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RADIATIVE TRANSFER IN REALISTIC PLANETARY ATMOSPHERES

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During the past six months we have completed an article on the interior radiances within an optically deep absorbing medium scattering according to the Haze L phase function. The dependence on the solar zenith angle, the single scattering albedo, and the optical depth within the medium is calculated by the matrix operator method. The development of the asymptotic angular distribution of the radiance in the diffusion region is illustrated through a number of examples; it depends only on the single scattering albedo and on the phase function for single scattering. The exact values of the radiance in the diffusion region are compared with values calculated from the approximate equations proposed by Van de Hulst. The variation of the radiance near the lower boundary of an optically thick medium is illustrated with examples.

The attenuation length is calculated for various single scattering albedos and compared with the corresponding values for Rayleigh scattering. The ratio of the upward to the downward flux is found to be remarkably constant within the medium. The heating rate is calculated and found to have a maximum value at an optical depth of two within a Haze L layer when the sun is at the zenith. The location of this maximum moves toward the top of the haze layer as the solar zenith angle increases and also as the single scattering albedo decreases. When the single scattering albedo is less than 0.8, the downward flux is so small within the diffusion region that experimental measurements are probably not possible.

Our method for calculating the radiance and color of the twilight sky has been improved and an article on this has been accepted for publication by the Journal of Atmospheric Sciences. These are the only calculations that have been made that include both the effects of refraction on the path of the photon in the earth's atmosphere as well as the important effect of refractive divergence (change in intensity due to focusing effects of atmosphere). Spherical geometry is used throughout these calculations with no plane parallel approximations. Refraction effects are taken into account through fine subdivision of the atmosphere into spherical shells of fixed index of refraction. Snell's law of refraction is used to calculate a new direction of travel each time that a photon traverses the interface between layers. Five different models of the atmosphere were used: a pure molecular scattering atmosphere; molecular atmosphere plus ozone absorption; three models with aerosol concentrations of 1, 3, and 10 times normal together with molecular scattering and ozone absorption. The results of the calculations are shown for various observation positions and local viewing angles in the solar plane for wavelength in the range of 0.40 to 0.75 .

We have extended the matrix operator method to calculate the complete Stokes matrix for an inhomogeneous atmosphere. This has been applied to the calculation of the radiance, polarization and ellipticity of the radiation in the earth's atmosphere as the aerosol amount in the atmosphere varies. The calculations are complete and the results are being analyzed.

The matrix operator method has been used to calculate the radiance, polarization, and ellipticity of the radiation scattered from homogeneous layers scattering according to the Rayleigh phase function and according to the Haze L model. The results have been calculated for layers of various optical thicknesses up to 16. These calculations are complete and the results are being analyzed.

Work has begun on reducing the results of high dispersion spectroscopic observations of Venus. These results include almost 3000 measurements of the lines in the carbon dioxide band at 8689 A and almost 2000 measurements of the carbon dioxide lines at 7820 and 7883 A. These observations can be used to study the variation of the cloud top temperatures on Venus.

Reports Issued

1. Matrix Operator Theory of Radiative Transfer. I. Rayleigh Scattering. Gilbert N. Plass, George W. Kattawar, and Frances E. Catchings.

2. Matrix Operator Theory of Radiative Transfer. II. Scattering from Maritime Haze. George W. Kattawar, Gilbert N. Plass, and Frances E. Catchings.

3. Degree and Plane of Polarization of Multiple Scattered Light. I. Homogeneous Cloud Layers. George W. Kattawar and Gilbert N. Plass.

4. Degree and Plane of Polarization of Multiple Scattered Light. II. Earth's Atmosphere with Aerosols. Gilbert N. Plass and George W. Kattawar.

5. Interior Radiances in Optically Deep Absorbing Media: I. Exact Solutions for One-Dimensional Model. George W. Kattawar and Gilbert N. Plass.

6. Interior Radiances in Optically Deep Absorbing Media. II. Rayleigh Scattering. Gilbert N. Plass, George W. Kattawar, and Judith Binstock.

7. The Influence of Ozone and Aerosols on the Brightness and Color of the Twilight Zone. Charles N. Adams, Gilbert N. Plass, and George W. Kattawar.

8. Phase Matrix Induced Symmetries for Multiple Scattering Using the Matrix Operator Method. Stephen J. Hitzfelder and George W. Kattawar.

9. Interior Radiances in Optically Deep Absorbing Media. III. Scattering from Haze L. George W. Kattawar and Gilbert N. Plass.

Publications

1. Matrix Operator Theory of Radiative Transfer. I. Rayleigh Scattering. Gilbert N. Plass, George W. Kattawar, and Frances E. Catchings, Applied Optics 12, 314-329 (1973).

2. Matrix Operator Theory of Radiative Transfer. II. Scattering from Maritime Haze. George W. Kattawar, Gilbert N. Plass, and Frances E. Catchings. Applied Optics 12, 1071-1084 (1973).

3. Degree and Plane of Polarization of Multiple Scattered Light. I. Homogeneous Cloud Layers. George W. Kattawar and Gilbert N. Plass. Applied Optics 11, 2851-2865 (1972).

4. Degree and Plane of Polarization of Multiple Scattered Light. II. Earth's Atmosphere with Aerosols. Gilbert N. Plass and George W. Kattawar. Applied Optics 11, 2866-2879 (1972).

5. Theorems on Symmetries and Flux Conservation in Radiative Transfer Using the Matrix Operator Theory. George W. Kattawar, Journal of Quantitative Spectroscopy and Radiative Transfer 13, 145-151 (1973).

6. An Explicit Form of the Mie Phase Matrix for Multiple Scattering Calculations in the I, Q, U, and V Representation. George W. Kattawar, Stephen J. Hitzfelder, and Judith Binstock. Journal of The Atmospheric Sciences 30, 289-295 (1973).

7. Interior Radiances in Optically Deep Absorbing Media. I. Exact Solutions for One-Dimensional Model. George W. Kattawar and Gilbert N. Plass. Journal of Quantitative Spectroscopy and Radiative Transfer 13, 1065-1080 (1973).

8. Interior Radiances in Optically Deep Absorbing Media. II. Rayleigh Scattering. Gilbert N. Plass, George W. Kattawar, and Judith Binstock. Journal of Quantitative Spectroscopy and Radiative Transfer 13, 1081-1096 (1973).

(Publications continued)

9. The Influence of Ozone and Aerosols on the Brightness and Color of the Twilight Zone. Charles N. Adams, Gilbert N. Plass, and George W. Kattawar. (Scheduled for Spetember 1974 issue of Journal of Atmospheric Sciences).

10. Interior Radiances in Optically Deep Absorbing Media. III. Scattering from Haze L. George W. Kattawar and Gilbert N. Plass. (Submitted to Journal of Quantitative Spectroscopy and Radiative Transfer).