Preface

This volume of *Light Scattering Reviews* is aimed at the presentation of recent advances in radiative transfer, light scattering, and polarimetry and consists of nine chapters prepared by leading experts in respective research areas. A state-of-the-art discrete-ordinate algorithm for the transfer of monochromatic unpolarized radiation in non-isothermal, vertically inhomogeneous media, as implemented in the computer code discrete-ordinate-method radiative transfer, DISORT, is reviewed by Laszlo et al. in chapter "The Discrete Ordinate Algorithm, DISORT for Radiative Transfer". Both the theoretical background and its algorithmic implementation are covered in detail. These include features common to solutions of many radiative transfer methods, including the discrete-ordinate method, and those specific to DISORT. The common features include expansions of the phase function and the intensity into a series of Legendre polynomials and Fourier series, respectively, which transform the radiative transfer equation into a set of equations that depend only on the optical depth and the zenith angle, and the transformation of the integro-differential equations into a set of ordinary differential equations by approximating the integral in the source function by a quadrature sum. The features specific to DISORT include the reduction of the order of the standard algebraic eigenvalue problem to increase efficiency in both homogenous and particular solutions of the system of coupled ordinary differential equations, application of the scaling transformation to make the solution unconditionally stable for arbitrary large values of optical depth, application of the δ-M method to handle highly anisotropic scattering, the correction of intensities by the Nakajima–Tanaka method, and the implementation of a realistic bidirectional bottom boundary condition as realized in version 3 of DISORT. Numerical considerations that make the implementation robust and efficient are also discussed. Examples of setting up DISORT runs are shown by using test cases with increasing complexity. Brief summaries of the versions released to date are provided as well. Chapter "Community Radiative Transfer Model for Air Quality Studies" prepared by Liu and Lu presents the latest community radiative transfer model (CRTM), which is applicable for passive optical, microwave, and infrared sensors. The CRTM has been used in operational radiance assimilations in supporting of weather forecasting and in the generation of satellite products. In this chapter, CRTM applications to assimilate aerosol optical depths derived from satellite measurements are discussed. In particular, the assimilation improves the analysis of aerosol mass concentrations. A retrieval algorithm and a retrieval product of carbon monoxide by using satellite measurements are introduced. Wei and Xu has presented the analytical solution of the time-dependent scalar and vector RTE in an infinite uniform medium with an arbitrary light scattering phase function using cumulant expansion in chapter "Analytical Solution of Radiative Transfer Using Cumulant Expansion". Analytical expressions for the exact distribution in angle and the spatial cumulants at any angle, exact up to an arbitrary high order, *n,* of photons are derived. By a cutoff at the second cumulant order, a Gaussian analytical approximate expressions of the scalar and vector photon spatial distribution is obtained as a function of the direction of light propagation and time, whose center position and half-width are always exact at arbitrary time. The center of this distribution advances and the half-width grows in time, depicting the evolution of the particle migration from near ballistic, through snake-like, and into the final diffusive regime. Contrary to what occurs in other approximation techniques, truncation of the cumulant expansion at order *n* is exact at that order and cumulants up to and including order *n* remain unchanged when contributions from higher orders are added. Various strategies to incorporate the boundary conditions in the cumulant solution are presented. The performance of the cumulant solution in an infinite and a semi-infinite medium is verified by exact numerical solutions with Monte Carlo simulations. At the end, the particular applications of the cumulant solution to RTE in biophotonics for optical imaging and in remote sensing for cloud ranging are discussed. Kolesov and Korpacheva have reviewed the radiative transfer theory in turbid media of different shapes in chapter "Radiative Transfer in Spherically and Cylindrically Symmetric Media". In particular, the authors have presented the research of radiative transfer in spherically and cylindrically symmetric media with anisotropic scattering of light. The problems of radiation transfer in an infinite homogeneous absorbing and anisotropically scattering media illuminated by a planar or point sources are considered. The relationship between the characteristics of the radiation fields in these two problems is obtained. Also an overview of the problems of radiation transfer in an infinite medium with arbitrary spherically symmetric distribution of sources is presented. The authors also discuss the structure of the radiation field in a sphere of a finite optical thickness and a spherical shell. The asymptotic expressions in the theory of radiation transfer in atmospheres with spherical symmetry are presented as well. The authors discuss the applications of the methods developed in the theory of radiative transfer in spherically symmetric media to the case of media with a cylindrical symmetry. They provide an overview of studies on the nonstationary radiative transfer in plane-parallel, spherical, and cylindrical media. Lock and Laven describe the Debye series for scattering by a sphere, a coated sphere, a multi-layer sphere, a tilted cylinder, and a prolate spheroid in chapter "The Debye Series and Its Use in Time-Domain Scattering". In electromagnetic scattering of an incident beam by a single particle possessing a reasonably high degree of symmetry, the Debye series decomposes the partial wave scattering and interior amplitudes into the contributions of a number of intuitive physical processes. The authors comment on the meaning of the various Debye series terms, and briefly recount the method by which the formulas of ray scattering can be derived from them. They also consider time-domain scattering of a short pulse by a spherical particle and describe the way in which the time-domain scattering signature naturally separates out the various Debye series terms. Lastly, the authors show how time-domain scattering further separates a number of cooperating sub-processes present in the individual Debye series terms. Kahnert et al. discuss the models of inhomogeneous particles used in light scattering computations in chapter "Morphological Models Forinhomogeneous Particles: Light Scattering by Aerosols, Cometary Dust, and Livingcells". Light scattering by chemically heterogeneous particles with inhomogeneous internal structure is an important field of study in such diverse disciplines as atmospheric science, astronomy, and biomedical optics. Accordingly, there is a large variety of particle morphologies, chemical compositions, and dielectric contrasts that have been considered in computational light scattering studies. Depending on the intended applications, physical particle properties, and computational constraints, one can find inhomogeneous particle models ranging from simple core-shell geometries to realistic quasi-replicas of natural particles. The authors review various approaches for representing the geometry of encapsulated light-absorbing carbon aerosols, mineral dust, volcanic ash, cometary dust, and biological particles. The effects of particle inhomogeneity on radiometric properties are discussed. The authors also consider effective medium approximations, i.e., approaches that aim at avoiding the computational difficulties related to particle inhomogeneity altogether by representing such particles by a homogeneous material with an effective refractive index. Chapter "Some Wave-Theoretic Problems in Radially in Homogeneous Media" prepared by Noontaplook et al. is aimed at consideration of wave-theoretic problems in radially inhomogeneous media. The wave-theoretic aspects are based on the solution of Maxwell's equations for scattering of plane electromagnetic waves from a dielectric (or "transparent") sphere in terms of the related Helmholtz equation. There is a connection with the time-independent Schrödinger equation in the following sense: the time-independent Schrödinger equation is identical in form to the wave equation for the scalar radiation potential for TE-polarized electromagnetic waves. In regions where the refractive index is constant, it is also identical to the scalar radiation potential for TM-polarized electromagnetic waves, but with different boundary conditions than for the TE case. The authors examine scattering of the TE mode from a piecewise-uniform radial inhomogeneity embedded in an external medium (as opposed to an off-axis inclusion). The corresponding theory for the TM mode is also developed, and the well-known connection with morphology-dependent resonances (MDRs) in these contexts is noted. Kimura et al. focus on numerical approaches to deducing the light scattering and thermal emission properties of primitive dust particles in planetary systems from astronomical observations in chapter "Light Scattering and Thermal Emission by Primitive Dust Particles in Planetary systems". The particles are agglomerates of small grains with sizes comparable to visible wavelength and compositions being mainly magnesium-rich silicates, iron-bearing metals, and organic refractory materials in pristine phases. These unique characteristics of primitive dust particles reflect their formation and evolution around main-sequence stars of essentially solar composition. The development of light scattering theories has been offering powerful tools to make a thorough investigation of light scattering and thermal emission by primitive dust agglomerates in such a circumstellar environment. In particular, the discrete dipole approximation, the T-matrix method, and effective medium approximations are the most popular techniques for practical use in astronomy. Numerical simulations of light scattering and thermal emission by dust agglomerates of submicrometer-sized constituent grains have a great potential to provide new state-of-the-art knowledge of primitive dust particles in planetary systems. What is essential to this end is to combine the simulations with comprehensive collections of relevant results from not only astronomical observations, but also in situ data analyses, laboratory sample analyses, laboratory analogue experiments, and theoretical studies on the origin and evolution of the particles. The concluding chapter "Polarimetry of Man-Made Objects" prepared by S. Savenkov is aimed at applications of environmental polarimetry. Polarimetry has already been an active area of research for about fifty years. A primary motivation for research in scatter polarimetry is to understand the interaction of polarized radiation with natural scenes and to search for useful discriminants to classify targets at a distance. In order to study the polarization response of various targets, the matrix models (i.e., 2 x 2 coherent Jones and Sinclair and 4 x 4 average power density Mueller (Stokes) and Kennaugh matrices etc.) and coherent and incoherent target decomposition techniques has been used. This comes to be the standard tools for targets characterization. Polarimetric decomposition methods allow a physical interpretation of the different scattering mechanisms inside a resolution cell. Thanks to such decompositions, it is possible to extract information related to the intrinsic physical and geometrical properties of the studied targets. This type of information is inestimable if intensity is measured only. The goal of this chapter is to explain the basics of polarimetric theory, outline its current state of the art, and review some of important applications to study the scattering behavior of various man-made and urban targets like buildings (tall and short), ships, oil rigs and spills, mines, bridges, etc. The author considers both optical range and radar polarimetry.

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