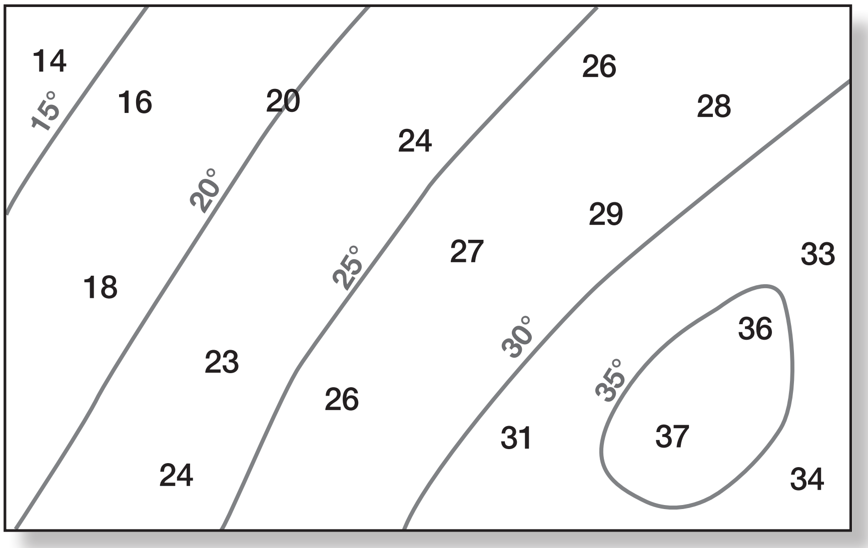


Figure 6-2: Temperature map with isotherms drawn.

Name ____ Section ___________________

EXERCISE 6 PROBLEMS—PART I

The following questions are based on the isotherm map in Figure 6-3, showing average January sea-level temperatures in °C and °F. Eight lettered points (labeled "A" to "H") are shown on the map.

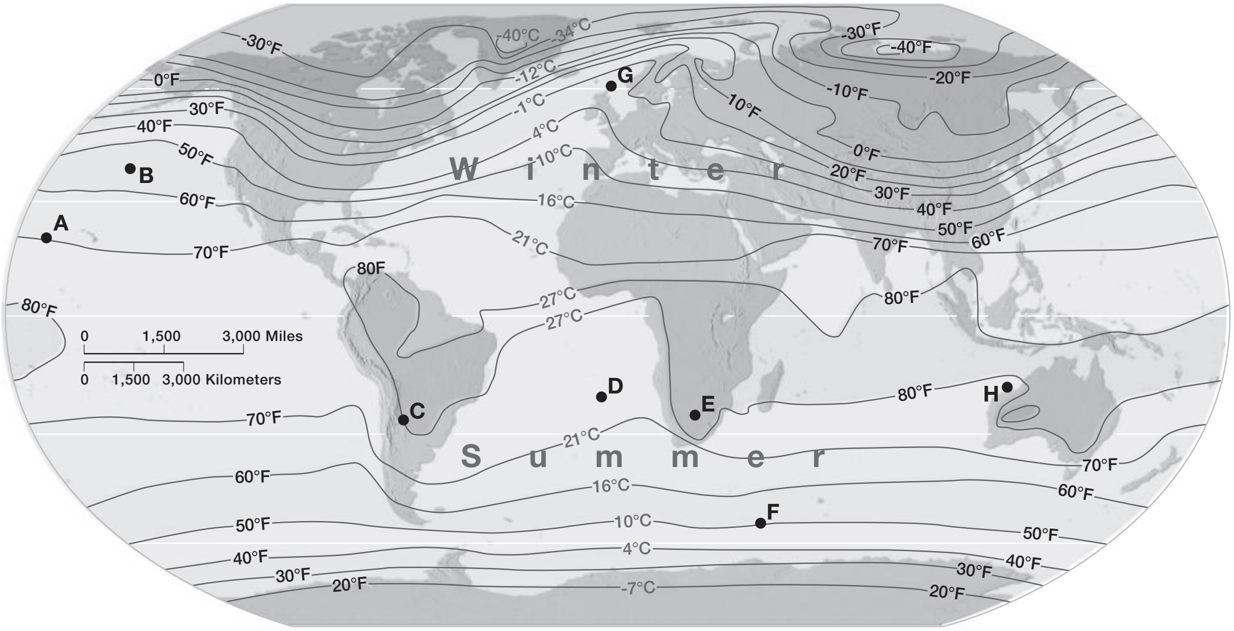


Figure 6-3: Average January sea-level temperatures (°C and °F). (Adapted from McKnight and Hess, *Physical Geography*, 9th ed.)

Determine the average January sea-level temperature at the following eight lettered points. Indicate if your answers are in °C or °F.

°C or °F (circle scale used)

A ______ E ______

B ______ F ______

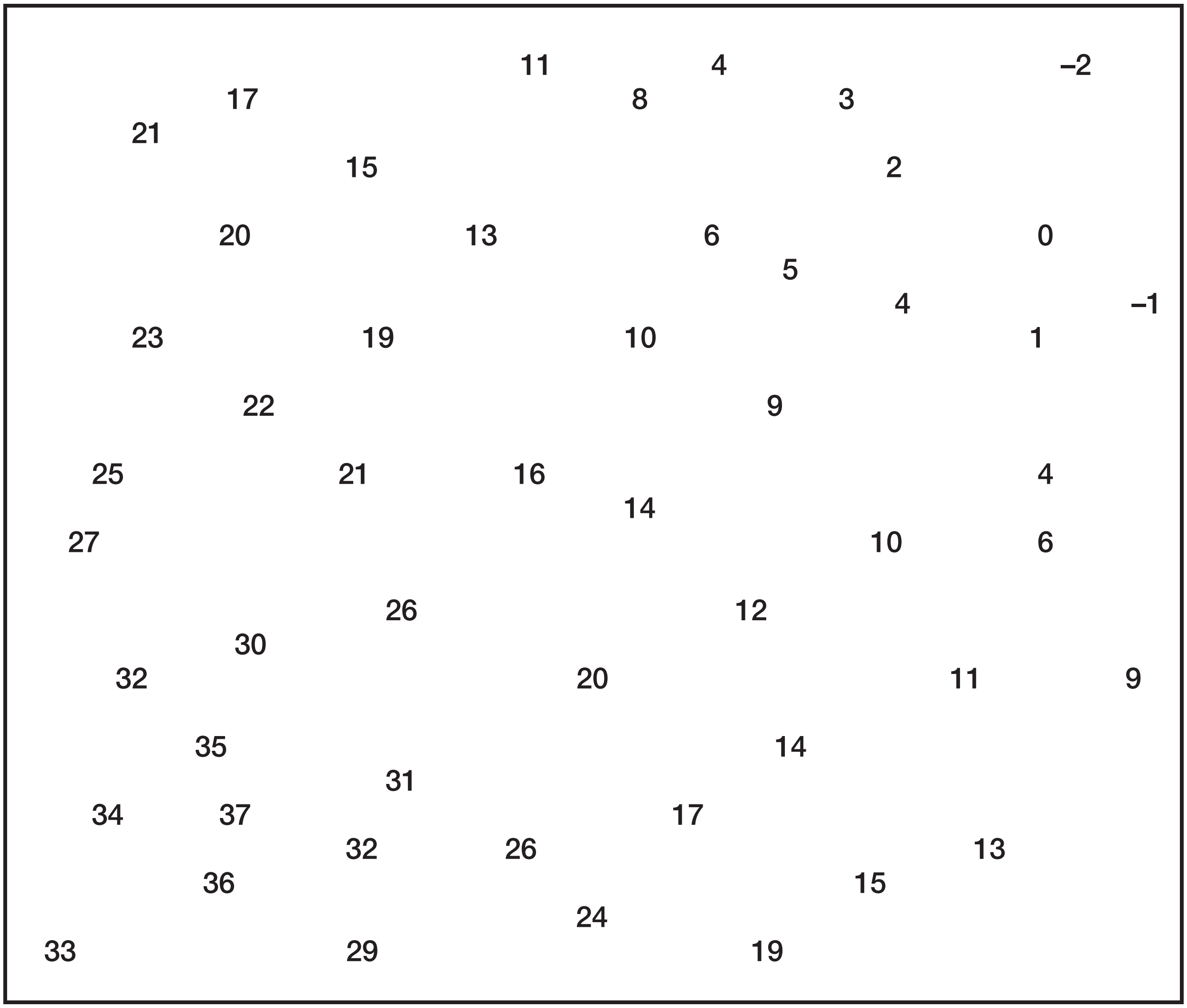
C ______ G ______

D ______ H ______

Name ____ Section ____________________

EXERCISE 6 PROBLEMS—PART II

This map shows the location of 52 cities. The temperature of each city is given in degrees. Draw isotherms at 5° intervals, beginning with the 0° isotherm in the upper right corner. Label each isotherm.



EXERCISE 7

Landscape Analysis with Google Earth™ & The National Map

Objective:	To learn how to use the online mapping services of *Google Earth*™ and *The National Map* to analyze landscapes.
Resources:	Internet access.
Reference:	Hess, Darrel. *McKnight's Physical Geography*, 12th ed., pp. 39–40 and 42.

GOOGLE EARTH™ AND THE NATIONAL MAP

In this exercise we introduce two of the most popular and useful online mapping services for landscape analysis: *Google Earth*™ and the U.S. Geological Survey's *The National Map*. In order to use Google Earth (GE), you must download and install free software on your computer (**http://earth.google.com**). You may use either Google Earth™ or Google Earth Pro™ for the exercises in this Lab Manual. Google Earth Pro™ is now free and has additional useful features not available with the original Google Earth™. The National Map (TNM) is accessed through a website (**http://nationalmap.gov**) and does not require you to install any software. In some regards, both applications let you do similar things: easily move to different parts of the United States (or the world, in the case of GE), then zoom in on a location, viewing roads, topography, and detailed aerial imagery. However, the applications differ in some important ways as well.

Google Earth™ contains an ever-growing amount of location information that is easily accessed, placemarked, and shared by individuals and businesses. With GE you can zoom in, rotate, and tilt your view of the surface below (aerial imagery "draped over" a three-dimensional digital elevation model of the terrain) and virtually "fly" over the landscape—a remarkable tool for landscape study in physical geography.

The National Map currently lacks the visual "bells and whistles" of GE, but it makes up for it by providing a remarkable number of high-quality map layers: consistently high-quality remotely sensed imagery, place names, hydrology, geology, contour lines, and many others. The purpose of TNM is to provide a seamless map of the entire United States that can be viewed at many different scales. Nearly all of the content of The National Map is in the public domain, free for all to use and download, whereas the Google Earth™ base map and much of its imagery may not be reproduced without permission.

In subsequent exercises in this Lab Manual, the latitudes and longitudes of many features are provided, enabling you to study these landscapes using Google Earth™ or The National Map. In addition, many exercises include specific questions based on Google Earth™, with predetermined locations you can visit with GE by opening files available on the Hess *Physical Geography Laboratory Manual*, 12th edition, website (**www.MasteringGeography.com**) or by scanning a QR ("quick response") code with a mobile device such as a smartphone to open a Google Earth™ "video."

We begin with a quick introduction to Google Earth™ and The National Map. Only the most basic functions of each are described, and with further exploration you will uncover much greater capabilities in both applications. Be sure to take advantage of the "Help" and tutorial functions offered by both applications to learn more about specific details. *Note: Google Earth™ and The National Map are constantly evolving applications—their functions and procedures may vary from that described here.*

GETTING STARTED WITH GOOGLE EARTH™

After installing the latest version of the free Google Earth™ or Google Earth Pro™ software on your computer, you may want to go through some of the introductory tutorials (click "Help" along the top of the screen). GE opens with a map of the world on the right and a sidebar with three menu panels on the left: *Search*, *Places*, and *Layers* (Figure 7-1). Any of these panels may be hidden from view by clicking the triangle next to the panel name.

Search Panel: The "Search" feature lets you find locations by entering a place name or address. You may also type in latitude and longitude coordinates and instantly "fly to" a specific location—this is one way you can navigate to locations when completing exercises in this Lab Manual. Enter latitude and longitude values in the same order as coordinates are given in this Lab Manual, but you needn't enter the symbols for degrees (°), minutes (′), or seconds (″)—just leave a blank space between each number and N or S for latitude, and E or W for longitude. So, the location of Mount St. Helens in Washington (46°11′55″ North, 122°11′15″ West) would be entered in the "Search" box as: 46 11 55 n 122 11 15 w (you may also enter latitude and longitude in decimal degree format: 46.1986 −122.1875; see Exercise 2). As soon as you click the search button, you'll fly to and zoom in on that location.

When searching for locations by street address, you may only need to enter the street address and zip code. For example, to find City College of San Francisco with an address of 50 Phelan Avenue, San Francisco, California 94112, you can simply enter "50 Phelan 94112" (this won't work for all addresses). When you search for locations by place name, a list of commercial establishments that have your search terms included may also appear.

Places Panel: The "Places" panel lets you keep track of locations you've "placemarked," as well as files opened from other sources (such as the Lab Manual website). (The procedures for creating placemarks and opening files are discussed later in this exercise.)

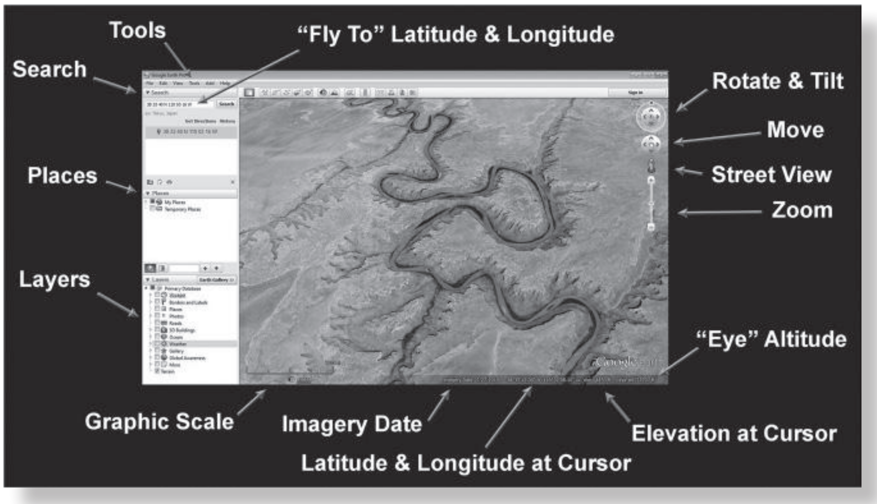


Figure 7-1: Google Earth Pro™ screen showing panels and navigation controls. (Google Earth™ is a trademark of Google, Inc.)

Layers Panel: The "Layers" panel lets you click on and off the many map layers of information available in GE. In this Lab Manual we're mostly interested in the terrain, so start off by checking "Terrain" and unchecking most (or all) of the other layers. You can then hide the Layers panel. If a "clock" icon appears next to the Imagery Date, you can select to view imagery from earlier years.

Navigating in Google Earth™: Once you have arrived at your map destination, use the controls along the right side of the screen to move around and change your perspective. The *Zoom* control changes the scale of the map—and so the apparent altitude of your "eye." The *Rotate and Tilt* control lets you rotate your vantage point and tilt your view up or down. The *Move* control moves you over the landscape in the direction you choose; if you've set the tilt control to a low angle, you'll have the sensation of flying over the virtual landscape below. You may also change location by clicking and dragging on the map with your mouse.

As you change the location of your cursor, notice that the latitude, longitude, and elevation values (shown along the bottom of the screen) also change. (If you don't see the latitude and longitude at the bottom of the screen, click "View" on the top toolbar and select "Status Bar.")

You can keep track of the direction you're viewing in GE by looking at the position of the "N" on the ring around the Rotate and Tilt control—when the N is in the "12:00 position" (top of the circle), the view is facing north; if the N is in the 6:00 position, you're facing south, and so on. To quickly reorient the map with north at the top of the screen, just click on the N.

Although the default settings of GE generally work well, you can adjust characteristics such as the measurement units shown, the format of latitude and longitude, and the amount of **vertical exaggeration** in the landscape. Select "Tools" from the top toolbar, and then "Options."

Ruler: You can measure distances on the GE map by using the "Ruler" function. From the top toolbar, select "Tools," then "Ruler" from the dropdown menu, or simply click on the Ruler button (Figure 7-2). Select the units of measurement (meters, miles, etc.). Use "Line" to measure distances along a single straight line, or "Path" to measure along a curved path by using a series of mouse clicks. With GE Pro you can also measure the area and perimeter of polygons you designate with mouse clicks. The ruler function measures straight line ("as the crow flies") distances, even though the ruler line you see on the screen may drape over the three-dimensional landscape and appear as if it is measuring the distance uphill or downhill.

Street View: To see the street-level images that are available in many locations, drag and hold the *Street View* icon over an area of interest. Release the icon and the screen will show ground-level photography (the quality and usefulness of the street view imagery varies somewhat from place to place).

Placemarks: You can mark locations in GE by adding *Placemarks*. Click the Placemark button near the top of the screen and an icon will appear on the map. Drag the icon to the location you desire and then give it a name in the dialogue box that appears. Your placemark then becomes an entry in the "My Places" folder on the "Places" panel (you may also add "Folders" to organize your placemarks). You can fly back to the location of any placemark on your list by double clicking on the placemark name.

Opening Lab Exercise Files in Google Earth™: For parts of some lab exercises you will be directed to the Hess *Physical Geography Laboratory Manual*, 12th edition, website at **www.MasteringGeography.com**, where you will select the appropriate Google Earth™ exercise from the menu. GE will open, and a KMZ file (compressed "Keyhole Markup Language" file) will

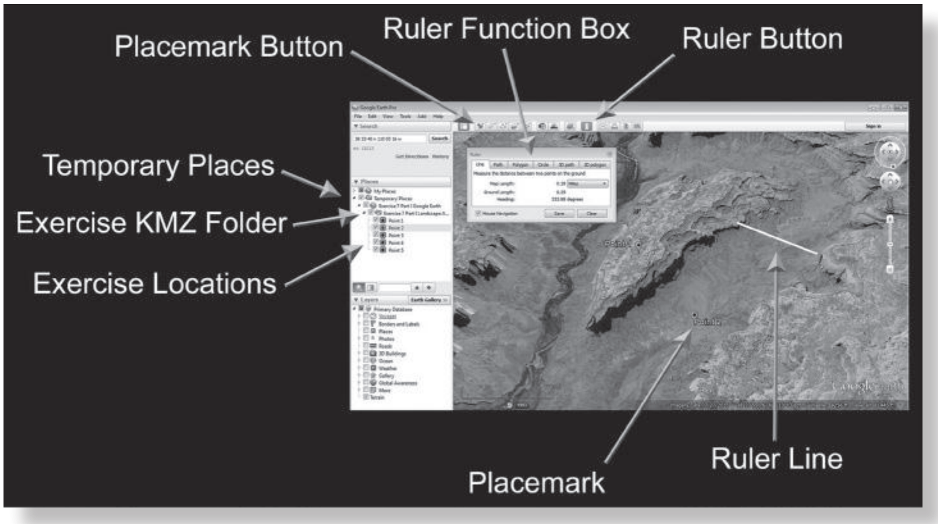


Figure 7-2: Google Earth Pro™ screen showing Temporary Places folder, placemarks, and ruler function. (Google Earth™ is a trademark of Google, Inc.)

appear in your "Temporary Places" folder on the Places panel. You may need to click on the "+" icon next to the folder to expose the one or more locations (*Point 1*, *Point 2*, and so on) you'll visit when completing the exercise. Be sure that the tiny box next to each placemark name is checked so that the placemark icons appear on the map.

Simply double click on a location name on the Places panel and GE will fly you to the correct location. Once there, you can further zoom in or change your view in GE; to return to the original view, just double click again on the location name on the Places panel.

Google Earth™ Videos: If you scan a QR code with a mobile device to view a Google Earth™ video for one of the lab exercises, GE software does not open. Instead, you'll see a screenshot video showing the landscape and placemarks noted in the exercise. You can pause or replay these videos as needed to study the landscape more carefully.

The Three-Dimensional Landscape in Google Earth™: It is important to keep in mind that the landscape you're viewing in Google Earth™ is a virtual one. In most cases, vertical (or near vertical) aerial imagery is "draped" over a digital elevation model (DEM) of the landscape by the GE software. In order to view such an image-over-DEM landscape from a low angle, the vertical aerial imagery must necessarily be "stretched" down over the topography. Although such views can be extremely useful when studying landforms, keep in mind that this computer-generated image does not provide the exact same view you would have were you *actually* flying over the landscape—interpret what you see with a critical eye.

GETTING STARTED WITH THE NATIONAL MAP

The National Map (TNM) can be accessed in two ways: with a simple "Online Viewer" (**http://viewer.nationalmap.gov/viewer/**), or with a more sophisticated "Download Platform" (**http://viewer.nationalmap.gov/basic/**). Both allow you to view maps, imagery, and data, although the Viewer is easier to use when just viewing maps and imagery (as you'll do in this exercise), whereas the Download Platform must be used to obtain imagery and data. For the problems in this exercise, using the Viewer is recommended. The USGS is in the process of allowing the acquisition and viewing of their maps, imagery, and data through a number of additional platforms—over time, the interface to TNM may vary from that described here.

Find a Place: You can search for locations by place name, or by typing in latitude and longitude coordinates in the "Search" box (Figure 7-3). As with GE, you can enter latitude and longitude without degree, minute, or second symbols, but you should leave space between each value. So, 38°33′40″ North, 110°03′16″ West, would be entered as: 38 33 40 n 110 03 16 w. Also as with GE, you may enter latitude and longitude in decimal degree format: 38.5611 −110.0544 (when using the Download Platform you must use decimal degree format with longitude first: −110.0544 38.5611). The latitude and longitude of the cursor position on the map is shown along the bottom of the screen (from the "Options" icon at the top right of the screen, you can change the display format of latitude and longitude). To hide the "Results" panel that appears at the left of the screen after a search, click the triangle on the upper right side of the panel.

Navigating in The National Map: You can point and click on the map to zoom in to any location. You may also change locations by clicking and dragging on the map with your mouse. To center the map on a particular point, hold down the shift key and click on that spot. The zoom control lets you quickly change scales of the map (the map scale is shown along the bottom of the screen). You may also zoom in by simply double clicking on the map.

Base Maps and Imagery: You can toggle between a shaded-relief topographic map ("Topo"), satellite/aerial imagery ("Imagery"), a combination of both ("Imagery Topo"), as well as hydrologic data and a simple shaded relief map, with the buttons in the upper right of the screen. The many available map layers are shown along the left side of the map by selecting "Overlays"—you can hide or open this left panel by clicking the triangle along the top right of the panel.

Tools: A number of measurement tools and other functions are available by opening the tool functions along the top of the map. For example, a "Ruler" function in the "Advanced" tab

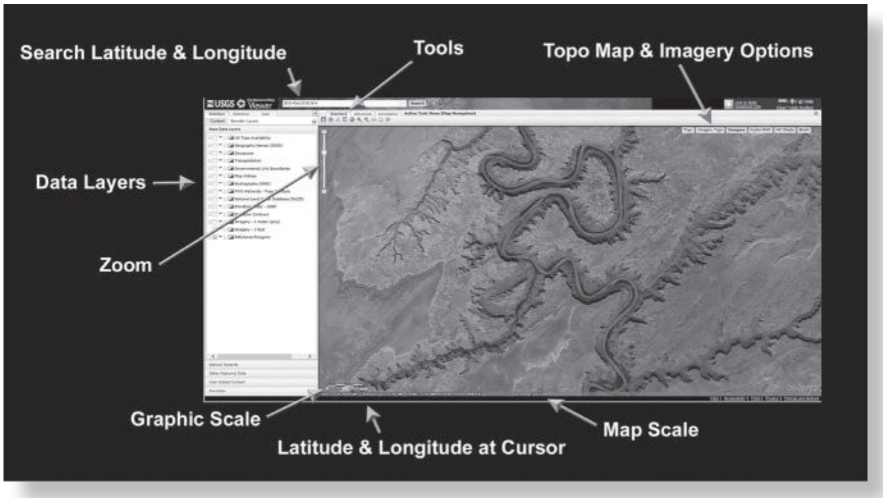


Figure 7-3: The National Map Online Viewer screen showing layers panel and navigation controls. (Adapted from U.S. Geological Survey)

lets you measure distances on the map or image—click once to start your measurement line; double click at the end of your measurement line and the distance will appear in a pop-up window (to clear your measurement lines off the screen, you may need to go to the "Standard" tab and click the "Clear Graphics" icon).

To determine elevations, from the "Standard" tab click on the "Spot Elevation" icon; click on the map, and the elevation of that point appears; click the Clear Graphics icon to clear elevations off the screen.

Downloading Maps: You can download maps and imagery from The National Map by using the Download Platform. However, if you simply want PDF files of topographic maps or orthophoto imagery maps, it is easier to use *U.S. Topo* (**http://nationalmap.gov/ustopo/**) described in Exercise 29.

GRADIENT

In landscape analysis, one way to describe the steepness of a slope is with **gradient**. Gradient describes the elevation change of a slope over a given distance. For example, if working with English units of measure, gradient is usually stated in feet of elevation change per mile. For example, if a slope changes elevation by 3200 feet over a distance of 2.5 miles, the gradient is:

$$\text{Gradient} = \frac{\text{Elevation change}}{\text{Number of miles}} = \frac{3200\text{ ft.}}{2.5\text{ miles}} = 1280\text{ feet/mile}$$

In subsequent lab exercises, you will learn how to calculate gradients using topographic maps. Gradients may also be determined in Google Earth™ and The National Map by using their ruler and elevation functions. For example, to determine gradients in GE, open the ruler function (with distances set to miles); click your mouse to anchor the ruler—note the elevation at your starting point. Extend the ruler along the slope to your stopping point and click again, noting the elevation at the stopping point. Divide the difference in elevation by the distance measured by the ruler to determine the gradient of the slope. You can measure the distance along a curved path (such as a stream course) by setting the ruler to "Path" and using multiple mouse clicks along the way.

Because gradient describes the ratio of elevation change to distance, if you are measuring a uniform slope (in other words, a slope that has a constant gradient over a long distance), your calculations should yield the same gradient for that slope whether you make your measurements over a short distance or over a long distance. In most cases, however, even if the slope is uniform, you'll end up with more accurate results if you take your measurements over a longer distance.

WHICH TO USE—GOOGLE EARTH™ OR THE NATIONAL MAP?

An obvious question to ask is which is better for landscape analysis, Google Earth™ or The National Map? The short answer is that both are useful. The National Map has a large—and growing—number of consistently high-quality public-domain data layers that may be viewed and easily downloaded. As with many other free Internet applications, Google Earth™ has become a way for businesses to reach potential customers, but it also provides the geographer with easy ways to save and share location information, and to manipulate the view of the landscape in remarkable ways.

Name ____ Section ____________________

EXERCISE 7 PROBLEMS—PART I—GOOGLE EARTH™

Answer the following questions after you have installed the free Google Earth™ software from **http://earth.google.com** and opened the program on your computer.

1. In the "Search" box, enter the latitude and longitude of Crater Lake in Oregon; remember, you don't need to enter the symbols for degrees, minutes, or seconds, but you do need to leave a space between each value: 42°56′20″ North, 122°06′25″ West.

   (a) What is the apparent altitude of your "eye" in this opening view?

   _______________ feet

   (b) Zoom out by clicking on the "−" symbol at the bottom of the zoom control until you can see the entire lake. What is the apparent altitude of the "eye" now?

   _______________ feet

   (c) Move your cursor around the rim of the caldera. What is the highest elevation you find around the rim of Crater Lake?

   _______________ feet

2. In the "Search" box, enter the address of your house or school. Zoom in as much as you can on your house or school building before image quality begins to break down.

   (a) Location: Latitude __________________ Longitude ___________________

   (b) Elevation: _______________

   (c) What time of day was this image taken? (circle) Morning / Midday / Afternoon

   (d) How can you tell?

   (e) What is the date of the imagery? __________________________

To answer problems 3 to 6, go to the Hess *Physical Geography Laboratory Manual*, 12th edition, website at **www.MasteringGeography.com**, then Exercise 7. Select "Exercise 7 Part I Google Earth" to open a KMZ file in Google Earth™. The opening view is the same region north of Canyonlands National Park and the Green River in Utah shown in Figure 32-3, Figure 32-4, and Map T-7.

3. In the Places panel, double click on "Point 1" to fly to this location. What is the elevation of Point 1? ________________ feet

4. (a) Double click on Point 2 to change your vantage point. What is the elevation of Point 2? ________________ feet

   (b) What is the relief (the difference in elevation) between Point 1 and Point 2? ________________ feet

5. Fly to Point 3. Click the "+" button on the Zoom control to move in closer to this sharp turn called "Bowknot Bend" along the Green River. Using the forward arrow on the Move control, fly over the landscape until you have a clear view of Point 3 along the river bottom. From this angle, it may appear that clouds are draped over the ridge between the tight loops in the river's course. The historical imagery you see was taken in 2003 from a vantage point nearly directly overhead of this area and the clouds were not really this low to the ground, so why do the clouds appear this way in Google Earth™?

6. Fly to Point 4 a short distance away. You are going to measure the gradient of this slope. Double click on Point 5 to move in closer and look directly down on this slope. Determine the gradient of the slope between Point 4 and Point 5.

   ________________ ÷ ________________ = ________________ feet/mile gradient
   (Elevation change) (Distance in miles)

EXERCISE 7 PROBLEMS—PART II—INTERNET

Go to The National Map (**http://viewer.nationalmap.gov/viewer/**). Once the viewer has opened, in the "Search" box, enter the latitude and longitude of the area north of Canyonlands National Park shown in Figure 32-3, Figure 32-4, and Maps T-7 and T-20: 38°33′40″ North, 110°03′16″ West. Select "Imagery" to see aerial imagery of this area. Zoom in until you have a close view of this half-circle-shaped hill encircled by a dry gorge.

1. Use the Spot Elevation function (from the "Standard" tab) to determine the relief of this hill:

   ________________ – ________________ = ________________ feet
   (Elevation at top of hill) (Elevation in bottom of dry gorge to north) (Relief)

2. (a) Was this aerial image taken in the morning or in the afternoon? ________________

   (b) How can you tell?

Lab Exercise 8

https://goo.gl/zbfPGo

EXERCISE 8

Geographic Information Systems and Remote Sensing

by Ryan Jensen, *Brigham Young University*

Objective: To learn the basics of GIS and remote sensing, become familiar with ArcGIS Online by displaying and investigating online datasets, and perform a proximity analysis using buffers and overlay in ArcGIS Online.

Resources: Computer (laptop or desktop) or tablet; Internet access.

Reference: Hess, Darrel. *McKnight's Physical Geography*, 12th ed., pp. 41–50.
Jensen, J. and R. Jensen. *Introductory Geographic Information Systems* (2013).

INTRODUCTION

Geographic information systems (GIS) are important tools that geographers and others use to map, analyze, and query spatial data. Remote sensing data, usually acquired from either an orbiting satellite or plane/drone/helicopter, are commonly used in GIS analysis. This lab will introduce you to the basics of GIS and remote sensing by stepping you through exercises using an online mapping program: Esri's *ArcGIS Online*.

First, we explain the basics of GIS and remote sensing. Then, you will create a free account in ArcGIS Online and begin to view and analyze data. You will finish the exercise by completing a GIS proximity and overlay analysis.

GIS AND REMOTE SENSING

Geographic information systems are computer software programs specifically designed to view, analyze, map, query, and explore spatial data. Professionals from many different disciplines regularly use GIS to examine spatial relationships. For example, police officers use GIS to map crime and determine where to maximize police presence. A tax assessor may use GIS to examine market values of homes in different neighborhoods and determine if there are any outliers above or below the mean housing value in each neighborhood. Wildlife biologists use GIS to identify habitat areas suitable for mule deer in the western United States. Epidemiologists use GIS to map disease and disease vectors to better understand disease dynamics and transmission. Wastewater managers use GIS to map the wastewater network. GIS allows researchers to examine a problem spatially using multiple data layers.

You have probably used both GIS data and analysis with a personal navigation device to get from one point to another. In fact, if you have a smartphone with you, it probably has the ability to first locate places of interest near you (e.g., restaurants, ATMs) and then identify the best route to get you there. Your phone combines very accurate GIS data layers and global positioning system (GPS) locations to determine the best routes.

Remote sensing refers to collecting information about an object without actually touching that object. All of you have probably used a remote sensing device, such as a camera. A camera measures reflected light from objects or phenomena within its view. It does so without ever touching the objects. A camera may measure reflected sunlight on a sunny day or reflectance from its own flash. Most cameras that people regularly use only measure information in visible light. Conversely, most scientific remote sensing instruments measure visible light and information in other electromagnetic regions (e.g., near infrared, infrared, **radar**). Remote sensing data collection usually occurs via orbiting sensors, aerial cameras, and active sensors, such as radar and *lidar*. Remote sensing images are viewed every day on local television during the weather segment when Doppler radar (see Exercise 21) and visible satellite images (via GOES; see Exercise 20) are displayed to demonstrate weather and rainfall patterns. Remote sensing data are used by the National Aeronautics and Space Administration (NASA) to measure global vegetation patterns (Figure 8-1; shown in color in Map T-31a in back of Lab Manual) and to monitor forest fires (Figure 8-2; shown in color as Map T-31b).

GIS and remote sensing are often used together. For example, remote sensing data can derive very accurate land cover maps using spectral information that can then be analyzed in a GIS. You have probably used an app where both GIS and remote sensing data are utilized. For example, when a navigation app routes you from one point to another it relies on many different datasets including the network and traffic data that may have been derived from traffic sensors (e.g., cameras), individual smartphones (where users have enabled certain information to be used), and fleet cars such as taxis. All of these data are utilized dynamically in real time to enable you to travel on the fastest route. In fact, if traffic congestion occurs along your route, the navigation app may attempt to reroute you to a faster route that may have been longer in distance.

Figure 8-3 (shown in color as Map T-31c in the back of the Lab Manual) highlights a route from Los Angeles to Malibu in California, delimited in several colors along the route: Blue means

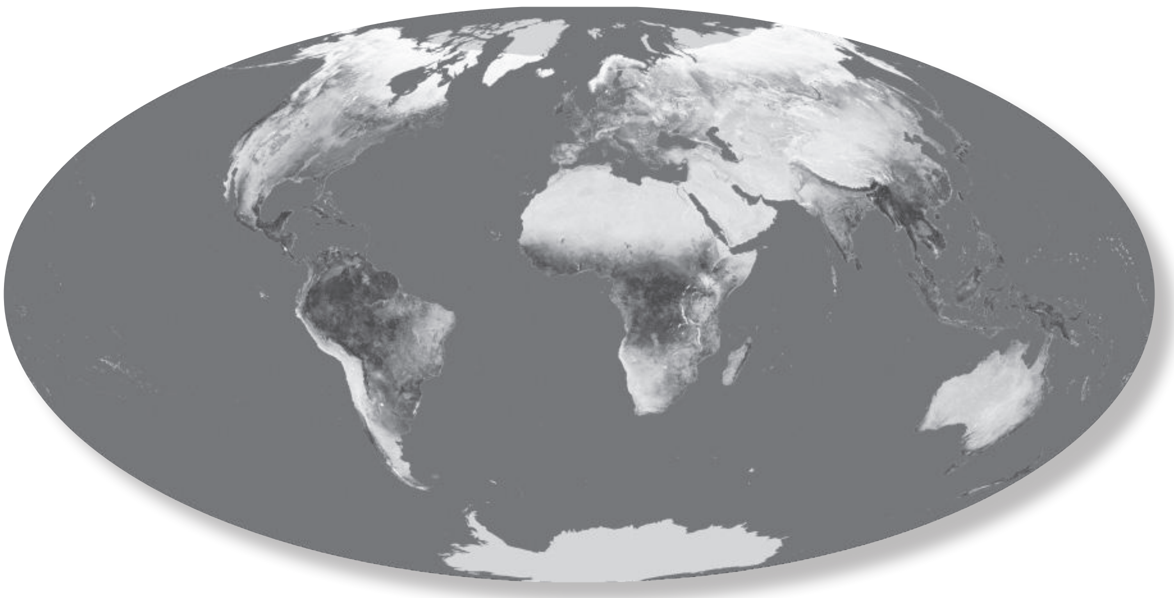


Figure 8-1: A vegetation map of the world (November 1 – December 1, 2007) derived using remote sensing data. This map is shown in color as Map T-31a in the back of the Lab Manual. (From NASA)

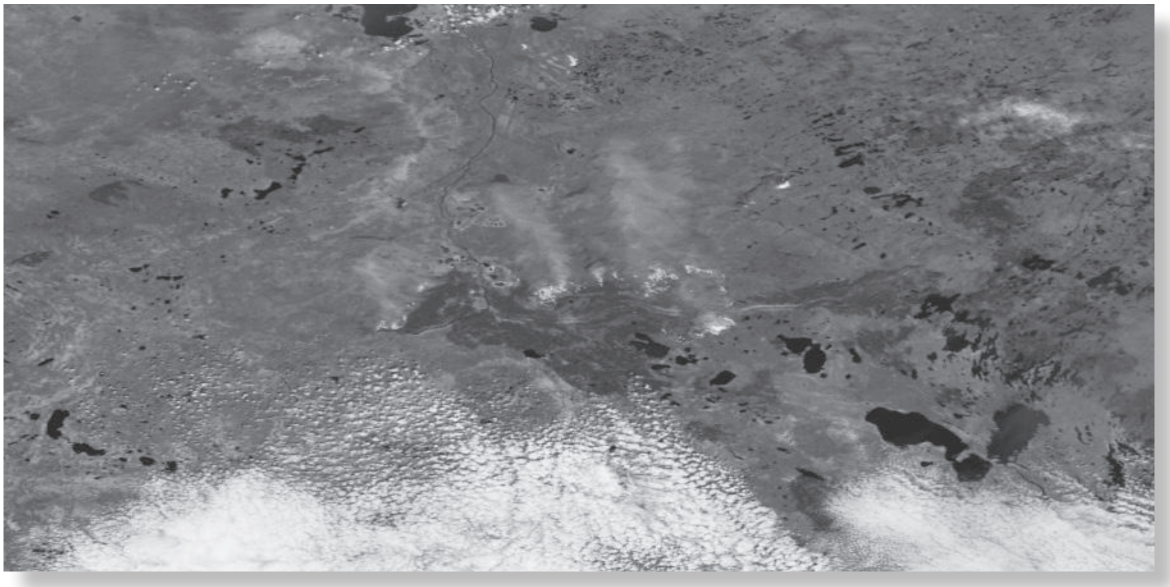


Figure 8-2: This image was acquired of the Fort McMurray, Canada, wildfire in May 2016. This map is shown in color as Map T-31b in the back of the Lab Manual. (From NASA)

no traffic and normal speeds; yellow signifies slow traffic; red indicates very slow or stopped traffic. Note the optional route in gray and the option for public transit, and that many cultural (city names, etc.) and physical geography (mountain ranges, ocean bathymetry, etc.) are described. Also, the land area displays a remote sensing image to give context to the route's landscape. Although this routing ability may seem simple, many different layers of GIS and remote sensing data and analysis are incorporated into the final solution. Routing apps, software, and websites integrate these different datasets and arrive at a solution seamlessly so that end users see only the results.

Figure 8-3: Route from Los Angeles, California to Malibu, California in derived in Google Maps. This map is shown in color as Map T-31c in the back of the Lab Manual. (From Google Maps™)

GIS is particularly useful for combining (or overlaying) different maps to determine the relationships between different variables. In addition, finding proximity and enclosure of multiple variables is also useful. This is done by combining different map layers into a single map and joining their attributes. Examples of this kind of analysis include the following:

- A biologist may combine a vegetation layer with an elevation layer to see if elevation has any effect on vegetation.
- A developer may want to determine what parcels of land for sale are within the 100-year floodplain.
- A police officer may be interested in what crimes occur in what neighborhoods.

There are two ways to obtain GIS and remote sensing datasets: (1) create them yourself, or (2) use what others have already created. Usually spatial data analysts will first search for necessary data from reputable online data repositories, because many spatial datasets have already been collected. Most governmental entities collect and serve a huge amount of spatial data layers. Usually, these data are available for free or at cost of reproduction based on governmental laws and policies that regulate data ownership and distribution. Further, data obtained and served by the government must often adhere to certain accuracy standards before they can be served. These accuracy standards are dependent on the agency/government collecting the data and how the data were originally designed to be used.

Before using any spatial data, it is important to consider the following data characteristics:

- Who collected the data?
- How were the data collected?
- When were the data collected?
- How accurate are the data?
- What projection and coordinate system do the data use?
- Are there any restrictions to using the data?
- Do you have other questions about the data?

The answers to each of these questions are often found in a “metadata” file that describes the characteristics of each dataset. Always make sure that you read and understand the metadata before you use any data that you did not collect yourself. Further, if you collect data yourself using GPS or some other method, make sure that you create a metadata file that answers all of the previous questions.

GIS and remote sensing data can be found in many different locations. Figure 8-4 is a table that contains a list of Internet sites where data can be found.

Name	Owner	Address
Earth Explorer	U.S. Geological Survey	http://earthexplorer.usgs.gov
U.S. National Wetlands Inventory	U.S. Fish and Wildlife Service	https://www.fws.gov/wetlands/data/data-download.html
Water Resources of the United States	U.S. Geological Survey	http://water.usgs.gov/maps.html
Data from NASA’s Missions, Research, and Activities	National Aeronautics and Space Administration	http://www.nasa.gov/open/data.html
Datasets and Images	National Aeronautics and Space Administration	http://data.giss.nasa.gov
U.S. Census Data	U.S. Census Bureau	http://www.census.gov/data.html

Figure 8-4: Useful Internet sites to find GIS and remote sensing data.

Name ____ Section ____________________

EXERCISE 8 PROBLEMS—PART I—INTERNET

ARCGIS ONLINE

In this section you view data layers in ArcGIS Online. ArcGIS Online provides users with multiple datasets and the ability to analyze data.

You will need to create a free 60-day account to use ArcGIS Online. Go to the website **https://www.arcgis.com/home/index.html** and click on "Sign-up now" to create your account. On the next page click on "TRY ARCGIS" and follow the steps of setting up your account, including clicking on a link in an email. After you have set up your account, sign in to ArcGIS online and click on "Map." This will take you to the main Map page where you will be able to analyze spatial data and create maps online. You should see a screen that resembles Figure 8-5.

A GIS map of the United States should appear. Note that there are three tutorials along the left side of the screen that you could use to acquaint yourself with some of the basic abilities of ArcGIS Online.

You will now add a remote sensing data layer for a basemap. Click on "Basemap" and then on "Imagery." The map should now show an image of the United States.

Note in the upper right corner of the map a search box. Type in your address as completely as you can (e.g., 620 East 800 North, Provo, Utah 84606) and press the Return key.

1. How close is the map location to the actual location of your home? If it is not close, what are some reasons why?

Figure 8-5: Initial map screen in ArcGIS Online. Map image is the intellectual property of Esri and is used herein under license. Copyright © 2014 Esri and its licensors. All rights reserved.