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Book Reviews

Edited by Robert E. O'Malley, Jr.

Featured Review: Two Books on Weather Prediction Models.

Fundamentals of Numerical Weather Prediction. *By Jean Coiffier.* Cambridge University Press, Cambridge, UK, 2011. $85.00. xxii+340 pp., hardcover. ISBN 978-1-107-00103-9.

Spectral Numerical Weather Prediction Models. *By Martin Ehrendorfer.* SIAM, Philadelphia, 2012. $129.00. xxvi+498 pp., softcover. ISBN 978-1-611971-98-9.

The ability to simulate the complex flow of the atmosphere and to predict its evolution on a range of time-scales is one of the triumphs of twentieth century science. Computer models are now central for operational weather prediction and are our only real means of anticipating, in detail, the climatic consequences of changes in the constitution of the atmosphere.

There is a vast body of information contained in the journals about numerical weather prediction (NWP) and climate modeling, but good texts are relatively few, so the two books under review are to be welcomed. They are in many ways complementary, each having strengths and weaknesses.

The book *Fundamentals of Numerical Weather Prediction*, by Jean Coiffier, is based on courses in numerical weather prediction at Météo-France, but is completely updated. The author is well placed to write a book of this kind. He has a very wide knowledge of the subject and much practical experience. The level of scholarship exhibited in the writing is appropriately high. This book should attract wide interest. There is no other book that covers the forecast-model element of NWP in anything like the depth of this volume.

A comprehensive numerical weather prediction suite comprises observational data processing, assimilation, forecasting, verification, visualization, and more. Coiffier's book focuses on the forecasting element. The development proceeds from simple one-level models to more complex models in a pedagogically sensible manner.

The text is clear and the mathematical derivations are systematic and adequate in detail. A background in dynamical meteorology is not essential, although some prior knowledge of the subject, and also some exposure to basic numerical analysis, would be helpful.

The book opens with an overview of the development of NWP from the ENIAC integrations of 1950 through the second half of the twentieth century. It traces the development of models from the simple barotropic (single-level) filtered models to current models based on the nonhydrostatic equations. This evolution has run in parallel with the development of automatic computing machinery.

The systems of equations used for NWP, in particular the primitive equations, are then introduced and formulated in a variety of coordinate systems and using a selection of map projections. This enables readers with no previous exposure to dynamic meteorology to follow the remainder of the book.

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Discretization methods for solving the equations are then discussed, both finite difference methods (in Chapter 3) and the spectral method (in Chapter 4). The treatment in these chapters is clear and comprehensive. Spherical harmonic expansions, essential in many modern models, are described in detail.

The effects of discretization in both space and time are then examined. The simple yet powerful framework of the shallow water model is used to great effect here and in several other places in the book. The barotropic vorticity equation, the basis for the ENIAC integrations, is then considered. The following chapter introduces the baroclinic equations in a general vertical coordinate system. Then some specific baroclinic models are described.

A full chapter is devoted to the parameterization of physical processes, with particular attention paid to the interactions between physics and dynamics. The final chapter broadens out from the forecast component to the entire operational suite. It includes a good overview of modern variational data assimilation, and ends with a look at the prospects for future NWP systems.

One of the strengths of the book is the detailed treatment of the methods that are central for current models such as that of the European Centre for Medium-Range Weather Forecasts (ECMWF). The semi-implicit and semi-Lagrangian techniques are analyzed in fine detail, and the spectral method that underlines most current global models is very well treated. The methods described in the book are also used in current limited-area models, and two of the most recent nonhydrostatic models, AROME and WRF/ARF, are described in some detail in two appendices, of 12 and 18 pages, respectively.

Coiffier's book provides an excellent and comprehensive introduction to the field and can be recommended for anyone studying NWP and climate modeling. It is carefully researched and well written. My only serious criticism is the poor index, which, at just four pages, is quite inadequate for a book of this length and scope.

Spectral Numerical Weather Prediction Models, by Martin Ehrendorfer, is quite different in style. One of its primary goals is to provide comprehensive documentation of a model based on the hydrostatic primitive equations. The model is called the Primitive Equation Atmospheric Research Model Kernel (PEAK). This goal is achieved impressively, but at some cost. The sharp focus of the book reduces its general appeal as a text on NWP.

Part 1 of the book, with six chapters, is a comprehensive synopsis of those parts of dynamic meteorology needed as background for numerical weather prediction. It contains all the theoretical material required to build a model dynamical core. The basic equations are introduced and the methods of discretizing them and of solving them numerically are treated. The emphasis is on the hydrostatic primitive equations.

The goal of developing PEAK is kept constantly in view. Thus, in Chapter 3, on the primitive equations, a figure presents these equations in the form used in PEAK. A full chapter is devoted to the shallow water equations and another to the barotropic vorticity equation. Part 1 ends with a long chapter on balanced flow, and includes a treatment of barotropic and baroclinic instability.

Part 2, also with six chapters, deals with spectral numerical models. A good review of the spectral method is provided in Chapter 7. At 88 pages, this is the longest chapter in the book, and the treatment is quite comprehensive. The spectral method is illustrated by application to the nonlinear advection equation (the inviscid Burgers equation). Vertical discretization and time integration schemes are then dealt with in two shorter chapters.

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Next, the code structure of PEAK is described in considerable detail. In PEAK, some use is made of routines from the Numerical Algorithms Group (NAG) Library (http://www.nag.co.uk) and from the popular book *Numerical Recipes* [1]. The NAG code is optional, but it speeds up execution by some 50%. However, the NR codes are mandatory. The author states that "it is necessary to type in the contents" of a file listed on three pages of Appendix C.3. It is unfortunate that the copyright restrictions could not be overcome or circumvented. The chore of typing in code is a significant deterrent to prospective users.

Detailed instructions are given on how to set up PEAK. They appear to be clear and complete, although this reviewer has not undertaken the task. The model PEAK has been carefully validated and details of all tests are presented. The final chapter looks at the barotropic configuration of PEAK.

It has to be said that Ehrendorfer's book makes for difficult reading. In the preface, the author admits, "I am not a great book writer." There is a great deal of repetition: at 500 pages, the book is far too long. The language is convoluted and contorted; as a sample, a sentence in the preface reads: "May I add that I have at some places in the text, also when it gets very technical, added a ... ☺ symbol to encourage you in proceeding going through further details and to somehow lighten up the tone of the presentation." A thorough editing would have been more helpful than a smattering of smileys.

Despite these shortcomings, this is an important addition to the literature. The spectral transform method still has a great future for atmospheric modeling. The ECMWF model has been run with truncation T7999 (2.5 km resolution). With recent advances in devising faster Legendre transforms, the oft-predicted demise of the spectral method has receded again.

As a result of the focus of the book on PEAK, there are some significant omissions. There is no treatment of the widely used semi-Lagrangian advection schemes, and the normal modes of the linear shallow water equations (the Hough eigenmodes of the Laplace Tidal Equations) are also omitted.

Whereas Coiffier's book takes a broad view, and would serve well as a graduate textbook, Ehrendorfer's book is devoted to a specific model. On the other hand, it has exercises at the end of each chapter, something lacking in Coiffier's book. An excellent course in NWP could be constructed by taking the best from each of these books.

REFERENCE

[1] W. H. Press, S. A. Teukolsky, W. T. Vetterling, and B. P. Flannery, *Numerical Recipes in FORTRAN: The Art of Scientific Computing*, Cambridge University Press, Cambridge, UK, 1992.

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Operator Inequalities of the Jensen, Čebyšev and Grüss Type. *By S. S. Dragomir.* Springer, New York, 2012. $49.95. xii+121 pp., softcover. ISBN 978-1-4614-1520-6.

In the *theory of inequalities and applications*, Jensen's inequality plays a fundamental role due to the fact that many other classical results, such as the Hölder, Minkowski, Ky Fan, and the arithmetic-geometric-harmonic mean inequalities, are particular cases of it. It is also applied in various fields such as information theory and coding, probability theory and statistics, operator theory, and other areas of pure and applied mathematics. A simple