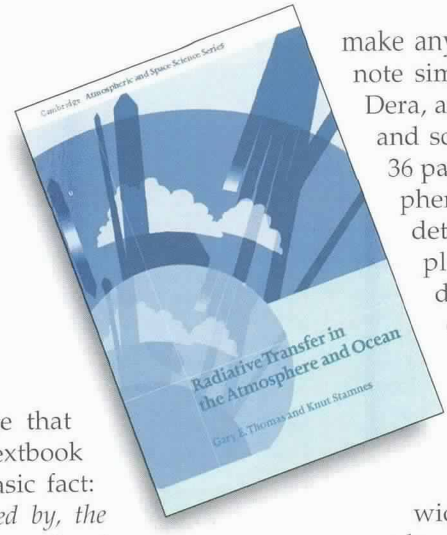
Radiative Transfer in the Atmosphere and Ocean



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