

## Introduction to Modern Climate Change

Third Edition

The third edition of this introductory textbook for both science students and non-science majors has been brought completely up to date. It reflects the most recent findings from the latest Intergovernmental Panel on Climate Change (IPCC) reports, as well as advances in the political arena around climate change. As in previous editions, it is tightly focused on anthropogenic climate change. The first part of the book concentrates on the science of modern climate change, including evidence that the Earth is warming and a basic description of climate physics. Concepts such as radiative forcing, climate feedbacks, and the carbon cycle are discussed and explained using basic physics and algebra. The second half of the book goes beyond the science to focus on the economics and policy options to address climate change. The book's goal is for a student to leave the class ready to engage in the public policy debate on the climate crisis.

**Andrew E. Dessler** is a climate scientist and professor of atmospheric sciences at Texas A&M University. He researches atmospheric chemistry, climate change, and climate change policy. He is a fellow of the American Geophysical Union and the American Association for the Advancement of Science. The first edition of this book won the Louis J. Battan Author's Award from the American Meteorological Society. He has authored two books on climate change: this one, and *The Science and Politics of Global Climate Change: A Guide to the Debate* (with Edward Parson, third edition 2019, Cambridge University Press).

“Andrew Dessler is that rare breed of scientist who can contribute at the leading edge of scientific discovery while adeptly explaining the science and its implications to lay audiences. With his newly revised edition of *Introduction to Modern Climate Change*, Dessler provides a comprehensive, up-to-date, and engaging account of the science, the impacts, and the policy dimensions of the climate crisis. Climate change is the defining challenge of our time and this textbook is the ideal choice to ensure students are informed about it.” Michael Mann, Penn State University, author of *The New Climate War* and *Dire Predictions*

“In a world dominated by headlines, Dr. Andrew Dessler’s *Introduction to Modern Climate Change* delivers a fresh take on something we’re all craving: fundamentals. The book begins with the physical science basis for climate change, from blackbody radiation to the fluxes and reservoirs of the carbon cycle, before delving into hot topics, from feedbacks to exponential growth. Dessler delivers a robust and much-needed framework for addressing modern global environmental change.” Hari Mix, Santa Clara University

“*Introduction to Modern Climate Change* has been my text of choice for a general education class on the topic. It provides students with the foundations of climate physics, places modern variations in the context of the geologic record, establishes the man-made nature of current trends, and (uniquely for textbooks on this matter) discusses the economic and political dimensions of the problem, and how best to respond to it. This new edition brings a significant upgrade by adding the most up-to-date numbers from the IPCC and the Paris Agreements, as well as a greatly expanded set of engaging graphics, conveying the information most pertinent to this existential crisis. I heartily recommend this approachable textbook to any student or scholar.” Julien Emile-Geay, University of Southern California

“*Introduction to Modern Climate Change* is essential reading for anyone interested in anthropogenic global warming. Andrew Dessler’s textbook is easily accessible for students from a range of backgrounds, as no prior knowledge of Earth Science is needed. It is the first resource I add to my reading lists, and the new color figures enhance it further. There are also important updates concerning the policies of climate change, such as the impact of the Trump Administration and the Paris Agreement.” Matt Smith, University of Worcester

“... an excellent textbook for the general audience of undergraduates ... In the third edition, there are more exercises than in earlier editions, allowing the instructor to emphasize those exercises depending on the particular department providing the course ... An important update is the transition to colored graphics throughout the book, which bring to life the arguments in the text ... Dessler is a very gifted writer for the general reader ... In this book, he engages the reader with relevant analogies from everyday life ... Most importantly, his presentation is clear. His arguments are strong and presented passionately ... I grade the third edition as *excellent*.” Gerald R. North, Texas A&M University

**From reviews of previous editions:**

“... a textbook about the scientific basis for global climate change that's well balanced, well written, highly illuminating, and accessible to non-science majors.” John M. Wallace, University of Washington

“I was so impressed with its simple and compelling coverage of the science of climate change, and, just as importantly, its social and political context. The students loved the book – some even commented that it was the first time they had actually understood and enjoyed reading a science book.” Steve Easterbrook, University of Toronto

“Dessler’s book is written so clearly that anyone can read it and understand the major issues in climate change. It hits just the right balance between rigor and comfort, making the whole topic more appealing and accessible to students.” Deborah Lawrence, University of Virginia

“The text provides a readable, concise summary of the science of climate change, but it is the non-scientific aspects of the book that set it apart ... a well-crafted textbook. The writing is very accessible without being too simplistic. The combination of a broad overview of the science and the policy of climate change is both novel and appropriate for ... an introductory-level survey course on climate change. Reading the book was a learning experience for me, and I would happily recommend this book to anyone seeking an introduction to climate change.” Guillaume Mauger, *Bulletin of the American Meteorological Society*

“The book reads extremely well: it uses stories, analogs, and examples to draw the reader into the story of the science of our changing planet. Despite the complexity of the actual science, Dessler presents the material in a clear manner and does it without drawing on mathematics any more difficult than simple algebra ... I recommend this book for anyone interested in learning more about climate change and the challenges it presents to humanity.” Donald J. Wuebbles, *Physics Today*

“Dessler has done an excellent job of clearly describing the different issues of climate change in a way that will be accessible to both science and non-science majors. I can see this book becoming the standard textbook for the growing number of introductory courses that discuss both the science and policy of climate change.” Darryn Waugh, Johns Hopkins University

“Dessler does an excellent job of simply explaining the science ... should be on the reading list of anyone with an interest in climate science, if for no other reason than that it introduces a complex subject in such a coherent and comprehensible fashion.” John Brittan, *The Leading Edge*

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THIRD EDITION

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**Andrew E. Dessler**

Texas A&M University



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**For Alex and Michael**

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## Preface

Future generations may well view climate change as the defining issue of our time. The worst-case climate change scenarios look truly terrible, but even middle-of-the-road ones portend unprecedented environmental change for human society. When looking back on our time and the choices we made (or didn't) to save our planet, young people will either cheer our foresight in dealing with this issue or curse our lack of it.

I want to stress that this isn't an advocacy book. Although I have opinions on this matter, and strong ones, I also believe that in this case facts speak louder than one's beliefs. Thus, in this textbook I limit myself to presenting the science of climate change and laying out the possible solutions and trade-offs among them. The hope is that an unbiased assessment of this issue will prove to people that climate change poses a serious risk to us all, and that reducing our emissions of greenhouse gases will head off that risk.

I recognize that, despite the stakes, the world has done close to nothing to avert the terrible outcomes presented by the scientists if we don't act now. Why, you might wonder? For one, we mostly respond to immediate threats, and climate change isn't happening fast enough to trigger real panic. Surely, we know that it will pose a threat to future generations; however, acting now would be quite onerous, on so many levels, and what reassurance do we have that re-designing our entire energy sector (or even the entire economy) to reduce carbon emissions won't cause havoc even before climate change will? In such a situation, it is easier to do nothing and wait for disaster to strike – which is why dams are frequently built after the flood, not before.

Nevertheless, every year that our society does nothing to address climate change makes solving the problem both harder and more expensive. Despite all this, I remain optimistic because problems often appear intractable at first. In the 1980s, as evidence mounted that industrial chemicals were depleting the atmospheric ozone layer, it was not at all clear that we could avoid this issue at a reasonable cost. The chemicals causing the ozone loss, namely chlorofluorocarbons, played an important role in our everyday life – in refrigeration, air-conditioning, and many industrial processes – just like fossil fuels, the main cause of modern climate change, play an important role in our society. Yet the cleverness of humans prevailed, leading to the development of a substitute chemical, which seamlessly and cheaply replaced the ozone-destroying halocarbons, at a cost so low that hardly anyone noticed when the substitution took place.

Solving the climate change problem will be harder than solving the ozone depletion problem – how much harder, no one knows. I am confident, though, that the ingenuity and creativeness of humans is such that we can succeed without damaging our standard of living. That said, there is only one way to find out, and that is to try to do it.

## Key Features

- While discussing all facets of climate change, this book focuses on how human activities have directly contributed to this problem.
- It describes the physics of climate change, allowing students to fully appreciate the science behind this phenomenon and the deep concern shared by the scientific community for the future of our planet.
- It also addresses its many other dimensions – science, economics, society, and politics as well as the moral and ethical questions posed by this problem. Indeed, virtually every government in the world has now accepted the reality of climate change, and the debate has, to a great extent, moved on to policy questions, including the economic and ethical repercussions that this has on our society.

## Updates Since the Previous Edition

- New and revised figures.
- Includes the latest development and research findings on climate change, from “attribution science” and its central role in informing discussions of responsibility for climate change to Earth’s climate sensitivity and its significantly narrowed bounds.
- Discusses the policy of climate change, the recent (anti-) environmental policy changes in countries such as the United States, and international negotiations and agreements such as the Paris Agreement.
- Identifies the synergies and trade-offs between climate change mitigation and adaptation policies.

## Book Organization

The first seven chapters of the book focus on the science of climate change. Chapter 1 defines the problem and provides definitions of weather, climate, and climate change. It also addresses an issue that most textbooks do not have to address: why the reader should believe this book as opposed to websites and other sources that give a completely different view of the climate problem. Chapter 2 explains the evidence that the Earth is warming. The evidence is so overwhelming that there is little argument anymore over this point, and my goal is for readers to come away from the chapter understanding this.

Chapter 3 covers the basic physics of electromagnetic radiation necessary to understand the climate. I use familiar examples in this chapter, such as the incandescent light bulb, to help the reader understand these important concepts. In Chapter 4, a simple energy-balance climate model is derived. It is shown how this simple model successfully explains the Earth’s climate as well as the climates of Mercury, Venus, and Mars. Chapter 5 covers the carbon cycle. Feedbacks, radiative forcing, and climate sensitivity are all discussed in Chapter 6.

Finally, Chapter 7 explains why scientists are so confident that humans are to blame for the recent warming that the Earth has experienced.

Chapter 8 begins an inexorable shift from physics to non-science issues. It discusses emissions scenarios and the social factors that control them, as well as what these scenarios mean for our climate over the next century. Chapter 9 covers the impacts of these changes on humans and on the world in which we live. Chapter 10 covers exponential mathematics. Exponential growth is a key factor in almost all fields of science, as well as in real life. In this chapter, I cover the math of exponential growth and explain the concepts of exponential discounting and the social cost of carbon.

Starting with Chapter 11, the discussion is entirely on the policy aspects of the problem. Chapter 11 discusses the four classes of responses to climate change, namely adaptation, mitigation, solar radiation management, and carbon dioxide removal, and their advantages, disadvantages, and trade-offs. The most contentious arguments over climate change policy are over mitigation, and Chapter 12 discusses in detail the two main policies advanced to reduce emissions: carbon taxes and cap-and-trade systems.

Chapter 13 provides a brief history of climate science and a history of the political debate over this issue, including discussions of the United Nations Framework Convention on Climate Change, the Kyoto Protocol, and the Paris Agreement. Finally, Chapter 14 pulls the last three chapters together by discussing how to decide which of our options we should adopt, particularly given the pervasive uncertainty in the problem.

Overall, it should be possible to cover each chapter in 3 hours of lecture. This makes it feasible to cover the entire book in one 14-week semester. At Texas A&M, the material in this book is being used in a one-semester class for non-science majors that satisfies the university's science distribution requirement. Thus, it is appropriate for undergraduates with any academic background and at any point in their college career.

## Readership and Pedagogy

Any serious understanding of climate change must be quantitative. Therefore, the book assumes a knowledge of simple algebra. No higher math is required, nor prior knowledge of any field of science – just an open mind and a willingness to learn.

To help students in their learning journey, each chapter includes: both quantitative and qualitative questions to test their knowledge of the topics discussed; chapter summaries outlining the major points of the chapter; and a list of important terms to familiarize themselves with and utilize in their discussion about climate change.

## Online Resources

Downloadable figures from the book, solutions to selected exercises and a test bank for instructors are available from [www.cambridge.org/dessler3](http://www.cambridge.org/dessler3). For additional reading and lecture videos, please link up to my website [www.andrewdessler.com](http://www.andrewdessler.com).

## Acknowledgments

This book could not have been written without the incredible work of the climate science community. Ignored by many, demonized by some, I believe that future generations will look back and say, “They nailed it.” I hope this book does justice to all of our hard work. The first edition of the book was written while I was on faculty development leave from Texas A&M University during fall 2010. I thank the university for this support.