

Preface

Weather is something we experience firsthand, but often we don't know why things happen the way they do. The fourteenth edition of *The Atmosphere* helps students understand why these things happen. This college-level textbook is a nontechnical survey of weather and the atmosphere, intended for students taking their first, and perhaps only, course in meteorology. Our goal in writing *The Atmosphere* is to help students understand the processes that control our weather and be able to apply this information in their daily lives.

New to This Edition

The fourteenth edition of *The Atmosphere* is streamlined to be more student oriented, with guideposts to a clear learning path from beginning to end of each chapter. We make use of experience gained from many years of teaching introductory weather and climate courses to add more process-oriented descriptions. Some chapters are reorganized and significantly revised to improve the flow of the discussion, and the material is updated based on current meteorology research. Most chapters have been reduced in length without cutting important content. Some of the textbook-wide changes include the following:

- An **improved active learning path** that creates a learning ladder, where each rung brings a deeper mastery of the material:
 - **Focus on Concepts**, appearing at the beginning of each chapter, lists learning objectives (many of which have been revised) to help students get a “lay of the land” before starting the chapter.
 - **Each major section** repeats the learning goal with a single bulleted visual to keep students focused.
 - Key concepts in every section are highlighted using one to two **pull quotes (NEW)** to help students synthesize the section information.
 - **Key terms** are in bold where they are defined in the text.
 - **Concept Checks** are a set of three to four questions placed at the end of each major section to help students test their recall of the main points of the section.
 - **Concepts in Review** tie back to Focus on Concepts (the learning objectives), summarize the main points (many revised) for each section, and now incorporate visual cues for each section to aid with recall and understanding. These reviews bring the learning path full circle for students.
 - **Review Questions (NEW)** provide students with an opportunity to test their understanding of the chapter as a whole.
 - Requiring a higher level of understanding, the **Give It Some Thought** section challenges students to synthesize concepts and apply this knowledge to answer questions.
- **By the Numbers** (formerly called Problems) requires students to use basic math skills to solve quantitative problems related to key concepts.
- **Beyond the Textbook (NEW)** features one to two links to websites with atmospheric, weather, or climate data (animated maps, tables, diagrams, etc.). Students answer data analysis questions based on actual current conditions or a specific locale. This allows students to see how concepts in the chapter play out in the real world and in real time.
- Updated figures make learning easier by illustrating processes and examples in each chapter. Once again we are privileged to work with Dennis Tasa, whose artistic creations are stunning. There are **129 figures** that are new or substantially revised to help clarify difficult concepts. There are **49 new photographs** of real-world weather situations to keep the textbook current and relevant.
- Weather safety is more fully integrated into the textbook. Every Severe & Hazardous Weather feature now contains **Weather Safety tips (NEW)**. Weather safety tips are also added to the text in several chapters.
- **Mastering Meteorology** delivers engaging, dynamic learning opportunities—focused on course objectives and responsive to each student's progress—that are proven to help students absorb course material and understand difficult concepts.
- **Integrated Mobile Media with accompanying review questions.** QR links to mobile-enabled *Videos* and *Geoscience Animations* are integrated throughout the chapters, giving students just-in-time access to animations of key physical processes and videos of real-world case studies and data visualizations. The video selection has been revised and updated. These media are also available in the Study Area of Mastering Meteorology. There are also short quizzes for each video in Mastering Meteorology.
- **SmartFigures** are brief, narrated video lessons that examine and explain concepts illustrated by key figures within the text. Students access SmartFigures on their

mobile devices by scanning Quick Response (QR) codes next to key figures. These media are also available in the Study Area of Mastering Meteorology, and teachers can assign them with automatically graded quizzes.

- A **Math Review** chapter is added to Mastering Meteorology.
- New end-of-chapter questions will be included in Mastering Meteorology.
- Significantly **updated and revised content**. A basic function of a college science textbook is to provide clear, understandable presentations that are accurate, engaging, and up-to-date. Our number-one goal is to keep *The Atmosphere* current, relevant, and highly readable for beginning students. In addition to new and improved figures, many discussions and examples have been updated and revised:
 - In Chapter 1, “Earth as a System” is revised with a new “What Powers the Earth System?” subsection. “Ozone Depletion: A Global Issue” is discussed in a new Box.
 - In Chapter 2, “Earth’s Rotation and Orbit” is streamlined, and “The Greenhouse Effect” is revised.
 - “Daily Temperature Cycle” and “Annual Temperature Cycle” are presented earlier in Chapter 3, and “Why Temperatures Vary” is reorganized. The chapter’s three boxes are updated.
 - In Chapter 4, the “Latent Heat” subsection is expanded, and “Atmospheric Stability” section is improved. A new box discusses the Stüve diagram.
 - In Chapter 5, “Precipitation Formation” provides more information on supercooled water, hail formation is expanded, and the radar discussion is updated.
 - In Chapter 6, “Measuring Atmospheric Pressure” includes electronic barometers. Pressure changes and friction discussions are revised to make these difficult concepts, and their relationship to wind, easier to understand. The chapter better explains the connections among curved flow aloft, convergence and divergence, rising and sinking motion, and surface wind systems.
 - Chapter 7 is significantly reorganized. “Scales of Atmospheric Motion” provides more examples, and “Land and Sea Breeze” is completely revised. “Global Distribution of Pressure and Precipitation” allows better comparison

between the two, with discussion of monsoons incorporated into the pressure discussion. The “Jet Streams” section is revised, and the “El Niño, La Niña, and the Southern Oscillation” is expanded to include a direct comparison between normal and El Niño conditions, with a look at the 2015–2016 El Niño.

- In Chapter 8, a new subsection, “Identifying Air Masses on Weather Maps,” gives students practical skills, and a new box, “Heat Waves,” is added. “Lake Effect Snow” discussion is moved to the “Air-Mass Modification” section.
- The main sections in Chapter 9 are reorganized so that the cyclone models are discussed one after the other. Tables identifying the passage of fronts better match the discussion of frontal elements, and many figures are updated to complement the text.
- Chapter 10 content is substantially improved and streamlined. The “Environment for Thunderstorm Development” subsection is revised, and “Ordinary Cell Thunderstorms” and “Severe Thunderstorms” sections are expanded. The radar discussion is updated under “Tornado Forecasting.”
- In Chapter 11, most main sections are renamed and reorganized. Hurricane components are discussed in more detail, and the section “Tracking and Monitoring Hurricanes” is updated and expanded to include aircraft reconnaissance.
- Forecasting information already addressed in earlier chapters is condensed in Chapter 12 to focus on updates to “Modern Weather Forecasting,” particularly weather satellites, quantitative forecasting, and thermodynamic diagrams.
- Air pollution statistics in Chapter 13 are updated, and the discussion of atmospheric stability improved.
- Chapter 14 incorporates the most recent IPCC findings. “Predicting Future Climate Change” is revised and updated.
- Chapter 15 is streamlined to focus on controls of climate and the main differences between climate types.
- In Chapter 16, the discussion of mirages is improved.

Distinguishing Features

Focus on Readability and Student Understanding

The language of this text is straightforward and *written to be understood*. Clear, readable discussions with a minimum of technical language are the rule. Frequent headings and subheadings help students follow discussions and identify the important ideas presented in each chapter. In the fourteenth edition, we have continued to improve readability by examining chapter organization and flow and by writing in a more personal style. Every

chapter has been condensed to streamline the material and focus on key concepts. Significant portions of several chapters were rewritten and reorganized to improve the flow from one concept to the next.

This course is intended for general-education students taking their first meteorology course. It does not try to go into every detail about weather systems—there are more advanced courses for that. While this book is written at a general-education level, it can certainly be used as a launching point for students who want to pursue the study of meteorology.

Focus on Basic Principles

Although many topical issues are addressed in the fourteenth edition of *The Atmosphere*, it should be emphasized that the main focus of this new edition remains the same: to promote student understanding of basic principles. As much as possible, we have attempted to provide the reader with a sense of the observational techniques and reasoning processes that constitute the science of meteorology.

Additional Learning Aids

In addition to the new and expanded learning path, the fourteenth edition continues to include these important learning aids:

- **Eye on the Atmosphere** features real-world imagery paired with active-learning questions to give students a chance to practice visual analysis tasks as they read. Instructors can discuss these in class or assign the questions to students from the book or MasteringMeteorology.
- Every chapter includes several **You might have wondered . . .** (formerly Students Sometimes Ask) features. Instructors and students continue to react favorably and indicate that the questions and answers sprinkled through each chapter add interest and relevance to discussions.
- The new edition continues to highlight **severe and hazardous weather**. Atmospheric hazards adversely affect millions of people worldwide every day. Severe weather events have a significance and fascination that go beyond ordinary weather phenomena. In addition to the two chapters focused entirely on thunderstorms and tornadoes (Chapter 10) and hurricanes (Chapter 11), the text contains 15 Severe and Hazardous Weather boxes devoted to a broad variety of topics—heat waves, winter storms, floods, air pollution episodes, drought, wildfires, cold waves, and more. Each box now includes **Weather Safety tips** and one or two active-learning questions to help students test their understanding and link these events to critical chapter concepts.

Acknowledgments

Writing a college textbook requires the talents and cooperation of many people. It is truly a team effort, and the authors are fortunate to be part of an extraordinary team at Pearson Education. In addition to being great people to work with, all are committed to producing the best textbooks possible. Special thanks to our Executive Editor, Nancy Whilton, who provided insight and guidance at crucial times. We also appreciate our conscientious Content Producer, Chandrika Madhavan, whose job it was to keep track of all that was going on—and a lot was going on. The fourteenth edition was certainly improved by the talents of our developmental editor, Veronica Jurgena. Many thanks. It was the job of the production team, led by Heidi Allgair at Cenveo® Publisher Services, to turn our manuscript into a finished product. The team also included copyeditor Sally Peyrefitte and photo researcher Kristin Piljay. We think these talented people did great work. All are true professionals, with whom we are very fortunate to be associated.

Working with Dennis Tasa, who is responsible for all of the text's outstanding illustrations, is always special for us. He has been part of our team for more than 30 years. We value not only his artistic talents, hard work, patience, and imagination, but his friendship as well.

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We are very grateful to Neva Duncan-Tabb (St. Petersburg College), who authored the *Instructor Resource Manual*, and to Jennifer Johnson (Ferris State University) for writing the *Test Bank*. We'd also like to thank Michael Burger and Sean Colgan for their help with Integrated Mobile Media.

We would like to welcome Redina Herman to the team. Redina has a PhD in atmospheric science from the University of Illinois, Urbana–Champaign. She has been teaching introductory and advanced meteorology courses for 15 years. Redina is involved in science education research and won the Western Illinois University College of Arts and Sciences award for Outstanding Teaching with Technology. Redina is also Western Illinois University's representative to the University Corporation for Atmospheric Research (UCAR), which runs the National Center for Atmospheric Research (NCAR). She adds a great deal of knowledge, experience, and enthusiasm to the team.

Last, but certainly not least, we gratefully acknowledge the support and encouragement of our significant others, Nancy Lutgens, Joanne Bannon, and Owen Finch. Preparation of *The Atmosphere*, fourteenth edition, would have been far more difficult without their patience and understanding.

Fred Lutgens

Ed Tarbuck

Redina Herman

Digital & Print Resources

For Students & Teachers

Mastering Meteorology™ with Pearson eText. The Mastering platform is the most widely used and effective online homework, tutorial, and assessment system for the sciences. It delivers self-paced tutorials that provide individualized coaching, focus on course objectives, and respond to each student's progress. The Mastering system helps teachers maximize class time with customizable, easy-to-assign, and automatically graded assessments that motivate students to learn outside class and arrive prepared for lecture.

Mastering Meteorology offers the following:

- Assignable activities that include GIS-inspired MapMaster™ interactive maps, Encounter Meteorology Google Earth Explorations, Videos, Geoscience Animations, Map Projection Tutorials, GeoTutor coaching activities on the toughest topics in the geosciences, GEODe Tutorials, end-of-chapter questions and exercises, reading quizzes, Test Bank questions, and more.
- A student Study Area with GIS-inspired MapMaster™ interactive maps, GEODe Tutorials, Videos, Geoscience Animations, web links, glossary flashcards, *In the News* articles, chapter quizzes, an optional Pearson eText, and more.

Pearson eText gives students access to the text whenever and wherever they can access the Internet. Features of Pearson eText include:

- Accessibility via smartphones and tablets (screen-reader ready).
- Seamlessly integrated videos and other rich media.
- Configurable reading settings, including resizable type and night-reading mode.
- Instructor and student note-taking, highlighting, bookmarking, and search.

www.masteringmeteorology.com.

Hazard City for Mastering Geography (0321970349) is a collection of 11 online problem-solving assignments in *Mastering Geography and Meteorology™* that demonstrate the work of practicing geoscientists and environmental professionals. The activities allow the student to step into the role of a practicing geoscientist to analyze potential disasters in the fictional town of *Hazard City*. Students learn to research and explore on their own in areas such as Map Reading, Ground Water Contamination, Volcanic Hazard Assessment, Earthquake Damage Assessment, Shoreline Property Assessment, and much more.

www.masteringmeteorology.com

- **Geoscience Animation Library on DVD, 5th Edition [0321716841]** Created through a unique collaboration among Pearson's leading geoscience authors, this resource offers over 100 animations covering the most difficult-to-visualize topics in meteorology, Earth science, physical geography, physical geology, and oceanography. Animations include audio narration and text transcript, with assignable multiple-choice quizzes to select animations in Mastering Meteorology to help students master these core physical process concepts.
- **Earth Report Videos on DVD [0321662989]** This three-DVD set is designed to help students visualize how human decisions and behavior have affected the environment and how individuals are taking steps toward recovery. With topics ranging from poor land management promoting the devastation of river systems in Central America to the struggles for electricity in China and Africa, these 13 videos from Television for the Environment's global *Earth Report* series recognize the efforts of individuals around the world to unite and protect the planet. Teachers can assign video clips with assessment in Mastering Meteorology.

For Students

- **Exercises for Weather & Climate, 9th edition, by Greg Carbone [0134041364]** This bestselling exercise manual's 17 exercises encourage students to review important ideas and concepts through problem solving, simulations, and guided thinking. The graphics program and computer-based simulations and tutorials help students grasp key concepts. Now with mobile-enabled Pre-Lab Videos and Pre- and Post-Lab quizzes in Mastering Meteorology, this manual is designed to complement any introductory meteorology or weather and climate course.
- **Goode's World Atlas, 23rd edition [0133864642]** First published by Rand McNally in 1923, Goode's World Atlas is the gold standard for college reference atlases. It

features hundreds of physical, political, and thematic maps, graphs, and tables, as well as a comprehensive pronouncing index. The 23rd Edition introduces dozens of new maps, incorporating the latest geographic scholarship and technologies, with expanded coverage of the Canadian Arctic, Europe's microstates, Africa's island states, and U.S. cities. It introduces several new thematic maps on critical topics such as: oceanic environments, earthquakes and tsunamis, desertification vulnerability, maritime political claims, megacities, human trafficking, labor migration . . . and many more topics important to contemporary geography. Available in eText formats from Pearson.



- ***Dire Predictions: Understanding Global Climate Change, 2nd edition, by Mike Mann and Lee Kump [0133909778]*** Periodic reports from the Intergovernmental Panel on Climate Change (IPCC) evaluate the risk of climate change brought on by humans. In just over 200 pages, this practical text presents and expands upon the essential findings of the IPCC in a visually stunning and undeniably powerful way to the lay reader. Scientific findings that provide validity to the implications of climate change are presented in clear-cut graphic elements, striking images, and understandable analogies. The second edition covers the latest climate change data and scientific consensus from the IPCC *Fifth Assessment Report* and integrates mobile media links to online media. The text is also available in various eText formats, including as a secondary eText upgrade option from *Elemental Geosystems' Mastering Geography™* courses.
- ***Encounter Physical Geography by Jess C. Porter and Stephen O'Connell [0321672526]*** Pearson's Encounter Series provides rich, interactive explorations of geoscience concepts through Google Earth activities, covering a range of topics in meteorology and physical geography. For those who do not use Mastering Meteorology, all chapter explorations are available in print workbooks, as well as in online quizzes at www.mygeoscienceplace.com, accommodating different classroom needs. Each exploration consists of a worksheet, a corresponding Google Earth KMZ file, and online quizzes whose results can be e-mailed to teachers.

For Teachers

Learning Catalytics is a “bring your own device” student engagement, assessment, and classroom intelligence system. With Learning Catalytics, you can:

- Assess students in real time, using open-ended tasks to probe student understanding.
- Understand immediately where students are and adjust your lecture accordingly.
- Improve your students' critical-thinking skills.
- Access rich analytics to understand student performance.
- Add your own questions to make Learning Catalytics fit your course exactly.
- Manage student interactions with intelligent grouping and timing.

Learning Catalytics is a technology that has grown out of 20 years of cutting-edge research, innovation, and implementation of interactive teaching and peer instruction. Available integrated with Mastering Meteorology.

- ***Instructor Resource Manual (download only) by Neva Duncan-Tabb, St. Petersburg College [0134800923]*** The *Instructor Resource Manual* is intended as a resource for both new and experienced instructors. It includes a variety of lecture outlines, teaching tips, advice about how to integrate visual supplements (including the Mastering Meteorology resources), answers to the textbook chapter questions, and various other ideas for the classroom. See www.pearsonhighered.com/irc.
- ***TestGen® Computerized Test Bank (download only) by Jennifer Johnson, Ferris State University [0134800907]*** TestGen® is a computerized test generator that lets instructors view and edit *Test Bank* questions, transfer questions to tests,

and print tests in a variety of customized formats. This *Test Bank* includes more than 2000 multiple-choice, fill-in-the-blank, and short-answer/essay questions. Questions are correlated to the text's Learning Outcomes, Pearson's Global Science Outcomes, the section of each chapter, the revised U.S. National Geography Standards, and Bloom's taxonomy to help instructors better map the assessments against both broad and specific teaching and learning objectives. The *Test Bank* is also available in Microsoft Word and is importable into systems such as Blackboard.

See www.pearsonhighered.com/irc.

- ***Instructor Resources [0134800915]*** Instructor Resources is a collection of resources to help teachers make efficient and effective use of their time. All digital resources can be found in one well-organized, easy-to-access place. The resources include:
 - All textbook images as JPEGs, PDFs, and PowerPoint™ presentations.
 - Pre-authored Lecture Outline PowerPoint™ presentations, which outline the concepts of each chapter with embedded art and can be customized to fit teachers' lecture requirements.
 - “Clicker” questions in PowerPoint™, which correlate to the text's Learning Outcomes, U.S. National Geography Standards, and Bloom's taxonomy.
 - The TestGen software, *Test Bank* questions, and answers for both MACs and PCs.
 - Electronic files of the *Instructor Resource Manual* and *Test Bank*.

This Instructor Resource content is available online via the Instructor Resources section of Mastering Meteorology and www.pearsonhighered.com/irc.