The Development of Atmospheric General Circulation Models: complexity, synthesis and Computation

Leo Donner, Wayne Schubert, and Richard Somerville, Eds., 2011, 272 pp., $85.00, hardbound, Cambridge University Press, ISBN 978-0-521-19006-0

This book starts out with a depiction of the emergence of atmospheric general circulation models (AGCMs), and continues with descriptions of their later evolution. Written by a group of major players in atmospheric sciences, this book contains a fascinating account of what happened at the very dawn of numerical weather prediction—most of which is rarely found in the literature—as well as discussions on the current course of AGCM development and prospects for the future.

This is a book suited for general readers who want to know how atmospheric general circulation models were first conceived and how their development was propelled by scientific advances and rigorous efforts of a few key people. It is also a book for those who want a glimpse of the present status of AGCMs, with an eye on their future development. But by and large, this is a book on the history of the science of AGCMs. When I opened the book, I could not help but read it from the beginning to the very end in a single go.

The chapters of the book connect some lesser-known but important links in the historical chain of events leading to the atmospheric model development. In 1945, several things happened at almost the same time: Vladimir Zworykin of the electronic company RCA, inventor of television transmitting and receiving devices, imagined human intervention in weather through computer calculations in his pamphlet on “Modern Computing Devices” and the flamboyant “Outline of Weather Proposal” (this was at the time of the nuclear bomb—the Manhattan Project); John Mauchly of the University of Pennsylvania, inventor of computers, went to the Weather Bureau to seek examples of weather applications using the EDVAC computer; John von Nuemann, who collaborated with Mauchly and interacted with Zworykin, wrote the architecture of computers. In January 1946, Francis Reichelderfer, chief of the Weather Bureau, convened a meeting with Zworykin, von Neumann, Harry Wexler, and a few others to discuss the subject. Wexler’s professor at MIT, Carl Rossby, started to interact with von Neumann in early 1946, and suggested that the Institute for Advanced Study (IAS) submit a proposal that he outlined on weather research to the Navy Office of Research and Invention (ORI). Von Neumann submitted the proposal on 7 May 1946 and ORI funded it on 19 July 1946. The content of the proposal, significantly influenced by Rossby with emphasis on science rather than premature applications, is still amazingly relevant to what is occurring at present: “. . . to examine the foundations of meteorology, to solve the basic problems of the general circulation, and to improve our understanding of atmospheric processes.” Also relevant to the present was an apparent underestimation of the complexity of the research at hand, because by the end of 1947, the project was waning down. It was at that time von Neumann and Wexler, with the help from Rossby, recruited Jule Charney and a few other young people to rejuvenate the project. The infusion of new energy and talent bore fruit: In 1950, Charney, Ragnar Fjørtoft, and von Neumann successfully produced the first calculation of the 500-hPa geopotential height with 24-hour lead time, setting the landmark of numerical weather prediction, while in 1955, Norman Phillips demonstrated the simulation of the general circulation, laying the milestone for the development of atmospheric general circulation models.

Readers of this book will also take notice that Charney’s 1950 model used 19-by-16 horizontal grid points with a spatial resolution of 736 kilometers and a single layer, while Phillips’s model used 16-by-17 grid points with two layers for a beta-plane channel of the whole atmosphere. Both models used equations of balanced flows, after taking a lesson from Richardson’s experience in trying to solve the primitive equations directly. This is a good example of where advances in the theoretical understanding of large-scale atmospheric circulations profoundly impacted the successes of numerical models. Charney’s work prompted the establishment of the Joint Numerical Weather Prediction Unit of (JNWPU) of the Weather Bureau and the military Weather Services—which was the predecessor of the present National Center for Environmental Prediction (NCEP). Phillips’s work prompted the establishment of the General Circulation Research Section in Washington, D.C. [now the Geophysical Fluid Dynamics Laboratory (GFDL) at Princeton University].

The account of history in the book is a record of imagination and pursuits, expectations and setbacks, reinvigoration and triumph. The process of how sciences are shaped by individual people and events is vividly described with great details. For people who wonder about the future direction of current research on anthropogenic climate change, this book should be a useful source of reflection and inspiration, just as Winston Churchill said: “The farther backward you can look, the farther forward you are likely to see.”

The book also contains a chapter on the coevolution of climate models with the Intergovernmental Panel on Climate Change (IPCC). Like the giants in early history, it is the courage and foresight of a few key individuals that initiated the IPCC—another era in atmospheric modeling. One of these giants was Bert Bolin, who served as chairman of the IPCC between 1988 and 1997. Twenty days before his death, the Norwegian Nobel Committee awarded the 2007 Nobel Peace Prize to the IPCC.

Complementing the historical flavor of the initial chapters, the book includes some modern topics on the crossing paths of numerical weather prediction and climate modeling, the use of observational data to constrain models, and numerical techniques in the digital age. These chapters are good references for people engaged in active research, and can be read separately as standalone material. The book also highlights the development trajectory of the coupling of atmospheric models with the oceans, and the coupling with land surfaces; however, these chapters are relatively brief.

This book is not a textbook. The scope and depth of the chapters are uneven. While some chapters are easy to follow by any reader with a basic scientific background, others contain sophisticated material with the intricacy of review articles in peer-reviewed journals. By necessity, the book cannot possibly cover all the topics on the development of atmospheric models. But in view of the current ongoing activities with Earth system models, it would be nice and timely to see future editions of the book include accounts of the development of atmospheric chemistry and aerosol models, and to expand on its current content on the coupling of atmospheric models with biogeophysical and biogeochemistry models.

All in all, this book is a delight to read and to own.

—Minghua Zhang

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For Further Reading

Zworykin, V. K., 1945: Outline of Weather Proposal. RCA Laboratories, 12 pp., + appendices. [Reproduced in full in *History of Meteorology*, **4**, 57–78.]