The ATMOSPHERE

The Atmosphere
An Introduction to Meteorology
TENTH EDITION

Frederick K. Lutgens • Edward J. Tarbuck

Illustrated by
Dennis Tasa

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Brief Contents

GEODe: Atmosphere

A copy of the *GEODe: Atmosphere* CD-ROM is packaged with each copy of *The Atmosphere, Tenth Edition*. This dynamic learning aid reinforces atmospheric science concepts by using tutorials, animations and interactive exercises.

Unit One: Introduction to the Atmosphere

1. A View of Earth
2. The Importance of Weather
3. Weather and Climate
4. Composition of the Atmosphere
5. Extent of the Atmosphere
6. Temperature Structure of the Atmosphere
7. In the Lab: Reading Weather Maps

Unit Two: Heating Earth's Surface and Atmosphere

1. Understanding Seasons, Part 1
2. Understanding Seasons, Part 2
3. Solar Radiation
4. What Happens to Incoming Solar Radiation?
5. The Greenhouse Effect
6. In the Lab: The Influence of Color on Albedo

Unit Three: Temperature Data and the Controls of Temperature

1. Basic Temperature Data
2. Controls of Temperature

Unit Four: Moisture and Cloud Formation

1. Movement of Water Through the Atmosphere
2. Water's Changes of State
3. Humidity: Water Vapor in the Air
4. The Basics of Cloud Formation: Adiabatic Cooling
5. Processes that Lift Air
6. The Critical Weathermaker: Atmospheric Stability
7. In the Lab: Atmospheric Stability

Unit Five: Forms of Condensation and Precipitation

1. Classifying Clouds
2. Types of Fog
3. How Precipitation Forms

Unit Six: Air Pressure and Wind

1. Measuring Air Pressure
2. Factors Affecting Wind
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Unit Seven: Basic Weather Patterns

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This *GEODe: Atmosphere* icon appears throughout the book wherever a text discussion has a corresponding activity on the CD-ROM.

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Preface

There are few aspects of the physical environment that influence our daily lives more than the phenomena we collectively call *weather.* The media regularly report a wide range of weather events as major news stories—an obvious reflection of people's interest and curiosity about the atmosphere.

The record-breaking 2005 hurricane season saw Katrina, Rita, and Wilma, among others, grab the headlines. Hurricane Katrina was by far the most costly U.S. weather disaster in both deaths and dollars in more than a century. It came on the heels of an extraordinary 2004 hurricane season that saw storms named Charley, Frances, Ivan, and Jeanne slam into Florida. Of course, hurricanes are not the only weather events to make the news. Nor'easters in New England, heavy rains triggering mudflows in California, drought and tornadoes in the Midwest, wildfires in parts of the West, and dense fogs that cause chain-reaction freeway pileups are all part of the news.

Not only does the atmosphere impact the lives of people, but people have a significant impact on the atmosphere as well. By altering the composition of Earth's atmosphere, people have diminished the stratosphere's ozone layer and created serious air-quality problems in urban and rural areas around the world. Moreover, many scientists warn that human-generated emissions are largely responsible for global warming, one of the most serious environmental issues facing humankind in the twenty-first century.

In order to understand the weather phenomena that affect our daily lives and the serious environmental problems related to the atmosphere, it is important to develop an understanding of meteorological principles. A basic meteorology course can take advantage of our interest and curiosity about the weather as well as our desire to understand the impact that people have on the atmospheric environment.

The Atmosphere: An Introduction to Meteorology, Tenth Edition, is designed to meet the needs of students who enroll in such a course. It is our hope that the knowledge gained by taking a class and using this book will encourage many to actively participate in bettering the environment, and others may be sufficiently stimulated to continue their study of meteorology. Equally important, however, is our belief that a basic understanding of the atmosphere and its processes will greatly enhance appreciation of our planet and thereby enrich the reader's life.

In addition to being informative and up to date, a major goal of *The Atmosphere* is to meet the need of beginning students for a readable and user-friendly text, a book that is a highly usable "tool" for learning basic meteorological principles and concepts.

Distinguishing Features

Readability

The language of this book is straightforward and *written to be understood.* Clear, readable discussions with a minimum of technical language are the rule. The frequent headings and subheadings help students follow discussions and identify the important ideas presented in each chapter. In the tenth edition, improved readability was achieved by examining chapter organization and flow and writing in a more personal style. Large portions of the text were substantially rewritten in an effort to make the material more understandable.

Illustrations and Photographs

Meteorology is highly visual. Therefore, photographs and artwork are a very important part of an introductory book. *The Atmosphere, Tenth Edition,* contains dozens of new high-quality photographs that were carefully selected to aid understanding, add realism, and heighten the interest of the reader. Among these are many new satellite images that provide a unique perspective of many atmospheric phenomena.

The illustrations in each new edition of *The Atmosphere* keep getting better and better. In the tenth edition more than 100 pieces of line art are new or revised. The new art illustrates ideas and concepts more clearly and realistically than ever before. Dennis Tasa, a gifted artist and respected science illustrator, carried out the art program.

Focus on Learning

The Atmosphere, Tenth Edition, consists of two products—a traditional college textbook and *GEODe: Atmosphere,* an interactive CD-ROM. Both contain helpful student learning aids.

End-of-Chapter Review. When a chapter has been completed, five useful devices help students review. First, the *Chapter Summary* recaps all the major points. Next, the *Vocabulary Review* provides a checklist of key terms with page references. Learning the language of meteorology helps students learn the material. This is followed by the *Review Questions* section, which helps students examine their knowledge of significant facts and ideas. In most chapters, *Problems,* many with a quantitative orientation, follow the review questions. Most problems

require only basic mathematical skills and allow students to enhance their understanding by applying skills and principles explained in the chapter. Each chapter closes with a reminder to visit the website for *The Atmosphere, Tenth Edition* (http://www.prenhall.com/lutgens). It contains many excellent opportunities for review and exploration.

GEODe: Atmosphere. Included with every copy of *The Atmosphere* is the interactive CD-ROM *GEODe: Atmosphere.* Prepared by the authors in conjunction with Dennis Tasa, this CD was extremely well received by students and instructors who used the last edition of *The Atmosphere. GEODe: Atmosphere* is a dynamic program that provides broad coverage of basic principles and reinforces key concepts by using tutorials, interactive exercises, animations, and "In the Lab" activities. A table of contents for the CD-ROM appears in the front matter for easy reference, and a special icon appears throughout the book wherever a text discussion has a corresponding *GEODe: Atmosphere* activity.

Environmental Issues and Atmospheric Hazards

Many of the serious environmental issues that face humanity are related to the atmosphere. This new edition includes up-to-date treatment of air pollution, ozone depletion, global warming, and more.

Because atmospheric hazards adversely affect millions of people worldwide every day, coverage of this topic has been expanded. At appropriate places throughout the book, students will have an opportunity to learn more about atmospheric hazards. Two entire chapters (Chapter 10, "Thunderstorms and Tornadoes" and Chapter 11, "Hurricanes") focus almost entirely on hazardous weather. In addition, a number of the book's special-interest boxes are devoted to a broad variety of atmospheric hazards, including heat waves, winter storms, floods, dust storms, drought, mudslides, and lightning.

Maintaining a Focus on Basic Principles

Although many topical issues are treated in the tenth edition of *The Atmosphere,* it should be emphasized that the main focus remains the same as that of its predecessors—to foster a basic understanding of the atmospheric environment. In keeping with this aim, the organization of the text remains intentionally traditional. Following an overview of the atmosphere in Chapter 1, the next 10 chapters are devoted to a presentation of the major elements and concepts of meteorology. Chapter 12, on weather analysis, follows and serves to reinforce and apply many of the concepts presented in the preceding chapters. Chapter 13 is devoted to the important issue of air pollution.

The text concludes with two chapters on climate (Chapters 14 and 15) and one devoted to optical phenomena (Chapter 16). Chapter 14, "The Changing Climate," explores a topic that is the focus of much public interest as well as scientific research: Is global climate changing and, if so, in what ways? How are people causing or contributing to these changes? The discussions in Chapter 14 have been carefully and thoroughly revised and updated to reflect the fast-changing nature of this sometimes controversial subject.

Highlights of the Tenth Edition

The tenth edition of *The Atmosphere* represents a thorough revision. Every part of the book was examined carefully with the dual goals of keeping topics current and improving the clarity of text discussions. Those familiar with preceding editions will see much that is new in the tenth edition. The list of specifics is long. Examples include the following:

- Chapter 1, "Introduction to the Atmosphere," includes a new, expanded treatment of the nature of scientific inquiry, an updated introduction to atmospheric hazards, and a revised, easier-to-follow discussion of Earth as a system.
- The treatment of temperature controls in Chapter 3 has been strengthened by the addition of several new examples and images.
- Chapters 4 and 5, which focus on humidity, clouds, and precipitation, include revised treatments of dew point and hail and an updated look at intentional weather modification.
- Chapter 9, "Weather Patterns," has a new section on the Alberta Clipper, while Chapter 10, "Thunderstorms and Tornadoes," has updated discussions, maps, and statistics on lightning and tornadoes as well as a new tornado case study (Box 10-3).
- Much of Chapter 11, "Hurricanes," has been revised in light of the extraordinary hurricane seasons of 2004 and 2005. Many new satellite images and photos are included to add relevance and interest.
- A significant portion of Chapter 12, "Weather Analysis and Forecasting," was revised. The goal was not only to make discussions more complete and up to date, but more readable and easier to understand. New figures include the addition of new upper-air charts to help illustrate their role in weather forecasting.
- Chapter 14, "The Changing Climate," has an expanded section on how climate change is detected. It includes a more complete look at the use of proxy data. The treatment of global warming has been updated to include data and examples from 2004 and 2005. The revised section on the possible consequences of global warming takes a closer look at the changing Arctic region. There are eight new graphs, charts, and satellite images to support these new discussions.

Additional Highlights

- "*Students Sometimes Ask…,*" a feature that was new in the ninth edition, has been retained and improved in the tenth edition. Instructors and students reacted favorably and indicated that the questions and answers sprinkled through each chapter add interest and relevance to text discussions.
- Although the total number of special-interest boxes in the tenth edition has not changed, eight are totally new and 10 others have been substantially revised.
- The number of satellite images and maps based on satellite data in the tenth edition has been significantly expanded. Such views help add perspective and clarity to many text discussions.

The Teaching and Learning Package

The authors and publisher have been pleased to work with a number of talented people who produced an excellent supplements package.

For the Student

GEODe: Atmosphere CD-ROM. Each copy of *The Atmosphere* comes with *GEODe: Atmosphere* by Fred Lutgens, Ed Tarbuck, and Dennis Tasa of Tasa Graphic Arts, Inc. *GEODe: Atmosphere* is a dynamic program that reinforces key concepts by using animations, tutorials, and interactive exercises. This well-received student-tested product provides broad coverage of basic principles. A special *Geode: Atmosphere* icon appears throughout the book wherever a text discussion has a corresponding *GEODe: Atmosphere* activity. This special offering gives students two valuable products (*GEODe: Atmosphere* and the textbook) for the price of one.

Website. *Atmospheric Science Online* contains numerious review quizzes from which students get immediate feedback. Other activities and resources help expand student understanding of atmospheric processes and phenomena. This website provides an excellent platform from which to start using the Internet for the study of meteorology. Please visit the site at **http://www.prenhall.com/lutgens.**

For the Professor

A wealth of valuable teaching tools is available.

Instructor's Manual 0-13-187472-1. A valuable resource for any professor, the *Instructor's Manual* contains learning objectives, chapter outlines, and suggested answers to the end-of-chapter questions.

Transparency Pack 0-13-187463-2. Includes over 100 full-color illustrations from the text, enlarged for excellent classroom visibility.

Instructor's Resource Center on CD/DVD (IRC) 0-13-187465-9. Provides high-quality electronic versions of select photos and all of the illustrations from the book, as well as customizable PowerPoint™ presentations, MS Word files of both the *Instructor's Manual* and *Tests,* and animations. This is a powerful resource for anyone who is using electronic media in the classroom. Create your own PowerPoint™ presentation with the materials provided, or customize PowerPoint™ with your own materials. Either way, this resource will streamline the preparation of your lectures.

Test Item File 0-13-88958-3. The *Test Item File* contains over 1500 questions covering multiple-choice, true/false, and short-answer questions and is available in print or electronic formats via the *eCatalog, Instructor's Resource Center.*

TestGen EQ/QuizMaster 0-13-187464-0. Computerized test generator that lets you view and edit test-bank questions, transfer questions to tests, and print the test in a variety of customized formats. Included in each package is the *QuizMaster-EQ* program, which lets you administer tests on a computer network, record student scores, and print diagnostic reports.

For the Laboratory

Exercises for Weather and Climate, 6/E 0-13-149701-4. Written by Greg Carbone. This lab manual, which complements Lutgens and Tarbuck's *The Atmosphere, Tenth Edition,* offers students an opportunity to review important ideas and concepts through problem solving, simulations, and guided thinking. This revised edition features an upgraded graphics program and eight computer-based simulations and tutorials that help students better learn key concepts. The lab manual is available at a reduced price when packaged with the text. The accompanying *Solutions Manual* contains all solutions to the labs 0–13-154789-5.

Acknowledgments

Writing a college textbook requires the talents and cooperation of many individuals. Working with Dennis Tasa, who is responsible for all of the text's outstanding illustrations and much of the developmental work on *GEODe: Atmosphere,* is always special for us. We not only value his outstanding artistic talents and imagination but his friendship as well.

Special thanks go to those colleagues who prepared in-depth reviews. Their critical comments and thoughtful input helped guide our work and clearly strengthened the text. We wish to thank:

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DONALD M. YOW, *Eastern Kentucky University*

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Frederick K. Lutgens
Edward J. Tarbuck

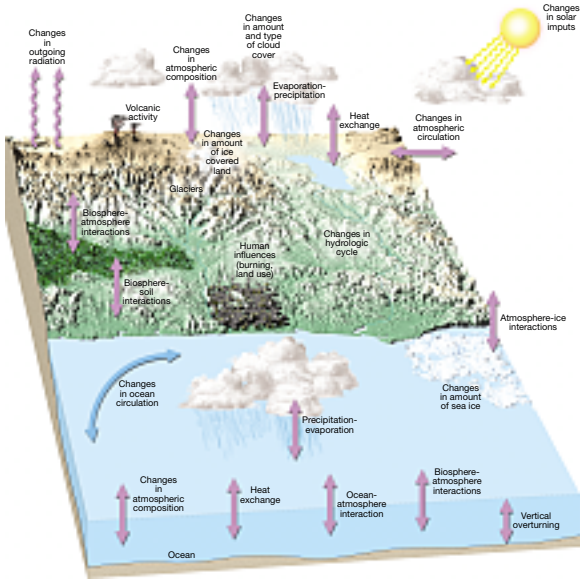
Distinguishing Features

The goal of *The Atmosphere, Tenth Edition* is to provide an informative, user-friendly text for introductory atmospheric science. *The Atmosphere* is crafted with a focus on five key areas:

- readability
- illustrations and photographs
- student learning
- environmental issues and atmospheric hazards
- basic physical principles

Readability

Fred Lutgens and Ed Tarbuck are known for their ability to make difficult physical processes understandable for introductory students. *The Atmosphere, Tenth Edition* is accessible to introductory students and contains the level of detail necessary for a survey course in atmospheric science. The frequent heading and subheadings help students follow discussions and identify the important ideas presented in each chapter.



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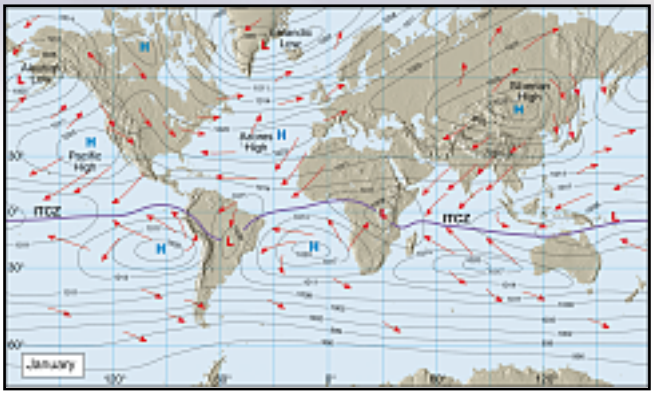

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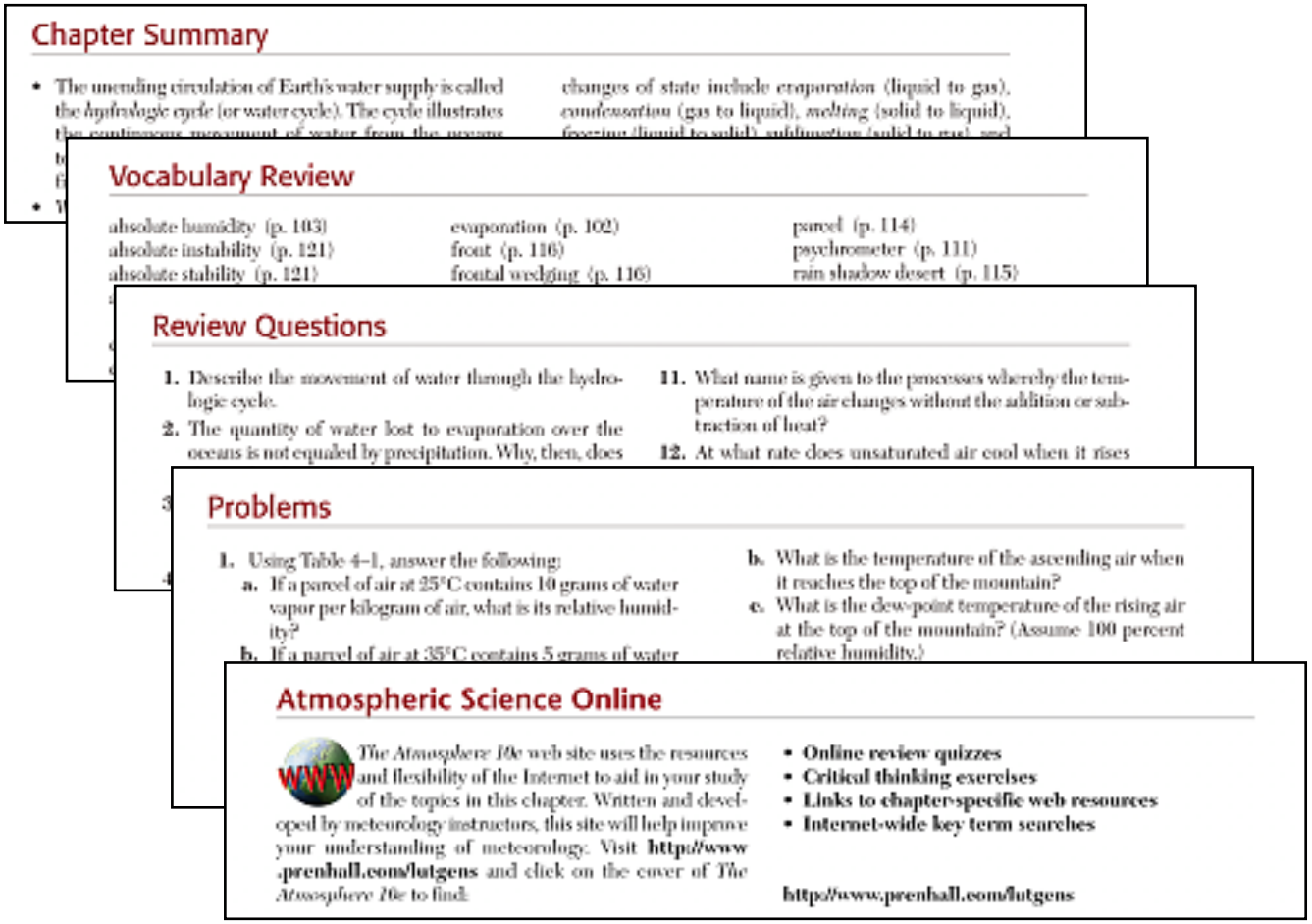
Focus on Learning

When a chapter has been completed, five useful devices help students review:

- Chapter Summary
- Vocabulary Review
- Review Questions
- Problems (in most chapters, many with a quantitative orientation)
- *The Atmosphere, Tenth Edition* Website has review quizzes and activities



Chapter Summary

- The unending circulation of Earth's water supply is called the *hydrologic cycle* (or water cycle). The cycle illustrates

changes of state include *evaporation* (liquid to gas), *condensation* (gas to liquid), *melting* (solid to liquid),

Vocabulary Review

absolute humidity (p. 103)
absolute instability (p. 121)
absolute stability (p. 121)
evaporation (p. 102)
front (p. 116)
frontal wedging (p. 116)
parcel (p. 114)
psychrometer (p. 111)
rain shadow desert (p. 115)

Review Questions

1. Describe the movement of water through the hydrologic cycle.
2. The quantity of water lost to evaporation over the oceans is not equaled by precipitation. Why, then, does
11. What name is given to the processes whereby the temperature of the air changes without the addition or subtraction of heat?
12. At what rate does unsaturated air cool when it rises

Problems

1. Using Table 4–1, answer the following:
   a. If a parcel of air at 25°C contains 10 grams of water vapor per kilogram of air, what is its relative humidity?
   b. If a parcel of air at 35°C contains 5 grams of water
   b. What is the temperature of the ascending air when it reaches the top of the mountain?
   c. What is the dew-point temperature of the rising air at the top of the mountain? (Assume 100 percent relative humidity.)

Atmospheric Science Online

WWW *The Atmosphere 10e* web site uses the resources and flexibility of the Internet to aid in your study of the topics in this chapter. Written and developed by meteorology instructors, this site will help improve your understanding of meteorology. Visit **http://www.prenhall.com/lutgens** and click on the cover of *The Atmosphere 10e* to find:

- **Online review quizzes**
- **Critical thinking exercises**
- **Links to chapter-specific web resources**
- **Internet-wide key term searches**

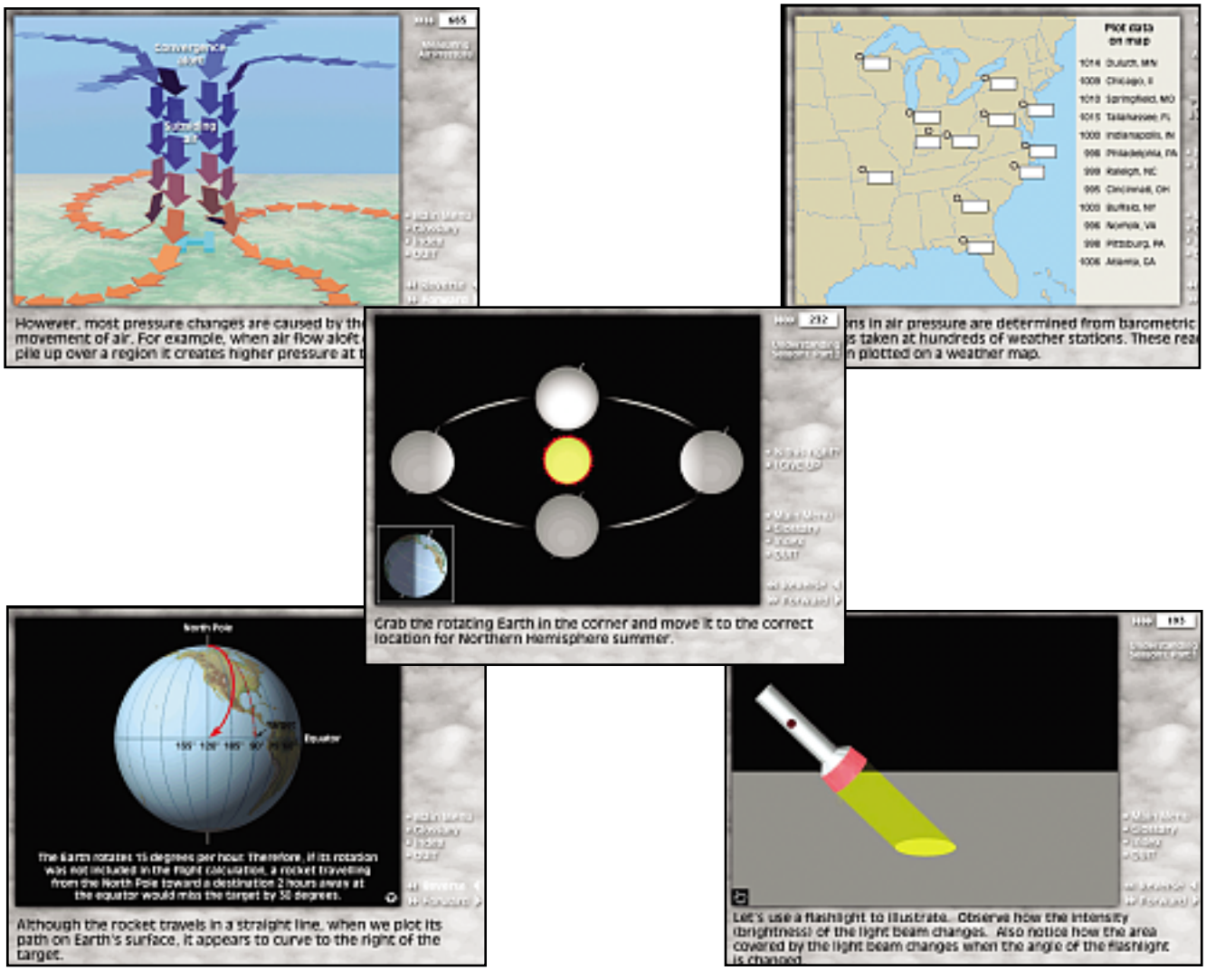
http://www.prenhall.com/lutgens

A Focus on Basic Principles

Although many topical issues are treated in the tenth edition of *The Atmosphere*, it should be emphasized that the main focus remains the same as that of its predecessors—to foster a basic understanding of the atmospheric environment.

GEODe: Atmosphere CD included with Every Copy of the Tenth Edition

Each copy of *The Atmosphere, Tenth Edition* comes with the interactive CD-ROM: *GEODe: Atmosphere. GEODe: Atmosphere* is a highly interactive CD-ROM tutorial that helps learners review key atmospheric-science concepts through a variety of interactive exercises. *GEODe: Atmosphere* provides broad coverage of basic topics in meteorology. The CD includes tutorials, interactive exercises, animations, and "In the Lab" activities.



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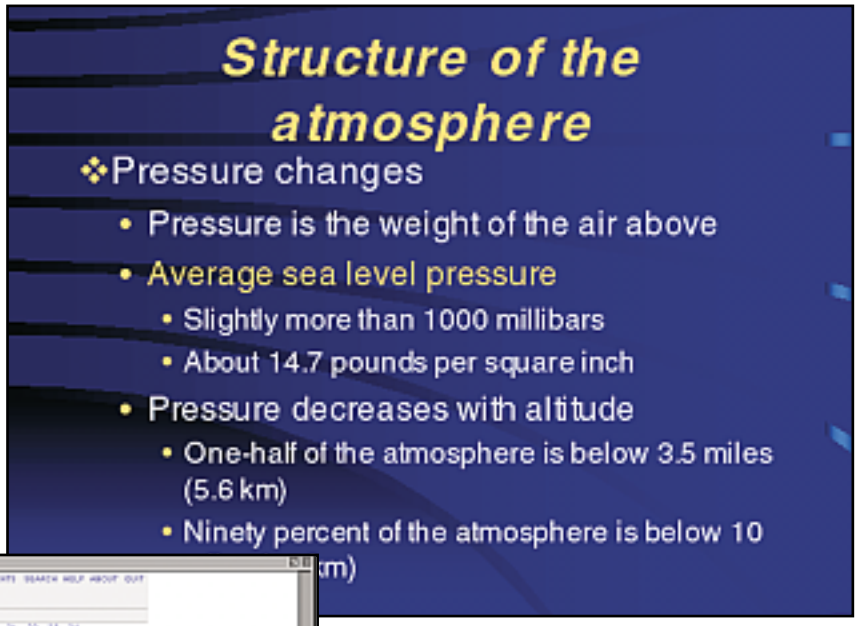
Lecture Presentation Tools

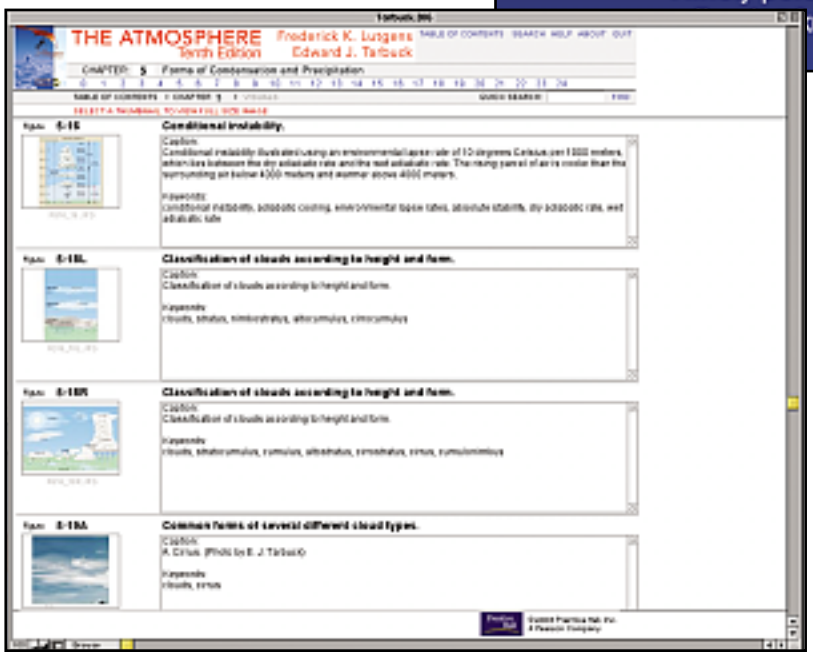
Transparencies (0-13-187463-2)

Transparency Set includes over 100 pieces of art from the text, all enlarged for excellent classroom visibility.

Instructor Resource Center on CD-ROM (IRC) (0-13-187465-9)

The *Instructor Resource Center on CD-ROM* provides high-quality electronic versions of photos and illustrations from the book, as well as customizable PowerPoint™ presentations, MS Word files of both the *Instructor's Manual* and *Tests,* and animations from *GEODe: Atmosphere.*





Images are high-resolution, low-compression, 16-bit jpeg files. To further guarantee classroom projection quality, all images are manually adjusted for color, brightness, and contrast. For easy reference and identification all images are organized by chapter.

Teaching and Learning Package

Many supplements are available to help you prepare for your course. These range from the traditional supplements you have come to expect to electronic media for use in your classroom.

Instructor Resources

Transparencies (0-13-187463-2)

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Instructors Resource Manual with Tests (0-13-187472-1)

A valuable resource for any professor, the *Instructor's Manual* contains learning objectives, chapter outlines and suggested answers to the end of chapter questions.

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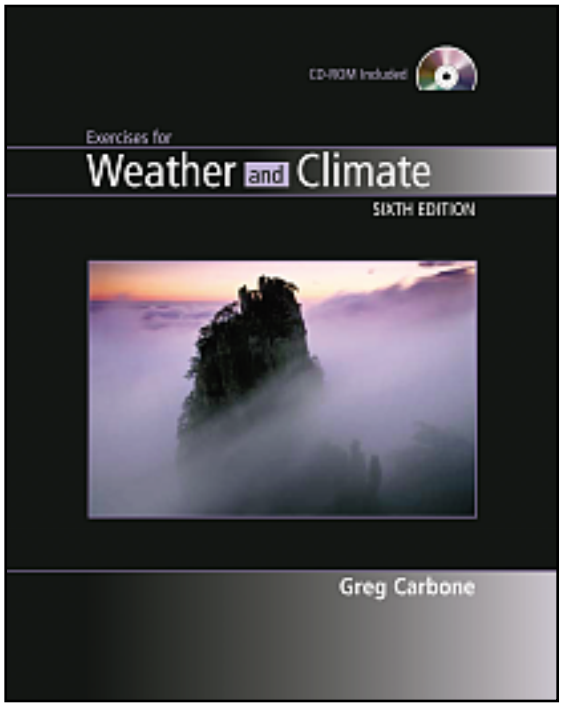
Student Resources

Online Study Guide

This on-line study guide, specific to the text, contains numerous review exercises (from which students get immediate feedback), exercises to expand one's understanding of meteorology, and resources for further exploration. This website provides an excellent platform from which to start using the Internet for the study of meteorology. Please visit the site at **http://www.prenhall.com/lutgens**

Lab Manual

Exercises for Weather and Climate
Sixth Edition
Greg Carbone



Appropriate for use with any introductory meteorology or weather and climate text, this laboratory manual (0-13-149701-4) consists of 17 exercises that present introductory principles in weather and climate to the student. Collectively the exercises combine data analysis, problem solving, and experimentation; the questions are designed to encourage critical thinking about the fundamental topics of atmospheric processes.

Accompanying *Solutions Manual* contains all solutions to the labs (0-13-154789-5).

Take 20% off *Lab Manual* price when valuepacked with *The Atmosphere, Tenth Edition* (0-13-187462-4).