Climate Modelling

Elisabeth A. Lloyd • Eric Winsberg
Editors

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Philosophical and Conceptual Issues

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Preface

We have both been fascinated by models for our entire careers. Climate models are especially interesting, because they are the largest and most complex of models and also, in some sense, the most mysterious. The systems are completely filled with nonlinear equations and unpredictability, yet some climate models are valued for their predictive capacities. Others are appreciated for their abilities to represent causal forces within climate systems and their interactions, and yet others represent those systems simply, elegantly, and yet powerfully.

There are numerous philosophical questions involving representation, grounding, and reality itself that arise when using climate models, as well as conceptual issues concerning the models as tools themselves. Yet there is no book or collection available that addresses these issues. We have aimed to collect a set of essays here that discusses these and other philosophical and conceptual questions about climate models. We asked some of the best philosophers and some of the best modelers to contribute to the book, and they agreed, to our delight.

Our book is intended to be enjoyed by policy-makers, climate scientists, and philosophers alike, as well as the general public. Some essays, such as those concerning policy and robustness, in parts 2 and 3 of the book, are very accessible. There are sections of part 1 that are more technical, such as the Santer et al. paper, but that is explained in Lloyd's essay and in Santer et al.'s "Fact Sheet" in part 1.

Sadly, there is rampant disinformation circulating about climate models today, despite concerted efforts by climate scientists to correct the public record. The essays contributed to this book provide a foundation for an informed discourse concerning climate models, one based on theory, facts, and evidence.

We have both learned a great deal about climate modeling through editing this collection, and our hope is that anyone dipping into the book will experience the same benefit. Of course, modeling is an ongoing activity, and many of the facets explored in this book will continue to fascinate both modelers, philosophers, and policy analysts for some time to come.

Bloomington, IN, USA — Elisabeth A. Lloyd
Tampa, FL, USA — Eric Winsberg
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As usual for a book of this size, many people were involved in the creation of it, and we are able to thank just a fraction of those, here. We would start by thanking Linda Mearns, Jeffrey Kiehl, and Doug Nychka for making Lisa Lloyd's (EAL's) visits to the National Center for Atmospheric Research (NCAR) possible over the years. They and many climate scientists, including Caspar Amman, Melissa Bukovsky, Jim Hurrell, Brian O'Neill, Claudia Tebaldi, Kevin Trenberth, Tom Wigley, and others too numerous to name, introduced me (EAL) to the fundamentals of climate science and climate modeling and also introduced me to many more scientists who would help Lisa along my journey. Being an Affiliate Scientist at NCAR has also helped me meet many scientists from around the world who contributed enormously to her learning and to this book, such as Reto Knutti, Ricky Rood, Jonathan Rougier, Gabriel Hegerl, and her co-author Vanessa Schweizer, among many others. Her co-organization of a running session at the American Geophysical Union (AGU) allowed the opportunity to meet yet more climate scientists, such as Michael Mann, a key figure in understanding climate. She would also like to thank Ben Santer, to whom a debt is also owed for help, patience, and heroism in the face of adversity.

During my many years of research into the philosophy and foundations of climate modeling, Lisa was supported financially by two sources, my endowed chair and the National Science Foundation (NSF). The Arnold and Maxine Tanis Chair of History and Philosophy of Science made my annual trips to NCAR possible, as well as the annual trips to the AGU. Lisa has had the privilege of knowing Bud and Maxine Tanis, and they are some of the finest and most lovely people She has met in my entire life. Lisa was also funded through two NSF Scholar Grants, "A case of objectivity in science: Climate change" (2007, #0646253) and "What is 'Value Added' in Regional Climate Modeling?" (2016–2017, #1632202). These grants helped make it possible for me to visit NCAR in Boulder for longer visits and to attend workshops and the AGU during those years. Lisa is indebted to Fred Kronz and the NSF for their support.

Finally, Lisa would also like to thank her research assistants, Chris ChoGlueck, Daniel Lindquist, and, most gratefully, Ryan Ketcham, for their patience and help over the several years that it took to get this book produced. She would also note that she owes much happiness and accomplishment to her beloved husband and partner, Teddy Alfrey. All of these people aided in overcoming the delaying effects of a car accident and spinal surgery on the production of this book. Lisa owes them a great deal indeed.

Eric Winsberg would like to thank the Institute of Advanced Study at Durham University, where he had the opportunity to learn about climate science from many of the practitioners affiliated with the university and to make climate science a focus of his philosophical study, and the Institute of Advanced Study on the Media Cultures of Computer Simulation at Leuphana University, which supported much of the work on this book. He would like to thank Jessica Williams for the support she gives him in all his endeavors.

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Mathias Frisch is a Professor for Philosophy at the Leibniz Universität Hannover, in Germany. He has held positions at both Northwestern University and the University of Maryland, where he taught until 2016. His research focuses on general philosophy of science, philosophy of physics, and philosophy and climate change. He has written two books: *Inconsistency, Asymmetry, and Non-Locality: A Philosophical Investigation of Classical Electrodynamics* (Oxford 2005) and *Causal Reasoning in Physics* (Cambridge 2014).

Peter J. Gleckler is a Research Scientist at the Program for Climate Model Diagnosis and Intercomparison at Lawrence Livermore National Laboratory, CA. His research involves the analysis, comparison, and evaluation of climate models. Working with National Oceanic and Atmospheric Administration (NOAA), he also applies climate models to study current problems in understanding the dynamics of climate, such as ocean warming and climate change. He has contributed to several Assessment Reports of the Intergovernmental Panel on Climate Change and continues to publish widely on model assessment and evaluation.

Leopold Haimberger is an Associate Professor at the Institute for Meteorology and Geophysics, University of Vienna. His research interests include diagnostics of atmospheric general circulation, analysis of radiosonde data, and numerical weather prediction. He served as a Contributing Author for the UN's Intergovernmental Panel on Climate Change 5th Assessment Report (2013), and he is a regular contributor to the Bulletin of the American Meteorological Society "State of the Climate" supplement.

Philip D. Jones is a Research Professor (and up to 2016 was the Research Director) of the Climatic Research Unit (CRU) and is now and a Professor in the School of Environmental Sciences at the University of East Anglia in Norwich. He is principally known for the time series of hemispheric and global surface temperatures, which he updates on a monthly basis. His other fields include climate change, detection and attribution of climate, proxy climate reconstructions, and climate extremes and impacts. He has produced over 450 research papers over the course of his career and is one of the most widely cited climate scientists publishing today. He is a Fellow of the Royal Meteorological Society and is an elected member of Academic Europaea, as well as being on the editorial board of *Climatic Change*. He has won numerous awards and prizes and is also a Fellow of the American Meteorological Society and the American Geophysical Union (AGU).

Thomas R. Karl is the former director of the National Oceanic and Atmospheric Administration's National Centers for Environmental Information (NCEI), retiring in August, 2016. He was the Lead Author on several Assessment Reports for the USA, including the 2006 study on tropospheric temperatures (CCSP), and the 2015 study published in the American Association for the Advancement of Science's *Science* journal, concerning the possible existence of a hiatus in global warming, of which he found no evidence, a finding that was later independently confirmed. He was the President and Fellow of the American Meteorological Society, and Chair of the U.S. Global Change Research Program (USGCRP) Subcommittee on Global Change Research. He has served as a Lead Author on several Assessment Reports of the Intergovernmental Panel on Climate Change, and is a fellow of the American Geophysical Union, and a National Associate of the National Research Council.

Stephen A. Klein is a Research Scientist in the Cloud Processes Research Group at the Department of Energy's Lawrence Livermore National Laboratory (DOE LLNL) in Livermore, California. His research interests include clouds, their role in climate change, and the fidelity with which climate models simulate clouds. He is a lead author or co-author on over 100 peer-reviewed publications. Prior to arriving at LLNL in 2004, he was a research scientist at the National Oceanic and Atmospheric Administration's Geophysical Fluid Dynamics Laboratory (NOAA GFDL), a leading climate modeling laboratory in Princeton, New Jersey. While there, he was a leader in the creation of the atmospheric portion of the GFDL CM2 climate model. Most recently, he has been leading a multipronged effort to determine the response of clouds to climate change.

Reto Knutti is a Professor in the Department of Environmental Systems Science at the Institute for Atmospheric and Climate Science at ETH Zurich, Switzerland. He has been a leading researcher into climate models and their foundations, publishing key papers concerning their structure, genealogy, and limits. He has also been a pivotal member of the Intergovernmental Panel on Climate Change for a number of years, leading Fifth Assessment WG1 Model projections. His research topics currently span the following fields: long-term projections, scenarios, climate targets, climate and carbon cycle feedbacks, uncertainties, model evaluation, model weighting, natural climate variability, detection and attribution, climate sensitivity, ocean heat uptake, extreme events, regional projections, climate services, and more.

John R. Lanzante is a Research Meteorologist at the Climate Impacts and Extremes Group at the Geophysical Fluid Dynamics Laboratory (GFDL)/ NOAA, Princeton University Forrestal Campus, Princeton, NJ. His research involves model-generated and observed data, focusing on large-scale climate diagnostics, on time scales ranging from days to decades. He is an expert in handling and analyzing weather balloon datasets and their preparation and maintenance. Much of his work involves Empirical Statistical Downscaling of climate model output and its critical evaluation. He is Associate Editor of *Journal of Climate* and has served as Contributing Author to several Assessment Reports, including the UN's Intergovernmental Panel on Climate Change Fourth Assessment.

Elisabeth A. Lloyd is a philosopher of climate science and evolutionary biology, as well as a scientist studying women's sexuality. She is Arnold and Maxine Tanis Chair of History and Philosophy of Science; Adjunct Professor in the Department of Biology; Adjunct Professor in the Department of Philosophy; Affiliated Faculty Scholar at The Kinsey Institute for Research in Sex, Gender, and Reproduction; Adjunct Faculty in the Center for the Integrative Study of Animal Behavior; and Faculty in the Cognitive Science Program. She works in the Department of History and Philosophy of Science and Medicine, Indiana University (Bloomington). She was previously Professor of Philosophy at University of California, Berkeley. She has published *The Structure and Confirmation of Evolutionary Theory* (Princeton) and *Science, Politics, and Evolution* (Cambridge). Her fourth book, *The Case of the Female Orgasm* (Harvard), won awards in both philosophy and science.

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Michael Mann is a Distinguished Professor of Meteorology and Director of the Earth System Science Center at The Pennsylvania State University, University Park, PA. One of the most noted climate scientists in the world starting with his creation with R.S. Bradley and M.K. Hughes of the so-called hockey-stick graph of global warming, he is the author of *The Hockey Stick and the Climate Wars:*

Dispatches from the Front Lines, co-author (w/Lee Kump) of *Dire Predictions: Understanding Climate Change* and *The Madhouse Effect*, with Tom Toles. He is a Fellow of the American Meteorological Society and the recipient of numerous prestigious national and international awards.

Alexandre Marcellesi studied philosophy of social science at UC San Diego with Nancy Cartwright, receiving his PhD for a dissertation on causation and evidence-based policy in 2016. He is currently enrolled in the NYU School of Law.

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Doug Nychka is Director of the Institute for Mathematics Applied to Geosciences (IMAGe) at the National Center for Atmospheric Research (NCAR) in Boulder, CO. He has a wide array of interests in data science, including nonparametric regression, detection and properties of nonlinear systems, and spatial statistics applied to large datasets. He has used Bayesian hierarchical modeling for paleoclimate reconstructions and other applications of statistics to climate observations and model experiments. He is a Fellow of the American Statistical Association and was awarded the Jerry Sacks Award for Multidisciplinary Research.

Jay Odenbaugh is an Associate Professor and Department Chair at the Department of Philosophy of Lewis and Clark College in Portland, Oregon. He specializes in the history and philosophy of science, especially of climate science, evolutionary biology, and ecology, as well as ethics and metaphysics. His work on complex and simple models in ecology has been especially influential.

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