Radiative Transfer in the Atmosphere and Ocean

Gary E. Thomas and Knut Stamnes
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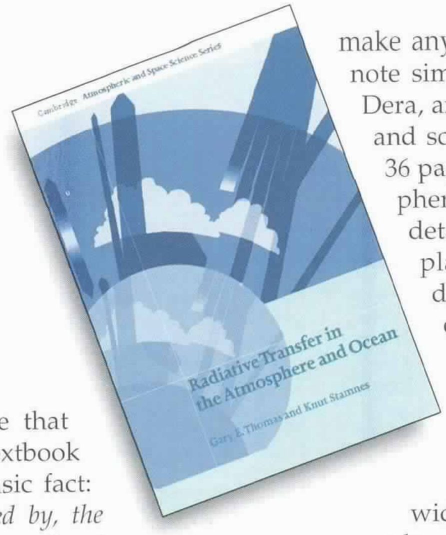

In their Preface the authors state that "... the time has come to write a textbook that acknowledges the following basic fact: *The radiation that enters, or is emitted by, the ocean encounters the same basic processes of scattering and absorption as those involved in atmospheric radiation.* [italicized in the original] There are no inherently different optical properties between atmospheric and aqueous media. Because the two media share a common interface that readily passes radiative energy, there is even more need for a unified approach." This statement and the book's title both promise to connect the two fields of atmospheric and oceanic radiative transfer, which historically have developed as almost independent disciplines, each with its own particular problems, nomenclature, and numerical methods. I therefore base my review in part on how well this text achieves this stated goal.

The text has twelve chapters, each of which begins with an introduction and ends with a summary, both of which are always well written and put the material into perspective. Each chapter includes problems and supplementary notes, which often connect the reader to the research literature. The authors consistently do an excellent job of explaining the physics underlying the mathematics of radiative transfer theory. In these aspects, the book is a pleasure to read.

Chapter 1 reviews the basics: characteristics of solar spectral flux, vertical structure of planetary atmospheres, radiative forcing and feedbacks in climate change, etc. Several pages are devoted to the vertical structure of the ocean, with one figure showing the absorption spectrum of pure water. Chapter 2 begins the discussion of radiative transfer theory. The nomenclature and notation correspond to that used in the atmospheric community (e.g., "intensity I" rather than "radiance L"). The radiative transfer equation is derived with the scattering term being treated symbolically as a source term.

Chapter 3 then discusses the physics of scattering and line-broadening processes in detail. The treatment is almost entirely atmospheric; only a few sentences make any mention of the ocean. Indeed, an endnote simply refers the reader to texts by Jerlov, Dera, and Mobley for a discussion of absorption and scattering in the ocean. Chapter 4 devotes 36 pages to absorption and emission by atmospheric gases. Do we then get an equally detailed discussion of absorption by phytoplankton, dissolved substances, organic detritus, and mineral particles? No, we get one page that simply sidesteps the complexities of absorption in the ocean with the statement that "The compositional variability from location to location makes it difficult to create 'standard' optical models, such as those used widely in atmospheric studies." True, but not very educational. Chapter 5 continues the discussion of radiative transfer theory. Reflection by surfaces is discussed, with only two pages being devoted to the sea surface. This very uneven treatment of the atmosphere and the ocean continues throughout the book.

Chapter 6 is a nice chapter on the formulation of radiative transfer problems in both plane and spherical geometries. Standard topics such as separation of the radiance into diffuse and direct (solar) components, scaling transformations, phase function approximations and expansions in Legendre polynomials, and Fourier decompositions are all well treated. Six idealized "prototype" problems are defined. As usual, the treatment is directed toward the needs of atmospheric radiative transfer. Chapter 7 then presents approximate solution methods for the prototype problems. These methods include the single-scattering approximation, the Eddington approximation, and a detailed discussion of various solutions based on two-stream approximations. Chapter 8, "Accurate Numerical Solutions of Prototype Problems," deals almost entirely with the Discrete Ordinates (DO) method of solving the radiative transfer equation. There is a section on how to couple the atmosphere and ocean in the DO formalism. However, that discussion assumes that the sea surface "is perfectly flat and exhibits only specular reflection." There is no mention of how, or even if, the DO formalism can be applied with wind-blown sea surfaces. A half dozen other accurate numerical methods, including the venerable and very important Monte Carlo methods, are dismissed in a single paragraph each. This is certainly acceptable, but the chapter should have been titled "The Discrete Ordinates Method."

Chapter 9 treats ultraviolet and visible radiative transfer. The optical properties of ozone, aerosols, water clouds, and ice clouds are presented. Three pages are then devoted to the optical properties of the ocean; this discussion is primarily a presentation of commonly used absorption and scattering models for Case 1 water. Modeling of short-wave radiation in the atmosphere is then discussed, followed by several pages on radiative transfer in the ocean. This latter discussion does little more than define diffuse attenuation coefficients, present a two-stream model for homogeneous water, and discuss the remotely sensed reflectance in terms of shape factors (a rehash of one research paper). There is simply no indication of the great and varied progress made in the last decade in modeling oceanic light propagation. Chapters 10, 11, and 12 treat infrared radiative transfer, including atmospheric band models, cloud and aerosol effects, and the role of the radiation budget in climate change. These chapters are all well done, but they make almost no mention of the ocean.

This is a good and well written book, worthy of a place next to other standard texts on atmospheric radiative transfer (such as those by Lenoble and Liou). However, fewer than ten per cent of the pages and problems relate to oceanic radiative transfer. There is almost no discussion of the central problems of optical oceanography, no side-by-side comparison of atmospheric and oceanic radiative transfer, and almost no presentation of observational data on oceanic absorption and scattering properties or underwater light fields. There is a lot in this book for atmospheric scientists, but there is very little for oceanographers. A reader coming to this text with no knowledge of either the atmosphere or the ocean likely would conclude that atmospheric radiative transfer is highly complex (true) but that oceanic radiative transfer is rather trivial and can be relegated to a few footnotes (definitely not true). This uneven treatment may even reinforce the idea that atmospheric and oceanic radiative transfer are much different subjects, best left to their respective research communities, which is exactly the opposite of what the authors intend. Unfortunately, the text that unifies atmospheric and oceanic radiative transfer has yet to be written.

One final point requires comment. The text references appendices A through S. However, the book itself contains only appendices A through E. Appendices F through S are supposedly found on a web site. At the time I received the galley proofs for this review on June 9, 2000, only appendices F and G were on the web site. Presumably H through S will follow soon. But more important than the tardy posting of these appendices is the question of whether this web site will still be available ten years from now. Coupling a web site with a hardcopy book opens the door to many possible improvements in education. But let us hope that any author contemplating this option understands the necessity for long-term maintenance of the web site.

Books Undergoing Review:

Beaches and Dunes of Developed Coasts
By
Karl F. Nordstrom
Cambridge University Press, Publisher

The Effects of UV Radiation in the Marine Environment
Edited by Stephen de Mora, Serge Demers and Maria Vernet
Cambridge University Press, Publisher

Tides: A Scientific History

David Edgar Cartwright
292 pages, Cambridge University Press
ISBN 0-521-62145-3

Review by Bruce Parker
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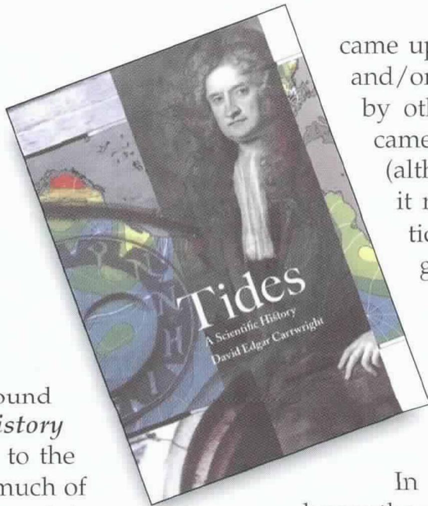

I should say right at the outset that I found David Cartwright's ***Tides: A Scientific History*** totally engrossing. This may partly be due to the fact that I have worked in the area of tides much of my career and so I found the idea of a review of the history of the development of tidal science seen through the eyes of one of its few living gurus irresistible. David Cartwright quite literally followed in the footsteps of Joseph Proudman and Arthur Doodson and worked side by side with Walter Munk, in the process making his own major contributions to tidal science, most notably in the areas of tidal analysis and prediction and the extraction of tides from satellite altimetry. That he downplays his own contributions, not even listing his own name in the author index (one will find some of his papers included in several of the References sections that follows each chapter), is a sign both of his own modesty and of the seriousness with which he treats the subject. For although he does provide some insights into personal aspects of the men who made contributions to tidal science over the centuries, for the most part Cartwright sticks to the development of the science itself. There are few if any who are in a better positionto examine this development and to put each contribution into a larger context. Cartwright does more than just chronicle various scientific papers written over the years. His expertise is fully utilized in his interpretation and critiquing of these works and in his estimation of their contribution to either the understanding of the tides or the useful application of tidal knowledge by particular users (for example, mariners).

The first five chapters of his book proceed chronologically beginning with the earliest ideas of thinkers in the ancient civilizations of Asia and Europe. The early history is fascinating, from the tidal dock built around 2000 BC in Lothal, India, to the world's first tide table (in the 10^{th} or 11^{th} century AD), etched in stone near Hangchow for predicting the arrival times of the spectacular tidal bore in the Qiantang River in China. Individual Indian, Chinese, Greek, Arab, and Roman thinkers all made the connection between the tides and the phases of the moon, and often deduced many of the daily, monthly, and even annual variations, only to have their work either forgotten, ignored, or disbelieved on religious grounds, and then to be rediscovered by a later scientist or philosopher. Equally interesting are the names of famous thinkers (among these Aristotle and Galileo) who came up with strange theories for the tides and/or rejected the correct ones presented by others. None of these early scientists came up with the actual *cause* of the tides (although a couple came very close) and it remained for Newton to explain the tides using his concept of universal gravitational attraction between all massive bodies, which is treated in detail by Cartwright in Chapter 5, along with the work of other scientists who built upon Newton's work, such as Maclaurin, Euler, and Bernoulli.

In Chapters 6 though 10 Cartwright leaves the chronological organization he used in the first five chapters for one more based on subject area, with Chapter 6 dealing with a history of tidal measurements. Chapter 7 deals with the work of Laplace, the second really important contributor to the development of tidal science (after Newton), along with other hydrodynamicists who found solutions for Laplace's tidal equations for various idealized ocean basins. Cartwright tries to keep the mathematics to a minimum, but some mathematical treatment is unavoidable. He appears to find the right balance, namely one that will probably satisfy the tidal research community while still getting the ideas across to physical oceanographers in general and other readers with some scientific and mathematical background. A few important mathematical treatments (such as development of the tide-generating potential) are included in Appendices.

Chapter 8 deals with local analysis and prediction, in particular the development of the harmonic analysis of tides by Kelvin, Darwin, Ferrel, and others, and the first use of mechanical analog tide prediction machines. Chapter 9 concentrates on the development of cotidal line charts for the world's oceans and their dynamic implications. Chapter 10 deals with tides of the geosphere (air tides, earth tides, and magnetic tides) and its place in the new science of geophysics. Chapter 11 deals with various tidal researches that took place between the two World Wars, including the work of Proudman and Doodson at the Liverpool Tidal Institute. The impact of computers beginning in 1950 is treated in Chapters 12, and includes the development of numerical tide models for the world ocean and innovations in tidal analysis such as Munk and Cartwright's "response method." A wide variety of instrument technology and its impact on understanding tides is treated in Chapter 13, with satellite technology left for special attention in Chapter 14. Chapter 15 covers miscellaneous topics, such as long-period tides and oceanic tidal dissipation, and ends with Cartwright's final retrospect of the subject.

Although at the beginning of this review I mentioned that my strong interest in the subject of tides might have been partly responsible for my great enjoyment of this book, I should make it very clear that I think this book will be an enjoyable and educational reading experience even for those who haven't worked in this discipline. The history alone should be enough to interest many readers. Cartwright says he wishes to convey " the historical growth of ideas over the centuries"and that aspect is definitely interesting. Although not meant to be a teaching text for tides, this book should also be of benefit for those studying the tides, since sometimes a clearer comprehension of a subject can be gained by learning how the understanding of that subject evolved. While Cartwright states that his history is more concerned with the global aspects of tidal science, there are not too many aspects of the tides that Cartwright does not cover. (The nonlinear aspects of tides in shallow-water may be, in fact, the only subject that does not get any real coverage, and that subject is relatively recent in its major growth.) Thus, this book will also serve as a good reference, where you can go to find an initial understanding of some aspect of the tide, along with the best papers for learning more. But don't be surprised if you find yourself reading whole sections of the book that you might never have intended to.