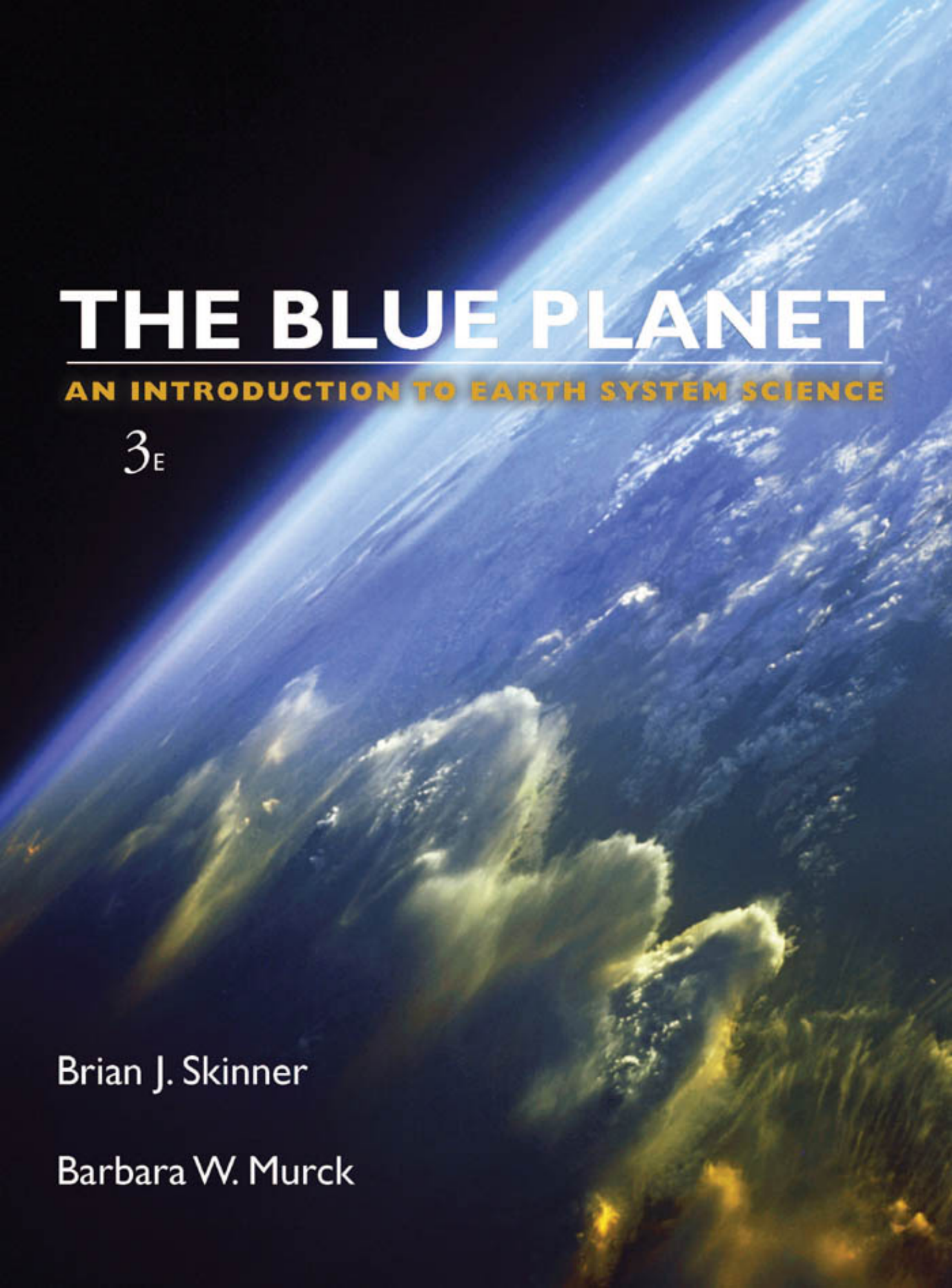
THE BLUE PLANET
AN INTRODUCTION TO EARTH SYSTEM SCIENCE
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Brian J. Skinner
Barbara W. Murck

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3RD EDITION

The Blue PLANET

An Introduction to Earth System Science

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WILEY
JOHN WILEY & SONS, INC.

VICE PRESIDENT AND EXECUTIVE PUBLISHER	Jay O'Callaghan
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PRODUCTION SERVICES	Furino Production
COVER IMAGE	NASA/Science Source/Photo Researchers, Inc.

This book was set in Sabon by MPS Limited, a Macmillan Company, Chennai, India and printed and bound by Courier Companies. The cover was printed by Courier Companies.

This book is printed on acid-free paper. ♾

Library of Congress Cataloging-in-Publication Data

Skinner, Brian J., 1928–
The blue planet: an introduction to earth system science/—3rd ed. Brian J. Skinner, Barbara Murck.
p. cm.
Includes bibliographical references.
ISBN 978-0-471-23643-6 (hardback)
I. Murck, Barbara Winifred, 1954– II. Title.
QB631.S57 2011
550—dc22

2010032269

Main Book ISBN 978-0-471-23643-6

Binder-Ready Version ISBN 978-0-470-55648-1

Printed in the United States of America

10 9 8 7 6 5 4 3 2 1

Preface

The first people to leave Earth's orbit and see the far side of the Moon were the astronauts of Apollo 8. On Christmas Eve 1968, when Apollo moved out from behind the Moon, crew members Borman, Lovell, and Anders saw a wonderful sight: it was Earth, rising above the barren lunar landscape. Photographs of the scene have become iconic reminders of our planet's splendid isolation in space. Many years earlier, in 1948, a famous English scientist, Sir Fred Hoyle, predicted that the first images of Earth from space would change forever the way we think about our planet. How prescient that prediction was. It was the first giant step in the development of a holistic view of Earth. From space the atmosphere seems like a surface smear, the oceans are great blue blotches, and the brown continents are crossed by bands of green vegetation. The oneness of all the parts of Earth is immediately apparent.

This book is an introduction to the science of the holistic view of Earth. It is about the interactions between the different parts of Earth—how matter and energy move between the atmosphere, hydrosphere, biosphere, and geosphere (by which we mean the solid Earth). The assemblage of parts and interactions has come to be called the *Earth system*. This book is about the *science of the Earth system*. It is also a book about the way we humans, now 7 billion of us, are influencing the way the Earth system works.

PURPOSE OF THE BOOK

Earth system science is rapidly changing the way people study and think about Earth. People have always been concerned with local climate and weather; now they are also concerned with the global climate, and whether humans are causing it to change. People have always been concerned with local water availability and quality; now they are also concerned with the status of water resources and aquatic ecosystems—both freshwater and marine—around the world. From space it can be seen that winds blow dust from the Sahara desert across the Atlantic Ocean; knowing where to look, scientists can detect dust in ocean sediments and discover that it affects life in the Caribbean islands. This holistic way of thinking about interconnections and interrelationships is changing the way scientists study Earth. We have written this book to introduce students to the developing science of the Earth system.

Courses about Earth system science are being taught with increasing frequency in different academic departments. Such courses may have titles such as Global Change, Earth Science, Biospherics, The Global Environment, Planet Earth, or even Environmental Science, but the approach for all of them is increasingly that of studying Earth as an assemblage of interacting parts and processes.

THE SYSTEMS APPROACH

The key to understanding Earth as a system of many parts is to appreciate the interactions between the parts and to understand how energy and matter move around the system. Earth is, to a very close approximation, a closed system; by this we mean that it neither gains nor loses matter, but energy can both enter and leave the system. For the sake of study and measurement we divide Earth into a large number of subsystems, each of which is an open system, meaning that both matter and energy can move back and forth between them. Earth system science, then, is the study of Earth as an assemblage of open systems, and the goal of the science is to eventually understand the interactions among all parts of the assemblage. In this way, the effects throughout the system caused by a perturbation in one part of the assemblage—say, a volcanic eruption, or a rise in the carbon dioxide content of the atmosphere—can be estimated and forecast.

The traditional way to study Earth was to consider the various parts in isolation from each other. One group of scientists studied the atmosphere, another group the oceans, still another the geosphere, and yet another, the assemblage of life forms. Communication and interaction between the different groups were once rare. Earth system science is removing barriers, and interdisciplinary interactions today are common among those who study the Earth system.

THE BOOK'S ORGANIZATION

Reflecting this emphasis on a systems approach, the book is organized into six parts, each containing three chapters, except for Part One, The Earth System: Our Place in Space, which has four chapters. Parts Two through Six address the principal subsystems of the Earth system: Geosphere,

Hydrosphere, Atmosphere, Biosphere, and Anthroposphere, in that order.

The chapters in Part One start with a The Earth System, a discussion of systems, cycles and feedbacks. The second chapter, Energy, starts by introducing the Laws of Thermodynamics, then moves to the sources of Earth's energy and how energy cycles through the Earth system. Chapter 3 discusses Matter, and new in this edition is a section on organic matter. The final chapter in Part One, Space and Time, concerns Earth's place in the solar system, including a discussion of the structure and dynamics of the Sun, the energy from the Sun that reaches Earth, and time scales of Earth history.

The three chapters of Part Two are concerned with The Geosphere: Earth Beneath Our Feet. Chapter 5, The Tectonic Cycle, discusses the outflow of Earth's internal heat energy and the resulting motions of the mantle and lithosphere. The nature, locations and dynamics of volcanic eruptions are the focus of Chapter 6 (Earthquakes and Volcanoes), and Chapter 7 (The Rock Cycle) examines the collective interactions at Earth's surface between the atmosphere, hydrosphere, biosphere and the geosphere.

The chapters of Part Three examine The Hydrosphere: Earth's Blanket of Water and Ice, and its essential role in the Earth system. Chapter 8 deals with The Hydrologic Cycle, Chapter 9 with The Cryosphere, and Chapter 10 discusses The World Ocean. The three chapters of Part Three pay special attention to the role of the hydrosphere in the climate system, and in meeting the needs of both natural systems and human society.

Part Four, The Atmosphere: Earth's Gaseous Envelope, comprises three chapters devoted to the nature and role of the atmosphere. Chapter 11, The Atmosphere, discusses the structure and dynamics of the atmosphere. Chapter 12, Wind and Weather Systems, discusses both global and local circulation patterns. Chapter 13, The Climate System, examines in detail what we know about past climates and the causes of climatic changes.

The three chapters of Part Five, The Biosphere: Life on Earth, discuss the characteristics of the biosphere and the role of life in the Earth system. Chapter 14, Life, Death, and Evolution, discusses the basic processes of life, and how life has adapted to and altered the Earth system over the course of the planet's history. Chapter 15, Ecosystems, Biomes, and Cycles of Life, discusses the importance of material recycling in ecosystems, the minimum characteristics of a life-supporting system, and how biogeochemical cycles can be influenced by human activities. Chapter 16, on Populations, Communities, and Change, considers carrying capacity, and factors that affect the health and limit the growth of populations; special attention is given to biodiversity and to current threats to diversity.

The final section, Part Six, concerns The Anthroposphere: Humans and the Earth System. Chapter 17 addresses The Resource Cycle, with a particular focus on the different roles of renewable and nonrenewable resources in the growth and health of the human population. Chapter 18 discusses Mineral and Energy Resources, and how their use affects various parts of the Earth system. The final chapter in the book pulls together the many lines of evidence discussed in earlier chapters in assessing The Changing Earth System as a result of human activities.

Although we have given careful consideration to the organization of the book, we realize that not all instructors may favor the one we have adopted. Therefore, the parts and chapters have been written so that, so far as possible, they stand alone, and that some reorganization of topics is possible without serious loss of continuity.

THE ILLUSTRATIONS

As with previous editions of this text, special attention has been devoted to the artwork and photographs that illuminate discussions in the text. Because no country or continent holds a monopoly on relevant and interesting examples, we have selected photographs, maps, and illustrations from around the world in order to provide a global perspective of Earth system science. The art program has benefited from talented artists who have worked closely with the authors to make their illustrations both attractive and scientifically accurate. Many of the illustrations and photographs in this edition are new to the text, and we think both instructors and students will find them engaging and educational, as well as beautiful.

FEATURES

- *Part Opener.* Each of the six parts of the book opens with a brief statement that outlines the part of the Earth system discussed in the part, and the connections with other parts of the system.
- *Chapter Overview.* Each chapter opens with a bulleted list of topics discussed in the chapter followed by a brief statement of the purpose of the chapter.
- *"A Closer Look" Boxes.* Within chapters, specialized and detailed topics are boxed under the heading "A Closer Look". The boxed material can be included or deleted at the discretion of the instructor.
- *"The Basics" Boxes.* Topics that need special explanation, such as "Electromagnetic Radiation" in Chapter 2, are boxed under the heading "The Basics".
- *"Make the Connection".* In each chapter one or more questions are inserted in the text, asking students to make the connection between some item in the chapter and the larger Earth system. For example, in Chapter 16, following a discussion of populations, the student is asked to think of a population of insects, animals or plants, then to list the number of things that might limit the growth of the population, and to identify whether the limitations come from the hydrosphere, atmosphere, geosphere, or the anthroposphere. In some cases there is no "one"

correct answer for the question; the goal is to get students to think about connections and relationships.

- *Summary and Review.* Each chapter closes with a summary of in-chapter material, a list of key terms, and a series of questions. The questions are of two kinds: (1) review questions that relate strictly to material in the chapter, or, under separate headings, to material in *A Closer Look* or *The Basics*; and discussion questions, which are intended for class or section discussion, sometimes calling for a bit of additional research. In most cases the discussion questions raise broader issues than those in the specific chapter to which they are attached.
- *Appendices and Glossary.* Three useful Appendices provide students with reference materials on units and conversions, naturally occurring elements and isotopes, and the properties of common minerals. The Glossary has been expanded and improved in this edition, and we think students will find it to be a very useful study tool.

NEW TO THIS EDITION

The most important change in this third edition of *The Blue Planet* is the addition of a new author, Barbara Murck of the University of Toronto. Professor Murck brings broad experience of fieldwork and research in the Earth and environmental sciences to the author team, and she is an award-winning teacher.

The third edition has been extensively reorganized based on constructive input from users of the previous two editions. For example, the two chapters on the solar system in the second edition have been combined into one chapter, and earthquakes and volcanoes are covered in a single chapter instead of two. In addition, the four chapters on the biosphere in the second edition have been extensively reorganized, tightened up, and improved, and are now three chapters. Even though a new chapter (Energy) has been added to the book, the condensing and rearrangement has produced a volume of 19 chapters instead of the 20 in the second edition.

Instructors' Companion Site (www.wiley.com/college/skinner). This comprehensive website includes numerous resources to help you enhance your course. These resources include:

- **Image Gallery**. We provide online electronic files for the line illustrations in the text, which the instructor can customize for presenting in class (for example, in handouts, overhead transparencies, or PowerPoints).
- A complete collection of **PowerPoint presentations** available in beautifully rendered, 4-color format, and have been resized and edited for maximum effectiveness in large lecture halls.
- A comprehensive **Test Bank** with multiple-choice, fill-in, and essay questions. The test bank is available in two formats: Word document and Respondus.
- **Pre-Lecture Clicker/PRS Questions** based on the "A Closer Look" and "The Basics" boxed features allows the instructor to connect the readings to the classroom lectures.
- **GeoDiscoveries Media Library**. This easy-to-use website offers lecture launchers that helps reinforce and illustrate key concepts from the text through the use of animations, videos, and interactive exercises. Students can use the resources for tutorials as well as self-quizzing to complement the textbook and enhance understanding of Earth System Science. Easy integration of this content into course management systems and homework assignments gives instructors the opportunity to integrate multimedia with their syllabi and with more traditional reading and writing assignments. Resources include:
  - Animations: Key diagrams and drawing from our rich signature art program have been animated to provide a virtual experience of difficult concepts. These animations have proven influential to the understanding of this content for visual learners.
  - Videos: Brief video clips provide real-world examples of geographic features, and put these examples into context with the concepts covered in the text.
  - Simulations: Computer-based models of geographic processes allow students to manipulate data and variables to explore and interact with virtual environments.
  - Interactive Exercises: Learning activities and games built off our presentation material. They give students an opportunity to test their understanding of key concepts and explore additional visual resources.
- **Google Earth™ Tours.** Virtual field trips allow students to discover and view geospheric landscapes around the world. Tours are available as .kmz files for use in Google Earth™ or other virtual atlas programs.
- Online **Case Studies** provide students with cases from around the world in which to see and explore the interaction of people and their environment. It was revised by Robert Ford.
- An online database of photographs, **www.ConceptCaching.com**, allows professors and students explore the atmosphere, hydrosphere, lithosphere, and biosphere. Photographs and GPS coordinates are "cached" and categorized along core concepts of geography and geology. Professors can access the images or submit their own by visiting www.ConceptCaching.com.

Student Companion Website (www.wiley.com/college/skinner). This easy to use and student-focused website helps reinforce and illustrate key concepts from the text. It also provides interactive media content that helps students prepare for tests and improve their grades. This website provides additional resources that compliment

the textbook and enhance your students' understanding of Physical Geography:

- **Chapter Review Quizzes** provide immediate feedback to true/false, multiple-choice, and short answer questions based on the end-of-chapter review questions.
- **Online Case Studies** provide cases from around the world in which to see and explore the interaction of people and their environment.
- **Google Earth™ Tours.** Virtual field trips allow students to discover and view geospheric landscapes around the world. Tours are available as .kmz files for use in Google Earth™ or other virtual atlas programs.

ACKNOWLEDGMENTS

Our many colleagues who prepared essays did so with grace and professional acumen. We are very grateful to them. We are extremely grateful for the guidance and judgment provided by colleagues who discussed this project in encounter groups and who reviewed all or part of the manuscript. They are:

David J. Anastasio, *Lehigh University*
Lisa Barlow, *University of Colorado*
John M. Bird, *Cornell University*
Stephen Boss, *University of Arkansas*
James W. Castel, *Clemson University*
Steven Dickman, *Binghampton University*
Bruce Fegley, *Washington University—St. Louis*
Robert Ford, *Westminster College*
Karen H. Fryer, *Ohio Wesleyan University*
Bart Geerts, *University of Wyoming*
H.G. Goodell, *University of Virginia*
Dr. Ezat Heydari, *Jackson State University*
Gregory S. Holden, *Colorado School of Mines*
Julia Allen Jones, *Oregon State University*
Dr. Adrienne Larocque, *University of Manitoba*
Keenan Lee, *Colorado School of Mines*
Thomas Lee McGehee, *Texas A&M University*
Harold L. Levin, *Washington University—St. Louis*
Dan L. McNally, *Bryant College*
Chris Migliaccio, *Miami-Dade Community College*
Robert L. Nusbaum, *College of Charleston*
Roy E. Plotnick, *University of Illinois*
Gene Rankey, *University of Kansas*
Doug Reynolds, *Central Washington University*
Kathryn A. Schubel, *Lafayette College*
Kevin Selkregg, *Jamestown Community College*
Lynn Shelby, *Murray State University*
Leslie Sherman, *Providence College*
Christian Shorey, *Colorado School of Mines*
John T. Snow, *University of Oklahoma*
K. Sian Davies-Vollum, *Amherst College*
Cameron Wake, *University of New Hampshire*
Nick Zentner, *Central Washington University*

We would like to express our thanks to Steve Porter and Dan Botkin, who contributed so much effort and expertise to the production of the first two editions of *The Blue Planet*.

The third edition was a long time coming, and many people have anticipated its arrival—thank you so much, all of you, for your patience and loyalty. That the third edition is now here is due in no small part to the perseverance of Ryan Flahive, Executive Editor and overseer of all things Geoscience-related for John Wiley and Sons. Many thanks also to Jay O'Callaghan, VP and Publisher, for his continued support of our work.

For this project it was great to be reunited with many old Wiley friends from earlier projects. Cliff Mills (Developmental Editor), it was wonderful to see your face again (virtually, at least). Jeanine Furino (Furino Production), you're a task-master of the highest order (that's a compliment), and thanks to you the book is complete, on time (more or less), and of extremely high quality. Anna Melhorn (Illustration Coordinator), MaryAnn Price (Photo Editor), and Lynn Pearlman (Senior Media Editor), your work is crucial in producing a book that is both visually stunning and educationally sound. Veronica Armour (Associate Editor, Geosciences) helped keep us on track, and Darnell Sessoms (Editorial Assistant) was always there to lend a hand. Margaret Barrett (Marketing Manager), thanks for all of your work to bring this new edition to our adopters and readers.

Finally, it shouldn't go without saying that we are grateful to our families, our colleagues, and our students at Yale University and the University of Toronto—and, of course, to each other. We love working together and we are extremely proud of the 3rd edition of *The Blue Planet*.

About *the* AUTHORS

Brian J. SKINNER

Brian Skinner was born and raised in Australia, studied at the University of Adelaide in South Australia, worked in the mining industry in Tasmania, and in 1951 entered the Graduate School of Arts and Sciences, Harvard University, from which he obtained his Ph.D. in 1954. Following a period as a research scientist in the United States Geological Survey in Washington D.C., he joined the faculty at Yale in 1966, where he continues his teaching and research as the Eugene Higgins Professor of Geology and Geophysics. Brian Skinner has been president of the Geochemical Society, the Geological Society of America, and the Society of Economic Geologists, He holds an honorary Doctor of Science from University of Toronto, and an honorary Doctor of Engineering from the Colorado School of Mines.

Barbara MURCK

Barbara Murck is a geologist and senior lecturer in environmental science at the University of Toronto, Mississauga. She completed her undergraduate degree in Geo-logical and Geophysical Sciences at Princeton University and then spent two years in the Peace Corps in West Africa, before returning to Ph.D. studies at the University of Toronto. Her subsequent teaching and research has involved an interesting combination of geology, natural hazards, environmental science, and environmental issues in the developing world, primarily in Africa and Asia. She also carries out practical research on pedagogy and was recently awarded the President's Teaching Award—the highest honor for teaching given by the University of Toronto. She has co-authored numerous books, including several with Brian Skinner.

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