Ecological Climatology

The third edition of Gordon Bonan's comprehensive textbook introduces an interdisciplinary framework to understand the interaction between terrestrial ecosystems and climate change. Ideal for advanced undergraduate and graduate students studying ecology, environmental science, atmospheric science, and geography, it reviews basic meteorological, hydrological, and ecological concepts to examine the physical, chemical, and biological processes by which terrestrial ecosystems affect and are affected by climate. This new edition has been thoroughly updated with new science and references. The scope has been expanded beyond its initial focus on energy, water, and carbon to include reactive gases and aerosols in the atmosphere. This new edition emphasizes Earth as a system, recognizing interconnections among the planet's physical, chemical, biological, and socioeconomic components, and emphasizing global environmental sustainability. Each chapter contains chapter summaries and review questions, and with over four hundred illustrations, including many in color, this textbook will once again be an essential student guide.

Gordon Bonan is senior scientist and head of the Terrestrial Sciences Section at the National Center for Atmospheric Research, Boulder, Colorado. His research focuses on the interactions of terrestrial ecosystems with climate using models of Earth's biosphere, atmosphere, hydrosphere, and geosphere. He has published more than 120 peer-reviewed articles on land-atmosphere coupling and how changes in vegetation alter climate. He is a member of the American Geophysical Union, American Meteorological Society, and Ecological Society of America. He is a Fellow of the American Geophysical Union and has served on advisory boards for numerous national and international organizations and as an editor for several journals.

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Concepts and Applications

Third edition

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To Amie, who made this possible

To David, Thomas, and Alice, for family

To Milo, Dancer, and Chloe, for hugs and head pats

Contents

Part III Hydrometeorology

Part VI Terrestrial Forcings and Feedbacks

Preface

I began conceiving this book in 1996. At that time, the influence of forests on climate was well-established at the microscale through the study of forest meteorology and biometeorology; that the terrestrial biosphere is essential for climate science and global models of climate was less universally accepted. The first edition was published in 2002. It was an effort to broaden the scope of ecology – to show ecologists the manner in which ecosystems influence climate – and to similarly broaden climate science to recognize the importance of terrestrial ecosystems. The second edition published in 2008 was a marked change from the first edition. It was a complete revision that reflected the expanded scope of the science, improved the organization of the material, and made it more accessible to students.

The third edition is yet another revision and update of the book. The intent has not changed, but the science has so vastly grown. Studies of biosphere–atmosphere interactions at the regional and global scale are now commonplace; all of the major international climate modeling centers include models of the terrestrial biosphere; the carbon cycle and anthropogenic land use and land-cover change are recognized as important facets of climate change; and climate science itself has evolved into a broader perspective of Earth system science. This is seen in the expanded breadth of the book. In the second edition, carbon cycle–climate coupling was still fairly novel. This third edition shows how important that has become to climate science, and additionally includes chapters on the nitrogen cycle, aerosols, and climate change mitigation. A concluding chapter ties together the various topics presented throughout the book. The influences of terrestrial ecosystems on climate must be seen in a larger context of human influences on the global environment and in light of planetary sustainability.

One prominent change over the years has been the extensive growth of the scientific literature. This third edition is not meant to be a survey of all relevant literature; that would be too tedious. Rather, I have highlighted key papers that, with online scholarly databases, provide a springboard to the science. To keep the book manageable, some material had to be deleted from the earlier editions. Many references to scientific studies have been removed or omitted. Nonetheless, this third edition provides a comprehensive survey of the state of the science. The challenge of organizing, synthesizing, and presenting the voluminous material in a comprehensible manner is tempered by the pleasure in seeing the extent to which the science has expanded over the years.

As in the previous editions, this book contains many mathematical equations, but only to illustrate concepts and not with the intent of being a modeling textbook. The book heavily references models, their scientific scope, and their application to understand biosphere–atmosphere interactions. The book also maintains land management, urban planning, and landscape design as a theme. The principles of ecological climatology are applicable to these studies. Unlike global change, land use occurs locally in our communities. It gives substance to environmental issues at spatial and temporal scales to which people can see and respond; we see these changes happen in our communities, often over a period of a few years.

As always, I am indebted to colleagues at the National Center for Atmospheric Research for supporting my efforts to write this third edition, in particular Sam Levis and Keith Oleson, whose long-standing commitment to the development and maintenance of community models, both since 1999, have allowed me to write this book. David Lawrence, too, assumed a leading role in community model development, allowing

me to focus my efforts on writing. And new colleagues – Rosie Fisher, Peter Lawrence, Will Wieder, Danica Lombardozzi, Quinn Thomas, Melannie Hartman, and Liz Burakowski – have similarly grown the science and supported community models. Finally, I am indebted to Matt Lloyd at Cambridge University Press, who has supported this endeavor over the many years.