# Chapter 2
# Representations of Earth

## Chapter Objectives

This chapter should enable your students to…

- 2.1 Explain the ways that Earth and its regions, places, and locations can be represented on a variety of visual media - maps, aerial photographs, and other imagery.
- 2.2 Assess the nature and useful applications of maps and map-like presentations of the planet, or parts of Earth, citing some examples.
- 2.3 Find and describe the locations of places using coordinate systems, use topographic maps to find elevations, and understand the three types of map scales.
- 2.4 Demonstrate knowledge of techniques that support geographic investigations, including mapping, spatial analysis, global positioning systems (GPS), geographic information systems (GIS), and remote sensing.
- 2.5 Evaluate the advantages and limitations of different kinds of representations of Earth and its areas.
- 2.6 Understand how the proper techniques, images, and maps can be used to best advantage in solving geographic problems.

## Chapter Outline

**I. Chapter Preview**

**II. Maps and Location on Earth**

A. Earth's Shape and Size

B. Globes and Great Circles

C. Latitude and Longitude

1. Measuring Latitude

2. Measuring Longitude

3. Decimal Degrees

**III. The Geographic Grid**

A. Parallels and Meridians

B. Longitude and Time

C. The International Date Line

D. The U.S. Public Lands Survey System

E. Global Navigational Satellite Systems

**IV. Maps and Map Projections**

A. Advantages of Maps

B. Limitations of Maps

C. Map Projections

1. Planar Projections
2. Conic Projections
3. Cylindrical Projections

D. Properties of Map Projections

1. Shape
2. Area
3. Distance
4. Direction
5. Compromise Projections

E. Map Basics

1. Legend
2. Scale
3. Direction

F. Thematic Maps

1. Discrete and Continuous Data

G. Topographic Maps

**V. Modern Mapmaking**

A. Geographic Information Systems

1. What a GIS Does
2. Data and Attribute Entry
3. Registration, Display, and Analysis
4. Digital Elevation Models
5. Visualization Models

B. Geographic Information System in the Workplace

**VI. Remote Sensing of the Environment**

A. Digital and Photographic Images

B. Remote Sensing Systems

1. Passive Systems

2. Active Remote Sensing Systems

**VII. Multispectral Remote Sensing**

## Chapter Summary

- The Earth can be represented using a variety of tools: maps, remote sensing (aerial photography), vertical exaggeration, and geographical information systems (GIS).
- The purpose of a map is to communicate spatial and locational information. Maps are an essential resource for navigation, community planning, surveying, history, meteorology, geology, political science, and many other career fields.
- Computer technology has revolutionized cartography (the science and profession of mapmaking) and digital imagery. Today, nearly all maps are developed and produced using computer technologies.
- All maps transform Earth into a flat object (map) by a process referred to as map projections. Map projections distort Earth by its shape, size, or a combination of size and shape. There are many examples of map projections, each having their advantages and limitations.
- Global Navigational Satellite Systems (GNSS) is the general term for satellite-based technologies that are used for determining locations on Earth. Global Positioning System (GPS), originally created for military applications, is now widely used in the United States. Today, GPS and GNNS are being adapted to many uses, from surveying and mapping to aircraft and marine navigation.
- Geographic information system (GIS) is a versatile computer-based system that is capable of storing different types of data in layers. GIS is extremely useful to geographers as they work to address problems that require large amounts of spatial data from a variety of sources.
- As technology has improved over the past decades, GIS and remote sensing systems such as near-infrared, thermal infrared, Radar, Lidar, and Sonar are playing an increasing role in shaping the decisions of businesses, governments, and citizens.

## Lecture Suggestions

- Have the class visit http://nationalmap.gov/small_scale/a_plss.html to learn more about the U.S. Public Lands Survey System.

- Visit http://www.colorado.edu/geography/gcraft/notes/mapproj/mapproj_f.html for visual examples of map projections.

- Visit http://www.nrcan.gc.ca/earth-sciences/geomatics/satellite-imagery-air-photos/satellite-imagery-products/educational-resources/9309 for a tutorial from Natural Resources Canada that provides information on the types of remote sensing used today.

- Visit http://www.esri.com and investigate some of the ways ArcGIS software can be used to create geographic projections. A free version of the software is available for 60 days. Using a software trial, students could learn how to create maps using ArcGIS, a common GIS software program used in government and industry.

## Key Terms

cartography
oblate spheroid
navigation
great circle
hemisphere
small circle
coordinate system
equator
latitude
sextant
prime meridian
longitude
decimal degrees
geographic grid
parallel
meridian
time zone
solar noon
International Date Line
U.S Public Lands Survey System
principal meridian
base line
township
section
Global Navigational Satellite Systems
global positioning system (GPS)
map projection
planar projection
conic projection
cylindrical projection
Mercator projection
conformal map
equal-area map
equidistance
azimuthal projection
gnomonic projection
compromise projection
legend
map scale
verbal scale
graphic (bar) scale
representative fraction (RF) scale
magnetic declination
azimuth
bearing
thematic map
discrete data
continuous data
isoline
topographic contour line
contour interval
profile
gradient
geographic information system (GIS)
digital map layers
digital elevation model (DEM)
draping
vertical exaggeration
visualization models
remote sensing
aerial photograph
digital image

pixel
spatial resolution
near-infrared (NIR)
thermal infrared (TIR)
radar
weather radar
imaging radar
lidar
sonar
multispectral remote sensing

## Answers to Questions for Review

1. A great circle marks the shortest distance between two points on a sphere (Earth).

2. M.A. Answers will depend on the student's location.

3. The distance between longitude degrees become shorter with increasing latitude, and longitude depends on the latitudinal location in question. Latitude degrees are about 111,000 meters each, so 111,000 m/60 minutes (in a degree) equals 1,850 meters per minute of latitude, and 1,850 m/60 seconds in a minute equals 30.8 meters or about 101 feet. So one second of latitude would be about 30.8 m or 101 feet. The level of precision using GPS varies depending on the unit. The most expensive units will provide sub-meter accuracy while more common units provide accuracy ranging from a meter to a few tens of meters.

4. M.A. Answer will depend on location. Those along the east coast of the United States (e.g., Washington D.C.) are five hours different than Greenwich, England. West coast citizens of the United States and Canada are 8 hours different. All locations in North and South America are later than England, while all locations in Asia are earlier.

5. You will "gain" a day when traveling from the United States to Japan. This means the date when you land will be the next day of the week (e.g. leave on Sunday, arrive on Monday).

6. The road and street grids of the Western and Midwestern United States that use this system have a square grid oriented to the cardinal directions of N, S, E, and W. Answers to the second half of this question will depend on location. M.A.

7. It is impossible to accurately depict a sphere or large parts of a sphere on flat paper without distortion. A conformal map shows correct shapes for mapped areas, and an equal-area map shows correct comparable areas of mapped regions (areas).

8. An RF scale is a fraction or proportion of one unit of map distance to the number of the same units that it represents on the map (e.g., 1:24,000). A verbal map scale is a written statement of the map's scale, such as one-inch equals 2,000 feet. This is the same as 1:24,000, but in a verbal scale it is OK to mix units.

9. In a GIS system, information presented in different scales will be normalized to a single scale so that data obtained from various sources can be used on the same scale.

10. Thematic map layers are digitally stored maps of individual features (roads, terrain, climate, vegetation patterns, rivers, lakes, etc.) that can be computer accessed and displayed in any desired combination for geographic analysis in a geographic information system. The finished map will combine whatever layers are needed for a particular study.

11. Before computers, maps had to be drawn individually and redrawn or modified by hand if they required updating of mapped information. Computers allow easy map drawing and revision, as well as the overlaying of mapped data and information.

12. Weather radar images show us patterns of precipitation and storms that would otherwise be hidden by cloud cover.

13. Color infrared images allow scientists to better visualize vegetation, urban land use, water features, etc. Thermal infrared images allow scientists to map changes in temperature, allowing them to map changes in temperature inside buildings, to find fire through smoke, etc. Digital elevation models are useful for examining changes in elevation across landscapes for the purpose of infrastructure planning, etc. Lidar images are useful for collecting high resolution elevation data, information on the built environment, information on the height of structures above the ground (beneficial for aircraft), etc.

## Answers to Consider and Respond Questions

**M.A. = Many answers possible**

1. M.A. for the specific vacation spot. If you were going walking or sightseeing in town, an official city map would be best. If you were hiking, a topographic map would best serve your purpose. Topographic maps show actual elevations with numbers, satellite images show a photographic like vertical image of the landscape, often in full color to see vegetation patterns. Road maps show distances that automobiles travel and the names of roads. All three provide general impressions of the geography of the area in question, and all three show major roads.

2. M. A. Answers will vary greatly among students. Some important layers would be roads, campsite locations, slope, geology, vegetation, location of natural resources, soils, elevations, locations of wildlife sightings, water bodies, and other park amenities.

## Answers to Practical Applications Questions

**M.A. = Many answers possible**

1. If it is Tuesday, 2 am in New York (75° W time zone, EST), it is 3 hours earlier in California (120° W time zone—PST), or 11 pm on Monday night (3 hours earlier for every 15 ° west and later for every 15° east).

   London is in the 0-degree time zone (GMT), and 75° east of New York, so it is 5 hours later than New York (75/15 = 6), or 7 am Tuesday morning in London.

   Sydney is in the 150-degree E time zone, east of London, so the time is 10 hours later, or 5 pm Tuesday night in Sydney, Australia.

2. The linear scale is 1:2400 and the vertical is 1 in = 100 ft. To make the conversion we first need to know that there are 12 inches in 1 foot. Then, we multiply the 12 inches by 100 ft to get 1,200 inches, so on the map 1 in = 1,200 inches, or the RF is 1:1200. Since 1,200 is half of 2,400, the vertical exaggeration is 2 as compared to the horizontal.

3. Students should use the formula: map distance/Earth distance = 1/ Representative Fraction Denominator. Using the distance relationship, 10 cm = 1 km. If we change this to meters: 0.10 m = 1000 m, so 0.10 m:1000 m = 1:RDF or 1:10,000. In feet/inches: 3.94 in = 3281.12 ft. If we change this to the same units 3.94 in = 39,372 inches (12 inches x 3,281.12). So 3.94:39,373 = 1:RFD, and RFD = 9993 (39,373/3.94) or an RF scale of 1:10,000 if rounded. Important: the units in an RF cancel in the numerator and denominator so an RF scale is a dimensionless number.

## Answers to Figure-Legend Questions

**M.A. = Many answers possible**

Figure 2.2 These hand-drawn depictions of the landscape are valuable, and very good at emphasizing topographic features and providing a good impression for the lay of the land.

Figure 2.5 Mansfield is at C-6. F-3 is the location of Cleveland.

Figure 2.6 Sextants are mechanical devices that operate without relying on any power source (other than that provided by the human operator). A battery-powered GPS unit could fail (imagine being lost in a remote area). Furthermore, a sextant provides a good demonstration of the relationship between Earth and the Sun, and how those relationships are linked to seasons and latitudinal position. In comparison, however, GPS provides both longitude and latitude and can be used either day or night —or when clouds obscure the Sun.

Figure 2.7 90° N latitude. Note: The north and south poles do not require a longitudinal position because lines of longitude converge at the poles.

Figure 2.8 Meridians are north-south lines that converge at the poles while parallels run east-west and do not converge. All meridians are half great circles while all parallels are small circles except for the one at the equator.

Figure 2.9 M.A. East coast of US – 5 hours; west coast of the US – 8 hours; etc.

Figure 2.10 The International Date Line jogs around a few locations to insure that countries, cities, towns, or island groups do not have different days within their borders.

Figure 2.11 The Township and Range System was developed after the eastern United States was settled. Thus, its impacts on land and distributions are seen only in the Midwest and western portion of the United States.

Figure 2.12 SE l/4 of the SE 1/4, Sec. 20, T3S, R2E.

Figure 2.13 Mountain ranges of this magnitude do not exist in the Midwest.

Figure 2.15 The use of GPS technology is becoming commonplace. A GPS unit can broadcast its position (e.g., placed in cars for location in theft recovery), and they are useful for wilderness hikers to find their positions relative to a map. Emergency vehicles have GPS units, so that a 911 operator can tell where the nearest emergency vehicle is to a place of need, or how to find a location - thus allowing faster response times.

Figure 2.17 The Moon was mapped using satellite observations of the terrain and other remote sensing techniques.

Figure 2.18 Different types of map projections are used for different reasons. For example, sometimes a certain type of projection is a better fit for the shape and latitudinal area of the area we wish to present on a map. Other times we may wish to preserve a particular map property, such as shape, distance (area), or direction.

Figure 2.19 The distortion is very great in regions away from the Equator. Greenland appears larger than South America on a Mercator projection when, in fact, it is only about 1/8th the area of South America.

Figure 2.20 The answer depends on the intended use of the map, if it is important to compare areas of regions, countries, continents, or other areas, preserving area is best. If it is important to show the accurate shape of the same kinds of areas then preserving shape is more important. No map of a large area can do both.

Figure 2.22 The Mercator projection does not distort shape but the gnomonic projection does. Both projections distort size. Most importantly a straight line on a Mercator projection is a line of true compass heading, while on the gnomonic projection a straight line represents the shortest route between two points.

Figure 2.26 M.A. Answer will vary depending on the student’s hometown.

Figure 2.27 M.A. Examples: discrete means only occurring at a specific location – mountain peaks (point), thunderstorm cells (area), coastline (line); continuous means any variable that has a measurable variable everywhere (air pressure, vegetation cover density).

Figure 2.28 Students should be able to get a general impression of the landscape by examining the topographic contour lines, particularly their shape and spacing.

Figure 2.29 Looking at the spacing, shapes, and the arrangement of contour line patterns we can visualize the relief. Close spacing of contours indicates steep terrain. Wide spacing indicates a gentler or perhaps a nearly flat slope.

Figure 2.30 A Geographic Information System (GIS) has almost unlimited uses in addition to environmental ones. Any situation that requires spatial information combined in layers can benefit from a GIS, including the allocation of emergency response systems, or finding the best (or worst) locations for economic, recreational, or agricultural activity. Virtually any kind of activity can benefit from a GIS.

Figure 2.32 The high potential earthquake hazard for the East Coast, the Midwest, and the New England area on a stable tectonic plate is a bit surprising. GIS can be used in a number of applications including: environmental assessment, business and government decisions, and visual representations.

Figure 2.35 Oblique views have a more natural look as compared to normal human vision. Vertical views are more map-like.

Figure 2.36 Near-infrared (b). Near infrared images show a stronger contrast between water (dark blue) and red growing vegetation so it is much easier to see the boundary between land and water (which is important for making maps of the location). Crops and other vegetation types can also be discriminated better when using a color infrared photograph as compared to a normal color print.

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| Figure 2.37 | Thermal infrared can be used to note the direction of storms as well as how energy is transported in the atmosphere. |
| Figure 2.39 | Examples: We can see road and street patterns. For example, a bridge crosses the center of one of the water bodies, and boundaries between land and water can be differentiated. Differences in water color are indicators of changes in depth or sediment load. Patterns of vegetation growth and other plots of land can be seen, including an area on the shoreline in the bottom right of (b). |

## Answers to Global Geoscience Watch Activity

1. b
2. b
3. a