The background of the cover is a photograph of a large waterfall cascading over dark, mossy rock formations. The water is captured with a long exposure, creating a soft, ethereal effect. In the distance, a rugged mountain peak is visible under a blue sky with scattered white clouds. The overall scene is a natural, scenic landscape.

ELEVENTH  
EDITION

# Physical GEOGRAPHY

James F. Petersen | Dorothy Sack | Robert E. Gabler

# PHYSICAL GEOGRAPHY



EDITION  
**11**

# PHYSICAL GEOGRAPHY

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# Preface

**P**hysical geography concerns understanding Earth as an integrated system, how it functions, and how it and its environments vary over space and time. Earth is a complex environmental system driven by interactions among factors that include climate, weather and the atmosphere, organisms and their communities, water, landforms, and soils. Understanding these factors and how they change and interact is crucial for making informed decisions about the use and preservation of Earth's environments and resources. Our interactions with the environment are also important, as they can either benefit or endanger our own living conditions as well those of future generations. The more we know about the Earth system and how it operates, the more effective we can be in working toward preservation, stewardship, and sustainability on a local, regional, and global basis.

Recognition of geography's importance to society as a major field of inquiry, and as a professional career focus, is growing along with environmental awareness. Geographic knowledge, skills, and techniques are increasingly valued in the workplace. Physical geographers use the latest technologies to observe, study, map, and measure features and processes and their interactions as parts of the Earth system. They work on understanding and modeling environmental responses and interactions. Physical geographers analyze digital images from satellites and aircraft, and employ digital mapmaking techniques (cartography), geographic information science (GIS), the global positioning system (GPS), and other tools for analysis and problem solving.

*Physical Geography 11<sup>th</sup> edition's* focus on relevance is supported by explanations of geographic tools and methods. Practical applications that use geographic data, maps, satellite images, and landscape photographs are provided in this book. These activities, along with the text material, encourage spatial thinking and give students opportunities to apply effectively the geographic knowledge they are acquiring.

At the college level, physical geography is an ideal science course for students who want to make informed decisions that consider environmental limits and possibilities as well as people's wants and needs. Today's students will be the decision makers of tomorrow, dealing with issues that affect what people need and want, while considering environmental limits and possibilities. It is for these students that *Physical Geography* has been written.

## Features

**Comprehensive View of the Earth System** *Physical Geography* introduces all major aspects of the Earth system, identifying physical phenomena and natural processes and stressing their characteristics, relationships, interactions, and distributions.

The text covers a wide range of topics, including the atmosphere, the solid Earth, oceans and other water bodies, and the living environments of our planet.

**Engaging Graphics** Visual aids greatly enhance the study of geography; therefore this text includes an array of illustrations and photographs that make the concepts come alive. There are more than 200 new or significantly improved images, figures, and graphics. Clear, easy to understand, and colorful diagrams illuminate important concepts. Stunning photographs that show excellent examples bring the physical world to the student. Locator maps accompany selected photographs to provide a spatial context and help students identify the place or feature's geographic position on Earth. Questions are included with most figures to invite interpretive thinking about Earth's features, environments, and concepts.

**Clear Explanations** The text uses an easily understandable, narrative style to explain the origins, development, significance, and distribution of processes, physical features, and events that occur within, on, or above Earth's surface. The writing style is targeted toward rapid comprehension and making the study of physical geography meaningful and enjoyable.

**Introduction to the Geographer's Tools** Digital technologies have revolutionized our abilities to study Earth's natural processes and environments. A full chapter is devoted to maps, digital imagery, data, and technologies used by geographers. Illustrations include maps and images with interpretations provided for the environmental attributes shown in the scenes. There are also introductory discussions of many techniques that geographers use for displaying and analyzing environmental features and processes, including remote sensing, geographic information systems, cartography, and global positioning systems.

**Focus on Student Interaction** The text continually encourages students to think, conceptualize, hypothesize, and interact with the subject matter of physical geography. Activities at the end of each chapter can be completed either individually or by a group, and are designed to engage students and promote active learning. Review questions reinforce concepts and prepare students for exams, and practical application assignments require active solutions, such as sketching a diagram, performing data calculation and analysis, or exploring geographic features using Google Earth<sup>®</sup>. Questions following most figure captions prompt students to think beyond, or to use, the map, graph, diagram, or image, and to give further consideration to the topic. Latitude/longitude coordinates for selected

photographs and climatic location examples invite students to further explore physical geography using satellite imagery provided by Google Earth or other Internet system for viewing Earth locations. Detailed learning objectives at the beginning of the chapters provide a means for assessing comprehension of the material.

**Three Unique Perspectives** Physical geography is a subject that seeks to develop an understanding and appreciation of our Earth and its environmental diversity. In approaching this goal, this textbook employs feature boxes that illustrate three major perspectives of physical geography. Through a **spatial science perspective**, physical geography focuses on understanding and explaining the locations, distribution, and spatial interactions of natural phenomena. Physical geography can also be approached from a **physical science perspective**, which applies the knowledge and methods of the natural and physical sciences, for example, by using the scientific method and systems analytical techniques. Through an **environmental science perspective**, physical geographers consider impacts, influences, and interactions among human and natural components of the environment. Basically, this means understanding how Earth's environments and environmental processes influence human life and how humans affect environments on scales from local to global.

**Map Interpretation Series** Developing map interpretation skills is a priority in a physical geography course, and beneficial in many career fields. To meet the needs of students who do not have access to a laboratory setting, this text includes map activities with, full-color maps generally printed at their original scale, satellite images, and interpretation questions. These maps give students an opportunity to develop valuable map-reading skills. In courses that have a lab section, the map interpretation features offer an excellent supplement to lab activities, where each student has access to the same map, image and activity. These interpretive activities provide strong links to lectures, the textbook content, and practical lab applications.

## New Features

**Understanding Map Content** Thematic maps have the ability to present a great deal of geographic data in graphic form. The goal of the **Understanding Map Content** feature is to help students understand the information, geographic-spatial representations, and data presented on a thematic map. Students are encouraged to answer questions based on a map's content. This opportunity for practice will increase students' comprehension of how much useful information is contained in a thematic map through the visual presentation of geographic data. These activities illustrate the usefulness of being able to read and really understand the information that maps present, not only while studying geography but also in their daily lives.

**Thinking Geographically** Most chapters dealing with Earth surface processes and landforms include map activities in the **Map Interpretation** series. These full-size topographic map excerpts are presented at the end of chapters that discuss elevation

(Chapter 2), lakes (Chapter 16), rivers (Chapter 17), deserts (Chapter 18), glaciers (Chapter 19), and coasts (Chapter 20). There is also a weather map and satellite image interpretation activity at the end of Chapter 7. Many chapters also include new images to interpret in the **Thinking Geographically** series. Students are asked to interpret an image that features a scene related to the chapter content. These images offer additional practice in looking closely and visually evaluating a landscape by recognizing the geographic features they see, their significance, how they may be related, and to think about how landscapes and landforms develop.

## Four Major Objectives

Ever since the first edition of this book, the authors have sought to accomplish four major objectives:

**To Meet the Academic Needs of the Student** In content and style, *Physical Geography*, 11th edition, was written specifically to meet the needs of students, the end-users of this textbook. Students can use the knowledge and understanding obtained through the text and its activities to help them make informed decisions involving the environment at the local, regional, and global scales. The book also considers the needs of beginning students—those with little or no background in the study of physical geography or other Earth sciences. Examples from throughout the world illustrate important concepts and help students bridge the gap between theory and practical application.

**To Integrate the Illustrations with the Written Text** The photographs, maps, satellite images, scientific visualizations, block diagrams, graphs, and line drawings have been carefully chosen to illustrate important concepts in physical geography. Figures are called out in the conceptual discussions so that students can easily make the connection between an illustration and its related text. Some examples of topics that are clearly explained through the integration of visuals and text include: map and image interpretation (Chapter 2), the seasons (Chapter 3), Earth's energy budget (Chapter 4), surface wind systems (Chapter 5), storms (Chapter 7), soils (Chapter 12), plate tectonics (Chapter 13), rivers (Chapter 17), glaciers (Chapter 19), and coastal processes (Chapter 20).

**To Communicate the Nature of Geography** The nature of geography and three major perspectives of physical geography (spatial science, physical science, and environmental science) are discussed in Chapter 1. In subsequent chapters, important geographic topics are discussed that involve all three of these perspectives. For example, location is a dominant topic in Chapter 2 and remains an important theme throughout the text. Spatial distributions are stressed, providing context to the elements of climate in Chapters 4 through 6. The changing Earth system is a central focus in Chapter 8. Characteristics of climate regions and their associated environments constitute Chapters 9 and 10. Spatial interactions are demonstrated in explanations of weather systems (Chapter 7), soils (Chapter 12), and volcanic and tectonic activity (Chapters 13 and 14). Feature boxes present interesting and important examples of each geographic perspective.

## To Fulfill the Major Requirements of Introductory Physical Science College Courses

The Earth as a system and the physical processes that are responsible for the location, distribution, and spatial relationships of physical phenomena beneath, at, and above Earth's surface are examined in detail. Scientific method, hypotheses, theories, and explanation are stressed. End-of-chapter questions that involve understanding, analyzing, and interpreting graphs of environmental data (or graphing data for analysis), quantitative transformation or calculation of environmental variables, and/or hands-on map analysis all support science learning. Models and systems are frequently cited in the discussion of important concepts, and scientific classification is presented in several chapters—some of these topics include air masses, tornadoes, and hurricanes (Chapter 7), climates (Chapters 8, 9, and 10), biogeography (Chapter 11), soils (Chapter 12), rivers (Chapter 17), and coasts (Chapter 20).

Physical geography plays a central role in understanding environmental aspects and issues, human–environment interactions, and approaches to environmental problem solving. The beginning students in this course include the professional geographers of tomorrow. Spreading the message about the importance, relevance, and career potential of geography in today's world is essential to the strength of geography at educational levels from precollegiate through university. *Physical Geography* seeks to reinforce that message.

## Eleventh Edition Revision

This new edition has been revised so that the latest and most important information is presented to those who are studying physical geography. Not only is our planet ever-changing, but so are the many ways that we study, observe, measure, and analyze Earth's characteristics, environments, and processes. New scientific findings and new ways of communicating those findings are continually being developed. The eleventh edition introduces or expands discussions of technology, such as LIDAR imaging and satellite weather maps. Students have greater access to geographic tools than ever before; therefore, latitude/longitude coordinates are provided for places shown in photographs and maps as well as climate stations that so students may further explore an area or phenomenon on their own, using an interactive mapping tool such as Google Earth.

As authors, we continually seek to include physical geography topics that will spark student interest. In this edition, climate change is given a greater emphasis, and sustainable living is discussed, along with global movements to better manage environmental impacts on Earth and its climate. Attention has been given to recent environmental concerns, findings, and occurrences of natural hazards—we explain the events, the conditions and processes that led to those events, and how they are related to physical geography.

This edition has been updated to include discussions of the most recent natural disasters, including Superstorm Sandy, flooding in the Atacama Desert (the world's driest place) and in other areas, heavy lake effect snowfalls in the eastern United States, wildfires throughout California and the West, recent volcanic eruptions,

strong storms, and tornado outbreaks. Recent disasters are discussed in terms of human impacts and efforts toward minimizing, or avoiding the effects of such tragedies in the future. These events and others are addressed as examples of Earth processes and human–environment interactions.

**New and Revised Text** Revising *Physical Geography* for an eleventh edition involved thoughtful consideration of the input from many reviewers with varied opinions. Many topics have been rewritten for greater clarity, discussions have been expanded where more explanation was required, and new feature boxes have been developed. Great concern has been given to recent occurrences of unusual weather conditions and the impacts of climate change. Earth systems approaches are reinforced with new content, illustrations, and examples.

Most sections of the book contain new material, line art, and photographs. For example, the following are some examples of the discussions and features that are new or improved in this edition: the importance of sustainable development (Chapter 1); geographic information systems, 3-D digital landscape models, and LIDAR (Chapter 2); star circles and Earth rotation (Chapter 3); photosynthesis, the greenhouse effect, and urban heat islands and green roofs (Chapter 4); global isobar map, volcanoes and air travel, and recent El Niño/La Niña conditions (Chapter 5); Hurricane/Superstorm Sandy, 3-D block diagrams of fronts and midlatitude cyclonic storms, and hazard warning systems on cell phones (Chapter 7); recent atmospheric CO<sub>2</sub> levels, climate change, Saharan dust and the Amazon rainforest (Chapter 9); lake effect snowfalls (Chapter 10); plant succession (Chapter 11); continental growth by accretion (Chapter 13); 2015 earthquake in Nepal (Chapter 14); deadly huge landslide in Oso, Washington, and lethal earthquake-induced avalanches on Mt. Everest (Chapter 15); cars in a sudden sinkhole collapse at the National Corvette Museum in Kentucky (Chapter 16); and removal of large dams on rivers and catastrophic flash floods in central Texas (Chapter 17).

**Enhanced Illustration Program** More than 200 new and updated figures are included in this edition. Textbook illustrations have been revised, updated, or improved, and many have been replaced by excellent new examples. Topics that are new or expanded in this edition required new, updated or improved figures, including numerous photographs, satellite images, maps, and all climographs. Selected photographs include a locator map to provide a spatial reference for the feature or place pictured. Additionally, two new illustrated features invite student inquiry: **Understanding Map Content** and **Thinking Geographically**. An example of one feature or the other appears in most chapters.

**Locate and Explore Activities** Exercises at the end of many chapters, titled Locate and Explore require you to use Google Earth or a similar technology. Google Earth allows you to interactively locate, display, and investigate geographic imagery and data from anywhere in the world. To perform these exercises, you should have the latest version of Google Earth installed on your computer. Some of the exercises require you

to use some data layers that are included with Google Earth, as well as some additional data layers that you must download. For detailed instructions about using Google Earth, and to download the necessary data, visit the book's Geography MindTap at [www.cengagebrain.com](http://www.cengagebrain.com).

## Acknowledgments

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Despite the painstaking efforts of all reviewers, there will always be questions of content, approach, and opinion associated with the text. The authors wish to make it clear that they accept full responsibility for all that is included in the eleventh edition of *Physical Geography*.

James F. Petersen  
Dorothy Sack  
Robert E. Gabler

# Foreword to the Student

## Why Study Geography?

In this global age, the study of geography is absolutely essential to an educated citizenry of a nation whose influence extends throughout the world. Geography deals with location, and a good sense of where places or features are, especially in relation to other places or features in the world. Such knowledge is an invaluable asset whether you are traveling, conducting international business, or browsing the Internet.

Geography examines the characteristics of places and areas on Earth, their roles as part of the Earth system, how they interact with other locations, and the changes and processes involved in these interactions. Geography also gives strong consideration to the relationships between humans and their environments. Today, everyone shares the responsibility of learning more about our physical environment so that we can preserve and protect it for future generations.

Geography provides essential information about the distribution of features on Earth's surface and the interconnections of places. The distribution pattern of volcanoes, for example, provides an excellent indication of where Earth's great crustal plates come in contact with one another; and the violent thunderstorms that plague Illinois on a given day may be directly associated with the low-pressure system spawned in Texas two days before. Geography, through a study of regions, provides a focus and a level of generalization that allows people to examine and understand the immensely varied environmental characteristics of Earth.

As you will note when reading Chapter 1, there are many approaches to the study of geography. Some courses are regional in nature; they may include an examination of one or all of the world's political, cultural, economic, or physical regions. Some courses are topical or systematic in nature, dealing with human geography, physical geography, or one of the major subfields of the two.

A great advantage of taking a general course in physical geography is the permanence of the knowledge learned. Although change is constant and often sudden in human aspects of geography, alterations of the physical environment on a global scale are generally slow unless they are influenced by human intervention. Theories and explanations may differ, but the broad patterns of atmospheric and oceanic circulation and of world climates, landforms, soils, natural vegetation, and physical landscapes will be the same tomorrow as they are today.

## Keys to Successful Study

Good study habits are essential if you are to master science courses such as physical geography, where the topics, explanations, and terminology are often complex and unfamiliar. To help you succeed in the course in which you are currently enrolled, we offer the following suggestions.

## Reading Assignments

- Read the assignments before the material is covered in class by the instructor.
- Compare what you have read with the instructor's presentation in class. Pay particular attention if the instructor introduces new examples or course content not included in the reading assignment.
- Ask questions in class and seek to understand any material that was not clear from your first reading of the assignment.
- Reread the assignment as soon after class as possible, concentrating on areas that were emphasized in class. Highlight only those items or phrases that you now consider to be important, and skim those sections already mastered.
- Record in your class notes important terms, your own comments, and summarized information from each reading assignment.

## Understanding Vocabulary

- Mastery of basic vocabulary often becomes a critical issue in the success or failure of students in a beginning science course.
- Focus on terms that appear in boldface type in your reading assignments. Do not overlook additional terms that the instructor may introduce in class.
- Develop your own definition of each term (representing a feature, process, or characteristic) or phrase and associate it with related terms in physical geography.
- Identify any physical processes associated with the term. Often, knowing the process will help to define the term.
- Whenever possible, associate terms with location.
- Consider the significance to humans of terms you are defining. Recognizing the significance of terms and phrases can make them relevant and easier to recall.

## Learning Earth Locations

- A good knowledge of place names and of the relative locations of physical and cultural phenomena on Earth is fundamental to the study of geography.
- Take personal responsibility for learning locations on Earth. Your instructor may identify important physical features and place names, but you must learn their locations for yourself.
- Thoroughly understand latitude, longitude, and the Earth grid. They are fundamental to finding and describing locations on maps and globes. Practice locating features by their latitude and longitude until you are entirely comfortable using the system.

- Develop a general knowledge of the world political map. The most common way of expressing the location of physical features is by identifying the political unit (state, country, or region) in which it can be found.
- Make liberal use of outline maps. They are a key to learning the names of states and countries and the locations of specific physical features. Personally placing features correctly on an outline map is often the best way to learn location.
- Cultivate the habit of using an atlas. The atlas does for the individual who encounters place names or the features they represent what the dictionary does for the individual who encounters a new vocabulary word.

## Utilizing Textbook Illustrations

The secret to making good use of maps, diagrams, and photographs lies in understanding why an illustration has been included in the textbook or incorporated as part of your instructor's presentation.

- Concentrate on the instructor's discussion. Taking notes about photographs, maps, graphs, and other illustrations will allow you to follow the same line of thought at a later date.
- Study all the textbook illustrations. Be sure to note which of them received considerable attention in the lecture. Do not quit examining an illustration until it makes sense to you, until you can read the map or graph, or until you can recognize what a diagram or photograph has been selected to explain.
- Hand-copy important diagrams and graphs. Few of us are graphic artists, but you might be surprised at how much better you understand a graph or line drawing after you reproduce it yourself.
- Read the captions of photographs and illustrations thoroughly and thoughtfully. If the information is included, be certain to note where a photograph was taken and in what way it is representative. What does it tell you about the feature, process, region, or site being illustrated?
- Attempt to place the concept that is being illustrated in new situations. Seek other opportunities to test your skills at interpreting similar maps, graphs, and photographs and think of other examples that support the text.
- Remember that all illustrations are reference tools, particularly tables, graphs, and diagrams. Refer to them often.

## Taking Class Notes

A good set of class notes is based on selectivity. You cannot, and should not, try to write down every word uttered by your classroom instructor.

- Learn to paraphrase. With the exception of specific quotations or definitions, put the instructor's ideas, explanations, and comments into your own words. You will understand them better when you read them over at a later time.
- Be succinct. Never use a sentence when a short phrase will do, and never use a phrase when a word will do. Start your recall process with your note taking by forcing yourself to rebuild an image, an explanation, or a concept from a few words.

- Outline where possible. Preparing an outline helps you to discern the logical organization of information. As you take notes, organize them under main headings and subheadings.
- Take the instructor at his or her word. If the instructor takes the time to make a list, then you should do so, too. If he or she writes something on the board, it should be in your notes. If the instructor's voice indicates special concern, take special notes.
- Come to class and take your own notes. Notes trigger the memory, but only if they are your notes.

## Doing Well on Tests

Follow these important study techniques to make the most of your time and effort preparing for tests.

- Practice distillation. Do not try to reread but skim the assignments carefully, taking notes in your own words that record as economically as possible the important definitions, descriptions, and explanations. Do the same with any supplementary readings, handouts, and laboratory exercises. It takes practice to use this technique, but it is much easier to remember a few key phrases that lead to ever-increasing amounts of organized information than it is to memorize all your notes. And the act of distillation in itself is a splendid memory device.
- Combine and reorganize. Merge all your notes into a coherent study outline.
- Become familiar with the type of questions that will be asked. Knowing whether the questions will be objective, short-answer, essay, or related to diagrams and other illustrations can help in your preparation. Some instructors make old tests available so that you can examine them or discover their evaluation styles if you inquire. If not, then turn to former students; there are usually some around the department or residence halls who have already experienced the instructor's tests.
- Anticipate the questions that will likely be on the test. The really successful students almost seem to be able to predict the test items before they appear. Take your educated guesses and turn them into real questions.
- Try cooperative study. This can best be described as role-playing and consists very simply of serving temporarily as the instructor. So go ahead and teach. If you can demonstrate a technique, illustrate an idea, or explain a process or theory to other students so that they can understand it, there is little doubt that you can answer test questions over the same material.
- Avoid the "all-nighter." Use the early evening hours the night before the test for a final unhurried review of your study outline. Then get a good night's sleep.

## The Importance of Maps

Like graphs, tables, and diagrams, maps are excellent reference tools. Familiarize yourself with the maps in your textbook to better judge when it is appropriate to seek information from these important sources.

Maps are especially useful for comparison purposes and to illustrate relationships or the possible associations of two

features, areas, or processes. But the map reader must beware. The associations of phenomena by their locations and distributions are not necessarily cause-and-effect relationships. In some instances the similarities in a distribution result from another factor that has not been considered or mapped. For example, a map of worldwide volcano distribution is almost exactly congruent with one of incidence of earthquakes, yet volcanoes are not the cause of major earthquakes. A third factor, the location of tectonic plate boundaries, explains the first two phenomena.

Finally, remember that a map is the most important tool of the professional geographer. It is also useful to all natural and social scientists, engineers, politicians, military planners, road builders, farmers, and countless others, but maps are essential expressions of the geographer's primary concern with location, distribution, and spatial interaction.

## About Your Textbook

This textbook has been written for you, the student. It has been written so that the text can be read and understood easily. Explanations are as clear, concise, and uncomplicated as possible. Illustrations have been designed to complement the text and to help you visualize the processes, places, and phenomena being discussed. In addition, the authors do not believe it is sufficient to offer you a textbook that simply provides information to pass a course. We urge you to think critically about what you read in the textbook and hear in class.

As you learn about the physical aspects of Earth environments, ask yourself what they mean to you and to people throughout the world. Make an honest attempt to consider how what you are learning relates to the problems and issues of today and tomorrow. Practice using your geographic skills and knowledge in new situations so that you will continue use them in the years ahead. Your textbook includes several special features that will support learning, encouraging you to go beyond memorization and to reason geographically.

**Chapter Activities** At the end of each chapter, Consider and Respond questions and Practical Applications require you to go beyond a routine chapter review. The questions and problems are designed so that you can apply your knowledge of physical geography and, on occasion, personally respond to critical issues in society today. Locate and Explore activities (found at the end of many chapters) teach you how to use the Google Earth application as an exploratory learning tool. Check with your instructor for answers to the problems.

**Caption Questions** Most illustrations and photographs in your textbook, have a caption that links the image with the chapter text it supports. Read the captions carefully because they explain the illustrations and may also contain new information. Wherever appropriate, questions at the ends of captions have been designed to help you seize the opportunity to consider your own personal reaction to the subject under consideration.

**Map Interpretation Series** A major goal of your textbook is to help you become an adept map reader, and the Map Interpretation Series in your text has been designed to help you reach that goal.

**Environmental Systems** Viewing Earth as a system comprising many subsystems is a fundamental concept for researchers, instructors, and students in physical geography. The concept is introduced in Chapter 1 and reappears frequently throughout your textbook. The interrelationships and dependencies among the variables and components of Earth systems are important. Many of the illustrations included in the text will help you visualize how systems work. There are also diagrams designed to help you understand how human activities can affect the delicate balance that exists within many Earth systems.

As authors of your textbook, we wish you well in your studies. It is our fond hope that you will become better informed about our home—Earth and its varied environments—and that you will enjoy the study of physical geography.



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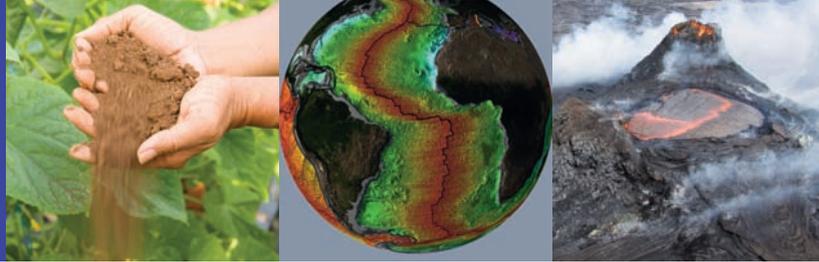
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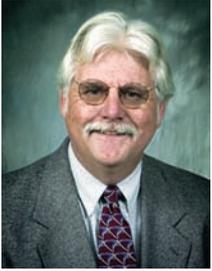
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# Author Biographies



J. Petersen

**James F. Petersen** James F. Petersen is Professor of Geography at Texas State University, in San Marcos, Texas. A broadly trained physical geographer with strong interests in geomorphology and Earth Science education, he enjoys writing about topics related to physical geography for the public. Involved in environmental interpretation, he has written guidebooks and a number of

field and trail guides for parks. Professor Petersen is a past President of the National Council for Geographic Education (NCGE), a recipient of a national teaching award, and received the NCGE's highest honor for distinguished service to geography education. He has written or served as a senior consultant for nationally published educational materials at levels from middle school through university. He has published articles that deal with education in geomorphology, climate history and climate change, the environmental history of central Texas, the role of field methods in geography, earthquake hazards, and geographic education in general. Believing in the value of learning in the field, every year since Professor Petersen began teaching he has taken students on extended field excursions to learn about Earth environments, locations, processes, and features through firsthand experience.



J. Petersen

**Dorothy Sack** Dorothy Sack, Professor of Geography at Ohio University in Athens, Ohio, is a physical geographer who specializes in geomorphology. Her primary research interests emphasize arid region landforms, particularly the geomorphic evidence of paleolakes, which contributes to our understanding of Earth's paleoclimate. Other research themes include the impact of

off-road vehicles on the landscape and the history of geomorphology. Professor Sack has published research in a variety of professional journals, academic volumes, and Utah Geological Survey publications. Her work has been funded by the National Geographic Society, National Science Foundation, Association of American Geographers (AAG), American Chemical Society, and other groups. She is active in professional organizations, having served as chair of both the Geomorphology and the History of Geography Specialty Groups of the AAG, and in other offices for the AAG, Geological Society of America, and History of Earth Sciences Society. She also serves on the editorial boards of *Geomorphology*, *Physical Geography*, and *Earth Sciences History*. Professor Sack enjoys teaching as well as research, and has received the Outstanding Teacher Award from Ohio University's College of Arts and Sciences.



J. Petersen

**Robert E. Gabler** During his nearly five decades of professional experience, Professor Gabler has taught geography at Hunter College, City of New York, Columbia University, and Western Illinois University, in addition to 5 years in public elementary and secondary schools. At times in his career at Western Illinois he served as Chairperson of the Geography and Geology

Department, Chairperson of the Geography Department, and University Director of International Programs. Professor Gabler received three University Presidential Citations for Teaching Excellence and University Service, served two terms as Chairperson of the Faculty Senate, edited the *Bulletin of the Illinois Geographical Society*, and authored numerous articles in state and national periodicals. He is a past President of the Illinois Geographical Society, former Director of Coordinators and past President of the National Council for Geographic Education (NCGE), and the recipient of the NCGE George J. Miller Distinguished Service Award.

# PHYSICAL GEOGRAPHY



# PHYSICAL GEOGRAPHY: EARTH ENVIRONMENTS AND SYSTEMS

# 1

## OBJECTIVES

WHEN YOU COMPLETE THIS CHAPTER YOU SHOULD BE ABLE TO:

- 1.1 Explain why physical geography examines both the natural world and human interaction with the natural world.
- 1.2 Discuss important ways in which geographic information and techniques are useful in different careers.
- 1.3 Describe the three major perspectives of physical geography: spatial science, physical science, and environmental science.
- 1.4 Think of Earth as a system of interacting parts that respond to both natural processes and human actions.
- 1.5 Illustrate with examples how some interactions between people and their environment are advantageous, whereas others are detrimental or hazardous.
- 1.6 Summarize how knowledge of physical geography contributes to a better understanding of the environment.
- 1.7 Recognize that every physical environment offers an array of advantages and challenges to human life and living conditions.
- 1.8 Explain how physical geography is relevant to your everyday life.

**PLANET EARTH IS HOME TO** a large and complex set of living organisms, including humans. Earth's surface is our natural habitat, providing us with air, water, nutrients, and shelter. Earth also receives enough sunlight to maintain livable temperatures and to power food production by plants through photosynthesis. Surrounded by the emptiness of space, life on Earth is dependent on the planet's self-contained natural resources that are extensive, but not limitless.

Only recently in the history of human life have we been able to view Earth in its entirety from space, giving us a fresh perspective on characteristics of the ocean, atmosphere, land masses, and natural vegetation. In addition to being able to see the physical Earth as a whole, technological advances in communication, transportation, and information sciences over the last several decades have led to an increasingly global social perspective. These developments, combined with population growth, make the world seem smaller, and have helped heighten awareness of the finite nature of Earth, its environments, and its resources.

## OUTLINE

The Study of Geography

Physical Geography

Geographic Tools and Technology

Major Perspectives in Physical Geography

Spatial Science Perspective

Geography's Spatial Science

Perspective: Natural Regions

Physical Science Perspective

Environmental Science Perspective

Geography's Environmental Science

Perspective: Human-Environment

Interactions

Using Models and Systems

Systems Analysis

Open and Closed Systems

Equilibrium in Earth Systems

Physical Geography and You

◀ Earth, our home, our natural habitat.  
NASA/NOAA/GSFC/Suomi NPP/VIIIRS/Norman Kuring

In physical geography we seek to understand as much as possible about the natural Earth—its characteristics, materials, and processes—so that humans (and Earth’s other organisms) can live on this planet long into the future in a healthy and sustainable way and with minimal risk from its inherent hazards. **Physical geography** is this study of the natural aspects of Earth as our habitat and home.

Earth is beautiful and intriguing—a dynamic life-giving planetary oasis of great environmental diversity. It is important for people to gain an understanding of the planet that sustains us—to learn about the components and processes that change and regulate Earth’s environmental conditions. In all fields of study, asking questions is an important step toward acquiring knowledge, explanations, and understanding. In physical geography, many of our questions are directed toward how Earth’s matter, energy, and processes interact to create the environmental diversity that exists on our planet.

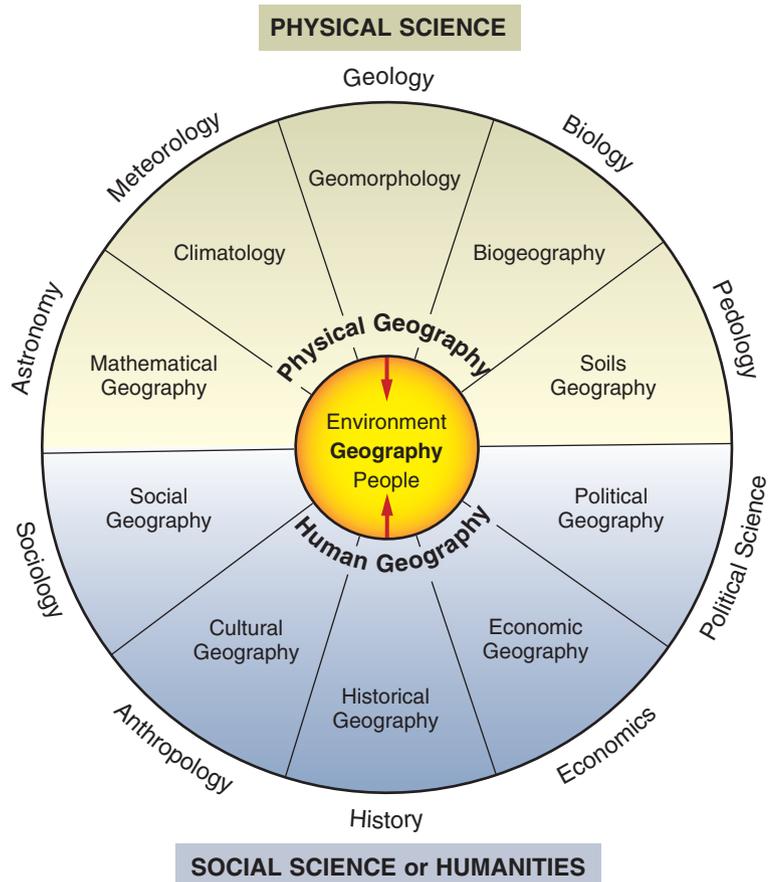
## The Study of Geography

Physical geography is a major part of the field of **geography**, which is the study of all aspects of Earth in its role as the home of people. The word *geography* comes from the Greek language. *Geo* refers to Earth, and *graphy* means picture or writing, thus the word itself designates a broad field of study. Geography as a whole includes the examination, description, and explanation of cultural as well as natural physical variables on Earth. Geography emphasizes how physical and cultural attributes vary from place to place, how places and features change over time, and the processes and interactions responsible for these variations. Geography is commonly considered the **spatial discipline** (the study of locational space) because it includes analyzing and explaining the locations, distributions, patterns, variations, and similarities or differences among phenomena on Earth’s surface. Geography is

an integrative discipline that brings together the physical and human dimensions of the world in the study of people, places, and environments. Its subject matter is the Earth’s surface and the processes that shape it, the relationships between people and environments, and the connections between people and places.

—*Geography for Life*, Geography Education Standards Project

Geographers are concerned with how physical and human processes affect, have affected, or will affect our planet and its natural



● **FIGURE 1.1** Geography has many subdivisions that are related to other disciplines with which they share some of their interests. Geographers, however, apply their own distinct perspectives and approaches to these areas of study.

*What advantage might a geographer have when working with other physical scientists seeking a solution to a problem?*

and human environments. They study processes that influenced Earth’s physical and cultural landscapes in the past, how processes affect landscapes today, how a landscape may change in the future, and the significance of process and landscape changes over space and time. Geography is distinctive among academic disciplines in its definition and central purpose and can involve studying any topic related to the analysis of natural or human processes on or near Earth’s surface. Because geography embraces the study of virtually any Earth phenomenon, the subject has several subdivisions. Typically, geographers specialize in one or more of these subfields (● Fig. 1.1). Geography also encompasses multiple approaches; some geographers are natural scientists, some are social scientists, and others use a humanities approach.

The broadest divisions of the field of geography are physical geography, which is the focus of our study, and human geography. Whereas physical geographers use a natural science approach to analyze the nonhuman elements of Earth’s environments, **human geography** concerns the nature, processes, and variations in space and time of human-generated phenomena, including culture; thus, human geographers use approaches from social science or

the humanities. Human geographers are, for example, concerned with such topics as population distributions, migration patterns, cultural patterns, the spread of ideas, cities and urbanization, industrial and commercial location, natural resource use, and transportation networks.

Geographers gather, organize, and analyze many kinds of data and information in seeking to explain locations, areas, patterns, distributions, and relationships over the surface of Earth. Many individual geographers, whether human or physical, solve problems or answer questions at the local or regional scale, rather than consider the entire planet at once. As a result, geographers are interested in defining meaningful **regions**, which are areas identified by distinctive characteristics that distinguish them from surrounding areas. The distinctive characteristics used to define a region can be physical, human, or a combination of factors, and a given location can belong to various types and sizes of regions depending on the criteria used and purposes for identifying the regions. *Regional geography* emphasizes the characteristics of a region or of multiple regions.

## Physical Geography

Physical geography focuses on understanding the natural processes and features of Earth. Physical geography, however, cannot exclude the human element because people affect, and are affected by, natural processes and features. Geographers are excellent observers of the world around them and generally take a *holistic approach* to problem solving, meaning that they are open to all factors that might be involved in the solution, including human factors. Being concerned with nearly all aspects of Earth, physical geographers are trained to view a natural environment and consider how it functions in its entirety (● Fig. 1.2). Yet, as in other fields of study, most individual physical geographers develop focused expertise in one or two subfields. For example, physical geography includes the study of weather and climate and some physical geographers are meteorologists or climatologists. *Meteorologists* consider the processes that affect daily weather, and they forecast weather conditions. *Climatologists* are interested in the averages and extremes of long-term weather data, regional climates, large-scale atmospheric circulation processes,



Martha Moran, Aspen Ranger District, White River National Forest

● **FIGURE 1.2** Physical geographers study all processes, features, and characteristics of the natural environment, including those related to weather, climate, rock structures, landforms, soils, vegetation, animals, water, and human impacts, several of which are represented in this view from the White River National Forest in Colorado.

*What elements of physical geography can you recognize in this scene?*

climate-related hazards, understanding climate change, and how climate and climate change impact people and the environment.

*Geomorphology*, another major subfield of physical geography, is the study of landforms and how the interactions of Earth's processes and surface materials contribute to landform development and modification. *Geomorphologists* work to understand variations in landforms, the processes that produce them, and the hazards that they pose for people. *Biogeographers* study the geographic ranges, distribution patterns, and assemblages of plant and animal species, seeking to discover the natural and human-induced environmental factors that influence them. *Biogeography* includes analyzing plant and animal distributions of the present and past and how they may change in the future. Other physical geographers, known as *soil scientists*, analyze and map soil types, determine the suitability of different soils for various uses, and work to conserve soil as a natural resource.

Water plays a critical role in many natural processes on Earth. Meteorology, climatology, geomorphology, biogeography, and soil science each involve water in some way. Physical geographers participate widely in the study of water, water bodies, and water resources, and physical geographers may also serve as *hydrologists*, *oceanographers*, or *glaciologists*. Many geographers contribute to the effective management of water resources to ensure that lakes, watersheds, springs, and groundwater sources meet human and environmental needs in terms of quality and quantity.

## Geographic Tools and Technology

Rapid advances over the last couple of decades in the *global positioning system (GPS)*, communication, and information science technologies have greatly enhanced our abilities to learn about Earth's physical geography. We locate points on Earth's surface more quickly, easily, and accurately; measure attributes of those ground points more precisely; and gather, manipulate, and share larger data sets than ever before. We obtain much data about Earth's surface remotely, such as from sophisticated instruments and sensors carried on board satellites and aircraft. Some problems, however, also require in-person fieldwork, often employing specialized instruments to aid in data collection, and fieldwork will probably always play an important role in physical geography (● Fig. 1.3).

Maps are essential components of geography. Maps function as sources of geographic data, tools to aid in the analysis and interpretation of geographic data, and means for displaying results of geographic studies. Geographers use satellite-based GPS technology to determine the precise location of points on Earth's surface, and digital technologies for mapmaking (**cartography**) and for conducting many aspects of map analysis.

Continuous satellite imaging of Earth has been ongoing for more than 40 years, which gives us an important perspective on environmental change. By recording from space various energy signals from Earth and producing images, we are able to measure, monitor, and map Earth processes and their effects, many of which are invisible to the naked eye. As methods of data processing and visual representation techniques improve, the geographer's ability to visualize environmental data and their change over time is

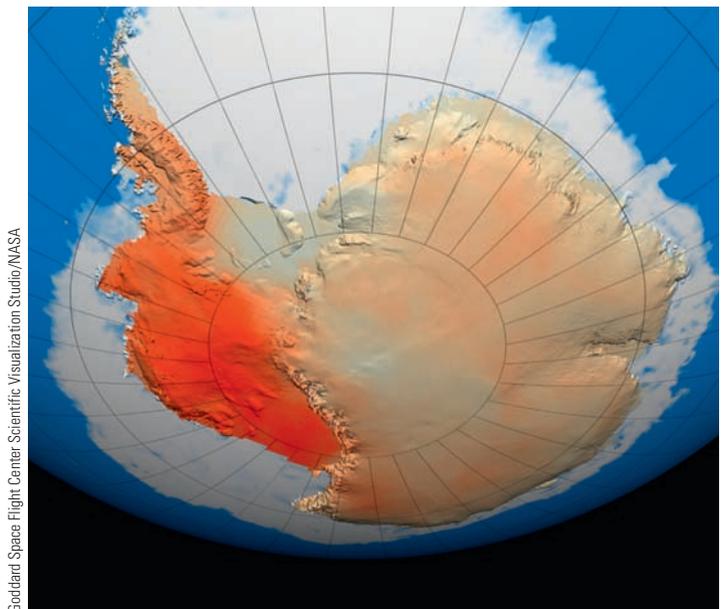


Kraivut Charoensiri

● **FIGURE 1.3** In addition to using the latest technological innovations for locating, observing, measuring, imaging, and mapping Earth and its environments, fieldwork remains an important element of information gathering in much of physical geography.

continually being enhanced with greater image resolution, increasingly sophisticated three-dimensional graphics, and animations that are more vivid and striking than ever (● Fig. 1.4).

Technology greatly aids in the collection, storage, analysis, and visualization of geographic data, as well as in the effective communication of results. But solving geographic problems also requires knowledgeable people who understand the content, scope, and nature of geographic information, methods, and techniques. Many geographers are gainfully employed in positions that apply technology to help understand our planet better, and their numbers are certain to increase in the future.



Goddard Space Flight Center/Scientific Visualization Studio/NASA

● **FIGURE 1.4** This computer-generated three-dimensional model of Antarctica was made by combining a 50-year history of temperature records from locations on the continent with recent satellite images of the ice surface. The red area has undergone the largest temperature increase in response to global warming.

# Major Perspectives in Physical Geography

Physical geographers use the **scientific method** to guide their learning about the processes and features on Earth. The scientific method entails developing valid explanations about the issue being studied by objectively testing hypotheses and analyzing all pertinent evidence and facts (● Fig. 1.5). Using the scientific method, new ideas or proposed answers to questions are accepted as valid only if they withstand rigorous objective testing.

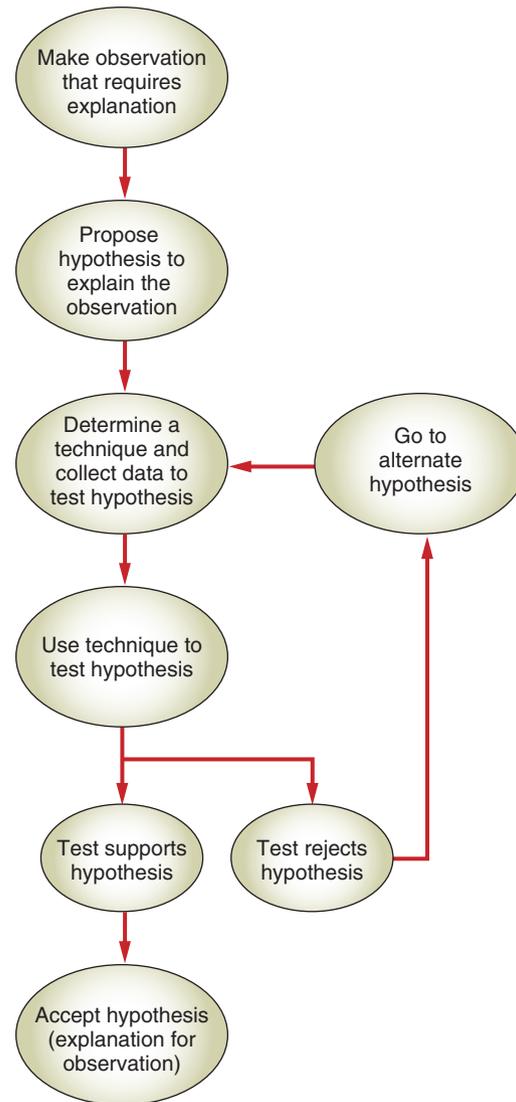
This textbook highlights three major perspectives, all using the scientific method, fundamental to physical geography: *spatial science*, *physical science*, and *environmental science*. This chapter introduces all three, whereas subsequent chapters vary in which perspective they emphasize. As you progress through the book, take note of how each perspective relates to the unique nature of geography as a discipline.

## Spatial Science Perspective

Physical geography uses the scientific method to study variations over space, thus it is a *spatial science*. Specific interests vary widely among physical geographers, but they share the common goals of understanding and explaining spatial variations on Earth's surface. The following five spatial topics—location, characteristics of places, spatial distribution and pattern, spatial interaction, and change over space and time—illustrate factors that geographers typically consider and problems that they address. Because learning the types of questions that geographers ask is a first step toward understanding the field of study, example questions are included for each topic.

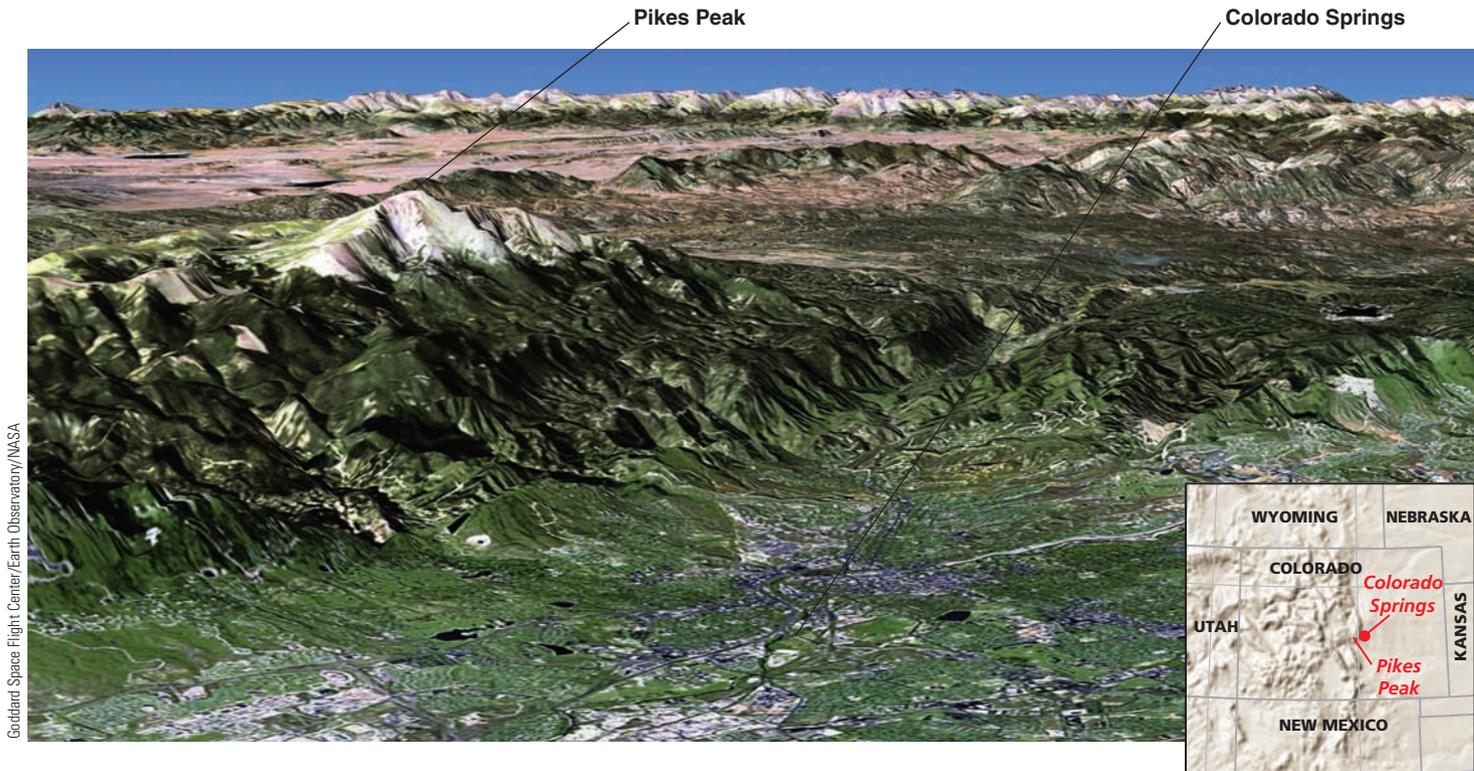
**Location** Geographic studies often begin with locational information. Describing a location usually uses one of two methods: **absolute location**, which is expressed by a coordinate system, and **relative location**, which identifies where a feature lies in relation to something else, usually a fairly well-known site. For example, Pikes Peak, in the Rocky Mountains of Colorado, with an elevation of 4302 meters (14,115 ft), has a location of latitude 38°51'N (north) and longitude 105°03'W (west). This kind of global address is an absolute location. However, another way to report its location would be as 36 kilometers (22 mi) west of Colorado Springs (● Fig. 1.6). This is an example of relative location because the position of the peak is given in relation to the city of Colorado Springs. Typical spatial questions involving location include the following: *Where are volcanoes (or other type of Earth feature) found, and where are they not found? Why are volcanoes located where they are? What methods can we use to locate volcanoes on Earth? How can we describe their location? What is the most likely or least likely location for a volcano?*

**Characteristics of Places** Physical geographers are interested in the environmental features and processes that make a place unique, as well as in the shared or similar characteristics



● **FIGURE 1.5** The scientific method, widely applicable in physical geography, follows these steps. For example:

1. **Make an observation that requires an explanation.** On a trip to the mountains, you feel colder at higher elevations than you do at lower elevations. Is that just a result of local conditions and weather changes on the day you were there, or is it a universal relationship?
2. **State the observation in the form of a testable hypothesis.** For example: Within a single mountain range, higher elevations have colder temperatures than lower elevations.
3. **Determine a technique or strategy for testing the hypothesis and for collecting the data needed to conduct the test.** You could test the hypothesis by selecting a mountain range to study and collecting temperature data for many days from weather stations at different elevations. Use temperature measurements made at the same time of day at all weather stations on any given day because the evidence must be collected under similar circumstances to minimize bias.
4. **Apply the technique or strategy to test the validity of the hypothesis.** Here you discover if the collected data support the hypothesis. The technique or strategy will indicate either accepting or rejecting the hypothesis. If the hypothesis is rejected, you could devise and test a different hypothesis to explain the initial observation. If the hypothesis is accepted, you have a reasonable explanation for the differences you felt in temperature.



● **FIGURE 1.6** A three-dimensional digital model shows the relative location of Pikes Peak to Colorado Springs, Colorado. Because this is a perspective view, the 36 kilometer (22 mi) distance appears to be shorter than its actual ground distance. A satellite image was merged with elevation data gathered by radar from the space shuttle to create this scene.

**What can you discern about the physical geographic characteristics of this place from the image?**

between places. For example, we might determine what physical geographic features give a particular mountain range its distinctive appearance or describe how one mountain range differs from another. Assessing the differences and similarities between two examples of the same general type of feature helps us better understand the processes influencing each. Another approach to learning about the characteristics of places is through analyzing the environmental advantages and challenges that exist in a locality. Example questions about the characteristics of places are: *How does an Australian desert compare to the Sonoran Desert of the southwestern United States? How do the grasslands of the North American Great Plains compare to the grasslands of Argentina? What environmental conditions make one county more agriculturally productive than another? How does the climate of Maine differ from the climate of Alaska, and why? What weather can we expect when traveling to a different country?*

**Spatial Distribution and Pattern** Two fundamental characteristics describe how features or events are arranged over space. **Spatial distribution** refers to the extent of the area or areas where the feature of interest exists. Tropical rainforests, for example, cover particular expanses of Earth’s surface, thus they are spatially distributed. Likewise, the parts of the United States where rain fell yesterday, or regions that have high potential for damaging earthquakes, have spatial distribution. **Spatial pattern** refers to how multiple individuals of the same type of feature or event

are arranged over Earth’s surface: Are they regularly or randomly spaced, clustered together, or far apart from each other? Population can be dense or sparse (● Fig. 1.7). The spatial pattern of earthquakes may be aligned on a map because earthquake faults display linear patterns. Some questions relevant to spatial distribution and spatial pattern are: *Where are certain features abundant, and where are they rare? How are particular factors or elements of physical geography arranged in space, and what spatial patterns exist, if any? What processes are responsible for these distributions or patterns? If a spatial pattern exists, what does it signify?*

**Spatial Interaction** Few processes on Earth operate in isolation because areas on our planet are interconnected, that is, they are linked to conditions elsewhere on Earth. A **spatial interaction** exists if a condition, an occurrence, or a process in one place has an impact on other places. Excessive rainfall in Minnesota and Wisconsin, for example, might lead to flooding along the Mississippi River in Missouri. Reducing the size of the tropical rainforest may have a widespread impact on world climates. The exact nature of many spatial interactions is often difficult to establish with complete confidence. It is much easier to determine that a condition at one location is *associated* with a condition at another without knowing if one event actually *causes* the other. For instance, it is well established that atypical weather in some parts of the world accompanies the presence of abnormally warm ocean waters off South America’s west coast, a



● **FIGURE 1.7** A nighttime satellite image provides good illustrations of distribution and pattern, shown here for part of North America. *Spatial distribution* is where features are located (or perhaps, absent). *Spatial pattern* refers to their arrangement. Geographers seek to explain observed spatial relationships.

**Can you locate two distributions and two patterns in this scene and propose possible explanations for each?**

condition called El Niño. Climatologists, however, are still working to clarify the nature of that link, and it is possible that circumstances leading to an El Niño separately induce the atypical weather conditions. Spatial interactions exist at all geographic scales: global, regional, and local. Physical geographers consider problems such as: *What effect will stricter pollution controls in North America have on the future size of the ozone hole over Antarctica? How do two spatially interacting variables affect each other? What important interconnections link the ocean to the atmosphere and the atmosphere to the land surface?*

**Change over Space and Time** Earth's features and landscapes are continuously changing over space and time and at a variety of spatial and temporal scales. Storm conditions intensify or weaken over time and travel from one region to another. Weather varies from day to day, over the seasons, and from year to year. Landslides, volcanic eruptions, and floods of different types and sizes modify the landscape at different rates. Coastlines are altered by storm waves, tsunamis, human actions, or changes in sea level. Desert areas expand and contract over the decades. Vegetation and wildlife communities return to areas once devastated by wildfires (● Fig. 1.8).



● **FIGURE 1.8** Earth's features and landscapes change continually, sometimes at spatial and temporal scales that make the change difficult for people to notice. Changes to vegetation caused by a regional fire are rapid and catastrophic (top and middle photos), whereas reestablishment of plant and animal communities (bottom photo) proceed much more slowly.