Book reviews

Scattering: Scattering and Inverse Scattering in Pure and Applied Science edited by Roy Pike and Pierre Sabatier (Academic Press, 2002). ISBN 0-126-13760-9. US$900.

This series of two volumes brings the concept of scattering in widely different fields – all the way from Nuclear Physics, Atmospheric Sciences to Chemical Physics – into a unified framework. Most of the topics were classified according to the physical scales of the scattering process. This two volume series easily qualifies as the encyclopedia of scattering. There are six parts in this two volume book covering the topics of: (a) scattering of waves by macroscopic targets; (b) microscopic physics and chemical physics; (c) nuclear physics; (d) particle scattering; (e) scattering at extreme physical scales such as scattering by black holes; and (f) scattering in mathematical and non-physical sciences. The editors have done a great job of bringing together the scattering concepts from widely varying disciplines into one book. According to the editors, the purpose of this book is not to develop a handbook of scattering theory, but to provide a survey of the state of the art. The goal is definitely met, and therefore this book is not meant for beginning learners of scattering theory. The first volume deals with most of the fundamentals in scattering. The book starts with formal definitions of 'scattering', the 'forward problem' and the 'inverse problem' that are again applicable to the wide disciplines covered in this book. The inverse problems of scattering theory have a lot of practical applications such as remote sensing. The intent of the editors is to focus on the inverse problems only to the extent that it serves to enhance the understanding of the scattering theory.

The first few chapters deal with the introductory concepts needed to understand scattering by a target or continuous medium or complex surfaces. These are followed by the theories of acoustic and electromagnetic scattering for objects of arbitrary shapes and inhomogeneities (Chapters 1.2 through 1.6). Scattering related to the topics of radar, ultrasound medical devices, antennas and polarimetry are covered in these sections. These chapters also cover a survey of computational methods for solving Maxwell's equations. The next set of chapters (1.7-1.8) cover the difficult topic of elastodynamic scattering that formulates problems related to seismology and seismic reflection, followed by a chapter (1.9) on scattering in oceans. One of the oldest topics of scattering principles, namely potential scattering, which describes the problems of 'motion of bodies in gravity potential' as well as 'electrostatics', is discussed next (chapters 2.1-2.2), followed by a discussion on inverse problems in this topic. Similar to electromagnetic scattering, light scattering is a topic that has generated a wide variety of applications and the concepts of light scattering are discussed in the next set of chapters (2.3-2.5). This chapter covers both the basic theory as well as the instrumentation required for spectroscopy. The subsequent chapters (2.6-4.3) in the book cover topics of atomic and molecular scattering, X-ray scattering, neutron scattering, electron diffraction and scattering as well as particle scattering in the field of particle physics. Then there is a big change in scale with a chapter (5.1) that deals with scattering on cosmic scales. The last set of chapters (6.1-6.3) revisits the mathematical foundations of scattering theory, with topics such as scattering and semigroup theory, scattering and number theory and scattering by a metric.

From the summary above, it is obvious that this book covers a wide variety of topics. This review has a specific focus, namely the 'significance of this book to the discipline of Atmospheric Sciences'. For atmospheric scientists, this is a good reference book on scattering theory. The book has an extensive amount of mathematical description of scattering theory in each chapter. For example, vector spherical harmonics that are useful to describe the scattering of electromagnetic waves by hydrometeors are described in the section on theoretical tools.

Sections relevant to Atmospheric Science exist at various places throughout the two-volume book. While there is a separate section on scattering in the atmosphere, that section primarily deals with molecular scattering, aerosol scattering, scattering from clouds and lidar sensing. The other important part of atmospheric scattering (scattering by precipitating particles) is covered in a variety of sections such as those describing radars and polarimetry in wave scattering applications. Acoustic and elastic scattering as well as scattering in oceans are discussed in separate sections each. Rayleigh scattering appears throughout the book in various contexts, and the specific mathematical background is discussed in the section on low-frequency scattering. In addition, the fundamentals of scattering by dielectric objects such as raindrops, including Mie scattering, are discussed in the chapter on specific theoretical tools, as well as scattering by obstacles.

The reader has to be careful to look for scattering by dielectric objects to find the required discussion on scattering by hydrometeors. Because of the broad scope of the book, all applications to Atmospheric Sciences may not be explicitly stated everywhere they appear.

At the time of preparing the review, this book had a list price of about US$900, approximately A$1700. At this price, not many readers will get a personal copy, but with the wide variety of topics covered, it is definitely a book for libraries. It is a reference book for scientists and graduate students, especially for those interested in a survey. The book has a broad scope, and therefore one may not find all the details in a topic of interest, but it will serve as a good reference to get started.

V. Chandrasekar

V. Chandrasekar (known as Chandra) is a Professor at Colorado State University, and has spent the last two decades working on Remote Sensing Research, with special emphasis on RF atmospheric sensing. He is a Co-Principal Investigator of the CSU-CHILL radar facility.

Mesoscale Meteorological Modeling (2nd Edition) by Roger A. Pielke, Sr. (Academic Press, 2002) ISBN 0-12-554766-8. $US 85.

The well-known monograph, *Mesoscale Meteorological Modeling*, has been revised and updated. The author, Roger A. Pielke, Sr, has been working at the forefront of mesoscale meteorological research for the past thirty years. His book is intended to provide an overview of modelling of atmospheric processes that have ‘a temporal and a horizontal spatial scale smaller than the conventional rawinsonde network, but significantly larger than individual cumulus clouds.’ His main audience is the researcher, but the revised edition also includes problem sets at the end of the chapters for use in classroom settings.

After a short introductory chapter, he describes the basic conservation equations in Chapter 2. These equations are simplified in Chapter 3 by the introduction of scale analysis, and are averaged in Chapter 4 to provide the mean and turbulent contributions that conform to the mesoscale model grid mesh. In Chapter 5 there is a short discussion of physical (laboratory) models, but most of the discussion is on linear analytical models. Up to this point the material presented is fairly standard. What is different is Pielke’s detailed discussion of Defant’s linear sea- and land-breeze model. This has been significantly extended in the revised edition to examine the difference between hydrostatic and non-hydrostatic solutions as a function of the horizontal length scale, large-scale stability, subgrid-scale heat diffusion, heating amplitude and surface friction.

Chapter 6 is devoted to tensor analysis and coordinate transformations. Pielke has extended this discussion to include the generalised hydrostatic equation, the generalised geostrophic wind, drainage flow and application of terrain-following coordinate systems. The theory and parametrisations of subgrid-scale fluxes in the surface and outer boundary layers, of radiation fluxes and of moist thermodynamic processes are described in Chapters 7 – 9, respectively. The parametrisation of the Monin-Obukhov profiles and the value of the von Karman constant, based on the Kansas Experiment, have been updated based on data from Högström’s experiments. The sections on the Gaussian plume model and the Lagrangian particle dispersion technique have been omitted, and the Kuo cumulus convection scheme has replaced the discussion of the Fritsch-Chappell scheme in the new edition. The assumptions underlying the parametrisations are carefully evaluated. Numerical methods of solution are presented in Chapter 10. Discussion of the finite element method has been deleted, but new sections on the Adams-Bashford differencing scheme, the flux correction method, and a more accurate method for the numerical solution of nonlinear partial differential equations have been added.

Chapters 11–13 discuss boundary and initial conditions, model evaluation, and examples of mesoscale models, respectively. An Arakawa-Lamb diagram showing the placement of grid variables, and material describing a snow surface as a lower boundary, the simple biosphere (SiB) model, the Multivariate Randomised Block Permutation (MRBP) statistical evaluation procedure, model sensitivity analyses, and vegetation and snow breezes have been added.

New Appendices characterising seven cumulus-cloud parameterisations, comparing three soil-vegetation-atmospheric transfer (SVAT) models, and indicating various sources of data sets have also been added.

Pielke covers a wide range of topics, both theoretical and practical. He is concerned with virtually all areas of mesoscale modelling. Much of the theory is readily available elsewhere, but the parametrisation details are more widely scattered, and it is helpful to have all of this information in one place. The references have been updated and expanded from 59 pages to 90 pages. There are the inevitable typos that have crept in during the conversion to the new edition, e.g. in Eqns 2-47, 4-10, and 11-21, but these are few.

I recommend this book to all those interested in mesoscale modelling. As computer capabilities, and consequently model resolution, increase interest in the mesoscale processes and forecasting will also increase. This book is a good place to start.

Dale Hess

Dale Hess is a member of the Model Development Group at the Bureau of Meteorology Research Centre and works on the Australian Air Quality Forecasting System.

Global Biogeochemical Cycles in the Climate System edited by E-D Schulze, M. Heimann, S. Harrison, E. Holland, J. Lloyd, I.C. Prentice and D. Schimel (Academic Press, 2001) ISBN 0-12-631260-5. $175.

Global biogeochemistry studies the changes in chemical composition of the land, ocean and atmosphere, and the influence of human activities. The Max Planck Institute (MPI) for Biogeochemistry was established to provide an intellectual focus for research on the global biogeochemical cycles. The book *Global Biogeochemical Cycles in the Climate System* collects the papers presented at a meeting celebrating the first anniversary of the MPI for Biogeochemistry.

This book covers a wide range of topics, from soil biochemistry, plant physiology to earth system science and some legal aspects of international environmental treaties. Some reviews are authoritative. New insights and recent advances in research and political and legal dimensions of the Kyoto protocol negotiation are also included. Despite the diversity and complexity of the subject, all chapters are well written and mathematics has been kept to the basic level.

The first three chapters discuss the uncertainties in our current knowledge about global biogeochemical systems. In Chapter 1, Professors Schulze and Schimel from MPI summarise major findings in three International Geosphere Biosphere Program (IGBP) Transect experiments, and call for more field measurements at regional scales. In Chapter 2, Professor Bengtsson from MPI discusses paleoclimatic evidence of various physical factors affecting our climate and concludes that the warming in the 20th century is of anthropogenic origin. However, the predicted future warming due to increased concentrations of greenhouse gases in the atmosphere by climate models differs significantly, because of limitations in model resolution and realistic representation of physical processes, errors in coupling the atmosphere and ocean and stochastic variability. In Chapter 3, Drs Brasseur and Holland point out that current atmospheric chemical transport models can reproduce major features in the global chemical systems, but large uncertainties still exist. Future improvements should include the coupling of a global atmospheric chemical model with a global biogeochemical model.

A comprehensive review is presented in Chapter 4 by Dr Raupach from CSIRO Australia on applying inverse methods to estimate the distribution of sources and sinks within a plant canopy. It is the best review on the subject I am aware of to date. The only deficiency of this chapter is the lack of discussion on the propagation of errors from measurement or model to the estimates of inversion, a topic that can be found in several published textbooks.

In Chapters 5 to 7, paleoclimatic evidence, including ice core data, is used to argue for significant feedback between the terrestrial biosphere and our climate system. Evidence is also presented on the complexity of the nonlinear biogeophysical feedback and its significant impact on the dynamics of the climate system. The biogeochemical feedback is also closely related to biogeophysical feedback. The challenge facing modellers is to explain those feedbacks and the observed temporal variations in the ice core records of CO_2, CH_4 and mineral dust aerosol using theoretical models.

The next four chapters are case studies of the moist tropical rainforests, savanna, temperate forests, tundra and boreal forests. The authors explore the influences of nutrient limitation on dry matter production and water use. They argue that the enhanced sequestration of C and N by woody plants in the tropical savanna is accompanied by an increase in emissions of NOx and non-methane hydrocarbon by trees and groundwater fluxes, which may have significant global implications, as 20 per cent of the land surface is covered by savanna.

The following five chapters describe some process-based studies of the biogeochemistry of terrestrial ecosystems. The authors point out deficiencies in the current measurements of soil carbon, in the representation of soil microbiology in soil biogeochemical models and in poorly understood processes in nitrogen cycling.

In Chapter 18, Professor Heimann from MPI presents another excellent review, discussing merits of measuring molecular oxygen and oxygen isotopes, and the potential benefits in constraining global carbon fluxes this way. In the next chapter, Drs Francey, Rayner and Allison from CSIRO Australia discuss current calibration issues in measuring long-lived atmospheric trace gases in the air. An international comparison strategy, GLOBALHUBS, is proposed. It will result in about an order of magnitude improvement in measurement precision and in reducing the uncertainty of current estimates of surface carbon fluxes by inversion from 1 Gt C year^{-1} to better than 0.1 Gt C year^{-1}. In Chapter 20, Drs Buchmann and Kaplan from MPI present another comprehensive review on the carbon isotope discrimination by different processes of terrestrial ecosystems. The authors present evidence that carbon isotopes can be used to detect differences in the ratio of carbon to water fluxes between different biomes and the variation due to climatic or environmental conditions. The next three chapters deal with several remaining aspects in the global biogeochemical cycles: geographical distributions of C3 and C4 plants, the speculated effects of altering biodiversity on the biogeochemistry, feedback between global biogeochemical systems and climate, and the atmospheric perspectives on the ocean carbon cycle. In Chapter 22, Professor Hal Mooney from Stanford University raises some profound questions about the relationship between biological diversity, evolution and biogeochemistry, such as whether species lose matter for biogeochemical cycling.

The last four chapters discuss several very topical issues. Dr Wolfrum from MPI discusses what commitments are for each signatory nation to the Framework Convention to Climate Change (FCCC) and Kyoto Protocol, and measures for implementing, monitoring and enforcing compliance. In Chapter 25, Drs Renn and coworkers in Germany identified six types of environmental risks and their management. In Chapter 26, Mr Benedick gives us some insights into why the Montreal protocol was successful and the obstacles to the implementation of the Kyoto protocol by signatory nations. He concludes that the Kyoto protocol is a step forward in the process, and recommends that earth system models should be used to provide scientific advice for future negotiations of all parties under the Kyoto protocol. In the last chapter, Dr Hasselmann from MPI uses a simple Global Environment and Society model and demonstrates that long-term emission abatement is far more effective in minimizing the global climate-damage cost than the short-term reduction measures, and that long-term measures are required to avert major climatic change. I found the last two chapters fascinating to read.

Overall this book presents a wide range of subjects in the field with great depth and understanding. However I found the arrangement of different chapters not very cohesive. The scale of the y-axis in Figure 11 of the last chapter is incorrect, and the colour figures are collectively printed between the pages of Chapter 4, probably to minimise printing costs. This book has a hard colour cover and a comprehensive subject index. It retails for about A$175 only. It is a great buy. I strongly recommend it to all scientists in the field of environmental sciences, earth system sciences and atmospheric sciences.

Ying Ping Wang

Ying Ping Wang is a principal research scientist working for CSIRO Atmospheric Research. He has spent the last fifteen years modelling physiological, ecological and biogeochemical processes of terrestrial ecosystems. His current interests are sources and sinks of greenhouse gases in terrestrial ecosystems.

Dynamical Paleoclimatology: Generalized Theory of Global Climate Change by Barry Saltzman (Academic Press, 2001). ISBN 0-126-17331-1. $138.

With the title *Dynamical Paleoclimatology: Generalized Theory of Global Climate Change*, Barry Saltzman is in some ways guilty of false packaging. Rather than proffering such a comprehensive (and what would be a welcomed!) theory, the author outlines a general strategy toward a dynamical understanding of climate change on the global scale. However, given that it is rare to closely tie together the observations and theory of climate as this book most definitely does, the title is more than forgivable.

It immediately becomes clear that the theory advanced here is a modest first step in attempting to explain the paleo-evolution of global ice mass and temperature – a point the author readily admits to in the Prologue and again in the book's final chapter. In between these two points of the book we are treated to an overview of many years of the author's research focus, the aim of which has been to develop theoretical models for predicting the long-term evolution of the climate system evident in the geologic record. It is on this latter work, along with that of many colleagues, that Saltzman has based the book.

The book is well organised, being divided into seventeen chapters which are grouped together under three parts: (I) Foundations; (II) Physics of separate domains; and (III) Unified dynamical theory. Part I begins by gathering the diverse source of climatic data (ice and marine cores, geomorphological evidence etc.) to provide a brief overview of the observations and of the techniques involved in obtaining the proxy data. Scientists interested in pursuing observational topics will find it helpful to have on hand Bradley's (1999) textbook. However, the overview given in Saltzman's book is more than adequate given that its emphasis is on the theoretical aspects of the subject. The book then moves on to cover the two building blocks of the dynamical framework followed later. Firstly, the text sets down the dynamical fundamentals such as the governing equations of motion, conservation laws, issues of averaging, and the external forcings pertinent to the problem. Secondly, Chapters 5 and 6 introduce the basic strategy of the book and the necessary background on dynamical systems theory, respectively. The material in chapter 6 is particularly well presented and should be transparent to those that are uninitiated in this approach.

The working hypothesis of the book is that the spectrum of paleoclimate variance is comprised of two ingredients: a 'slow response component' – global ice mass, atmospheric carbon dioxide and the thermohaline circulation; and a 'fast-response component', the atmosphere and surface climate state (e.g. biosphere, surface ocean) which come to a transient equilibrium with respect to the 'slow response component'. The overall strategy that Saltzman advocates in chapter 5 is not really theory, but instead it is a modelling methodology. The basic idea is to drive what he terms a 'super-GCM' (representing the fast-response fields) with a paleoclimate dynamics model (PDM) (describing the slow-response component), to create an all-encompassing climate system model (CSM). The forcing functions that drive the fast and slow-response systems are the Earth's topography, solar radiation and the chemical cycle. The CSM would then be integrated forward in time for millions of years from prescribed initial conditions with the changing forcing functions to simulate the observed variability in the climate records. However, as Saltzman points out, this is not a practical (or possible) way forward and a phenomenological approach is proposed to formulate the CSM.

Part II (chapters 7 through 11) are devoted to introducing separate models for each of the different components of the climate system spectrum identified in Part I that form the CSM. In Part III, the author turns to the dynamical systems theory introduced in chapter 6 to combine all of the separate models into a unified approach. Chapter 12 focuses on developing a general dynamical model governing global climate to explain the observed features. In chapter 15, this culminates in a model for the late Cenozoic global ice changes with seventeen variables, nine of which are free parameters of the problem. Not surprisingly, with so many tunable parameters, the author is able to form a close agreement between the model output and the various climate signals over the last 500,000 years or so. The basic idea is that this climate dynamical model is of a lower order than the real world, forming the 'center manifold' onto which the basic physics of the governing differential equations are projected, giving global fields with which the 'super-GCM' is forced. The book's final chapter then goes on to make suggestions, using the dynamical systems approach, on how to proceed to a more complete theory of climate evolution.

The book is well indexed and the bibliography is very up-to-date, extensive and will prove to be valuable in itself. Overall, the result is an interesting read, which relies heavily on the author's research interests over the years and as a result it has the understandable bias toward this viewpoint. It is very mathematical in parts, but the material is generally carefully written and clearly explained. The presentation is serious and systematic, yielding insights into the nature of climate change that are often left lacking in some of the existing textbooks. Throughout, the figures are of excellent quality and contribute much to the understanding. Most importantly, it is clear that the theory in the book is motivated by the observations and the theoretical results are repeatedly referred back to the motivating climate record. Occasionally, the book repeats itself: for example, this reviewer was reminded of the clear discussion of Lorenz's view of the almost-intransitive nature of climate on page 96, by re-reading it again on page 133.

This is an excellent book for self-study by a postgraduate-level student or researcher with a climate dynamics background. In addition, an applied mathematician who may wish to develop an appreciation for the more theoretical aspects of climatology or who has an interest in dynamical systems would be rewarded by this addition to their collection.

Reference

Bradley, R.S. 1999. Paleoclimatology: Reconstructing Climates of the Quaternary (2nd ed), Academic Press, *Int. Geophysics Series, Vol.64*, 613 pp.

Richard Wardle

Richard Wardle is a postdoctoral fellow in dynamical paleoclimatology in the School of Earth Sciences at the University of Melbourne. His interests involve using modelling approaches to understand the dynamics of the atmosphere and ocean, both past and