

The background of the cover is a dramatic, high-contrast photograph. It depicts a turbulent sea with white-capped waves crashing against a dark, rocky shore. In the lower right foreground, a portion of a ship's railing with ornate, curved metalwork is visible. To the left, a lighthouse with a dark, conical roof and a small lantern room is partially obscured by the spray and mist of the waves. The sky is filled with heavy, dark clouds, with a bright, ethereal light source breaking through in the center, creating a strong backlighting effect and illuminating the mist and the ship's railing. The overall mood is one of power, mystery, and the raw force of nature.

Meteorology

Understanding

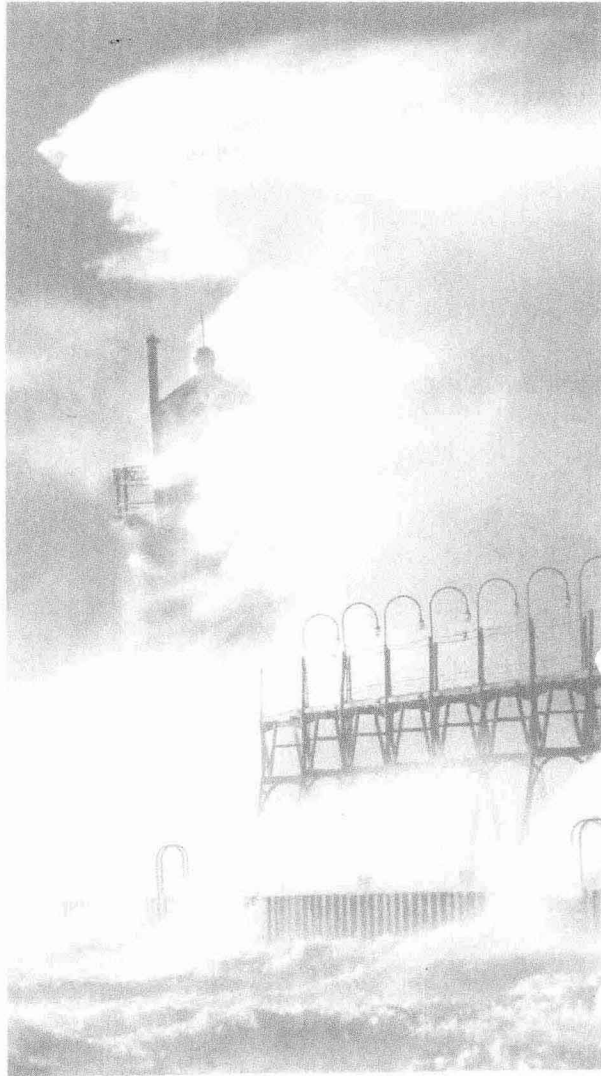
— the —
Atmosphere

Steven A. Ackerman

John A. Knox

Meteorology

Understanding the Atmosphere



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Printed in Canada
3 4 5 6 7 06 05 04 03

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Library of Congress Cataloging-in-Publication Data

Ackerman, Steven A.
Meteorology: understanding the atmosphere /
Steven Ackerman, John Knox.
p. cm.
Includes index.
ISBN 0-534-37199-X
1. Meteorology. I. Knox, John, 1965- II. Title.

QC861.3 .A34 2002
551.5—dc21

2001058237

Production Service: Graphic World, Inc.
Text Designer: Roy Neuhaus
Art Editor: Graphic World, Inc.
Photo Researcher: Terry Powell
Copy Editor: Graphic World Publishing Services
Illustrator: Graphic World, Inc.
Cover Designer: Roy Neuhaus
Cover Image: Taya Kashuba/Kalamazoo Gazette
Cover Printer: Transcontinental Printing Inc.
Compositor: Graphic World, Inc.
Printer: Transcontinental Printing Inc.

Brooks/Cole—Thomson Learning
511 Forest Lodge Road
Pacific Grove, CA 93950
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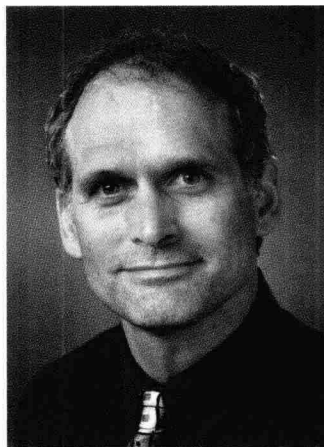
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To Anne, Erin, and Alana, who are always lovingly patient with my meteorological distractions. I thank my parents and siblings for their good humor.

S.A.A.

To my family, most of all Pam and Evan; to my students; and to the two people who most inspired me to study and teach meteorology: the late Dr. Lyle Horn of the University of Wisconsin and J.B. Elliott of the National Weather Service (Birmingham, retired)

J.A.K.



Preface



To The Student

Weather engulfs us. Its influence can be both dramatic and subtle. Weather tempers how we dress, how we live, the music we play, and the art we create. It can destroy our homes and threaten our lives. It affects our daily activities, leisure, holidays, transportation, commerce, agriculture, and nearly every other aspect of our lives. Our fascination with the weather has led to 24-hour weather networks, feature-length motion pictures, and an explosion of detailed weather data over the Internet.

Mark Twain said, “everyone talks about the weather, but nobody does anything about it.” You may not be able to change the weather, but you can discover the processes that determine weather. We think that learning about meteorology can and should be both enjoyable and relevant to your everyday life. Knowledge gained from reading this book can help you better understand nightly television weather reports and interpret news articles on severe weather, impending climate change, greenhouse warming, the depletion of the ozone layer, and the causes and effects of El Niño. You will experience and be influenced by these events throughout your lifetime. *Meteorology: Understanding the Atmosphere* will help you to grasp the fundamentals and gain an appreciation of the complexities involved with these issues.

The World Wide Web has enhanced your opportunity to learn meteorology by applying textbook concepts to real-time weather conditions. A flood of sophisticated weather information that once was restricted to a few scientists is now just a click away on the World Wide Web. *Meteorology: Understanding the Atmosphere* will help you to make sense of the abundant weather information available to you on the Internet, serving as a reference as you investigate current conditions. In addition, dozens of Java applets on our text’s Web site will help you understand the material in this book and allow you to explore topics in even greater detail.

Meteorology is a topic that easily generates interest in and an appreciation of a natural science. Our goal in writing this book was to provide you with a perspective on meteorology as a science in which observations play a key role. Thus, we provide many observations, both personal and from scientific instruments, throughout this book along with analysis of those observations. This approach of observing and then analyzing the atmosphere to gain an understanding is a scientific way of thinking, and it is how we, the authors, explore and understand the atmosphere ourselves. We hope that you find this approach exciting and that it inspires you to a lifetime of watching and understanding the weather.

To The Instructor

Meteorology: Understanding the Atmosphere is designed for use in a wide range of college and university introductory courses in meteorology and in weather and climate. This book is written in an interesting and clear manner that allows your students to immediately apply material to the world around them.

Our text emphasizes **observing the atmosphere and using those observations to explain atmospheric phenomena**. Just by paying attention to the weather outside, it is possible for a newcomer to the subject to observe key clues that explain how the atmosphere works. By learning how to interpret scientific observations of the atmosphere, students can deepen their understanding even more. The observations we examine in this text range from those made by students themselves to cutting-edge scientific measurements from radar and from space. Many of the images here have never appeared before in print. Throughout the text, weather phenomena come alive via conceptual models to explain their existence, visualization of their life cycles, and weather safety information to keep weather from becoming a killer.

This book focuses on understanding the basic concepts of meteorology. Most students have a better understanding of the world around them through observations and experiences than through mathematics. For this reason, throughout the text we begin by asking about a weather phenomenon, “what does it look like?” before delving into the theory behind it. Therefore, the book is accessible to those not majoring in geography or meteorology, while still providing detailed mathematics for more advanced students. We employ narratives and metaphors that in some chapters allow us to explore topics more deeply than is done in texts that use extensive mathematics.

Meteorology: Understanding the Atmosphere has several unique features. Weather maps and weather watches and warnings are introduced immediately in Chapter 1 to allow instructors the option of using current weather to explore topics discussed in each chapter. The physics of energy transfer in the atmosphere is presented in an accessible manner to students without a physics background in Chapter 2. These concepts are applied in Chapter 3 to describe observed temperature variations. Chapter 4 on the atmospheric water cycle combines clouds with other water phases. It is a concise and unified treatment of how water circulates through the atmosphere. Chapter 5 is an integrated approach that combines visual observations of the state of the atmosphere, including optics, with explanations of scientific measurements such as satellite imagery. Chapter 6 approaches the usually difficult discussion of forces via the simplifying idea of “balance,” which is also how today’s researchers make sense of this subject. These ideas are applied worldwide in Chapter 7 in the form of conceptual models of global winds.

The second half of our text examines topics in weather and climate in a variety of innovative ways. Tropical cyclones and El Niño are appropriately covered together in Chapter 8, a unified chapter on atmosphere–ocean interactions that reflects our growing appreciation of how the atmosphere and ocean interact to affect weather and climate. Chapter 9 enlivens the standard discussion of fronts and air masses with apt analogies to regional accents. Chapter 10 is a state-of-the-art chapter on extratropical cyclones and anticyclones, presented in the compelling contexts of the stories of the *Edmund Fitzgerald* shipwreck and the John F. Kennedy, Jr., plane crash. Chapter 11 views the life cycles of severe weather from a variety of angles: the ground, the air, Doppler radar, and satellite. Chapter 12 is a comprehensive look at small-scale winds across the United States and the globe. Chapter 13 is the most complete weather forecasting chapter ever written for this level and is made accessible with three narratives illustrating the advances in forecasting during the past century. Chapters 14 and 15 address past climates and climate change as mysteries to be solved, rather than as cataclysmic scenarios. Finally, complex topics,

such as global warming and adiabatic and diabatic temperature changes, are visited throughout the entire textbook.

The instructor-friendly structure of this book is based on our combined teaching experiences at five different universities. For example, Chapter 5 discusses how we observe the atmosphere using both our senses and scientific instruments. The modular structure of this chapter allows this material to be covered all at once or as a function of weather parameter. The tropical cyclone section in Chapter 8 comes early enough in the text that fall-semester instructors may easily cover it during hurricane season. Chapter 10 synthesizes and reinforces the material on forces, air masses and fronts from Chapters 6 and 9. Finally, Chapter 12's modular design allows instructors to cover as much, or as little, of small-scale winds as desired and to focus on a particular geographic region. Throughout the text, intertextual icons indicate related Java applets and Blue Skies exercises that expand your students' abilities to explore these topics beyond the confines of the lecture hall.

Our Web site—<http://info.brookscole.com/ackerman>—includes over three dozen unique Java applets that have been already acclaimed by the meteorology education community. These learning tools extend the textbook treatment of key topics such as weather map analysis, atmospheric circulation patterns, and numerical models.

Chapter Features

- Outlines and chapter goal lists at the beginning of each chapter
- Introductions focusing on observations of the atmosphere
- Intertextual icons that identify Java applets and Blue Skies exercises relating to material
- Extended boxes delving into advanced and unusual topics in each chapter
- End-of-chapter summaries to review the main ideas presented in the chapter
- A list of key terms at the end of each chapter
- Chapter-ending review questions that integrate chapter materials with the *Blue Skies* CD-ROM and the text's World Wide Web site

Web Features

The accompanying Web site includes over three dozen interactive Java applets that extend the textbook treatment of key topics such as weather map analysis, satellite interpretation, and numerical weather models. These applets are well tested and have received acclaim by the meteorology education community. The Web site also includes animations of weather phenomena and tools for assessing student learning.

Acknowledgments

This book could not have been possible without the efforts of many. Teri Hyde, Keith Dodson, and Nina Horne at Wadsworth and Brooks/Cole deserve special mention for their advice and captaining of the editorial process, which has resulted in a final product we are very proud of. Kim Leistner energized this project during its formative stages. Sam Subity has ably assisted in the development of this text's Web site, a key component of any 21st-century text. Tom Whittaker has created some of the world's best meteorological Java applets—try a few at info.brookscole.com/ackerman. Dick Morel became a special member of this project as a developmental editor and key advisor. Mike Ederer and John Denk at Graphic World Publishing Services shouldered much of the burden of editing and artwork. Terry Powell and her associates at The Photographer's Window dealt with myriad photo searches, and Stephanie Keough-Hedges handled a blizzard of

permissions requests. Greg Thompson, Cynthia Johnson and Don Lloyd, among others, receive our heartfelt thanks for sharing their stunning images. Stino Iacopelli assisted with Chapter 10, which includes portions of his award-winning research. (We regret that permission was denied to reprint the lyrics of the meteorologically accurate song “The Wreck of the Edmund Fitzgerald” in that same chapter.) Pam Naber Knox read every word of page-proofs and considerably improved the content of the entire book. Anne Pryor and Erin Pryor-Ackerman provided editorial comments on several chapters. Finally, we thank the colleagues who took the time out of their busy schedules to review all or parts of the manuscript, including:

Mark R. Anderson,
University of Nebraska at Lincoln

John Arnfield,
Ohio State University

Leanne Avila,
University of Wisconsin

Mark Binkley,
Mississippi State University

Steven Businger,
University of Hawaii

Donna Charlevoix,
*University of Illinois at
Urbana-Champaign*

William C. Culver,
St. Petersburg Junior College

Nancy Dignon,
Tallahassee Community College

John A. Ernst,
*Embry-Riddle Aeronautical
University*

Terri Gregory,
University of Wisconsin

Vince Gutowski,
Eastern Illinois University

Leonard Hume, Jr.,
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*University of Northern
British Columbia*

Stephen Jascourt,
UCAR/COMET

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Wilmington*

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College*

Rich Miller,
Milwaukee Area Technical College

Scott Robeson,
Indiana University

Robert Rohli,
Louisiana State University

Paul Ruscher,
Florida State University

Catherine Souch,
Indiana University at Indianapolis

Harold Taylor,
Stockton College of New Jersey

Stanton E. Tuller,
University of Victoria

Steve Vavrus,
University of Wisconsin

Anthony J. Vega,
Clarion University

Charles Weidman,
University of Arizona

Wayne Wendland,
*University of Illinois at
Urbana-Champaign*

Kay Williams,
Shippensburg University

Mark Wyman,
Cornell University

Mark Wysocki,
Cornell University

Douglas Yarger,
Iowa State University

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Introduction

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Atmospheric Evolution and Composition

Trace Gases and Aerosols

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Hydrologic Cycle

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Chlorofluorocarbons

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Atmospheric Pressure and Density

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Box 1.2: The Ideal Gas Law

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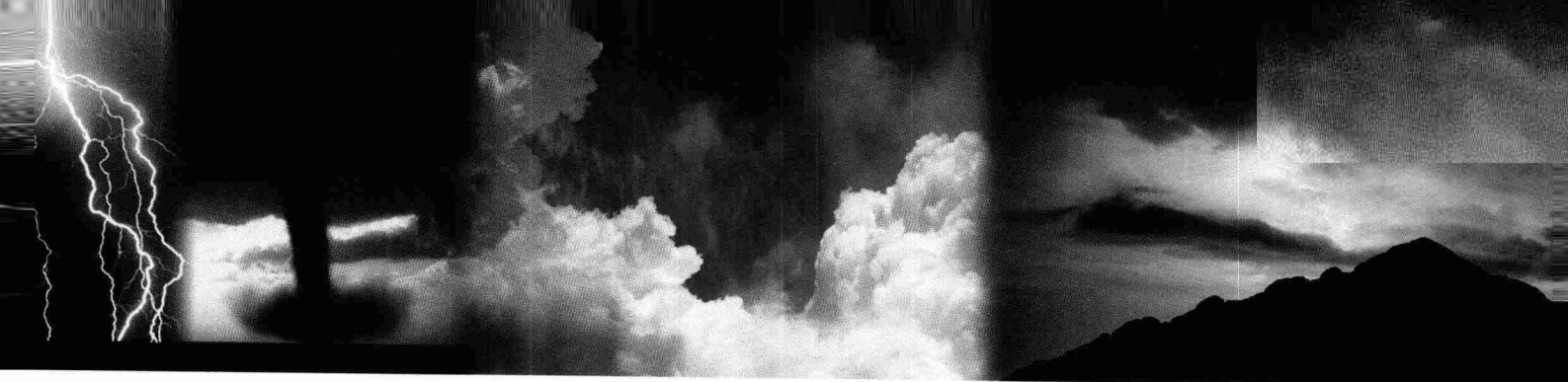
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