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Atmospheric Transmittance/Radiance: Computer Code LOWTRAN 5

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Chief Scientist

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report describes a computer code for predicting atmospheric transmittance and the thermal radiation emitted by the atmosphere and earth from 350 to 40,000 cm^{-1} at a spectral resolution of 20 cm^{-1}. The program is based on the LOWTRAN 4 (1978) computer code. New altitude and relative-humidity dependent aerosol models and new fog models are included in the code. In addition, the new code structure consists of a main program and 19 subroutines.

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20. Abstract (Continued)

The computer code contains representative (geographical and seasonal) atmospheric models and representative aerosol models with an option to replace them with user-derived or measured values. The program can be run in one of two modes, namely, to compute only atmospheric transmittance or both atmospheric transmittance and radiance for any given slant path geometry.

Preface

We wish to acknowledge the contributions made by Major Peter Soliz of the Air Force Avionics Laboratory and Major Vernon Bliss of the Foreign Technology Division to the further development of the LOWTRAN model through discussions, comments, and testing of the code presented in this report.

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Atmospheric Transmittance/Radiance:
Computer Code LOWTRAN 5

1. INTRODUCTION

This report describes a Fortran computer code, LOWTRAN 5, designed to calculate atmospheric transmittance and radiance for a given atmospheric path at moderate spectral resolution. This code is an extension of the current LOWTRAN atmospheric code, LOWTRAN 4[1] (and its predecessors LOWTRAN 3B,[2] LOWTRAN 3,[3] and LOWTRAN 2[4]). All the options and capabilities of the LOWTRAN 4 code have been retained. New altitude and relative humidity dependent aerosol models and new fog models have been incorporated into LOWTRAN 5. In addition, extensive restructuring of the code into subroutines has been made for improved logical flow of the program and user understanding.

(Received for publication 20 February 1980)

[1] Selby, J.E.A., Kneizys, F.X., Chetwynd Jr., J.H., and McClatchey, R.A. (1978) Atmospheric Transmittance/Radiance: Computer Code LOWTRAN 4, AFGL-TR-78-0053, AD A058 643.

[2] Selby, J.E.A., Shettle, E.P., and McClatchey, R.A. (1976) Atmospheric Transmittance from 0.25 to 28.5 μm: Supplement LOWTRAN 3B, AFGL-TR-76-0258, AD A040 701.

[3] Selby, J.E.A., and McClatchey, R.A. (1975) Atmospheric Transmittance from 0.25 to 28.5 μm: Computer Code LOWTRAN 3, AFCRL-TR-75-0255, AD A017 734.

[4] Selby, J.E.A., and McClatchey, R.A. (1972) Atmospheric Transmittance from 0.25 to 28.5 μm: Computer Code LOWTRAN 2, AFCRL-TR-72-0745, AD 763 721.

The LOWTRAN code calculates atmospheric transmittance and radiance, averaged over 20-cm^{-1} intervals in steps of 5 cm^{-1} from 350 to 40, 000 cm^{-1} (0.25 to 28.5 μm). The code uses a single-parameter band model for molecular absorption, and includes the effects of continuum absorption, molecular scattering and aerosol extinction. Refraction and earth curvature are included in the calculation for slant atmospheric paths. The code contains representative atmospheric and aerosol models, and the option to replace them with user-derived or measured values.

In this report, the model atmospheres and the new aerosol models in the code are described in Sections 2 and 3. Following this is a discussion of the spherical geometry with refraction used in the program. In Sections 5 and 6, a detailed description of the calculation of atmospheric transmittance and radiance is given. The structure of the computer code is presented in Section 7, with a listing of the code in Appendix A and a definition of symbols used in the main program given in Appendix B. User instructions for the LOWTRAN code are given in Section 8. Examples of the output of the program and illustrations of transmittance and radiance spectra calculated from the code are presented in Sections 9 and 10. A comparison of the new LOWTRAN aerosol models with measurements is made in Section 11. In Section 12, an example of the sensitivity of the code to meteorological input parameters is given. Comments on the use and limitations of the code are given in the last section.

In Appendix C, a segmented loader map of the LOWTRAN code run on the AFGL CDC 6600 is given. A discussion of the method used in the program to calculate water vapor density, relative humidity, and dew-point temperature is contained in Appendix D.

An additional set of stratospheric water vapor profiles for use in LOWTRAN is described in Appendix E. In Appendix F, some previous LOWTRAN transmittance and radiance comparisons with measurements have been reprinted.

The LOWTRAN 5 code will be made available from the National Climatic Center, Federal Building, Asheville, NC 28801. It is requested that users receiving the code, remove cards LOW 320, 330 and 340 from the main program (see Appendix A) and keypunch their name, affiliation, and address on these cards. These cards will be used to update the AFGL LOWTRAN mailing list and for notification to users of changes in the code. They should be mailed to F. X. Kneizys, AFGL/OPI, Hanscom AFB, Bedford, MA 01731.

2. MODEL ATMOSPHERES

The altitude, pressure, temperature, water vapor density, and ozone density for the U.S. Standard atmosphere and five seasonal model atmospheres are provided as basic input data for LOWTRAN. The model atmospheres correspond to the 1962 U.S. Standard atmosphere[5] and the five supplementary models; that is, Tropical (15°N), Midlatitude Summer (45°N, July), Midlatitude Winter (45°N, January), Subarctic Summer (60°N, July), and Subarctic Winter (60°N, January). The different models are digitized in 1-km steps from 0 to 25 km, 5-km steps from 25 to 50 km, then at 70 km and 100 km directly as given by McClatchey et al.[6]

The water vapor and ozone altitude profiles added to the 1962 U.S. Standard atmosphere by McClatchey et al[6] were obtained from Sissenwine et al[7] and Hering et al[8] respectively, and correspond to mean annual values. The water vapor densities for the 1962 U.S. Standard atmosphere correspond to relative humidities of approximately 50 percent for altitudes up to 10 km, whereas the relative humidity values for the other supplementary models tend to decrease with altitude from approximately 80 percent at sea level to approximately 30 percent at 10-km altitude. The Sissenwine profiles are representative of "moist" stratospheric water vapor content. Alternative "dry" stratospheric water vapor profiles are provided in LOWTRAN using subroutine DRYSTR discussed in Appendix E.

The temperature profiles for the six model atmospheres as a function of altitude are shown in Figure 1. The pressure profiles are given in Figure 2. Figures 3a and 3b show the water vapor density vs altitude from 0 to 100 km, and an expanded profile from 0 to 30 km. Figures 4a and 4b and Figures 5a and 5b show similar profiles for ozone and for the uniformly mixed gases.

It is assumed in this report that mixing ratios of the gases, CO_2, N_2O, CH_4, CO, N_2, and O_2 remain constant at all altitudes at the following values: 330, 0.28, 1.6, 0.075, 7.905×10^5, and 2.095×10^5 parts per million respectively. These gases as a whole, with the exception of nitrogen, will be referred to as the uniformly mixed gases.

Measurements made from balloon flights[9], have shown the existence of nitric acid in the earth's atmosphere. Although nitric acid is of only minor importance in atmospheric transmittance calculations, it has been shown to be a significant source of stratospheric emission, particularly in the atmospheric window region from 10 to 12 μm. Therefore, nitric acid has been added to the model atmospheres as a separate atmospheric absorber.

The concentration of atmospheric nitric acid varies with altitude and also appears to depend on latitude and season. Figure 6 shows the volume mixing ratio

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Because of the large number of references cited above, they will not be listed here. See References, page 141.

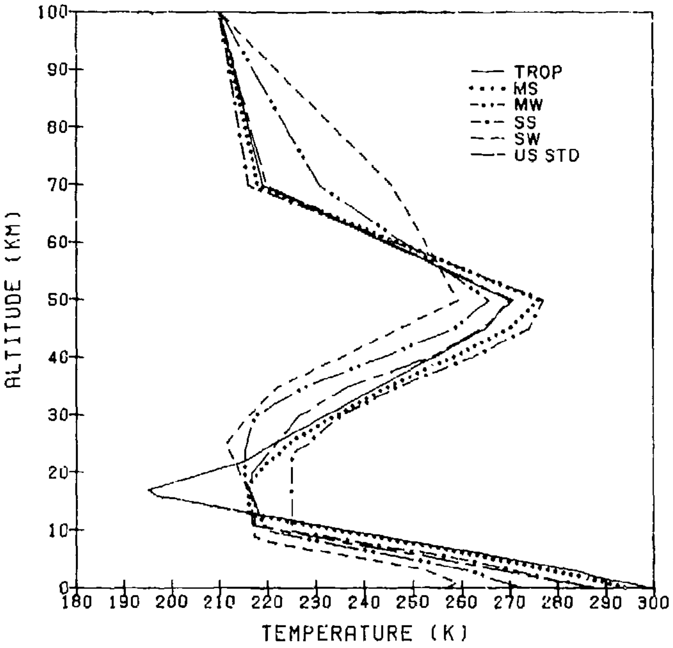

Figure 1. Temperature vs Altitude for the Six Model Atmospheres

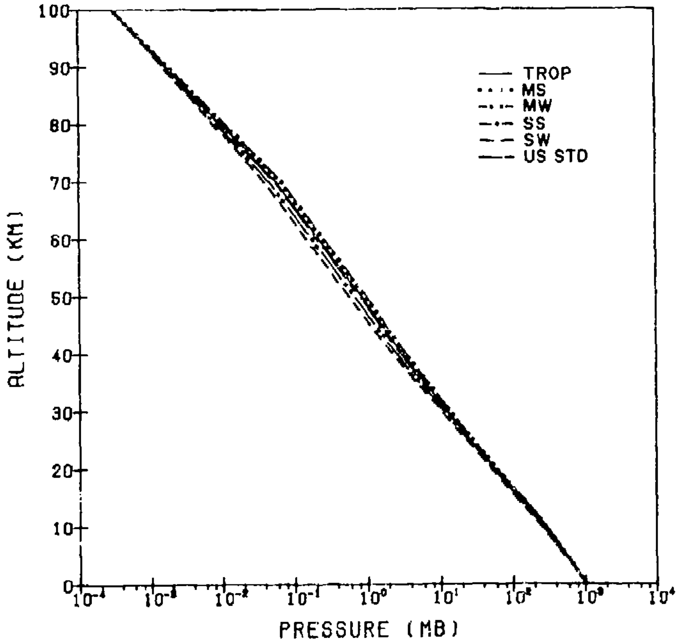

Figure 2. Pressure vs Altitude for the Six Model Atmospheres

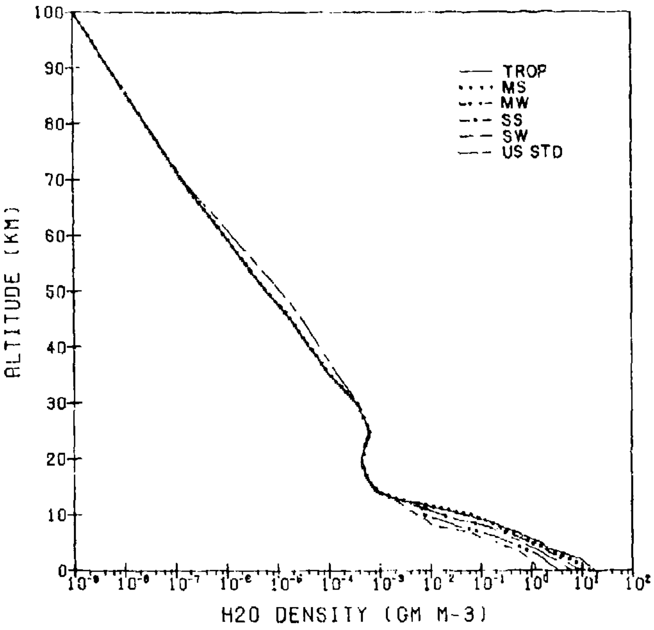

Figure 3a. Water Vapor Density Profiles vs Altitude for the Six Model Atmospheres

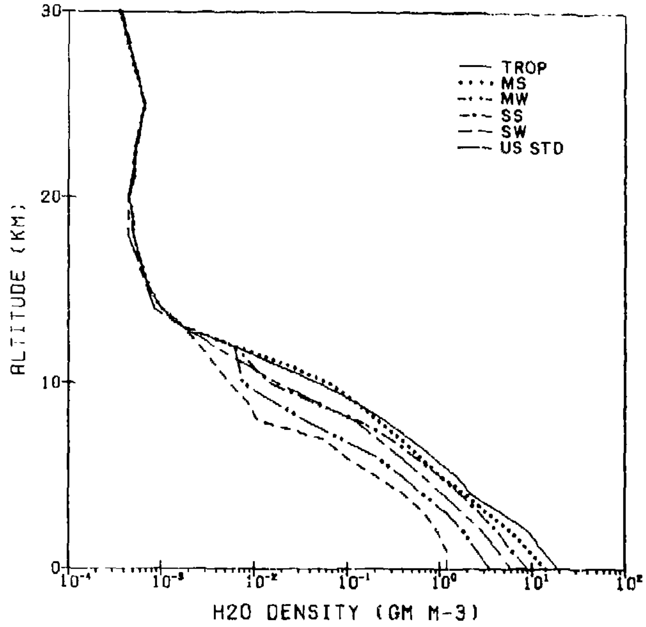

Figure 3b. Water Vapor Density Profiles vs Altitude for the Six Model Atmospheres with the Region from 0 to 30 km Expanded

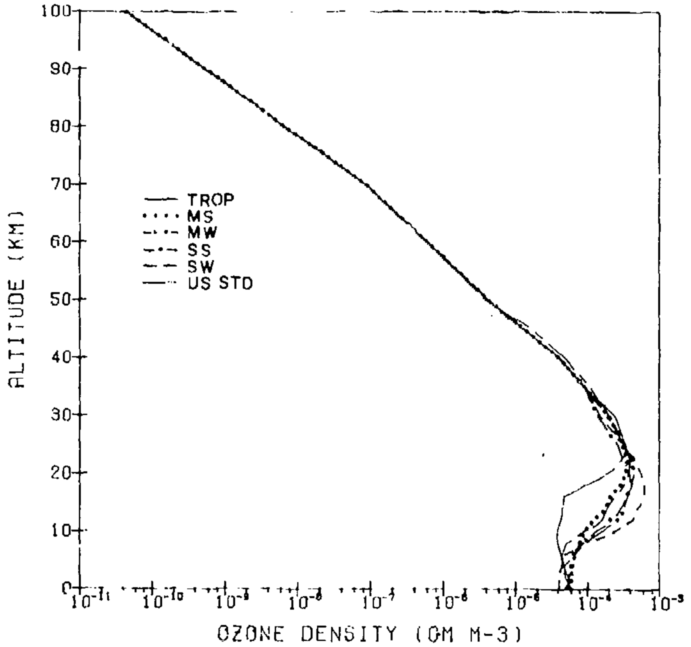

Figure 4a. Ozone Density Profiles vs Altitude for the Six Model Atmospheres

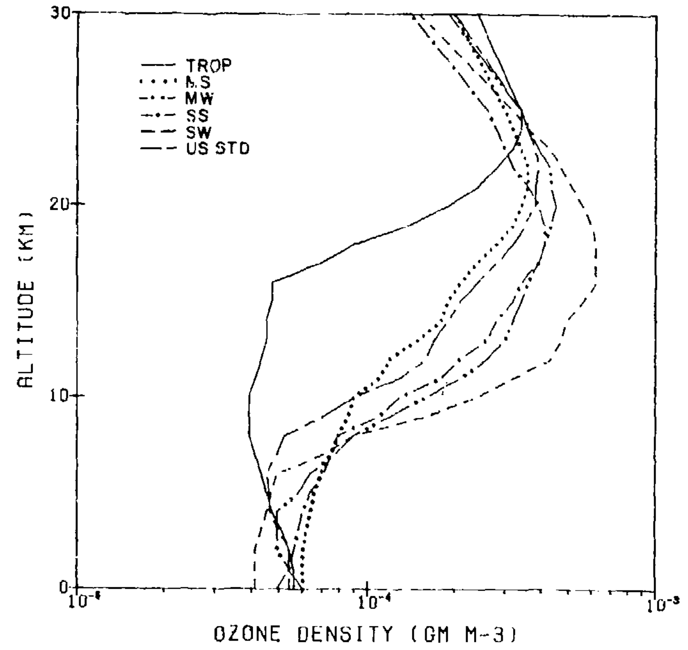

Figure 4b. Ozone Density Profiles vs Altitude for the Six Model Atmospheres with the Region from 0 to 30 km Expanded

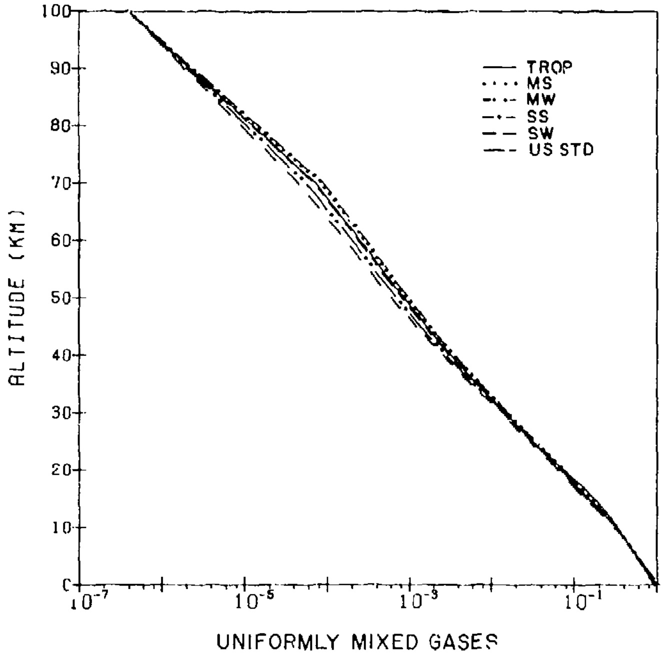

Figure 5a. Profile of $(P/P_0)(T_0/T)$, the Relative Air Density, vs Altitude for the Six Model Atmospheres. The density of the uniformly mixed gases is proportional to this quantity. $P_0 = 1013$ mb and $T_0 = 273$ K

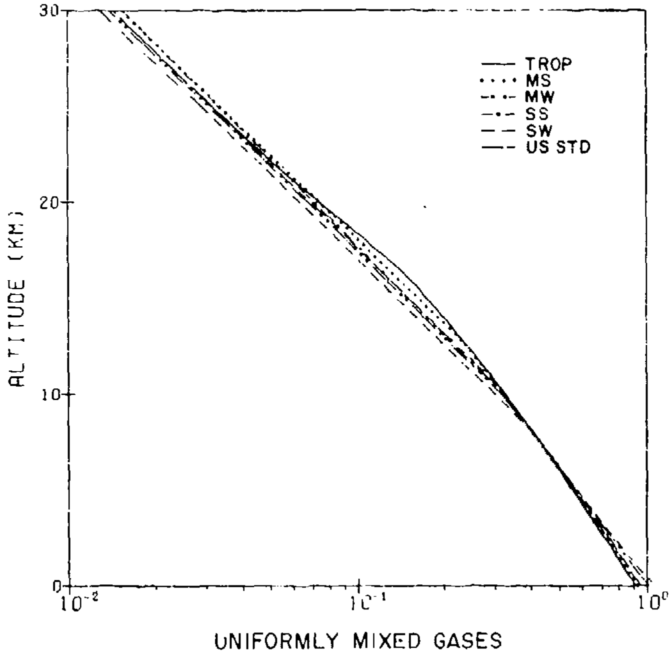

Figure 5b. Profile of $(P/P_0)(T_0/T)$, the Relative Air Density, vs Altitude for the Six Model Atmospheres with the Region from 0 to 30 km Expanded

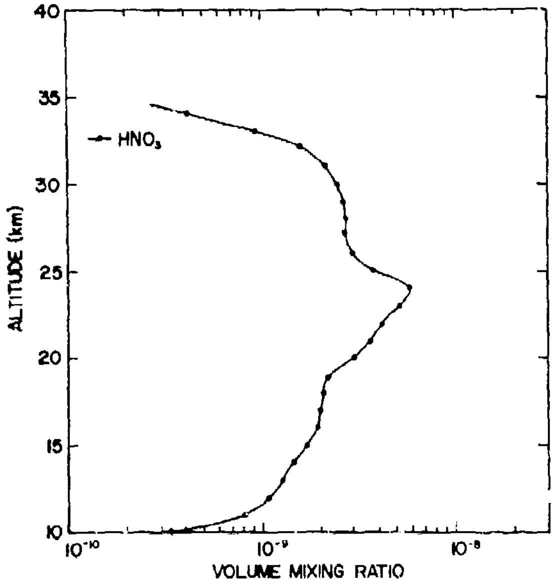

Figure 6. Volume Mixing Ratio Profile for Nitric Acid vs Altitude, from the Measurements of Evans, Kerr, and Wardle[10]. This single profile is used with all of the six model atmospheres

profile of atmospheric nitric acid as a function of altitude from the measurements of Evans, Kerr, and Wardle.[10] For the purpose of this report, we have chosen this profile to represent a mean nitric acid profile for the six model atmospheres in the LOWTRAN program. This profile appears in a data statement in the program. If a more definitive nitric acid profile for a given latitude and season is available, the user can change the nitric acid concentration by simply replacing the data statement given in the program.

In addition to the model atmospheres provided in this report, the user has the option of inserting his own model atmosphere (specifically designed for direct insertion of radiosonde data), or of building another model by combining various parts of the six standard models.

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[10] Evans, W.F., Kerr, J.B., and Wardle, D.I. (1975) The AES Stratospheric Balloon Measurements Project: Preliminary Results, Atmospheric Environment Service, Downsview, Ontario, Canada, Report No. APRB 30 X 4.

3. AEROSOL MODELS

3.1 Introduction

The aerosol models built into LOWTRAN 5 have been completely revised from the earlier versions of the LOWTRAN code. Previous versions of LOWTRAN used the same model for aerosol composition and size distribution at all altitudes, simply changing the concentrations of the aerosols with height which means that the wavelength dependence of the aerosol extinction was independent of altitude.

The variation of the aerosol optical properties with altitude is now modeled by dividing the atmosphere into four height regions each having a different type of aerosol. These regions are the boundary or mixing layer (0 to 2 km), the upper troposphere (2 to 10 km), the lower stratosphere (10 to 30 km), and the upper atmosphere (30 to 100 km).

The earlier versions of LOWTRAN neglected changes in aerosol properties caused by variations in relative humidity. These aerosol models were representative of moderate relative humidities (around 80 percent). The models for the troposphere (rural, urban, maritime and tropospheric) which were previously used in LOWTRAN 3B and 4 have been updated according to more recent measurements and also are now given as a function of the relative humidity. In addition, two different fog models have been introduced into the program.

Only a brief description of the new aerosol models and their experimental and theoretical bases will be presented in this report since they are described elsewhere in detail.[11, 12]

3.2 Vertical Distribution in the Lower Atmosphere

The range of conditions in the boundary layer (up to 2 km) is represented by three different aerosol models (rural, urban, or maritime) for each of several

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11. Shettle, E. P., and Fenn, R. W. (1976) Models of the Atmospheric Aerosols and their Optical Properties, in AGARD Conference Proceedings No. 183 Optical Propagation in the Atmosphere. Presented at the Electromagnetic Wave Propagation Panel Symposium, Lyngby, Denmark, 27-31 October 1975, AGARD-CP-183, available from U.S. National Technical Information Service (No. AD-A028-615).

12. Shettle, E. P., and Fenn, R. W. (1979) Models of the Aerosols of the Lower Atmosphere and the Effects of Humidity Variations on their Optical Properties, AFGL-TR-79-0214, 17 September.

meteorological ranges[*] between 2 and 50 km, and as a function of humidity. In the boundary layer the shape of the aerosol size distribution and the composition of the three surface models are assumed to be invariant with altitude. Therefore only the total particle number is being varied. Although the total number density of air molecules decreases approximately exponentially with altitude, there is considerable experimental data which show that the aerosol concentration very often has a rather different vertical profile. One finds that, especially under moderate to low visibility conditions, the aerosols are concentrated in a uniformly mixed layer from the surface up to about 1- to 2-km altitude and that this haze layer has a rather sharp top, which appears to be associated with the height of the minimum temperature lapse rate.[13]

The vertical distribution for clear to very clear conditions, or meteorological ranges from 23 and 50 km, is taken to be exponential, similar to the profiles used in previous versions of LOWTRAN. However, for the hazy conditions (10-, 5-, and 2-km meteorological ranges) the aerosol extinction is taken to be independent of height up to 1 km with a pronounced decrease above that height.

Above the boundary layer in the troposphere the distribution and nature of the atmospheric aerosols becomes less sensitive to geography and weather variations. Instead, the seasonal variations are considered to be the dominating factor. The aerosol concentration measurements of Blifford and Ringer[16] and Hoffman et al[17]

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[*] The terms "meteorological range" and "visibility" are not always used correctly in the literature. Correctly,[14, 15] visibility is the greatest distance at which it is just possible to see and identify with the unaided eye: (a) in the daytime, a dark object against the horizon sky; and (b) at night, a known moderately intense light source. Meteorological range is defined quantitatively, eliminating the subjective nature of the observer and the distinction between day and night. Meteorological range V is defined by the Koschmieder formula

$$V = \frac{1}{\beta} \ln \frac{1}{\epsilon} = \frac{3.912}{\beta}$$

where β is the extinction coefficient, and ϵ is the threshold contrast, set equal to 0.02. As used in the LOWTRAN computer code, the inputs are in terms of meteorological range, with β, the extinction coefficient, evaluated at 0.55 μm. If only an observer visibility V_{obs} is available, the meteorological range can be estimated as $V \approx (1.3 \pm 0.3) \cdot V_{obs}$.

13. Johnson, R.W., Hering, W.S., Gordon, J.I., and Fitch, B.W. (1979) Preliminary Analysis and Modelling Based Upon Project OPAQUE Profile and Surface Data, AFGL-TR-79-0285, November.

14. Huschke, R.E. (editor) (1959) Glossary of Meteorology, American Meteorlogical Society, Boston, MA, 638 pp.

15. Middleton, W.E.K. (1952) Vision Through the Atmosphere, Univ. of Toronto Press, 250 pp.

16. Blifford, I.H., and Ringer, L.D. (1969) The size and number distribution of aerosols in the continental troposphere, J. Atmos. Sci. 26:716-726.

17. Hofmann, R.J., Rosen, J.M., Pepin, T.J., and Pinnick, R.G. (1975) Stratospheric aerosol measurements I: Time variations at northern latitudes, J. Atmos. Sci. 32:1446-1456.

indicate that there is an increase in the particulate concentration in the upper troposphere during the spring and summer months. This is also supported by an analysis of searchlight data by Elterman et al.[18]

The vertical distribution of the aerosol concentrations for the different models is shown in Figure 7. Between 2 and 30 km, where a distinction on a seasonal basis is made, the spring-summer conditions are indicated with a solid line and fall-winter conditions are indicated by a dashed line.

3.3 Effects of Humidity Variations on Aerosol Properties

The basic effect of changes in the relative humidity on the aerosols, is that as the relative humidity increases, the water vapor condenses out of the atmosphere onto the existing atmospheric particulates. This condensed water increases the size of the aerosols, and changes their composition and their effective refractive index. The resulting effect of the aerosols on the absorption and scattering of light will correspondingly be modified. There have been a number of studies of the change of aerosol properties as a function of relative humidity.[12, 19] The most comprehensive of these, especially in terms of the resulting effects on the aerosol properties is the work of Hänel.[19, 20]

The growth of the particulates as a function of relative humidity is based on the results tabulated by Hänel[19] for different types of aerosols. Once the wet aerosol particle size is determined, the complex refractive index is calculated as the volume-weighted average of the refractive indices of the dry aerosol substance and water.[21]

3.4 Rural Aerosols

The "rural model" is intended to represent the aerosol conditions one finds in continental areas which are not directly influenced by urban and/or industrial aerosol sources. This continental, rural aerosol background is partly the product of reactions between various gases in the atmosphere and partly due to dust particles picked up from the surface. The particle concentration is largely dependent

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[18] 18. Elterman, L., Wexler, R., and Chang, D.T. (1969) Features of tropospheric and stratospheric dust, Appl. Opt. 8:893-903.

[19] 19. Hänel, Gottfried (1976) The properties of atmospheric aerosol particles as functions of the relative humidity at thermodynamic equilibrium with the surrounding moist air, in Advances in Geophysics, Vol 19:73-188, Edited by H. E. Landsberg, J. Van Mieghem, Academic Press, New York.

[20] 20. Hänel, Gottfried (1972) Computation of the extinction of visible radiation by atmospheric aerosol particles as a function of the relative humidity, based upon measured properties, Aerosol Sci. 3:377-386.

[21] 21. Hale, George M., and Querry, Marvin R. (1973) Optical constants of water in the 200-nm to 200-um wavelength region, Appl. Opt. 12:555-563.

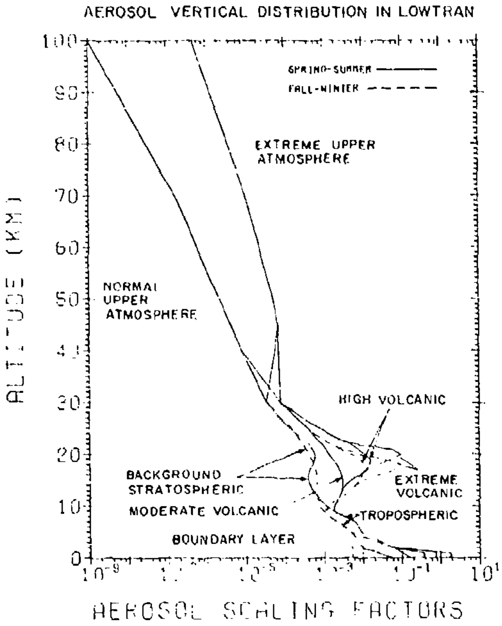

Figure 7a. Vertical Profiles of Aerosol Scaling Factors vs Altitude

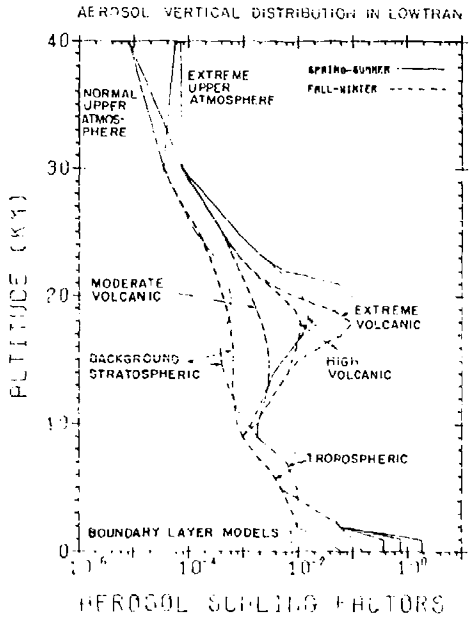

Figure 7b. Vertical Profiles of Aerosol Scaling Factors vs Altitude with the Region from 0 to 40 km Expanded

on the history of the air mass carrying the aerosol particles. In stagnating air masses, for example, under winter-type temperature inversions, the concentrations may increase to values causing the surface layer visibilities to drop to a few kilometers.

The rural aerosols are assumed to be composed of a mixture of 70 percent of water-soluble substance (ammonium and calcium sulfate and also organic compounds) and 30 percent dust-like aerosols. The refractive index for these components is based on the measurements of Volz.[22, 23]

The rural aerosol size distribution is parameterized as the sum of two log-normal size distributions, to represent the multimodal nature of the atmospheric aerosols that has been discussed in various studies. These parameters for rural model size distribution fall within what Whitby and Cantrell[24] give as a typical range of values for the accumulation (small) and coarse (large) particle modes.

To allow for the dependence of the humidity effects on the size of the dry aerosol, the growth of the aerosol was computed separately for the accumulation and coarse particle components. In computing the aerosol growth, changes in the width of the size distribution was assumed negligible so only the mode radius was modified by humidity changes. The effective refractive indices for the two size components are then computed as function of relative humidity.

Using Mie theory for scattering by spherical particles, the extinction and absorption coefficients for each of several different relative humidities were calculated. Figure 8 shows the resulting values for the different relative humidities which are stored in the LOWTRAN code. The values have been normalized to an extinction coefficient of 1.0 at a wavelength of 0.55 μ, which is the way values are used in the program.

3.5 Urban Aerosol Model

In urban areas the rural aerosol background gets modified by the addition of aerosols from combustion products and industrial sources. The urban aerosol model therefore was taken to be a mixture of the rural aerosol with carbonaceous aerosols. The sootlike aerosols are assumed to have the same size distribution as both components of the rural model. The proportions of the sootlike aerosols and the rural type of aerosol mixture are assumed to be 20 percent and 80 percent

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22. Volz, Frederic E. (1972) Infrared absorption by atmospheric aerosol substances, J. Geophys. Res. **77**:1017-1031.

23. Volz, Frederic E. (1973) Infrared optical constants of ammonium sulfate, Sahara dust, volcanic pumice, and flyash, Appl. Opt. **12**:564-568.

24. Whitby, K. T., and Cantrell, B. (1975) Atmospheric aerosols — characteristics and measurement, International Conf. on Environmental Sensing and Assessment, Vol. 2, Las Vegas, Nev., 14-19 September.

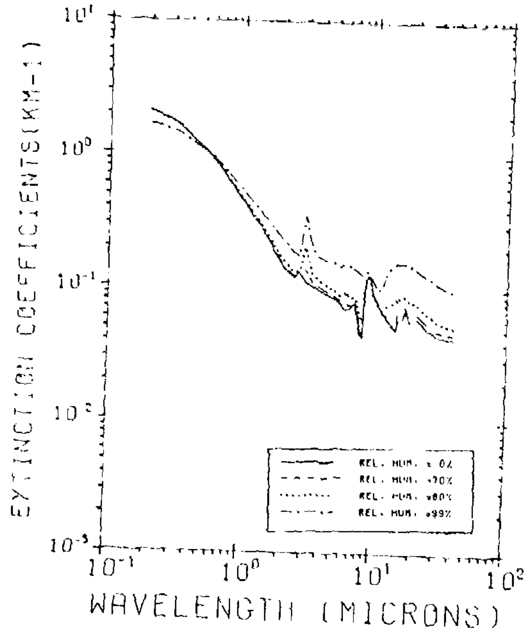

Figure 8a. Extinction Coefficients for the Rural Aerosol Model (Normalized to 1.0 at 0.55 μ)

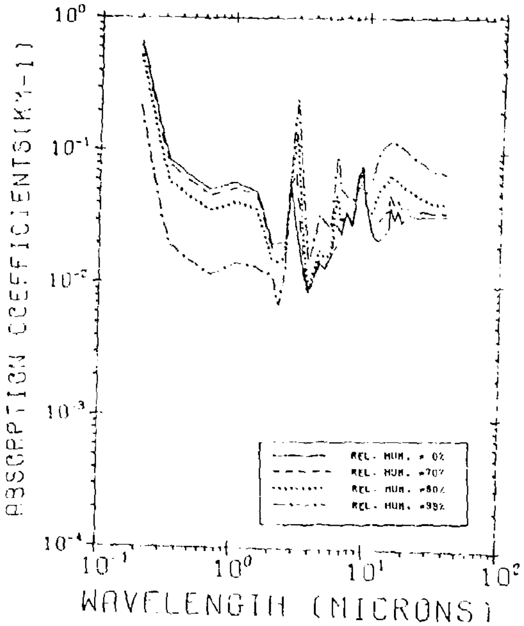

Figure 8b. Absorption Coefficients for the Rural Aerosol Model Corresponding to Figure 8a

respectively. The refractive index of the sootlike aerosols was based on the soot data in Twitty and Weinman's[25] survey of the refractive index of carbonaceous materials.

Figure 9 shows the extinction and absorption coefficients for the urban models vs wavelength. As with the rural model the values are normalized so the extinction coefficient is 1.0, at a wavelength of $0.55\ \mu$.

3.6 Maritime Aerosol Model

The composition and distribution of aerosols of oceanic origin is significantly different from continental aerosol types. These aerosols are largely sea-salt particles which are produced by the evaporation of sea-spray droplets and then have again grown due to accretion of water under high relative humidity conditions. Together with a background aerosol of more or less pronounced continental character they form a fairly uniform maritime aerosol which is representative of the boundary layer in the lower 2 to 3 km of the atmosphere over the oceans, but which also will occur over the continents in a maritime air mass. This maritime model should be distinguished from the direct sea-spray aerosol which exists in the lower 10 to 20 meters above the ocean surface and which is strongly dependent on wind speed.

The maritime aerosol model, therefore, has been composed of two components: one which developed from sea spray; and a continental component which is assumed identical to the rural aerosol with the exception that the very large particles were eliminated, since they will eventually be lost due to fallout as the air masses move across the oceans. This model is similar to the one suggested by Junge[26, 27] and is supported by a large body of experimental data.[12]

The refractive index is the same as that for a solution of sea salt in water, using a volume-weighted average of the refractive indices of water and sea salt. The refractive index of the sea salt is primarily taken from the measurements of Volz.[28] The normalized extinction and absorption coefficients vs wavelength for the maritime aerosols are shown in Figure 10 for several relative humidities.

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25. Twitty, J.T., and Weinman, J.A. (1971) Radiative properties of carbonaceous aerosols, *J. Appl. Meteor.* 10:725-731.

26. Junge, Christian E. (1963) *Air Chemistry and Radioactivity*, 382 pp., Academic Press, New York.

27. Junge, C.E. (1972) Our knowledge of the physico-chemistry of aerosols in the undisturbed marine environment, *J. Geophys. Res.* 77:5183-5200.

28. Volz, Frederic E. (1972) Infrared refractive index of atmospheric aerosol substance, *Appl. Opt.* 11:755-759.

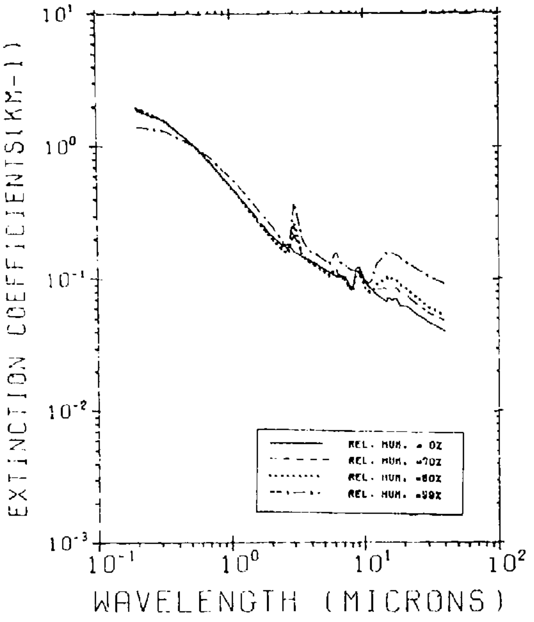

Figure 9a. Extinction Coefficients for the Urban Aerosol Model (Normalized to 1.0 at 0.55 μ)

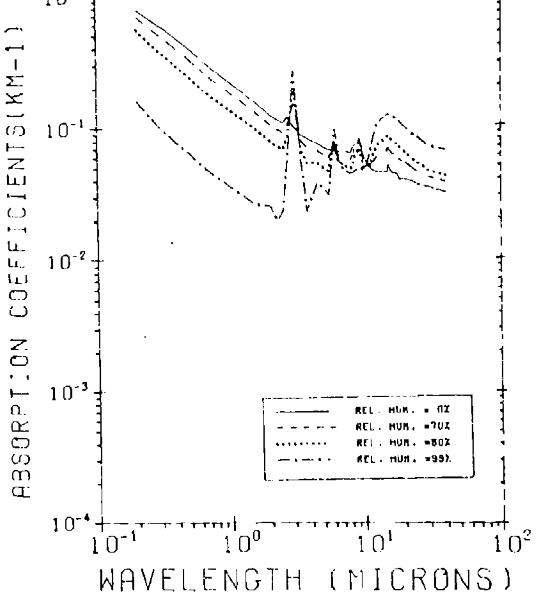

Figure 9b. Absorption Coefficients for the Urban Aerosol Model Corresponding to Figure 9a

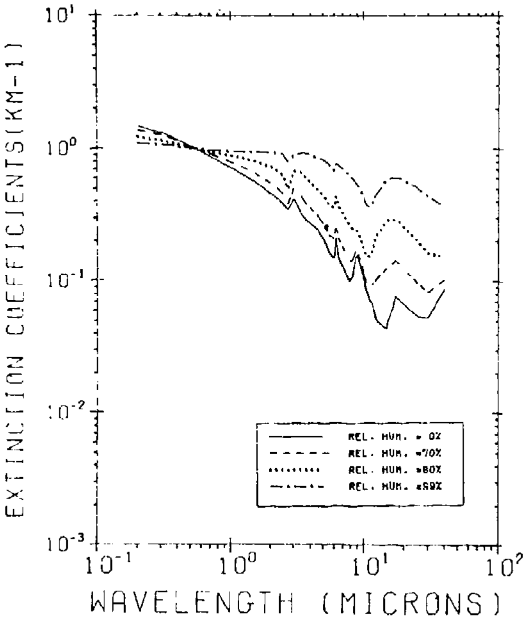

Figure 10a. Extinction Coefficients for the Maritime Aerosol Model (Normalized to 1.0 at 0.55 μ)

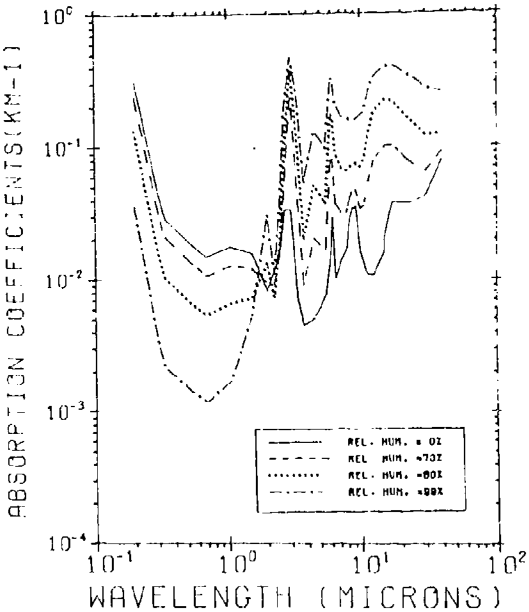

Figure 10b. Absorption Coefficients for the Maritime Aerosol Model Corresponding to Figure 10a

3.7 Tropospheric Aerosol Model

Above the boundary layer in the troposphere, the aerosol properties become more uniform and can be described by a general tropospheric aerosol model. The tropospheric model represents an extremely clear condition and can be represented by the rural model without the large particle component. Larger aerosol particles will be depleted due to settling with time. This is consistent with the changes in aerosol size distribution with altitude suggested by Whitby and Cantrell.[24]

There is some indication from experimental data, that the tropospheric aerosol concentrations are somewhat higher during the spring-summer season than during the fall-winter period.[16, 17] Different vertical distributions are given to represent these seasonal changes (see Section 3.2).

The dependence of the particle size on relative humidity is the same as for the small particle component of the rural model. The resulting normalized extinction and absorption coefficients are shown in Figure 11 for the different relative humidities.

3.8 Fog Models

When the air becomes nearly saturated with water vapor (relative humidity close to 100 percent), fog can form (assuming sufficient condensation nuclei are present). Saturation of the air can occur as the result of two different processes; the mixing of air masses with different temperatures and/or humidities (advection fogs), or by cooling of the air to the point where its temperature approaches the dew-point temperature (radiation fogs).[29]

To represent the range of the different types of fog, we use two of the fog models presented by Silverman and Sprague,[30] following the work of Dyachenko.[31] These were chosen to represent the range of measured size distributions, and correspond to what Silverman and Sprague[30] identified as typical of radiation fogs and advection fogs, although they also describe developing and mature fogs, respectively. The normalized extinction and absorption coefficients for the two fog models are shown in Figure 12 as a function of wavelength.

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[29] Byers, H.R. (1959) General Meteorology, 540 pp., McGraw Hill, New York.

[30] Silverman, B.A., and Sprague, E.D. (1970) Airborne measurement of in-cloud visibility, 271-276, Second National Conference on Weather Modification, Santa Barbara, CA, 6-9 April 1970, American Meteorological Society.

[31] Dyanchenko, P.V. (1962) Experimental Application of the Method of Mathematical Statistics to Microstructural Fog and Cloud Research, Trans. A.I. Voyekova, Main Geophys. Obser.

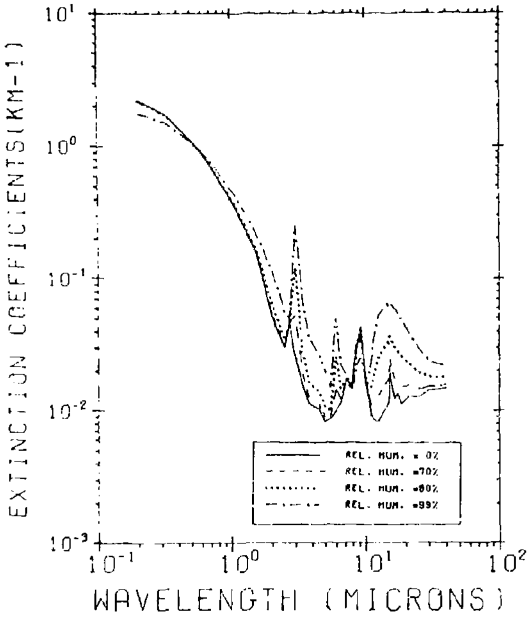

Figure 11a. Extinction Coefficients for the Tropospheric Aerosol Model (Normalized to 1.0 at 0.55 μ)

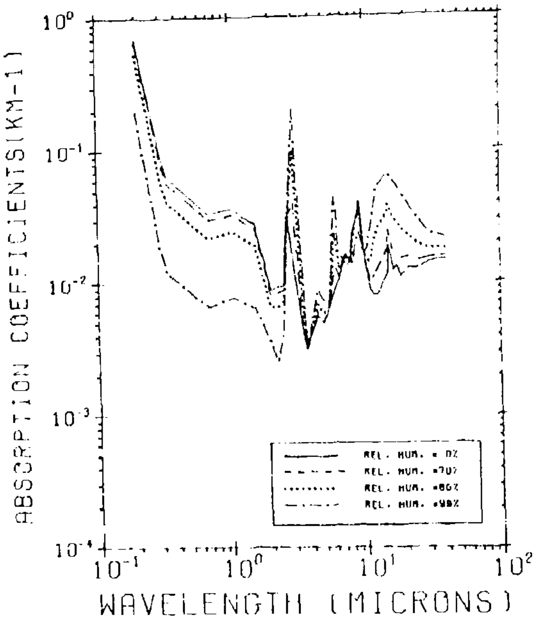

Figure 11b. Absorption Coefficients for the Tropospheric Aerosol Model Corresponding to Figure 11a

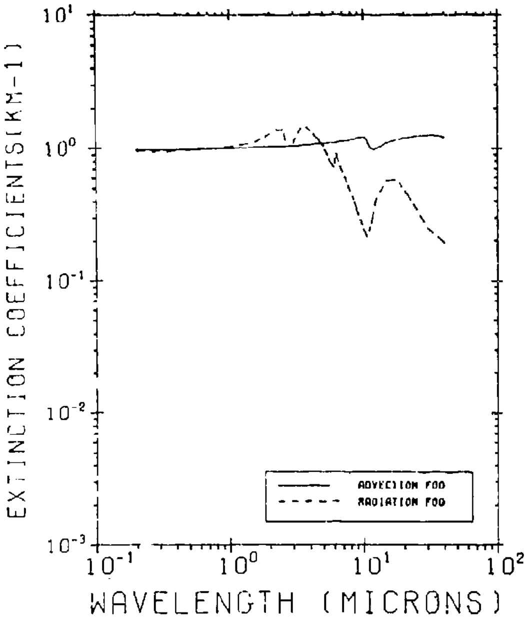

Figure 12a. Extinction Coefficients for the Fog Models (Normalized to 1.0 at 0.55 μ)

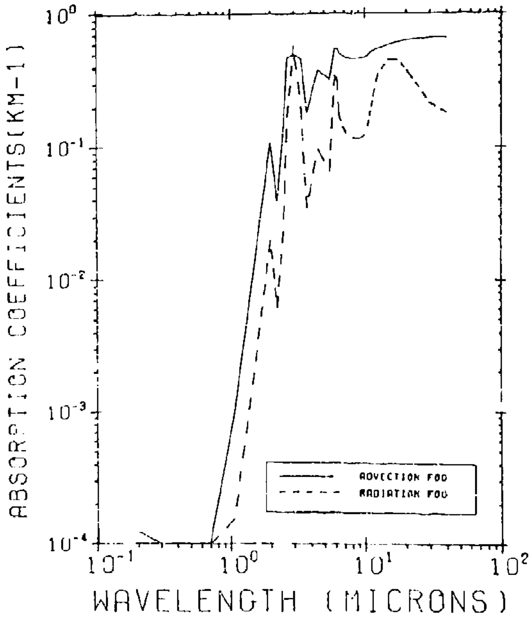

Figure 12b. Absorption Coefficients for the Fog Models Corresponding to Figure 12a

3.9 Aerosol Vertical Distribution in the Stratosphere and Mesosphere

Measurement programs carried out over many years show that in the 10- to 30-km region there exists a background aerosol in the stratosphere which has a rather uniform global distribution. This background aerosol is considered to be mostly composed of sulfate particles formed by photochemical reactions.

These background levels are occasiona[illegible] [illegible]ed by factors of 100 or more due to the injection of dust from massive vol[illegible] [illegible]ptions. Once such particles have been injected into the stratosphere they [illegible] [illegible]ead out over large portions of the globe by the stratospheric circulation and diffusion processes, and it requires months or even years for them to become slowly removed from the stratosphere.[32, 33, 34]

There occurs also a seasonal and geographic variation of the stratospheric aerosol layer which is related to the height of the tropopause; a peak in the aerosol mixing ratio (that is, ratio of aerosol to air molecules) occurs several kilometers above the tropopause.[17, 35]

The range of possible vertical distributions is represented by four different profiles (background stratospheric, moderate, high and extreme volcanic). Each of these distributions is then modified according to the season. The different scaling factors for these vertical profiles are shown in Figure 7.

The vertical distribution in the upper atmosphere above 30 to 40 km is very uncertain because of the difficulty of obtaining reliable data. In situ measurements are limited to those obtained by rocket flights, and these altitudes are beyond the normal operational range of most lidar and searchlight systems which provide most of the remotely sensed data up to 30 or 40 km.

The most likely profile for this region is the one labelled as "Normal Upper Atmosphere" in Figure 7; it corresponds to a constant turbidity ratio of ≈ 0.2 above 40 km. This agrees with the aerosol extinction profile obtained by Cunnold et al[36] by inverting measurements of the horizon radiance from an X-15 aircraft.

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32. Reiter, E.R. (1971) Atmospheric Transport Processes Part 2: Chemical Tracers, U.S. Atomic Energy Commission, Oak Ridge, TN (TID-25314) 382 pp.
33. Volz, F.E. (1975) Distribution of turbidity after the 1912 Katmei Eruption in Alaska, J. Geophys. Res. 80:2643-2648.
34. Volz, F.E. (1975) Burden of volcanic dust and nuclear debris after injection into the stratosphere at 40°-58°N., J. Geophys. Res. 80:2649-2652.
35. Rosen, J.M., Hofmann, D.J., and Laby, J. (1975) Stratospheric measurements II: the worldwide distribution, J. Atmos. Sci. 32:1457-1462.
36. Cunnold, D.M., Gray, C.R., and Merritt, D.C. (1973) Stratospheric aerosol layer detection, J. Geophys. Res. 78:920-931.

Measurements of the solar extinction through the atmospheric limb from the Apollo-Soyuz mission[37] tend to support this model.

Ivlev's[38, 39] model for the upper atmosphere is shown as the curve labelled "Extreme Upper Atmosphere" in Figure 7. It is largely based on twilight observations[40] which neglected multiple-scattering effects. As a consequence, the model has to assume very high particulate concentrations in the upper atmosphere in order to be consistent with observations.

Nevertheless, extinction coefficients for the extreme upper-atmospheric model are consistent with the extreme values that have been observed in layers of a few kilometers thickness by lidar,[41, 42] inferred from rocket observations of skylight,[43, 44] and studies of noctilucent clouds.[45]

3.10 Stratospheric Aerosol Models

3.10.1 COMPOSITION OF BACKGROUND STRATOSPHERIC AEROSOLS

The background stratospheric aerosols are taken to be a 75 percent solution of sulfuric acid in water following the work of Rosen[46] and Toon and Pollack.[47] The complex refractive index as a function of wavelength is based on the measurements of Remsberg[48, 49] and Palmer and Williams.[50]

The size distribution is chosen to be consistent with the concentrations oi the particles with diameters greater than 0.3 μ and those greater than 0.5 μ measured by Hofman et al[17, 35] and the concentration of condensation nuclei observed by Rosen et al[51] and Käselau.[52] The normalized extinction and absorption coefficients are shown in Figure 13.

3.10.2 VOLCANIC AEROSOL MODELS

There are two volcanic size distribution models: a "fresh volcanic model" which represents the size distribution of aerosols shortly after a volcanic eruption; and an "aged volcanic model" representing the aerosol about a year after an eruption. Both size distributions were chosen mainly on the basis of Mossop's[53] measurements following the eruption of Mt. Agung.

The refractive index for these models is based on the measurements of Volz.[23] The resulting normalized extinction and absorption coefficients for these two models are shown in Figure 13.

Because of the large number of references cited above, they will not be listed here. See References, page 141.

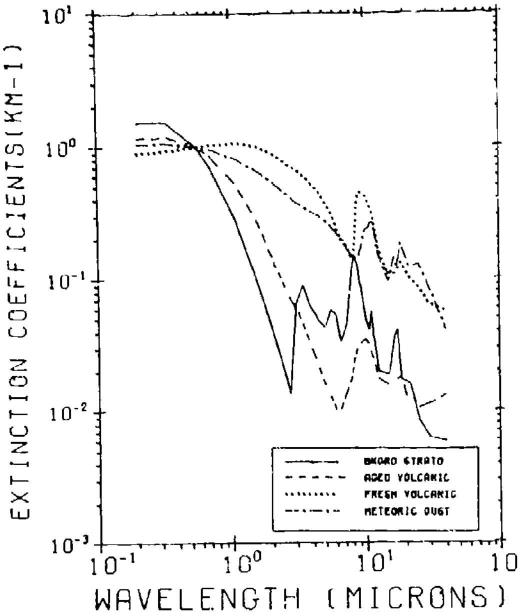

Figure 13a. Extinction Coefficients for the Upper Atmospheric Aerosol Models (Normalized to 1.0 at 0.55 μ)

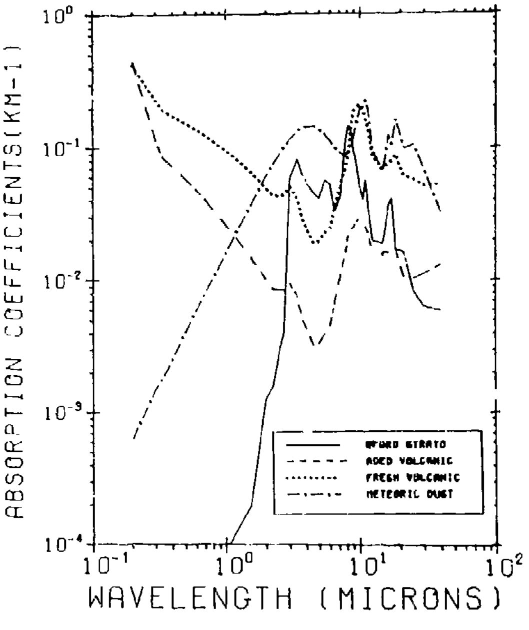

Figure 13b. Absorption Coefficients for the Upper Atmospheric Aerosol Models Corresponding to Figure 13a

3.11 Upper Atmosphere Aerosol Model

The major component of the normal upper-atmospheric aerosols is considered to be meteoric dust, which is consistent with the conclusions reached by Newkirk and Eddy[54] and later Rosen[55] in his review article. Meteoric or cometary dust also form some of the layers occasionally observed in the upper atmosphere. Poultney[42, 56] has related the lidar observations of layers in the upper atmosphere either to cometary sources of micrometeoroid showers or noctilucent cloud observations. Divari et al[57] have related observations of increased brightness of the twilight sky to the Orinid meteor shower.

The refractive index of meteoric dust is based on the work of Shettle and Volz[58] who determined the complex refractive index for a mixture of chondrite dust which represents the major type of meteorite falling on the earth.[59]

The size distribution is similar in shape to the one developed by Farlow and Ferry[60] by applying Kornblum's[61, 62] theoretical analysis (of the micrometeoroid interaction with the atmosphere and their resulting concentration in the mesosphere) to the NASA[63] model of the meteoroid influx to the atmosphere. There are two important differences between the present size distribution model and Farlow and Ferry's.[60] First, the present model has proportionately more smaller particles,

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54. Newkirk, G. Jr., and Eddy, J.A. (1964) Light Scattering by Particles in the Upper Atmosphere, J. Atmos. Sci. 21:35-60.

55. Rosen, J.M. (1969) Stratospheric dust and its relationship to the meteoric influx, Space Sci. Rev. 9:58-89.

56. Poultney, S.K. (1974) Times, locations and significance of cometary micrometeoroid influxes in the earth's atmosphere, Space Res. 14:707-708.

57. Divari, N.B., Zaginalio, Yu. I., and Koval'chuk, L.V. (1973) Meteoric dust in the upper atmosphere, Solar System Res. 7:191-195. (Translated from Astronomicheskii Vestnik 7:223-230).

58. Shettle, E.P., and Volz, F.E. (1976) Optical constants for a meteoric dust aerosol model, in Atmospheric Aerosols: Their Optical Properties and Effects, a Topical Meeting on Atmospheric Aerosols sponsored by Optical Society of America and NASA Langley Research Center, Williamsburg, Virginia, 13-15 December 1976, NASA CP-2004.

59. Gaffey, M.J. (1974) A Systematic Study of the Spectral Reflectivity Characteristics of the Meteorite Classes with Applications to the Interpretation of Asteroid Spectra for Mineralogical and Petrological Information, Ph.D Thesis, M.I.T.

60. Farlow, N.H., and Ferry, G.V. (1972) Cosmic dust in the mesophere, Space Res. 12:369-380.

61. Kornblum, J.J. (1969) Micrometeoroid interaction with the atmosphere, J. Geophys. Res. 74:1893-1907.

62. Kornblum, J.J. (1969) Concentration and collection of meteoric dust in the atmosphere, J. Geophys. Res. 74:1908-1919.

63. National Aeronautics and Space Administration (1969) Meteoroid Environment Model, 1969 (Near Earth to Lunar Surface), NASA SP-8013 (March 1969).

and second, the number densities for all size ranges are several orders of magnitude larger than in Farlow and Ferry's[60] model. These differences are consistent with rocket observations in the upper atmosphere.[60, 64, 65]

The normalized extinction and absorption coefficients for this meteoric dust model for the aerosols of the upper atmosphere are shown in Figure 13 as a function of wavelength.

3.12 Use of the Aerosol Models

The aerosol models defined in this report are representative of various general types of environments. Yet, the simple question: "Which model should be used for what location and weather situation?" is difficult to answer precisely. Some discussion on this point is necessary to give the user some guidance in choosing the appropriate model for a given condition.

3.12.1 BOUNDARY LAYER MODELS

For the boundary layer of the atmosphere up to 1 to 2 km above the surface, the composition of the aerosol particles is primarily controlled by sources (natural and man-made) at the earth's surface. The aerosol content of the atmosphere at a given location, will therefore depend on the trajectory of the local air mass during the preceding several days, and the meteorological history of the air mass. The amount of mixing in the atmosphere is controlled by the temperature profile and the winds. Precipitation will tend to wash the aerosol out of the atmosphere, although it should be noted that "frontal showers" often mark the boundary between two different air masses with generally different histories and correspondingly different aerosol contents.

The "rural" and the "urban" model are intended to distinguish between aerosol types of natural and man-made origin over a land area. Clearly, the man-made aerosol will be predominantly found in urban-industrial areas. However, it is quite likely that after the passage of a cold front, clear polar air also covers an urban area and that therefore the rural aerosol model, which is free of the component of industrial-carbonaceous aerosols, is more applicable. After a few days, as the clean air mass begins to accumulate local pollution however, the urban model will once again become more representative.

Conversely, very often the pollution plume from major urban-industrial areas may, under stagnant weather conditions, diffuse over portions of a continent (for example, Central Europe, Northeastern United States), including its rural sections.

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[64] Soberman, R.K., and Hemenway, C.L. (1965) Meteoric dust in the upper atmosphere, J. Geophys. Res. 70:4943-4949.

[65] Lindblad, B.A., Arinder, G., and Wiesel, T. (1973) Continued rocket observations of micrometeorites, Space Res. 13:1113-1120.

There is also a distinct difference between the composition of aerosols over the ocean and those over land areas due to the different surface-based sources. Aerosols in maritime environments have a very pronounced component of sea-salt particles from the sea water. Sea-salt particles are formed from sea spray from breaking waves. The larger particles fall out, but the smaller particles are transported up with the atmospheric mixing in the boundary layer. In coastal regions the relative proportions of particles of continental and oceanic origins will vary, depending on the strength and direction of the prevailing winds at time of observation.

While changes in visibility are often associated with changes in the relative humidity, (as the relative humidity approaches 100 percent the visibility tends to decrease), it is not possible to define a unique functional relationship between the visibility and relative humidity in the natural atmosphere. The reason for this is that any change in atmospheric moisture content is generally also associated with a change in the aerosol population itself due to change of the air mass. Only if the aerosol is contained in a closed system, where only the humidity changes, can such a unique relationship be developed. The measurements presented by Filippov and Mirumyants[66] clearly illustrate the difficulties in defining a simple unique expression relating visibility and relative humidity.

3.12.2 TROPOSPHERIC AEROSOL MODEL

The tropospheric aerosol model has been developed primarily for application in the troposphere, above the boundary layer, where the aerosols are not as sensitive to local surface sources. However, the tropospheric model should be used near ground level for particularly clear and calm conditions (in pollution-free areas with visibilities greater than 30 to 40 km), where there has been little turbulent mixing for a period of 1 to 2 days, permitting the larger particles to have settled out of the atmosphere without being replaced by dust blown into the air from the surface. (The sedimentation rate of a 10-μm radius aerosol particle in the lower troposphere is approximately 1 km per day.[67])

3.12.3 FOG MODELS

The fog models described in Section 3.9 were presented in terms of the atmospheric conditions leading to the development of the fog, so this provides a good basis for deciding which fog model to use. In more general terms, the visibilities will be less than 200 m for thick fogs and the extinction will be virtually

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66. Filippov, V.L., and Mirumyants, S.O. (1972) Aerosol extinction of visible and infrared radiation as a function of air humidity, Izv. Atmos. Oceanic Phys. **8**:571-574.

67. Kasten, F. (1968) Falling speed of aerosol particles, J. Appl. Meteor. **7**:944-947.

independent of wavelength. For these conditions the advection fog model should be used. For light to moderate fogs, the visibility will be 200 to 1000 m and there will be a noticeable difference between the extinction for visible wavelengths and in the 8- to 12-μm window. For such cases the radiation fog model should be used. For thin fog conditions where the visibility may be 1 to 2 km, the 99 percent relative humidity aerosol models may represent the wavelength dependence of the atmospheric extinction as well as any of the fog models.

3.12.4 STRATOSPHERIC AND UPPER ATMOSPHERE MODELS

The background stratospheric model is representative of present (1980)* stratospheric conditions. At irregular intervals (on the order of years) there are volcanic eruptions which inject significant amounts of aerosols into the stratosphere. For the first few months following such an eruption the fresh volcanic size distribution model would generally be the best one to use, and for the next year or so after that the aged volcanic size distribution model should be used.

The choice of which vertical distribution profile to use would depend on the severity of the volcanic eruption and how long ago it was. The moderate volcanic profile is representative of the stratospheric conditions throughout the Northern Hemisphere during the mid and late 1960's following the eruption of Mt. Agung. It is also typical of conditions during late 1974 and 1975 after the Volcan de Fuego eruption.

The high and extreme volcanic models are somewhat speculative as there have been no direct measurements of the vertical distribution of aerosol for such conditions. They are however consistent with the total optical thickness for aerosols inferred shortly after several major volcanic eruptions,[33, 34, 68] such as Katmai and Krakatoa, as well as the effects of Mt. Agung in the Southern Hemisphere.

3.12.5 SEASONAL AND LATITUDE DEPENDENCE OF AEROSOL VERTICAL DISTRIBUTION

In the mid-latitudes as the names suggest the spring-summer aerosol vertical profiles are intended to be used during the spring and summer seasons and the fall-winter profiles used during the fall and winter seasons. However, the seasonal changes in aerosol distribution are partially a reflection of the changes in

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[*] Note added in Proof. The eruption of Mt. St. Helens (May 1980) injected significant amounts of volcanic dust into the atmosphere. However, it appears most of it remained in the troposphere where it can be expected to settle out or be washed out within a few weeks. On the basis of the limited quantitative information available at this early date, a best guess would be to use the moderate volcanic profile to represent the amount added to the stratosphere.

68. Diermendjian, D. (1973) On volcanic and other turbidity anomalies, <u>Advances in Geophys.</u> <u>16</u>:267-296.

Table 1. Typical Conditions for Aerosol Model Applications

1. Lower Atmospheric Models

1.1 Rural Model

1) Natural environment, midlatitude, overland.
2) Clean air in urban regions, following passage of a cold front.

1.2 Urban Model

1) Urban industrial aerosol.
2) Stagnant polluted air extending into rural regions.

1.3 Maritime Model

1) Mid-ocean (at least 300 km offshore) with moderate winds (above the first 10 to 20 meters).
2) Continental areas under strong prevailing wind from the ocean.

1.4 Tropospheric Model

1) Atmospheric region between top of boundary layer (approximately 2 km) and tropopause (8-18 km, depending on latitude and season).

2) Clean, calm air (meteorological range ≥ 40 km) in surface layer over land.

1.5 Fog Models

1.5.1 Advective Fog

1) Mixing of air masses of different moisture content and temperature, leading to saturation.
2) Lacking specific knowledge on the formation process, for mature fogs with meteorological range: $V \leq 200$ meters.

1.5.2 Radiation Fog

1) Radiational cooling of the air to the dew point at night.
2) Lacking specific knowledge on the formation process, for developing fogs or meteorological ranges: $200 \leq V \leq 1000$ meters.

1.5.3 99 Percent Relative Humidity Aerosol Models

1) Light fogs ($1 \leq V \leq 2$ km).

2. Stratospheric and Mesopheric Aerosol Models

2.1 Background Stratospheric Model

For time periods without any direct influence of volcanic dust contamination, for example, 1977 to present (1980). (See footnote pg. 39)

2.2 Moderate Volcanic Profile with Fresh Aged Particle Size Distribution

For optical thickness approximately 0.03, up to a few years after eruption, for example, Northern Hemisphere, 1964 to 1968.

2.3 High Volcanic Profile and Fresh or Aged Particle Size Distribution

For optical thickness approximately 0.1, up to a few months after eruption, for example, Southern Hemisphere, 1964-1965.

2.4 Extreme Volcanic Profile with Fresh Particle Size Distribution

For optical thickness approximately 0.3 or higher, up to a few weeks after a major eruption, for example, 1883 (Krakatoa) or 1912 (Katmai).

the tropopause height (especially for stratospheric aerosols). So in the tropical regions where the tropopause is generally higher, it is recommended that the spring-summer aerosol profile be used. Analogously is the subarctic regions where the tropopause is lower, it is recommended that the fall-winter profile be used.

3.12.6 GENERAL REMARKS ON APPLICABILITY OF THE AEROSOL MODELS

Typical conditions for which the different aerosol models apply as discussed in detail above are summarized in Table 1. However, it must be emphasized that these models only represent a simplified version of typical conditions. It is not practical to include all the details of natural aerosol distributions nor are existing experimental data sufficient to describe the frequency of occurrence of the different conditions. While these aerosol models were developed to be as representative as possible of different atmospheric conditions, it should be kept in mind that the "rural" aerosol model does not necessarily exactly reproduce the optical properties in a given rural location at a specific time and date, any more than the mid-latitude summer model atmosphere would exactly reproduce the actual temperature and water vapor profiles for that same specific time and location.

4. GEOMETRY

In general, earth curvature has a greater influence on the path length (and hence on the transmittance) than atmospheric refraction. For long slant paths with zenith angles close to 90° in the lower layers of the atmosphere, however, refractive effects can cause a significant increase in the path length (up to 30 percent for a 90° path to space from ground level). Figure 14 shows the effect of atmospheric refraction on defining the minimum height of a path trajectory from space. The minimum height referred to here is also known as the tangent height. In Figure 14 the difference between the geometrical (no refraction) and the actual minimum height is plotted against the actual minimum height for three different model atmospheres. The sketch in the upper right-hand corner of Figure 14 indicates that there is also a discrepancy in the earth center angle β subtended by the trajectory, when refraction is significant. The difference $\beta - \beta'$ shown in Figure 14 is equal to the total angular deviation ψ of the trajectory due to refraction.

For many applications it is necessary to account not only for the effect of refraction and earth curvature on the transmittance over a given path trajectory, but also on the purely geometrical aspects of the trajectory itself. For example, the total deviation ψ, angle of arrival ϕ, or angle β subtended by the path trajectory may be required as illustrated in Figure 15. LOWTRAN calculates the quantities

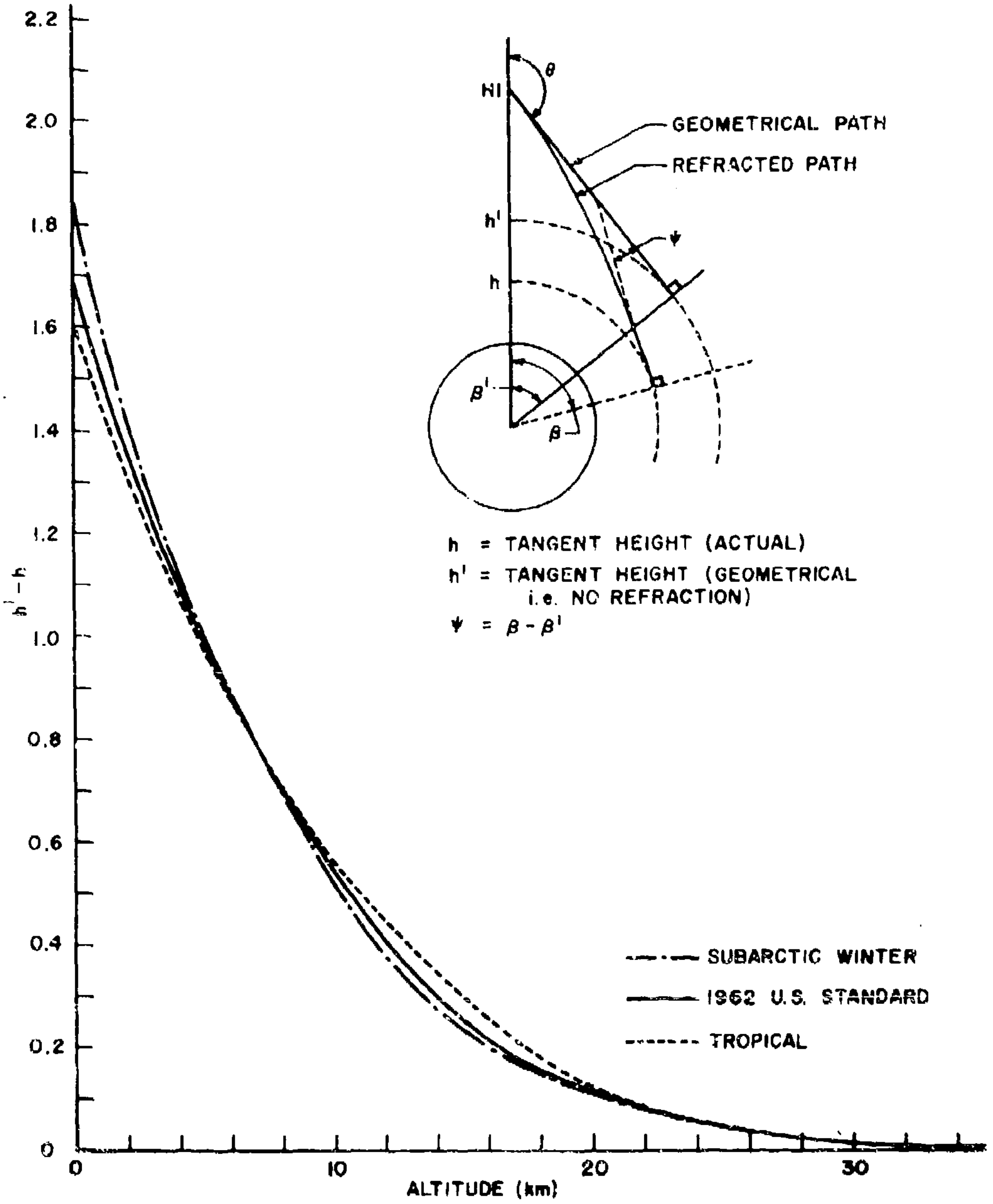

Figure 14. The Difference Between Unrefracted and Refracted Tangent Height Positions as a Function of Altitude for Three Model Atmospheres Based on the 33-Layer Model

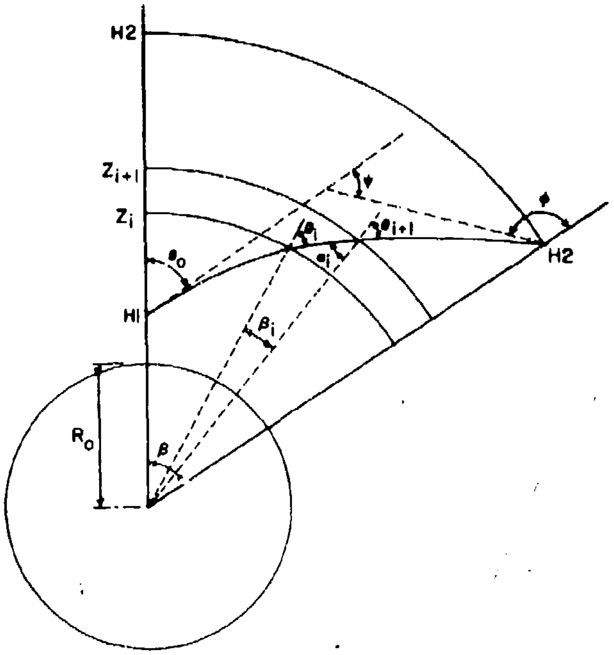

Figure 15. General Schematic of a Refracted Path From Altitudes H1 to H2 Showing the Angles Defining the Trajectory

ψ, ϕ, β and slant range on the basis of a layered atmosphere in the following paragraphs.

The earth's atmosphere is assumed to be divided into a series of concentric spherical layers for each of which a mean refractive index is defined. However, the non-sphericity of the earth is taken into account to some extent by using a different earth radius for each latitude (associated with a given model atmosphere).

Consider the trajectory of a ray passing from heights H1 to H2 at an initial zenith angle θ_o. Let z_i and z_{i+1} define the boundary heights of a given layer, and let θ_i and θ_{i+1} be the local zenith angles at the respective boundaries (see Figure 15). Then at a height of z_{i+1}, the angle of refraction is θ_{i+1}. The angle of incidence α_i at height z_{i+1} can be defined as

$$\sin \alpha_i = (R_o + z_i) \sin \theta_i / (R_o + z_{i+1}) \quad . \tag{1}$$

Applying Snell's law at boundary z_{i+1}, we have

$$n_i \sin \alpha_i = n_{i+1} \sin \theta_{i+1} \tag{2}$$

where n_i and n_{i+1} are the mean refractive indices of the layers above z_i and z_{i+1} respectively.

Substituting for $\sin \alpha_i$ in Eq. (2), we have

$$n_i(R_o + z_i) \sin \theta_i = n_{i+1} (R_o + z_{i+1}) \sin \theta_{i+1} \quad . \tag{3}$$

It follows from symmetry that

$$\begin{aligned} n_i(R_o + z_i) \sin \theta_i &= n_{i-1} (R_o + z_{i-1}) \sin \theta_{i-1} \\ &= n_o (R_o + H1) \sin \theta_o \\ &= \text{const} \quad . \end{aligned} \tag{4}$$

Therefore, the angle of refraction at any level z can be written in terms of the initial input conditions and the refractive index n_o of the layer above H1 as

$$\sin \theta = n_o (R_o + H1) \sin \theta_o / n(R_o + z) \quad . \tag{5}$$

The angle β_i subtended at the center of the earth by the intersection of the ray with the layer z_i to z_{i+1} is given by

$$\beta_i = \theta_i - \alpha_i \quad . \tag{6}$$

Thus the total earth center angle subtended by the ray when traversing the atmosphere from H1 to H2 is

$$\beta = \sum_i^{m-1} (\theta_i - \alpha_i) \tag{7}$$

$$= \sum_i^{m-1} [\sin^{-1} \{A/n_i(R_o + z_i)\} - \sin^{-1} \{A/n_i(R_o + z_{i+1})\}] \tag{8}$$

where m is the number of levels between H1 and H2, and $A = n_o(R_o + H1) \sin \theta_o$.

The angle of arrival ϕ of the ray at H_2 is given by

$$\phi = 180^\circ - \sin^{-1} \{A/n_{m-1}(R_o + H2)\} \quad . \tag{9}$$

The total angular deviation of the trajector ψ is given by

$$\psi = \beta - \phi - \theta_o + 180 \quad . \tag{10}$$

The effective path length between levels z_i and z_{i+1} is given by

$$DS_i = (R_o + z_{i+1}) \sin \beta_i / \sin \theta_i \text{ for } 0^\circ < \theta < 180^\circ \tag{11}$$

for $\theta = 0^\circ$ and 180°, $DS_i = z_{i+1} - z_i$. If we assume that the equivalent absorber amount per unit path length ω for a given gas varies exponentially with altitude, we can write

$$\int_{z_i}^{z_{i+1}} \omega \, dz = H_i [\omega(z_i) - \omega(z_{i+1})] \tag{12}$$

where $H_i = (z_{i+1} - z_i)/\log_e [\omega(z_i)/\omega(z_{i+1})]$. The amount of absorber W_i along a path of length DS_i between altitudes z_i and z_{i+1} is therefore given by

$$W_i = \int_0^{DS_i} \omega \, ds$$

$$= \frac{DS_i}{z_{i+1} - z_i} \int_{z_i}^{z_{i+1}} \omega \, dz$$

$$= \frac{DS_i[\omega(z_i) - \omega(z_{i+1})]}{\log_e[\omega(z_i)/\omega(z_{i+1})]} \quad . \tag{13}$$

The total equivalent absorber amount W for a given atmosphere path is given by the sum of the W_i values for all layers; that is, $W = \sum_{i=1}^{m-1} W_i$ where m is the number of of levels traversed by the path.

4.1 Refractive Index of Air

The following simplified version of Edlen's[69] expression for the refractive index of air is used in LOWTRAN

$$(n_a - 1)\, 10^{+6} = \left(77.46 + \frac{0.459}{\lambda^2}\right) \frac{P}{T} - \frac{p_{H_2O}}{1013} \left(43.49 - \frac{0.347}{\lambda^2}\right) \quad , \qquad (14)$$

where p_{H_2O} and P refer respectively to the partial pressure of water vapor and atmospheric pressure in millibars, T is atmospheric temperature in degrees Kelvin, and λ is the wavelength in micrometers (μm).

The above expression has been used over the entire wavelength range 0.2 to 28.5 μm in LOWTRAN. Although Edlen's[69] expression for the refractive index of air is widely used in both the visible and infrared spectral regions, it is questionable how far it should be used into the untraviolet and into the far infrared since the formula is based primarily on measurements made in the visible part of the spectrum from 0.43 to 0.8 μm.

4.2 Geometrical Path Configurations

When using LOWTRAN, the type of atmospheric path for which a calculation is to be made must be specified according to one of the three broad categories listed below.

TYPE 1. Horizontal path; that is, a constant pressure path where the effects of earth curvature and refraction are negligible.

TYPE 2. Slant paths between two altitudes from H1 to H2.

TYPE 3. Slant paths to space from initial altitude H1.

The variations within the latter two categories for both upward and downward path trajectories can be seen from Figure 16.

It will be noted that two trajectories are possible for a given set of input parameters, H1, H2, and θ for a downward looking path (TYPE 2), provided that H2 lies between H1 and the minimum height, HMIN.

In most instances, the reader will not be aware that two paths are possible for a given set of input conditions. For such a case, LOWTRAN will execute the shorter path condition (Figure 16d) and print out a message to the effect that the case shown in Figure 16e does exist. Should the reader decide to run the latter case, he need only set the parameter LEN equal to unity and resubmit the case.

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[69] Edlen, B. (1966) Metrologia 2:12.

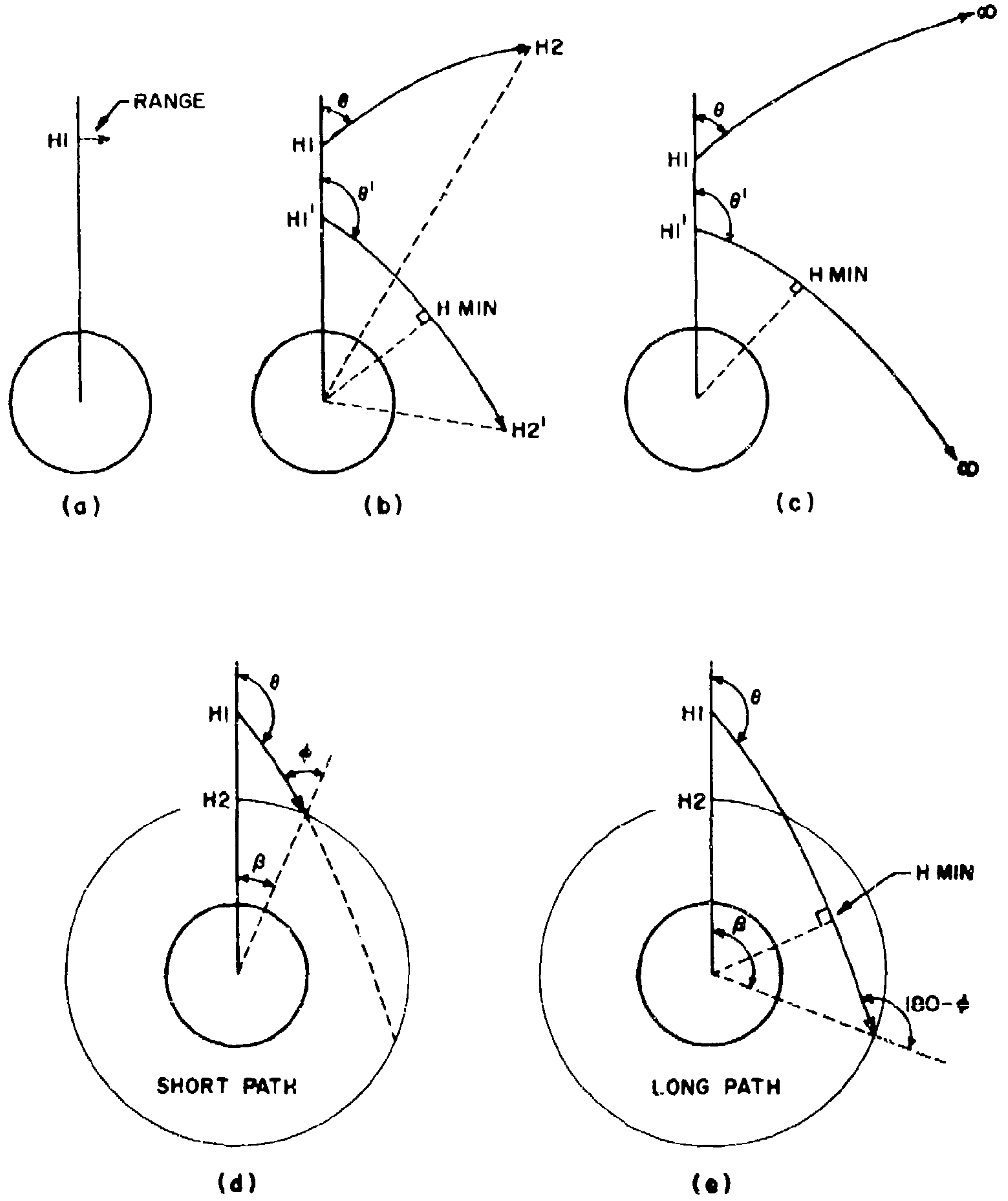

Figure 16. Geometrical Path Configurations: (a) Horizontal Paths, (b) Slant Paths Between Two Altitudes H1 and H2, (c) Slant Paths to Space, (d) A Possible Trajectory for a Downward-Looking Short Path where HMIN < H2 < H1, and (e) A Possible Trajectory for a Downward-Looking Long Path Where HMIN < H2 < H1

5. ATMOSPHERIC TRANSMITTANCE

In the LOWTRAN model, the total atmospheric transmittance at a given wavenumber averaged over a 20-cm^{-1} interval is given by the product of the average transmittances due to molecular band absorption, molecular scattering, aerosol extinction, and molecular continuum absorption. The molecular band absorption is composed of four components; namely the separate transmittances of water vapor, ozone, nitric acid and the uniformly mixed gases (CO_2, N_2O, CH_4, CO, O_2 and N_2).

The average transmittance due to molecular band absorption is represented by a single parameter empirical transmittance function. The argument of the transmittance function is the product of a wavenumber dependent absorption coefficient and "an equivalent absorber amount" for the atmospheric path.

5.1 Molecular Band Transmittance

In the LOWTRAN transmittance model, the average transmittance $\overline{\tau}$ over a 20-cm^{-1} interval (due to molecular absorption) is represented by a single parameter model of the form

$$\overline{\tau} = f(C_\nu \, \omega^* DS) \tag{15}$$

where C_ν is the LOWTRAN wavenumber-dependent absorption coefficient and ω^* is an "equivalent absorber density" for the atmospheric path, DS, defined in terms of the pressure P(z), temperature T(z), concentration of absorber ω and an empirical constant n as follows

$$\omega^* = \omega \left\{ \frac{P(z)}{P_o} \sqrt{\frac{T_o}{T(z)}} \right\}^n \tag{16}$$

where P_o and T_o correspond to STP (1 atm, 273K). If Eq. (16) is substituted in Eq. (15) and n is set to zero and unity, respectively, Eq. (15) reverts to the well-known weak-line and strong-line approximations common to most band models.

The form of the function f and parameter n was determined empirically using both laboratory transmittance data and available molecular line constants. In both cases, the transmittance was degraded in resolution to 20 cm^{-1} throughout the entire spectral range covered here. It was found that the functions f for H_2O and the combined contributions of the uniformly mixed gases were essentially identical, although the parameter n differed in the two cases. Mean values of n were determined to be 0.9 for H_2O, 0.75 for the uniformly mixed gases, and 0.4 for ozone.

Figures 17a, b and c show the LOWTRAN "equivalent absorber densities" given by Eq. (16) and the true absorber densities vs altitude for water vapor, ozone and the uniformly mixed gases. The profiles shown in these figures are for the 1962 U.S. Standard atmosphere, (MODEL = 6).

Figure 18 shows the LOWTRAN empirical transmittance functions defined by Eq. (15) vs the $\log_{10}$ of the effective optical depth ($C_\nu \omega * DS$). The solid function shown is used for water vapor and the uniformly mixed gases.* The dashed function is applicable to ozone.

For sufficiently small values of the argument $C_\nu \omega * DS$, the transmittance functions f were modified for calculations for atmospheric layers of small optical thickness. For cases where ($0.999 \leq \bar{\tau} \leq 1$) the transmittance functions have the analytic form

$$\bar{\tau} = 1 - a\,(C_\nu \omega * DS)^b \tag{17}$$

with a = 0.088 and b = 0.81 for H_2O and the uniformly mixed gases and a = 0.055 and b = 1.03 for ozone. This pseudo-linear approximation in Eq. (17) is used in the computer program for transmittances between 0.999 and 1.

The parameters a and b were determined from a least-squares fit of the empirically derived transmittance function in Eq. (15).

Absorption coefficients for water vapor, ozone, and the combined effects of the uniformly mixed gases, digitized from the spectral curves of McClatchey et al,[6] are included as data for LOWTRAN. The transmittance spectra from which the coefficients were derived were first degraded in resolution to 20 cm^{-1} and the data points were digitized at steps of 5 cm^{-1}. For the ultraviolet and visible ozone bands, the absorption coefficients were digitized at 500 cm^{-1} and 200 cm^{-1} intervals respectively.

The absorption coefficients for water vapor are shown in Figures 19a and b. Figure 19a shows the coefficients in the region from 350 to 5000 cm^{-1} and Figure 19b the region from 4000 to 24,000 cm^{-1}.

Figures 20a, b, and c show the absorption coefficients for ozone. Figure 20a spans the spectral region from 350 to 5000 cm^{-1}, Figure 20b the region from 4000 to 24,000 cm^{-1}, and Figure 20c the region from 20,000 to 50,000 cm^{-1}.

The absorption coefficients for the uniformly mixed gases are shown in Figures 21a and b. The spectral region from 350 to 5000 cm^{-1} is shown in Figure 21a and the region from 4000 to 14,000 cm^{-1} in Figure 21b.

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*Gruenzel[70] has pointed out that in previous versions of LOWTRAN, the value of FW for T = 0.88 was in error. The correct value is 0.4838, not 0.4342.

70. Gruenzel, R.R. (1978) Applied Optics 17:2591.

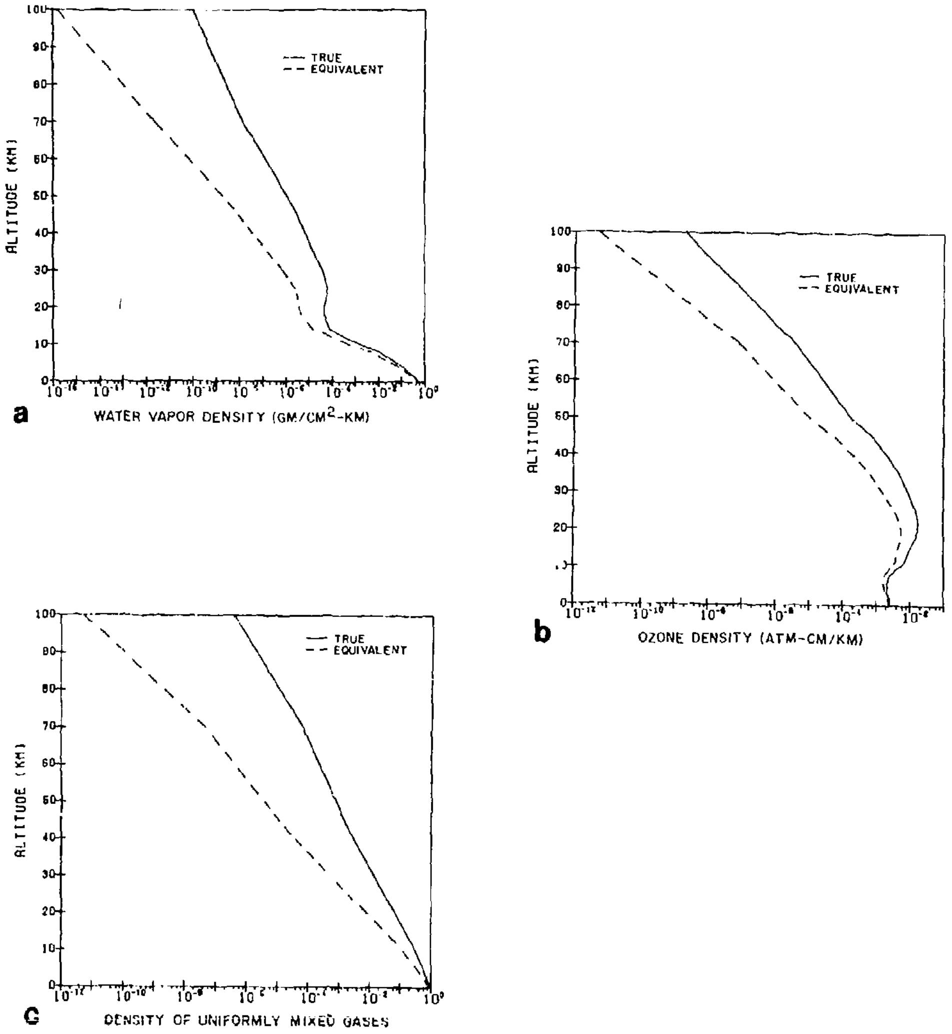

Figure 17. Profiles of True and "Equivalent" Density vs Altitude, 1962 U.S. Standard Atmosphere: a. water vapor, b. ozone, and c. uniformly mixed gases (relative to STP)

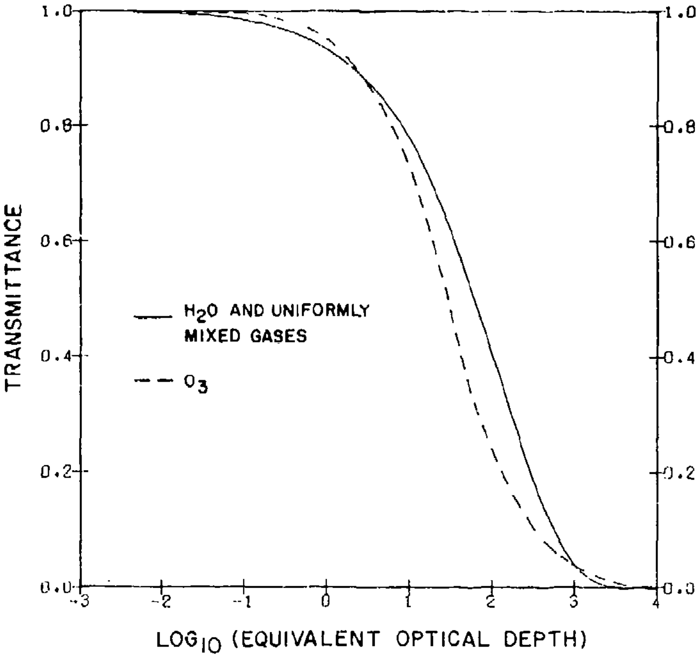

Figure 18. LOWTRAN Empirical Transmittance Functions vs Log_{10} of the Effective Optical Depth ($C_\nu \omega$ * DS)

5.2 Nitric Acid

The transmittance due to HNO_3 has been assumed to lie in the weak-line or linear region. Absorption coefficients digitized at 5-cm^{-1} intervals for the 5.9-μm, 7.5-μm, and 11.3-μm bands of HNO_3 have been incorporated into the LOWTRAN program as a subroutine (Subroutine HNO3). These coefficients were obtained by Goldman, Kyle, and Bonomo[71] by fitting their experimental results with the statistical band model approximation, and are shown in Figure 22.

5.3 Nitrogen Continuum Absorption

The continuum due to collision-induced absorption by nitrogen in the 4-μm region, is included in LOWTRAN based on the measurements of Reddy and Cho[72] and Shapiro and Gush[73] (see also McClatchey et al[6]) and is shown in Figure 23.

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[71] Goldman, A., Kyle, T.G., and Bonomo, F.W. (1971) Statistical band model parameters and integrated intensities for the 5.9-μ, 7.5-μ, and 11.3-μ bands of HNO_3 vapor, Appl. Opt. 1:65.

[72] Reddy, S.R., and Cho, C.W. (1965) Canad. J. Physics 43:2331.

[73] Shapiro, M.M., and Gush, H.P. (1966) Canad. J. Physics 44:949.

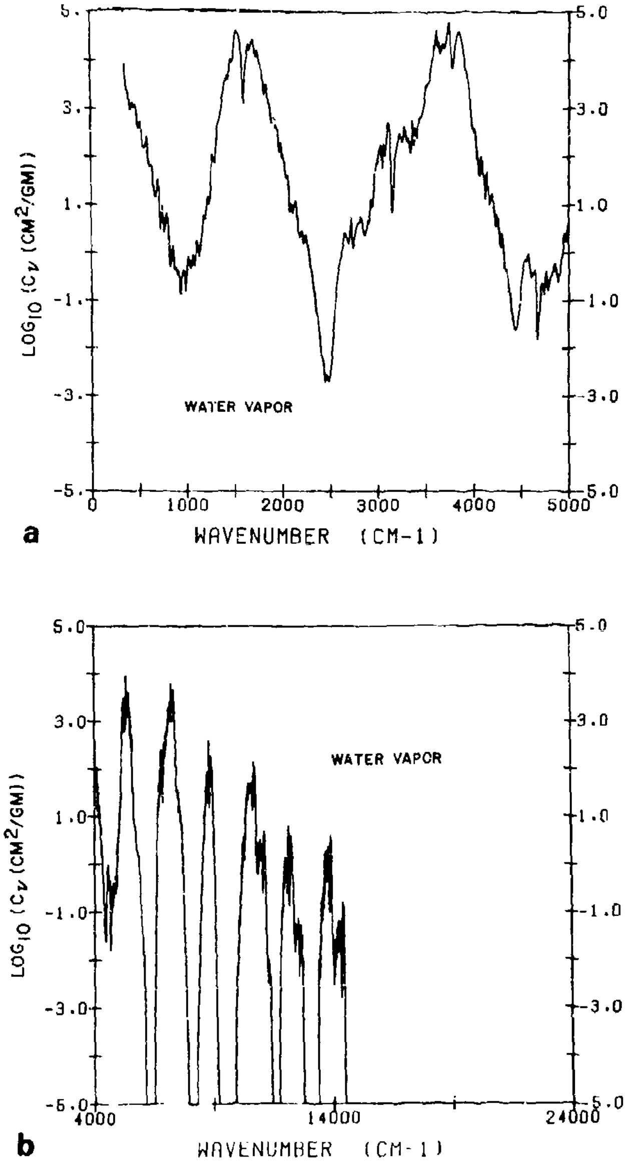

Figure 19. Absorption Coefficient C_ν for Water Vapor: a. from 350 to 5000 cm^{-1}, b. from 4000 to 24, 000 cm^{-1}

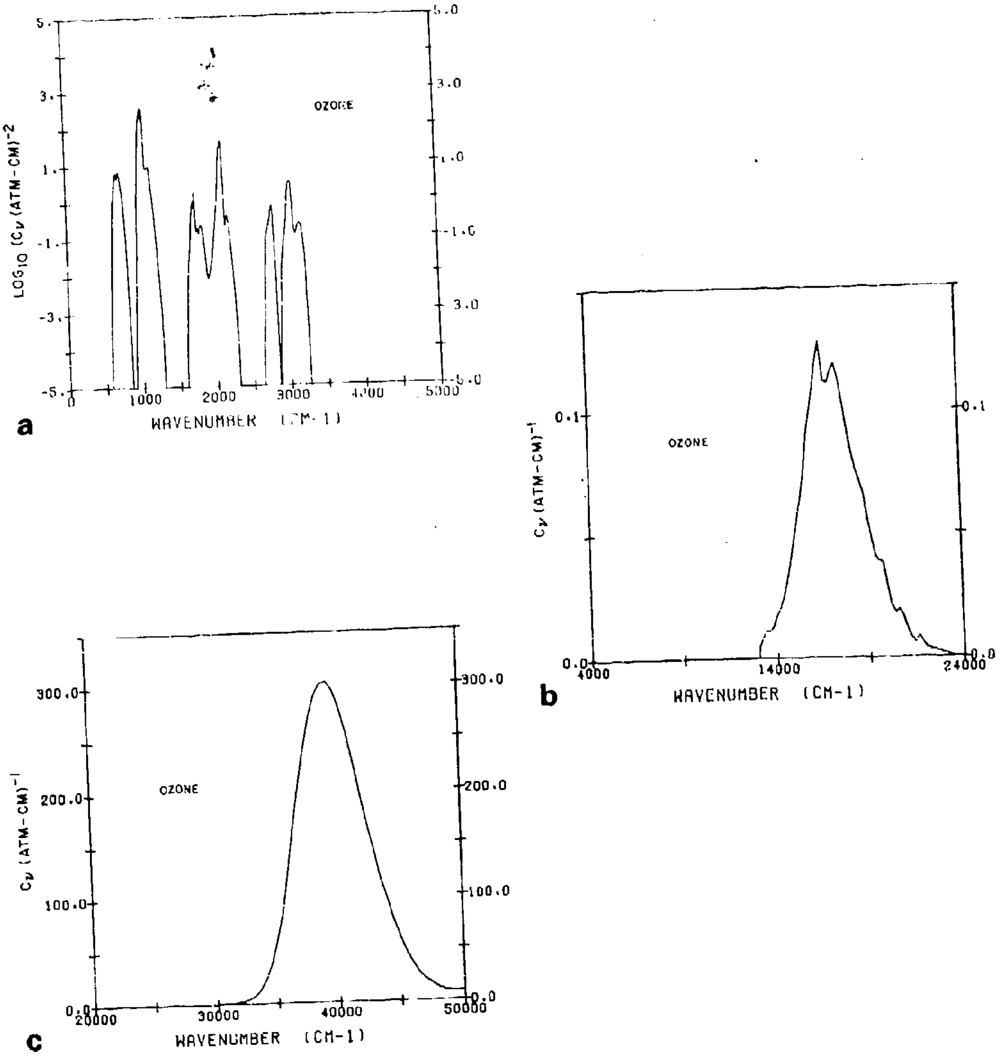

Figure 20. Absorption Coefficient C_ν for Ozone: a. from 350 to 5000 cm^{-1}, b. from 4000 to 24,000 cm^{-1}, c. from 20,000 to 50,000 cm^{-1}

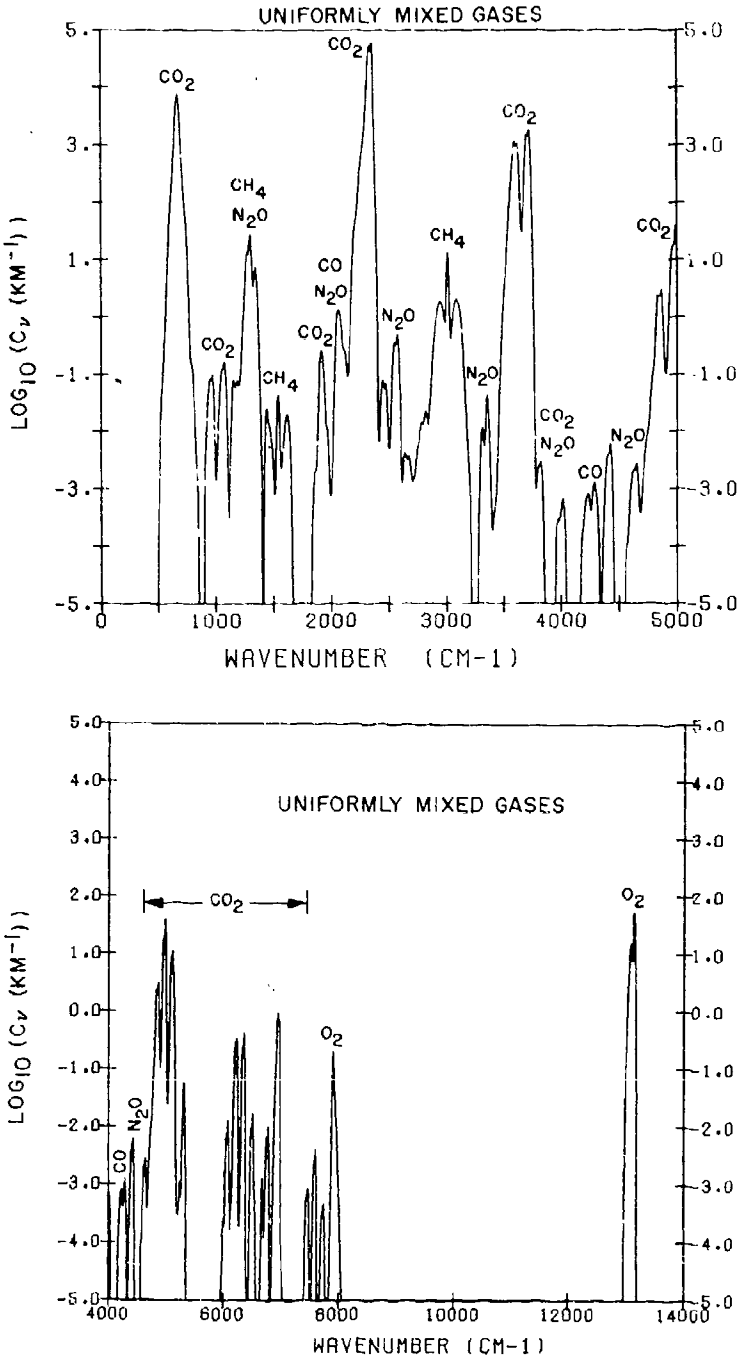

Figure 21. Absorption Coefficient C_ν for the Uniformly Mixed Gases: a. from 350 to 5000 cm^{-1}, b. from 4000 to 14, 000 cm^{-1}

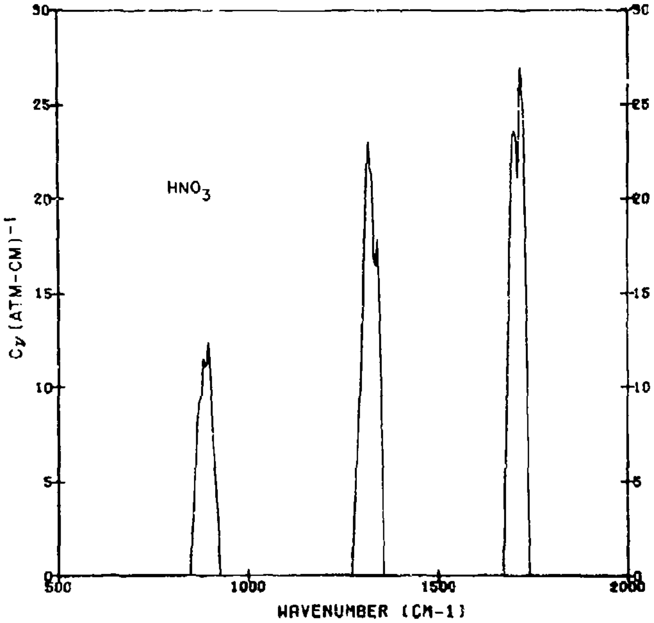

Figure 22. Absorption Coefficient C_ν for Nitric Acid, from 500 to 2000 cm^{-1}

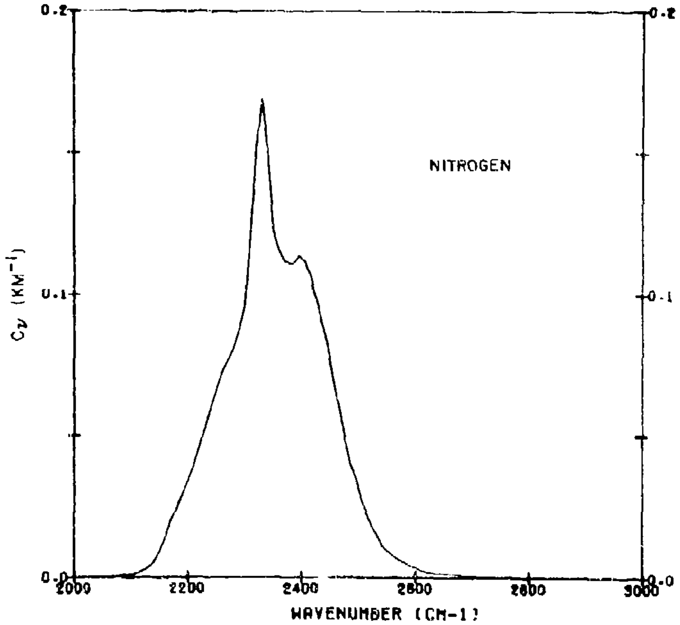

Figure 23. Absorption Coefficient C_ν for the Nitrogen Continuum, from 2000 to 3000 cm^{-1}

The transmittance due to continuum absorption is assumed to follow a simple exponential law.

5.4 Molecular Scattering

The attenuation coefficient (km^{-1}) due to molecular scattering, ABS(6), is introduced into LOWTRAN via the following expression

$$ABS(6) = \nu^4/(9.26799 \times 10^{18} - 1.07123 \times 10^9 \times \nu^2) \qquad (18)$$

where ν is in wavenumbers (cm^{-1}). The above expression was obtained from a least-square fit to molecular scattering coefficients published by Penndorf[74] and is shown in Figure 24. This function is a change from the previous LOWTRAN codes and improves the fit in the ultraviolet. The errors in the new function are now less than 1/2 percent from 0.2 to 20 μ.

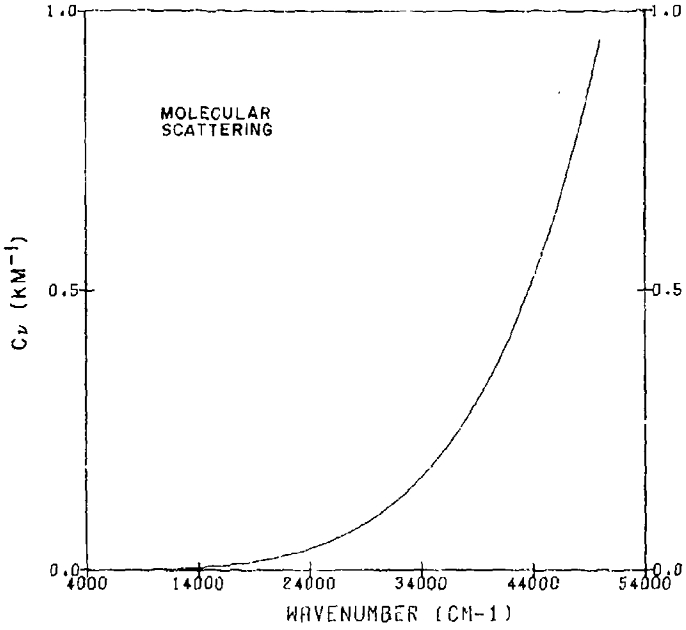

Figure 24. Attenuation Coefficient C_ν Due to Molecular Scattering, from 4000 to 54,000 cm^{-1}

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[74] Penndorf, R. (1957) Tables of the Refractive Index for Standard Air and the Rayleigh Scattering Coefficient for the Spectral Region between 0.2 and 20 μ and Their Application to Atmospheric Optics, J. Opt. Soc. Amer. 47:176-182.

5.5 Water Vapor Continuum

The attenuation due to the water vapor continuum still eludes a complete theoretical explanation. At present, it appears that it results from the accumulated attenuation of the distant wings of H_2O absorption lines, emanating principally in the far infrared part of the spectrum. This attenuation due to molecular line broadening occurs as a result of collisional interactions between molecules; that is, collisions between two H_2O molecules and those of other gases (principally H_2O:N_2 collisions). Other postulates, such as the phenomenon being caused by other absorption mechanisms involving H_2O dimers, remain possibilities yet to be proven.

However, all that can be done at present is to account for the water vapor continuum phenomenon empirically, based on limited experimental measurements, until better line shape theories become available. It should be emphasized that further accurate and well-controlled measurements are urgently required in order to account for this phenomenon in real atmospheric situations with confidence.

The general formulation used to account for the water vapor continuum attenuation at a fixed temperature, has been to define the transmittance $\overline{\tau}(\nu)$ for a path length, DS, as follows

$$\overline{\tau}(\nu) = e^{-k(\nu)DS}$$

where the attenuation coefficient $k(\nu)$ is given by

$$k(\nu) = [C_S P_{H_2O} + C_N(P_T - P_{H_2O})]\,\omega \tag{19}$$

or

$$k(\nu) = C_S \left[P_{H_2O} + \frac{C_N}{C_S}(P_T - P_{H_2O}) \right] \omega$$

where P_{H_2O} and P_T refer to the water vapor partial pressure and the ambient pressure respectively (atm), and ω defines the quantity of water vapor per unit path length (gm cm^{-2} km^{-1}). The quantities C_S and C_N are generally referred to as the self- and foreign (nitrogen)-broadening coefficients for water vapor.

5.5.1 8- TO 11-μm H_2O CONTINUUM

Recently, a review of available water vapor continuum experimental measurements were made by Roberts et al[75] in the 10-μm region. These workers found

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[75] Roberts, R.E., Selby, J.E.A., and Biberman, L.M. (1976) Infrared continuum absorption by atmospheric water vapor in the 8-12 μm window, Applied Optics 14:2085.

that an empirical expression of the form given in Eq. (20) (below), provided a good fit to the wavenumber dependence of the measured water vapor continuum attenuation coefficients at 296 K. Also, the water vapor continuum attenuation coefficient has been found to have a significant temperature dependence. Based on the laboratory measurements of Burch[76] using samples of water vapor at elevated temperatures, an approximate empirical expression was obtained by Roberts et al[75] for the temperature dependence which is given in Eq. (21) below. It was found that the attenuation coefficient due to the water vapor continuum increases as the temperature decreases. That is, for a fixed amount of water vapor in a given path, one would expect more absorption at colder temperatures and less absorption at warmer temperatures. This is a somewhat unusual phenomenon. In practice one finds less water vapor in the atmosphere under cold conditions, therefore, the effect of temperature on the attenuation in the 8- to 14-μm region plays two competing roles, through the total water content of the path and the attenuation coefficient.

The empirical fits to the wavenumber and temperature dependence of the water vapor continuum described in Roberts et al[75] have been used in LOWTRAN with the appropriate conversion of units, as follows:

The attenuation coefficient C_s gm^{-1} cm^{+2} atm^{-1} at 296 K is given by the following expression in the 8- to 14-μm region

$$C_s(\nu,\ 296) = 4.18 + 5578 \exp\left(-7.87 \times 10^{-3}\ \nu\right) \tag{20}$$

where ν is the wavenumber in cm^{-1} (note that $\nu = 10^4/\lambda$, where λ is the wavelength in μm).

Figure 25a shows a plot of $C_s(\nu,\ 296)$ vs wavenumber in the 8- to 14-μm region.

The temperature dependence of the coefficient C_s was found to vary as

$$C_s(\nu, T) = C_s(\nu,\ 296) \exp\left[1800\ \left(\frac{1}{T} - \frac{1}{296}\right)\right] \tag{21}$$

where T is the temperature in degrees Kelvin.

Equation (21) can be rewritten as follows

$$C_s(\nu, T) = C_s(\nu,\ 296) \exp\left[6.08\ \left(\frac{296}{T} - 1\right)\right] \quad . \tag{22}$$

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[76] Burch, D.E. (1970) Semiannual Technical Report: Investigation of the Absorption of Infrared Radiation by Atmospheric Gases, Aeronutronic Report U-4784, ASTLA (AD 702117).

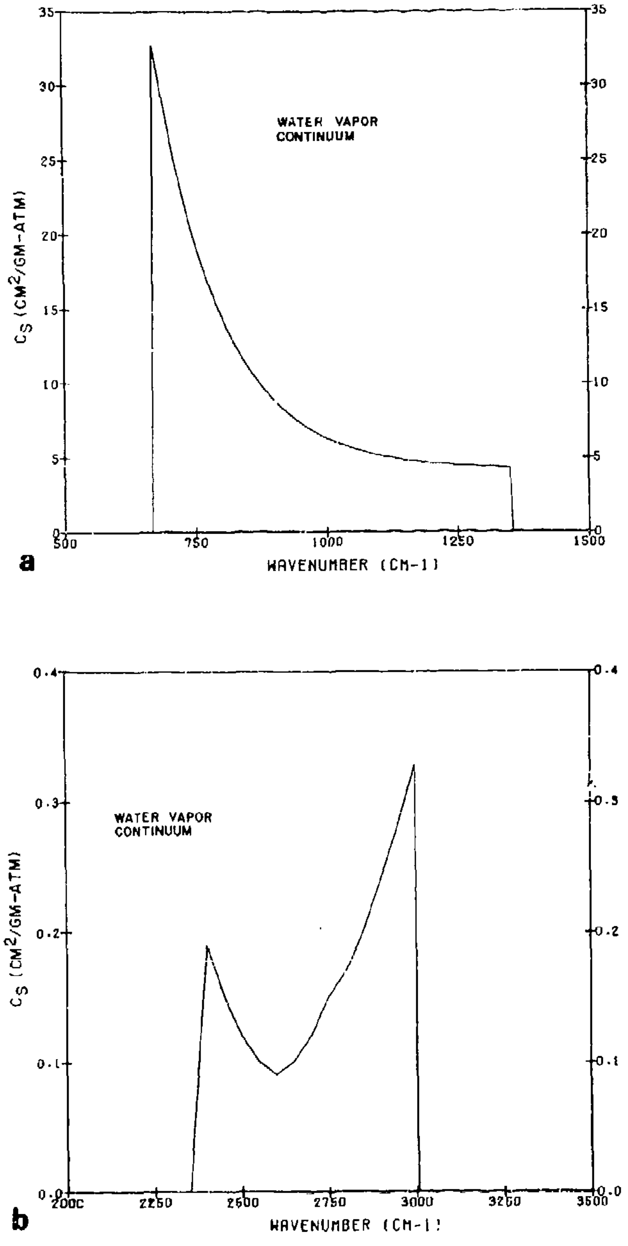

Figure 25. Water Vapor Continuum Attenuation Coefficient C_s at 296 K: a. in the 8- to 12-μ region, b. in the 3.5- to 4.2-μ region

The second term in Eq. (19), defined as C_N/C_S, represents the ratio of the foreign (nitrogen)-broadening coefficient to the self-broadening coefficient.

In LOWTRAN, a value at 296 K of 0.002 for the parameter C_N/C_S is used, based on the review of the measurements. It is assumed that C_N/C_S does not vary with temperature (since no supporting measurements are available).

The transmittance due to the water vapor continuum in the 8- to 14-μm region is calculated for a horizontal path of length DS (km) at altitude z using the following expression in LOWTRAN

$$\bar{\tau}(\nu) = \exp\left[-C_s(\nu, 296)W(z)DS\right] \qquad (23)$$

where W(z) is the effective H_2O absorber amount per unit path lengh (in gm cm^{-2} atm km^{-1}) at altitude z, and C_s (ν, 296) is the water vapor (self-broadened) attenuation coefficient obtained from laboratory measurements at a temperature of 296 K.

The quantity W(z) is given by

$$W(z) = w(z) \left\{ P_{H_2O} \exp\left[6.08\left(\frac{296}{T(z)} - 1\right)\right] + 0.002\,(P_T - P_{H_2O}) \right\} \qquad (24)$$

where

$w(z)$ = gm cm^{-2}/km of H_2O in the path at temperature T,

P_{H_2O} = H_2O partial pressure (atm) at altitude z,

P_T = ambient (total) pressure (atm) at altitude z, and

$T(z)$ = ambient temperature at altitude z (degrees Kelvin).

Note that the temperature dependence of the attenuation coefficient $C_s(\nu, T)$ given in Eq. (22) has been incorporated into the expression for W in Eq. (24). The reason for this is so that the temperature variation over a given atmospheric slant path is weighted equally with the water content along the path.

5.5.2 3.5- TO 4.2-μm H_2O CONTINUUM

Using the laboratory measurements of Burch et al,[77] an empirical expression was obtained for the temperature dependence of the attenuation coefficients in the 3- to 5-μm region. The measurements reported in Burch et al[77] were for samples of pure water vapor made at elevated temperatures, and have been confirmed independently by White et al.[78]

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77. Burch, D.E., Gryvnak, D.A., and Pembrook, J.D. (1971) Philco Ford Corp. Aeronutronic Report U-4897, ASTIA (AD 882876).

78. White, K.O., Watkins, W.R., Tuer, T.W., Smith, F.G., and Meredith, R.E. (1975) J. Opt. Soc. Amer. 65:1201.

It was found that

$$C_s(\nu, T) = C_s(\nu, 296) \exp \left[4.56 \left(\frac{296}{T} - 1\right)\right] \qquad (25)$$

provides an approximate fit to the measurements for pure water vapor extrapolated to a temperature of 296 K.

The attenuation coefficients at 296 K used in LOWTRAN for the 3.4- to 4.2-μm region have been digitized directly from the extrapolations reported by Burch et al,[77] and are shown in Figure 25b.

From the limited measurements available, it appears that the temperature dependence of the water vapor continuum (due to self broadening) in the 3.5- to 4.2-μm region is not as strong as that in the 8- to 14-μm region.

A value for the nitrogen-broadening coefficient of 0.12 was obtained by Burch et al[77] for a temperature of 428 K. Since no other measurements are available at the time of writing, this value will be used in LOWTRAN with the same temperature correction as is applied to the self-broadening term (see Eq. (26)).

As for the 8- to 14-μm region, the transmittance for a horizontal path of length DS (km) can be calculated using Eq. (23), where the parameter W(z) is now given by the following expression for the 3.5- to 4.2-μm region

$$W(z) = w(z) \left[P_{H_2O} + 0.12 \, (P_T - P_{H_2O})\right] \exp \left[4.56 \left(\frac{296}{T(z)} - 1\right)\right] \qquad (26)$$

As in Eq. (24), the temperature dependence of the attenuation coefficient has been incorporated into Eq. (26). It will be noted that the nitrogen-broadening coefficient in the 4-μm region is more significant relative to the self-broadening term than in the 10-μm region. Again it should be emphasized that the above expressions are approximate and further measurements are required to determine the temperature dependence of the nitrogen-broadening coefficient, as well as more accurate values for the wavelength dependence of the self-broadening coefficient at ambient temperatures (for example, 296 K) and its temperature dependence.

5.6 Aerosol Transmittance

Within a given atmospheric layer of path length, DS, in km, the transmittance, $\overline{\tau}(\nu)$, due to aerosol extinction is given by

$$\overline{\tau}(\nu) = \text{EXP}\,[-\text{EXTV}(\nu) \times \text{HAZE} \times \text{DS}] \qquad (27)$$

where EXTV(ν) is the normalized extinction coefficient for the wavenumber ν of the appropriate aerosol model and altitude. HAZE is the aerosol scaling factor (see Section 3).

EXTV(ν) is found by interpolation of the values stored in the code for the required wavenumber and relative humidity. HAZE is determined by interpolation of the appropriate aerosol scaling factor profiles according to the meteorological range and season.

6. ATMOSPHERIC RADIANCE

The LOWTRAN program has the option to calculate atmospheric and earth radiance. A numerical evaluation of the integral form of the equation of radiative transfer is used in the program. The emission from aerosols and the treatment of aerosol and molecular scattering is considered only in the zeroth order. Additional contributions to atmospheric emission from radiation scattered one or more times are neglected. Local thermodynamic equilibrium is assumed in the atmosphere.

The average atmospheric radiance (over a 20-cm^{-1} interval) at the wavenumber, ν, along a given line-of-sight in terms of the LOWTRAN transmittance parameters is given by

$$I(\nu) = \int_{\bar{\tau}_a^b}^{1} d\bar{\tau}_a \, B(\nu, T)\, \bar{\tau}_s + B(\nu, T_b)\, \bar{\tau}_t^b \tag{28}$$

where the integral represents the atmospheric contribution and the second term is the contribution of the boundary, (for example, the surface of the earth or a cloud top) and

$\bar{\tau}_a$ = average transmittance due to absorption,

$\bar{\tau}_s$ = average transmittance due to scattering,

$\bar{\tau}_t = \bar{\tau}_a \bar{\tau}_s$ = average total transmittance,

$\bar{\tau}_a^b, \bar{\tau}_t^b$ = average total transmittances from the observer to boundary,

$B(\nu, T)$ = average Planck (blackbody) function corresponding to the frequency ν and the temperature T of an atmospheric layer.

T_b = temperature of the boundary.

The emissivity of the boundary is assumed to be unity.

The LOWTRAN band model approach used here assumes that since the blackbody function is a slowly varying function of frequency we can represent the average value of the radiance in terms of the average values of the transmittance and the blackbody function. $\bar{\tau}_a$, $\bar{\tau}_s$, and $\bar{\tau}_t$ vary from 1 to $\bar{\tau}_a^b$, $\bar{\tau}_s^b$, and $\bar{\tau}_t^b$ along the observer's line-of-sight. For lines of sight which do not intersect the earth or a cloud layer, the second term in Eq. (28) is omitted.

The numerical analogue to Eq. (28) has been incorporated in the LOWTRAN computer program. The numerical integration of the radiance along a line-of-sight for a given model atmosphere defined at N levels is given by

$$I(\nu) = \sum_{i=1}^{N-1} (\bar{\tau}_a(i) - \bar{\tau}_a(i+1))\, B\left(\nu\,,\ \frac{T(i) + T(i+1)}{2}\right) \left(\frac{\bar{\tau}_s(i) + \bar{\tau}_s(i+1)}{2}\right)$$

$$+ B(\nu, T_b)\bar{\tau}_t^b \quad . \qquad (29)$$

Thus, the spectral radiance from a given atmospheric slant path (line-of-sight) can be calculated by dividing the atmosphere into a series of isothermal layers and summing the radiance contributions from each of the layers along the line-of-sight, that is, numerically evaluating Eq. (28). This can be clearly seen from the following simple example.

Neglecting scattering, consider a three-layered atmosphere characterized by temperatures T_1, T_2, and T_3 as shown in Figure 26. Let $\bar{\tau}_1$, $\bar{\tau}_2$, and $\bar{\tau}_3$ be the transmittances from the ground to the boundaries of each of the layers respectively (see Figure 26a). Figure 26b shows the corresponding case for an observer in space (distinguished by primed $\bar{\tau}$ values). Then from Eq. (29) the total downward spectral radiance for an observer on the ground (looking upwards) is given by

$$I(\nu)\downarrow\ = (1 - \bar{\tau}_1)B(\nu, T_1) + (\bar{\tau}_1 - \bar{\tau}_2)B(\nu, T_2) + (\bar{\tau}_2 - \bar{\tau}_3)B(\nu, T_3) \quad . \qquad (30)$$

Similarly for an observer looking down from the top of the atmosphere (see Figure 26b), the total upward spectral radiance is given by

$$I(\nu)\uparrow\ = (1 - \tau'_1)B(\nu, T_3) + (\tau'_1 - \tau'_2)B(\nu, T_2) + (\tau'_2 - \tau'_3)B(\nu, T_1) + \tau'_3\, B(\nu, T_b) \quad . \qquad (31)$$

A comparison of Eqs. (30) and (31) shows that in addition to the boundary contributions to the total upward spectral radiance, the total downward and the total upward spectral radiances from the same atmospheric layers are not the same but depend on the position of the observer relative to a given atmospheric slant path. In the LOWTRAN radiance program, the position of the observer is always defined by the input parameter, H1.

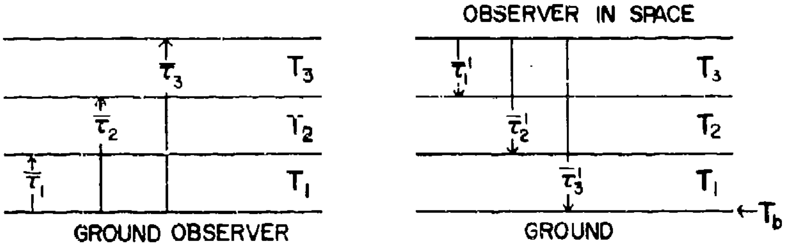

Figure 26. Upward and Downward Atmospheric Paths Through a Three-Layered Atmosphere for Radiance Calculations

It should be emphasized that in the calculation of radiance as given by Eq. (28), scattering is treated only as a loss mechanism and is not included as a source.

In a recent paper by Ben-Shalom et al,[79] it has been noted that for certain atmospheric paths of high optical depth where multiple-scattered radiation is significant, the algorithm used in LOWTRAN underestimates the background radiation. The authors have proposed a "conservative scattering" solution for these cases where only the total extinction is used for the radiative transfer calculations. However, no assessment of the validity of the "conservative scattering" method proposed vs the "zero scattering" algorithm in LOWTRAN for the various paths encountered in the atmosphere has been made.

Until a general multiple-scattering solution for radiative transfer is available in the code, it is recommended that users of LOWTRAN examine the scattering contribution along a given atmospheric path. For scattering in the linear region, the present LOWTRAN algorithm should be appropriate. For high-scattering conditions, users might consider modifying the radiance algorithm as Ben-Shalom et al[79] have proposed.

7. PROGRAM STRUCTURE

In addition to the inclusion of new aerosol models and new aerosol extinction coefficients into the LOWTRAN code, extensive reprograming of the code has been made for improved logical flow of the program and user understanding. As shown in Figure 27, the LOWTRAN code structure consists of a main program, LOWEM, and 19 subroutines. A listing of the code is given in Appendix A. The data file,

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[79] Ben-Shalom, A., Barzilia, B., Cabib, D., Devir, A.D., Lipson, S.G., and Oppenheim, U.P. (1980) Applied Optics Vol. 19, No. 6, p. 838.

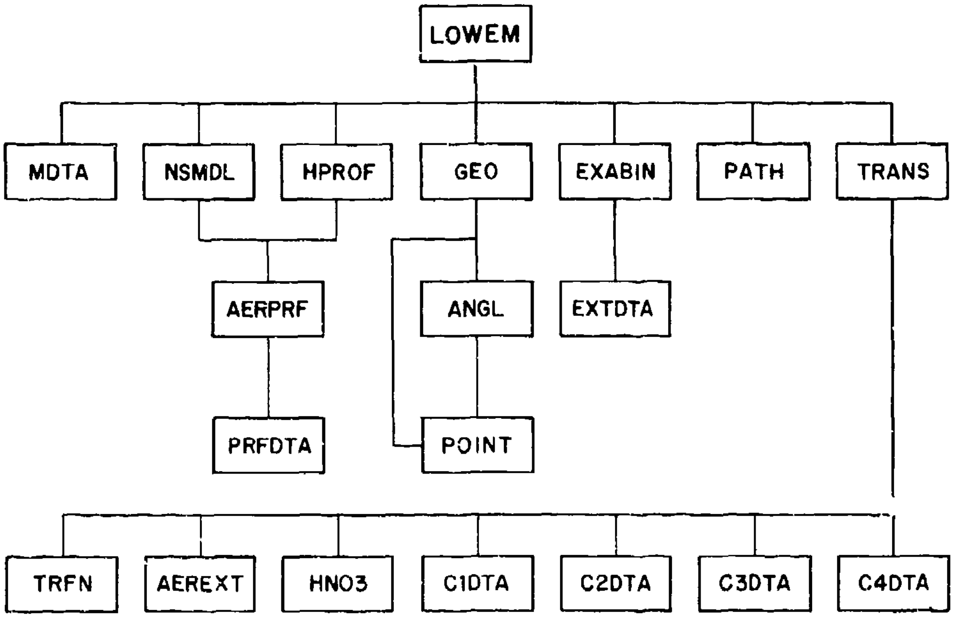

Figure 27. LOWTRAN Program Structure

TAPE5, used in previous LOWTRAN codes has been eliminated. The information from this file has been incorporated into the code in data statements.

In the main program, LOWEM, four control cards are read in for standard execution of the code. New aerosol control parameters have been added to these cards, as will be explained in the instructions for using the code in Section 8.

The transmittance and radiance output tables are also written to the mass storage file, TAPE7, declared on the PROGRAM LOWEM card. The subroutines, MDTA, NSMDL, HPROF, GEO, EXABIN, PATH, and TRANS are called from the main program. A definition of symbols in PROGRAM LOWEM is given in Appendix B.

Subroutine MDTA, called from the main program, contains the altitudes, pressure, temperature, water vapor and ozone density profiles of the six model atmospheres. The nitric acid volume mixing ratio profile is also stored in the subroutine.

Subroutine NSMDL is called from the main program for user defined model atmospheres or aerosol models (MODEL = 0 or MODEL = 7). The input cards and options for the user defined models are explained in Section 8. Subroutine AERPRF is called from this subroutine.

Subroutine HPROF, called from the main program, sets up the appropriate HORIZONTAL PROFILES of molecular and aerosol-absorber densities in LOWTRAN units, using either the model data from MDTA or the user-defined model data from NSMDL. Subroutine AERPRF is also called from this subroutine.

Subroutine AERPRF, called from either NSMDL or HPROF, sets up the appropriate aerosol HORIZONTAL PROFILES for the model selected. Subroutine PRFDTA, called from AERPRF, contains the altitude-dependent profiles of the aerosol models allowed by the program, stored in data statements.

Subroutine GEO, called from the main program, is the spherical geometry subroutine, with correction for refraction, used to calculate the absorber amounts along the atmospheric slant path. The VERTICAL PROFILES and the equivalent absorber amounts are determined in this subroutine. The matrix, WLAY, is also defined in this subroutine for use with subroutine PATH, for radiance calculations. Subroutine ANGL and POINT are called from this subroutine.

Subroutine ANGL is called from GEO to calculate the initial zenith angle for the atmospheric slant path, when the initial and final altitudes and the earth center angle are specified. Subroutine POINT is also called from ANGL.

Subroutine POINT, called from GEO and ANGL, is used to compute the mean refractive index above and below a given altitude and to interpolate exponentially the equivalent absorber densities at that altitude.

Subroutine EXABIN is called from the main program to load the extinction and absorption coefficients for the four aerosol altitude regions appropriate to the aerosol model selected by the user. Interpolation of the boundary layer aerosol coefficients based on relative humidity is performed in this subroutine. Subroutine EXTDTA is called from EXABIN.

The aerosol extinction and absorption coefficients and wavelengths of all the aerosol models are stored in subroutine EXTDTA, called from EXABIN.

Subroutine PATH, called from the main program for radiance calculations, loads the cumulative absorber amounts along the atmospheric slant path into the matrix, WPATH. This data is transferred to PATH from GEO through the vertical profile matrix, WLAY.

Subroutine TRANS, called from the main program, calculates the transmittance and radiance between the wavenumbers, V1 and V2, in steps of DV for the atmospheric slant path. Subroutines TRFN, AEREXT, HNO3, C1DTA, C2DTA, C3DTA, and C4DTA are called by TRANS.

The LOWTRAN transmittance functions for water vapor, ozone, and the uniformly mixed gases are stored in data statements in subroutine TRFN.

Subroutine AEREXT interpolates the aerosol extinction coefficients for the four altitude regions to obtain the proper values at the wavenumber, ν.

Subroutine HNO3 determines the nitric acid absorption coefficient at the wavenumber, ν, from the arrays stored in the subroutine.

The molecular water vapor absorption coefficient is determined at a specified wavenumber from the array, C1, stored in subroutine C1DTA.

The absorption coefficient for the uniformly mixed gases at a specified wavenumber is determined from the array, C2, stored in subroutine C2DTA.

The infrared absorption coefficient for ozone at the wavenumber, ν, is obtained from the array, C3, stored in subroutine C3DTA.

Subroutine C4DTA, called from TRANS, contains data arrays for the nitrogen continuum absorption (C4), the 4-μm water vapor continuum absorption (C5), and the ozone ultra-violet and visible absorption (C8).

With the new code structured into subroutines, the program has been run on the AFGL CDC6600, using segment loading of computer code to reduce central memory storage requirements. A load map using the segment option is shown in Appendix C.

With segment loading of the code, the core storage requirements for execution are reduced by approximately a factor of two over conventional loading of the program. Similar type segment loading of the LOWTRAN code would allow possible use of the code on minicomputers.

8. INSTRUCTIONS FOR USING LOWTRAN 5

The instructions for using LOWTRAN 5 are similar to those for previous LOWTRAN codes. New control parameters defining the aerosol profiles and extinction coefficients have been added to the first input card. Changes have also been made in the input of aerosol models in user-defined atmospheres (MODEL = 7). As mentioned previously, the data file, TAPE 5, has been eliminated and made part of the Fortran code.

In general, for standard atmospheric models, only four input cards are required to run the program for a given problem. The formats for these four cards and definitions of the input parameters on these cards are given below.

8.1 Input Data and Formats

The data necessary to specify a given problem are given on the four cards as follows:

CARD 1	MODEL, IHAZE, ITYPE, LEN, JP, IM, M1, M2, M3, ML, IEMISS, RO, TBOUND, ISEASN, IVULCN, VIS FORMAT (11I3, 2F10.3, 2I3, F10.3)
CARD 2	H1, H2, ANGLE, RANGE, BETA FORMAT (5F10.3)

CARD 3	V1, V2, DV	FORMAT (3F10.3)
CARD 4	IXY	FORMAT (I3)

Definitions of the above quantities will be discussed in Section 8.2.

If the quantity MODEL given in CARD 1 is set equal to 0 or 7 (which is the case if meteorological data are used as input to the program), then the above card sequence (and format for CARD 2) is changed. These cases will be described in Section 8.3.

8.2 Basic Instructions

The various quantities to be specified on each of the four control cards (summarized in Section 8.1) will be discussed in this section.

8.2.1 CARD 1 – MODEL, IHAZE, ITYPE, LEN, JP, IM, M1, M2, M3, ML, IEMISS, RO, TBOUND, ISEASN, IVULCN, VIS

The parameter MODEL selects one of six geographical model atmospheres or specifies that user-defined meteorological data are to be used in place of the standard models. ITYPE and LEN determine one of three types of atmospheric paths for a given problem. JP is a user option to suppress printing of profiles and tables in the output. IEMISS selects the mode of program execution (transmittance or radiance). IM, M1, M2, M3, ML, RO, and TBOUND are additional input parameters for non-standard cases. IHAZE, ISEASN, IVULCN, and VIS are control parameters used to select the profiles and types of extinction coefficients for the aerosol models (N.B. VIS is now specified on CARD1).

MODEL = 0 if meteorological data are specified (for horizontal paths only)*.
= 1 selects TROPICAL MODEL ATMOSPHERE.
= 2 selects MIDLATITUDE SUMMER.
= 3 selects MIDLATITUDE WINTER.
= 4 selects SUBARCTIC SUMMER.
= 5 selects SUBARCTIC WINTER.
= 6 selects 1962 U.S. STANDARD
= 7 if a new model atmosphere (or radiosonde data) is to be inserted.

ITYPE = 1 for a horizontal (constant-pressure) path.
= 2 for a vertical or slant path between two altitudes.
= 3 for a vertical or slant path to space.

The TYPE 1 path should not be confused with a long 90° path where the local height of the end of the trajectory is at a significantly different height. In such a case, specify the path according to ITYPE = 2.

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*In these cases the format for Card 2 changes (see non-standard conditions, Section 8.3).

LEN = 0 for normal operation of program.

= 1 selects the downward TYPE 2 LONG path.

The parameter LEN can be ignored (that is, left blank) for the majority of cases. It need only be used for a downward-looking path (H2 < H1) when two paths are possible for the same input parameters. In such a case, a computer printout statement will be given indicating that the user has two choices for the problem and that the shorter path has been executed. Set LEN = 1 for the longer case.

JP = 0 for normal operation of program.

= 1 to suppress printing of transmittance table/or radiance table and horizontal and vertical profiles.

The control parameter, IEMISS, determines the mode of execution of the program.

IEMISS = 0 for program execution in transmittance mode.

= 1 for program execution in radiance mode.

A message is printed to the user on the output file indicating the mode of program execution.

Table 2A summarizes the use of these five control parameters specified on CARD1. For non-standard cases, provision is made on CARD1 for additional user options with the parameters IM, M1, M2, M3, ML, RO, and TBOUND.

IM = 0 for normal operation of program or when subsequent calculations are to be run with MODEL = 7.

= 1 when radiosonde data are to be read in initially.

ML = Number of levels to be read in for MODEL = 7.

Note that IM and ML are only used when MODEL = 7 and then only on the first calculations when the data are read in.

M1 = M2 = M3 = 0 for normal operation of program.

The parameters M1, M2, and M3 can each take integer values between 0 and 6 and are used to modify or supplement the altitude profiles of temperature and pressure, water vapor, and ozone respectively, for any given atmospheric model specified by MODEL.

For example:

M1 = 1 selects the TROPICAL temperature and pressure altitude profiles.

= 2 selects the MIDLATITUDE SUMMER temperature and pressure altitude profiles.

= 6 selects the 1962 U.S. STANDARD temperature and pressure altitude profiles.

M2 = 1 selects the TROPICAL water vapor altitude profile.

= 2 selects the MIDLATITUDE SUMMER water vapor altitude profile.

= 6 selects the 1962 U.S. STANDARD water vapor altitude profile.

Table 2a. LOWTRAN CARD 1 Input Parameters: MODEL, ITYPE, LEN, JP, IEMISS

CARD 1	MODEL, IHAZE, ITYPE, LEN, JP, IM, M1, M2, M3, ML, IEMISS, RO, TBOUND, ISEASN, IVULCN, VIS FORMAT (11I3, 2F10.3, 2I3, F10.3)

COL 3	MODEL	COL 9	ITYPE	COL 12	LEN	COL 15	JP	COL 33	IEMISS
0	USER * DEFINED	1	HORIZONTAL PATH	0	SHORT PATH	0	NORMAL OUTPUT	0	TRANS-MITTANCE
1	TROPICAL	2	SLANT PATH H1 TO H2	1	LONG PATH	1	SHORT OUTPUT	1	RADIANCE
2	MIDLATITUDE SUMMER	3	SLANT PATH H1 TO SPACE						
3	MIDLATITUDE WINTER								
4	SUBARCTIC SUMMER								
5	SUBARCTIC WINTER								
6	1962 U.S. STANDARD								
7	USER * DEFINED								

* OPTIONS FOR NON-STANDARD MODELS

IM, M1, M2, M3, ML, RO, TBOUND LEFT BLANK FOR STANDARD CASES
REFER TO TEXT FOR NON-STANDARD CASES

M3 = 1 selects the TROPICAL ozone altitude profile.
= 2 selects the MIDLATITUDE SUMMER ozone altitude profile.
= 6 selects the 1962 U.S. STANDARD ozone altitude profile.

RO = radius of the earth (km) at the particular geographical location at which the calculation is to be performed.

If RO is left blank, the program will use the midlatitude value of 6371.23 km if MODEL is set equal to 0 or 7. Otherwise the earth radius for the appropriate standard model atmosphere (specified by MODEL) will be used.

TBOUND = temperature of the earth (^{o}K) at the location at which the calculation is to be performed.

TBOUND is only used in the radiance mode of the program for slant paths which intersect the earth. If TBOUND is left blank, the program will use the temperature of the first atmospheric layer as the boundary temperature.

IHAZE, ISEASN, IVULCN, and VIS select the altitude- and seasonal-dependent aerosol profiles and aerosol extinction coefficients. IHAZE specifies a horizontal meteorological range and specifies the type of extinction for the boundary-layer aerosols (0 to 2 km). The relative humidity dependence of the boundary-layer aerosol extinction coefficients is based on the water vapor content of the model atmosphere selected by MODEL. ISEASN selects the seasonal dependence of the profiles for both the tropospheric (2 to 10 km) and stratospheric (10 to 30 km) aerosols. IVULCN is used to select both the profile and extinction type for the stratospheric aerosols and to determine transition profiles above the stratosphere to 100 km. VIS, the meteorological range, when specified, will supersede the default meteorological range in the boundary-layer aerosol profile set by IHAZE.

IHAZE = 0 no aerosol attenuation included in the calculation.
= 1 RURAL extinction, 23-km VIS.
= 2 RURAL extinction, 5-km VIS.
= 3 MARITIME extinction, 23-km VIS.
= 4 MARITIME extinction, 5-km VIS.
= 5 URBAN extinction, 5-km VIS.
= 6 TROPOSPHERIC extinction, 50-km VIS.
= 7 USER-DEFINED extinction, 23-km VIS. (Read into the program immediately after CARD1. Refer to the main program LOWEM in Appendix A for the input format of the coefficients).
= 8 FOG1 (Advection Fog) extinction, 0.2-km VIS.
= 9 FOG2 (Radiation Fog) extinction, 0.5-km VIS.

As noted above, IHAZE selects the type of extinction and a default meteorological range for the boundary-layer aerosol models only. If VIS is also specified on CARD1 it will override the default IHAZE value. Interpolation of the extinction coefficients based on relative humidity is performed only for the RURAL, MARITIME, URBAN, and TROPOSPHERIC coefficients used in the boundary layer (0 to 2-km altitude).

ISEASN = 0 season determined by the value of MODEL:
SPRING-SUMMER for MODEL = 0, 1, 2, 4, 6, 7
FALL-WINTER for MODEL = 3, 5
= 1 SPRING-SUMMER
= 2 FALL-WINTER

ISEASN selects the appropriate seasonal aerosol profile for both the tropospheric and stratospheric aerosols. Only the tropospheric aerosol extinction coefficients are used with the 2- to 10-km profiles.

IVULCN = 0, 1 BACKGROUND STRATOSPHERIC profile and extinction
= 2 MODERATE VOLCANIC profile and AGED VOLCANIC extinction
= 3 HIGH VOLCANIC profile and FRESH VOLCANIC extinction
= 4 HIGH VOLCANIC profile and AGED VOLCANIC extinction
= 5 MODERATE VOLCANIC profile and FRESH VOLCANIC extinction

The parameter IVULCN controls both the selection of the aerosol profile as well as the type of extinction for the stratospheric aerosols. It also selects appropriate transition profiles above the stratosphere to 100 km. Meteoric dust extinction coefficients are always used for altitudes from 30 to 100 km.

VIS = meteorological range (km) (when specified, supersedes default value set by IHAZE)

Table 2B summarizes the use of aerosol control parameters on CARD 1.

Table 2b. LOWTRAN CARD 1 Input Parameters: IHAZE, ISEASN, IVULCN, VIS

CARD 1	MODEL, IHAZE, ITYPE, LEN, JP, IM, M1, M2, M3, ML, IEMISS, RO, TBOUND, ISEASN, IVULCN, VIS FORMAT (11I3, 2F10.3, 2I3, F10.3)								
IHAZE			ISEASN		IVULCN				
COL 6	VIS* (KM)	EXTINCTION	COL 56	SEASON	COL 59	SEASON	PROFILE	EXTINCTION	PROFILE/EXTINCTION
0	NO AEROSOLS								
1	23	RURAL	0	SET BY MODEL		SET BY MODEL			METEORIC DUST EXTINCTION
2	5		1	SPRING-SUMMER		SPRING-SUMMER			
3	23	MARITIME	2	FALL-WINTER		FALL-WINTER			
4	5		TROPOSPHERIC PROFILE/TROPOSPHERIC EXTINCTION		0		BACKGROUND STRATOSPHERIC	BACKGROUND STRATOSPHERIC	NORMAL ATMOSPHERIC PROFILE
5	5	URBAN			1				
6	50	TROPOSPHERIC			2		MODERATE VOLCANIC	AGED VOLCANIC	TRANSITION PROFILES -VOLCANIC TO NORMAL
7	23	USER DEFINED			3		HIGH VOLCANIC	FRESH VOLCANIC	
8	0.2	FOG 1			4		HIGH VOLCANIC	AGED VOLCANIC	
9	0.5	FOG 2			5		MODERATE VOLCANIC	FRESH VOLCANIC	
← 0 TO 2 KM →			← 2 TO 10 KM →		← 10 TO 30 KM →				← 30 TO 100 KM →
* VIS>0, OVERRIDES DEFAULT MET. RANGE									

In the case where MODEL = 7, the new atmosphere (model or radiosonde data) is inserted between CARDS 1 and 2 (see Section 8.3).

8.2.2 CARD 2 — H1, H2, ANGLE, RANGE, BETA

CARD 2 is used to define the geometrical path parameters for a given problem.

H1 = initial altitude (km)

H2 = final altitude (km)

It is important to emphasize here that in the radiance mode of program execution (IEMISS=1), H1, the initial altitude, always defines the position of the observer (or sensor). H1 and H2 cannot be used interchangeably as in the transmittance mode.

ANGLE = initial zenith angle (degrees) as measured from H1

RANGE = path length (km)

BETA = earth center angle subtended by H1 and H2 (degrees)

It is not necessary to specify every quantity given above; only those that adequately describe the problem according to the parameter ITYPE (as described below)

(1) Horizontal Paths (ITYPE = 1)

(a) specify H1, RANGE

(b) If non-standard meteorological data are to be used, that is, if MODEL = 0 on CARD 1, then refer to Section 8.3 for parameters and format of CARD 2.

(2) Slant Paths to Space (ITYPE = 3)

(a) specify H1, ANGLE

(b) specify H1, HMIN (for limb-viewing problem where HMIN is the required tangent height or minimum altitude of the path trajectory.

(3) Slant Paths Between Two Altitudes (ITYPE = 2)

(a) specify H1, H2, ANGLE

(b) specify H1, ANGLE, RANGE

(c) specify H1, H2, RANGE

For cases (b) and (c), the program will calculate H2 and ANGLE respectively, assuming no refraction; then proceed as for case (a). This method of defining the problem should be used when refraction effects are not important; for example, for ranges of a few tens of km at zenith angles less than 80°. It can also be used for larger angles (including 90°) provided that the path lies within one atmospheric layer.

(d) specify H1, H2, BETA. Leave ANGLE and RANGE blank in this case. This method can be used when the geometrical configuration of the source and receiver is known accurately, but the initial zenith angle is not known precisely due to atmospheric refraction effects. Beta is most frequently determined by the user from ground range information.

In the cases of 2(b) and 3(d) above, the subroutine ANGLE is called in the program to determine the appropriate input zenith angle by an iterative technique taking into account atmospheric refraction.

In the case where MODEL = 7, the new model atmosphere (or radiosonde data) is inserted between CARDS 1 and 2.

Table 3 lists the options on CARD 2 provided to the user for the different types of atmospheric paths.

Table 3. LOWTRAN CARD 2 Input Parameters: H1, H2, ANGLE, RANGE, BETA

CARD 2	H1, H2, ANGLE, RANGE, BETA FORMAT (5F10.3)				
	H1 (KM)	H2 (KM)	ANGLE (°)	RANGE (KM)	BETA (°)
ITYPE					
1	X			X	
2	X	X	X		
	X		X	X	
	X	X		X	
	X	X			X
3	X		X		
	X	X (HMIN)			
X - PARAMETER MUST BE DEFINED					

8.2.3 CARD 3 – V1, V2, DV

The spectral range over which transmittance data are required and the spectral increments at which the data are to be printed out is determined by CARD 3.

V1 = initial frequency in wavenumbers (cm^{-1})

V2 = final frequency in wavenumbers (cm^{-1}) where V2 > V1

DV = frequency increment (or step size) (cm^{-1})

(Note that $\nu = 10^4/\lambda$ where ν is the frequency in cm^{-1} and λ is the wavelength in microns, and that DV can only take values which are a multiple of 5.)

8.2.4 CARD 4 – IXY

The control parameter IXY can cause the program to recycle, so that a series of problems can be run with one submission of LOWTRAN. Five values of IXY can be used to provide the options given on the following pages.

IXY = 0 or blank card to end of program
= 1 to select a new CARD 3 and CARD 4 only (assuming other parameters are unchanged)
= 2 to select a new data sequence (CARDS 1, 2, 3, and 4)
= 3 to select a new CARD 2 and CARD 4 only (assuming other parameters are unchanged)
= 4 to select a new CARD 1 and CARD 4 only (assuming other parameters are unchanged)

Thus, if for the same model atmosphere and type of atmospheric path the reader wishes to make further transmittance calculations in different spectral intervals V1' to V2' etc. and for a different step size (DV' etc.), then IXY is set equal to 1. In this case, the card sequence is as follows and can be repeated as many times as required.

CARD 4 IXY = 1
CARD 5 V1' V2' DV'
CARD 6 IXY = 1
CARD 7 V1'' V2'' DV''
CARD 8 IXY = 0

The final IXY card should always be a blank or zero. When using the IXY = 1 option, the wavelength dependence of the refractive index is not changed (use IXY = 2 option if this is required).

To make successive transmittance computations where just the geographical model atmosphere is changed and/or with or without aerosol attenuation, set IXY = 4 and construct a data card sequence along the same lines as given above. This sequence of recycling can be repeated successively.

When a series of problems is to be executed (with one submission of LOWTRAN) involving the standard atmospheric models (MODEL = 1 to 6) as well as cases involving MODEL = 0 and MODEL = 7, then the order in which the data are set up becomes very important. Note the following sequence.

1. Run all problems using MODEL = 1 through 6 first.
2. Secondly, run all problems involving the use of MODEL = 0.
3. Run all problems involving the use of MODEL = 7 last. The reason for running MODEL = 7 cases last is that when a new atmospheric model is read in,

the altitudes may not correspond with those given in the standard models and the program will erase them. Similarly, if a MODEL = 0 case is run following a MODEL = 7 case, the first level of MODEL 7 is erased.

Table 4 summarizes the user-control parameters on CARD 3 and CARD 4.

Table 4. LOWTRAN CARD 3 and CARD 4 Input Parameters: V1, V2, DV, IXY

CARD 3	V1, V2, DV FORMAT (3F10.3)			
	V1 (CM-1)	V2 (CM-1)	DV (CM-1)	DV VALUES MULTIPLE OF 5 CM-1
CARD 4	IXY FORMAT (I3)			
COL 3	IXY			
0	END OF PROGRAM.			
1	READ NEW CARDS 3 AND 4.			
2	READ NEW CARDS 1, 2, 3, AND 4.			
3	READ NEW CARDS 2 AND 4.			
4	READ NEW CARDS 1 AND 4.			

8.3 Non-Standard Conditions

Three options are available if atmospheric transmittance calculations are required for non-standard conditions. Here non-standard refers to conditions other than those specified by the six model atmospheres provided by LOWTRAN, which are selected by the parameter MODEL on CARD 1. The three options enable the user to insert:

(1) His own model atmosphere(s) in place of any (or all) of the six standard models, provided that the data are in exactly the same format and are specified at the same altitudes as in the DATA statements in the LOWTRAN code (Subroutine MDTA). In this case the appropriate print statements in LOWTRAN (that identify the atmospheric model used) must be changed correspondingly.

(2) An additional atmospheric model (MODEL 7), which can be in the form of radiosonde data. The data need not be specified at the same altitudes as in the standard models.

(3) Meteorological conditions for a given horizontal path calculation (MODEL = 0 case).

The first of these options requires the most effort and needs no further discussion here, other than a reference to Appendix A for a summary of the standard model atmosphere parameters, units, and formats.

8.3.1 ADDITIONAL ATMOSPHERIC MODEL (MODEL = 7)

New model atmospheres can be inserted between CARDS 1 and 2 provided the parameters MODEL and IM are set equal to 7 and 1 respectively on CARD 1. The number of atmospheric levels to be inserted (ML) must also be specified on CARD 1. New altitude-dependent aerosol control options have been added to the MODEL = 7 cards to provide more flexibility to the user in modeling aerosol extinction.

The appropriate meteorological parameters and format for the atmospheric data are given below

Z, P, T, DP, RH, WH, WO, AHAZE, VIS1, IHA1, ISEA1, IVUL1
FORMAT (3F10.3, 2F5.1, 3E10.3, F7.3, 3I1)

Z = altitude (km)
P = pressure (mb)
T = ambient temperature (^{o}C)
DP = dew-point temperature (^{o}C)
RH = relative humidity (%)
WH = water vapor density (gm m^{-3})
WO = ozone density (gm m^{-3})
AHAZE = aerosol number density (normalized by the user to the required meteorological range using the LOWTRAN extinction coefficients)
VIS1 = meteorological range (km) for the altitude, Z
IHA1 = aerosol extinction and meteorological range control for the altitude, Z
ISEA1 = aerosol season control for the altitude, Z
IVUL1 = aerosol profile and extinction control for the altitude, Z

Note that it is only necessary to specify those quantities underlined with a full line and one of the quantities underlined with the dashed line.

If the ozone density (WO) is not known then a value can be obtained from one of the standard atmospheric models (for the appropriate latitude and season) by using the parameter M3 on CARD 1.

Also note that for M1 > 0 on CARD 1, both pressure and temperature are now interpolated from the model atmosphere (MODEL=M1) for the altitude Z.

For the modeling of the aerosol profiles and extinction coefficients, if AHAZE, VIS1, ISEA1 and IVUL1 are left blank on the MODEL 7 input card, then the aerosol control parameters, IHAZE, ISEASN, IVULCN and VIS on CARD 1 will control the modeling of the altitude-dependent aerosol parameters as described in Section 8.2. LOWTRAN will use the aerosol models contained in the program and interpolate the profiles to the same altitudes as the radiosonde (or new model atmosphere) data.

The additional aerosol options on the MODEL 7 card have been added primarily to provide more user flexibility in modeling altitude-dependent aerosols such as low ground fogs where finer altitude resolution is required to specify the aerosol profile. These options are categorized as follows:

(a) AHAZE > 0, VIS1 = IHA1 = ISEA1 = IVUL1 = 0

For this case, the program will use the value of AHAZE at the altitude, Z, to define the aerosol profile. The parameters on CARD 1 will be used only to select the type of aerosol extinction coefficients to be used in the (0-2 km), (2-10 km), (10-30 km), and (30-100 km) altitude regions as in the MODEL=1 to six cases. VIS on CARD 1 is not used. The user must scale the AHAZE values to the proper sea-level meteorological range.

(b) AHAZE > 0, either IHA1 > 0 or IVUL1 > 0, ISEA1 = 0

where IHA1 = 1 to 9 with the same extinction coefficient options as IHAZE in Section 8.2, and IVUL1 = 1 to 5 with the same extinction coefficient options as IVULCN in Section 8.2. When IHA1 is defined, it will select the type of extinction coefficient to be used with AHAZE at the altitude, Z, and correspondingly when IVUL1 is defined. Only four different altitude regions are allowed for the aerosols in the program. The boundary altitudes are determined from the altitude, Z, on the MODEL 7 card when either IHA1 or IVUL1 changes value. These boundaries do not necessarily have to correspond to the default values in the standard models.

(c) AHAZE = 0, either one or all of the parameters VIS1, IHA1, ISEA1 and IVUL1 defined

where ISEA1 = 1 or 2 with the same seasonal profile options as ISEASN in Section 8.2. The aerosol profiles and extinction coefficients will be determined by the values of these parameters at each altitude Z. Again, as in (b) only four altitude regions for the aerosols are allowed in the program, with the boundaries of the regions determined by the altitude Z when the control parameters change. Note also that IHA1 takes precedence over IVUL1 in the selection of the type of extinction coefficients. Examples of the use of these aerosol options are shown in Section 9.

Although data for cloud extinction is not provided in the LOWTRAN code, these additional aerosol options do allow for user cloud modeling in the atmosphere with the aerosol control parameters on the MODEL 7 card.

Note that IHAZE must be defined to some initial value greater than zero to calculate aerosol extinction and that at least two altitudes are needed to define an aerosol altitude region.

8.3.2 HORIZONTAL PATHS (MODEL = 0)

If meteorological data are to be used for horizontal path atmospheric transmittance calculations, then set MODEL = 0 on CARD 1. The following parameters can then be specified on CARD 2.

CARD 2 H1, P, T, DP, RH, WH, WO, RANGE (FORMAT 3F10.3, 2F5.1, 2E10.3, F10.3) where the above parameters refer to altitude (km), pressure (mb) ambient temperature (°C), dew-point temperature (°C), relative humidity (%), water vapor density (gm m^{-3}), ozone density (gm m^{-3}), and path length (km) respectively.

The format for the above card is similar to that for inputting radiosonde data (MODEL = 7). Again, it is only necessary to specify the quantities underlined with the solid line and one of the quantities underlined with the dashed line. The ozone density WO can be specified using the parameter M3 on CARD 1 if measurements are not available. In the latter case, a value will be calculated at altitude H1 based on the appropriate model atmosphere selected by M3.

The aerosol control parameters for the MODEL = 0 cases are on CARD1 as described in Section 8.2.

9. EXAMPLES OF PROGRAM OUTPUT

Seven cases, representative of different types of atmospheric slant paths, mode of program execution, and atmospheric and aerosol models are presented in this section. The input cards to the program for these cases are listed in Table 5. A description of the program output for each of the cases, calculated from LOWTRAN, follows.

Case 1. Calculate the transmittance from 900 to 1145 cm^{-1} in steps of 5 cm^{-1} for a slant path from 20 km to space at a zenith angle of 90°, for the U.S. Standard model atmosphere, and a 23-km meteorological range for the rural aerosol model.

The output for Case 1 is given in Table 6. A message indicating the mode of execution of the program is printed as the first line of output. For this problem, execution will be in the transmittance mode.

The parameters defining the atmospheric slant path, model atmosphere, aerosol model, and wavenumber range are next printed out.

Table 5. Input Cards for the Seven Test Cases

```
********************************************************************************************
*  CASE 1 * CARD 1 *    6  1  3                                                            *
*         * CARD 2 *    20.                 90.                                            *
*         * CARD 3 *    900.      1145.     5.                                             *
*         * CARD 4 *    2                                                                  *
********************************************************************************************
*  CASE 2 * CARD 1 *    6  1  3                                1                           *
*         * CARD 2 *    20.                 90.                                            *
*         * CARD 3 *    900.      1145.     5.                                             *
*         * CARD 4 *    2                                                                  *
********************************************************************************************
*  CASE 3 * CARD 1 *    6  1  1                                                            *
*         * CARD 2 *    0.        0.        0.         1.        0.                          *
*         * CARD 3 *    900.      1145.     5.                                             *
*         * CARD 4 *    2                                                                  *
********************************************************************************************
*  CASE 4 * CARD 1 *    2  3  2                                                            *
*         * CARD 2 *    12.0      0.        180.                                           *
*         * CARD 3 *    900.      1145.     5.                                             *
*         * CARD 4 *    2                                                                  *
********************************************************************************************
*  CASE 5 * CARD 1 *    0  1  1  0  0  1  1  0  3                                          *
*         *MODEL=0 *    0.        1000.     10.           40.                       10.    *
*         * CARD 3 *    900.      1145.     5.                                             *
*         * CARD 4 *    2                                                                  *
********************************************************************************************
*  CASE 6 * CARD 1 *    7  3  2  0  0  1  0  0  2 21                                       *
*         *MODEL=7 *   0.         1015.     24.4      21.4                                 *
*         *MODEL=7 *   0.136      1000.     22.       19.4                                 *
*         *MODEL=7 *   0.550      950.      17.8      16.1                                 *
*         *MODEL=7 *   1.08       902.      14.6      11.9                                 *
*         *MODEL=7 *   1.526      856.      12.8      5.8                                  *
*         *MODEL=7 *   1.65       832.      12.8      -6.2                                 *
*         *MODEL=7 *   2.27      775.       11.8      -18.2                                *
*         *MODEL=7 *   3.14       750.      7.2       -20.8                                *
*         *MODEL=7 *   5.92       500.      -10.1     -28.1                                *
*         *MODEL=7 *   5.996     488.       -11.5     -27.5                                *
*         *MODEL=7 *   7.510      400.      -19.5     -31.5                                *
*         *MODEL=7 *   8.72       335.      -28.5     -41.5                                *
*         *MODEL=7 *   9.18       318.      -32.7     -39.7                                *
*         *MODEL=7 *   9.59       300.      -35.3     -43.3                                *
*         *MODEL=7 *   9.72       294.      -34.7     -42.7                                *
*         *MODEL=7 *   10.22      281.      -38.7     -45.7                                *
*         *MODEL=7 *   11.83      250.      -44.7     -50.                                 *
*         *MODEL=7 *   12.25      200.      -57.1     -50.                                 *
*         *MODEL=7 *   13.6       161.     -69.5      -50.                                 *
*         *MODEL=7 *   14.65      150.      -71.1     -50.                                 *
*         *MODEL=7 *   16.45      100.      -70.9     -50.                                 *
*         * CARD 2 *   0.01       9.55      35.5                                           *
*         * CARD 3 *    900.      1145.     5.                                             *
*         * CARD 4 *    2                                                                  *
********************************************************************************************
*  CASE 7 * CARD 1 *    7  9  2  0  0  1  6  6  6 12                                       *
*         *MODEL=7 *    .0                                                                 *
*         *MODEL=7 *    .2                                                                 *
*         *MODEL=7 *   .201                                                      23.   1   *
*         *MODEL=7 *   1.0                                                       23.   1   *
*         *MODEL=7 *   2.0                                                       23.   1   *
*         *MODEL=7 *   2.01                                                                *
*         *MODEL=7 *   5.                                                                  *
*         *MODEL=7 *   10.                                                                 *
*         *MODEL=7 *   11.                                                                 *
*         *MODEL=7 *   30.                                                                 *
*         *MODEL=7 *   35.                                                                 *
*         *MODEL=7 *   70.                                                                 *
*         * CARD 2 *   0.         10.                                                      *
*         * CARD 3 *    900.      1145.     5.                                             *
*         * CARD 4 *    2                                                                  *
********************************************************************************************
```

Table 6. Program Output for Case 1

```
PROGRAM WILL BE EXECUTED IN THE TRANSMISSION MODE
6  1  3  5  0  0  0  0  0  0  0      0.000      0.000  0  0      0.080
           20.000      0.000     90.000     0.000      0.000
 900.000  1145.000      5.000

        SLANT PATH TO SPACE FROM ALTITUDE H1 = 20.000 KM, ZENITH ANGLE = 90.000 DEGREES

                    HAZE MODEL  = 23.0 KM VISUAL RANGE AT SEA LEVEL

                 MODEL ATMOSPHERE 6 = 1962 US STANDARD

                  HAZE MODEL  1 =     RURAL       VIS= 23.0KM

                 SEASON =    SPRIG SUMM

                 VERTICAL PROFILE AEROSOL MODEL =        STRAT BKGR

        FREQUENCY RANGE V1=   900.0 CM-1 TO V2=  1145.0 CM-1 FOR DV =   5.0 CM-1   (  8.73 - 11.11 MICRONS )


        HORIZONTAL PROFILES

 ID      ALT       P          T          H2O       CO2+        O3         N2       H2O(10M)     MOLS      (N-1)      O3(UV)
  1      0.00 1013.000   288.100   5.760E-01 9.294E-01 2.493E-03 7.385E-01 6.574E-03 9.481E-01 2.595E-04 2.520E-03
  2      1.00  898.600   281.600   7.719E-01 7.776E-01 2.387E-03 6.014E-01 3.832E-03 8.604E-01 2.353E-04 2.520E-03
  3      2.00  795.000   275.100   2.324E-01 6.490E-01 2.284E-03 4.875E-01 2.127E-03 7.792E-01 2.129E-04 2.520E-03
  4      3.00  701.200   268.700   1.302E-01 5.373E-01 2.021E-03 3.929E-01 9.347E-04 7.037E-01 1.921E-04 2.333E-03
  5      4.00  616.600   262.200   7.157E-02 4.437E-01 1.775E-03 3.152E-01 4.504E-04 6.341E-01 1.729E-04 2.147E-03
  6      5.00  540.500   255.700   3.745E-02 3.648E-01 1.692E-03 2.515E-01 1.927E-04 5.700E-01 1.552E-04 2.147E-03
  7      6.00  472.200   249.200   1.992E-02 2.983E-01 1.576E-03 1.995E-01 8.679E-05 5.109E-01 1.390E-04 2.100E-03
  8      7.00  411.100   242.700   9.636E-03 2.428E-01 1.632E-03 1.573E-01 3.559E-05 4.567E-01 1.241E-04 2.287E-03
  9      8.00  356.500   236.200   5.205E-03 1.964E-01 1.645E-03 1.232E-01 1.567E-05 4.070E-01 1.104E-04 2.427E-03
 10      9.00  308.000   229.700   1.703E-03 1.580E-01 2.131E-03 9.590E-02 4.079E-06 3.616E-01 9.792E-05 3.313E-03
 11     10.00  265.000   223.200   5.897E-04 1.263E-01 2.556E-03 7.412E-02 1.181E-06 3.201E-01 8.654E-05 4.200E-03
 12     11.00  227.000   216.800   2.368E-04 1.003E-01 3.493E-03 5.681E-02 4.288E-07 2.823E-01 7.525E-05 6.067E-03
 13     12.00  194.000   216.600   9.779E-05 7.627E-02 4.038E-03 4.155E-02 1.543E-07 2.415E-01 6.434E-05 7.467E-03
 14     13.00  165.800   216.600   3.919E-05 5.794E-02 4.029E-03 3.035E-02 6.189E-08 2.064E-01 5.499E-05 7.933E-03
 15     14.00  141.700   216.600   1.588E-05 4.402E-02 4.229E-03 2.217E-02 2.415E-08 1.764E-01 4.699E-05 6.667E-03
 16     15.00  121.100   216.600   1.182E-05 3.344E-02 4.389E-03 1.619E-02 1.769E-08 1.508E-01 4.016E-05 9.800E-03
 17     16.00  103.500   216.600   8.591E-06 2.540E-02 4.711E-03 1.183E-02 1.281E-08 1.288E-01 3.433E-05 1.120E-02
 18     17.00   88.500   216.600   6.435E-06 1.931E-02 5.162E-03 8.647E-03 9.334E-09 1.102E-01 2.935E-05 1.307E-02
 19     18.00   75.650   216.600   4.728E-06 1.468E-02 5.541E-03 6.316E-03 6.749E-09 9.418E-02 2.509E-05 1.493E-02
 20     19.00   64.670   216.600   4.106E-06 1.115E-02 5.592E-03 4.617E-03 5.796E-09 8.051E-02 2.145E-05 1.633E-02
 21     20.00   55.290   216.600   3.565E-06 8.479E-03 5.804E-03 3.375E-03 4.961E-09 6.883E-02 1.830E-05 1.773E-02
 22     21.00   47.290   217.600   3.372E-06 6.409E-03 5.440E-03 2.452E-03 4.686E-09 5.860E-02 1.559E-05 1.773E-02
 23     22.00   40.470   218.600   3.169E-06 4.850E-03 5.248E-03 1.783E-03 4.387E-09 4.992E-02 1.329E-05 1.820E-02
 24     23.00   34.670   219.600   3.016E-06 3.676E-03 4.803E-03 1.380E-03 4.171E-09 4.257E-02 1.133E-05 1.773E-02
 25     24.00   29.720   220.600   2.804E-06 2.790E-03 4.274E-03 9.488E-04 3.876E-09 3.633E-02 9.673E-06 1.680E-02
 26     25.00   25.490   221.600   2.637E-06 2.119E-03 3.793E-03 6.932E-04 3.660E-09 3.102E-02 6.502E-06 1.587E-02
 27     30.00   11.970   226.500   7.514E-07 5.479E-04 1.642E-03 1.475E-04 9.944E-10 1.425E-02 2.988E-06 9.333E-03
 28     35.00    5.746   236.500   1.624E-07 1.429E-04 6.674E-04 3.195E-05 1.943E-10 6.551E-03 1.380E-06 5.133E-03
 29     40.00    2.871   253.400   3.531E-08 3.860E-05 2.222E-04 7.192E-06 3.942E-11 3.055E-03 6.574E-07 2.287E-03
 30     45.00    1.491   264.200   9.178E-09 1.158E-05 5.882E-05 1.822E-06 9.676E-12 1.522E-03 3.226E-07 7.933E-04
 31     50.00     .798   270.600   1.939E-09 3.751E-06 1.072E-05 5.032E-07 1.922E-12 7.950E-04 1.239E-07 1.867E-04
 32     70.00     .055   219.700   2.406E-12 4.662E-08 8.259E-08 3.293E-09 1.653E-15 6.775E-05 9.787E-09 4.013E-06
 33    100.00     .000   210.000   1.502E-16 5.422E-12 5.181E-12 1.046E-13 6.054E-20 3.862E-07 5.548E-11 2.067E-09
 34  99999.00    0.000   210.000   0.        0.        0.        0.        0.        0.        0.        0.
```

Table 6. Program Output for Case 1 (Cont.)

```
         HORIZONTAL PROFILES
ID      ALT        P          T        H2O(49)      HNO3        AER1       AER2        AER3        AER4      (AER1*RH)     RH1
 1      0.00 1013.000   288.100   8.479E-02 0.          1.580E-01 0.          0.          0.          7.226E+00 4.575E+01
 2      1.00  898.600   281.600   5.897E-02 0.          9.910E-02 0.          0.          0.          4.862E+00 4.906E+01
 3      2.00  795.000   275.100   3.993E-02 0.          6.210E-02 0.          0.          0.          3.238E+00 5.214E+01
 4      3.00  701.200   268.700   2.432E-02 0.          0.          3.460E-02 0.          0.          0.          0.
 5      4.00  616.600   262.200   1.459E-02 0.          0.          1.850E-02 0.          0.          0.          0.
 6      5.00  540.500   255.700   8.494E-03 0.          0.          9.310E-03 0.          0.          0.          0.
 7      6.00  472.200   249.200   5.779E-03 0.          0.          7.710E-03 0.          0.          0.          0.
 8      7.00  411.100   242.700   2.796E-03 0.          0.          6.230E-03 0.          0.          0.          0.
 9      8.00  356.500   236.200   1.612E-03 4.070E-55 0.          3.370E-03 0.          0.          0.          0.
10      9.00  308.000   229.700   6.265E-04 3.616E-06 0.          1.870E-03 0.          0.          0.          0.
11     10.00  265.000   223.200   2.502E-04 1.056E-05 0.          0.          1.140E-03 0.          0.          0.
12     11.00  227.000   216.800   1.167E-04 2.259E-05 0.          0.          7.990E-04 0.          0.          0.
13     12.00  194.000   216.600   4.525E-05 2.898E-05 0.          0.          6.410E-04 0.          0.          0.
14     13.00  165.800   216.600   1.681E-05 2.890E-05 0.          0.          5.170E-04 0.          0.          0.
15     14.00  141.700   216.600   7.502E-06 2.822E-05 0.          0.          4.420E-04 0.          0.          0.
16     15.00  121.100   216.600   5.496E-06 2.714E-05 0.          0.          3.950E-04 0.          0.          0.
17     16.00  103.500   216.600   3.979E-06 2.448E-05 0.          0.          3.820E-04 0.          0.          0.
18     17.00   88.500   216.600   2.321E-06 2.203E-05 0.          0.          4.250E-04 0.          0.          0.
19     18.00   75.650   216.600   2.199E-06 1.978E-05 0.          0.          5.200E-04 0.          0.          0.
20     19.00   64.670   216.600   1.794E-06 1.852E-05 0.          0.          5.810E-04 0.          0.          0.
21     20.00   55.290   216.600   1.577E-06 2.065E-05 0.          0.          5.890E-04 0.          0.          0.
22     21.00   47.290   217.600   1.391E-06 2.168E-05 0.          0.          5.020E-04 0.          0.          0.
23     22.00   40.470   218.600   1.253E-06 2.097E-05 0.          0.          4.200E-04 0.          0.          0.
24     23.00   34.670   219.600   1.144E-06 2.214E-05 0.          0.          3.300E-04 0.          0.          0.
25     24.00   29.720   220.600   1.221E-06 2.180E-05 0.          0.          1.380E-04 0.          0.          0.
26     25.00   25.490   221.600   9.214E-07 1.179E-05 0.          0.          1.310E-04 0.          0.          0.
27     30.00   11.970   226.500   2.184E-07 3.705E-06 0.          0.          3.320E-05 0.          0.          0.
28     35.00    5.746   236.500   3.431E-08 1.441E-07 0.          0.          0.          1.540E-05 0.          0.
29     40.00    2.871   250.400   4.306E-19 3.055E-57 0.          0.          0.          7.990E-06 0.          0.
30     45.00    1.491   264.200   3.787E-10 0.          0.          0.          0.          4.010E-06 0.          0.
31     50.00     .798   270.600   1.749E-10 0.          0.          0.          0.          2.100E-06 0.          0.
32     70.00     .055   219.700   4.779E-13 0.          0.          0.          0.          1.600E-07 0.          0.
33    100.00     .000   210.000   2.706E-17 0.          0.          0.          0.          9.310E-10 0.          0.
34  99999.00    0.000   210.000   0.          0.          0.          0.          0.          0.          0.          0.

FROM POINT, HEIGHT=   20.0000 KM,N= 21,NP= 1,REF. INDEX ABOVE & BELOW X=  .1930E-04  .2145E-04,IP=  1
            EQUIV. ABSORBED AMOUNTS PER KM AT X=  .357E-05  .842E-02  .590E-02  .332E-02  .498E-08  .688E-01 0.            .17[illegible]E-01


    TX(12-14)= 0.          .589E-03 0.1
```

Table 6. Program Output for Case 1 (Cont.)

```
           VERTICAL PROFILE

 IC   ALT       H2O       CO2+      O3        N2        H2O(10M)  HOLS         AER1      O3(UV)      PSI      PHI       BETA     THETA    RANGE
                          H2O(4M)   HNO3      AER2      AER3      AER4                                                                    ORANGE

 21  20.000 3.921E-04 6.362E-01 6.759E-01 3.266E-01 5.463E-07 7.288E+00 0.         2.005E+00   -.0000  91.0135   1.1135  [illegible]  113.1
     21.000           1.652E-04 2.347E-03 0.                  6.155E-02 0.                                                                  113.06

 22  21.000 5.457E-04 1.100E+00 8.479E-01 4.256E-01 7.600E-07 9.749E+00 0.         2.852E+00    .0088  91.4270   1.4358  68.9954   160.2
     22.000           2.274E-04 3.399E-03 0.                  8.321E-02 0.                                                                   47.13

 23  22.000 6.584E-04 1.253E+00 1.070E+00 4.809E-01 9.148E-07 1.141E+01 0.         3.502E+00    .0141  91.7458   1.7599  68.5783   196.4
     23.000           2.707E-04 4.177E-03 0.                  9.612E-02 0.                                                                   36.16

 24  23.000 7.460E-04 1.351E+00 1.208E+00 5.190E-01 1.038E-06 1.261E+01 0.         4.028E+00    .0178  92.0153   2.0331  68.2579   226.9
     24.000           3.017E-04 4.947E-03 0.                  1.036E-01 0.                                                                   30.50

 25  24.000 8.199E-04 1.417E+00 1.316E+00 5.368E-01 1.139E-06 1.351E+01 0.         4.467E+00    .0205  92.2531   2.2736  67.9675   253.7
     25.000           3.298E-04 5.785E-03 0.                  1.080E-01 0.                                                                   26 87

 26  25.000 9.790E-04 1.539E+00 1.587E+00 5.740E-01 1.354E-06 1.579E+01 0.         5.764E+00    .0251  93.1309   3.2161  67.7515   359.1
     30.000           3.812E-04 6.020E-03 0.                  1.155E-01 0.                                                                  105.37

 27  30.000 1.009E-03 1.563E+00 1.674E+00 5.801E-01 1.394E-06 1.659E+01 0.         6.332E+00    .0288  93.9088   3.9375  66.6127   439.9
     35.000           3.893E-04 6.109E-03 0.                  1.155E-01 0.                                                                   80.79

 28  35.000 1.016E-03 1.569E+00 1.702E+00 5.813E-01 1.401E-06 1.690E+01 0.         6.572E+00    .0301  94.5146   4.5447  66.0925   503.0
     40.000           3.903E-04 6.109E-03 0.                  1.155E-01 7.963E-04                                                            63.09

 29  40.000 1.017E-03 1.570E+00 1.709E+00 5.815E-01 1.402E-06 1.703E+01 0.         6.656E+00    .0306  95.0481   5.0767  65.4660   568.0
     45.000           3.904E-04 6.109E-03 0.                  1.155E-01 1.143E-03                                                            59.99

 30  45.000 1.017E-03 1.571E+00 1.711E+00 5.816E-01 1.402E-06 1.709E+01 0.         6.679E+00    .0306  95.5300   5.5608  64.9521   622.2
     50.000           3.905E-04 6.109E-03 0.                  1.155E-01 1.303E-03                                                            54.24

 31  50.000 1.017E-03 1.571E+00 1.711E+00 5.816E-01 1.402E-06 1.714E+01 0.         6.688E+00    .0310  97.1353   7.1663  64.4701   803.5
     70.000           3.905E-04 6.109E-03 0.                  1.155E-01 1.439E-03                                                           181.31

 32  70.000 1.017E-03 1.571E+00 1.711E+00 5.816E-01 1.402E-06 1.715E+01 0.         6.688E+00    .0310  99.0120   9.0430  62 8647  1017.1
    100.000           3.905E-04 6.109E-03 0.                  1.155E-01 1.446E-03                                                           213.58

 33 100.000 1.017E-03 1.571E+00 1.711E+00 5.816E-01 1.402E-06 1.715E+01 0.         6.688E 00    .0310 176.5553  86.5863  80.9880*******
    ********          3.905E-04 6.109E-03 0.                  1.155E-01 1.446E-03                                                          *******

 34********* 1.017E-03 1.571E+00 1.711E+00 5.816E-01 1.402E-06 1.715E+01 0.        6.688E+00    .0309 176.5553  86.5563   3.4447*******
    ********          3.905E-04 6.109E-03 0.                  1.155E-01 1.446E-03                                                             0.00

        EQUIVALENT SEA LEVEL ABSORBER AMOUNTS

                   WATER VAPOUR     CO2 ETC.      OZONE     NITROGEN (CONT)  H2O  (CONT)     MOL  SCAT       AER1         OZONE(U-V)
                    GM CM-2           KM         ATM CM          KM         GM CM-2           KM                             ATM CM
                                                                                                                      NITRIC ACID*

        W(1-9)=     .102E-02       .157E+01     .171E+01      .582E+00      .140E-05        .171E+02       0.                .669E+01
                                                                            .390E-03                                          .611E-02

                         AER2          AER3          AER4       R.H. MEAN
        W(12-15)=   0.             1.155E-01     1.446E-03      0.*
```

Table 6. Program Output for Case 1 (Cont.)

```
ICH       1    6   10   15
EXTINCTION AND ABSORPTION COEFFICIENTS

  FREQ WAVELENGTH   TOTAL     H2O      CO2+     OZONE  N2 CONT  H2O CONT MOL SCAT  AEROSOL  AEROSOL   INTEGRATED NITRIC ACID
  CM-1  MICRONS     TRANS    TRANS    TRANS    TRANS    TRANS    TRANS    TRANS    TRANS     ABS     ABSORPTION    TRANS
   900  11.1111     .9315    .9999   1.0000   1.0000   1.0000   1.0000   1.0000    .9936    .0063         .1705    .9340*
   905  11.0497     .9477    .9999    .9991   1.0000   1.0000   1.0000   1.0000    .9933    .0066         .4316    .9552*
   910  10.9890     .9552    .9998    .9988   1.0000   1.0000   1.0000   1.0000    .9931    .0068         .6556    .9632*
   915  10.9290     .9617    .9998    .9977    .9999   1.0000   1.0000   1.0000    .9933    .0066         .8476    .9705*
   920  10.8696     .9726    .9998    .9964    .9999   1.0000   1.0000   1.0000    .9936    .0063         .9845    .9826*
   925  10.8108     .9878    .9999    .9943    .9997   1.0000   1.0000   1.0000    .9939    .0060        1.0454   1.0000*
   930  10.7527     .9851    .9999    .9916    .9993   1.0000   1.0000   1.0000    .9942    .0057        1.1196   1.0000*
   935  10.6952     .9812    .9999    .9882    .9985   1.0000   1.0000   1.0000    .9945    .0054        1.2139   1.0000*
   940  10.6383     .9773    .9999    .9855    .9970   1.0000   1.0000   1.0000    .9947    .0052        1.3274   1.0000*
   945  10.5820     .9728    .9999    .9836    .9942   1.0000   1.0000   1.0000    .9949    .0050        1.4632   1.0000*
   950  10.5263     .9352    .9999    .9627    .9465   1.0000   1.0000   1.0000    .9948    .0051        1.8371   1.0000*
   955  10.4712     .8745    .9998    .9831    .8944   1.0000   1.0000   1.0000    .9947    .0052        2.4646   1.0000*
   960  10.4167     .8346    .9998    .9829    .8538   1.0000   1.0000   1.0000    .9946    .0053        3.2917   1.0000*
   965  10.3627     .7784    .9998    .9827    .7966   1.0000   1.0000   1.0000    .9945    .0054        4.3996   1.0000*
   970  10.3093     .7066    .9998    .9815    .7246   1.0000   1.0000   1.0000    .9944    .0055        5.8667   1.0000*
   975  10.2564     .6347    .9998    .9802    .6509   1.0000   1.0000   1.0000    .9943    .0055        7.6934   1.0000*
   980  10.2041     .5111    .9999    .9831    .5229   1.0000   1.0000   1.0000    .9943    .0056       10.1381   1.0000*
   985  10.1523     .3931    .9999    .9884    .4001   1.0000   1.0000   1.0000    .9942    .0057       13.1724   1.0000*
   990  10.1010     .2775    .9999    .9938    .2812   1.0000   1.0000   1.0000    .9941    .0058       16.7036   1.0000*
   995  10.0503     .2273    .9999    .9974    .2290   1.0000   1.0000   1.0000    .9940    .0059       20.6455   1.0000*
  1000  10.0000     .1747    .9998    .9989    .1760   1.0000   1.0000   1.0000    .9939    .0060       24.7756   1.0000*
  1005   9.9502     .1402    .9998    .9993    .1413   1.0000   1.0000   1.0000    .9936    .0063       29.0738   1.0000*
  1010   9.9010     .1163    .9998    .9992    .1173   1.0000   1.0000   1.0000    .9934    .0065       33.4921   1.0000*
  1015   9.8522     .0952    .9997    .9985    .0960   1.0000   1.0000   1.0000    .9931    .0068       38.0161   1.0000*
  1020   9.8039     .0840    .9998    .9972    .0848   1.0000   1.0000   1.0000    .9929    .0071       42.5963   1.0000*
  1025   9.7561     .0806    .9997    .9949    .0816   1.0000   1.0000   1.0000    .9926    .0073       47.1933   1.0000*
  1030   9.7087     .0774    .9998    .9929    .0786   1.0000   1.0000   1.0000    .9924    .0075       51.8461   1.0000*
  1035   9.6618     .0560    .9998    .9684    .0571   1.0000   1.0000   1.0000    .9921    .0078       56.5262   1.0000*
  1040   9.6154     .0633    .9998    .9848    .0645   1.0000   1.0000   1.0000    .9919    .0080       61.2112   1.0000*
  1045   9.5694     .1162    .9998    .9808    .1195   1.0000   1.0000   1.0000    .9916    .0083       65.6300   1.0000*
  1050   9.5238     .0581    .9998    .9794    .0722   1.0000   1.0000   1.0000    .9914    .0085       70.2095   1.0000*
  1055   9.4787     .0597    .9998    .9774    .0617   1.0000   1.0000   1.0000    .9911    .0087       74.9906   1.0000*
  1060   9.4340     .0720    .9997    .9770    .0744   1.0000   1.0000   1.0000    .9909    .0090       79.6368   1.0000*
  1065   9.3897     .0944    .9997    .9758    .0976   1.0000   1.0000   1.0000    .9907    .0092       84.1590   1.0000*
  1070   9.3458     .1607    .9997    .9731    .1668   1.0000   1.0000   1.0000    .9904    .0094       88.3556   1.0000*
  1075   9.3023     .5035    .9997    .9727    .5229   1.0000   1.0000   1.0000    .9902    .0097       90.6386   1.0000*
  1080   9.2593     .6284    .9998    .9754    .6509   1.0000   1.0000   1.0000    .9900    .0099       92.6959   1.0000*
  1085   9.2166     .6450    .9998    .9822    .6637   1.0000   1.0000   1.0000    .9898    .0101       94.4706   1.0000*
  1090   9.1743     .6571    .9998    .9872    .6727   1.0000   1.0000   1.0000    .9896    .0103       96.1853   1.0000*
  1095   9.1324     .6615    .9997    .9941    .6727   1.0000   1.0000   1.0000    .9895    .0104       97.8775   1.0000*
  1100   9.0909     .6680    .9996    .9973    .6773   1.0000   1.0000   1.0000    .9894    .0105       99.5376   1.0000*
  1105   9.0498     .6646    .9995    .9992    .6727   1.0000   1.0000   1.0000    .9893    .0106      101.2144   1.0000*
  1110   9.0090     .6558    .9994    .9996    .6637   1.0000   1.0000   1.0000    .9891    .0107      102.9352   1.0000*
  1115   8.9686     .6472    .9995    .9998    .6551   1.0000   1.0000   1.0000    .9887    .0112      104.6991   1.0000*
  1120   8.9286     .6426    .9996    .9995    .6509   1.0000   1.0000   1.0000    .9882    .0117      106.4859   1.0000*
  1125   8.8889     .6379    .9997    .9989    .6467   1.0000   1.0000   1.0000    .9877    .0122      108.2966   1.0000*
  1130   8.8496     .6411    .9997    .9983    .6509   1.0000   1.0000   1.0000    .9872    .0127      110.0913   1.0000*
  1135   8.8106     .5608    .9996    .9960    .5727   1.0000   1.0000   1.0000    .9866    .0132      111.7871   1.0000*
  1140   8.7719     .7009    .9996    .9922    .7166   1.0000   1.0000   1.0000    .9861    .0137      113.2629   1.0000*
  1145   8.7336     .7410    .9996    .9872    .7519   1.0000   1.0000   1.0000    .9856    .0142      113.9303   1.0000*
INTEGRATED ABSORPTION FROM  900 TO 1145 CM-1 =     113.93AVERAGE TRANSMITTANCE = .5350
 2
```

Following the heading HORIZONTAL PROFILES are two pages of output, each of 12 columns. On the first page, the first four columns list a running integer associated with each level (level indicator), the level altitude in km, the level pressure (mb), and the level temperature (^{O}K). The next six columns give the equivalent absorber amounts per km for the following absorbing species: water vapor, uniformly mixed gases, ozone, nitrogen continuum, water vapor continuum (10 μm), and molecular scattering. The last two columns give the mean refractive index modulus (n - 1) from that level to the level above, and the equivalent absorber amount per km for the UV ozone.

On the second page, the first four columns, listing the level indicator, altitude, pressure, and temperature are repeated. The next two columns give the equivalent absorber amount per km for the water vapor continuum (4 μm) and for nitric acid. The next four columns give the aerosol amounts per km for the four altitude regions provided for in the program. The last two columns list the product of the aerosol density times the percent relative humidity and the percent relative humidity for the boundary-layer region.

Following the horizontal profiles, level information at H1 calculated in subroutine POINT is printed.

A heading VERTICAL PROFILES is then printed followed by two lines of output per atmospheric layer. The first column is an integer level indicator. The second column gives the altitudes of the levels traversed by the atmospheric slant path. The next eight columns give the integrated equivalent absorber amounts from the initial altitude to the level above (with the species identified as in the header). The next four columns are labelled PSI, PHI, BETA, and THETA, and correspond to the angles ψ, ϕ, β, and θ described in Section 4. Columns PSI and BETA give the accumulated values of ψ and β to the level above. Columns THETA and PHI give the local zenith angle corresponding to that level and the angle of arrival at the level above, respectively. In the last column, the accumulated slant range, RANGE, is printed, and below it the differential slant range of the levels traversed.

The total equivalent absorber amounts along the atmospheric path are then summarized in their appropriate units.

Control parameters for the altitude-dependent aerosol extinction and absorption coefficients are then printed from Subroutine EXABIN.

A transmittance table, containing 13 columns, now follows. The first three columns give the frequency (cm^{-1}) wavelength (μm), and total transmittance. The next seven columns show the individual transmittance due to water vapor, uniformly mixed gases, ozone, nitrogen (4 μm) continuum, total water vapor continuum, molecular scattering, and total aerosol extinction. The next two columns give absorption due to aerosols and the cumulative integrated absorption. The latter quantity can be used to determine the average transmittance over any given spectral interval within the spectral range covered by the calculation. The last column gives the transmittance of nitric acid. Finally, the total integrated absorption from V1 to V2 is printed out (units are cm^{-1}) together with the average transmittance over the band.

Case 2. Calculate the radiance at H1 for the same conditions as in Case 1. The output of the program, shown in Table 7, is identical to that of Case 1 up to and including the printing of the aerosol control parameters.

Two parameters, J1 and J2, are then printed out. These parameters control the loading of the cumulative absorber amounts into the matrix, WPATH.

A heading CUMULATIVE ABSORBER AMOUNTS FOR THE ATMOSPHERIC PATH is then printed followed by 16 columns. The first column gives an integer associated with the layer traversal by the atmospheric slant path. The following 10 columns give the cumulative absorber amounts for the following species: water vapor, uniformly mixed gases, ozone, nitrogen continuum, water vapor continuum (10 μm), molecular scattering, aerosol extinction (boundary layer), UV ozone, water vapor continuum (4 μm) and nitric acid. The next column is the average temperature of the layer.

Below this output, the layer ID is repeated and the other three altitude-dependent, cumulative aerosol absorber amounts are printed.

A radiance table, containing six columns, now follows. The first two columns give the frequency (cm^{-1}) and the wavelength (μm). The next two columns give the radiance in units of W/cm^2-ster-cm^{-1} and W/cm^2-ster-μm. The next column gives the cumulative integrated radiance (W/cm^2-ster). The last column is the total transmittance.

Finally, the maximum and minimum radiances and their frequencies, the integrated absorption, the average transmittance, and the total integrated radiance are printed.

Case 3. Calculate the transmittance from 900 to 1145 cm^{-1} in steps of 5 cm^{-1} for a 1-km horizontal path at sea level, using the U.S. Standard atmosphere and the rural, 23-km meteorological range, aerosol model.

The output for Case 3, shown in Table 8, with the exception of the omission of the vertical profiles, is similar to that described for Case 1.

Case 4. Calculate the transmittance from 900 to 1145 cm^{-1} in steps of 5 cm^{-1}, for a slant path from 12 km to ground (0 km) at a zenith angle of 180°, using the midlatitude summer model atmosphere and a maritime, 23 km meteorological range aerosol model.

The output for this case, shown in Table 9, is similar to that described for Case 1.

Table 7. Program Output for Case 2

```
PROGRAM WILL BE EXECUTED IN THE EMISSION MODE
6  1  3  0  0  0  0  0  0  0  1      0.000      0.000  0  0      0.000
            20.000      0.000    90.000      0.000      0.000
 900.000  1145.000      5.000

        SLANT PATH TO SPACE FROM ALTITUDE H1 = 20.000 KM, ZENITH ANGLE = 90.000 DEGREES

                  HAZE MODEL  = 23.0 KM VISUAL RANGE AT SEA LEVEL

              MODEL ATMOSPHERE 6 = 1962 US STANDARD

                HAZE MODEL  1 =     RURAL       VIS= 23.0KM

              SEASON =    SPRIG SUMM

              VERTICAL PROFILE AEROSOL MODEL =       STRAT BKGR

        FREQUENCY RANGE V1=   900.0 CM-1 TO V2=  1145.0 CM-1 FOR DV =   5.0 CM-1    ( 8.73 - 11.11 MICRONS )

        HORIZONTAL PROFILES

ID      ALT       P          T        H2O       CO2+        O3         N2      H2O(10M)     MOLS       (N-1)      O3(UV)
 1      0.00 1013.000  288.100  5.760E-01 8.294E-01 2.497E-03 7.385E-01 6.574E-03 9.481E-01 2.595E-04 2.520E-03
 2      1.00  898.600  281.600  3.719E-01 7.776E-01 2.307E-03 6.014E-01 3.832E-03 8.604E-01 2.393E-04 2.524E-03
 3      2.00  795.000  275.100  2.324E-01 6.480E-01 2.284E-03 4.875E-01 2.127E-03 7.792E-01 2.129E-04 2.520E-03
 4      3.00  701.200  268.700  1.302E-01 5.373E-01 2.021E-03 3.929E-01 9.847E-04 7.037E-01 1.921E-04 2.333E-03
 5      4.00  616.600  262.200  7.157E-02 4.437E-01 1.775E-03 3.152E-01 4.504E-04 6.341E-01 1.729E-04 2.147E-03
 6      5.00  540.500  255.700  3.746E-02 3.649E-01 1.592E-03 2.515E-01 1.927E-04 5.703E-01 1.552E-04 2.147E-03
 7      6.00  472.200  249.200  1.997E-02 2.983E-01 1.576E-03 1.995E-01 8.679E-05 5.109E-01 1.390E-04 2.100E-03
 8      7.00  411.100  242.700  9.136E-03 2.428E-01 1.632E-03 1.573E-01 3.559E-05 4.567E-01 1.241E-04 2.287E-03
 9      8.00  356.500  236.200  5.005E-03 1.964E-01 1.645E-03 1.232E-01 1.567E-05 4.070E-01 1.104E-04 2.427E-03
10      9.00  308.000  229.700  1.703E-03 1.580E-01 2.131E-03 9.590E-02 4.079E-06 3.616E-01 9.792E-05 3.313E-03
11     10.00  265.000  223.200  5.397E-04 1.263E-01 2.558E-03 7.412E-02 1.181E-06 3.201E-01 8.654E-05 4.200E-03
12     11.00  227.000  216.800  2.369E-04 1.[illegible]E-01 3.493E-03 5.681E-02 4.288E-07 2.823E-01 7.525E-05 6.067E-03
13     12.00  194.000  216.600  9.379E-05 7.627E-02 4.038E-03 4.155E-02 1.543E-07 2.415E-01 6.434E-05 7.467E-03
14     13.00  165.800  216.600  3.719E-05 5.794E-02 4.029E-03 3.035E-02 6.189E-08 2.064E-01 5.499E-05 7.933E-03
15     14.00  141.700  216.600  1.588E-05 4.402E-02 4.229E-03 2.217E-02 2.415E-08 1.764E-01 4.699E-05 8.867E-03
16     15.00  121.100  216.600  1.182E-05 3.344E-02 4.389E-03 1.619E-02 1.769E-08 1.508E-01 4.016E-05 9.800E-03
17     16.00  103.500  216.600  8.591E-06 2.540E-02 4.711E-03 1.183E-02 1.281E-08 1.288E-01 3.433E-05 1.120E-02
18     17.00   88.500  216.600  5.435E-06 1.931E-02 5.162E-03 8.647E-03 9.334E-09 1.102E-01 2.935E-05 1.307E-02
19     18.00   75.650  216.600  4.728E-06 1.468E-02 5.541E-03 6.318E-03 6.749E-09 9.418E-02 2.509E-05 1.493E-02
20     19.00   64.670  216.600  4.106E-06 1.115E-02 5.692E-03 4.617E-03 5.796E-09 8.051E-02 2.145E-05 1.633E-02
21     20.00   55.290  216.600  3.567E-06 8.479E-03 5.804E-03 3.375E-03 4.981E-09 6.883E-02 1.830E-05 1.773E-02
22     21.00   47.290  217.600  3.772E-06 6.405E-03 5.448E-03 2.452E-03 4.686E-09 5.860E-02 1.559E-05 1.773E-02
23     22.00   40.470  218.600  3.169E-06 4.850E-03 5.248E-03 1.783E-03 4.387E-09 4.992E-02 1.329E-05 1.820E-02
24     23.00   34.670  219.600  3.115E-06 3.676E-03 4.803E-03 1.300E-03 4.171E-09 4.257E-02 1.133E-05 1.773E-02
25     24.00   29.720  220.600  2.994E-06 2.790E-03 4.274E-03 9.485E-04 3.878E-09 3.633E-02 9.673E-06 1.680E-02
26     25.00   25.490  221.600  2.637E-06 2.119E-03 3.793E-03 5.932E-04 3.660E-09 3.102E-02 6.502E-06 1.587E-02
27     30.00   11.970  226.500  7.514E-07 9.479E-04 1.642E-03 1.479E-04 9.944E-10 1.425E-02 2.988E-06 9.333E-03
28     35.00    5.746  236.500  1.624E-07 1.429E-04 6.674E-04 3.195E-05 1.943E-10 6.551E-03 1.380E-06 5.133E-03
29     40.00    2.871  253.400  3.531E-08 3.860E-05 2.222E-04 7.192E-06 3.942E-11 3.055E-03 6.574E-07 2.287E-03
30     45.00    1.491  264.200  9.179E-09 1.158E-05 5.882E-05 1.822E-06 9.676E-12 1.522E-03 3.328E-07 7.933E-04
31     50.00     .798  270.600  1.939E-09 3.751E-06 1.072E-05 5.032E-07 1.922E-12 7.950E-04 1.239E-07 1.867E-04
32     70.00     .052  219.700  2.406E-12 4.662E-08 8.259E-08 3.293E-09 1.653E-15 6.775E-05 9.787E-09 4.013E-06
33    100.00     .000  210.000  1.502E-16 5.422E-12 5.181E-12 1.046E-13 6.054E-20 3.862E-07 5.548E-11 2.007E-09
34  99999.00    0.000  210.000  0.        0.        0.        0.        0.        0.        0.        0.
```

Table 7. Program Output for Case 2 (Cont.)

```
          HORIZONTAL PROFILES
ID     ALT      P        T       H2O(WM)      HNO3        AER1       AER2       AER3       AER4     (AER1*RH)     RH%
 1     0.00 1013.000  288.100  8.479E-02 0.             1.580E-01 0.         0.         0.         7.228E+00 4.575E+01
 2     1.00  898.600  281.600  5.997E-02 0.             9.910E-02 0.         0.         0.         4.262E+00 4.906E+01
 3     2.00  795.000  275.100  3.393E-02 0.             6.210E-02 0.         0.         0.         3.238E+00 5.214E+01
 4     3.00  701.200  268.700  2.432E-02 0.             0.         3.460E-02 0.         0.         0.         0.
 5     4.00  616.600  262.200  1.469E-02 0.             0.         1.850E-02 0.         0.         0.         0.
 6     5.00  540.500  255.700  8.494E-03 0.             0.         9.310E-03 0.         0.         0.         0.
 7     6.00  472.200  249.200  5.139E-03 0.             0.         7.710E-03 0.         0.         0.         0.
 8     7.00  411.100  242.700  2.796E-03 0.             0.         6.230E-03 0.         0.         0.         0.
 9     8.00  356.500  236.200  1.512E-03 4.070E-55 0.             3.370E-03 0.         0.         0.         0.
10     9.00  308.000  229.700  6.266E-04 3.616E-06 0.             1.820E-03 0.         0.         0.         0.
11    10.00  265.000  223.200  2.502E-04 1.056E-05 0.             0.         1.140E-03 0.         0.         0.
12    11.00  227.000  216.800  1.167E-04 2.259E-05 0.             0.         7.990E-04 0.         0.         0.
13    12.00  194.000  216.600  4.525E-05 2.698E-05 0.             0.         6.410E-04 0.         0.         0.
14    13.00  165.800  216.600  1.481E-05 2.890E-05 0.             0.         5.170E-04 0.         0.         0.
15    14.00  141.700  216.600  7.502E-06 2.822E-05 0.             0.         4.420E-04 0.         0.         0.
16    15.00  121.100  216.600  5.496E-06 2.714E-05 0.             0.         3.950E-04 0.         0.         0.
17    16.00  103.500  216.600  3.979E-06 2.448E-05 0.             0.         3.820E-04 0.         0.         0.
18    17.00   88.500  216.600  2.901E-06 2.203E-05 0.             0.         4.250E-04 0.         0.         0.
19    18.00   75.650  216.600  2.099E-06 1.978E-05 0.             0.         5.200E-04 0.         0.         0.
20    19.00   64.670  216.600  1.794E-06 1.852E-05 0.             0.         5.810E-04 0.         0.         0.
21    20.00   55.290  216.500  1.533E-06 2.065E-05 0.             0.         5.890E-04 0.         0.         0.
22    21.00   47.290  217.600  1.390E-06 2.168E-05 0.             0.         5.020E-04 0.         0.         0.
23    22.00   40.470  218.600  1.257E-06 2.097E-05 0.             0.         4.200E-04 0.         0.         0.
24    23.00   34.670  219.600  1.144E-06 2.214E-05 0.             0.         3.000E-04 0.         0.         0.
25    24.00   29.720  220.600  1.021E-06 2.180E-05 0.             0.         1.980E-04 0.         0.         0.
26    25.00   25.490  221.600  9.214E-07 1.179E-05 0.             0.         1.310E-04 0.         0.         0.
27    30.00   11.970  226.500  2.184E-07 3.705E-06 0.             0.         3.320E-05 0.         0.         0.
28    35.00    5.746  236.500  7.431E-08 1.441E-07 0.             0.         0.         1.640E-05 0.         0.
29    40.00    2.871  253.400  4.906E-09 3.055E-57 0.             0.         0.         7.990E-06 0.         0.
30    45.00    1.491  264.200  9.787E-10 0.             0.         0.         0.         4.010E-06 0.         0.
31    50.00     .798  270.600  1.746E-11 0.             0.         0.         0.         2.100E-06 0.         0.
32    70.00     .055  219.700  4.779E-13 0.             0.         0.         0.         1.600E-07 0.         0.
33   100.00     .000  210.000  2.306E-17 0.             0.         0.         0.         9.310E-10 0.         0.
34 99999.00    0.000  210.000  0.         0.             0.         0.         0.         0.         0.         0.

FROM POINT\ HEIGHT=   20.0000 KM,N= 21,NP= 1,REF. INDEX ABOVE & BELOW X=  .1830E-04  .2145E-04,IF=  1
          EQUIV. ABSORBER AMOUNTS PER KM AT X=  .357E-05  .148E-02  .580E-02  .338E-02  .498E-08  .688E-01 0.          .177E-01


     TX(12-14) = 0.          .589E-03 0.1
```

Table 7. Program Output for Case 2 (Cont.)

```
            VERTICAL PROFILES

IC  ALT      H2O       CO2+      O3        N2        H2O(10M)  MOLS     AER1         O3(UV)      PSI      PHI      BETA     THETA    RANGE
                       H2O(4M)   HNO3      AER2      AER3      AER4                                                                DRANGE

21  20.000 3.921E-04 8.362E-01 6.759E-01 3.266E-01 5.463E-07 7.188E+00 0.          2.005E+00  -.0000  91.0135   1.0135  90.0000   113.1
    21.000           1.652E-04 2.393E-03 0.                  6.155E-02 0.                                                            113.06

22  21.000 5.462E-04 1.100E+00 8.879E-01 4.256E-01 7.600E-07 9.744E+00 0.          2.852E+00   .0088  91.4270   1.4358  88.9554   160.2
    22.000           2.274E-04 3.398E-03 0.                  8.321E-02 0.                                                             47.13

23  22.000 6.581E-04 1.253E+00 1.071E+00 4.809E-01 9.148E-07 1.141E+01 0.          3.502E+00   .0141  91.7458   1.7599  88.5763   196.4
    23.000           2.707E-04 4.177E-03 0.                  9.612E-02 0.                                                             36.18

24  23.000 7.468E-04 1.351E+00 1.208E+00 5.150E-01 1.038E-06 1.261E+01 0.          4.028E+00   .0176  92.0153   2.0331  88.2579   226.9
    24.000           3.037E-04 4.847E-03 0.                  1.036E-01 0.                                                             30.50

25  24.000 8.199E-04 1.417E+00 1.316E+00 5.368E-01 1.139E-06 1.351E+01 0.          4.467E+00   .0205  92.2501   2.2736  87.9875   253.7
    25.000           3.298E-04 5.085E-03 0.                  1.080E-01 0.                                                             26.67

26  25.000 9.790E-04 1.539E+00 1.587E+00 5.740E-01 1.254E-06 1.579E+01 0.          5.764E+00   .0251  93.1909   3.2161  87.7515   359.1
    30.000           3.812E-04 5.020E-03 0.                  1.155E-01 0.                                                            105.37

27  30.000 1.010E-03 1.565E+00 1.674E+00 5.801E-01 1.394E-06 1.659E+01 0.          6.332E+00   .0288  93.9086   3.9376  86.8127   439.9
    35.000           3.893E-04 6.103E-03 0.                  1.155E-01 0.                                                             80.79

28  35.000 1.016E-03 1.569E+00 1.702E+00 5.813E-01 1.401E-06 1.690E+01 0.          6.572E+00   .0301  94.5146   4.5447  86.0925   508.0
    40.000           3.903E-04 6.109E-03 0.                  1.155E-01 7.963E-04                                                      68.09

29  40.000 1.017E-03 1.570E+00 1.709E+00 5.815E-01 1.402E-06 1.703E+01 0.          6.656E+00   .0306  95.0481   5.0707  85.4860   568.
    45.000           3.904E-04 6.109E-03 0.                  1.155E-01 1.143E-03                                                      59.99

30  45.000 1.017E-03 1.571E+00 1.711E+00 5.816E-01 1.402E-06 1.709E+01 0.          6.679E+00   .0308  95.5306   5.5608  84.9521   622.2
    50.000           3.905E-04 6.109E-03 0.                  1.155E-01 1.303E-03                                                      54.24

31  50.000 1.017E-03 1.571E+00 1.711E+00 5.816E-01 1.402E-06 1.714E+01 0.          6.688E+00   .0310  97.1353   7.1563  84.4731   803.5
    70.000           3.905E-04 6.109E-03 0.                  1.155E-01 1.439E-03                                                     181.31

32  70.000 1.017E-03 1.571E+00 1.711E+00 5.816E-01 1.402E-06 1.715E+01 0.          6.688E+00   .0314  99.0126   9.0436  82.8647  1017.1
   100.000           3.905E-04 6.109E-03 0.                  1.155E-01 1.446E-03                                                     213.58

33 100.000 1.017E-03 1.571E+00 1.711E+00 5.816E-01 1.402E-06 1.715E+01 0.          6.689E+00   .0316 176.5553  86.5863  6[illegible].988*******
   ********          3.905E-04 6.109E-03 0.                  1.155E-01 1.446E-03                                                    *******

34******** 1.017E-03 1.571E+00 1.711E+00 5.816E-01 1.402E-06 1.715E+01 0.          6.688E+00   .0309 176.5553  86.5863   3.4447*******
   ********          3.905E-04 6.109E-03 0.                  1.155E-01 1.446E-03                                                        .00

            EQUIVALENT SEA LEVEL ABSORBER AMOUNTS

                     WATER VAPOUR      CO2 ETC.       OZONE      NITROGEN (CONT)  H2O  (CONT)     MOL   SCAT       AER1          OZONE(U-V)
                      GM CM-2           KM           ATM CM          KM          GM CM-2         KM                                ATM CM
                                                                                                                              NITRIC ACID*

            W(1-8)=    .102E-02        .157E+01      .171E+01      .582E+00      .140E-05       .171E+02      0.                  .669E+01
                                                                                 .350E-02                                          .611E-02

                            AER2              AER3          AER4         R.H. MEAN
            W(12-15)=    0.                1.155E-01     1.446E-03      0.
```

Table 7. Program Output for Case 2 (Cont.)

```
ICH      1    5   10   15
EXTINCTION AND ABSORPTION COEFFICIENTS
21 34


                       CUMULATIVE ABSORBER AMOUNTS FOR THE ATMOSPHERIC PATH

       H2O        CO2+        O3          N2         H2O C       MOL S      AER1        O3 UV       H2O C       HNO3        TAVE
  1  3.921E-04  8.362E-01  6.759E-01  3.256E-01  5.453E-07  7.188E+00  0.         2.005E+00  1.652E-04  2.393E-03  217.100
  2  5.462E-04  1.100E+00  8.879E-01  4.256E-01  7.600E-07  9.740E+00  0.         2.852E+00  2.274E-04  3.398E-03  218.100
  3  5.581E-04  1.253E+00  1.070E+00  4.809E-01  9.148E-07  1.141E+01  0.         3.502E+00  2.707E-04  4.177E-03  219.100
  4  7.465E-04  1.351E+00  1.208E+00  5.150E-01  1.038E-06  1.261E+01  0.         4.028E+00  3.037E-04  4.847E-03  220.100
  5  9.199E-04  1.417E+00  1.316E+00  5.358E-01  1.139E-06  1.351E+01  0.         4.467E+00  3.298E-04  5.285E-03  221.100
  6  9.790E-04  1.539E+00  1.587E+00  5.740E-01  1.354E-06  1.579E+01  0.         5.764E+00  3.812E-04  6.020E-03  224.050
  7  1.010E-03  1.567E+00  1.674E+00  5.801E-01  1.394E-06  1.659E+01  0.         6.232E+00  3.893E-04  6.109E-03  231.500
  8  1.016E-03  1.569E+00  1.702E+00  5.813E-01  1.401E-06  1.690E+01  0.         6.572E+00  3.903E-04  6.109E-03  244.950
  9  1.017E-03  1.570E+00  1.709E+00  5.815E-01  1.402E-06  1.703E+01  0.         6.656E+00  3.904E-04  6.109E-03  258.800
 10  1.017E-03  1.571E+00  1.711E+00  5.815E-01  1.402E-06  1.709E+01  0.         6.679E+00  3.905E-04  6.109E-03  267.400
 11  1.017E-03  1.571E+00  1.711E+00  5.816E-01  1.402E-06  1.714E+01  0.         6.688E+00  3.905E-04  6.109E-03  245.150
 12  1.017E-03  1.571E+00  1.711E+00  5.816E-01  1.402E-06  1.715E+01  0.         6.688E+00  3.905E-04  6.109E-03  214.850
 13  1.017E-03  1.571E+00  1.711E+00  5.816E-01  1.402E-06  1.715E+01  0.         6.688E+00  3.905E-04  6.109E-03  210.000

ID    AER2         AER3        AER4
  1  0.          6.155E-02  0.
  2  0.          8.321E-02  0.
  3  0.          9.612E-02  0.
  4  0.          1.036E-01  0.
  5  0.          1.080E-01  0.
  6  0.          1.155E-01  0.
  7  0.          1.155E-01  0.
  8  0.          1.155E-01  7.963E-04
  9  0.          1.155E-01  1.143E-03
 10  0.          1.155E-01  1.303E-03
 11  0.          1.155E-01  1.439E-03
 12  0.          1.155E-01  1.446E-03
 13  0.          1.155E-01  1.446E-03
```

Table 7. Program Output for Case 2 (Cont.)

```
                              RADIANCE(WATTS/CM2-STER-XXX):
 FR(CM-1)   WVL(MICRON)      PER CM-1     PER MICRON     INTEGRAL            TRANS
    900.0    11.111111     .16164E-06    .13093E-04    .40410E-06          .931759
    905.0    11.049724     .12192E-06    .99852E-05    .10137E-05           947745
    910.0    10.989011     .10297E-06    .85266E-05    .15285E-05          .955162
    915.0    10.928962     .86637E-07    .72534E-05    .19617E-05          .961666
    920.0    10.869565     .60854E-07    .51507E-05    .22664E-05          .972621
    925.0    10.810811     .26577E-07    .22740E-05    .23988E-05          .987833
    930.0    10.752688     .31905E-07    .27594E-05    .25584E-05          .985119
    935.0    10.695187     .39754E-07    .34754E-05    .27571E-05          .981171
    940.0    10.638298     .47081E-07    .41601E-05    .29525E-05          .977301
    945.0    10.582011     .55364E-07    .49442E-05    .32694E-05          .972640
    950.0    10.526316     .15285E-06    .13795E-04    .40336E-05          .925223
    955.0    10.471204     .25232E-06    .23012E-04    .52952E-05          .874511
    960.0    10.416667     .32513E-06    .29964E-04    .69209E-05          .834569
    965.0    10.362694     .42639E-06    .39707E-04    .90528E-05          .778423
    970.0    10.309278     .55343E-06    .52072E-04    .11820E-04          .706579
    975.0    10.256410     .67475E-06     64143E-04    .15194E-04          .634653
    980.0    10.204082     .83156E-06    .84665E-04    .19601E-04          .511063
    985.0    10.152284     .10724E-05    .10405E-03    .24964E-04          .393142
    990.0    10.101010     .12275E-05    .12031E-03    .31101E-04          .277756
    995.0    10.050251     .12792E-05    .12665E-03    .37497E-04          .227030
   1000.0    10.000000     .13341E-05    .13341E-03    .44168E-04          .174697
   1005.0     9.950249     .13591E-05    .13728E-03    .50964E-04          .140230
   1010.0     9.900990     .13670E-05    .13953E-03    .57803E-04          .116348
   1015.0     9.852217     .13719E-05    .14134E-03    .64662E-04          .095201
   1020.0     9.803922     .13614E-05    .14164E-03    .71469E-04          .083967
   1025.0     9.756098     .13408E-05    .14087E-03    .78173E-04          .084599
   1030.0     9.708738     .13200E-05    .14004E-03    .84773E-04          .077442
   1035.0     9.661836     .13220E-05    .14161E-03    .91383E-04          .055971
   1040.0     9.615385     .12896E-05    .13948E-03    .97831E-04          .063006
   1045.0     9.569378     .12018E-05    .13124E-03    .10364E-03          .116238
   1050.0     9.523810     .12359E-05    .13626E-03    .11002E-03          .068097
   1055.0     9.478673     .12228E-05    .13610E-03    .11613E-03          .059749
   1060.0     9.433962     .11856E-05    .13321E-03    .12206E-03          .071993
   1065.0     9.389671     .11397E-05    .12926E-03    .12776E-03          .094354
   1070.0     9.345794     .10455E-05    .11977E-03    .13299E-03          .160674
   1075.0     9.302326     .63249E-06    .73093E-04    .13615E-03          .503533
   1080.0     9.259259     .46608E-06    .54597E-04    .13849E-03          .628418
   1085.0     9.216590     .44050E-06    .51856E-04    .14069E-03          .645048
   1090.0     9.174312     .41827E-06    .49694E-04    .14278E-03          .657076
   1095.0     9.132420     .40534E-06    .48601E-04    .14431E-03          .661553
   1100.0     9.090909     .39039E-06    .47238E-04    .14676E-03          .667975
   1105.0     9.049774     .38683E-06    .47233E-04    .14870E-03          .664648
   1110.0     9.009009     .38916E-06    .47949E-04    .15064E-03          .655836
   1115.0     8.968610     .39428E-06    .46521E-04    .15259E-03          .647215
   1120.0     8.928571     .38734E-06    .48588E-04    .15453E-03          .642639
   1125.0     8.888889     .38452E-06    .48666E-04    .15645E-03          .637666
   1130.0     8.849558     .37413E-06    .47772E-04    .15832E-03          .641652
   1135.0     8.810573     .34808E-06    .44840E-04    .16006E-03          .660839
   1140.0     8.771930     .30124E-06    .39149E-04    .16157E-03          .700852
   1145.0     8.733624     .25515E-06    .33451E-04    .16221E-03          .741014
INTEGRATED ABSORPTION FROM  900 TO 1145 CM-1 =    113.93AVERAGE TRANSMITTANCE = .5350
INTEGRATED RADIANCE =  .16221E-03WATT CM -2 SR
RADMIN      925.000  .26577E-07
RADMAX      1015.000  .13719E-05
 2
```

Table 8. Program Output for Case 3

```
PROGRAM WILL BE EXECUTED IN THE TRANSMISSION MODE
6  1  1  0  0  0  0  0  0  0  0     0.000     0.000  0  0      0.000
          0.000     0.000     0.000     1.000     0.000
 900.000 1145.000     5.000

        HORIZONTAL PATH, ALTITUDE =  0.000 KM,RANGE =  1.000 KM

                  HAZE MODEL  = 23.0 KM VISUAL RANGE AT SEA LEVEL

              MODEL ATMOSPHERE 6 = 1962 US STANDARD

                HAZE MODEL  1 =    RURAL      VIS= 23.0KM

              SEASON =    SPRIG SUMM

              VERTICAL PROFILE AEROSOL MODEL =        STRAT BKGD

        FREQUENCY RANGE V1=   900.0 CM-1 TO V2=  1145.0 CM-1 FOR DV =   5.0 CM-1   ( 8.73 - 11.11 MICRONS )

        HORIZONTAL PROFILES

ID      ALT        P         T        H2O       CO2+       O3         N2      H20(10M)     MOLS      (N-1)     O3(UV)
 1     0.00 1013.000   288.100  5.763E-01 9.294E-01 2.493E-03 7.385E-01 6.574E-03 9.481E-01 2.595E-04 2.520E-03
 2     1.00  898.600   281.600  3.719E-01 7.776E-01 2.387E-03 6.014E-01 3.832E-03 8.604E-01 2.353E-04 2.520E-03
 3     2.00  795.000   275.100  2.324E-01 6.480E-01 2.284E-03 4.875E-01 2.127E-03 7.792E-01 2.129E-04 2.520E-03
 4     3.00  701.200   268.700  1.302E-01 5.375E-01 2.021E-03 3.929E-01 9.847E-04 7.037E-01 1.921E-04 2.333E-03
 5     4.00  616.600   262.200  7.167E-02 4.437E-01 1.775E-03 3.152E-01 4.504E-04 6.341E-01 1.729E-04 2.147E-03
 6     5.00  540.500   255.700  3.746E-02 3.648E-01 1.692E-03 2.515E-01 1.927E-04 5.730E-01 1.552E-04 2.147E-03
 7     6.00  472.200   249.200  1.992E-02 2.983E-01 1.576E-03 1.995E-01 8.679E-05 5.109E-01 1.390E-04 2.100E-03
 8     7.00  411.100   242.700  9.436E-03 2.428E-01 1.632E-03 1.573E-01 3.559E-05 4.567E-01 1.241E-04 2.287E-03
 9     8.00  356.500   236.200  5.215E-03 1.964E-01 1.645E-03 1.232E-01 1.567E-05 4.070E-01 1.104E-04 2.427E-03
10     9.00  308.000   229.700  1.707E-03 1.580E-01 2.131E-03 9.591E-02 4.079E-06 3.616E-01 9.792E-05 3.313E-03
11    10.00  265.000   223.200  5.897E-04 1.263E-01 2.558E-03 7.412E-02 1.181E-06 3.201E-01 8.654E-05 4.200E-03
12    11.00  227.000   216.800  2.761E-04 1.003E-01 3.493E-03 5.681E-02 4.288E-07 2.823E-01 7.525E-05 6.067E-03
13    12.00  194.000   216.600  9.279E-05 7.627E-02 4.038E-03 4.155E-02 1.543E-07 2.415E-01 6.434E-05 7.467E-03
14    13.00  165.800   216.600  3.919E-05 5.794E-02 4.029E-03 3.035E-02 6.189E-08 2.064E-01 5.499E-05 7.933E-03
15    14.00  141.700   216.600  1.588E-05 4.402E-02 4.229E-03 2.217E-02 2.415E-08 1.764E-01 4.699E-05 8.867E-03
16    15.00  121.100   216.600  1.182E-05 3.344E-02 4.389E-03 1.619E-02 1.769E-08 1.508E-01 4.016E-05 9.800E-03
17    16.00  103.500   216.600  8.591E-06 2.540E-02 4.711E-03 1.183E-02 1.281E-08 1.288E-01 3.433E-05 1.120E-02
18    17.00   88.500   216.600  6.435E-06 1.931E-02 5.162E-03 8.647E-03 9.334E-09 1.102E-01 2.935E-05 1.307E-02
19    18.00   75.650   216.600  4.729E-06 1.468E-02 5.541E-03 6.318E-03 6.749E-09 9.418E-02 2.509E-05 1.493E-02
20    19.00   64.670   216.600  4.106E-06 1.115E-02 5.692E-03 4.617E-03 5.796E-09 8.051E-02 2.145E-05 1.633E-02
21    20.00   55.290   216.600  3.965E-06 8.479E-03 5.804E-03 3.375E-03 4.981E-09 6.883E-02 1.830E-05 1.773E-02
22    21.00   47.290   217.600  3.372E-06 6.409E-03 5.448E-03 2.452E-03 4.686E-09 5.860E-02 1.559E-05 1.773E-02
23    22.00   40.470   218.600  3.169E-06 4.850E-03 5.248E-03 1.783E-03 4.387E-09 4.992E-02 1.329E-05 1.820E-02
24    23.00   34.670   219.600  3.016E-06 3.676E-03 4.803E-03 1.300E-03 4.171E-09 4.257E-02 1.133E-05 1.773E-02
25    24.00   29.720   220.600  2.804E-06 2.790E-03 4.274E-03 9.488E-04 3.878E-09 3.633E-02 9.673E-06 1.680E-02
26    25.00   25.490   221.600  2.637E-06 2.119E-03 3.793E-03 6.932E-04 3.660E-09 3.102E-02 6.502E-06 1.587E-02
27    30.00   11.970   226.500  7.614E-07 5.479E-04 1.642E-03 1.479E-04 9.944E-10 1.425E-02 2.988E-06 9.333E-03
28    35.00    5.746   236.500  1.624E-07 1.429E-04 6.574E-04 3.195E-05 1.943E-10 6.551E-03 1.380E-06 5.133E-03
29    40.00    2.871   253.400  3.531E-08 3.860E-05 2.222E-04 7.192E-06 3.942E-11 3.055E-03 6.574E-07 2.287E-03
30    45.00    1.491   264.200  9.178E-09 1.150E-05 5.882E-05 1.822E-06 9.676E-12 1.522E-03 3.328E-07 7.933E-04
31    50.00     .798   270.650  1.939E-09 3.751E-06 1.072E-05 5.032E-07 1.922E-12 7.950E-04 1.239E-07 1.867E-04
32    70.00     .055   219.700  2.405E-12 4.662E-08 8.259E-08 3.293E-09 1.653E-15 6.775E-05 9.787E-09 4.013E-06
33   100.00     .000   210.000  1.502E-16 5.422E-12 5.181E-12 1.046E-13 6.054E-20 3.862E-07 5.548E-11 2.007E-09
34 99999.00    0.000   210.000  0.        0.        0.        0.        0.        0.        0.        0.
```

Table 8. Program Output for Case 3 (Cont.)

```
          HORIZONTAL PROFILES
IC      ALT        P          T       H2O(4M)     HNO3         AER1        AER2        AER3        AER4      (AER1*RH)     RH1
 1      0.00  1013.000   288.100  5.479E-02 0.           1.580E-01 0.          0.          0.          7.228E+00 4.575E+01
 2      1.00   898.600   281.600  5.897E-02 0.           9.910E-02 0.          0.          0.          4.862E+00 4.506E+01
 3      2.00   795.000   275.100  3.393E-02 0.           6.210E-02 0.          0.          0.          3.238E+00 5.214E+01
 4      3.00   701.200   268.700  2.432E-02 0.           0.          3.460E-02 0.          0.          0.          0.
 5      4.00   616.600   262.200  1.469E-02 0.           0.          1.850E-02 0.          0.          0.          0.
 6      5.00   540.500   255.700  8.494E-03 0.           0.          9.310E-03 0.          0.          0.          0.
 7      6.00   472.200   249.200  5.039E-03 0.           0.          7.710E-03 0.          0.          0.          0.
 8      7.00   411.100   242.700  2.796E-03 0.           0.          6.230E-03 0.          0.          0.          0.
 9      8.00   356.500   236.200  1.612E-03 4.070E-55 0.          3.370E-03 0.          0.          0.          0.
10      9.00   308.000   229.700  5.266E-04 3.616E-06 0.          1.820E-03 0.          0.          0.          0.
11     10.00   265.000   223.200  2.502E-04 1.056E-05 0.          0.          1.140E-03 0.          0.          0.
12     11.00   227.000   216.800  1.167E-04 2.259E-05 0.          0.          7.990E-04 0.          0.          0.
13     12.00   194.000   216.600  4.525E-05 2.898E-05 0.          0.          5.410E-04 0.          0.          0.
14     13.00   165.800   216.600  1.881E-05 2.890E-05 0.          0.          5.170E-04 0.          0.          0.
15     14.00   141.700   216.600  7.502E-06 2.822E-05 0.          0.          4.420E-04 0.          0.          0.
16     15.00   121.100   216.600  5.496E-06 2.714E-05 0.          0.          3.950E-04 0.          0.          0.
17     16.00   103.500   216.600  3.379E-06 2.448E-05 0.          0.          3.820E-04 0.          0.          0.
18     17.00    88.500   216.600  2.901E-06 2.203E-05 0.          0.          4.250E-04 0.          0.          0.
19     18.00    75.650   216.600  2.098E-06 1.978E-05 0.          0.          5.200E-04 0.          0.          0.
20     19.00    64.670   216.600  1.794E-06 1.852E-05 0.          0.          5.810E-04 0.          0.          0.
21     20.00    55.290   216.600  1.537E-06 2.065E-05 0.          0.          5.890E-04 0.          0.          0.
22     21.00    47.290   217.600  1.390E-06 2.168E-05 0.          0.          5.020E-04 0.          0.          0.
23     22.00    40.470   218.600  1.253E-06 2.097E-05 0.          0.          4.200E-04 0.          0.          0.
24     23.00    34.670   219.600  1.144E-06 2.214E-05 0.          0.          3.300E-04 0.          0.          0.
25     24.00    29.720   220.600  1.021E-06 2.180E-05 0.          0.          1.980E-04 0.          0.          0.
26     25.00    25.430   221.600  9.714E-07 1.179E-05 0.          0.          1.310E-04 0.          0.          0.
27     30.00    11.970   226.500  2.184E-07 3.705E-06 0.          0.          3.320E-05 0.          0.          0.
28     35.00     5.746   236.500  3.431E-08 1.441E-07 0.          0.          0.          1.640E-05 0.          0.
29     40.00     2.871   253.400  4.306E-09 3.055E-57 0.          0.          0.          7.990E-06 0.          0.
30     45.00     1.491   264.200  9.787E-10 0.           0.          0.          0.          4.010E-06 0.          0.
31     50.00      .798   270.650  1.743E-10 0.           0.          0.          0.          2.100E-06 0.          0.
32     70.00      .055   219.700  4.779E-13 0.           0.          0.          0.          1.600E-07 0.          0.
33    100.00      .000   210.000  2.706E-17 0.           0.          0.          0.          9.310E-10 0.          0.
34  99999.00     0.000   210.000  0.          0.           0.          0.          0.          0.          0.          0.

FROM POINT\ HEIGHT=     0.0000 KM,N=  1,NP= 1,REF. INDEX ABOVE & BELOW X=  .2595E-03 0.          ,IP=  1
          EQUIV. ABSORBER AMOUNTS PER KM AT X=  .576E+00  .929E+00  .249E-02  .739E+00  .657E-02  .948E+00  .158E+00  .252E-02


   TX(12-14)= 0.        0.        0.1


        EQUIVALENT SEA LEVEL ABSORBER AMOUNTS

                     WATER VAPOUR    CO2 ETC.      OZONE    NITROGEN (CONT)  H2C  (CONT)    HCL   SCAT       AER1        OZONE(U-V)
                      GM CM-2          KM         ATM CM         KM          GM CM-2         KM                             ATM CM
                                                                                                                     NITRIC ACID:

        W(1-8)=       .576E+00     .929E+00     .249E-02     .739E+00      .657E-02       .948E+00        .156E+00       .252E-02
                                                                           .848E-01                                      0.


                          AER2          AER3          AER4      R.H. MEAN
        W(12-15)=     0.           0.            0.            4.575E+01

ICH      1    6   10   15
EXTINCTION AND ABSORPTION COEFFICIENTS
```

Table 8. Program Output for Case 3 (Cont.)

```
FREQ WAVELENGTH  TOTAL     H2O     CO2+    OZONE  N2 CONT  H2O CONT MOL SCAT  AEROSOL  AEROSOL   INTEGRATED NITRIC ACID
CM-1  MICRONS    TRANS    TRANS   TRANS    TRANS   TRANS    TRANS    TRANS    TRANS     ABS     ABSORPTION    TRANS
 900  11.1111    .9117    .9776  1.0000   1.0000  1.0000    .9434   1.0000    .9885    .0042        .2207    1.0000
 905  11.0497    .9100    .9753   .9994   1.0000  1.0000    .9446   1.0000    .9884    .0042        .6704    1.0000
 910  10.9890    .9100    .9745   .9992   1.0000  1.0000    .9456   1.0000    .9883    .0043       1.1204    1.0000
 915  10.9290    .9100    .9741   .9985   1.0000  1.0000    .9467   1.0000    .9882    .0044       1.5703    1.0000
 920  10.8696    .9116    .9756   .9978   1.0000  1.0000    .9477   1.0000    .9881    .0045       2.0125    1.0000
 925  10.8108    .9201    .9854   .9963   1.0000  1.0000    .9486   1.0000    .9879    .0046   [illegible]   1.0000
 930  10.7527    .9205    .9869   .9945   1.0000  1.0000    .9496   1.0000    .9878    .0047   [illegible]   1.0000
 935  10.6952    .9234    .9881   .9923   1.0000  1.0000    .9505   1.0000    .9877    .0049       3.2[illegible]75 1.0000
 940  10.6383    .9175    .9859   .9906   1.0000  1.0000    .9513   1.0000    .9875    .0050       3.6197    1.0000
 945  10.5820    .9125    .9814   .9891   1.0000  1.0000    .9521   1.0000    .9874    .0051       4.0571    1.0000
 950  10.5263    .9094    .9783   .9881    .9999  1.0000    .9529   1.0000    .9872    .0052       4.5101    1.0000
 955  10.4712    .9075    .9753   .9866    .9998  1.0000    .9537   1.0000    .9871    .0053       4.9728    1.0000
 960  10.4167    .9066    .9741   .9884    .9997  1.0000    .9544   1.0000    .9869    .0054       5.4356    1.0000
 965  10.3627    .9064    .9737   .9881    .9996  1.0000    .9551   1.0000    .9868    .0055       5.9[illegible]75 1.0000
 970  10.3093    .9046    .9733   .9862    .9993  1.0000    .9558   1.0000    .9866    .0057       6.3847    1.0000
 975  10.2564    .9058    .9745   .9862    .9989  1.0000    .9565   1.0000    .9865    .0058       6.8558    1.0000
 980  10.2041    .9115    .9787   .9886    .9980  1.0000    .9571   1.0000    .9863    .0059       7.2576    1.0000
 985  10.1523    .9163    .9830   .9924    .9966  1.0000    .9577   1.0000    .9862    .0060       7.7[illegible]64 1.0000
 990  10.1010    .9229    .9865   .9959    .9940  1.0000    .9583   1.0000    .9860    .0061       8.0317    1.0000
 995  10.0503    .9180    .9809   .9984    .9916  1.0000    .9588   1.0000    .9859    .0062       8.5[illegible]19 1.0000
1000  10.0000    .9089    .9745   .9992    .9869  1.0000    .9594   1.0000    .9857    .0063       8.9581    1.0000
1005   9.9502    .9023    .9714   .9996    .9824  1.0000    .9599   1.0000    .9854    .0067       9.4466    1.0000
1010   9.9010    .8931    .9658   .9995    .9780  1.0000    .9604   1.0000    .9850    .0071       9.9809    1.0000
1015   9.8522    .8618    .9579   .9990    .9729  1.0000    .9609   1.0000    .9847    .0075      10.5719    1.0000
1020   9.8039    .8625    .9641   .9983    .9690  1.0000    .9613   1.0000    .9843    .0079      11.1594    1.0000
1025   9.7561    .8787    .9633   .9967    .9674  1.0000    .9618   1.0000    .9840    .0083      11.7657    1.0000
1030   9.7087    .8777    .9647   .9953    .9659  1.0000    .9622   1.0000    .9836    .0086      12.3776    1.0000
1035   9.6618    .8675    .9698   .9924    .9522  1.0000    .9626   1.0000    .9833    .0090      13.0397    1.0000
1040   9.6154    .8724    .9718   .9902    .9577  1.0000    .9630   1.0000    .9830    .0094      13.6777    1.0000
1045   9.5694    .8885    .9726   .9862    .9785  1.0000    .9634   1.0000    .9826    .0097      14.2352    1.0000
1050   9.5238    .8693    .9698   .9850    .9612  1.0000    .9638   1.0000    .9823    .0101      14.8667    1.0000
1055   9.4787    .8604    .9664   .9838    .9559  1.0000    .9641   1.0000    .9820    .0105      15.5665    1.0000
1060   9.4340    .8610    .9595   .9836    .9635  1.0000    .9644   1.0000    .9817    .0108      15.2818    1.0000
1065   9.3897    .8662    .9563   .9829    .9734  1.0000    .9648   1.0000    .9813    .0112      16.95[illegible]8 1.0000
1070   9.3458    .8793    .9602   .9812    .9858  1.0000    .9651   1.0000    .9810    .0115      17.5543    1.0000
1075   9.3023    .8910    .9613   .9809    .9980  1.0000    .9654   1.0000    .9807    .0119      18.0992    1.0000
1080   9.2593    .9037    .9692   .9826    .9989  1.0000    .9657   1.0000    .9804    .0122      18.5957    1.0000
1085   9.2166    .9053    .9692   .9875    .9990  1.0000    .9659   1.0000    .9801    .0126      19.0689    1.0000
1090   9.1743    .9045    .9641   .9917    .9990  1.0000    .9662   1.0000    .9800    .0125      19.5463    1.0000
1095   9.1324    .9020    .9569   .9961    .9990  1.0000    .9665   1.0000    .9800    .0123      20.0364    1.0000
1100   9.0909    .8930    .9450   .9983    .9990  1.0000    .9667   1.0000    .9801    .0120      20.5714    1.0000
1105   9.0498    .8846    .9348   .9995    .9990  1.0000    .9670   1.0000    .9801    .0117      21.1484    1.0000
1110   9.0090    .8823    .9320   .9997    .9990  1.0000    .9672   1.0000    .9801    .0115      21.7367    1.0000
1115   8.9686    .8809    .9385   .9999    .9989  1.0000    .9674   1.0000    .9802    .0113      22.2921    1.0000
1120   8.9286    .8952    .9450   .9997    .9989  1.0000    .9676   1.0000    .9803    .0112      22.8162    1.0000
1125   8.8889    .9027    .9530   .9993    .9989  1.0000    .9678   1.0000    .9804    .0111      23.3[illegible]29 1.0000
1130   8.8496    .9080    .9589   .9987    .9989  1.0000    .9680   1.0000    .9805    .0110      23.7629    1.0000
1135   8.8106    .9003    .9517   .9973    .9990  1.0000    .9682   1.0000    .9806    .0109      24.2613    1.0000
1140   8.7719    .8944    .9473   .9948    .9992  1.0000    .9684   1.0000    .9808    .0108      24.7693    1.0000
1145   8.7336    .8891    .9442   .9917    .9994  1.0000    .9686   1.0000    .9809    .0107      25.[illegible]665 1.0000
INTEGRATED ABSORPTION FROM  900 TO 1145 CM-1 =      25.07AVERAGE TRANSMITTANCE = .8977
 2
```

Table 9. Program Output for Case 4

```
PROGRAM WILL BE EXECUTED IN THE TRANSMISSION MODE
2  3  2  0  0  0  0  0  0  0  1      0.000      0.000  0  0       0.000
            12.000      0.000   180.000      0.000      0.000
         H1= 12.000KM,H2=  0.000KM,ANGLE=180.0000GEOM. RANGE =  12.00KM,BETA=  .00000
 900.000  1145.000      5.000


         SLANT PATH BETWEEN ALTITUDES H1 AND H2 WHERE H1 = 12.000 KM H2 =  0.000 KM,ZENITH ANGLE =180.000 DEGREES

                   HAZE MODEL  = 23.0 KM VISUAL RANGE AT SEA LEVEL

               MODEL ATMOSPHERE 2 = MIDLATITUDE SUMMER

                 HAZE MODEL  3 =  MARITIME     VIS= 23.0KM

               SEASON =    SPRIG SUMM

               VERTICAL PROFILE AERCSOL MODEL =        STRAT BKGR

         FREQUENCY RANGE V1=   900.0 CM-1 TO V2=  1145.0 CM-1 FOR DV =   5.0 CM-1   (  8.73 - 11.11 MICRONS )

         HORIZONTAL PROFILES

ID      ALT       P         T          H2O       CO2+        O3         N2      H2O(10M)     MOLS      (N-1)     O3(UV)
 1      0.00 1013.000   294.000   1.354E+00 3.038E-01 2.759E-03 7.164E-01 3.013E-02 9.291E-01 2.533E-04 2.800E-03
 2      1.00  902.000   290.000   8.155E-01 7.517E-01 2.641E-03 5.798E-01 1.460E-02 6.387E-01 2.290E-04 2.800E-03
 3      2.00  802.000   285.000   4.691E-01 6.268E-01 2.529E-03 4.705E-01 6.646E-03 7.588E-01 2.073E-04 2.800E-03
 4      3.00  710.000   279.000   2.774E-01 5.215E-01 2.499E-03 3.807E-01 2.467E-03 6.862E-01 1.875E-04 2.893E-03
 5      4.00  628.000   273.000   1.736E-01 4.335E-01 2.467E-03 3.077E-01 9.847E-04 6.203E-01 1.694E-04 2.987E-03
 6      5.00  554.000   267.000   5.869E-02 3.589E-01 2.430E-03 2.476E-01 3.448E-04 5.595E-01 1.526E-04 3.080E-03
 7      6.00  487.000   261.000   3.221E-02 2.955E-01 2.424E-03 1.980E-01 1.585E-04 5.031E-01 1.370E-04 3.220E-03
 8      7.00  426.000   255.000   1.750E-02 2.414E-01 2.505E-03 1.568E-01 7.340E-05 4.505E-01 1.228E-04 3.500E-03
 9      8.00  372.000   248.000   8.203E-03 1.978E-01 2.518E-03 1.247E-01 3.159E-05 4.045E-01 1.099E-04 3.667E-03
10      9.00  324.000   242.000   4.542E-03 1.607E-01 2.606E-03 9.814E-02 1.384E-05 3.610E-01 9.817E-05 4.013E-03
11     10.00  281.000   235.000   2.160E-03 1.384E-01 2.592E-03 7.714E-02 5.677E-06 3.224E-01 8.741E-05 4.200E-03
12     11.00  243.000   229.000   6.590E-04 1.048E-01 3.004E-03 5.997E-02 1.355E-06 2.861E-01 7.756E-05 5.133E-03
13     12.00  209.000   222.000   1.591E-04 8.400E-02 3.105E-03 4.648E-02 2.752E-07 2.539E-01 6.856E-05 5.600E-03
14     13.00  179.000   216.000   4.204E-05 6.650E-02 3.668E-03 3.552E-02 6.665E-08 2.235E-01 5.953E-05 7.000E-03
15     14.00  153.000   216.000   2.028E-05 5.053E-02 4.133E-03 2.595E-02 3.114E-08 1.910E-01 5.075E-05 8.400E-03
16     15.00  130.000   216.000   1.731E-05 3.809E-02 4.088E-03 1.874E-02 2.005E-08 1.623E-01 4.322E-05 8.867E-03
17     16.00  111.000   216.000   9.723E-06 2.882E-02 4.241E-03 1.366E-02 1.441E-08 1.386E-01 3.694E-05 9.800E-03
18     17.00   95.000   216.000   7.395E-06 2.195E-02 4.555E-03 1.001E-02 1.080E-08 1.186E-01 3.160E-05 1.120E-02
19     18.00   81.200   216.000   5.733E-06 1.668E-02 4.990E-03 7.310E-03 8.250E-09 1.014E-01 2.697E-05 1.307E-02
20     19.00   69.500   217.000   4.574E-06 1.262E-02 5.354E-03 5.318E-03 5.941E-09 8.636E-02 2.298E-05 1.493E-02
21     20.00   59.500   218.000   3.884E-06 9.556E-03 5.341E-03 3.871E-03 5.464E-09 7.360E-02 1.953E-05 1.587E-02
22     21.00   51.000   219.000   3.874E-06 7.251E-03 5.312E-03 2.825E-03 5.355E-09 6.279E-02 1.671E-05 1.680E-02
23     22.00   43.700   220.000   3.321E-06 5.499E-03 4.989E-03 2.060E-03 4.613E-09 5.356E-02 1.425E-05 1.680E-02
24     23.00   37.600   222.000   3.059E-06 4.174E-03 4.429E-03 1.504E-03 4.233E-09 4.567E-02 1.215E-05 1.587E-02
25     24.00   32.200   223.000   2.950E-06 3.163E-03 3.914E-03 1.096E-03 4.082E-09 3.894E-02 1.038E-05 1.493E-02
26     25.00   27.700   224.000   2.871E-06 2.415E-03 3.452E-03 8.055E-04 3.988E-09 3.334E-02 6.975E-06 1.400E-02
27     30.00   13.200   234.000   7.763E-07 6.217E-04 1.696E-03 1.713E-04 1.007E-09 1.521E-02 3.216E-06 9.333E-03
28     35.00    6.520   245.000   1.231E-07 1.698E-04 5.830E-04 3.901E-05 1.464E-10 7.176E-03 1.531E-06 4.293E-03
29     40.00    3.330   258.000   2.569E-08 4.881E-05 1.966E-04 9.417E-06 2.880E-11 3.480E-03 7.524E-07 1.913E-03
30     45.00    1.760   270.000   6.265E-09 1.502E-05 4.785E-05 2.457E-06 6.682E-12 1.758E-03 3.859E-07 6.067E-04
31     50.00     .951   276.000   1.187E-09 4.964E-06 1.232E-05 6.942E-07 1.191E-12 9.291E-04 1.454E-07 2.007E-04
32     70.00     .067   218.000   2.587E-12 5.632E-08 8.944E-08 4.923E-09 1.872E-15 8.300E-05 1.198E-08 4.013E-06
33    100.00     .000   210.000   1.499E-16 5.397E-12 5.175E-12 1.041E-13 6.038E-20 3.852E-07 5.533E-11 2.007E-09
34  99999.00    0.000   210.000   0.        0.        0.        0.        0.        0.        0.        0.
```

Table 9. Program Output for Case 4 (Cont.)

```
         HORIZONTAL PROFILES
IC     ALT       P         T        H2O(4M)      HNO3        AER1        AER2        AER3        AER4      (AER1*RH)    RH!
 1     0.00  1013.000   294.000   1.971E-01 0.          1.580E-01 0.          0.          0.          1.211E+01 7.665E+01
 2     1.00   902.000   290.000   1.203E-01 0.          9.910E-02 0.          0.          0.          6.380E+00 6.436E+01
 3     2.00   802.000   285.000   7.159E-02 0.          6.210E-02 0.          0.          0.          3.445E+00 5.548E+01
 4     3.00   710.000   279.000   3.825E-02 0.          0.          3.460E-02 0.          0.          0.          0.
 5     4.00   628.000   273.000   2.134E-02 0.          0.          1.850E-02 0.          0.          0.          0.
 6     5.00   554.000   267.000   1.094E-02 0.          0.          9.310E-03 0.          0.          0.          0.
 7     6.00   487.000   261.000   6.558E-03 0.          0.          7.710E-03 0.          0.          0.          0.
 8     7.00   426.000   255.000   3.316E-03 0.          0.          6.230E-03 0.          0.          0.          0.
 9     8.00   372.000   248.000   2.247E-03 4.045E-55 0.          3.370E-03 0.          0.          0.          0.
10     9.00   324.000   242.000   1.278E-03 3.610E-06 0.          1.820E-03 0.          0.          0.          0.
11    10.00   281.000   235.000   6.971E-04 1.064E-05 0.          0.          1.140E-03 0.          0.          0.
12    11.00   243.000   229.000   2.406E-04 2.289E-05 0.          0.          7.990E-04 0.          0.          0.
13    12.00   209.000   222.000   6.793E-05 3.046E-05 0.          0.          6.410E-04 0.          0.          0.
14    13.00   179.000   216.000   2.165E-05 3.128E-05 0.          0.          5.170E-04 0.          0.          0.
15    14.00   153.000   216.000   9.912E-06 3.056E-05 0.          0.          4.420E-04 0.          0.          0.
16    15.00   130.000   216.000   6.335E-06 2.921E-05 0.          0.          3.950E-04 0.          0.          0.
17    16.00   111.000   216.000   4.556E-06 2.633E-05 0.          0.          3.820E-04 0.          0.          0.
18    17.00    95.000   216.000   3.412E-06 2.372E-05 0.          0.          4.250E-04 0.          0.          0.
19    18.00    81.200   216.000   2.504E-06 2.129E-05 0.          0.          5.200E-04 0.          0.          0.
20    19.00    69.500   217.000   2.172E-06 1.986E-05 0.          0.          5.810E-04 0.          0.          0.
21    20.00    59.500   218.000   1.621E-06 2.208E-05 0.          0.          5.890E-04 0.          0.          0.
22    21.00    51.000   219.000   1.531E-06 2.323E-05 0.          0.          5.020E-04 0.          0.          0.
23    22.00    43.700   220.000   1.276E-06 2.250E-05 0.          0.          4.200E-04 0.          0.          0.
24    23.00    37.600   222.000   1.100E-06 2.375E-05 0.          0.          3.000E-04 0.          0.          0.
25    24.00    32.200   223.000   1.018E-06 2.336E-05 0.          0.          1.980E-04 0.          0.          0.
26    25.00    27.700   224.000   9.523E-07 1.267E-05 0.          0.          1.310E-04 0.          0.          0.
27    30.00    13.200   234.000   1.985E-07 3.955E-06 0.          0.          3.320E-05 0.          0.          0.
28    35.00     6.520   245.000   2.195E-08 1.579E-07 0.          0.          0.          1.640E-05 0.          0.
29    40.00     3.330   258.000   3.321E-09 3.480E-57 0.          0.          0.          7.990E-06 0.          0.
30    45.00     1.760   270.000   6.145E-10 0.          0.          0.          0.          4.010E-06 0.          0.
31    50.00      .951   276.000   9.977E-11 0.          0.          0.          0.          2.100E-06 0.          0.
32    70.00      .067   218.000   5.689E-13 0.          0.          0.          0.          1.600E-07 0.          0.
33   100.00      .000   210.000   2.300E-17 0.          0.          0.          0.          9.310E-10 0.          0.
34 99999.00     0.000   210.000   0.          0.          0.          0.          0.          0.          0.          0.

FROM POINT\ HEIGHT=   12.0000 KM,N= 13,NP= 1,REF. INDEX ABOVE & BELOW X=  .6856E-04  .7756E-04,IP=  1
             EQUIV. ABSORBER AMOUNTS PER KM AT X=  .159E-03  .840E-01  .310E-02  .465E-01  .275E-06  .254E+00 0.          .564E-02


     TX(12-14)= 0.          .641E-03 0.1


FROM POINT\ HEIGHT=    0.0000 KM,N=  1,NP= 1,REF. INDEX ABOVE & BELOW X=  .2533E-03 0.         ,IP=  1
             EQUIV. ABSORBER AMOUNTS PER KM AT X=  .135E+01  .904E+00  .276E-02  .716E+00  .301E-01  .929E+00  .152E+00  .380E-02


     TX(12-14)= 0.          0.          0.1

HMIN =  -6371.230
```

Table 9. Program Output for Case 4 (Cont.)

```
          VERTICAL PROFILES

IC   ALT      H2O        CO2+        O3         N2       H2O(10M)    MOLS        AER1      O3(UV)       PSI        PHI        BETA     THETA      RANGE
                        H2O(4M)     HNO3       AER2       AER3       AER4                                                                        ORANGE


 12  12.000 3.518E-04 9.400E-02 3.054E-03 5.294E-02 6.773E-07 2.697E-01 0.          5.363E-03     .0000     -.0000     -.0000 180.0000      1.0
     11.000           1.365E-04 2.550E-05 0.                  7.171E-04 0.                                                                     1.00

 11  11.000 1.616E-03 2.111E-01 5.847E-03 1.211E-01 3.694E-06 5.736E-01 0.          1.001E-02     .0000     -.0000     -.0000 180.0000      2.0
     10.000           5.657E-04 4.249E-05 0.                  1.677E-03 0.                                                                     1.00

 10  10.000 4.821E-03 3.561E-01 8.445E-03 2.084E-01 1.286E-05 9.149E-01 0.          1.412E-02     .0000     -.0000     -.0000 180.0000      3.0
      9.000           1.524E-03 4.699E-05 0.                  1.677E-03 0.                                                                     1.00

  9   9.000 1.130E-02 5.347E-01 1.101E-02 3.192E-01 3.437E-05 1.297E+00 0.          1.797E-02     .0000     -.0000     -.0000 180.0000      4.0
      8.000           3.241E-03 4.902E-05 2.516E-03 1.677E-03 0.                                                                          1.00

  8   8.000 2.402E-02 7.536E-01 1.352E-02 4.594E-01 8.396E-05 1.724E+00 0.          2.156E-02     .0000     -.0000     -.0000 180.0000      5.0
      7.000           6.246E-03 4.902E-05 7.170E-03 1.677E-03 0.                                                                          1.00

  7   7.000 4.813E-02 1.021E+00 1.599E-02 6.360E-01 1.946E-04 2.201E+00 0.          2.492E-02     .0000     -.0000     -.0000 180.0000      6.0
      6.000           1.137E-02 4.902E-05 1.411E-02 1.677E-03 0.                                                                          1.00

  6   6.000 9.226E-02 1.347E+00 1.841E-02 8.579E-01 4.344E-04 2.731E+00 0.          2.807E-02     .0000     -.0000     -.0000 180.0000      7.0
      5.000           1.994E-02 4.902E-05 2.260E-02 1.677E-03 0.                                                                          1.00

  5   5.000 1.794E-01 1.742E+00 2.085E-02 1.134E+00 1.044E-03 3.321E+00 0.          3.110E-02     .0000     -.0000     -.0000 180.0000      8.0
      4.000           3.550E-02 4.902E-05 3.598E-02 1.677E-03 0.                                                                          1.00

  4   4.000 3.538E-01 2.218E+00 2.335E-02 1.477E+00 2.558E-03 3.973E+00 0.          3.404E-02     .0000     -.0000     -.0000 180.0000      9.0
      3.000           6.448E-02 4.902E-05 6.170E-02 1.677E-03 0.                                                                          1.00

  3   3.000 6.939E-01 2.791E+00 2.586E-02 1.901E+00 6.874E-03 4.655E+00 0.          3.689E-02     .0000     -.0000     -.0000 180.0000     10.0
      2.000           1.177E-01 4.902E-05 6.170E-02 1.677E-03 0.                                                                          1.00

  2   2.000 1.320E+00 3.478E+00 2.845E-02 2.425E+00 1.698E-02 5.493E+00 7.916E-02 3.965E-02     .0000     -.0000     -.0000 180.0000     11.0
      1.000           2.115E-01 4.902E-05 6.170E-02 1.677E-03 0.                                                                          1.00

  1   1.000 2.783E+00 4.304E+00 3.114E-02 3.070E+00 3.842E-02 6.377E+00 2.054E-01 4.249E-02     .0000     -.0000     -.0000 180.0000     12.0
      0.000           3.671E-01 4.902E-05 6.170E-02 1.677E-03 0.                                                                          1.00

-6371.230

        EQUIVALENT SEA LEVEL ABSORBED AMOUNTS

                    WATER VAPOUR      CO2 ETC.       OZONE     NITROGEN (CONT)  H2O  (CONT)      MOL   SCAT       AER1          OZONE(U-V)
                      GM CM-2           KM          ATM CM          KM          GM CM-2          KM                               ATM CM
                                                                                                                            NITRIC ACID:

        W(1-8)=        .238E+01       .430E+01      .311E-01      .307E+01      .384E-01        .638E+01       .205E+00        .425E-01
                                                                                 .367E+00                                      .490E-04


                          AER2          AER3              AER4      P.M. MEAN
        W(12-15)=      6.170E-02     1.677E-03      0.              6.671E+01

 ICH      3    6   10    15
 EXTINCTION AND ABSORPTION COEFFICIENTS
```

Table 9. Program Output for Case 4 (Cont.)

```
FREQ WAVELENGTH  TOTAL     H2O      CO2+    OZONE  N2 CONT  H2O CONT MCL SCAT  AEROSOL  AEROSOL    INTEGRATED NITRIC ACID
CM-1  MICRONS    TRANS    TRANS    TRANS    TRANS   TRANS    TRANS    TRANS    TRANS     ABS      ABSORPTION    TRANS
 900  11.1111    .6576    .9429   1.0000   1.0000  1.0000    .7114   1.0000    .9848    .0090         .8560    .9995
 905  11.0497    .6575    .9379    .9980   1.0000  1.0000    .7164   1.0000    .9808    .0088        2.5686    .9996
 910  10.9890    .6598    .9360    .9968   1.0000  1.0000    .7212   1.0000    .9808    .0086        4.2697    .9997
 915  10.9290    .6613    .9351    .9947   1.0000  1.0000    .7258   1.0000    .9806    .0085        5.9604    .9998
 920  10.8696    .6668    .9388    .9921   1.0000  1.0000    .7303   1.0000    .9804    .0083        7.6263    .9999
 925  10.8108    .6842    .9626    .9870   1.0000  1.0000    .7347   1.0000    .9802    .0082        9.2051   1.0000
 930  10.7527    .6869    .9660    .9820   1.0000  1.0000    .7389   1.0000    .9801    .0080       10.7704   1.0000
 935  10.6952    .6885    .9589    .9763   1.0000  1.0000    .7429   1.0000    .9799    .0079       12.3276   1.0000
 940  10.6383    .6854    .9638    .9721   1.0000  1.0000    .7468   1.0000    .9797    .0077       13.9304   1.0000
 945  10.5820    .6778    .9519    .9685    .9999  1.0000    .7506   1.0000    .9795    .0076       15.5116   1.0000
 950  10.5263    .6733    .9445    .9662    .9990  1.0000    .7543   1.0000    .9791    .0076       17.1450   1.0000
 955  10.4712    .6714    .9379    .9673    .9977  1.0000    .7578   1.0000    .9787    .0076       18.7880   1.0000
 960  10.4167    .6708    .9351    .9668    .9963  1.0000    .7613   1.0000    .9784    .0076       20.4340   1.0000
 965  10.3627    .6707    .9341    .9662    .9938  1.0000    .7646   1.0000    .9780    .0076       22.0605   1.0000
 970  10.3093    .6669    .9332    .9617    .9900  1.0000    .7678   1.0000    .9776    .0076       23.7461   1.0000
 975  10.2564    .6674    .9360    .9617    .9842  1.0000    .7708   1.0000    .9773    .0076       25.4092   1.0000
 980  10.2041    .6730    .9453    .9673    .9736  1.0000    .7738   1.0000    .9769    .0076       27.0444   1.0000
 985  10.1523    .6801    .9565    .9767    .9599  1.0000    .7767   1.0000    .9766    .0076       28.6437   1.0000
 990  10.1010    .6765    .9655    .9858    .9341  1.0000    .7794   1.0000    .9762    .0076       30.2612   1.0000
 995  10.0503    .6571    .9506    .9941    .9111  1.0000    .7821   1.0000    .9759    .0076       31.9756   1.0000
1000  10.0000    .6285    .9360    .9971    .8798  1.0000    .7847   1.0000    .9755    .0076       33.8331   1.0000
1005   9.9502    .6059    .9286    .9985    .8515  1.0000    .7872   1.0000    .9749    .0078       35.8037   1.0000
1010   9.9010    .5820    .9187    .9981    .8252  1.0000    .7896   1.0000    .9742    .0081       37.8937   1.0000
1015   9.8522    .5538    .9051    .9963    .7966  1.0000    .7919   1.0000    .9736    .0084       40.1246   1.0000
1020   9.8039    .5444    .9152    .9937    .7748  1.0000    .7941   1.0000    .9730    .0087       42.4025   1.0000
1025   9.7561    .5359    .9130    .9867    .7683  1.0000    .7962   1.0000    .9723    .0089       44.7178   1.0000
1030   9.7087    .5330    .9164    .9842    .7618  1.0000    .7983   1.0000    .9717    .0092       47.0529   1.0000
1035   9.6618    .4911    .9251    .9767    .6993  1.0000    .8003   1.0000    .9711    .0095       49.5974   1.0000
1040   9.6154    .5091    .9295    .9709    .7246  1.0000    .8022   1.0000    .9705    .0097       52.0519   1.0000
1045   9.5694    .5781    .9313    .9617    .8277  1.0000    .8041   1.0000    .9699    .0100       54.1613   1.0000
1050   9.5238    .5126    .9251    .9587    .7399  1.0000    .8059   1.0000    .9693    .0102       56.5984   1.0000
1055   9.4787    .4926    .9198    .9554    .7165  1.0000    .8076   1.0000    .9688    .0105       59.1353   1.0000
1060   9.4340    .5091    .9062    .9547    .7510  1.0000    .8092   1.0000    .9682    .0107       61.5960   1.0000
1065   9.3897    .5384    .9006    .9528    .7997  1.0000    .8108   1.0000    .9676    .0110       63.8982   1.0000
1070   9.3458    .5931    .9073    .9478    .8734  1.0000    .8124   1.0000    .9670    .0112       65.9476   1.0000
1075   9.3023    .6597    .9095    .9471    .9736  1.0000    .8139   1.0000    .9665    .0115       67.6495   1.0000
1080   9.2593    .6821    .9242    .9521    .9842  1.0000    .8153   1.0000    .9659    .0117       69.2392   1.0000
1085   9.2166    .6928    .9242    .9651    .9853  1.0000    .8167   1.0000    .9654    .0119       70.7750   1.0000
1090   9.1743    .6943    .9152    .9747    .9859  1.0000    .8180   1.0000    .9650    .0119       72.3037   1.0000
1095   9.1324    .6931    .9017    .9865    .9859  1.0000    .8192   1.0000    .9646    .0117       73.8381   1.0000
1100   9.0909    .6821    .8795    .9939    .9863  1.0000    .8205   1.0000    .9643    .0116       75.4275   1.0000
1105   9.0498    .6711    .8609    .9982    .9859  1.0000    .8217   1.0000    .9640    .0114       77.0721   1.0000
1110   9.0090    .6678    .8556    .9991    .9853  1.0000    .8228   1.0000    .9636    .0112       78.7331   1.0000
1115   8.9686    .6775    .8671    .9996    .9846  1.0000    .8239   1.0000    .9636    .0112       80.3456   1.0000
1120   8.9286    .6874    .8795    .9990    .9842  1.0000    .8249   1.0000    .9637    .0111       81.9086   1.0000
1125   8.8889    .6985    .8941    .9975    .9839  1.0000    .8260   1.0000    .9637    .0111       83.4164   1.0000
1130   8.8496    .7364    .9051    .9951    .9842  1.0000    .8269   1.0000    .9638    .0111       84.8842   1.0000
1135   8.8106    .6949    .8915    .9909    .9859  1.0000    .8279   1.0000    .9638    .0111       86.4096   1.0000
1140   8.7719    .6864    .8835    .9830    .9893  1.0000    .8288   1.0000    .9639    .0111       87.9777   1.0000
1145   8.7336    .6783    .8779    .9747    .9920  1.0000    .8296   1.0000    .9639    .0111       88.7604   1.0000
INTEGRATED ABSORPTION FROM  900 TO 1145 CM-1 =     88.78AVERAGE TRANSMITTANCE = .6376
 2
```

Case 5. Calculate the transmittance from 900 to 1145 cm^{-1} in steps of 5 cm^{-1}, using the MODEL = 0 option to define a 10-km horizontal path at 0-km altitude, at a pressure of 1000 mb, an ambient temperature of $10^{o}C$, and a relative humidity of 40 percent. Use the midlatitude winter ozone profile, and a 23-km meteorological range, rural aerosol model.

The output, shown in Table 10, is similar to the horizontal path case, Case 3, given in Table 4.

Case 6. Calculate, using the MODEL = 7 option, for a given set of radiosonde data the transmittance from 900 to 1145 cm^{-1} in steps of 5 cm^{-1} for a slant path from 0.21 km to 8.55 km at a zenith angle of 35.5^{o}. Use a 23-km sea-level meteorological range for the maritime aerosol model and the ozone distribution of the midlatitude summer atmospheric model.

In this example, the radiosonde data consists of 21 levels with the following parameters given: altitude (km), pressure (mb), ambient temperature (^{o}C) and dew-point temperature (^{o}C).

The output for Case 6 is given in Table 11. The only change in the output from a standard run occurs of the first page of the output. Each MODEL = 7 input card is printed followed by the internal model profile parameters derived from this card. Also, detailed information on the aerosol profile and type of extinction is printed for each level. The rest of the output is the same as that described for the previous standard transmittance cases.

Case 7. Calculate the transmittance from 900 to 1145 cm^{-1} in steps of 5 cm^{-1} for a vertical path from ground to 10 km (zenith angle = 0^{o}). Using the MODEL = 7 option, provide for a radiation fog (0.5 km meteorological range) from ground to 200 meters altitude and a rural aerosol model (23-km meteorological range) from 200 meters to 2-km altitude. Use the U.S. Standard model atmosphere profile for the molecular absorber amounts and for the pressure and temperature profile.

In this example, only the altitudes of the levels and the aerosol control parameters need to be specified on the MODEL = 7 cards. The program output for this case is given in Table 12 and is similar to that of Case 6.

Table 10. Program Output for Case 5

```
PROGRAM WILL BE EXECUTED IN THE TRANSMISSION MODE
0  1  1  0  0  0  0  0  3  0  0     0.000     0.000  0  0      0.000
       INPUT METEOROLOGICAL DATA\
       Z=   0.00 KM, P=1000.00 MB,T= 10.0 C, DEW PT.TEMP  0.0 C, REL HUMIDITY= 40.0 %, H2O DENSITY= 0.        GM M-3
        OZONE DENSITY= 0.        GM M-3,  RANGE=    10.000 KM
   0.000  1000.000    10.000  0.0 40.0 C.         0.          0.              0.000  0  0  0:
   0.000  1000.000   283.150  0.0 40.0  .378E+01  .600E-04  .156E+00    23.000  1  1  1  1    RURAL                               RURAL
 900.000  1145.000     5.000

        HORIZONTAL PATH, ALTITUDE =  0.000 KM,RANGE = 10.000 KM

                  HAZE MODEL  = 23.0 KM VISUAL RANGE AT SEA LEVEL

                HAZE MODEL  1 =    RURAL       VIS= 23.0KM

              SEASON =    SPRIG SUMM

              VERTICAL PROFILE AEROSOL MODEL =       STRAT BKGR

        FREQUENCY RANGE V1=   900.0 CM-1 TO V2=  1145.0 CM-1 FOR DV =   5.0 CM-1   (  8.73 - 11.11 MICRONS )


        HORIZONTAL PROFILES

IC      ALT       P        T        H2O      CO2+        O3        N2     H2O(10M)    HCLS     (N-1)     O3(UV)
 1      0.00 1000.000  283.150  7.661E-01 9.305E-01 2.766E-03 7.387E-01 3.181E-03 9.523E-01 0.        2.800E-03



        HORIZONTAL PROFILES
IC      ALT       P        T       H2O(4M)     HNO3      AER1      AER2      AER3      AER4    (AER1*RH)     RH!
 1      0.00 1000.000  283.150  5.714E-02 0.        1.560E-01 0.        0.        0.        6.320E+00 4.000E+01

FROM POINT\ HEIGHT=    0.0000 KM,N=  1,NP= 1,REF. INDEX ABOVE & BELOW X= 0.         0.        ,IP=  1
          EQUIV. ABSORBER AMOUNTS PER KM AT X=  .368E+00  .930E+00  .277E-02  .739E+00  .318E-02  .952E+00  .156E+00  .280E-02


    TX(12-14)= 0.        0.        1.0


        EQUIVALENT SEA LEVEL ABSORBER AMOUNTS

                  WATER VAPOUR     CO2 ETC.      OZONE     NITROGEN (CONT)  H2O  (CONT)     HCL   SCAT      AER1        OZONE(U-V)
                    GM CM-2          KM         ATM CM           KM         GM CM-2          KM                            ATM CM
                                                                                                                      NITRIC ACID!

        W(1-8)=      .368E+01     .930E+01     .277E-01     .739E+01       .318E-01      .952E+01      .156E+01      .280E-01
                                                                            .571E+00                                   0

                             AER2         AER3          AER4     R.H. MEAN
        W(12-15)=      0.           0.           0.            4.000E+01

ICH       1    6   10   15
EXTINCTION AND ABSORPTION COEFFICIENTS
```

Table 10. Program Output for Case 5 (Cont.)

```
FREQ WAVELENGTH  TOTAL     H20      CO2+     OZONE  N2 CONT  H2O CONT MOL SCAT AEROSOL  AEROSOL   INTEGRATED NITRIC ACID
CM-1  MICRONS    TRANS    TRANS    TRANS     TRANS   TRANS    TRANS    TRANS    TRANS     ABS     ABSORPTION    TRANS
 900  11.1111    .6225    .9261   1.0000    1.0000  1.0000    .7544   1.0000    .8910    .0408        .9458   1.00000
 905  11.0497    .6194    .9208    .9961    1.0000  1.0000    .7587   1.0000    .8901    .0410       2.8467   1.00000
 910  10.9890    .6195    .9188    .9942    1.0000  1.0000    .7629   1.0000    .8891    .0414       4.7486   1.00000
 915  10.9290    .6189    .9176    .9907    1.0000  1.0000    .7670   1.0000    .8879    .0426       6.6544   1.00000
 920  10.8696    .6207    .9217    .9852    1.0000  1.0000    .7709   1.0000    .8866    .0438       8.5505   1.00000
 925  10.8108    .6380    .9507    .9784    1.0000  1.0000    .7747   1.0000    .8854    .0450      10.3608   1.00000
 930  10.7527    .6375    .9546    .9703    1.0000  1.0000    .7784   1.0000    .8842    .0462      12.1733   1.00000
 935  10.6952    .6351    .9579    .9603    1.0000  1.0000    .7819   1.0000    .8830    .0473      13.9980   1.00000
 940  10.6383    .6284    .9520    .9531    1.0000  1.0000    .7853   1.0000    .8819    .0484      15.8562   1.00000
 945  10.5820    .6166    .9371    .9475     .9999  1.0000    .7886   1.0000    .8807    .0496      17.7734   1.00000
 950  10.5263    .6095    .9278    .9443     .9991  1.0000    .7918   1.0000    .8792    .0507      19.7259   1.00000
 955  10.4712    .6066    .9208    .9459     .9980  1.0000    .7949   1.0000    .8779    .0518      21.6929   1.00000
 960  10.4167    .6045    .9176    .9451     .9966  1.0000    .7979   1.0000    .8765    .0529      23.6705   1.00000
 965  10.3627    .6031    .9165    .9443     .9944  1.0000    .8007   1.0000    .8751    .0540      25.6545   1.00000
 970  10.3093    .5973    .9154    .9377     .9911  1.0000    .8035   1.0000    .8738    .0551      27.6685   1.00000
 975  10.2564    .5975    .9188    .9377     .9860  1.0000    .8062   1.0000    .8725    .0562      29.6810   1.00000
 980  10.2041    .6042    .9287    .9459     .9762  1.0000    .8087   1.0000    .8712    .0573      31.66[illegible]   1.00000
 985  10.1523    .6163    .9430    .9608     .9639  1.0000    .8112   1.0000    .8699    .0583      33.5785   1.00000
 990  10.1010    .6191    .9539    .9765     .9405  1.0000    .8136   1.0000    .8686    .0594      35.4829   1.00000
 995  10.0503    .6011    .9352    .9891     .9184  1.0000    .8159   1.0000    .8673    .0604      37.4772   1.00000
1000  10.0000    .5757    .9188    .9945     .8892  1.0000    .8181   1.0000    .8661    .0614      39.5987   1.00000
1005   9.9502    .5543    .9097    .9970     .8631  1.0000    .8203   1.0000    .8629    .0651      41.8284   1.00000
1010   9.9010    .5294    .8969    .9963     .8379  1.0000    .8223   1.0000    .8598    .0688      44.1615   1.00000
1015   9.8522    .5018    .8810    .9932     .8119  1.0000    .8243   1.0000    .8567    .0725      46.6726   1.00000
1020   9.8039    .4923    .8929    .9881     .7909  1.0000    .8262   1.0000    .8537    .0760      49.2113   1.00000
1025   9.7561    .4827    .8903    .9807     .7848  1.0000    .8281   1.0000    .8507    .0796      51.7978   1.00000
1030   9.7087    .4778    .8942    .9738     .7785  1.0000    .8299   1.0000    .8478    .0831      54.4128   1.00000
1035   9.6618    .4408    .9052    .9608     .7213  1.0000    .8316   1.0000    .8449    .0865      57.2088   1.00000
1040   9.6154    .4523    .9108    .9511     .7442  1.0000    .8332   1.0000    .8420    .0899      59.9472   1.00000
1045   9.5694    .5041    .9131    .9377     .8404  1.0000    .8348   1.0000    .8392    .0932      62.4266    .00000
1050   9.5238    .4484    .9052    .9331     .7590  1.0000    .8364   1.0000    .8364    .0967      65.1844      000
1055   9.4787    .4291    .8982    .9285     .7367  1.0000    .8378   1.0000    .8336    .1000      68.0389   1.00000
1060   9.4340    .4388    .8824    .9276     .7688  1.0000    .8393   1.0000    .8309    .1032      70.9447   1.00000
1065   9.3897    .4592    .8750    .9250     .8149  1.0000    .8406   1.0000    .8282    .1064      73.5468   1.00000
1070   9.3458    .4985    .8637    .9185     .8837  1.0000    .8420   1.0000    .8256    .1095      76.0559   1.00000
1075   9.3023    .5508    .8863    .9173     .9762  1.0000    .8432   1.0000    .8229    .1126      78.3020   1.00000
1080   9.2593    .5707    .9041    .9241     .9860  1.0000    .8445   1.0000    .8204    .1157      80.4487   1.00000
1085   9.2166    .5818    .9041    .9428     .9870  1.0000    .8456   1.0000    .8178    .1187      82.5397   1.00000
1090   9.1743    .5647    .8929    .9577     .9877  1.0000    .8468   1.0000    .8170    .1165      84.6182   1.00000
1095   9.1324    .5865    .8766    .9776     .9877  1.0000    .8479   1.0000    .8173    .1161      86.6855   1.00000
1100   9.0909    .5753    .8467    .9886     .9888  1.0000    .8489   1.0000    .8176    .1138      88.8087   1.00000
1105   9.0498    .5651    .8259    .9964     .9877  1.0000    .8499   1.0000    .8179    .1115      90.9834   1.00000
1110   9.0090    .5625    .8200    .9983     .9870  1.0000    .8509   1.0000    .8182    .1092      93.1748   1.00000
1115   8.9686    .5737    .8338    .9992     .9863  1.0000    .8518   1.0000    .8190    .1078      95.3045   1.00000
1120   8.9286    .5839    .8487    .9981     .9860  1.0000    .8527   1.0000    .8199    .1068      97.3850   1.00000
1125   8.8889    .5950    .8673    .9952     .9857  1.0000    .8536   1.0000    .8208    .1058      99.4049   1.00000
1130   8.8496    .6043    .8810    .9910     .9868  1.0000    .8544   1.0000    .8216    .1048     101.3832   1.00000
1135   8.8106    .5904    .8542    .9833     .9877  1.0000    .8552   1.0000    .8225    .1038     103.4312   1.00000
1140   8.7719    .5796    .8541    .9719     .9907  1.0000    .8560   1.0000    .8234    .1028     105.5335   1.00000
1145   8.7336    .5686    .8469    .9577     .9929  1.0000    .8568   1.0000    .8242    .1019     106.6119   1.00000
INTEGRATED ABSORPTION FROM  900 TO 1145 CM-1 =     106.61AVERAGE TRANSMITTANCE = .5648
 2
```

Table 11. Program Output for Case 6

```
PROGRAM WILL BE EXECUTED IN THE TRANSMISSION MODE
7  3  2  0  0  1  0  0  2 21  0       0.000      0.000  0  0       0.000
MODEL ATMOSPHERE NO. 7
  Z (KM)    P (MB)     T (C) DEW PT %RH  H2O(GM.M-3) O3(GM.M-3) NO. DEN.                                    AEROSOL PROFILE       EXTINCTION
   0.000  1015.000     24.400 21.4  0.0 0.          0.          0.         0.000  0  0  0!
   0.000  1015.000    297.550 21.4  0.0  .186E+02   .600E-04   .158E+00   23.000  3  1  1  3  MARITIME                                 MARITIME
    .136  1000.000     22.000 19.4  0.0 0.          0.          0.         0.000  0  0  0!
    .136  1000.000    295.150 19.4  0.0  .165E+02   .600E-04   .148E+00   23.000  3  1  1  3  MARITIME                                 MARITIME
    .560   950.000     17.800 16.1  0.0 0.          0.          0.         0.000  0  0  0!
    .560   950.000    290.950 16.1  0.0  .136E+02   .600E-04   .122E+00   23.000  3  1  1  3  MARITIME                                 MARITIME
   1.080   892.000     14.600 11.9  0.0 0.          0.          0.         0.000  0  0  0!
   1.080   892.000    287.950 11.9  0.0  .105E+02   .600E-04   .955E-01   23.000  3  1  1  3  MARITIME                                 MARITIME
   1.526   850.000     12.800  5.8  0.0 0.          0.          0.         0.000  0  0  0!
   1.526   850.000    285.950  5.8  0.0  .599E+01   .600E-04   .775E-01   23.000  3  1  1  3  MARITIME                                 MARITIME
   1.650   832.000     12.800 -6.2  0.0 0.          0.          0.         0.000  0  0  0!
   1.650   832.000    295.950 -6.2  0.0  .292E+01   .600E-04   .731E-01   23.000  3  1  1  3  MARITIME                                 MARITIME
   2.270   775.000     11.200-18.2  0.0 0.          0.          0.         0.000  0  0  0!
   2.270   775.000    284.350-18.2  0.0  .111E+01   .605E-04   .530E-01   23.000  3  1  1  6             SPRIG SUMM                    TROPOSPHER
   3.140   700.000      7.200-20.8  0.0 0.          0.          0.         0.000  0  0  0!
   3.140   700.000    280.350-20.6  0.0  .905E+00   .623E-04   .317E-01   23.000  3  1  1  6             SPRIG SUMM                    TROPOSPHER
   5.820   500.000    -10.100-28.1  0.0 0.          0.          0.         0.000  0  0  0!
   5.820   500.000    263.050-28.1  0.0  .501E+00   .685E-04   .798E-02   23.000  3  1  1  6             SPRIG SUMM                    TROPOSPHER
   5.990   488.000    -11.500-27.5  0.0 0.          0.          0.         0.000  0  0  0!
   5.990   488.000    261.650-27.5  0.0  .533E+00   .694E-04   .772E-02   23.000  3  1  1  6             SPRIG SUMM                    TROPOSPHER
   7.510   400.000    -19.500-31.5  0.0 0.          0.          0.         0.000  0  0  0!
   7.510   400.000    254.650-31.5  0.0  .377E+00   .770E-04   .455E-02   23.000  3  1  1  6             SPRIG SUMM                    TROPOSPHER
   8.720   338.000    -28.500-41.5  0.0 0.          0.          0.         0.000  0  0  0!
   8.720   338.000    244.650-41.5  0.0  .143E+00   .840E-04   .216E-02   23.000  3  1  1  6             SPRIG SUMM                    TROPOSPHER
   9.180   318.000    -32.700-39.7  0.0 0.          0.          0.         0.000  0  0  0!
   9.180   318.000    240.450-39.7  0.0  .176E+00   .867E-04   .167E-02   23.000  3  1  1 10             SPRIG SUMM STRAT BKGR  BACK STRA
   9.590   300.000    -35.300-43.3  0.0 0.          0.          0.         0.000  0  0  0!
   9.590   300.000    237.850-43.3  0.0  .122E+00   .683E-04   .138E-02   23.000  3  1  1 10             SPRIG SUMM STRAT BKGR  BACK STRA
   9.720   294.000    -34.700-42.7  0.0 0.          0.          0.         0.000  0  0  0!
   9.720   294.000    238.450-42.7  0.0  .129E+00   .889E-04   .130E-02   23.000  3  1  1 10             SPRIG SUMM STRAT BKGR  BACK STRA
  10.020   281.000    -38.700-45.7  0.0 0.          0.          0.         0.000  0  0  0!
  10.020   281.000    234.450-45.7  0.0  .951E-01   .904E-04   .113E-02   23.000  3  1  1 10             SPRIG SUMM STRAT BKGR  BACK STRA
  10.830   250.000    -44.700-50.0  0.0 0.          0.          0.         0.000  0  0  0!
  10.830   250.000    228.450-50.0  0.0  .502E-01   .106E-03   .845E-03   23.000  3  1  1 10             SPRIG SUMM STRAT BKGR  BACK STRA
  12.290   200.000    -57.100-50.0  0.0 0.          0.          0.         0.000  0  0  0!
  12.290   200.000    216.050-50.0  0.0  .636E-01   .126E-03   .602E-03   23.000  3  1  1 10             SPRIG SUMM STRAT BKGR  BACK STRA
  13.610   161.000    -69.500-50.0  0.0 0.          0.          0.         0.000  0  0  0!
  13.610   161.000    203.650-50.0  0.0  .675E-01   .167E-03   .471E-03   23.000  3  1  1 10             SP IG SUMM STRAT BKGR  BACK STRA
  14.050   150.000    -71.100-50.0  0.0 0.          0.          0.         0.000  0  0  0!
  14.050   150.000    202.050-50.0  0.0  .581E-01   .180E-03   .440E-03   23.000  3  1  1 10             SPRIG SUMM STRAT BKGR  BACK STRA
  15.450   120.000    -70.900-50.0  0.0 0.          0.          0.         0.000  0  0  0!
  15.450   120.000    202.250-50.0  0.0  .580E-01   .223E-03   .401E-03   23.000  3  1  1 10             SPRIG SUMM STRAT BKGR  BACK STRA
            .210         8.550    35.500      0.000      0.000
        H1=   .210KM,H2=  8.550KM,ANGLE= 35.500GEOM. RANGE =  10.24KM,BETA=  .05341
 900.000  1145.000        5.000

         SLANT PATH BETWEEN ALTITUDES H1 AND H2 WHERE H1 =   .210 KM H2 =  8.550 KM,ZENITH ANGLE = 35.500 DEGREES

                   HAZE MODEL  = 23.0 KM VISUAL RANGE AT SEA LEVEL

                 HAZE MODEL  3 =  MARITIME      VIS= 23.0KM

               SEASON =    SPRIG SUMM

               VERTICAL PROFILE AEROSOL MODEL =         STRAT BKGR

         FREQUENCY RANGE V1=   900.0 CM-1 TO V2=  1145.0 CM-1 FOR DV =   5.0 CM-1   ( 8.73 - 11.11 MICRONS )
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Table 11. Program Output for Case 6 (Cont.)

```
         HORIZONTAL PROFILES

 ID    ALT      P         T       H2O      CO2+       O3        N2     H2O(10M)    MOLS      (N-1)     O3(UV)
  1    0.00 1015.000  297.550  1.789E+00 8.921E-01 2.755E-03 7.064E-01 4.891E-02 9.198E-01 2.623E-04 2.800E-03
  2     .14 1000.000  295.150  1.579E+00 8.789E-01 2.743E-03 6.941E-01 4.064E-02 9.136E-01 2.568E-04 2.800E-03
  3     .56  950.000  290.950  1.250E+00 8.194E-01 2.695E-03 6.400E-01 2.987E-02 8.804E-01 2.458E-04 2.800E-03
  4    1.08  892.000  287.950  9.125E-01 7.444E-01 2.633E-03 5.731E-01 1.891E-02 8.353E-01 2.346E-04 2.800E-03
  5    1.53  850.000  285.950  5.844E-01 6.907E-01 2.585E-03 5.259E-01 9.039E-03 8.015E-01 2.275E-04 2.800E-03
  6    1.65  832.000  285.950  2.397E-01 6.654E-01 2.564E-03 5.038E-01 1.850E-03 7.846E-01 2.179E-04 2.800E-03
  7    2.27  775.000  284.950  8.585E-02 5.905E-01 2.517E-03 4.395E-01 3.740E-04 7.334E-01 2.020E-04 2.825E-03
  8    3.14  700.000  280.350  6.416E-02 5.053E-01 2.494E-03 3.674E-01 2.721E-04 6.733E-01 1.703E-04 2.906E-03
  9    5.82  500.000  263.050  2.700E-02 3.061E-01 2.427E-03 2.062E-01 1.139E-04 5.125E-01 1.458E-04 3.194E-03
 10    5.99  485.000  261.650  2.914E-02 2.955E-01 2.424E-03 1.980E-01 1.264E-04 5.029E-01 1.333E-04 3.219E-03
 11    7.51  400.000  253.650  1.590E-02 2.178E-01 2.515E-03 1.354E-01 7.518E-05 4.252E-01 1.146E-04 3.594E-03
 12    8.72  338.000  244.650  5.505E-03 1.704E-01 2.583E-03 1.051E-01 1.775E-05 3.725E-01 1.047E-04 3.919E-03
 13    9.18  318.000  240.450  6.564E-03 1.569E-01 2.611E-03 9.545E-02 2.484E-05 3.566E-01 1.001E-04 4.046E-03
 14    9.59  300.000  237.650  4.322E-03 1.438E-01 2.605E-03 8.635E-02 1.429E-05 3.401E-01 9.660E-05 4.122E-03
 15    9.72  294.000  238.450  4.516E-03 1.383E-01 2.598E-03 8.262E-02 1.540E-05 3.325E-01 9.417E-05 4.147E-03
 16   10.02  281.000  234.450  3.211E-03 1.308E-01 2.603E-03 7.741E-02 1.004E-05 3.232E-01 8.881E-05 4.217E-03
 17   10.83  250.000  228.450  1.852E-03 1.105E-01 2.938E-03 6.370E-02 5.248E-06 2.951E-01 7.824E-05 4.961E-03
 18   12.29  200.000  216.050  1.642E-03 8.073E-02 3.272E-03 4.433E-02 6.290E-06 2.496E-01 6.647E-05 5.574E-03
 19   13.60  161.000  203.650  1.472E-03 5.991E-02 3.968E-03 3.139E-02 8.815E-06 2.132E-01 5.937E-05 7.809E-03
 20   14.05  150.000  202.050  1.397E-03 5.350E-02 4.167E-03 2.757E-02 9.224E-06 2.002E-01 4.250E-05 8.423E-03
 21   16.45  100.000  202.250  9.685E-04 2.628E-02 4.377E-03 1.224E-02 8.481E-06 1.333E-01 0.        1.041E-02

         HORIZONTAL PROFILES
 ID    ALT      P         T      H2O(4M)     HNO3      AER1      AER2      AER3      AER4    (AER1*RH)    RH%
  1    0.00 1015.000  297.550  2.581E-01 0.        1.580E-01 0.        0.        0.        1.710E+01 8.294E+01
  2     .14 1000.000  295.150  2.313E-01 0.        1.483E-01 0.        0.        0.        1.758E+01 8.484E+01
  3     .56  950.000  290.950  1.894E-01 0.        1.207E-01 0.        0.        0.        1.090E+01 8.957E+01
  4    1.08  892.000  287.950  1.402E-01 0.        9.546E-02 0.        0.        0.        7.874E+00 8.246E+01
  5    1.53  850.000  285.950  8.914E-02 0.        7.750E-02 0.        0.        0.        4.804E+00 6.198E+01
  6    1.65  832.000  285.950  7.489E-02 0.        7.314E-02 0.        0.        0.        1.880E+00 2.571E+01
  7    2.27  775.000  284.950  1.237E-02 0.        0.        5.303E-02 0.        0.        0.        0.
  8    3.14  700.000  280.350  9.803E-03 0.        0.        3.170E-02 0.        0.        0.        0.
  9    5.82  500.000  263.050  5.302E-03 0.        0.        7.976E-03 0.        0.        0.        0.
 10    5.99  485.000  261.650  5.657E-03 0.        0.        7.725E-03 0.        0.        0.        0.
 11    7.51  400.000  253.650  3.358E-03 0.        0.        4.554E-03 0.        0.        0.        0.
 12    8.72  338.000  244.650  1.495E-03 7.098E-20 0.        2.163E-03 0.        0.        0.        0.
 13    9.18  318.000  240.450  1.908E-03 4.421E-06 0.        0.        1.673E-03 0.        0.        0.
 14    9.59  300.000  237.850  1.322E-03 5.879E-06 0.        0.        1.381E-03 0.        0.        0.
 15    9.72  294.000  238.450  1.359E-03 7.854E-06 0.        0.        1.300E-03 0.        0.        0.
 16   10.02  281.000  234.450  1.051E-03 1.086E-05 0.        0.        1.132E-03 0.        0.        0.
 17   10.83  250.000  228.450  6.877E-04 2.031E-05 0.        0.        8.488E-04 0.        0.        0.
 18   12.29  200.000  216.050  8.170E-04 3.132E-05 0.        0.        6.022E-04 0.        0.        0.
 19   13.60  161.000  203.650  1.021E-03 3.233E-05 0.        0.        4.706E-04 0.        0.        0.
 20   14.05  150.000  202.050  1.011E-03 3.222E-05 0.        0.        4.395E-04 0.        0.        0.
 21   16.45  100.000  202.250  6.599E-04 2.592E-05 0.        0.        4.008E-04 0.        0.        0.

FROM POINT\ HEIGHT=      .2100 KM,N=  2,NP= 0,REF. INDEX ABOVE & BELOW X=  .2560E-03  .2607E-03,IP=  1
          EQUIV. ABSORBER AMOUNTS PER KM AT X=  .152E+01  .868E+00  .273E-02  .684E+00  .385E-01  .908E+00  .143E+00  .280E-02


    TX(12-14)= 0.        0.        0.1


FROM POINT\ HEIGHT=    8.5500 KM,N= 11,NP= 0,REF. INDEX ABOVE & BELOW X=  .1080E-03  .1156E-03,IP=  1
          EQUIV. ABSORBER AMOUNTS PER KM AT X=  .654E-02  .176E+00  .257E-02  .109E+00  .217E-04  .384E+00 0.         .387E-02


    TX(12-14)=  .240E-02 0.        0.1
```

Table 11. Program Output for Case 6 (Cont.)

```
            VERTICAL PROFILES

IC   ALT      H2O       CO2+       O2        N2       H2O(10M)    MOLS       AER1      O3(UV)      PSI      PHI       BETA    THETA    RANGE
                      H2O(4M)     HNO3      AER2      AER3       AER4                                                                ORANGE

 2    .210 5.926E-01 3.627E-01 1.167E-03 2.846E-01 1.462E-02 3.847E-01 5.682E-02 1.204E-03   0.0003 144.5022   .0022  35.5044     .4
      .560           8.852E-02 0.        0.        0.        0.                                                                      .43

 3    .560 1.278E+00 8.617E-01 2.868E-03 6.716E-01 2.993E-02 5.321E-01 1.258E-01 2.992E-03    .0004 144.5052   .0056  35.4982    1.1
     1.080           1.930E-01 0.        0.        0.        0.                                                                      .64

 4   1.080 1.681E+00 1.255E+00 4.298E-03 9.724E-01 3.726E-02 1.380E+00 1.730E-01 4.526E-03    .0009 144.5076   .0084  35.4953    1.6
     1.526           2.548E-01 0.        0.        0.        0.                                                                      .55

 5   1.526 1.740E+00 1.358E+00 4.690E-03 1.051E+00 3.795E-02 1.501E+00 1.845E-01 4.952E-03    .0012 144.5081   .0092  35.4927    1.8
     1.650           2.636E-01 0.        0.        0.        0.                                                                      .15

 6   1.650 1.854E+00 1.835E+00 5.625E-03 1.409E+00 3.855E-02 2.079E+00 1.845E-01 7.094E-03    .0016 144.5117   .0132  35.4923    2.5
     2.270           2.831E-01 0.        0.        0.        0.                                                                      .76

 7   2.270 1.933E+00 2.420E+00 9.301E-03 1.839E+00 3.899E-02 2.850E+00 1.845E-01 1.016E-02    .0022 144.5166   .0188  35.4890    3.6
     3.140           2.919E-01 0.        4.429E-02 0.        0.                                                                     1.07

 8   3.140 2.075E+00 3.728E+00 1.740E-02 2.758E+00 3.959E-02 4.769E+00 1.845E-01 2.019E-02    .0035 144.5324   .0359  35.4847    6.9
     5.820           3.169E-01 0.        1.009E-01 0.        0.                                                                     3.29

 9   5.820 2.080E+00 3.790E+00 1.790E-02 2.800E+00 3.962E-02 4.875E+00 1.845E-01 2.086E-02    .0045 144.5325   .0370  35.4886    7.1
     5.990           3.171E-01 0.        1.025E-01 0.        0.                                                                      .21

10   5.990 2.122E+00 4.266E+00 2.251E-02 3.113E+00 3.960E-02 5.739E+00 1.845E-01 2.721E-02    .0050 144.5418   .0468  35.4686    9.0
     7.510           3.259E-01 0.        1.137E-01 0.        0.                                                                     1.87

11   7.510 2.135E+00 4.516E+00 2.576E-02 3.270E+00 3.985E-02 6.252E+00 1.845E-01 3.197E-02    .0057 144.5477   .0534  35.4590   10.2
     8.550           3.293E-01 0.        1.180E-01 0.        0.                                                                     1.28

         EQUIVALENT SEA LEVEL ABSORBER AMOUNTS

                       WATER VAPOUR     CO2 ETC.      OZONE     NITROGEN (CONT)  H2O  (CONT)     MOL  SCAT      AER1          OZONE(U-V)
                        GM CM-2           KM         ATM CM          KM          GM CM-2          KM                            ATM CM
                                                                                                                          NITRIC ACID?

         W(1-8)=        .214E+01      .452E+01      .258E-01       .327E+01       .799E-01       .625E+01      .134E+00      .323E-01
                                                                                  .329E+00

                             AER2          AER3          AER4      R.H. MEAN
         W(12-15)=      1.180E-01      0.            0.            8.019E+01

ICH       3    6   10   15
EXTINCTION AND ABSORPTION COEFFICIENTS
```

Table 11. Program Output for Case 6 (Cont.)

```
FREQ WAVELENGTH  TOTAL    H2O     CO2+    OZONE  N2 CONT  H2O CONT MOL SCAT AEROSOL  AEROSOL   INTEGRATED NITRIC ACID
CM-1  MICRONS    TRANS   TRANS   TRANS    TRANS   TRANS    TRANS    TRANS    TRANS     ABS    ABSORPTION    TRANS
 900  11.1111    .6451   .9466  1.0000   1.0000  1.0000    .7025   1.0000    .9701    .0204       .8872    1.0000
 905  11.0497    .6454   .9419   .9979   1.0000  1.0000    .7075   1.0000    .9744    .0198      2.6641    1.0000
 910  10.9890    .6482   .9404   .9967   1.0000  1.0000    .7125   1.0000    .9707    .0193      4.4191    1.0000
 915  10.9290    .6505   .9395   .9945   1.0000  1.0000    .7172   1.0000    .9747    .0188      6.1667    1.0000
 920  10.8696    .6551   .9427   .9918   1.0000  1.0000    .7218   1.0000    .9707    .0183      7.8513    1.0000
 925  10.8108    .6713   .9653   .9865   1.0000  1.0000    .7263   1.0000    .9706    .0178      9.5347    1.0000
 930  10.7527    .6742   .9687   .9815   1.0000  1.0000    .7306   1.0000    .9706    .0174     11.1636    1.0000
 935  10.6952    .6755   .9711   .9755   1.0000  1.0000    .7347   1.0000    .9706    .0169     12.7851    1.0000
 940  10.6383    .6730   .9665   .9712   1.0000  1.0000    .7388   1.0000    .9706    .0164     14.4210    1.0000
 945  10.5820    .6658   .9550   .9673    .9999  1.0000    .7427   1.0000    .9705    .0160     16.0922    1.0000
 950  10.5263    .6620   .9482   .9650    .9992  1.0000    .7464   1.0000    .9700    .0159     17.7022    1.0000
 955  10.4712    .6605   .9419   .9662    .9981  1.0000    .7501   1.0000    .9696    .0158     19.4792    1.0000
 960  10.4167    .6604   .9395   .9656    .9969  1.0000    .7536   1.0000    .9691    .0157     21.1770    1.0000
 965  10.3627    .6607   .9386   .9650    .9948  1.0000    .7570   1.0000    .9687    .0155     22.8734    1.0000
 970  10.3093    .6574   .9377   .9605    .9917  1.0000    .7602   1.0000    .9623    .0154     24.5863    1.0000
 975  10.2564    .6587   .9404   .9605    .9870  1.0000    .7634   1.0000    .9678    .0153     26.2930    1.0000
 980  10.2041    .6647   .9490   .9662    .9778  1.0000    .7664   1.0000    .9674    .0152     27.9694    1.0000
 985  10.1523    .6732   .9596   .9759    .9663  1.0000    .7694   1.0000    .9670    .0151     29.6034    1.0000
 990  10.1010    .6719   .9682   .9853    .9437  1.0000    .7722   1.0000    .9665    .0149     31.2437    1.0000
 995  10.0503    .6555   .9537   .9939    .9236  1.0000    .7750   1.0000    .9661    .0148     32 9663    1.0000
1000  10.0000    .6299   .9404   .9969    .8948  1.0000    .7776   1.0000    .9657    .0147     34.8166    1.0000
1005   9.9502    .6099   .9330   .9984    .8697  1.0000    .7802   1.0000    .9650    .0149     36.7671    1.0000
1010   9.9010    .5876   .9231   .9981    .8452  1.0000    .7826   1.0000    .9643    .0152     38.8285    1.0000
1015   9.8522    .5631   .9104   .9962    .8208  1.0000    .7850   1.0000    .9635    .0154     41.0135    1.0000
1020   9.8039    .5546   .9205   .9934    .8004  1.0000    .7873   1.0000    .9628    .0156     43.2394    1.0000
1025   9.7561    .5475   .9184   .9882    .7943  1.0000    .7895   1.0000    .9621    .0158     45.5017    1.0000
1030   9.7087    .5436   .9214   .9837    .7861  1.0000    .7916   1.0000    .9614    .0161     47.7835    1.0000
1035   9.6618    .5170   .9293   .9759    .7332  1.0000    .7937   1.0000    .9607    .0163     50.2487    1.0000
1040   9.6154    .5229   .9339   .9701    .7556  1.0000    .7957   1.0000    .9600    .0165     52.6341    1.0000
1045   9.5694    .5828   .9358   .9655    .8475  1.0000    .7976   1.0000    .9594    .0167     54.7260    1.0000
1050   9.5238    .5243   .9293   .9573    .7691  1.0000    .7994   1.0000    .9587    .0169     57.0983    1.0000
1055   9.4787    .5062   .9240   .9540    .7482  1.0000    .8012   1.0000    .9580    .0171     59.5671    1.0000
1060   9.4340    .5282   .9115   .9534    .7780  1.0000    .8029   1.0000    .9574    .0173     61.9660    1.0000
1065   9.3897    .5462   .9059   .9514    .8233  1.0000    .8045   1.0000    .9567    .0175     64 2251    1.0000
1070   9.3458    .5913   .9127   .9462    .8893  1.0000    .8061   1.0000    .9561    .0177     66.2756    1.0000
1075   9.3023    .6527   .9150   .9454    .9778  1.0000    .8076   1.0000    .9554    .0179     68.0123    1.0000
1080   9.2593    .6731   .9284   .9507    .9870  1.0000    .8091   1.0000    .9548    .0181     69.6470    1.0000
1085   9.2166    .6838   .9284   .9639    .9881  1.0000    .8105   1.0000    .9542    .0183     71.2286    1.0000
1090   9.1743    .6864   .9205   .9739    .9888  1.0000    .8119   1.0000    .9538    .0182     72.7960    1.0000
1095   9.1324    .6857   .9070   .9860    .9888  1.0000    .8132   1.0000    .9535    .0180     74.3676    1.0000
1100   9.0909    .6759   .8859   .9937    .9891  1.0000    .8144   1.0000    .9533    .0177     75.9885     .0000
1105   9.0498    .6661   .8683   .9982    .9888  1.0000    .8157   1.0000    .9530    .0175     77.6575    1.0000
1110   9.0090    .6634   .8636   .9990    .9881  1.0000    .8168   1.0000    .9528    .0172     79.3404    1.0000
1115   8.9686    .6724   .8745   .9996    .9874  1.0000    .8180   1.0000    .9526    .0171     80.9782    1.0000
1120   8.9286    .6813   .8859   .9989    .9870  1.0000    .8190   1.0000    .9524    .0171     82.5716    1.0000
1125   8.8889    .6913   .9003   .9973    .9867  1.0000    .8201   1.0000    .9522    .0170     84.1323    1.0000
1130   8.8496    .6989   .9104   .9949    .9878  1.0000    .8211   1.0000    .9520    .0169     85.6182    1.0000
1135   8.8106    .6880   .8977   .9905    .9886  1.0000    .8221   1.0000    .9519    .0169     87.2782    1.0000
1140   8.7719    .6787   .8698   .9825    .9913  1.0000    .8230   1.0000    .9517    .0168     88.7646    1.0000
1145   8.7336    .6708   .8845   .9739    .9933  1.0000    .8239   1.0000    .9515    .0168     89 6.74    1.0000
INTEGRATED ABSORPTION FROM  900 TO 1145 CM-1 =     89 ,1AVERAGE TRANSMITTANCE = .6343
 2
```

Table 12. Program Output for Case 7

```
PROGRAM WILL BE EXECUTED IN THE TRANSMISSION MODE
7  9  2  0  0  1  6  6  6 12  0      0.000      0.000  0  0      0.000
MODEL ATMOSPHERE NO. 7
  Z (KM)    P (MB)     T (C) DEW PT %RH  H2O(GM.M-3) O3(GM.M-3) NO. DEN.                                       AEROSOL PROFILE      EXTINCTION
   0.000      0.000      0.000  0.0  0.0 0.          0.          0.           0.000  0  0  0*
   0.000   1013.000    288.100  0.0  0.0  .590E+01   .540E-04   .749E+01       .500  9  1  1  9 FOG2 (RAD)                              FOG2 (RAD)
    .200      0.000      0.000  0.0  0.0 0.          0.          0.           0.000  0  0  0*
    .200    989.011    286.788  0.0  0.0  .551E+01   .540E-04   .749E+01       .500  9  1  1  9 FOG2 (RAD)                              FOG2 (RAD)
    .231      0.000      0.000  0.0  0.0 0.          0.          0.          23.000  1  0  0*
    .231    985.892    286.792  0.0  0.0  .551E+01   .540E-04   .144E+00      23.000  1  1  1  1     RURAL                                  RURAL
   1.000      0.000      0.000  0.0  0.0 0.          0.          0.          23.000  1  0  0*
   1.000    898.600    281.600  0.0  0.0  .420E+01   .540E-04   .991E-01      23.000  1  1  1  1     RURAL                                  RURAL
   2.000      0.000      0.000  0.0  0.0 0.          0.          0.          23.000  1  0  0*
   2.000    795.020    275.100  0.0  0.0  .290E+01   .540E-04   .621E-01      23.000  1  1  1  1     RURAL                                  RURAL
   2.010      0.000      0.000  0.0  0.0 0.          0.          0.           0.000  0  0  0*
   2.010    794.113    275.035  0.0  0.0  .289E+01   .540E-04   .617E-01       .500  9  1  1  6              SPRIG SUMM              TROPOSPHER
   5.000      0.000      0.000  0.0  0.0 0.          0.          0.           0.000  0  0  0*
   5.000    540.500    255.700  0.0  0.0  .540E+00   .460E-04   .931E-02       .500  9  1  1  6              SPRIG SUMM              TROPOSPHER
  10.000      0.000      0.000  0.0  0.0 0.          0.          0.           0.000  0  0  0*
  10.000    265.000    223.200  0.0  0.0  .180E-01   .900E-04   .114E-02       .500  9  1  1 10              SPRIG SUMM STRAT BKGR  BACK STRA
  11.000      0.000      0.000  0.0  0.0 0.          0.          0.           0.000  0  0  0*
  11.000    227.000    216.800  0.0  0.0  .320E-02   .130E-03   .799E-03       .500  9  1  1 10              SPRIG SUMM STRAT BKGR  BACK STRA
  30.000      0.000      0.000  0.0  0.0 0.          0.          0.           0.000  0  0  0*
  30.000     11.970    226.500  0.0  0.0  .380E-03   .200E-03   .332E-04       .500  9  1  1 10              SPRIG SUMM STRAT BKGR  BACK STRA
  35.000      0.000      0.000  0.0  0.0 0.          0.          0.           0.000  0  0  0*
  35.000      5.746    236.500  0.0  0.0  .160E-03   .110E-03   .164E-04       .500  9  1  1 10                         STRAT BKGR  BACK STRA
  70.000      0.000      0.000  0.0  0.0 0.          0.          0.           0.000  0  0  0*
  70.000       .055    219.700  0.0  0.0  .150E-06   .860E-07   .160E-06       .500  9  1  1 10                         STRAT BKGR  BACK STRA
               0.000     10.000      0.000      0.000      0.000
        H1=  0.000KM,H2= 10.000KM,ANGLE=  0.0000DEG. RANGE =  10.00KM,BETA= 0.00000
 900.000   1145.000      5.000


        SLANT PATH BETWEEN ALTITUDES H1 AND H2 WHERE H1 =  0.000 KM H2 = 10.000 KM,ZENITH ANGLE =  0.000 DEGREES

                    HAZE MODEL  =   .5 KM VISUAL RANGE AT SEA LEVEL

                  HAZE MODEL  9 = FOG2 (RAD)     VIS=   .5KM

               SEASON =    SPRIG SUMM

               VERTICAL PROFILE AEROSOL MODEL =       STRAT BKGR

        FREQUENCY RANGE V1=   900.0 CM-1 TO V2=  1145.0 CM-1 FOR DV =    5.0 CM-1   (  8.73 - 11.11 MICRONS )
```

Table 12. Program Output for Case 7 (Cont.)

```
          HORIZONTAL PROFILES

 ID      ALT       P          T          H2O       CO2+         O3          N2      H2O(10M)      MCLS       (N-1)       O3(UV)
  1     0.00 1013.000   288.100   5.760E-01 3.294E-01 2.493E-03 7.385E-01 5.574E-03 9.481E-01 2.594E-04 2.520E-03
  2      .20  989.010   286.798   5.278E-01 8.968E-01 2.472E-03 7.086E-01 5.899E-03 9.299E-01 2.668E-04 2.520E-03
  3      .20  988.892   286.782   5.275E-01 8.966E-01 2.472E-03 7.087E-01 5.896E-03 9.298E-01 2.569E-04 2.520E-03
  4     1.00  898.600   281.600   3.719E-01 7.776E-01 2.387E-03 6.014E-01 3.832E-03 8.604E-01 2.353E-04 2.520E-03
  5     2.00  795.000   275.100   2.324E-01 5.480E-01 2.264E-03 4.875E-01 2.127E-03 7.792E-01 2.236E-04 2.520E-03
  6     2.01  794.003   275.035   2.311E-01 6.468E-01 2.281E-03 4.864E-01 2.111E-03 7.784E-01 1.936E-04 2.518E-03
  7     5.00  540.500   255.700   3.746E-02 3.648E-01 1.692E-03 2.515E-01 1.927E-04 5.700E-01 1.278E-04 2.147E-03
  8    10.00  265.000   223.200   5.297E-04 1.263E-01 2.558E-03 7.412E-02 1.181E-06 3.201E-01 8.654E-05 4.200E-03
  9    11.00  227.005   216.800   2.368E-04 1.0     01 3.493E-03 5.681E-02 4.288E-07 2.823E-01 4.260E-05 6.067E-03
 10    30.00   11.970   226.500   7.614E-07 5.       4 1.642E-03 1.479E-04 9.944E-10 1.425E-02 2.988E-06 9.333E-03
 11    35.00    5.746   236.500   1.524E-07 1.4      4 6.674E-04 3.195E-05 1.943E-10 6.551E-03 9.508E-07 5.133E-03
 12    70.00     .055   219.700   2.406E-12 4.662E-08 3.259E-08 3.293E-09 1.653E-15 6.775E-05 0.          4.013E-06


          HORIZONTAL PROFILES
 ID      ALT       P          T       H2O(4M)      HNO3        AER1        AER2        AER3        AER4      (AER1*RH)       RH
  1     0.00 1013.000   288.100   8.473E-02 0.          7.495E+00 0.          0.          0.          0.          4.575E+01
  2      .20  989.010   286.768   7.887E-02 0.          7.495E+00 0.          0.          0.          0.          4.635E+01
  3      .20  988.892   286.762   7.879E-02 0.          0.          1.439E-01 0.          0.          6.669E+00 4.635E+01
  4     1.00  898.600   281.600   5.897E-02 0.          0.          9.910E-02 0.          0.          4.862E+00 4.906E+01
  5     2.00  795.000   275.100   3.993E-02 0.          0.          6.210E-02 0.          0.          3.238E+00 5.214E+01
  6     2.01  794.003   275.035   3.973E-02 0.          0.          0.          6.174E-02 0.          0.          0.
  7     5.00  540.500   255.700   8.494E-03 0.          0.          0.          9.310E-03 0.          0.          0.
  8    10.00  265.000   223.200   2.502E-04 1.056E-05 0.          0.          0.          1.140E-03 0.          0.
  9    11.00  227.000   216.800   1.167E-04 2.259E-05 0.          0.          0.          7.990E-04 0.          0.
 10    30.00   11.970   226.500   2.184E-07 3.705E-06 0.          0.          0.          3.320E-05 0.          0.
 11    35.00    5.746   236.500   3.471E-08 1.441E-07 0.          0.          0.          1.640E-05 0.          0.
 12    70.00     .055   219.700   4.770E-13 0.          0.          0.          0.          1.600E-07 0.          0.

FROM POINT\ HEIGHT=    0.0000 KM,N=  1,NP= 1,REF. INDEX ABOVE & BELOW X=  .2694E-03 0.          ,IP=  1
        EQUIV. ABSORBER AMOUNTS PER KM AT X=  .576E+00  .929E+00  .249E-02  .739E+00  .657E-02  .948E+00  .749E+01  .252E-02


   TX(12-14)= 0.         0.         0.T


FROM POINT\ HEIGHT=   10.0000 KM,N=  8,NP= 1,REF. INDEX ABOVE & BELOW X=  .8654E-04  .1278E-03,IP=  1
        EQUIV  ABSORBER AMOUNTS PER KM AT X=  .593E-03  .126E+00  .256E-02  .741E-01  .118E-05  .320E+00 0.          .420E-02


   TX(12-14)= 0.         0.         .114E-02
```

Table 12. Program Output for Case 7 (Cont.)

```
          VERTICAL PROFILES

  IC   ALT       H2O       CO2+       O3        N2       H2O(10M)    MCLS       AER1      O3(UV)      PSI       PHI       SET1      THETA    RANGE
                          H2O(4M)    HNO3      AER2       AER3       AER4                                                                   CRANGE

   1   0.000 1.103E-01 1.626E-01 4.555E-04 1.447E-01 1.246E-03 1.878E-01 1.499E+00 5.040E-04   0.0000 180.0000   0.0000    0.0000      .2
        .200           1.635E-02 0.        0.        0.        0.                                                                      .20

   2    .200 1.108E-01 1.975E-01 4.590E-04 1.454E-01 1.252E-03 1.887E-01 1.499E+00 5.065E-04   0.0000 180.0000   0.0000    0.0000      .2
        .201           1.643E-02 0.        0.        0.        0.                                                                      .00

   3    .201 4.666E-01 8.512E-01 2.440E-03 6.676E-01 5.079E-03 5.034E-01 1.499E+00 2.520E-03   0.0000 180.0000   0.0000    0.0000     1.0
       1.000           7.108E-02 0.        9.595E-02 0.        0.                                                                      .80

   4   1.000 7.633E-01 1.562E+00 4.776E-03 1.210E+00 7.976E-03 1.773E+00 1.499E+00 5.040E-03   0.0000 180.0000   0.0000    0.0000     2.0
       2.000           1.199E-01 0.        1.751E-01 0.        0.                                                                     1.00

   5   2.000 7.656E-01 1.566E+00 4.799E-03 1.215E+00 7.997E-03 1.731E+00 1.499E+00 5.065E-03   0.0000 180.0000   0.0000    0.0000     2.0
       2.010           1.207E-01 0.        1.751E-01 0.        0.                                                                      .01

   6   2.010 1.084E+00 3.041E+00 1.069E-02 2.280E+00 1.039E-02 3.730E+00 1.499E+00 1.202E-02   0.0000 180.0000   0.0000    0.0000     5.0
       5.000           1.809E-01 0.        1.751E-01 8.286E-02 0.                                                                     2.99

   7   5.000 1.128E+00 4.165E+00 2.117E-02 3.106E+00 1.358E-02 5.896E+00 1.499E+00 2.732E-02   0.0000 180.0000   0.0000    0.0000    10.0
      10.000           1.925E-01 0.        1.751E-01 8.286E-02 0.                                                                     5.00

          EQUIVALENT SEA LEVEL ABSORBER AMOUNTS

                     WATER VAPOUR       CO2 ETC.        OZONE     NITROGEN (CONT)  H2O  (CONT)       MOL  SCAT       AER1          OZONE(U-V)
                      GM CM-2             KM           ATM CM          KM          GM CM-2           KM                             ATM CM
                                                                                                                                NITRIC ACID*

          W(1-8)=      .113E+01         .416E+01       .212E-01       .301E+01      .106E-01         .590E+01       .150E+01       .273E-01
                                                                                    .193E+00                                      0.

                         AER2             AER3            AER4         R.H. MEAN
          W(12-15)=    1.751E-01        8.286E-02       0.              4.890E+01

 ICH       9    1    6   10
 EXTINCTION AND ABSORPTION COEFFICIENTS
```

Table 12. Program Output for Case 7 (Cont.)

```
FREQ WAVELENGTH  TOTAL     H2O      CO2+     OZONE   N2 CONT  H2O CONT MOL SCAT  AEROSOL  AEROSOL     INTEGRATED NITRIC ACID
CM-1  MICRONS    TRANS     TRANS    TRANS    TRANS    TRANS    TRANS    TRANS    TRANS     ABS       ABSORPTION    TRANS
 900  11.1111    .5943     .9646   1.0000   1.0000   1.0000    .9106   1.0000    .6774    .2614        1.0128   1.0000!
 905  11.0497    .5980     .9612    .9981   1.0000   1.0000    .9124   1.0000    .6833    .2540        3.0228   1.0000!
 910  10.9890    .6025     .9600    .9969   1.0000   1.0000    .9140   1.0000    .6888    .2467        5.0105   1.0000!
 915  10.9290    .6050     .9594    .9948   1.0000   1.0000    .9156   1.0000    .6923    .2399        6.9656   1.0000!
 920  10.8696    .6030     .9617    .9923   1.0000   1.0000    .9172   1.0000    .6958    .2330        8.9406   1.0000!
 925  10.8108    .6210     .9775    .9874   1.0000   1.0000    .9187   1.0000    .6993    .2263       10.8445   1.0000!
 930  10.7527    .6224     .9798    .9823   1.0000   1.0000    .9201   1.0000    .7028    .2195       12.7288   1.0000!
 935  10.6952    .6236     .9811    .9768   1.0000   1.0000    .9215   1.0000    .7063    .2127       14.6105   1.0000!
 940  10.6383    .6231     .9783    .9726   1.0000   1.0000    .9228   1.0000    .7097    .2060       16.4952   1.0000!
 945  10.5820    .6193     .9710    .9693    .9999   1.0000    .9241   1.0000    .7121    .1999       18.3990   1.0000!
 950  10.5263    .6126     .9657    .9670    .9993   1.0000    .9254   1.0000    .7094    .1976       20.3359   1.0000!
 955  10.4712    .6084     .9612    .9682    .9985   1.0000    .9266   1.0000    .7068    .1954       22.2939   1.0000!
 960  10.4167    .6043     .9594    .9676    .9975   1.0000    .9277   1.0000    .7041    .1931       24.2696   1.0000!
 965  10.3627    .6016     .9587    .9670    .9958   1.0000    .9288   1.0000    .7016    .1909       26.2620   1.0000!
 970  10.3093    .5952     .9581    .9625    .9931   1.0000    .9299   1.0000    .6990    .1886       28.2859   1.0000!
 975  10.2564    .5930     .9600    .9625    .9899   1.0000    .9309   1.0000    .6965    .1864       30.3207   1.0000!
 980  10.2041    .5938     .9663    .9682    .9814   1.0000    .9319   1.0000    .6940    .1842       32.3517   1.0000!
 985  10.1523    .5966     .9735    .9772    .9719   1.0000    .9328   1.0000    .6916    .1820       34.3689   1.0000!
 990  10.1010    .5918     .9794    .9862    .9523   1.0000    .9337   1.0000    .6892    .1799       36.4097   1.0000!
 995  10.0503    .5797     .9702    .9943    .9364   1.0000    .9346   1.0000    .6868    .1777       38.5110   1.0000!
1000  10.0000    .5582     .9600    .9971    .9107   1.0000    .9355   1.0000    .6845    .1756       40.7195   1.0000!
1005   9.9502    .5379     .9548    .9986    .8867   1.0000    .9363   1.0000    .6796    .1755       43.0305   1.0000!
1010   9.9010    .5163     .9472    .9982    .8644   1.0000    .9370   1.0000    .6749    .1754       45.4466   1.0000!
1015   9.8522    .4941     .9374    .9964    .8418   1.0000    .9378   1.0000    .6702    .1753       47.9760   1.0000!
1020   9.8039    .4837     .9448    .9939    .8246   1.0000    .9385   1.0000    .6656    .1753       50.5577   1.0000!
1025   9.7561    .4747     .9433    .9890    .8196   1.0000    .9392   1.0000    .6610    .1752       53.1843   1.0000!
1030   9.7087    .4675     .9456    .9845    .8137   1.0000    .9399   1.0000    .6566    .1751       55.8470   1.0000!
1035   9.6618    .4362     .9522    .9772    .7643   1.0000    .9405   1.0000    .6522    .1750       58.6658   1.0000!
1040   9.6154    .4435     .9555    .9714    .7836   1.0000    .9412   1.0000    .6479    .1749       61.4435   1.0000!
1045   9.5694    .4837     .9568    .9625    .8665   1.0000    .9418   1.0000    .6436    .1749       64.0302   1.0000!
1050   9.5238    .4382     .9522    .9596    .7959   1.0000    .9423   1.0000    .6394    .1748       66.8393   1.0000!
1055   9.4787    .4221     .9400    .9563    .7773   1.0000    .9429   1.0000    .6353    .1747       69.7288   1.0000!
1060   9.4340    .4298     .9383    .9557    .8049   1.0000    .9434   1.0000    .6313    .1746       72.5796   1.0000!
1065   9.3897    .4450     .9336    .9537    .8441   1.0000    .9439   1.0000    .6273    .1745       75.3545   1.0000!
1070   9.3458    .4750     .9393    .9490    .9052   1.0000    .9444   1.0000    .6234    .1745       77.9796   1.0000!
1075   9.3023    .5126     .9409    .9482    .9814   1.0000    .9449   1.0000    .6195    .1744       80.4168   1.0000!
1080   9.2593    .5225     .9516    .9530    .9899   1.0000    .9453   1.0000    .6157    .1743       82.8041   1.0000!
1085   9.2166    .5269     .9516    .9659    .9906   1.0000    .9458   1.0000    .6120    .1742       85.1693   1.0000!
1090   9.1743    .5255     .9448    .9753    .9910   1.0000    .9462   1.0000    .6082    .1739       87.5419   1.0000!
1095   9.1324    .5229     .9346    .9869    .9910   1.0000    .9466   1.0000    .6043    .1733       89.9277   1.0000!
1100   9.0909    .5151     .9192    .9941    .9912   1.0000    .9470   1.0000    .6005    .1728       92.3523   1.0000!
1105   9.0498    .5065     .9056    .9983    .9910   1.0000    .9474   1.0000    .5968    .1723       94.8196   1.0000!
1110   9.0090    .5019     .9022    .9991    .9906   1.0000    .9477   1.0000    .5931    .1718       97.3101   1.0000!
1115   8.9686    .5041     .9101    .9996    .9902   1.0000    .9481   1.0000    .5892    .1715       99.7944   1.0000!
1120   8.9286    .5045     .9192    .9990    .9899   1.0000    .9484   1.0000    .5852    .1714      102.2719   1.0000!
1125   8.8889    .5057     .9290    .9976    .9896   1.0000    .9487   1.0000    .5813    .1712      104.7432   1.0000!
1130   8.8496    .5060     .9374    .9952    .9899   1.0000    .9490   1.0000    .5774    .1711      107.2130   1.0000!
1135   8.8106    .4959     .9273    .9911    .9910   1.0000    .9493   1.0000    .5736    .1709      109.7335   1.0000!
1140   8.7719    .4970     .9220    .9833    .9928   1.0000    .9496   1.0000    .5698    .1707      112.2983   1.0000!
1145   8.7336    .4789     .9181    .9753    .9945   1.0000    .9499   1.0000    .5661    .1706      113.6012   1.0000!
INTEGRATED ABSORPTION FROM  900 TO 1145 CM-1 =     113.50AVERAGE TRANSMITTANCE = .5363
```

10. EXAMPLES OF TRANSMITTANCE AND RADIANCE SPECTRA

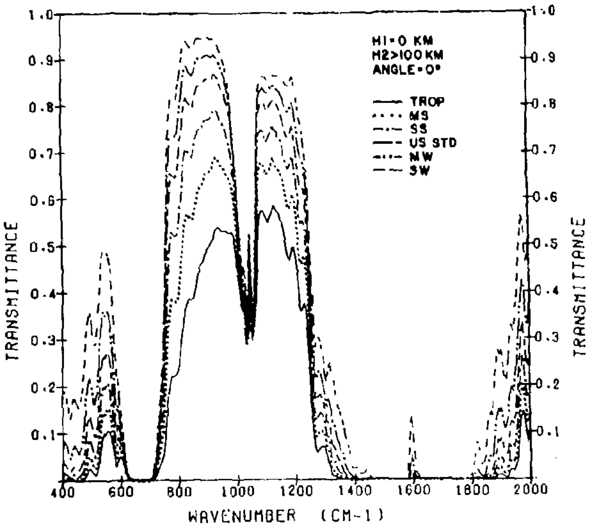
Some examples of transmittance and radiance spectra obtained from LOWTRAN 5 are presented in Figures 28 through 41. Figures 28 to 30 show the variations in transmittance and radiance with the six model atmospheres for three atmospheric paths. The rural aerosol model, with a 23-km VIS, was used for the boundary layer, and the default aerosol models for the rest of the atmosphere. The spectral regions shown are between 400 and 2000 cm^{-1} and between 2000 and 3600 cm^{-1}.

Figures 31 to 38 show the variation in transmittance and radiance with atmospheric slant path for the U.S. Standard model atmosphere and the rural, 23-km VIS, aerosol model for the spectral region between 400 and 4000 cm^{-1}. These figures show the range of observer altitudes, zenith angles, and atmospheric slant paths to which the code can be applied to model transmittance and radiance for specific atmospheric problems.

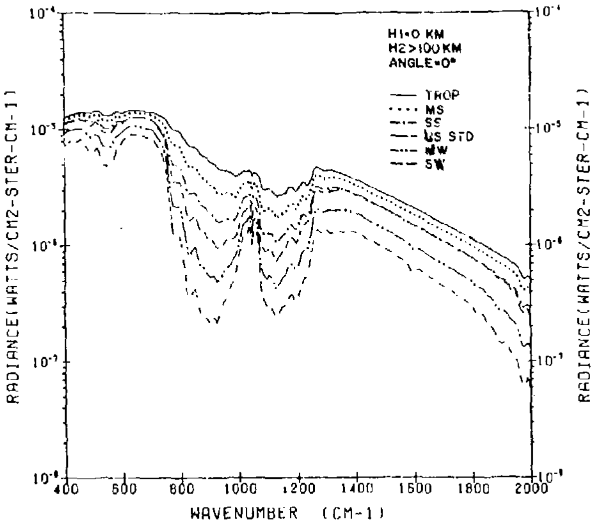
Figure 39 shows the transmittance from ground to space from 0.25 to 4 μm. This calculation used the U.S. Standard model atmosphere and the rural aerosol model with a 23-km VIS.

Figure 40 shows the variation in transmittance in the spectral region between 400 and 4000 cm^{-1} for the rural, maritime, urban, and tropospheric aerosol models. The calculation is for a 10-km horizontal sea-level path using the U.S Standard model atmosphere and a 23-km VIS.

Figure 41 shows the transmittance of the two fog models in LOWTRAN for a 0.2-km horizontal sea-level path and a 1-km VIS in the spectral regions from 400 to 4000 cm^{-1}.

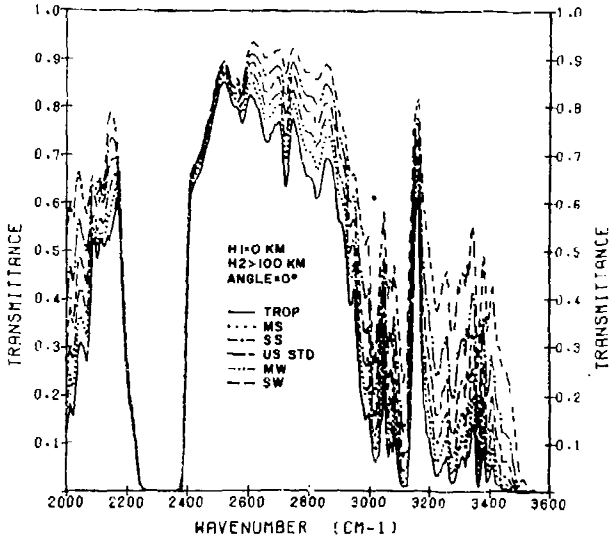


a. transmittance, from 400 to 2000 cm^{-1}

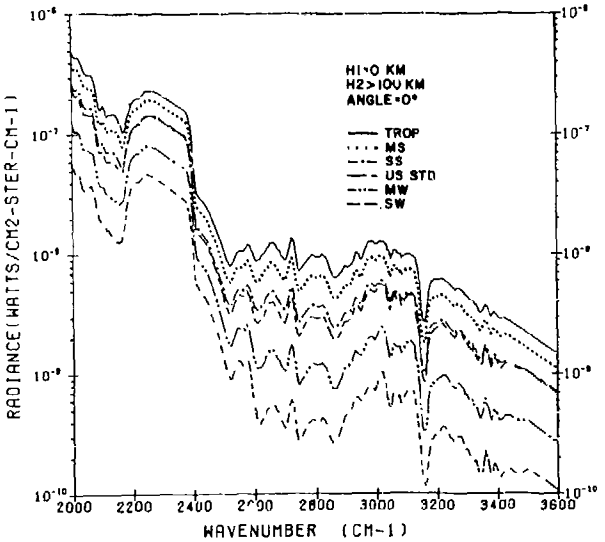


b. radiance, from 400 to 2000 cm^{-1}

Figure 28. Transmittance and Radiance Spectra for a Vertical Path Looking to Space From the Ground ($H1 = 0$, $H2 \geq 100$ km, ANGLE = 0°), with the Rural Aerosol Model (IHAZE = 1, VIS = 23 km), and for the Six Model Atmospheres

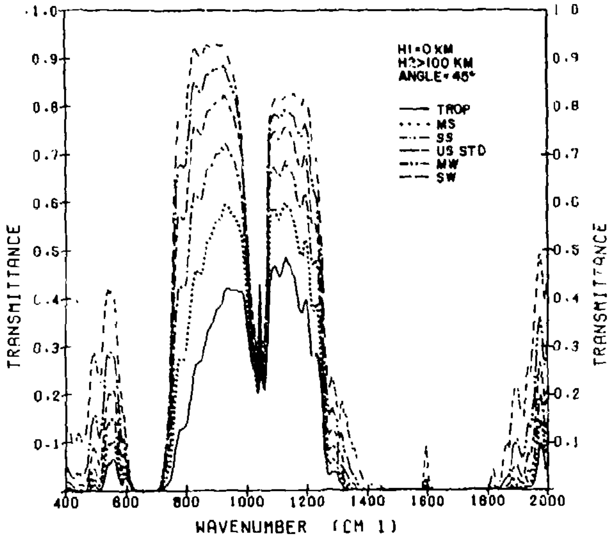


c. transmittance, from 2000 to 3600 cm^{-1}

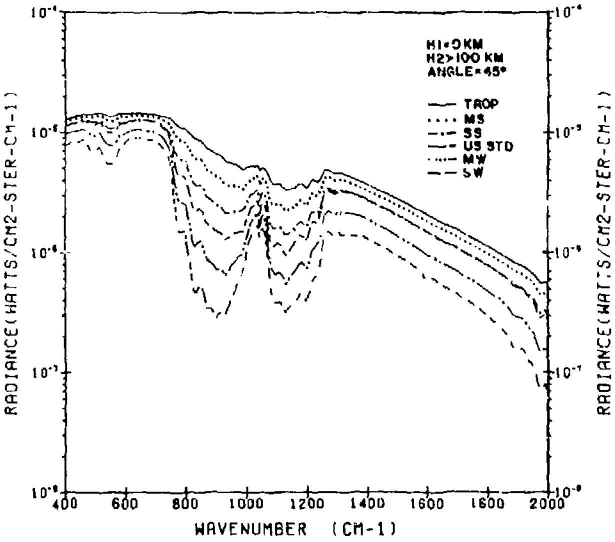


d. radiance, from 2000 to 3600 cm^{-1}

Figure 28. Transmittance and Radiance Spectra for a Vertical Path Looking to Space From the Ground (H1 = 0, H2 $\geq$ 100 km, ANGLE = 0°), with the Rural Aerosol Model (IHAZE = 1, VIS = 23 km), and for the Six Model Atmospheres (Cont.)

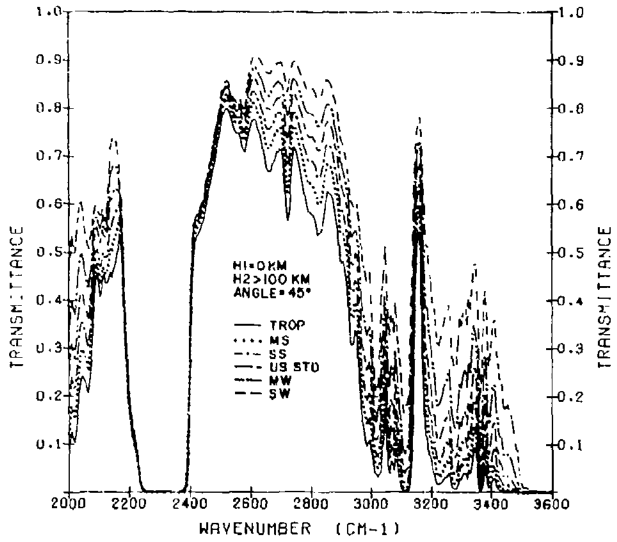


a. transmittance, from 400 to 2000 cm^{-1}

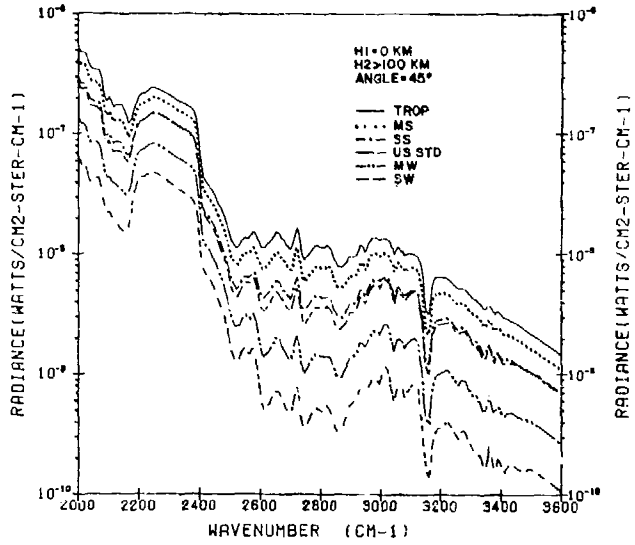


b. radiance, from 400 to 2000 cm^{-1}

Figure 29. Transmittance and Radiance Spectra for a Slant Path at 45° Looking to Space From the Ground (H1 = 0, H2 $\geq$ 100 km, ANGLE = 45°) with the Rural Aerosol Model (IHAZE = 1, VIS = 23 km), and for the Six Model Atmospheres

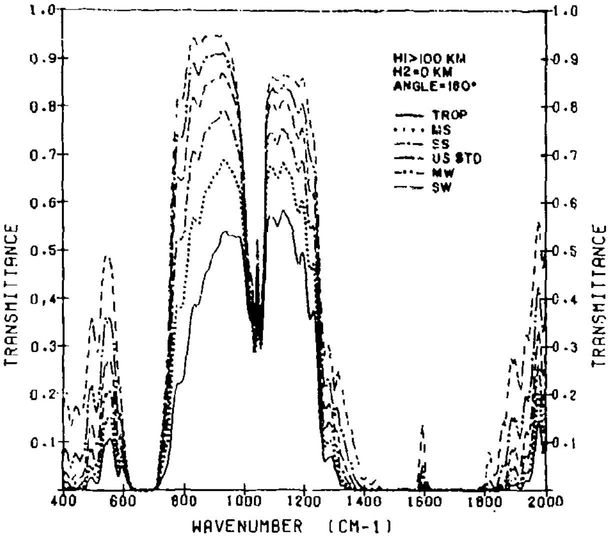


c. transmittance, from 2000 to 3600 cm^{-1}

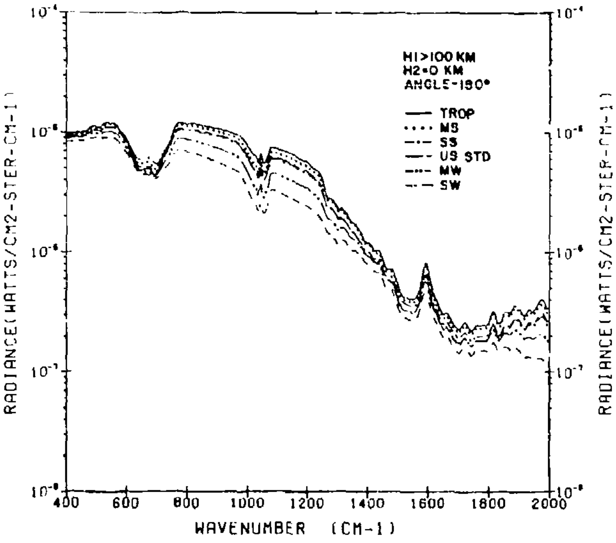


d. radiance, from 2000 to 3600 cm^{-1}

Figure 29. Transmittance and Radiance Spectra for a Slant Path at 45° Looking to Space From the Ground (H1 = 0, H2 ≥ 100 km, ANGLE = 45°) with the Rural Aerosol Model (IHAZE = 1, VIS = 23 km), and for the Six Model Atmospheres (Cont.)

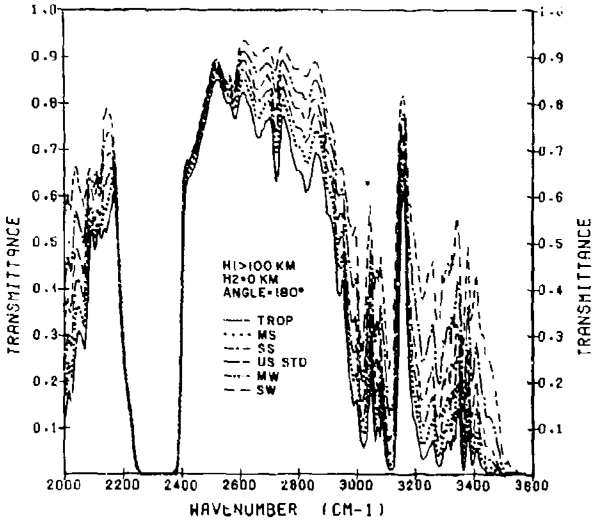


a. transmittance from 400 to 2000 cm^{-1}

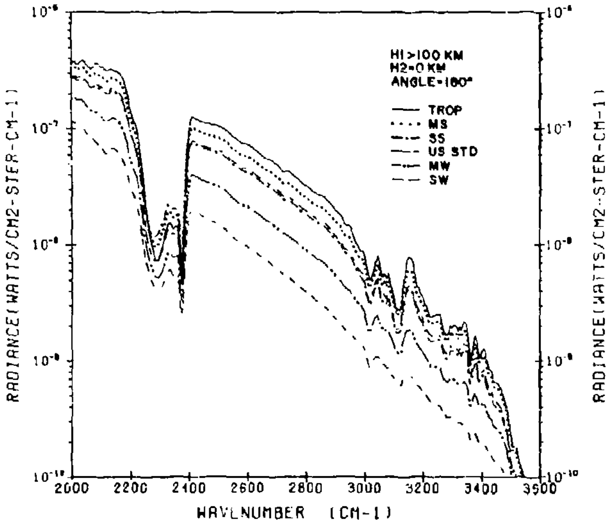


b. radiance from 400 to 2000 cm^{-1}

Figure 30. Transmittance and Radiance Spectra for a Vertical Path Looking at the Ground From Space (H1 ≥ 100 km, H2 = 0, ANGLE = 180°) With the Rural Aerosol Model (IHAZE = 1, VIS = 23 km) and for the Six Model Atmospheres



c. transmittance from 2000 to 3600 cm^{-1}



d. radiance from 2000 to 3600 cm^{-1}

Figure 30. Transmittance and Radiance Spectra for a Vertical Path Looking at the Ground From Space ($H1 \geq 100$ km, $H2 = 0$, $ANGLE = 180^{\circ}$) With the Rural Aerosol Model (IHAZE = 1, VIS = 23 km) and for the Six Model Atmospheres (Cont.)

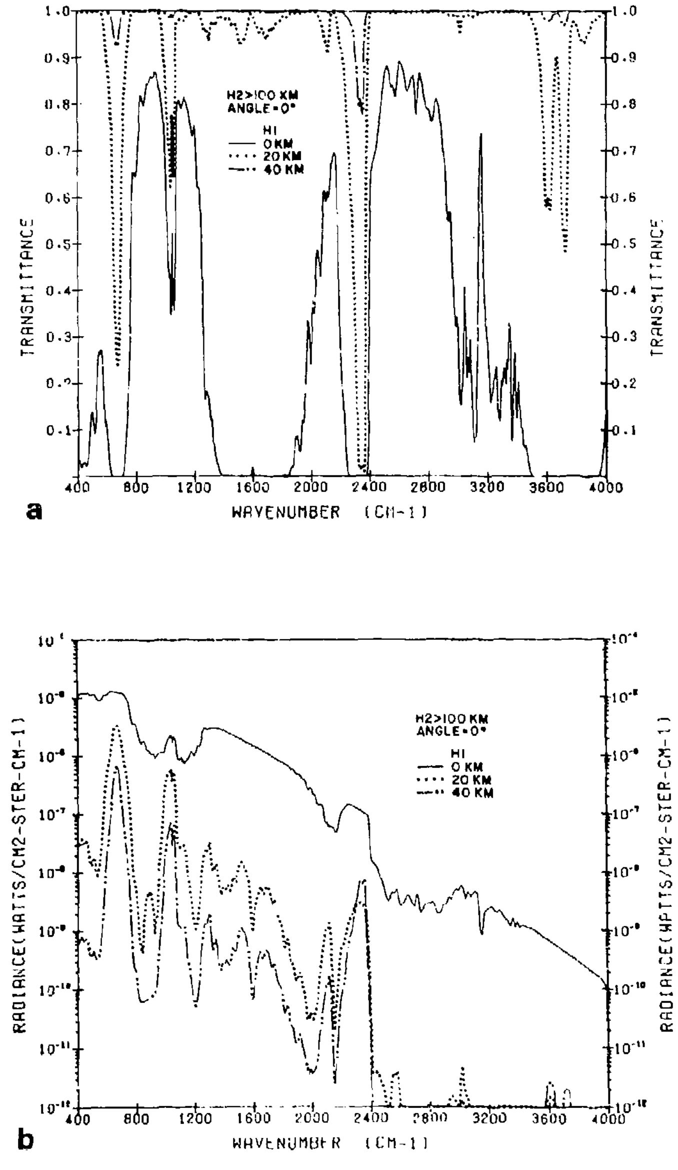


Figure 31. Transmittance and Radiance Spectra for a Vertical Path Looking to Space From H1 (H1 = 0, 20 km, 40 km, H2 ≥ 100 km, ANGLE = 0°) the Rural Aerosol Model (IHAZE = 1, VIS = 23 km) and the U.S. Standard Atmosphere (MODEL = 6), From 400 to 4000 cm^{-1}: a. transmittance, b. radiance

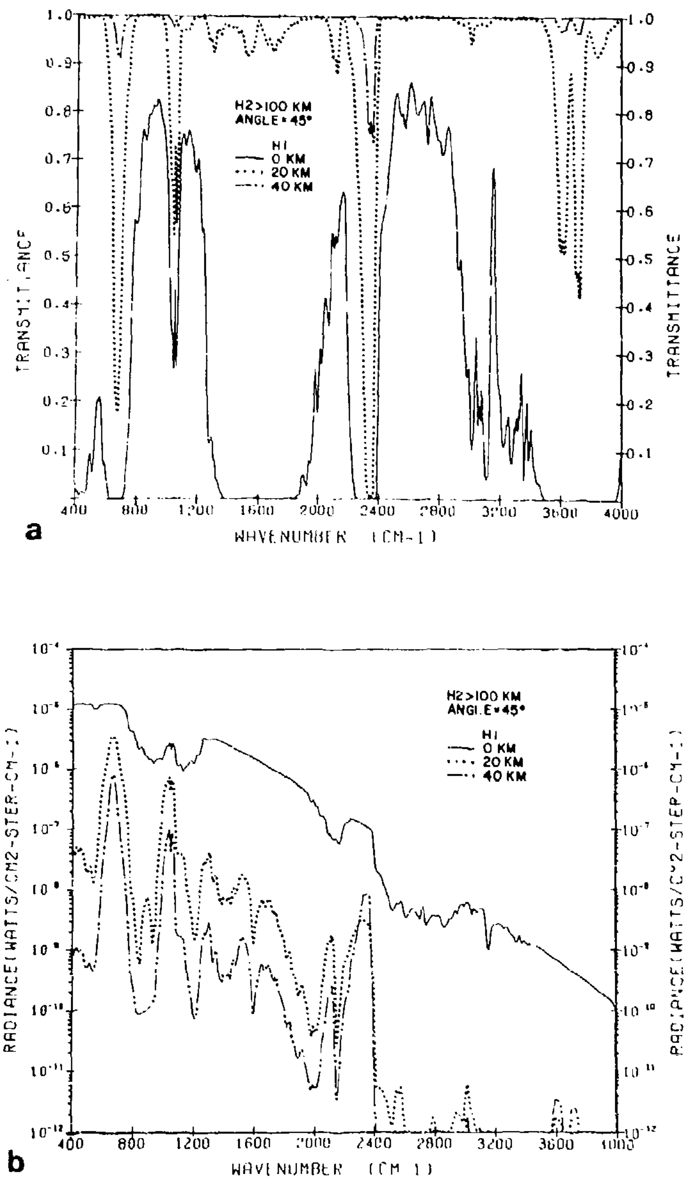


Figure 32. Transmittance and Radiance Spectra for a Slant Path at 45° Looking to Space From H1 (H1 = 0, 20 km, 40 km, ANGLE = 45°) With the Rural Aerosol Model (IHAZE = 1, VIS = 23 km) and the U.S. Standard Atmosphere (MODEL = 6) From 400 to 4000 cm^{-1}: a. transmittance, b. radiance

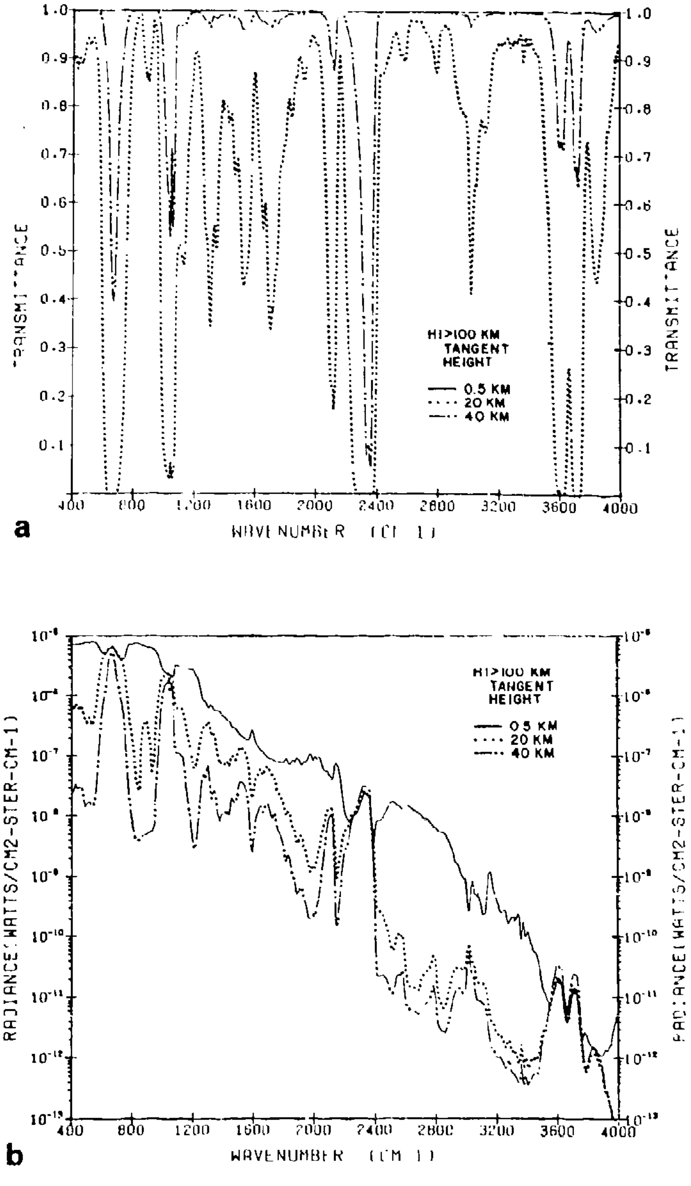


Figure 33. Transmittance and Radiance Spectra for a Slant Path Looking From Space to Space Through a Tangent Height of HMIN (ITYPE = 3, H1 ≥ 100 km, HMIN = 0.5 km, 20 km, 40 km) With the Rural Aerosol Model (IHAZE = 1, VIS = 23 km) and the U.S. Standard Atmosphere, From 400 to 4000 cm^{-1}:
a. transmittance (for HMIN = 0.5 km, the transmittance is ~ zero between 400 and 4000 cm^{-1}),
b. radiance

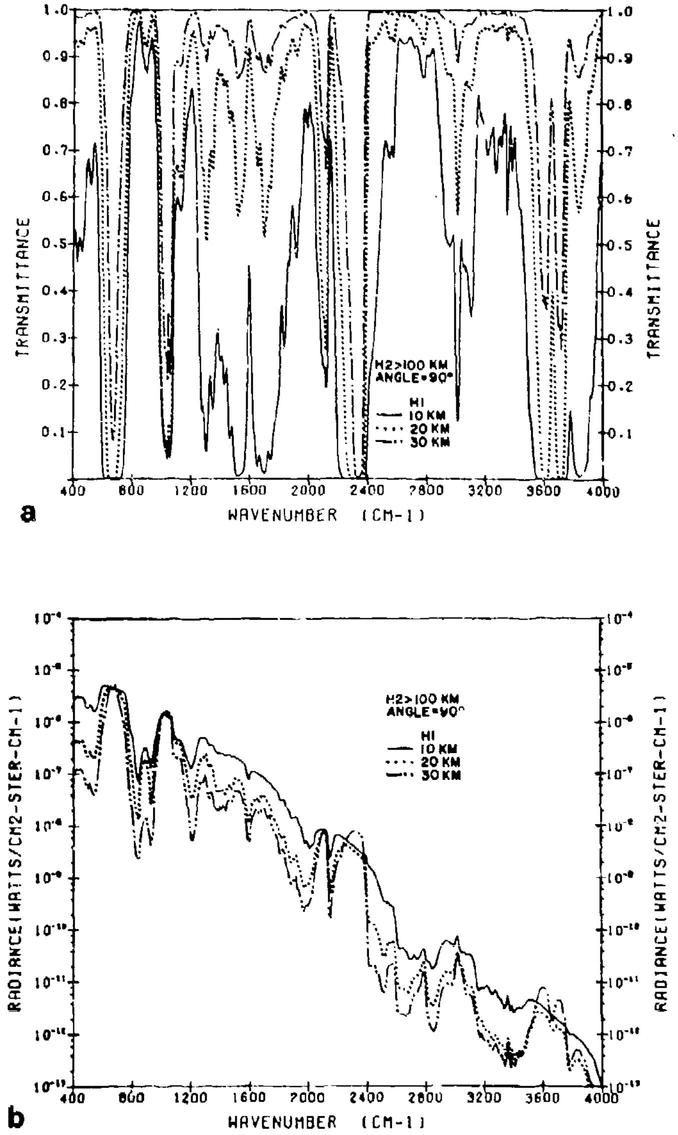


Figure 34. Transmittance and Radiance Spectra for a Slant Path Looking to Space From a Tangent Height of H1 (ITYPE = 3, H1 = 10, 20, 30 km, ANGLE = 90°) With the Rural Aerosol Model (IHAZE = 1, VIS = 23 km) and the U.S. Standard Atmosphere (MODEL = 6); From 400 to 4000 cm^{-1}: a. transmittance, b. radiance

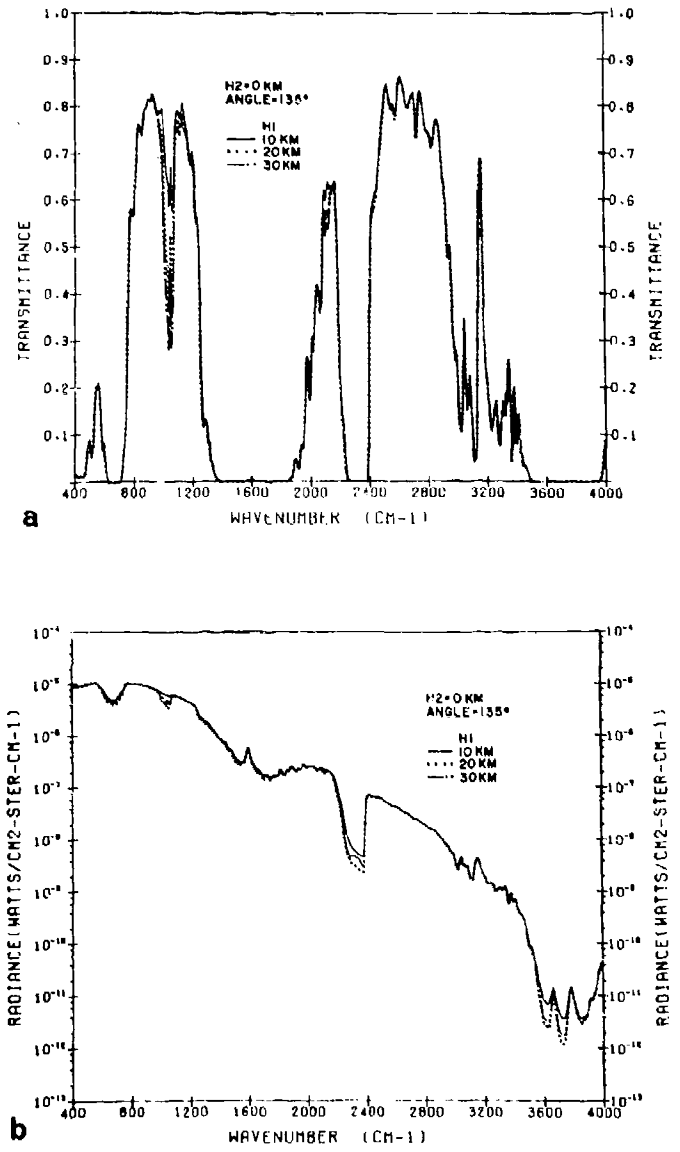


Figure 35. Transmittance and Radiance Spectra for a Slant Path Looking to the Ground From H1 (H1 = 10, 20, 30 km, H2 = 0 km, ANGLE = 135°) With the Rural Aerosol Model (IHAZE = 1, VIS = 23 km) and the U.S. Standard Atmosphere (MODEL = 6), From 400 to 4000 cm^{-1}: a. transmittance, b. radiance

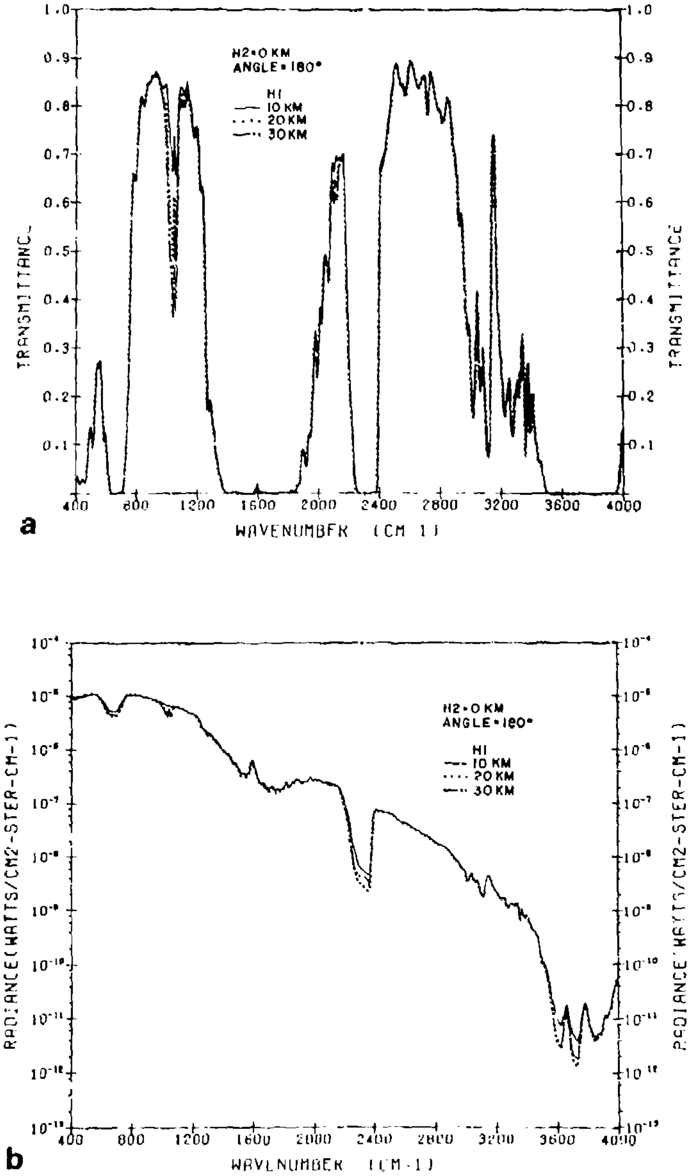


Figure 36. Transmittance and Radiance Spectra for a Vertical Path Looking at the Ground From H1 (H1 = 10, 20, 30 km, ANGLE = 180°) With the Rural Aerosol Model (IHAZE = 1, VIS = 23 km) and the U.S. Standard Atmosphere (MODEL = 6) From 400 to 4000 cm^{-1}: a. transmittance, b. radiance

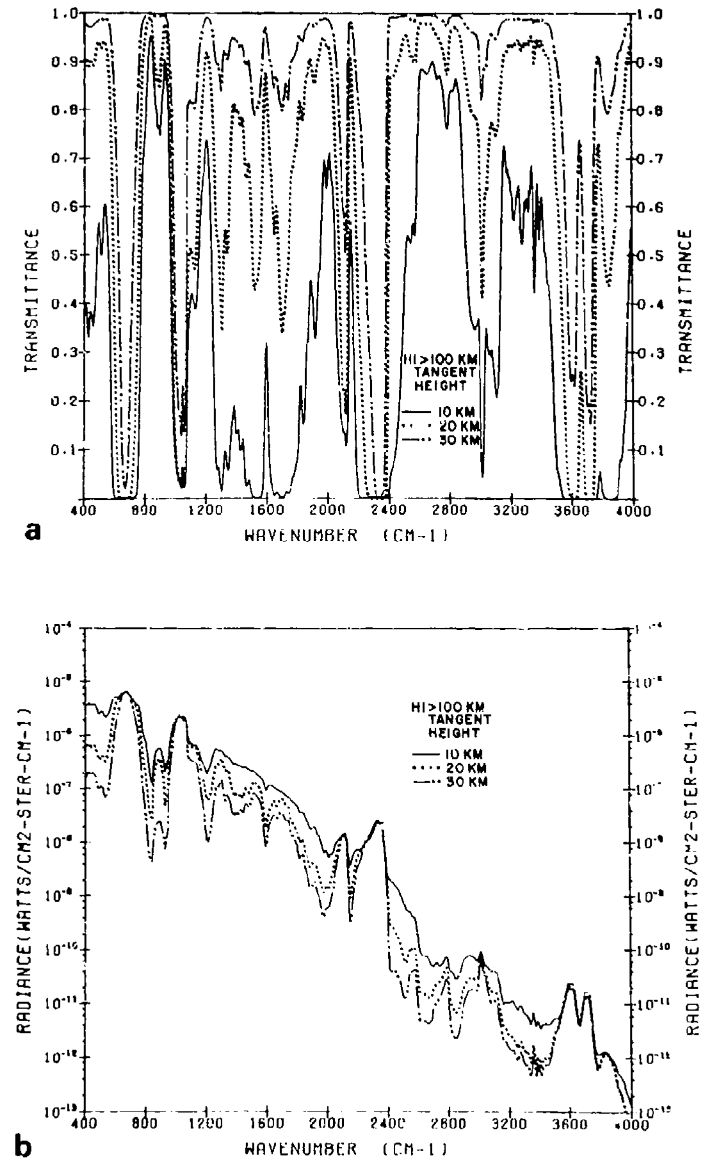


Figure 37. Transmittance and Radiance Spectra for a Slant Path From Space to Space Through a Tangent Height HMIN (ITYPE = 3, H1 ≥ 100 km, HMIN = 10, 20, 30 km) With the Rural Aerosol Model (IHAZE = 1, VIS = 23 km) and the U.S. Standard Atmosphere (MODEL = 6) From 400 to 4000 cm^{-1}: a. transmittance, b. radiance

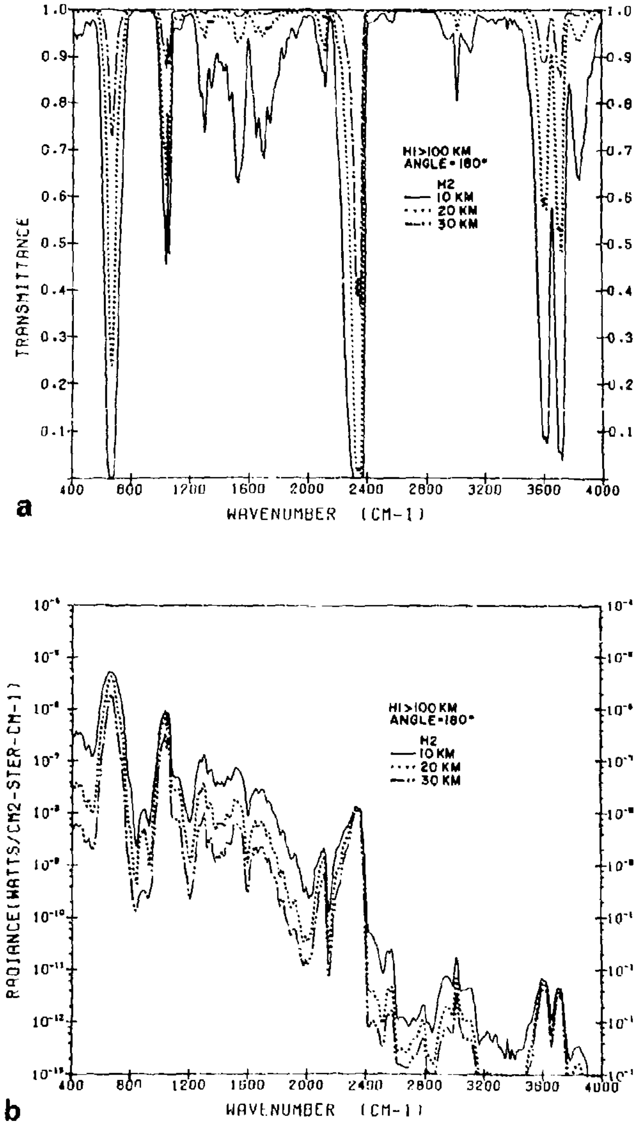


Figure 38. Transmittance and Radiance Spectra for a Vertical Path Looking From Space to H2 (H1 > 100 km, H2 = 10, 20, 30 km, ANGLE = 180°) With the Rural Aerosol Model (IHAZE = 1, VIS = 23 km) and the U.S. Standard Atmosphere (MODEL = 6) From 400 to 4000 cm^{-1}: a. transmittance, b. radiance (atmospheric radiance only, assuming no boundaries)

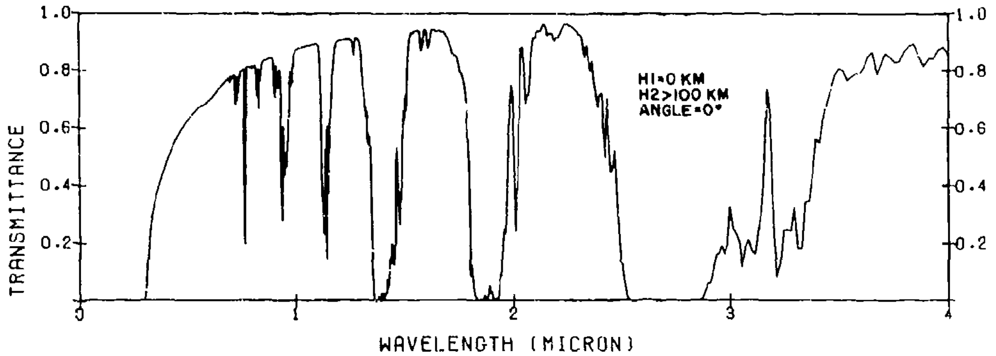


Figure 39. Transmittance Spectra for a Vertical Path From Ground to Space From 0.25 to 4 μ, Using the Rural Aerosol Model, 23-km VIS and the U.S. Standard Model Atmosphere

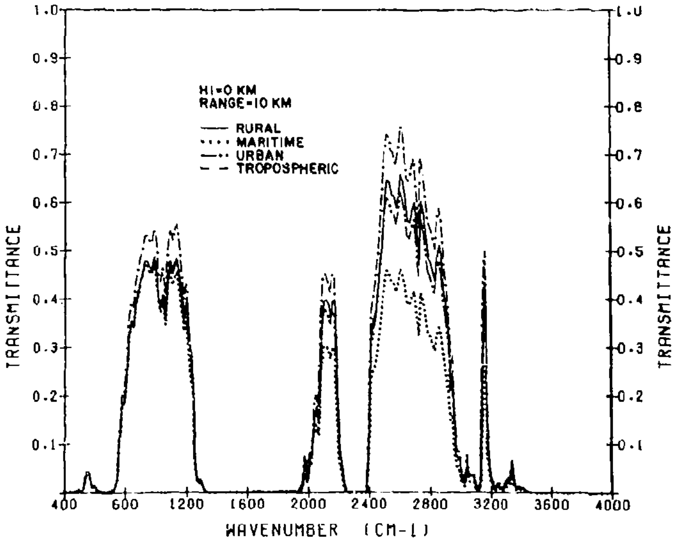


Figure 40. Transmittance Spectra for a 10-km Horizontal Path at Sea Level for the Rural, Maritime, Urban, and Tropospheric Aerosol Models Using the U.S. Standard Model Atmosphere and a VIS of 23 km

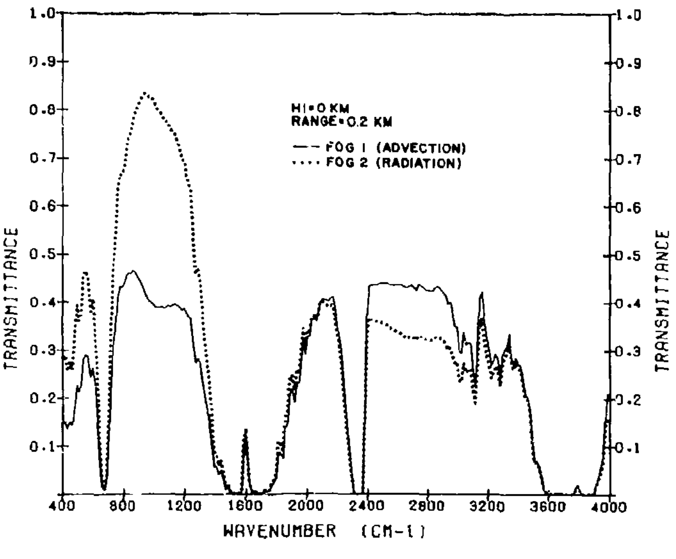


Figure 41. Transmittance Spectra for the Advection Fog (Fog 1) and the Radiation Fog (Fog 2) Models, for a 0.2-km Horizontal Path at Sea Level, With the U.S. Standard Model Atmosphere and a 1-km VIS, From 400 to 4000 cm^{-1}

11. AEROSOL MODEL COMPARISON WITH MEASUREMENTS

Between January and September 1970, EMI Ltd. made a series of measurements of infrared transmittance at various wavelengths over the sea.[80, 81] Under the conditions of the setup, the experiment was largely a measurement of aerosol extinction and it provides a data set against which the LOWTRAN maritime aerosol model can be tested. This section will review these measurements briefly and compare them with LOWTRAN calculations.

11.1 Measurements

The EMI measurements were made over a 20-km path across Mounts Bay at the southwestern tip of England. Most of the path was several kilometers offshore. The source for the transmittance measurements was a 3800-K carbon arc blackbody while the receiver was a Golay cell mounted at the focus of a 76-cm diameter

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[80] Arnold, D.H., Lake, D.B., and Sanders, R. (1970) Comparative Measurements of Infrared Transmission Over a Long Overseas Path, EMI Report DMP 3736.

[81] Arnold, D.H. and Sanders, R. (1971) Comparative Measurements of Infrared Transmission Over A Long Overseas Path, EMI Report DMP 3858.

mirror. Various filters could be placed in front of the detector. In this report, data will be presented on three filters: their filter response functions are shown in Figure 42.

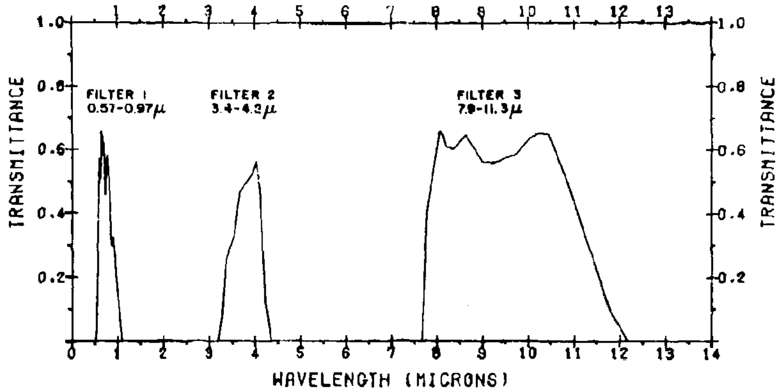

Figure 42. System Response Functions for Three of the Filters From the EMI Measurements: 1. 0.57 to 0.97 μ; 2. 3.5 to 4.2 μ; 3. 7.9 to 11.3 μ

In addition to the transmittance, other physical parameters were measured at one end of the path, including: air temperature, relative humidity (from a wet and dry bulb thermometer), wind speed (estimated according to the Beaufort scale), wind direction, and visibility (estimated by an observer viewing six landmarks around Mounts Bay). A block of data consisted of the measurement of these physical parameters plus the detector response for each of the filters consecutively.

11.2 Calibration

The measurements were calibrated by selecting one particular data block with the highest (relative) measured transmittance for the 7.9- to 11.3-μ filter: for this case the absolute transmittance was calculated using the data from Altshuler.[82] Comparing the absolute calculated value of the transmittance with the relative measured value allowed the baseline for this filter to be set. The system response for the other filters relative to the 7.9- to 11.3-μ filter was also measured over a short path with negligible attenuation. From the absolute transmittance for the 7.9- to 11.3-μ filter and the relative responses of the other filters, the baselines for the other filters could be set.

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82. Altshuler, T.L. (1961) Infrared Transmission and Background Radiation by Clear Atmospheres, GE Report 61SD 199, AD401923.

The data are actually presented as "effective atmospheric extinction coefficients" σ which are related to the filter-averaged transmittance $\overline{T}$ by

$$\sigma = -(\ln \overline{T})/L \tag{32}$$

where L is the path length; in this case 20 km. (Note that σ is merely the log of the transmittance and is not comparable to a band model extinction coefficient. Since the transmittances span four orders of magnitude, it is necessary to present the data on a log scale.) As will be seen later, the quality of the calibration appears to be good.

11.3 LOWTRAN Calculations

To compare with the measured transmittances, the equivalent filter-weighted transmittance for each data block was calculated using LOWTRAN 5. The required inputs to LOWTRAN were given by the path length (20.0 km) the pressure (assumed to be 1013.25 mb), and the measured temperature and relative humidity. The inputs relating to the aerosol extinction are the aerosol model and the meteorological range. For most calculations the maritime aerosol model was used. However, the observer-estimated value of visual range reported in the data was found to be inaccurate and unrepresentative of the conditions along the path.

To circumvent this problem with the observer estimated visibility, it was decided to use the measured value of the extinction for filter 1 (0.57-0.97 μ) to derive a value for the meteorological range. The meteorological range, VIS, is defined as the path length over which the transmittance at 0.55 μ is 0.02. From this definition and from Beer's law

$$\text{VIS} = \frac{3.912}{\sigma(0.55)} \tag{33}$$

where σ (0.55) is the total extinction coefficient at 0.55 μ and 3.912 = ln (0.02). (See footnote on page 22, Section 3.2.)

In the spectral region from 0.57 μ to 0.97 μ, the extinction coefficient is dominated by the aerosol extinction coefficient which in LOWTRAN depends only upon the wavelength, VIS, and to a lesser extent, the relative humidity. Neglecting the relative humidity dependence for now, if $\sigma_1{}^*$ is the calculated mean filter-weighted aerosol extinction coefficient for filter 1, then $\sigma_1{}^* = \sigma\,(0.55)\,B$, where B is a constant. One can then write

$$\text{VIS} = \frac{3.912 \times B}{\sigma_1{}^*} \tag{34}$$

Now between 0.57 and 0.97 μ, the aerosol extinction coefficient varies slowly with wavelength, especially for the maritime aerosol model (see Figure 10a). For this reason we can approximate $\sigma_1{*}$ by the measured effective atmospheric extinction coefficient σ_1 (Eq. (32)) even though the spectral weighting is different for the two quantities. Therefore, to the degree of approximation noted above, one can write

$$\text{VIS} = 3.912 \times B/\sigma_1$$

In practice, the constant B was determined empirically by assuming an initial value of B and calculating the "effective extinction coefficient" (that is, $-L^{-1} \ln \overline{T}_1$, where $\overline{T}_1$ is mean transmittance for filter 1 calculated by LOWTRAN) for each case in the data set. B was then adjusted until the mean of this value averaged over the sample equalled the mean of the measured values σ_1.

11.4 Results of the Comparison

This section will present the results of the comparison of the measured and calculated extinctions for various subsets of the measured data. In the figures to be presented, the axes will represent the "effective extinction coefficient", that is, $(-\ln \overline{T})/L$, where $\overline{T}$ is the filter-weighted mean transmittance over the path length $L = 20$ km. The solid line in each figure is a 45° line through the origin while the dashed line is a least-squares fit of the calculated extinctions to the measured ones. Note that since both the measured and the calculated extinctions contain errors, simple least-squares theory is not strictly applicable in this case.

Figure 43 shows the calculated vs the measured effective extinction coefficient for the 7.9- to 11.3-μ filter for the 50 cases of highest meteorological range (that is, the lowest extinction in filter 1). The maritime aerosol model was used in the calculations; however, due to the combination of the spectral region and the high visibility, the maximum calculated aerosol extinction in these cases is less than 0.02 km^{-1}. This graph then is primarily a demonstration of molecular extinction.

The regression line gives an indication of the quality of fit. The fact that the y-intercept is nearly zero indicates that the calibration of the measurements is good while the slope of the line of 1.09 indicates that the average fit is within 10 percent. The standard deviation about the regression line is 0.016 km^{-1}; the random uncertainty between the measured and the calculated extinctions can be taken as plus or minus two standard deviations or ± 0.032 km^{-1}. The mean transmittance for this set of points is about 0.09. For the level of transmittance, the uncertainty in the "effective extinction coefficient" of ± 0.032 km^{-1} translates to an uncertainty in the transmittance of about ± 0.06.

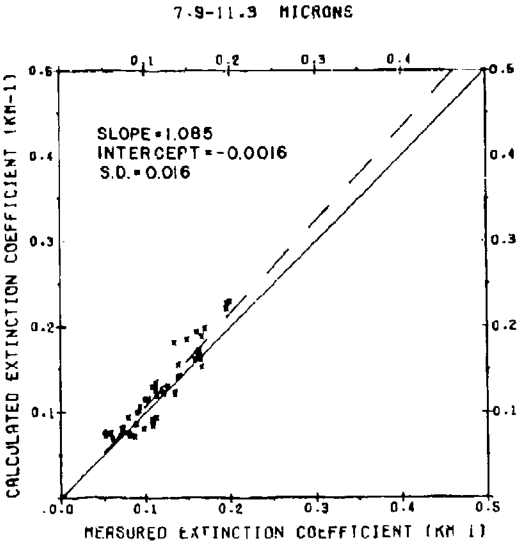

Figure 43. Comparison of the Calculated vs the Measured "Effective Extinction Coefficients" for the 7.9- to 11.3-μ Filter for the 50 Cases of Highest VIS, Using the Maritime Aerosol Model. The dashed line is a simple least-squares fit of the calculated to the measured data: the slope, the intercept and the standard deviation about the regression line are given

Since the calibration error appears to be negligible, all further regression lines will be constrained to pass through the origin.

The maritime aerosol model is designed to be representative of moderate wind speed conditions over the open ocean. To test the validity of this model, those cases for which the wind was off the ocean and between 6 and 17 m/sec (Beaufort scale 4 to 7) were selected. The results for this subset of the data for the 3.4 to 4.2 μ and for the 7.9- to 11.3-μ filters are shown in Figures 44a and b. In both cases, slope of the regression line is not significantly different from 1, indicating a good average fit between the calculated and the measured extinctions. Also, the standard deviations about the regression lines are not significantly greater than that in Figure 43, indicating the same level of random error.

To demonstrate the results when an inappropriate aerosol model is used, the subset of the cases for which the wind was offshore was chosen and the LOWTRAN transmittances were calculated, again using the maritime aerosol model. The results for the 3.4- to 4.2-μ and the 7.9- to 11.3-μ filters are shown in Figures 45a and b. In Figure 45a the calculated extinctions in the 4-μ region are clearly

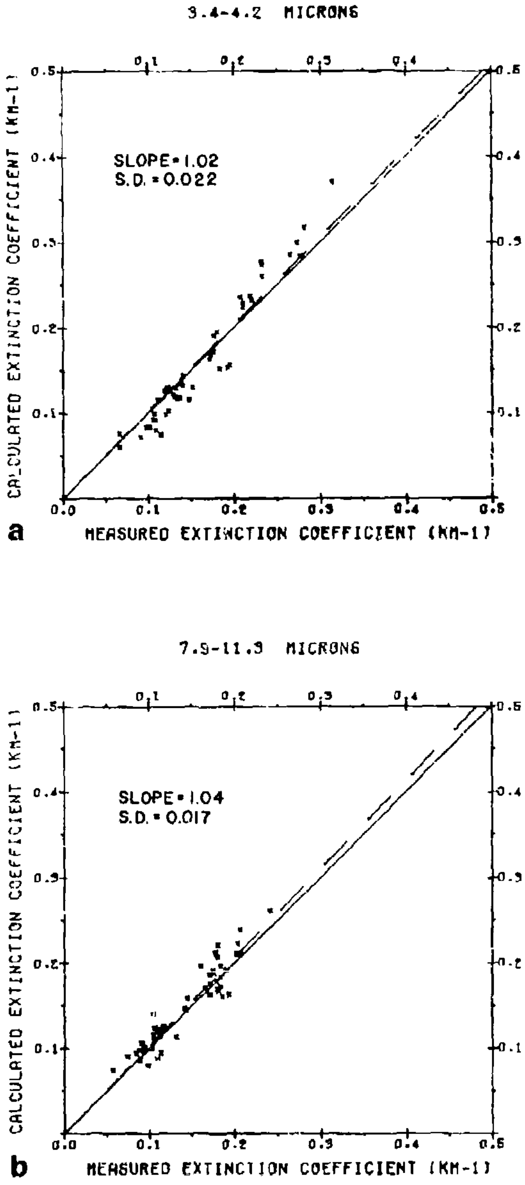

Figure 44. Calculated vs the Measured "Effective Extinction Coefficients" for the Cases of Onshore Winds of Moderate Intensity, Using the Maritime Aerosol Model: a. 3.4 to 4.2 μ, b. 7.9 to 11.3 μ. The dashed line is a simple least-squares fit through the origin of the calculated to the measured data

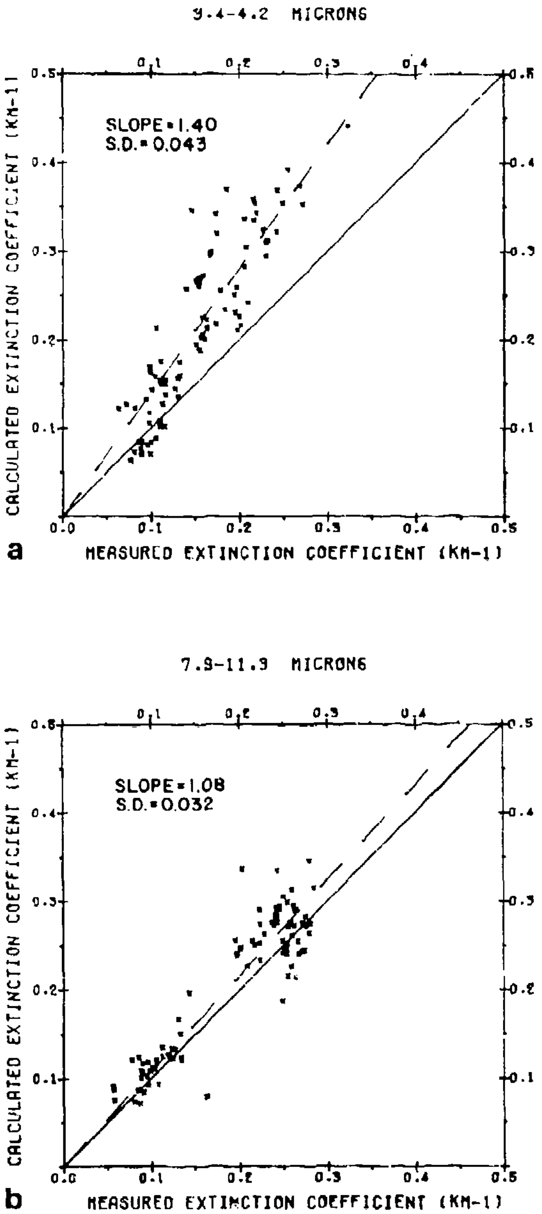

Figure 45. Calculated vs Measured "Effective Extinction Coefficients" for the Cases of Offshore Winds, Using the Maritime Aerosol Model: a. 3.4 to 4.2 μ, b. 7.9 to 11.3 μ

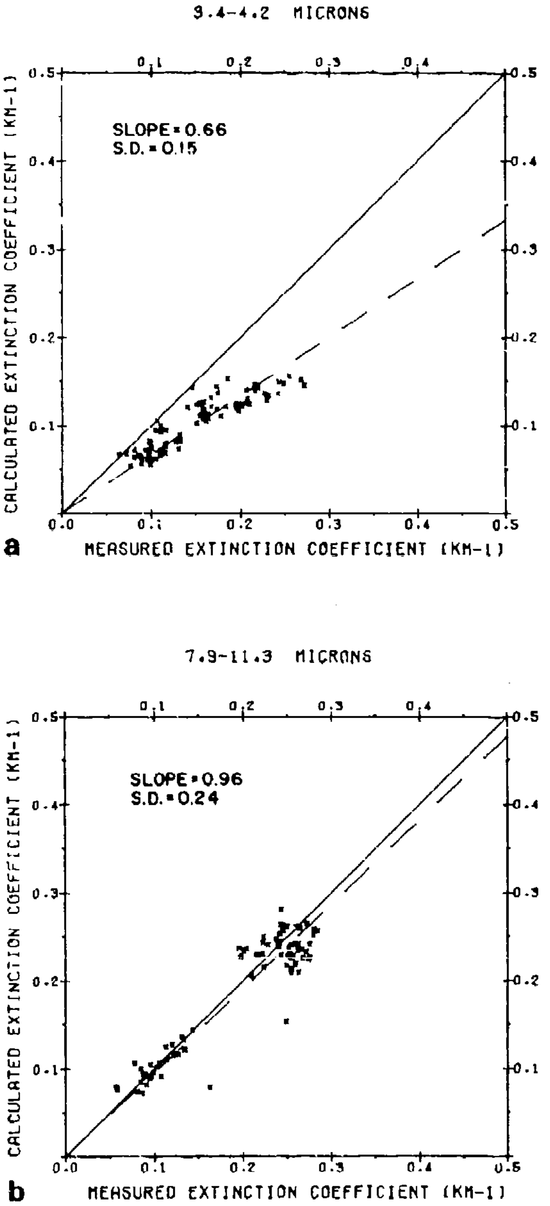

Figure 46. Calculated vs Measured "Effective Extinction Coefficients" for the Cases of Offshore Winds, Using the Rural Aerosol Model: a. 3.4 to 4.2 μ, b. 7.9 to 11.3 μ

too large, by almost a factor of 2 for the high extinction cases. For the 10-μ filter shown in Figure 45b, the slope of the regression line is only slightly greater than that in Figure 44b, where the proper aerosol model is used, and is the same as in Figure 43, where aerosol extinction is relatively unimportant. The scatter of points in both Figures 45a and b is double that in Figures 44a and b respectively.

Since the maritime aerosol model is inappropriate for these cases for which the wind blows off the land (at least for the shorter wavelengths), these cases were rerun using the rural aerosol model (and adjusting B in Eq. (34) so that LOWTRAN returns the same calculated extinction for filter 1 as was measured). These results are shown in Figures 46a and b. In Figure 46a, the calculated extinction in the 4-μ region are now too low, again by a factor of almost 2 in the high extinction cases. In Figure 46b, the slope of the regression line has been reduced to slightly less than 1.0, but it is still not significantly different from 1.0. The scatter of these points using the rural model is less than those using the maritime model in about the same proportions as the reduction of the slopes of the regression lines.

The conclusions that can be drawn from these data are as follows: in the 4-μ region, the maritime aerosol model provides a reasonably accurate description of open ocean, moderate wind-speed conditions. For air masses originating over land, the maritime model gives far too much extinction. The rural model is not appropriate for the offshore wind cases either, probably because as the wind blows over the short stretch of water it generates sea spray and picks up some marine-type aerosols. For the cases of offshore winds the most appropriate model is some average of the maritime and the rural models.

In the 10-μ region, aerosol extinction is less important than in the 4-μ region, so that the choice of the aerosol model is less critical. Again the maritime model gives an accurate description of an open ocean, moderate wind-speed condition. However, even in situations where an inappropriate aerosol model is used, the results may not be greatly in error.

12. SENSITIVITY TO METEOROLOGICAL INPUT PARAMETERS

In this section, an example of variations in transmittance, calculated from the LOWTRAN model, due to uncertainties in meteorological input parameters is presented. It is given to illustrate one method of determining the sensitivity of the program to meteorological conditions, which could be applied by LOWTRAN users to a specific atmospheric problem. A more definitive study in this area, using a similar approach for electro-optical systems application, has been carried out by Snyder[83] of the Naval Oceans Systems Center.

In general, the transmittance, $\overline{\tau}_k$, calculated from LOWTRAN for an atmospheric path at a given wavenumber, ν_k, depends on an array of meteorological input parameters, x_i.

$$\overline{\tau}_k = \overline{\tau}(x_1, \ldots, x_i, \ldots, x_N, \nu_k) \tag{35}$$

The N-parameters, x_i, correspond to temperature, pressure, molecular absorber amounts, aerosol type and amounts, meteorological range, path length, etc.

Assuming that the variations in the input parameters, Δx_i, are completely independent, the variation in the total transmittance can be written as

$$\Delta\overline{\tau}_k = \pm \left[\sum_{i=1}^{N} \left(\frac{\partial \overline{\tau}_k}{\partial x_i} \right)^2 (\Delta x_i)^2 \right]^{1/2} . \tag{36}$$

Equation (36) defines the rms variation in total transmittance at the wavenumber, ν_k, for independent variations in the meteorological input parameters. It does not include LOWTRAN model uncertainties such as the band model approximation for molecular absorption or the assumption of homogeneous layering of the atmosphere, with thermal equilibrium in each layer.

Since the transmittance is usually a highly non-linear function of the input parameters, the partial derivatives, $(\partial\overline{\tau}_k/\partial x_i)$, of the transmittance in Eq. (36) must be calculated numerically, starting from a given set of input conditions and a specific atmospheric path. The atmospheric case chosen for this example is a horizontal path of 2 km at sea level, with a meteorological range of 4 km for the rural aerosol model, and the 1962 U.S. Standard atmospheric model. The transmittance for this case from 500 to 3000 cm^{-1} is shown in Figure 47.

The partial derivatives of the transmittance were calculated from this set of starting conditions by successive runs of LOWTRAN in which the various meteorological parameters were varied one at a time between 500 and 3000 cm^{-1}. The partial derivatives of the transmittance were stored in an (NxM) matrix, where N is the number of meteorological parameters varied and M the number of wavenumber points. Figure 48 shows the partial derivative of the transmittance with respect to the water vapor density for this path and Figure 49 the derivative in transmittance with respect to meteorological range.

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[83] Snyder, F. P. (1978) The Effects of Meteorological Uncertainties on Electro-Optical Transmittance Calculations, Naval Oceans Systems Center, San Diego, California, NOSC-TN-440.

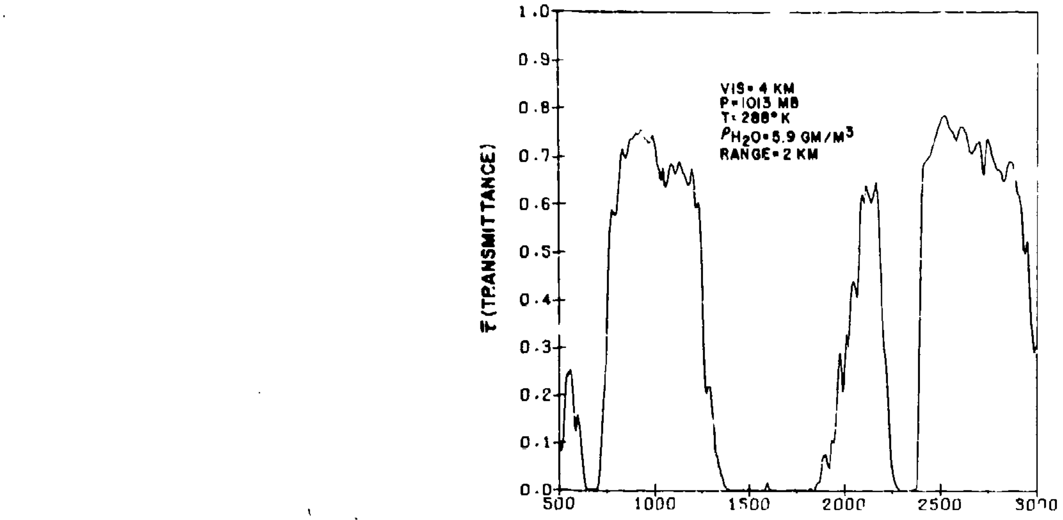

Figure 47. Total Transmittance vs Wavenumber for a 2-km Path at Sea Level With the U.S. Standard Atmosphere Model and a VIS of 4 km for the Rural Aerosol Model

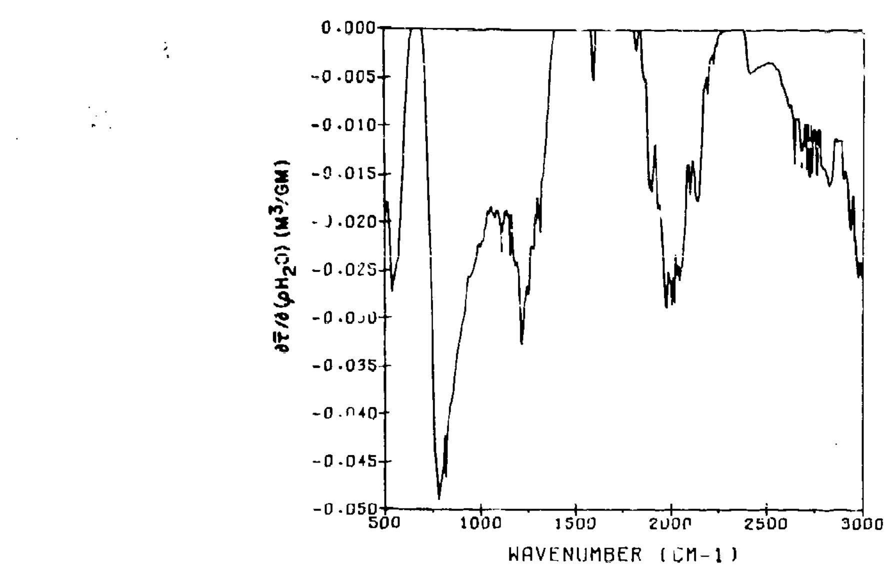

Figure 48. Partial Derivative of the Total Transmittance for the Case in Figure 47 With Respect to the Water Vapor Density

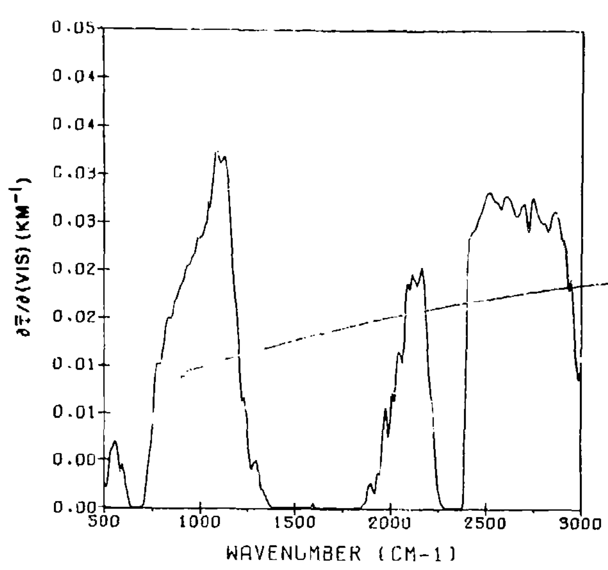

Figure 49. Partial Derivative of the Total Transmittance for the Case in Figure 47 With Respect to VIS

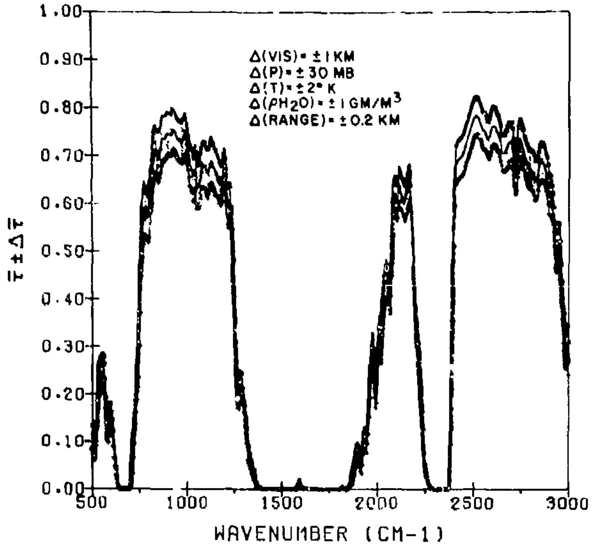

Figure 50. Total Transmittance for the Case in Figure 47 Plus and Minus the RMS Deviation for the Variation in the Meteorological Input Parameters Shown on the Figure

The variation in the total transmittance is shown in Figure 50. Uncertainties in five input parameters (pressure, temperature, meteorological range, water-vapor density, and path length) were assumed for this atmospheric path. For the values used, transmittances varied by approximately ±5 percent in the window regions (1000 and 2500 cm^{-1}).

13. COMMENTS

It should be remembered that the transmittance and radiance values obtained from LOWTRAN are at a spectral resolution of 20 cm^{-1}, although the output can be obtained at 5-cm^{-1} intervals.

The program will round off input frequencies to the nearest frequency at which spectral data are given.

The overall accuracy in transmittance, which this technique provides, is better than 10 percent. The largest errors may occur in the distant wings of strongly absorbing bands in regions which such bands overlap appreciably.

The reason for this error is twofold. First, the spectral curves in Figures 19 to 21, Section 5 are based on a single absorber parameter and cannot be defined for a wide range of atmospheric paths without some loss in accuracy.

Secondly, the transmittance in the window regions between strong bands generally lies in the weak-line approximation region, where the transmittance is a function of the quantity of absorber present and not of the product of absorber amount and pressure. The one-dimensional prediction scheme presented in this report is less accurate for such conditions. The digitized data were obtained for conditions representative of moderate atmospheric paths and will tend to overestimate the transmittance for very long paths and underestimate the transmittance for very short paths, in the spectral regions described above.

As the transmittance approaches 1.0, the percentage error in transmittance decreases toward zero but the uncertainty in the absorption (or radiance) increases.

Additional constraints on both the validity of the model as well as the range of applicability are introduced for atmospheric radiance calculations. As mentioned above the atmospheric radiance becomes less accurate for very short paths. In addition, the radiance calculations assume local thermodynamic equilibrium exists in each layer of the model atmospheres. This assumption will break down for radiance calculations in the upper atmosphere. Therefore, because of the limitations in the LOWTRAN model for short paths (or small absorber amounts) and deviations from thermal equilibrium (both conditions which occur in the upper atmosphere) it is recommended that the LOWTRAN radiance calculations be restricted to altitudes below 40 km.

For the shorter wavelengths (<5 μm), scattered solar radiation becomes an important source of background radiation. Since this is not included in the LOWTRAN model at the present time, radiance calculations at the shorter wavelengths with a sunlit atmosphere should be made with caution. A single scattering solar-radiance code (SPOT) for plane-parallel geometry has been developed by Lampley and Blattner.[84] This code uses LOWTRAN 4 for the atmospheric attenuation of the solar flux.

Because of the nature of the program — which uses a layered atmosphere — errors can be introduced into the refraction calculation, since we assume each layer to have a mean refractive index associated with it. This is particularly true for a long path in one layer near ground level where one would expect refraction to be a maximum; but in fact, for such a condition the program may indicate no refraction at all. If problems like these are encountered, the number of levels must be increased in the altitude region of interest.

An additional note should be made here on the calculation of transmittance. Although the code will calculate total transmittance for a given atmospheric path in either mode of program execution, the time is increased by a factor of N in the radiance mode, where N is the number of atmospheric layers along a given path.

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84. Lampley, C.M., and Blattner, W.G.M. (1978) E-O Sensor Signal Recognition Simulation: Computer Code Spot I, Atmospheric Sciences Laboratory, White Sands, NM, Report RRA-T7809.

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Appendix A

Listing of Program

A listing of the Fortran program LOWTRAN 5 (PROGRAM LOWEM) is given in Table A1 together with the 19 subroutines, as described in Section 7 and summarized in Table A2. A definition of symbols used in the main program is given in Appendix B. A segmented loader map of the LOWTRAN 5 code, from the AFGL CDC 6600, is listed in Appendix C. An additional subroutine (DRYSTR), used to generate "dry" stratospheric water vapor profiles is described in Appendix E.

Table A1. Listing of Fortran Code LOWTRAN 5

```
      PROGRAM LOWEM(INPUT=128,OUTPUT=128,TAPE6=OUTPUT,TAPE7=64)
C     ******************************************************************
C     LOWTRAN     1 NOV 79
C
*               AUTHORS
*               F.X.KNEIZYS
*               E. P. SHETTLE
*               L. W. ABREU
*               J. H. CHETWYND JR.
*               J.E.A. SELBY
*               W. O. GALLERY
*               R. W. FENN
*               R. A. MCCLATCHEY
C
C     PROGRAM LOWTRAN  CALCULATES THE TRANSMITTANCE    AND/OR RADIANCE
C     OF THE ATMOSPHERE
C     FROM 350 CM-1 TO 40000 CM-1 (0.25 TO 28.57 MICRONS) AT 20 CM-1
C     SPECTRAL RESOLUTION ON A LINEAR WAVENUMBER SCALE.
C     REFRACTION AND EARTH CURVATURE EFFECTS ARE INCLUDED.    ATMOSPHERE
C     IS LAYERED IN ONE KM. INTERVALS BETWEEN 0 AND 25 KM., 5 KM. INTER-
C     VALS TO 50 KM., A TWENTY KM. INTERVAL TO 70 KM., AND A THIRTY KM.
C     INTERVAL TO 100 KM.
C     ******************************************************************
C
C     THE FOLLOWING CARDS SHOULD BE KEYPUNCHED BY THE USER
C     AND MAILED TO: F.X.KNEIZYS,AFGL/OPI,HANSCOM AFB,MASS 01731
C     THE CARDS WILL BE USED TO UPDATE THE AFGL MALING LIST
C     AND FOR NOTIFICATION TO THE USER OF ERRORS IN THE CODE
C
C
C              (USE COLUMNS 21 TO 72)
C     LOWT5    NAME
C     LOWT5 COMPANY
C     LOWT5 ADDRESS
C
C
C     ******************************************************************
C     PROGRAM ACTIVATED BY SUBMISSION OF FOUR CARD SEQUENCE AS FOLLOWS
C
C     CARD 1 MODEL,IHAZE,ITYPE,LEN,JP,IM,M1,M2,M3,ML,IEMISS,RO,TBOUND,
C     1ISEASN,IVULCN,VIS
C                                  FORMAT(11I3,2F10.3,2I3,F10.3)
C     CARD 2 H1,H2,ANGLE,RANGE,BETA                  FORMAT(7F10.3)
C     CARD 3 V1, V2, DV                              FORMAT(7F10.3)
C     CARD 4 IXY                                     FORMAT(I3)
C
C     MODEL=1,2,3,4,5 OR 6 SELECTS ONE OF THE FOLLOWING MODEL ATMOSPHERE
C     TROPICAL,MIDLATITUDE SUMMER,MIDLATITUDE WINTER,SUBARCTIC SUMMER,
C     SUBARCTIC WINTER,OR THE 1962 U.S.  STANDARD RESPECTIVELY
C     MODEL=0 FOR HORIZ. PATH WHEN METEOROL. DATA USED\INSTEAD OF CARD 2
C     READ H1,P(MB),T(DEG C),DEW PT.TEMP(DEG C),%REL HUMIDITY,H2O DENSIT
C     (GM.M-3),O3 DENSITY(GM.M-3), RANGE(KM) WITH FORMAT 429.
C     MODEL=7 WHEN NEW MODEL ATMOSPHERE(E.G. RADIOSONDE DATA) USED.
C     DATA CARDS ARE READ IN BETWEEN CARDS 1 AND 2, AND SHOULD CONTAIN\
C     ALTITUDE(KM.),PRESSURE,TEMP,DEW PT.TEMP,REL. HUMIDITY,H2O DENSITY,
C     O3 DENSITY,AEROSOL NO  DENSITY      ,VIS1,IHA1,ISEA1,IVUL1  FORMAT
C     435  SEE NSMDL FOR DETAILS.
C     NOTE THAT EITHER DEW PT. TEMP.OR REL. HUMIDITY CAN BE USED.
C
C     M1,M2,M3, ARE USED TO CHANGE TEMP,H2O, AND O3 ALTITUDE PROFILES.
```

Table A1. Listing of Fortran Code LOWTRAN 5 (Cont.)

```
C          IEMISS=0=TRANSMISSION MODE / IEMISS=1=EMISSION MODE                  LOW  610
C          TBOUND=TEMPERATURE OF EARTH IN DEGREES KELVIN                        LOW  620
C          IF TBOUND = ZERO, ASSUMES AIR TEMPERATURE OF MODEL ATMOS.            LOW  630
C                                                                               LOW  640
C      IF IHAZE=0 NO AEROSOL EXTINCTION IS COMPUTED                             LOW  650
CCC    VIS PARAMETER ON CARD 1 OVERRIDES DEFAULT IHAZE VALUE                    LOW  660
CCC    NOTE EXPANSION OF IHAZE PARAMETER                                        LOW  670
C      IHAZE=1  RURAL-23KM                                                      LOW  680
C      IHAZE=2  RURAL- 5KM                                                      LOW  690
C      IHAZE=3  MARITIME-23KM                                                   LOW  700
C      IHAZE=4 MARITIME-5KM                                                     LOW  710
C      IHAZE=5 URBAN-5KM                                                        LOW  720
C      IHAZE=6 TROPOSPHERIC-50KM                                                LOW  730
C      IHAZE=7  USER DEFINED                                                    LOW  740
C      IHAZE=8 FOG1 - DEFAULT VISIBILITY =0.2KM                                 LOW  750
C      IHAZE=9 FOG2 - DEFAULT VISIBILITY =0.5KM                                 LOW  760
C      VISIBILITY PROFILES  (NEW PARAMETER-ISEASN)                              LOW  770
C      ISEASN=0  DEFAULTS TO SEASON OF MODEL                                    LOW  780
C      ISEASN=1 SPRING-SUMMER                                                   LOW  790
C      ISEASN=2  FALL-WINTER                                                    LOW  800
C      NEW PARAMETER - IVULCN                                                   LOW  810
C                 10-30KM AEROSOL TYPE/VIS PROFILE                              LOW  820
C      IVULCN=0  DEFAULT TO STRATOSPHERIC BACKGROUND                            LOW  830
C      IVULCN=1  STRATOSPHERIC BACKGROUND                                       LOW  840
C      IVULCN=2  AGED VOLCANIC TYPE/MODERATE VOLCANIC PROFILE                   LOW  850
C      IVULCN=3  FRESH VOLCANIC TYPE/HIGH VOLCANIC PROFILE                      LOW  860
C      IVULCN=4  AGED VOLCANIC TYPE/HIGH VOLCANIC PROFILE                       LOW  870
C      IVULCN=5  FRESH VOLCANIC TYPE/MODERATE VOLCANIC PROFILE                  LOW  880
C                                                                               LOW  890
C      ITYPE=1,2  OR 3 INDICATES THE TYPE OF ATMOSPHERIC PATH                   LOW  900
C      ITYPE=3,VERTICAL OR SLANT PATH TO SPACE                                  LOW  910
C      ITYPE=2,VERTICAL OR SLANT PATH BETWEEN TWO ALTITUDES                     LOW  920
C      ITYPE=1, CORRESPONDS TO A HORIZONTAL (CONSTANT PRESSURE) PATH            LOW  930
C                                                                               LOW  940
C      H1=OBSERVER ALTITUDE (KM)                                                LOW  950
C      H2=SOURCE  ALTITUDE (KM)                                                 LOW  960
C      ANGLE= ZENITH ANGLE AT H1 (DEGREES)                                      LOW  970
C      RANGE=PATH LENGTH (KM)                                                   LOW  980
C      BETA=EARTH CENTRE ANGLE                                                  LOW  990
C      VIS = VISUAL RANGE AT SEA LEVEL (KM)                                     LOW 1000
C      (IF ITYPE=1 READ H1 AND RANGE;IF ITYPE=3 READ H1 AND ANGLE.              LOW 1010
C      IF ITYPE=2 READ H1 AND TWO OTHER PARAMETERS E.G. H2 AND ANGLE)           LOW 1020
C                                                                               LOW 1030
C      V1=INITIAL FREQUENCY (WAVENUMBER CM-1 ) INTEGER VALUE                    LOW 1040
C      V2=FINAL FREQUENCY(WAVENUMBER CM-1 ) INTEGER VALUE                       LOW 1050
C      DV= FREQUENCY INTERVALS AT WHICH TRANSMITTANCE IS PRINTED                LOW 1060
C      NOTE  DV MUST BE A MULTIPLE OF 5 CM-1                                    LOW 1070
C                                                                               LOW 1080
C      IXY=0  TO END DATA ,=1 FOR NEW V1,V2,DV ONLY , =2 TO CONTINUE DATALOW 1090
C      IXY=3 FOR NEW CARD 2 ONLY,=4 FOR NEW CARD 1 ONLY.                        LOW 1100
C      *****************************************************************LOW 1110
       COMMON /CARD1/ MODEL,IHAZE,ITYPE,LEN,JP,IM,M1,M2,M3,ML,IEMISS,RO  LOW 1120
     1 ,TBOUND,ISEASN,IVULCN,VIS                                                LOW 1130
       COMMON /CARD2/ H1,H2,ANGLE,RANGE,BETA,HMIN,RE                            LOW 1140
       COMMON /CARD3/ V1,V2,DV,AVW,CO,CW,W(15),E(15),CA,AI                      LOW 1150
       COMMON /CNTRL/ LENST,KMAX,M,IJ,J1,J2,JMIN,JEXTRA,IL,IKMAX,NLL,NP1 LOW 1160
     1,IFIND,NL,TKLO                                                            LOW 1170
       COMMON /MDATA/ Z(34),P(7,34),T(7,34),WH(7,34),WO(7,34)                   LOW 1180
     * ,SEASN(2),VULCN(5),VSB(9),HZ(15),HMIX(34)                                LOW 1190
       COMMON RELHUM(34),HSTOR(34),EH(15,34),ICH(4),VH(15),TX(15)               LOW 1200
```

Table A1. Listing of Fortran Code LOWTRAN 5 (Cont.)

```
      COMMON WLAY(34,15),WPATH(68,15),TBBY(68)
      COMMON ABSC(4,40),EXTC(4,40),VX2(40)
      IXY=0
      CALL M01A
      KMAX=15
      PI=2.0*ASIN(1.0)
      CA=PI/180.
   10 CONTINUE
      RE=6371.23
      IFIND=0
C     JP NE 0  SUPPRESS PRINT
      READ 105, MODEL,IHAZE,ITYPE,LEN,JP,IM,M1,M2,M3,ML,IEMISS,RO,TBOUND
     1,ISEASN,IVULCN,VIS
C     IEMISS=0=TRANSMISSION MODE / IEMISS=1=EMISSION MODE
      IF (IEMISS.EQ.1) PRINT 110
      IF (IEMISS.EQ.0) PRINT 115
      LENST=LEN
      PRINT 105, MODEL,IHAZE,ITYPE,LEN,JP,IM,M1,M2,M3,ML,IEMISS,RO,TBOUN
     1D,ISEASN,IVULCN,VIS
   15 M=MODEL
      IF((M.EQ.3.OR.M.EQ.5).AND.ISEASN.EQ.0) ISEASN=2
      IF (VIS.LE.0.0.AND.IHAZE.GT.0) VIS=VSB(IHAZE)
      ICH(1)=IHAZE
      ICH(2)=6
      ICH(3)=9+IVULCN
      ICH(4)=15
      IF (ICH(1).LE.0) ICH(1)=1
      IF (ICH(3).LE.9) ICH(3)=10
      IF (MODEL.EQ.1) RE=6378.39
      IF (MODEL.EQ.4) RE=6356.91
      IF (MODEL.EQ.5) RE=6356.91
      IF (IHAZE.NE.7) GO TO 20
      READ 200, (DUMMY,EXTC(1,I),ABSC(1,I),I=1,40)
   20 IF (RO.GT.0.0) RE=RO
      IF (MODEL.EQ.7.AND.IM.NE.0) GO TO 35
      IF (IXY.GT.3) GO TO 65
      IF (MODEL.EQ.0) GO TO 35
   25 READ 120, H1,H2,ANGLE,RANGE,BETA
      PRINT 195, H1,H2,ANGLE,RANGE,BETA
      X1=RE+H1
      IF (ITYPE.EQ.3) GO TO 40
      IF (ITYPE.EQ.1) GO TO 65
      X2=RE+H2
      IF (RANGE.EQ.0.) GO TO 50
      PRINT 195, H1,H2,ANGLE,RANGE,BETA
      IF (H2.EQ.0.0.AND.ANGLE.NE.0.0) GO TO 30
      ANGLE=ACOS((.5*((H2-H1)*(1.+X2/X1)/RANGE-RANGE/X1))/CA
      GO TO 60
   30 X2=SQRT((X1/RANGE+RANGE/X1+2.0*COS(ANGLE*CA))*X1*RANGE)
      H2=X2-RE
      GO TO 60
   35 CONTINUE
      IF (ML.LE.0) ML=1
      CALL NSMDL
      IM=0
      IF (MODEL.EQ.0) GO TO 65
      NL=ML
C     NOTE THAT Z(I) MAY NOT CORRESPOND TO THE VALUES GIVEN FOR STANDARD
C     MODEL ATMOSPHERES
      IF (IXY.GT.3) GO TO 65
```

Table A1. Listing of Fortran Code LOWTRAN 5 (Cont.)

```
   GO TO 25
40 IF (RANGE.GT.0.0) GO TO 45
   IF (H2.GT.0.0.AND.H2.LT.H1) IFIND=1
   GO TO 65
45 ITYPE=2
   BETA=ACOS(0.5*(RANGE*RANGE/(X1*X2)-X2/X1-X1/X2))/CA
50 IF (BETA.EQ.0.) GO TO 55
   IFIND=1
   BET=CA*BETA
   X2=RE+H2
   ANGLE=ATAN(X2*SIN(BET)/(X2*COS(BET)-X1))/CA
   RANGE=X2*SIN(BET)/SIN(ANGLE*CA)
   BET=BETA
   GO TO 65
55 RANGE=(X2/X1)**2-(SIN(ANGLE*CA))**2
   IF (RANGE.GE.0.0) RANGE=X1*(SQRT(RANGE)-ABS(COS(ANGLE*CA)))
60 IF (ANGLE.NE.0..OR.ANGLE.NE.180.) BET=ASIN(RANGE*SIN(ANGLE*CA)/X2)
   IF(ANGLE.LT.0.) ANGLE=ANGLE+180.
   IF (RANGE.LT.0.0) RANGE=-RANGE
   BET=BET/CA
   PRINT 195, H1,H2,ANGLE,RANGE,BET
65 CONTINUE
   IF (IXY.LE.2) READ 120, V1,V2,DV
   IF (IXY.LE.2) PRINT 120, V1,V2,DV
   IF (ITYPE.EQ.1) PRINT 125, H1,RANGE
   IF (ITYPE.EQ.2) PRINT 130, H1,H2,ANGLE
   IF (ITYPE.EQ.3) PRINT 135, H1,ANGLE
   IF (MODEL.EQ.0) M=7
   IF (VIS.GT.0.0) PRINT 175, VIS
   IF (M.EQ.1) PRINT 140, MODEL
   IF (M.EQ.2) PRINT 145, MODEL
   IF (M.EQ.3) PRINT 150, MODEL
   IF (M.EQ.4) PRINT 155, MODEL
   IF (M.EQ.5) PRINT 165, MODEL
   IF (M.EQ.6) PRINT 160, MODEL
   IF (IHAZE.EQ.0) PRINT 190
   IF (IHAZE.NE.0) PRINT 170, IHAZE,HZ(IHAZE),VIS
   IF (ISEASN.EQ.0) PRINT 205, SEASN(1)
   IF (ISEASN.NE.0) PRINT 205, SEASN(ISEASN)
   IF (IVULCN.EQ.0) PRINT 210, VULCN(1)
   IF (IVULCN.NE.0) PRINT 210, VULCN(IVULCN)
   AVW=10000./V1
   ALAM=10000./V2
   PRINT 180, V1,V2,DV,ALAM,AVW
   CALL HPROF
   CALL GEO
   CALL EXABIN
70    WRITE(7,105)MODEL,IHAZE,ITYPE,LEN,JP,IM,M1,M2,M3,ML,IEMISS,RO,
  1 TBOUND,ISEASN,IVULCN,VIS
   WRITE(7,120) H1,H2,ANGLE,RANGE,BETA
   WRITE(7,120)V1,V2,DV
   IF (IEMISS.EQ.0) GO TO 75
   CALL PATH
   PRINT 215
   PRINT 220
75 CALL TRANS
   READ 105, IXY
   END FILE 7
   JEXTRA=0
   IFIND=0
```

Table A1. Listing of Fortran Code LOWTRAN 5 (Cont.)

```
      PRINT 195, IXY
      IF (IXY.EQ.0) GO TO 95
      GO TO (80,10,85,10,95), IXY
   80 READ 120, V1,V2,DV
      AVW=10000./V1
      ALAM=10000./V2
      PRINT 180, V1,V2,DV,ALAM,AVW
      GO TO 70
   85 IF (IEMISS.EQ.1) PRINT 110
      IF (IEMISS.EQ.0) PRINT 115
      IF (MODEL.EQ.0) GO TO 35
      GO TO 25
   95 STOP
C
  100 FORMAT (3I3,6F11.4)
  105 FORMAT (11I3,2F10.3,2I3,F11.3)
  110 FORMAT (47H1 PROGRAM WILL BE EXECUTED IN THE EMISSION MODE)
  115 FORMAT (51H1 PROGRAM WILL BE EXECUTED IN THE TRANSMISSION MODE)
  120 FORMAT (3F10.3)
  125 FORMAT (//10X,28H HORIZONTAL PATH, ALTITUDE =,F7.3,11H KM,RANGE =,
     1F7.3,3H KM)
  130 FORMAT (//10X,59H SLANT PATH BETWEEN ALTITUDES H1 AND H2 WHERE H1
     1=,F7.3,8H KM H2 =,F7.3,18H KM,ZENITH ANGLE =,F7.3,8H DEGREES)
  135 FORMAT (//10X,39H SLANT PATH TO SPACE FROM ALTITUDE H1 =,F7.3,19H
     1KM, ZENITH ANGLE =,F7.3,8H DEGREES)
  140 FORMAT (/20X,18H MODEL ATMOSPHERE ,I1,11H = TROPICAL)
  145 FORMAT (/20X,18H MODEL ATMOSPHERE ,I1,21H = MIDLATITUDE SUMMER)
  150 FORMAT (/20X,18H MODEL ATMOSPHERE ,I1,21H = MIDLATITUDE WINTER)
  155 FORMAT (/20X,18H MODEL ATMOSPHERE ,I1,21H = SUB-ARCTIC SUMMER )
  160 FORMAT (/20X,18H MODEL ATMOSPHERE ,I1,21H = 1962 US STANDARD  )
  165 FORMAT (/20X,18H MODEL ATMOSPHERE ,I1,21H = SUB-ARCTIC WINTER )
  170 FORMAT (/20X,15H   HAZE MODEL  ,I1,3H = ,A10,9H    VIS=,F5.1,2HKM)
  175 FORMAT (/25X,13HHAZE MODEL  =,F5.1,29H KM VISUAL RANGE AT SEA LEVE
     1L)
  180 FORMAT (/10X,21H FREQUENCY RANGE V1= ,F7.1,13H CM-1 TO V2= ,F7.1,1
     14H CM-1 FOR DV =,F6.1,9H CM-1    (,F6.2,3H - ,F5.2,10H MICRONS ))
  185 FORMAT (10X,7F10.3)
  190 FORMAT (/20X,39HAEROSOL SCATTERING NOT COMPUTED,IHAZE=0)
  195 FORMAT (10X,4H H1=,F7.3,6HKM,H2=,F7.3,9HKM,ANGLE=,F8.4,13HGECM. RA
     1NGE =,F7.2,8HKM,BETA=,F8.5)
  200 FORMAT (4(F6.2,2F7.5))
  205 FORMAT (/20X,10H SEASON = ,A13)
  210 FORMAT (/20X,34H VERTICAL PROFILE AEROSOL MODEL = ,A16)
  215 FORMAT (1H1,50X,33HRADIANCE(WATTS/CM2-STER-XXX))
  220 FORMAT (30X,47HFR(CM-1) WVL(MICRON)      PER CM-1   PER MICRON,26H
     1      INTEGRAL         TRANS)
      END
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Table A1. Listing of Fortran Code LOWTRAN 5 (Cont.)

```
      SUBROUTINE MDTA                                                   MDT   10
C                                                                       MDT   20
C     MODEL ATMOSPHERE DATA                                             MDT   30
C                                                                       MDT   40
      COMMON /CARD1/ MODEL,IHAZE,ITYPE,LEN,JP,IM,M1,M2,M3,ML,IEMISS,RO  MDT   50
     1 ,TBOUND,ISEASN,IVULCN,VIS                                        MDT   60
      COMMON /CARD2/ H1,H2,ANGLE,RANGE,BETA,HMIN,RE                     MDT   70
      COMMON /CARD3/ V1,V2,DV,AVW,CO,CH,W(15),E(15),CA,PI               MDT   80
      COMMON /CNTRL/ LENST,KMAX,M,IJ,J1,J2,JMIN,JEXTRA,IL,IKMAX,NLL,NP1 MDT   90
     1,IFIND,NL,IKLO                                                    MDT  100
      COMMON /MDATA/ Z(34),P(7,34),T(7,34),WH(7,34),WO(7,34)            MDT  110
     1 ,SEASN(2),VULCN(5),VSB(9),HZ(15),HMIX(34)                        MDT  120
      COMMON RELHUM(34),HSTOR(34),EH(15,34),ICH(4),VH(15),TX(15)        MDT  130
      COMMON WLAY(34,15),WPATH(68,15),TBBY(68)                          MDT  140
      COMMON ABSC(4,40),EXTC(4,40),VX2(40)                              MDT  150
      DATA IATM/   6/,NL/  34/                                          MDT  160
      DATA( Z(I),I=1, 34)/                                              MDT  170
     1    0.,     1.,     2.,     3.,     4.,     5.,     6.,     7.,     8.,   MDT  180
     2    9.,    10.,    11.,    12.,    13.,    14.,    15.,    16.,    17.,   MDT  190
     3   18.,    19.,    20.,    21.,    22.,    23.,    24.,    25.,    30.,   MDT  200
     4   35.,    40.,    45.,    50.,    70.,   100.,99999./                    MDT  210
      DATA( P(1,I),I=1, 34)/                                            MDT  220
     1 1.013E+03, 9.040E+02, 8.050E+02, 7.150E+02, 6.330E+02, 5.590E+02,MDT  230
     2 4.920E+02, 4.320E+02, 3.780E+02, 3.290E+02, 2.860E+02, 2.470E+02,MDT  240
     3 2.130E+02, 1.820E+02, 1.560E+02, 1.320E+02, 1.110E+02, 9.370E+01,MDT  250
     4 7.890E+01, 6.660E+01, 5.650E+01, 4.800E+01, 4.090E+01, 3.500E+01,MDT  260
     5 3.000E+01, 2.570E+01, 1.220E+01, 6.000E+00, 3.050E+00, 1.590E+00,MDT  270
     6 8.540E-01, 5.790E-02, 3.000E-04, 0.        /                     MDT  280
      DATA( P(2,I),I=1, 34)/                                            MDT  290
     1 1.013E+03, 9.020E+02, 8.020E+02, 7.100E+02, 6.280E+02, 5.540E+02,MDT  300
     2 4.870E+02, 4.260E+02, 3.720E+02, 3.240E+02, 2.810E+02, 2.430E+02,MDT  310
     3 2.090E+02, 1.790E+02, 1.530E+02, 1.300E+02, 1.110E+02, 9.500E+01,MDT  320
     4 8.120E+01, 6.950E+01, 5.950E+01, 5.100E+01, 4.370E+01, 3.760E+01,MDT  330
     5 3.220E+01, 2.770E+01, 1.320E+01, 6.520E+00, 3.330E+00, 1.760E+00,MDT  340
     6 9.510E-01, 6.710E-02, 3.000E-04, 0.        /                     MDT  350
      DATA( P(3,I),I=1, 34)/                                            MDT  360
     1 1.018E+03, 8.973E+02, 7.897E+02, 6.938E+02, 6.081E+02, 5.313E+02,MDT  370
     2 4.627E+02, 4.016E+02, 3.473E+02, 2.992E+02, 2.568E+02, 2.199E+02,MDT  380
     3 1.882E+02, 1.610E+02, 1.378E+02, 1.178E+02, 1.007E+02, 8.610E+01,MDT  390
     4 7.350E+01, 6.280E+01, 5.370E+01, 4.580E+01, 3.910E+01, 3.340E+01,MDT  400
     5 2.860E+01, 2.430E+01, 1.110E+01, 5.180E+00, 2.530E+00, 1.290E+00,MDT  410
     6 6.820E-01, 4.670E-02, 3.000E-04, 0.        /                     MDT  420
      DATA( P(4,I),I=1, 34)/                                            MDT  430
     1 1.010E+03, 8.960E+02, 7.929E+02, 7.000E+02, 6.160E+02, 5.410E+02,MDT  440
     2 4.730E+02, 4.130E+02, 3.590E+02, 3.107E+02, 2.677E+02, 2.300E+02,MDT  450
     3 1.977E+02, 1.700E+02, 1.460E+02, 1.250E+02, 1.060E+02, 9.280E+01,MDT  460
     4 7.980E+01, 6.860E+01, 5.890E+01, 5.070E+01, 4.360E+01, 3.750E+01,MDT  470
     5 3.227E+01, 2.780E+01, 1.340E+01, 6.610E+00, 3.400E+00, 1.810E+00,MDT  480
     6 9.870E-01, 7.070E-02, 3.000E-04, 0.        /                     MDT  490
      DATA( P(5,I),I=1, 34)/                                            MDT  500
     1 1.013E+03, 8.878E+02, 7.775E+02, 6.798E+02, 5.932E+02, 5.158E+02,MDT  510
     2 4.467E+02, 3.853E+02, 3.308E+02, 2.829E+02, 2.418E+02, 2.067E+02,MDT  520
     3 1.766E+02, 1.510E+02, 1.291E+02, 1.103E+02, 9.431E+01, 8.058E+01,MDT  530
     4 6.882E+01, 5.875E+01, 5.014E+01, 4.277E+01, 3.647E+01, 3.109E+01,MDT  540
     5 2.649E+01, 2.256E+01, 1.020E+01, 4.701E+00, 2.243E+00, 1.113E+00,MDT  550
     6 5.719E-01, 4.016E-02, 3.000E-04, 0.        /                     MDT  560
      DATA( P(6,I),I=1, 34)/                                            MDT  570
     1 1.013E+03, 8.986E+02, 7.950E+02, 7.012E+02, 6.166E+02, 5.405E+02,MDT  580
     2 4.722E+02, 4.111E+02, 3.565E+02, 3.080E+02, 2.650E+02, 2.270E+02,MDT  590
     3 1.940E+02, 1.658E+02, 1.417E+02, 1.211E+02, 1.035E+02, 8.850E+01,MDT  600
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Table A1. Listing of Fortran Code LOWTRAN 5 (Cont.)

```
4 7.565E+01, 6.467E+01, 5.529E+01, 4.729E+01, 4.047E+01, 3.467E+01,MDT   610
5 2.972E+01, 2.549E+01, 1.197E+01, 5.746E+00, 2.871E+00, 1.491E+00,MDT   620
6 7.978E-01, 5.520E-02, 3.008E-04, 0.        /                      MDT   630
 DATA( T(1,I),I=1, 34)/                                             MDT   640
1 3.000E+02, 2.940E+02, 2.880E+02, 2.840E+02, 2.770E+02, 2.700E+02,MDT   650
2 2.640E+02, 2.570E+02, 2.500E+02, 2.440E+02, 2.370E+02, 2.300E+02,MDT   660
3 2.240E+02, 2.170E+02, 2.100E+02, 2.040E+02, 1.970E+02, 1.950E+02,MDT   670
4 1.990E+02, 2.030E+02, 2.070E+02, 2.110E+02, 2.150E+02, 2.170E+02,MDT   680
5 2.190E+02, 2.210E+02, 2.320E+02, 2.430E+02, 2.540E+02, 2.650E+02,MDT   690
6 2.700E+02, 2.190E+02, 2.100E+02, 2.100E+02/                      MDT   700
 DATA( T(2,I),I=1, 34)/                                             MDT   710
1 2.940E+02, 2.900E+02, 2.850E+02, 2.790E+02, 2.730E+02, 2.670E+02,MDT   720
2 2.610E+02, 2.550E+02, 2.480E+02, 2.420E+02, 2.350E+02, 2.290E+02,MDT   730
3 2.220E+02, 2.160E+02, 2.160E+02, 2.160E+02, 2.160E+02, 2.160E+02,MDT   740
4 2.160E+02, 2.170E+02, 2.180E+02, 2.190E+02, 2.200E+02, 2.220E+02,MDT   750
5 2.230E+02, 2.240E+02, 2.340E+02, 2.450E+02, 2.580E+02, 2.700E+02,MDT   760
6 2.760E+02, 2.180E+02, 2.100E+02, 2.100E+02/                      MDT   770
 DATA( T(3,I),I=1, 34)/                                             MDT   780
1 2.722E+02, 2.687E+02, 2.652E+02, 2.617E+02, 2.557E+02, 2.497E+02,MDT   790
2 2.437E+02, 2.377E+02, 2.317E+02, 2.257E+02, 2.197E+02, 2.192E+02,MDT   800
3 2.187E+02, 2.182E+02, 2.177E+02, 2.172E+02, 2.167E+02, 2.162E+02,MDT   810
4 2.157E+02, 2.152E+02, 2.152E+02, 2.152E+02, 2.152E+02, 2.152E+02,MDT   820
5 2.152E+02, 2.152E+02, 2.174E+02, 2.278E+02, 2.432E+02, 2.585E+02,MDT   830
6 2.657E+02, 2.307E+02, 2.102E+02, 2.100E+02/                      MDT   840
 DATA( T(4,I),I=1, 34)/                                             MDT   850
1 2.870E+02, 2.820E+02, 2.760E+02, 2.710E+02, 2.660E+02, 2.600E+02,MDT   860
2 2.530E+02, 2.460E+02, 2.390E+02, 2.320E+02, 2.250E+02, 2.250E+02,MDT   870
3 2.250E+02, 2.250E+02, 2.250E+02, 2.250E+02, 2.250E+02, 2.250E+02,MDT   880
4 2.250E+02, 2.250E+02, 2.250E+02, 2.250E+02, 2.250E+02, 2.250E+02,MDT   890
5 2.260E+02, 2.280E+02, 2.350E+02, 2.470E+02, 2.620E+02, 2.740E+02,MDT   900
6 2.770E+02, 2.160E+02, 2.100E+02, 2.100E+02/                      MDT   910
 DATA( T(5,I),I=1, 34)/                                             MDT   920
1 2.571E+02, 2.591E+02, 2.559E+02, 2.527E+02, 2.477E+02, 2.409E+02,MDT   930
2 2.341E+02, 2.273E+02, 2.206E+02, 2.172E+02, 2.172E+02, 2.172E+02,MDT   940
3 2.172E+02, 2.172E+02, 2.172E+02, 2.172E+02, 2.166E+02, 2.160E+02,MDT   950
4 2.154E+02, 2.148E+02, 2.141E+02, 2.136E+02, 2.130E+02, 2.124E+02,MDT   960
5 2.118E+02, 2.112E+02, 2.160E+02, 2.222E+02, 2.347E+02, 2.470E+02,MDT   970
6 2.593E+02, 2.457E+02, 2.100E+02, 2.100E+02/                      MDT   980
 DATA( T(6,I),I=1, 34)/                                             MDT   990
1 2.881E+02, 2.816E+02, 2.751E+02, 2.687E+02, 2.622E+02, 2.557E+02,MDT  1000
2 2.492E+02, 2.427E+02, 2.362E+02, 2.297E+02, 2.232E+02, 2.168E+02,MDT  1010
3 2.166E+02, 2.166E+02, 2.166E+02, 2.166E+02, 2.166E+02, 2.166E+02,MDT  1020
4 2.166E+02, 2.166E+02, 2.166E+02, 2.176E+02, 2.186E+02, 2.196E+02,MDT  1030
5 2.206E+02, 2.216E+02, 2.265E+02, 2.365E+02, 2.534E+02, 2.642E+02,MDT  1040
6 2.706E+02, 2.197E+02, 2.100E+02, 2.100E+02/                      MDT  1050
 DATA(WH(1,I),I=1, 34)/                                             MDT  1060
1 1.900E+01, 1.300E+01, 9.300E+00, 4.700E+00, 2.200E+00, 1.500E+00,MDT  1070
2 8.500E-01, 4.700E-01, 2.500E-01, 1.200E-01, 5.000E-02, 1.700E-02,MDT  1080
3 6.000E-03, 1.800E-03, 1.000E-03, 7.600E-04, 6.400E-04, 5.600E-04,MDT  1090
4 5.000E-04, 4.900E-04, 4.500E-04, 5.100E-04, 5.100E-04, 5.400E-04,MDT  1100
5 6.000E-04, 6.700E-04, 3.600E-04, 1.100E-04, 4.300E-05, 1.900E-05,MDT  1110
6 6.300E-06, 1.400E-07, 1.000E-09, 0.        /                      MDT  1120
 DATA(WH(2,I),I=1, 34)/                                             MDT  1130
1 1.400E+01, 9.300E+00, 5.900E+00, 3.300E+00, 1.900E+00, 1.000E+00,MDT  1140
2 6.100E-01, 3.700E-01, 2.100E-01, 1.200E-01, 6.400E-02, 2.200E-02,MDT  1150
3 6.000E-03, 1.800E-03, 1.000E-03, 7.600E-04, 6.400E-04, 5.600E-04,MDT  1160
4 5.000E-04, 4.900E-04, 4.500E-04, 5.100E-04, 5.100E-04, 5.400E-04,MDT  1170
5 6.000E-04, 6.700E-04, 3.600E-04, 1.100E-04, 4.300E-05, 1.900E-05,MDT  1180
6 6.300E-06, 1.400E-07, 1.000E-09, 0.        /                      MDT  1190
 DATA(WH(3,I),I=1, 34)/                                             MDT  1200
```

Table A1. Listing of Fortran Code LOWTRAN 5 (Cont.)

```
1 3.500E+00, 2.500E+00, 1.800E+00, 1.200E+00, 6.600E-01, 3.800E-01,MDT 1210
2 2.100E-01, 8.500E-02, 3.500E-02, 1.600E-02, 7.500E-03, 6.900E-03,MDT 1220
3 6.000E-03, 1.800E-03, 1.000E-03, 7.600E-04, 6.400E-04, 5.600E-04,MDT 1230
4 5.000E-04, 4.900E-04, 4.500E-04, 5.100E-04, 5.100E-04, 5.400E-04,MDT 1240
5 6.000E-04, 6.700E-04, 3.600E-04, 1.100E-04, 4.300E-05, 1.900E-05,MDT 1250
6 6.300E-06, 1.400E-07, 1.000E-09, 0.        /                     MDT 1260
 DATA(WH(4,I),I=1, 34)/                                             MDT 1270
1 9.100E+00, 6.000E+00, 4.200E+00, 2.700E+00, 1.700E+00, 1.000E+00,MDT 1280
2 5.400E-01, 2.900E-01, 1.300E-01, 4.200E-02, 1.500E-02, 9.400E-03,MDT 1290
3 6.000E-03, 1.800E-03, 1.000E-03, 7.600E-04, 6.400E-04, 5.600E-04,MDT 1300
4 5.000E-04, 4.900E-04, 4.500E-04, 5.100E-04, 5.100E-04, 5.400E-04,MDT 1310
5 6.000E-04, 6.700E-04, 3.600E-04, 1.100E-04, 4.300E-05, 1.900E-05,MDT 1320
6 6.300E-06, 1.400E-07, 1.000E-09, 0.        /                     MDT 1330
 DATA(WH(5,I),I=1, 34)/                                             MDT 1340
1 1.200E+00, 1.200E+00, 9.400E-01, 6.800E-01, 4.100E-01, 2.000E-01,MDT 1350
2 9.800E-02, 5.400E-02, 1.100E-02, 8.400E-03, 5.500E-03, 3.800E-03,MDT 1360
3 2.600E-03, 1.800E-03, 1.000E-03, 7.600E-04, 6.400E-04, 5.600E-04,MDT 1370
4 5.000E-04, 4.900E-04, 4.500E-04, 5.100E-04, 5.100E-04, 5.400E-04,MDT 1380
5 6.000E-04, 6.700E-04, 3.600E-04, 1.100E-04, 4.300E-05, 1.900E-05,MDT 1390
6 6.300E-06, 1.400E-07, 1.000E-09, 0.        /                     MDT 1400
 DATA(WH(6,I),I=1, 34)/                                             MDT 1410
1 5.900E+00, 4.200E+00, 2.900E+00, 1.800E+00, 1.100E+00, 6.400E-01,MDT 1420
2 3.800E-01, 2.100E-01, 1.200E-01, 4.600E-02, 1.800E-02, 8.200E-03,MDT 1430
3 3.700E-03, 1.800E-03, 8.400E-04, 7.200E-04, 6.100E-04, 5.200E-04,MDT 1440
4 4.400E-04, 4.400E-04, 4.400E-04, 4.800E-04, 5.200E-04, 5.700E-04,MDT 1450
5 6.100E-04, 6.600E-04, 3.800E-04, 1.600E-04, 6.700E-05, 3.200E-05,MDT 1460
6 1.200E-05, 1.500E-07, 1.000E-09, 0.        /                     MDT 1470
 DATA(WO(1,I),I=1, 34)/                                             MDT 1480
1 5.600E-05, 5.600E-05, 5.400E-05, 5.100E-05, 4.700E-05, 4.500E-05,MDT 1490
2 4.300E-05, 4.100E-05, 3.300E-05, 3.900E-05, 3.900E-05, 4.100E-05,MDT 1500
3 4.300E-05, 4.500E-05, 4.500E-05, 4.700E-05, 4.700E-05, 6.900E-05,MDT 1510
4 9.000E-05, 1.400E-04, 1.900E-04, 2.400E-04, 2.800E-04, 3.200E-04,MDT 1520
5 3.400E-04, 3.400E-04, 2.400E-04, 9.200E-05, 4.100E-05, 1.300E-05,MDT 1530
6 4.300E-06, 8.600E-08, 4.300E-11, 0.        /                     MDT 1540
 DATA(WO(2,I),I=1, 34)/                                             MDT 1550
1 6.000E-05, 6.000E-05, 6.000E-05, 6.200E-05, 6.400E-05, 6.600E-05,MDT 1560
2 6.900E-05, 7.500E-05, 7.900E-05, 8.600E-05, 9.000E-05, 1.100E-04,MDT 1570
3 1.200E-04, 1.500E-04, 1.800E-04, 1.900E-04, 2.100E-04, 2.400E-04,MDT 1580
4 2.800E-04, 3.200E-04, 3.400E-04, 3.600E-04, 3.600E-04, 3.400E-04,MDT 1590
5 3.200E-04, 3.000E-04, 2.000E-04, 9.200E-05, 4.100E-05, 1.300E-05,MDT 1600
6 4.300E-06, 8.600E-08, 4.300E-11, 0.        /                     MDT 1610
 DATA(WO(3,I),I=1, 34)/                                             MDT 1620
1 6.000E-05, 5.400E-05, 4.900E-05, 4.900E-05, 4.900E-05, 5.800E-05,MDT 1630
2 6.400E-05, 7.700E-05, 9.000E-05, 1.200E-04, 1.600E-04, 2.100E-04,MDT 1640
3 2.600E-04, 3.000E-04, 3.200E-04, 3.400E-04, 3.600E-04, 3.900E-04,MDT 1650
4 4.100E-04, 4.300E-04, 4.500E-04, 4.300E-04, 4.300E-04, 3.900E-04,MDT 1660
5 3.600E-04, 3.400E-04, 1.900E-04, 9.200E-05, 4.100E-05, 1.300E-05,MDT 1670
6 4.300E-06, 8.600E-08, 4.300E-11, 0.        /                     MDT 1680
 DATA(WO(4,I),I=1, 34)/                                             MDT 1690
1 4.900E-05, 5.400E-05, 5.600E-05, 5.800E-05, 6.000E-05, 6.400E-05,MDT 1700
2 7.100E-05, 7.500E-05, 7.900E-05, 1.100E-04, 1.300E-04, 1.800E-04,MDT 1710
3 2.100E-04, 2.600E-04, 2.800E-04, 3.200E-04, 3.400E-04, 3.900E-04,MDT 1720
4 4.100E-04, 4.100E-04, 3.900E-04, 3.600E-04, 3.200E-04, 3.000E-04,MDT 1730
5 2.800E-04, 2.600E-04, 1.400E-04, 9.200E-05, 4.100E-05, 1.300E-05,MDT 1740
6 4.300E-06, 8.600E-08, 4.300E-11, 0.        /                     MDT 1750
 DATA(WO(5,I),I=1, 34)/                                             MDT 1760
1 4.100E-05, 4.100E-05, 4.100E-05, 4.300E-05, 4.500E-05, 4.700E-05,MDT 1770
2 4.900E-05, 7.100E-05, 9.000E-05, 1.600E-04, 2.400E-04, 3.200E-04,MDT 1780
3 4.300E-04, 4.700E-04, 4.300E-04, 5.600E-04, 6.200E-04, 6.200E-04,MDT 1790
4 6.200E-04, 6.000E-04, 5.600E-04, 5.100E-04, 4.700E-04, 4.300E-04,MDT 1800
```

Table A1. Listing of Fortran Code LOWTRAN 5 (Cont.)

```
     5 3.600E-04, 3.200E-04, 1.500E-04, 9.200E-05, 4.100E-05, 1.300E-05,MDT 1810
     6 4.300E-06, 8.600E-08, 4.300E-11, 0.        /                    MDT 1820
      DATA(HO(6,I),I=1, 34)/                                            MDT 1830
     1 5.400E-05, 5.400E-05, 5.400E-05, 5.000E-05, 4.600E-05, 4.600E-05,MDT 1840
     2 4.500E-05, 4.900E-05, 5.200E-05, 7.100E-05, 9.000E-05, 1.300E-04,MDT 1850
     3 1.600E-04, 1.700E-04, 1.900E-04, 2.100E-04, 2.400E-04, 2.800E-04,MDT 1860
     4 3.200E-04, 3.500E-04, 3.800E-04, 3.800E-04, 3.900E-04, 3.800E-04,MDT 1870
     5 3.600E-04, 3.400E-04, 2.000E-04, 1.100E-04, 4.900E-05, 1.700E-05,MDT 1880
     6 4.000E-06, 8.600E-08, 4.300E-11, 0.        /                    MDT 1890
C     HMIX(I)=HNO3 VOLUME MIXING RATIOS TIMES E+9 FROM EVANS  PROFILE   MDT 1900
      DATA HMIX/9*0.,0.1,0.33,0.8,1.2,1.4,1.6,1.8,1.9,2.0,2.1,2.3,3.0,3.MDT 1910
     17,4.2,5.2,6.0,3.8,2.6,0.22,6*0.0/                                 MDT 1920
      DATA (VSB(KKK),KKK=1,9)/23.,5.,23.,5.,5.,50.,23.,0.2,0.5/         MDT 1930
      DATA HZ(1)/10H   RURAL   /,HZ(2)/10H   RURAL  /,                  MDT 1940
     1HZ(3)/10H MARITIME /,HZ(4)/10H MARITIME /,HZ(5)/10H   URBAN  /,   MDT 1950
     2HZ(6)/10HTROPOSPHER/,HZ(7)/10HUSER DEFIN/,HZ(8)/10HFOG1 (ADV)/,   MDT 1960
     3HZ(9)/10HFOG2 (RAD)/                                              MDT 1970
     4,HZ(10)/10H BACK STRA/,HZ(11)/10H AGED VOL /,HZ(12)/10HFRESH VOL /MDT 1980
     5 ,HZ(15)/10H MET DUST  /                                          MDT 1990
      DATA SEASN(1)/10HSPRIG SUMM/,SEASN(2)/10HFALL WINTR/              MDT 2000
      DATA VULCN(1)/10HSTRAT BKGR/,VULCN(2)/10HAG VO-MDVO/,             MDT 2010
     1VULCN(3)/10HFR VO-HIVO/,VULCN(4)/10HAG VO-HIVO/,VULCN(5)/10HFR VO-MDT 2020
     2MDVO/                                                             MDT 2030
      HMIX(29)=1.0E-50                                                  MDT 2040
      HMIX(9)=HMIX(29)                                                  MDT 2050
      HZ(13)=HZ(11)                                                     MDT 2060
      HZ(14)=HZ(12)                                                     MDT 2070
      RETURN                                                            MDT 2080
      END                                                               MDT 2090
```

Table A1. Listing of Fortran Code LOWTRAN 5 (Cont.)

```
      SUBROUTINE NSMOL                                                  NSM   10
C                                                                       NSM   20
C     USED FOR USER DEFINED ATMOSPHERIC MODELS (MODEL=0 OR 7)           NSM   30
C     DEFINES ALTITUDE DEPENDENT VARIABLES Z,P,T,WH,WO AND HAZE         NSM   40
C     LOADS HAZE INTO APPROPRATE EH LOCATION                            NSM   50
C                                                                       NSM   60
      COMMON /CARD1/ MODEL,IHAZE,ITYPE,LEN,JP,IM,M1,M2,M3,ML,IEMISS,RO  NSM   70
     1 ,TBOUND,ISEASN,IVULCN,VIS                                        NSM   80
      COMMON /CARD2/ H1,H2,ANGLE,RANGE,BETA,HMIN,RE                     NSM   90
      COMMON /CARD3/ V1,V2,DV,AVW,CO,CW,W(15),E(15),CA,FI               NSM  100
      COMMON /CNTRL/ LENST,KMAX,M,IJ,J1,J2,JMIN,JEXTRA,IL,IKMAX,NLL,NF1 NSM  110
     1,IFIND,NL,IKLO                                                    NSM  120
      COMMON /MDATA/ Z(34),P(7,34),T(7,34),WH(7,34),WO(7,34)            NSM  130
     1 ,SEASN(2),VULCN(5),VSB(9),HZ(15),HMIX(34)                        NSM  140
      COMMON RELHUM(34),HSTOR(34),EH(15,34),ICH(4),VH(15),TX(15)        NSM  150
      COMMON HLAY(34,15),WPATH(68,15),TBBY(68)                          NSM  160
      COMMON ABSC(4,40),EXTC(4,40),VX2(40)                              NSM  170
      F(A)=EXP(18.9766-14.9595*A-2.43882*A*A)*A                         NSM  180
      RV=4.6150E-3                                                      NSM  190
      T0=273.15                                                         NSM  200
      IC1=1                                                             NSM  210
      N=7                                                               NSM  220
      IF(IVULCN.LE.0) IVULCN=1                                          NSM  230
      IF(ISEASN.LE.0) ISEASN=1                                          NSM  240
C     FOR MODEL EQ ZERO                                                 NSM  250
      IHA1=0                                                            NSM  260
      ISEA1=0                                                           NSM  270
      IVUL1=0                                                           NSM  280
      VIS1=0.                                                           NSM  290
      AHAZE=0.                                                          NSM  300
C       END OF MODEL ZERO DEFAULT                                       NSM  310
      IF (M.NE.0) PRINT 100                                             NSM  320
      DO 65 K=1,ML                                                      NSM  330
      AHOL=10H                                                          NSM  340
      AHOL1=10H                                                         NSM  350
      AHOL2=10H                                                         NSM  360
      AHOL3=10H                                                         NSM  370
      IF (M.EQ.0) READ 85, H1,P(7,1),TMP,DP,RH,WH(7,K),WO(7,K),RANGE    NSM  380
      IF (M.EQ.0) PRINT 90, H1,P(7,1),TMP,DP,RH,WH(7,K),WO(7,K),RANGE   NSM  390
      IF (M.GT.0) READ 80, Z(K),P(7,K),TMP,DP,RH,WH(7,K),WO(7,K),AHAZE,VNSM  400
     1IS1,IHA1,ISEA1,IVUL1                                              NSM  410
      IF (M.EQ.0) Z(K)=H1                                               NSM  420
      PRINT 95, Z(K),P(7,K),TMP,DP,RH,WH(7,K),WO(7,K),AHAZE,VIS1,IHA1,ISNSM  430
     1EA1,IVUL1                                                         NSM  440
C     IHA1  IS IHAZE FOR THIS LAYER                                     NSM  450
C     ISEA1 IS ISEASN FOR THIS LAYER                                    NSM  460
C     IVUL1 IS IVULCN FOR THE LAYER                                     NSM  470
      IF(ISEA1.EQ.0) ISEA1=ISEASN                                       NSM  480
      IF(IHA1.GT.0.OR.IVUL1.GT.0) GO TO 10                              NSM  490
      ITYAER=IHAZE                                                      NSM  500
      IF (Z(K).GT.2.0) ITYAER=6                                         NSM  510
      IF (Z(K).GT.9.0) ITYAER=IVULCN+9                                  NSM  520
      IF (Z(K).GT.30.) ITYAER=15                                        NSM  530
      IHA1=IHAZE                                                        NSM  540
      IVUL1=IVULCN                                                      NSM  550
      GO TO 15                                                          NSM  560
10    IF(IVUL1.GT.0)ITYAER=IVUL1+9                                      NSM  570
      IF(IHA1.GT.0) ITYAER=IHA1                                         NSM  580
      IF(ITYAER.GT.15) ITYAER=15                                        NSM  590
      IF(IHA1.LE.0) IHA1=IHAZE                                          NSM  600
```

Table A1. Listing of Fortran Code LOWTRAN 5 (Cont.)

```
      IF(IVUL1.LE.0) IVUL1=IVULCN                                       NSM  610
   15 IF (K.EQ.1) GO TO 20                                              NSM  620
      IF(N.EQ.7.AND.ITYAER.EQ.6.AND.Z(K).GT.2.0) GO TO 17               NSM  630
      IF (ITYAER.EQ.ICH(IC1)) GO TO 20                                  NSM  640
17    IC1=IC1+1                                                         NSM  650
      N=IC1+10                                                          NSM  660
      IF (IC1.LE.4) GO TO 20                                            NSM  670
      IC1=4                                                             NSM  680
      N=14                                                              NSM  690
      ITYAER=ICH(IC1)                                                   NSM  700
   20 ICH(IC1)=ITYAER                                                   NSM  710
      J=IFIX(Z(K)+1.0E-5)+1                                             NSM  720
      IF (Z(K).GE.25.0) J=(Z(K)-25.0)/5.0+26.                           NSM  730
      IF (Z(K).GE.50.0) J=(Z(K)-50.0)/20.0+31.                          NSM  740
      IF (Z(K).GE.70.0) J=(Z(K)-70.0)/30.0+32.                          NSM  750
      IF (J.GT.33) J=33                                                 NSM  760
      FAC=Z(K)-FLOAT(J-1)                                               NSM  770
      IF (J.LT.26) GO TO 25                                             NSM  780
      FAC=(Z(K)-5.0*FLOAT(J-26)-25.)/5.                                 NSM  790
      IF (J.GE.31) FAC=(Z(K)-50.0)/20.                                  NSM  800
      IF (J.GE.32) FAC=(Z(K)-70.0)/30.                                  NSM  810
      IF (FAC.GT.1.0) FAC=1.0                                           NSM  820
   25 L=J+1                                                             NSM  830
      T(7,K)=TMP+T0                                                     NSM  840
      IF (M1.GT.0) P(7,K)=P(M1,J)*(P(M1,L)/P(M1,J))**FAC                NSM  850
      IF (M1.GT.0) T(7,K)=T(M1,J)*(T(M1,L)/T(M1,J))**FAC                NSM  860
      IF (M2.GT.0) WH(7,K)=WH(M2,J)*(WH(M2,L)/WH(M2,J))**FAC            NSM  870
      IF (WH(7,K).GT.0.0) GO TO 35                                      NSM  880
      IF (RH.GT.0.0) GO TO 30                                           NSM  890
      DPK=T0+DP                                                         NSM  900
      TT=T0/DPK                                                         NSM  910
      WH(7,K)=DPK*F(TT)/T(7,K)                                          NSM  920
      GO TO 35                                                          NSM  930
   30 TA=T0/T(7,K)                                                      NSM  940
      RHSAT=F(TA)                                                       NSM  950
      RHD=.01*RH                                                        NSM  960
      DN=(1.0-(1.0-RHD)*RHSAT*RV*T(7,K)/P(7,K))                         NSM  970
      WH(7,K)=RHSAT*RHD/DN                                              NSM  980
   35 CONTINUE                                                          NSM  990
      IF (M3.GT.0) WO(7,K)=WO(M3,J)*(WO(M3,L)/WO(M3,J))**FAC            NSM 1000
      HSTOR(K)=0.                                                       NSM 1010
      IF (HMIX(J).LE.0.) GO TO 40                                       NSM 1020
      IF (HMIX(L).LE.0.) GO TO 40                                       NSM 1030
      HSTOR(K)=HMIX(J)*(HMIX(L)/HMIX(J))**FAC                           NSM 1040
   40 CONTINUE                                                          NSM 1050
      EH(7,K)=0.                                                        NSM 1060
      EH(12,K)=0.                                                       NSM 1070
      EH(13,K)=0.                                                       NSM 1080
      EH(14,K)=0.                                                       NSM 1090
      EH(15,K)=0.                                                       NSM 1100
      IF(IHAZE.EQ.0) GO TO 60                                           NSM 1110
      IF (VIS1.LE.0.0) VIS1=VIS                                         NSM 1120
      IF (AHAZE.EQ.0.0) GO TO 45                                        NSM 1130
      EH(N,K)=AHAZE                                                     NSM 1140
C     AHAZE IS IN LOWTRAN NUMBER DENSITY UNITS                          NSM 1150
      GO TO 55                                                          NSM 1160
   45 CALL AERPRF (J,VIS1,HAZ1,IHA1,ISEA1,IVUL1,NN)                     NSM 1170
      CALL AERPRF (L,VIS1,HAZ2,IHA1,ISEA1,IVUL1,NN)                     NSM 1180
      HAZE=0.                                                           NSM 1190
      IF ((HAZ1.LE.0.0).OR.(HAZ2.LE.0.0)) GO TO 50                      NSM 1200
```

Table A1. Listing of Fortran Code LOWTRAN 5 (Cont.)

```
      HAZE=HAZ1*(HAZ2/HAZ1)**FAC                                        NSM 1210
   50 EH(N,K)=HAZE                                                      NSM 1220
   55 AHOL=HZ(ITYAER)                                                   NSM 1230
      IF (AHAZE.NE.0.) GO TO 60                                         NSM 1240
      IF (Z(K).LE.2.0) AHOL1=HZ(IHA1)                                   NSM 1250
      IF ((Z(K).GT.2.0).AND.(Z(K).LE.30.)) AHOL2=SEASN(ISEA1)           NSM 1260
      IF (Z(K).GT.9.0) AHOL3=VULCN(IVUL1)                               NSM 1270
   60 PRINT 95, Z(K),P(7,K),T(7,K),DP,RH,WH(7,K),WO(7,K),EH(N,K),VIS1,IHNSM 1280
     1A1,ISEA1,IVUL1,ITYAER,AHOL1,AHOL2,AHOL3,AHOL                      NSM 1290
   65 CONTINUE                                                          NSM 1300
      IF (IC1.LT.4) GO TO 75                                            NSM 1310
      IC2=IC1+1                                                         NSM 1320
      DO 70 K=IC2,4                                                     NSM 1330
   70 ICH(K)=ICH(K-1)                                                   NSM 1340
   75 CONTINUE                                                          NSM 1350
      RETURN                                                            NSM 1360
C                                                                       NSM 1370
   80 FORMAT (3F10.3,2F5.1,2E10.3,E10.3,F7.3,3I1)                       NSM 1380
   85 FORMAT (3F10.3,2F5.1,2E10.3,2F10.3)                               NSM 1390
   90 FORMAT (10X,26HINPUT METEOROLOGICAL DATA\/10X,2HZ=,F7.2,7H KM, P=,NSM 1400
     1F7.2,6H MB,T=,F5.1,15H C, DEW PT.TEMP,F5.1,17H C, REL HUMIDITY=,F5NSM 1410
     2.1,16H %, H2O DENSITY=,1PE9.2,7H GM M-3/10X,15H OZONE DENSITY=,E9.NSM 1420
     32,16H GM M-3,  RANGE=,0PF10.3,4H KM )                            NSM 1430
   95 FORMAT (3F10.3,2F5.1,3E10.3,F10.3,4I3,4(1X,A10))                  NSM 1440
  100 FORMAT (24H  MODEL ATMOSPHERE NO. 7,/4X,6HZ (KM),3X,6HP (MB),4X,49NSM 1450
     1HT (C) DEW PT %RH  H2O(GM.M-3) O3(GM.M-3) NO. DEN.,30X,15HAEROSOL NSM 1460
     2PROFILE,6X,10HEXTINCTION)                                         NSM 1470
      END                                                               NSM 1480
```

Table A1. Listing of Fortran Code LOWTRAN 5 (Cont.)

```
      SUBROUTINE HPROF
C                                              REVISED 12 DEC 1979
C     DEFINES THE ATMOSPHERIC DENSITY PROFILE OF THE MOLECULAR AND
C        AEROSOL AMOUNTS FOR THE MODEL SELECTED
C
      COMMON /CARD1/ MODEL,IHAZE,ITYPE,LEN,JP,IM,M1,M2,M3,ML,IEMISS,RO
     1 ,TBOUND,ISEASN,IVULCN,VIS
      COMMON /CARD2/ H1,H2,ANGLE,RANGE,BETA,HMIN,RE
      COMMON /CARD3/ V1,V2,DV,AVW,CO,CW,W(15),E(15),CA,PI
      COMMON /CNTRL/ LENST,KMAX,M,IJ,J1,J2,JMIN,JEXTRA,IL,IKMAX,NLL,NP1
     1,IFIND,NL,IKLO
      COMMON /MDATA/ Z(34),P(7,34),T(7,34),WH(7,34),WO(7,34)
     1 ,SEASN(2),VULCN(5),VSB(9),HZ(15),HMIX(34)
      COMMON RELHUM(34),HSTOR(34),EH(15,34),ICH(4),VH(15),TX(15)
      COMMON WLAY(34,15),WPATH(68,15),TBBY(68)
      COMMON ABSC(4,40),EXTC(4,40),VX2(40)
      F(A)=EXP(18.9766-14.9595*A-2.43882*A*A)*A
      DO 5 I=1,34
      DO 5 J=1,KMAX
    5 WLAY(I,J)=0.
C      RV = H2O GAS CONSTANT
      AVW=0.5E-4*(V1+V2)
      AVW=AVW*AVW
      CO=77.46+.459*AVW
      CW=43.487-0.3473*AVW
      IF(TBOUND.LE.0.AND.(M1.LE.0.OR.M.EQ.7))TBOUND=T(M,1)
      IF(TBOUND.LE.0.AND.M1.GT.0.AND.M.LT.7) TBOUND=T(M1,1)
      IF (JP.EQ.0) PRINT 45
      IF (JP.EQ.0) PRINT 50
      IF (M.LT.7) ML=NL
      RV=4.6150E-3
      DO 25 I=1,ML
      PS=P(M,I)/1013.0
      TS=273.15/T(M,I)
      WTEMP=WH(M,I)
      IF(M1.GT.0.AND.M.LT.7)PS=P(M1,I)/1013.
      IF(M1.GT.0.AND.M.LT.7) TS=273.15/T(M1,I)
      IF(M2.GT.0.AND.M.LT.7) WTEMP=WH(M2,I)
      RELHUM(I)=0.
      IF (Z(I).GT.2.0) GO TO 10
      RHOSTR=(PS*1013.0)*(TS/273.15)/RV
      RELHUM(I)=100.0*(WTEMP/F(TS))*((RHOSTR-F(TS))/  (RHOSTR-WTEMP))
10    D=0.1*WTEMP
      X=PS*TS
      PT=PS*SQRT(TS)
      EH(1,I)=D*PT**0.9
      EH(2,I)=X*PT**0.75
      EH(4,I)=0.8*PT*X
      PPW=4.56E-5*D*273.15/TS
      TS1=(296.0/273.15)*TS
      EH(5,I)=D*PPW*EXP(6.08*(TS1-1.0))+0.002*D*(PS-PPW)
      EH(10,I)=D*(PPW+0.12*(PS-PPW))*EXP(4.56*(TS1-1.0))
      EH(6,I)=X
C     SUBROUTINE AERPRF COMPUTES EH(7,I)
C     EH(7,I)=AEROSOL FOR 0-2KM
C     EH(12,I)=AEROSOL FOR 2-9KM
C     EH(13,I)=AEROSOL FOR 9-30KM
C     EH(14,I)=AEROSOL FOR 30-100KM
      IF (M.NE.7) CALL AERPRF (I,VIS,HAZE,IHAZE,ISEASN,IVULCN,N)
      IF (M.EQ.7) GO TO 15
```

Table A1. Listing of Fortran Code LOWTRAN 5 (Cont.)

```
      EH(7,I)=0.                                                        HPR  610
      EH(12,I)=0.                                                       HPR  620
      EH(13,I)=0.                                                       HPR  630
      EH(14,I)=0.                                                       HPR  640
      EH(15,I)=0.                                                       HPR  650
      EH(N,I)=HAZE                                                      HPR  660
   15 CONTINUE                                                          HPR  670
      EH(15,I)=RELHUM(I)*EH(7,I)                                        HPR  680
      IF(ICH(1).GT.7)EH(15,I)=RELHUM(I)*EH(12,I)                        HPR  690
      EH(8,I)=46.6667*WO(M,I)                                           HPR  700
      IF (M3.GT.0.AND.M.LT.7) EH(8,I)=46.667*WO(M3,I)                   HPR  710
      EH(3,I)=EH(8,I)*PT**0.4                                           HPR  720
C     EH(11,I)=HNO3 ABSORBER AMOUNT (ATM-CM)/KM                         HPR  730
      EH(11,I)=PS*TS*HMIX(I)*1.0E-04                                    HPR  740
      IF (M.EQ.7) EH(11,I)=PS*TS*HSTOR(I)*1.0E-04                       HPR  750
      EH(9,I)=1.0                                                       HPR  760
      REF=1.0E-6*(CO*X*1013.0/273.15-PPW*CW)                            HPR  770
      IF (I.EQ.ML) GO TO 20                                             HPR  780
      P2=P(M,I+1)                                                       HPR  790
      T2=T(M,I+1)                                                       HPR  800
      W2=WH(M,I+1)                                                      HPR  810
      IF(M1.GT.0.AND.M.LT.7) P2=P(M1,I+1)                               HPR  820
      IF (M1.GT.0.AND.M.LT.7) T2=T(M1,I+1)                              HPR  830
      IF (M2.GT.0.AND.M.LT.7) W2=WH(M2,I+1)                             HPR  840
      PPW=4.56E-6*W2*T2                                                 HPR  850
      EH(5,I)=0.5*(REF+1.0E-6*(CO*P2/T2-PPW*CW))                        HPR  860
   20 IF (I.EQ.ML) EH(9,I)=0.                                           HPR  870
      IF (JP.NE.0) GO TO 25                                             HPR  880
      P1=P(M,I)                                                         HPR  890
      T1=T(M,I)                                                         HPR  900
      IF(M1.GT.0.AND.M.LT.7) P1=P(M1,I)                                 HPR  910
      IF(M1.GT.0.AND.M.LT.7) T1=T(M1,I)                                 HPR  920
      PRINT 40, I,Z(I),P1,T1,(EH(K,I),K=1,6),EH(9,I),EH(8,I)            HPR  930
   25 CONTINUE                                                          HPR  940
      IF(JP.EQ.0) WRITE (6,55)                                          HPR  950
      DO 35 I=1,ML                                                      HPR  960
      IF (JP.NE.0) GO TO 30                                             HPR  970
      P1=P(M,I)                                                         HPR  980
      T1=T(M,I)                                                         HPR  990
      IF(M1.GT.0.AND.M.LT.7) P1=P(M1,I)                                 HPR 1000
      IF(M1.GT.0.AND.M.LT.7) T1=T(M1,I)                                 HPR 1010
      PRINT 40, I,Z(I),P1,T1,(EH(K,I),K=10,11),EH(7,I),(EH(K,I),K=12,15)HPR 1020
     1,RELHUM(I)                                                        HPR 1030
   30 EH(9,I)=EH(9,I)+1.                                                HPR 1040
   35 CONTINUE                                                          HPR 1050
      RETURN                                                            HPR 1060
C                                                                       HPR 1070
   40 FORMAT (I4,0PF9.2,F9.3,F9.3,1X,1P8E10.3)                          HPR 1080
   45 FORMAT (1H1,///10X,20H HORIZONTAL PROFILES/)                      HPR 1090
   50 FORMAT (4H  IC,5X,3HALT,6X,1HP,8X,1HT,8X,3HH2O,6X,4HCO2+,8X,2HO3,8HHPR 1100
     1X,2HN2,5X,8HH2O(10M),4X,4HMOLS,5X,5H(N-1),4X,6HO3(UV))            HPR 1110
   55 FORMAT (1H1,///10X,20H HORIZONTAL PROFILES/,4H  IC,5X,3HALT,6X,1HPHPR 1120
     1,8X,1HT,6X,7HH2O(4M),5X,4HHNO3,6X,4HAER1,6X,4HAER2,6X,4HAER3,6X,4HHPR 1130
     2AER4,3X,9H(AER1*RH),5X,2HRH)                                      HPR 1140
      END                                                               HPR 1150
```

Table A1. Listing of Fortran Code LOWTRAN 5 (Cont.)

```
      SUBROUTINE AERPRF (I,VIS,HAZE,IHAZE,ISEASN,IVULCN,N)
C     WILL COMPUTE HORIZONTAL PROFILES FOR AEROSOLS
      COMMON/PRFDTA/ZHT(34),HZ2K(34,5),FAWI50(34),FAWI23(34),SPSU50(34),
     1SPSU23(34),BASTFW(34),VUMOFW(34),HIVUFW(34),EXVUFW(34),BASTSS(34),
     2VUMOSS(34),HIVUSS(34),EXVUSS(34),UPNATM(34),VUTONO(34),
     3VUTOEX(34),EXUPAT(34)
      DIMENSION VS(5)
      DATA (VS(J),J=1,5)/50.,23.,10.,5.,2./
      HAZE=0.
      CALL PRFDTA
      N=7
      IF (IHAZE.EQ.0) RETURN
      IF (ZHT(I).GT.2.0) GO TO 15
      DO 5 J=2,5
      IF (VIS.GE.VS(J)) GO TO 10
    5 CONTINUE
      J=5
   10 CONST=1./(1./VS(J)-1./VS(J-1))
      HAZE=CONST*((HZ2K(I,J)-HZ2K(I,J-1))/VIS+HZ2K(I,J-1)/VS(J)-HZ2K(I,J
     1)/VS(J-1))
      RETURN
   15 IF (ZHT(I).GT.9.0) GO TO 35
      N=12
      CONST=1./(1./23.-1./50.)
      IF (ISEASN.GT.1) GO TO 25
      IF (VIS.LE.23.) HAZE=SPSU23(I)
      IF (VIS.LE.23.) RETURN
      IF (ZHT(I).GT.4.0) GO TO 20
      HAZE=CONST*((SPSU23(I)-SPSU50(I))/VIS+SPSU50(I)/23.-SPSU23(I)/50.)
      RETURN
   20 HAZE=SPSU50(I)
      RETURN
   25 IF (VIS.LE.23.) HAZE=FAWI23(I)
      IF (VIS.LE.23.) RETURN
      IF (ZHT(I).GT.4.0) GO TO 30
      HAZE=CONST*((FAWI23(I)-FAWI50(I))/VIS+FAWI50(I)/23.-FAWI23(I)/50.)
      RETURN
   30 HAZE=FAWI50(I)
      RETURN
   35 IF (ZHT(I).GT.30.0) GO TO 75
      N=13
      HAZE=BASTSS(I)
      IF (ISEASN.GT.1) GO TO 55
      IF (IVULCN.EQ.0) HAZE=BASTSS(I)
      IF (IVULCN.EQ.0) RETURN
      GO TO (40,45,50,50,45), IVULCN
   40 HAZE=BASTSS(I)
      RETURN
   45 HAZE=VUMOSS(I)
      RETURN
   50 HAZE=HIVUSS(I)
      RETURN
   55 IF (IVULCN.EQ.0) HAZE=BASTFW(I)
      IF (IVULCN.EQ.0) RETURN
      GO TO (60,65,70,70,65), IVULCN
   60 HAZE=BASTFW(I)
      RETURN
   65 HAZE=VUMOFW(I)
      RETURN
   70 HAZE=HIVUFW(I)
      RETURN
   75 N=14
      IF (IVULCN.GT.1) GO TO 80
      HAZE=UPNATM(I)
      RETURN
   80 HAZE=VUTONO(I)
      RETURN
      END
```

Table A1. Listing of Fortran Code LOWTRAN 5 (Cont.)

```
      SUBROUTINE PRFDTA
C                                         REVISED 16 JUNE 1980
C        AEROSOL PROFILE DATA
C
      COMMON/PRFDTA/ZHT(34),HZ2K(34,5),FAWI50(34),FAWI23(34),SPSU50(34),
     1SPSU23(34),BASTFW(34),VUMOFW(34),HIVUFW(34),EXVUFW(34),BASTSS(34),
     2VUMOSS(34),HIVUSS(34),EXVUSS(34),UPNATM(34),VUTONO(34),
     3VUTOEX(34),EXUPAT(34)
      DATA(ZHT(I),I=1, 34)/
     *    0.,     1.,     2.,     3.,     4.,     5.,     6.,     7.,     8.,
     *    9.,    10.,    11.,    12.,    13.,    14.,    15.,    16.,    17.,
     *   18.,    19.,    20.,    21.,    22.,    23.,    24.,    25.,    30.,
     *   35.,    40.,    45.,    50.,    70.,   100.,99999./
      DATA (  HZ2K(  1,I) ,I=  1,  5)/
     1 6.62E-02, 1.58E-01, 3.79E-01, 7.70E-01, 1.54E+00/
      DATA (  HZ2K(  2,I) ,I=  1,  5)/
     1 4.15E-02, 9.91E-02, 3.79E-01, 7.70E-01, 1.54E+00/
      DATA (  HZ2K(  3,I) ,I=  1,  5)/
     1 2.60E-02, 6.21E-02, 6.21E-02, 6.21E-02, 6.21E-02/
      DATA(FAWI50(I),I=  4, 10)/
     1 1.14E-02, 6.43E-03, 4.85E-03, 3.54E-03, 2.31E-03, 1.41E-03,
     2 9.80E-04/
      DATA(FAWI23(I),I=  4, 10)/
     1 2.72E-02, 1.20E-02, 4.85E-03, 3.54E-03, 2.31E-03, 1.41E-03,
     2 9.80E-04/
      DATA(SPSU50(I),I=  4, 10)/
     1 1.46E-02, 1.02E-02, 9.31E-03, 7.71E-03, 6.23E-03, 3.37E-03,
     2 1.82E-03/
      DATA(SPSU23(I),I=  4, 10)/
     1 2.46E-02, 1.85E-02, 9.31E-03, 7.71E-03, 6.23E-03, 3.37E-03,
     2 1.82E-03/
      DATA(BASTFW(I),I= 11, 27)/
     1 7.87E-04, 7.14E-04, 6.64E-04, 6.23E-04, 6.45E-04, 6.43E-04,
     2 6.41E-04, 6.00E-04, 5.62E-04, 4.91E-04, 4.23E-04, 3.52E-04,
     3 2.95E-04, 2.42E-04, 1.90E-04, 1.50E-04, 3.32E-05/
      DATA(VUMOFW(I),I= 11, 27)/
     1 1.38E-03, 1.79E-03, 2.21E-03, 2.75E-03, 2.89E-03, 2.92E-03,
     2 2.73E-03, 2.46E-03, 2.10E-03, 1.71E-03, 1.35E-03, 1.09E-03,
     3 8.60E-04, 6.60E-04, 5.15E-04, 4.09E-04, 7.60E-05/
      DATA(HIVUFW(I),I= 11, 27)/
     1 1.71E-03, 2.31E-03, 3.25E-03, 4.52E-03, 6.40E-03, 7.81E-03,
     2 9.42E-03, 1.07E-02, 1.10E-02, 8.60E-03, 5.10E-03, 2.70E-03,
     3 1.46E-03, 8.90E-04, 5.80E-04, 4.09E-04, 7.60E-05/
      DATA(EXVUFW(I),I= 11, 27)/
     1 1.71E-03, 2.31E-03, 3.25E-03, 4.52E-03, 6.40E-03, 1.01E-02,
     2 2.35E-02, 6.10E-02, 1.00E-01, 4.00E-02, 9.15E-03, 3.13E-03,
     3 1.46E-03, 8.90E-04, 5.80E-04, 4.09E-04, 7.60E-05/
      DATA(BASTSS(I),I= 11, 27)/
     1 1.14E-03, 7.99E-04, 6.41E-04, 5.17E-04, 4.42E-04, 3.95E-04,
     2 3.82E-04, 4.25E-04, 5.20E-04, 5.81E-04, [illegible]-04, 5.02E-04,
     3 4.20E-04, 3.00E-04, 1.98E-04, 1.31E-04, 3.32E-05/
      DATA(VUMOSS(I),I= 11, 27)/
     1 1.85E-03, 2.12E-03, 2.45E-03, 2.80E-03, 2.89E-03, 2.92E-03,
     2 2.73E-03, 2.46E-03, 2.10E-03, 1.71E-03, 1.35E-03, 1.09E-03,
     3 8.60E-04, 6.60E-04, 5.15E-04, 4.09E-04, 7.60E-05/
      DATA(HIVUSS(I),I= 11, 27)/
     1 1.85E-03, 2.12E-03, 2.45E-03, 2.80E-03, 3.60E-03, 5.23E-03,
     2 8.11E-03, 1.20E-02, 1.52E-02, 1.53E-02, 1.17E-02, 7.09E-03,
     3 4.50E-03, 2.40E-03, 1.28E-03, 7.76E-04, 7.60E-05/
      DATA(EXVUSS(I),I= 11, 27)/
```

Table A1. Listing of Fortran Code LOWTRAN 5 (Cont.)

```
     1 1.85E-03, 2.12E-03, 2.45E-03, 2.80E-03, 3.60E-03, 5.23E-03,        PRF  610
     2 8.11E-03, 1.27E-02, 2.32E-02, 4.85E-02, 1.00E-01, 5.50E-02,        PRF  620
     3 6.10E-03, 2.40E-03, 1.28E-03, 7.76E-04, 7.60E-05/                  PRF  630
      DATA(UPNATM(I),I= 27, 34)/                                          PRF  640
     1 3.32E-05, 1.64E-05, 7.99E-06, 4.01E-06, 2.10E-06, 1.60E-07,        PRF  650
     2 9.31E-10, 0.        /                                              PRF  660
      DATA(VUTONO(I),I= 27, 34)/                                          PRF  670
     1 7.60E-05, 2.45E-05, 7.99E-06, 4.01E-06, 2.10E-06, 1.60E-07,        PRF  680
     2 9.31E-10, 0.        /                                              PRF  690
      DATA(VUTOEX(I),I= 27, 34)/                                          PRF  700
     1 7.60E-05, 7.20E-05, 6.95E-05, 6.60E-05, 5.04E-05, 1.03E-05,        PRF  710
     2 4.50E-07, 0.        /                                              PRF  720
      DATA(EXUPAT(I),I= 27, 34)/                                          PRF  730
     1 3.32E-05, 4.25E-05, 5.59E-05, 6.60E-05, 5.04E-05, 1.03E-05,        PRF  740
     2 4.50E-07, 0.        /                                              PRF  750
CCC          0-2KM                                                        PRF  760
CCC            HZ2K=5 VIS PROFILES- 50KM,23KM,10KM,5KM,2KM                PRF  770
CCC          >2-9KM                                                       PRF  780
CCC            FAWI50=FALL/WINTER   50KM VIS                              PRF  790
CCC            FAWI23=FALL/WINTER    23KM VIS                             PRF  800
CCC            SPSU50=SPRING/SUMMER  50KM VIS                             PRF  810
CCC            SPSU23=SPRING/SUMMER  23KM VIS                             PRF  820
CCC          >9-30KM                                                      PRF  830
CCC            BASTFW=BACKGROUND STRATOSPHERIC   FALL/WINTER              PRF  840
CCC            VUMOFW=MODERATE VOLCANIC          FALL/WINTER              PRF  850
CCC            HIVUFW=HIGH VOLCANIC              FALL/WINTER              PRF  860
CCC            EXVUFW=EXTREME VOLCANIC           FALL/WINTER              PRF  870
CCC            BASTSS,VUMOSS,HIVUSS,EXVUSS=      SPRING/SUMMER            PRF  880
CCC          >30-100KM                                                    PRF  890
CCC            UPNATM=NORMAL UPPER ATMOSPHERIC                            PRF  900
CCC            VUTONO=TRANSITION FROM VOLCANIC TO NORMAL                  PRF  910
CCC            VUTOEX=TRANSITION FROM VOLCANIC TO EXTREME                 PRF  920
CCC            EXUPAT=EXTREME UPPER ATMOSPHERIC                           PRF  930
CCC   READ IN AEROSOL MODELS   EXTINCTION AND ABSORPTION COEFFICIENTS     PRF  940
      RETURN                                                              PRF  950
      END                                                                 PRF  960
```

Table A1. Listing of Fortran Code LOWTRAN 5 (Cont.)

```
      SUBROUTINE GEO
C
C     SPHERICAL GEOMETRY WITH REFRACTION
C     DEFINES ABSORBER AMOUNTS FOR THE ATMOSPHERIC SLANT PATH
C     USED,TO SET UP VERTICAL PROFILE ARRAY VH AND DEFINES MATRIX
C     WLAY, FOR USE IN SUBROUTINE PATH
C
      COMMON /CARD1/ MODEL,IHAZE,ITYPE,LEN,JP,IM,M1,M2,M3,ML,IEMISS,RO
     1 ,TBOUND,ISEASN,IVULCN,VIS
      COMMON /CARD2/ H1,H2,ANGLE,RANGE,BETA,HMIN,RE
      COMMON /CARD3/ V1,V2,DV,AVW,CO,CW,W(15),E(15),CA,PI
      COMMON /CNTRL/ LENST,KMAX,M,IJ,J1,J2,JMIN,JEXTRA,IL,IKMAX,NLL,NP1
     1,IFIND,NL,IKLO
      COMMON /MDATA/ Z(34),P(7,34),T(7,34),WH(7,34),WO(7,34)
     1 ,SEASN(2),VULCN(5),VSB(9),HZ(15),HMIX(34)
      COMMON RELHUM(34),HSTOR(34),EH(15,34),ICH(4),VH(15),TX(15)
      COMMON WLAY(34,15),WPATH(68,15),TBBY(68)
      COMMON ABSC(4,40),EXTC(4,40),VX2(40)
      JSTOP=0
      JEXTRA=0
      IF (IFIND.EQ.1) CALL ANGL (H1,H2,ANGLE,BETA,LENST,M,NL,RE,PI,ML)
      IFIND=0
      LEN=LENST
      IF (ITYPE.EQ.1) GO TO 20
      DO 5 K=1,KMAX
      VH(K)=0.0
    5 CONTINUE
      BETA=0.0
      SR=0.0
      IP=0
C      NOW DEFINE CONSTANT PRESSURE PATH QUANTITES  EH(1-8)
      Y=CA*ANGLE
      SPHI=SIN(Y)
      R1=(RE+H1)*SPHI
      IF (H1.GT.Z(NL)) GO TO 10
      GO TO 20
   10 X=(RE+Z(NL))/(RE+H1)
      IF (SPHI.GT.X) GO TO 15
      H1=Z(NL)
      J1=NL
      SPHI=SPH1/X
      ANGLE=180.0-ASIN(SPHI)/CA
      R1=(RE+H1)*SPHI
      GO TO 20
   15 HMIN=R1-RE
      PRINT 235, HMIN
      GO TO 210
   20 CONTINUE
      IP=1
      X1=H1
      CALL POINT (H1,YN,N,NP1,IP)
      J1=N
      TX1=TX(9)
      DO 25 K=1,KMAX
   25 E(K)=TX(K)
      IF (ITYPE.EQ.1) GO TO 80
      IF (ITYPE.EQ.3) H2=Z(NL)
      IF (ANGLE.GT.90,0) GO TO 90
   30 IF (ANGLE.GT.90.0.AND.NP1.GT.0) J1=J1+1
      J2=NL
```

Table A1. Listing of Fortran Code LOWTRAN 5 (Cont.)

```
      IF (ITYPE.EQ.3) GO TO 35                                          GEO  610
      CALL POINT (H2,YN,N,NP,IP)                                        GEO  620
      J2=N                                                              GEO  630
      IF (NP.GT.0) J2=J2-1                                              GEO  640
   35 DO 40 K=1,KMAX                                                    GEO  650
      IF (K.EQ.9) GO TO 40                                              GEO  660
      EH(K,J1)=F(K)                                                     GEO  670
      IF (ITYPE.EQ.3) GO TO 40                                          GEO  680
      EH(K,J2+1)=TX(K)                                                  GEO  690
   40 CONTINUE                                                          GEO  700
      IF (J1.EQ.J2) TX1=TX1+YN-EH(9,J1)                                 GEO  710
C****  NOW DEFINE VERTICAL PATH QUANTITIES VH                            GEO  720
      IF (JP.EQ.0) PRINT 225                                            GEO  730
      DO 45 K=1,KMAX                                                    GEO  740
   45 W(K)=0.                                                           GEO  750
      DO 75 I=J1,J2                                                     GEO  760
      X1=Z(I)                                                           GEO  770
      X2=Z(I+1)                                                         GEO  780
      IF (I.EQ.J1) X1=H1                                                GEO  790
      IF (I.EQ.J2) X2=H2                                                GEO  800
      DZ=X2-X1                                                          GEO  810
      IF (I.EQ.NL) DZ=Z(I)-Z(I-1)                                       GEO  820
      DS=DZ                                                             GEO  830
C        UPWARD TRAJECTORY                                              GEO  840
      RX=(RE+X1)/(RE+X2)                                                GEO  850
      THETA=ASIN(SPHI)/CA                                               GEO  860
      PHI=ASIN(SPHI*RX)/CA                                              GEO  870
      BET=THETA-PHI                                                     GEO  880
      SALP=RX*SPHI                                                      GEO  890
      IF (SPHI.GT.1.E-10) DS=(RE+X2)*SIN(BET*CA)/SPHI                   GEO  900
      BETA=BETA+BET                                                     GEO  910
      PSI=BETA+PHI-ANGLE                                                GEO  920
      PHI=180.-PHI                                                      GEO  930
      SR=SR+DS                                                          GEO  940
      JEXTRA=0                                                          GEO  950
      DO 70 K=1,KMAX                                                    GEO  960
      EV=DS*EH(K,I)                                                     GEO  970
      IF (I.EQ.NL) GO TO 50                                             GEO  980
      IF (EH(K,I).EQ.0.0.OR.EH(K,I+1).EQ.0.0) GO TO 55                  GEO  990
      IF (ABS((EH(K,I)/EH(K,I+1))-1.0).LT.1.0E-6) GO TO 60              GEO 1000
      EV=DS*(EH(K,I)-EH(K,I+1))/ALOG(EH(K,I)/EH(K,I+1))                 GEO 1010
      GO TO 60                                                          GEO 1020
   50 IF (EH(K,I).EQ.0.0) GO TO 55                                      GEO 1030
      IF (EH(K,I-1).EQ.0.0) GO TO 55                                    GEO 1040
      IF (ABS((EH(K,I-1)/EH(K,I))-1.0).LT.1.0E-6) GO TO 60              GEO 1050
      EV=EV/ALOG(EH(K,I-1)/EH(K,I))                                     GEO 1060
      GO TO 60                                                          GEO 1070
   55 EV=0.                                                             GEO 1080
   60 VH(K)=VH(K)+EV                                                    GEO 1090
      IF (I.EQ.JSTOP) GO TO 65                                          GEO 1100
      WLAY(I,K)=EV+W(K)                                                 GEO 1110
      W(K)=0.                                                           GEO 1120
      GO TO 70                                                          GEO 1130
   65 W(K)=EV                                                           GEO 1140
      IF (J1.NE.J2) GO TO 70                                            GEO 1150
      WLAY(J2+1,K)=W(K)                                                 GEO 1160
      W(K)=0.                                                           GEO 1170
      JEXTRA=1                                                          GEO 1180
   70 CONTINUE                                                          GEO 1190
      IF (JP.EQ.0) PRINT 245, I,X1,(VH(L),L=1,8),PSI,PHI,BETA,THETA,SR  GEO 1200
```

Table A1. Listing of Fortran Code LOWTRAN 5 (Cont.)

```
      IF (JP.EQ.0) PRINT 240, X2,(VH(L),L=10,14),DS                     GEO 1210
      IF (I.GE.NL) GO TO 75                                             GEO 1220
      IF (I+1.EQ.J2) EH(9,I+1)=YN                                       GEO 1230
      IF (I.EQ.J1) EH(9,I)=TX1                                          GEO 1240
      RN=EH(9,I+1)/EH(9,I)                                              GEO 1250
      SPHI=SPHI*RX/RN                                                   GEO 1260
      IF (SALP.GE.RN) SPHI=SALP                                         GEO 1270
   75 CONTINUE                                                          GEO 1280
      GO TO 190                                                         GEO 1290
C     HORIZONTAL PATH                                                   GEO 1300
   80 DO 85 K=1,KMAX                                                    GEO 1310
      W(K)=RANGE*EH(K,1)                                                GEO 1320
      IF (M.GT.0) W(K)=RANGE*TX(K)                                      GEO 1330
      VH(K)=W(K)                                                        GEO 1340
   85 CONTINUE                                                          GEO 1350
      GO TO 200                                                         GEO 1360
   90 CONTINUE                                                          GEO 1370
C       DOWNWARD TRAJECTORY                                             GEO 1380
      K2=0                                                              GEO 1390
      IF (NP1.EQ.1) J1=J1-1                                             GEO 1400
      J2=J1+1                                                           GEO 1410
      J=J1+1                                                            GEO 1420
      YN1=YN                                                            GEO 1430
      IF (H2.GT.Z(J1+1).OR.H1.EQ.H2) GO TO 100                          GEO 1440
      IF (NP1.EQ.1.AND.H2.GE.Z(J1+1)) GO TO 100                         GEO 1450
      CALL POINT (H2,YN,N,NP2,IP)                                       GEO 1460
      DO 95 K=1,KMAX                                                    GEO 1470
   95 W(K)=TX(K)                                                        GEO 1480
      TX2=TX(9)                                                         GEO 1490
      YN2=YN                                                            GEO 1500
      IF (H2.LT.H1) H=H2                                                GEO 1510
      J2=N                                                              GEO 1520
      IF (J1.EQ.J2) TX2=TX1+YN2-EH(9,N)                                 GEO 1530
      IF (H2.GT.H1) TX1=TX2                                             GEO 1540
      IF (J1.EQ.J2.AND.H2.LT.H1) YN1=TX2                                GEO 1550
  100 A0=(RE+H1)*SPHI*YN1                                               GEO 1560
      IF (H2.GE.H1) YN2=YN1                                             GEO 1570
      DO 105 I=1,J1                                                     GEO 1580
      HMIN=A0/EH(9,I)-RE                                                GEO 1590
      IF (I.EQ.J1) HMIN=A0/YN1-RE                                       GEO 1600
      JMIN=I                                                            GEO 1610
      IF (HMIN.LE.Z(I+1)) GO TO 110                                     GEO 1620
  105 CONTINUE                                                          GEO 1630
  110 X=HMIN                                                            GEO 1640
      IF (HMIN.LE.0.0) GO TO 120                                        GEO 1650
      CALL POINT (X,YN,N,NP,IP)                                         GEO 1660
      JMIN=N                                                            GEO 1670
      TX3=TX(9)                                                         GEO 1680
      IF (J2.EQ.N.OR.J1.EQ.N) TX3=YN2+TX(9)-EH(9,N)                     GEO 1690
      IF (TX3.LT.0.0) TX3=TX(9)                                         GEO 1700
      IF (J1.EQ.N.AND.H2.GE.H1) GO TO 115                               GEO 1710
      HMIN=A0/TX3-RE                                                    GEO 1720
      IF (ABS(X-HMIN).GT.0.0001) GO TO 110                              GEO 1730
  115 IF (J1.EQ.N.AND.H2.GE.H1) YN1=TX3                                 GEO 1740
      IF (J2.EQ.N.AND.J1.NE.J2) YN2=TX3                                 GEO 1750
      IF (H2.GE.H1) TX2=TX3                                             GEO 1760
      IF (H2.GE.H1) J2=N                                                GEO 1770
      IF (H2.GE.H1.OR.H2.LT.HMIN) H=HMIN                                GEO 1780
      PRINT 250, HMIN                                                   GEO 1790
      IF (H2.LT.HMIN) J2=N                                              GEO 1800
```

Table A1. Listing of Fortran Code LOWTRAN 5 (Cont.)

```
      IF (H2.LT.HMIN) PRINT 270, HMIN                                   GEO 1810
      GO TO 125                                                         GEO 1820
  120 PRINT 250, HMIN                                                   GEO 1830
      IF (H2.LT.H1) GO TO 125                                           GEO 1840
      IF (ITYPE.EQ.3.OR.H2.GE.H1) PRINT 255                             GEO 1850
      ITYPE=2                                                           GEO 1860
      TX2=EH(9,1)                                                       GEO 1870
      JMIN=0                                                            GEO 1880
      J2=1                                                              GEO 1890
      H2=0.0                                                            GEO 1900
      H=0.0                                                             GEO 1910
C****  NOW DEFINE VERTICAL PATH QUANTITIES VH                           GEO 1920
  125 IF (JP.EQ.0) PRINT 225                                            GEO 1930
      JSTOR=J-1                                                         GEO 1940
      DO 155 I=1,NL                                                     GEO 1950
      J=J-1                                                             GEO 1960
      REF=EH(9,J)                                                       GEO 1970
      IF (I.EQ.1) REF=YN1                                               GEO 1980
      IF (I.EQ.1.AND.K2.EQ.1) REF=YN2                                   GEO 1990
      IF (J.EQ.J2.AND.K2.EQ.0) REF=TX2                                  GEO 2000
      IF (I.NE.1) X1=Z(J+1)                                             GEO 2010
      X2=Z(J)                                                           GEO 2020
      IF (J.EQ.J2.AND.K2.EQ.0) X2=H                                     GEO 2030
      IF (J.EQ.JMIN.AND.K2.EQ.1) X2=HMIN                                GEO 2040
      HM=(RE+X1)*SPHI-RE                                                GEO 2050
      IF (HM.GT.Z(J).AND.HM.GT.X2) X2=HM                                GEO 2060
      RX=(RE+X1)/(RE+X2)                                                GEO 2070
      DS=X1-X2                                                          GEO 2080
      ALP=90.0                                                          GEO 2090
      THET=ASIN(SPHI)/CA                                                GEO 2100
      SALP=RX*SPHI                                                      GEO 2110
      IF (ABS(X2-HM).GT.1.0E-5) ALP=ASIN(SALP)/CA                       GEO 2120
      BET=ALP-THET                                                      GEO 2130
      IF (SPHI.GT.1.0E-10) DS=(RE+X2)*SIN(BET*CA)/SPHI                  GEO 2140
      THETA=180.0-THET                                                  GEO 2150
      BETA=BETA+BET                                                     GEO 2160
      PSI=BETA-ALP-ANGLE+180.0                                          GEO 2170
      SR=SR+DS                                                          GEO 2180
      DO 150 K=1,KMAX                                                   GEO 2190
      AJ=EH(K,J)                                                        GEO 2200
      BJ=EH(K,J+1)                                                      GEO 2210
      IF (J.EQ.J1) BJ=F(K)                                              GEO 2220
      IF (J.EQ.J2.AND.H2.LT.H1.AND.H2.GT.0.0) AJ=W(K)                   GEO 2230
      IF (J.EQ.JMIN.AND.H2.GE.H1) AJ=TX(K)                              GEO 2240
      IF (J.EQ.JMIN.AND.ABS(H2-HM).LT.1.0E-5) AJ=TX(K)                  GEO 2250
      IF (K2.EQ.0) GO TO 130                                            GEO 2260
      IF (J.EQ.J2) BJ=W(K)                                              GEO 2270
      IF (J.EQ.JMIN) AJ=TX(K)                                           GEO 2280
  130 IF (AJ.EQ.0.0.OR.BJ.EQ.0.0) GO TO 140                             GEO 2290
      IF (ABS((AJ/BJ)-1.0).LE.1.0E-6) GO TO 135                         GEO 2300
      EV=DS*(AJ-BJ)/ALOG(AJ/BJ)                                         GEO 2310
      GO TO 145                                                         GEO 2320
  135 EV=DS*AJ                                                          GEO 2330
      GO TO 145                                                         GEO 2340
  140 EV=0.0                                                            GEO 2350
  145 VH(K)=VH(K)+EV                                                    GEO 2360
  150 WLAY(J,K)=EV                                                      GEO 2370
      IF (JP.EQ.0) PRINT 245, J,X1,(VH(L),L=1,8),PSI,ALP,BETA,THETA,SR  GEO 2380
      IF (JP.EQ.0) PRINT 240, X2,(VH(L),L=10,14),DS                     GEO 2390
      IF (J.EQ.J2.AND.H2.GE.H1) GO TO 180                               GEO 2400
```

Table A1. Listing of Fortran Code LOWTRAN 5 (Cont.)

```
      IF (J.EQ.JMIN.AND.K2.EQ.1) GO TO 170                              GEO 2410
      IF (J.NE.1) RN=REF/EH(9,J-1)                                      GEO 2420
      IF (J.EQ.J2+1) RN=REF/TX2                                         GEO 2430
      IF (J.EQ.J2.AND.K2.EQ.0) RN=REF/YN2                               GEO 2440
      IF (J.EQ.(JMIN+1).AND.K2.EQ.1) RN=REF/TX3                         GEO 2450
      IF (SALP.GE.RN) RN=1.0                                            GEO 2460
      SPHI=SALP*RN                                                      GEO 2470
      IF (J.EQ.J2.AND.K2.EQ.0) GO TO 160                                GEO 2480
  155 CONTINUE                                                          GEO 2490
  160 IF (HMIN.LE.0.0) GO TO 190                                        GEO 2500
      IF (LEN.EQ.0) PRINT 260                                           GEO 2510
      IF (LEN.EQ.0) GO TO 190                                           GEO 2520
      IF (LEN.EQ.1) PRINT 265                                           GEO 2530
      K2=1                                                              GEO 2540
      X1=X2                                                             GEO 2550
      IF (ABS(X1-HMIN).LE.0.001) GO TO 190                              GEO 2560
      H=HMIN                                                            GEO 2570
      J=J2+1                                                            GEO 2580
      IF (NP2.EQ.1) J=J-1                                               GEO 2590
      B=BETA                                                            GEO 2600
      PH=180.0-ASIN(SPHI)/CA                                            GEO 2610
      TS=SR                                                             GEO 2620
      PS=PSI                                                            GEO 2630
      DO 165 K=1,KMAX                                                   GEO 2640
  165 E(K)=VH(K)                                                        GEO 2650
      GO TO 125                                                         GEO 2660
  170 BETA=2.*BETA-B                                                    GEO 2670
      PSI=2.*PSI-PS                                                     GEO 2680
      SR=2.*SR-TS                                                       GEO 2690
C       LONG PATH, TAKEN                                                GEO 2700
      PHI=PH                                                            GEO 2710
      DO 175 K=1,KMAX                                                   GEO 2720
  175 VH(K)=2.*VH(K)-E(K)                                               GEO 2730
      GO TO 190                                                         GEO 2740
  180 DO 185 K=1,KMAX                                                   GEO 2750
  185 VH(K)=2.0*VH(K)                                                   GEO 2760
      BETA=2.0*BETA                                                     GEO 2770
      SR=2.0*SR                                                         GEO 2780
      IF (H2.EQ.H1) GO TO 190                                           GEO 2790
      RN=TX1/YN1                                                        GEO 2800
      SPHI=SIN(ANGLE*CA)                                                GEO 2810
      IF (SPHI.LT.RN) SPHI=SPHI/RN                                      GEO 2820
      GO TO 30                                                          GEO 2830
  190 CONTINUE                                                          GEO 2840
      IF (ANGLE.GT.90.0) PRINT 215, HM                                  GEO 2850
      DO 195 K=1,KMAX                                                   GEO 2860
      W(K)=VH(K)                                                        GEO 2870
  195 CONTINUE                                                          GEO 2880
  200 WRITE (6,220)                                                     GEO 2890
      WRITE (6,280)                                                     GEO 2900
      WRITE (6,230) (W(I),I=1,8),W(10),W(11)                            GEO 2910
      IF(W(7).GT.0.0.AND.ICH(1).LE.7) W(15)=W(15)/W(7)                  GEO 2920
      IF(W(12).GT.0.0.AND.ICH(1).GT.7) W(15)=W(15)/W(12)                GEO 2930
  205 WRITE (6,275) (W(I),I=12,15)                                      GEO 2940
      I=1                                                               GEO 2950
  210 RETURN                                                            GEO 2960
C                                                                       GEO 2970
  215 FORMAT (7F10.3)                                                   GEO 2980
  220 FORMAT (/10X,38H EQUIVALENT SEA LEVEL ABSORBER AMOUNTS//21X,112H WGEO 2990
     1ATER VAPOUR    CO2 ETC.       OZONE    NITROGEN (CONT)  H2O  (CONGEO 3000
```

Table A1. Listing of Fortran Code LOWTRAN 5 (Cont.)

```
     2T)       MOL   SCAT       AER1        OZONE(U-V)/24X,7HGM CM-2,10X,2HKGEO 3010
     3H,10X,5HATM CM,10X,2HKM,9X,7HGM CM-2,10X,2HKM.11X,5X,10X,6HATM CM)GEO 3020
 225 FORMAT (1H1,/10X,20H   VERTICAL PROFILES,//,1X,2HID,3X,3HALT,6X,3HGEO 3030
     1H2O,7X,4HCO2+,6X,2HO3,9X,2HN2,6X,8HH2O(10M),4X,4HMOLS,6X,4HAER1,5XGEO 3040
     2,6HO3(UV),5X,3HPSI,6X,3HPHI,6X,4HBETA,4X,5HTHETA,4X,5HRANGE,/,14X,GEO 3050
     35H     ,4X,7HH2O(4M),5X,4HHNO3,6X,4HAER2,6X,4HAER3,6X,4HAER4,3X,,5GEO 3060
     48X,6HORANGE//)                                                   GEO 3070
 230 FORMAT (/10X,8H W(1-8)=8(E14.3)/74X,E14.3,28X,E14.3/)             GEO 3080
 235 FORMAT (69H TRAJECTORY MISSES EARTHS ATMOSPHERE. CLOSEST DISTANCE GEO 3090
     1OF APPROACH IS,F10.2,1X,/,1X,18HEND OF CALCULATION)              GEO 3100
 240 FORMAT (4X,F8.3,10X,1P5E10.3,56X,0PF7.2,/)                        GEO 3110
 245 FORMAT (I4,F8.3,1P8E10.3,0P4F9.4,F7.1)                            GEO 3120
 250 FORMAT (8H HMIN = ,F10.3)                                         GEO 3130
 255 FORMAT (64H PATH INTERSECTS EARTH - PATH CHANGED TO TYPE 2 WITH H2GEO 3140
     1 = 0.0 KM)                                                       GEO 3150
 260 FORMAT (84H CHOICE OF TWO PATHS FOR THIS CASE -SHORTEST PATH TAKENGEO 3160
     1.  FOR LONGER PATH SET LEN=1.)                                   GEO 3170
 265 FORMAT (85H CHOICE OF TWO PATHS FOR THIS CASE -LONGEST PATH TAKEN.GEO 3180
     1    FOR SHORT PATH SET LEN = 0 )                                 GEO 3190
 270 FORMAT (74H H2 WAS SET LESS THAN HMIN AND HAS BEEN RESET EQUAL TO GEO 3200
     1     HMIN I.E. H2 = ,F10.3)                                      GEO 3210
 275 FORMAT (/30X,4HAER2,10X,4HAER3,10X,4HAER4,5X,9HR.H. MEAN,/10X,10H GEO 3220
     1W(12-15)=,4(1PE14.3)/)                                           GEO 3230
 280 FORMAT (118X,11HNITRIC ACID)                                      GEO 3240
   . END                                                               GEO 3250
```

Table A1. Listing of Fortran Code LOWTRAN 5 (Cont.)

```
      SUBROUTINE ANGL (H1,H2,ANGLE,B1,LEN,M,NL,RE,PI,ML)
      COMMON /MDATA/ Z(34),P(7,34),T(7,34),WH(7,34),WO(7,34)
     1 ,SEASN(2),VULCN(5),VSB(9),HZ(15),HMIX(34)
      COMMON RELHUM(34),HSTOR(34),EH(15,34),ICH(4),VH(15),TX(15)
      COMMON WLAY(34,15),WPATH(68,15),TBBY(68)
      COMMON ABSC(4,40),EXTC(4,40),VX2(40)
C     ******************************************************************
C
C     THIS SUBROUTINE CALCULATES THE INITIAL ZENITH ANGLE (ANGLE)
C     TAKING INTO ACCOUNT REFRACTION EFFECTS GIVEN H1,H2, AND BETA
C     (WHERE BETA IS THE EARTH CENTRE ANGLE SUBTENDED BY H1 AND H2 ),
C     ASSUMING THE REFRACTIVE INDEX TO BE CONSTANT IN A GIVEN LAYER.
C     FOR GREATER ACCURACY INCREASE THE NUMBER OF LEVELS IN THE MODEL
C     ATMOSPHERE.
C
C     THIS SUBROUTINE CAN BE REMOVED FROM THE PROGRAM IF NOT REQUIRED.
C     ******************************************************************
      IP=99
      CA=PI/180.
      X1=RE+H1
      X2=RE+H2
      LEN=0.
      IT=0
      B1=B1*CA
      TANG=X2*SIN(B1)/(X2*COS(B1)-X1)
      THET=ATAN(TANG)
      IF (THET.LT.0.0) THET=THET+PI
      SPHI=SIN(THET)
      ANG=THET/CA
      TN=THET
      TH=TN-0.5*CA
    5 ANGLE=THET
      FBT=0.
      BETA=0.
      BET1=0
      BET2=0
      FBT1=0
      FBT2=0
      FBT3=0.0
      IF (B1.LE.0.0) GO TO 10
      Y=2.*THET
      IF (Y-PI.GT.1.0E-8) GO TO 45
      IF (IP.EQ.100) GO TO 30
      XMIN=X2*COS(B1)-RE
      IF (XMIN-H1) 40,20,20
   10 HMIN=H2
      H2=H1
      H1=HMIN
   15 ANGLE=0.5*PI
      THET=ANGLE
      SPHI=1.0
      ANG=ANGLE/CA
   20 IP=100
      CALL POINT (H1,YN,N,NP,IP)
      J1=N
      TX1=TX(9)
   25 CALL POINT (H2,YN,N,NP,IP)
      IF (NP.EQ.1) N=N-1
      J2=N
      IF (J1.EQ.J2) TX1=TX1+YN-EH(9,J1)
```

Table A1. Listing of Fortran Code LOWTRAN 5 (Cont.)

```
30 DO 35 J=J1,J2
   X1=RE+Z(J)                                                ANG  610
   X2=RE+Z(J+1)                                              ANG  620
   IF (J.EQ.J1) X1=RE+H1                                     ANG  630
   IF (J.EQ.J2) X2=RE+H2                                     ANG  640
   SALP=X1*SPHI/X2                                           ANG  650
   ALP=ASIN(SALP)                                            ANG  660
   RN=EH(9,J+1)/EH(9,J)                                      ANG  670
   IF ((J+1).EQ.J2) RN=YN/EH(9,J)                            ANG  680
   IF (J.EQ.J1) RN=EH(9,J+1)/TX1                             ANG  690
   IF ((J+1).EQ.J2.AND.J.EQ.J1) RN=YN/TX1                    ANG  700
   BET=THET-ALP                                              ANG  710
   FB=-TAN(ALP)                                              ANG  720
   IF (J.NE.J1) FB=FB+TAN(THET)                              ANG  730
   FBT=FBT+FB                                                ANG  740
   BETA=BETA+BET                                             ANG  750
   TH1=THET/CA                                               ANG  760
   BE=BET/CA                                                 ANG  770
   C=ALP/CA                                                  ANG  780
   IF (X2.EQ.RE+H2) C=PI-ALP                                 ANG  790
   IF (SALP.GE.RN) RN=1.                                     ANG  800
   SPHI=SALP/RN                                              ANG  810
   THET=ASIN(SPHI)                                           ANG  820
35 CONTINUE                                                  ANG  830
   IF (P1.LE.0.0) GO TO 125                                  ANG  840
   GO TO 115                                                 ANG  850
40 CONTINUE                                                  ANG  860
   TANG=-TANG                                                ANG  870
   ANGLE=PI-ANGLE                                            ANG  880
   TN=ANGLE                                                  ANG  890
   ANG=ANGLE/CA                                              ANG  900
   IF (H1.LE.0.0) GO TO 15                                   ANG  910
45 CONTINUE                                                  ANG  920
   IP=101                                                    ANG  930
   CALL POINT (H1,YN,N,NP1,IP)                               ANG  940
   TX1=TX(9)                                                 ANG  950
   YN1=YN                                                    ANG  960
   IF (NP1.EQ.1) N=N-1                                       ANG  970
   J2=ML                                                     ANG  980
   IF (M.EQ.7) J2=ML                                         ANG  990
   J1=N                                                      ANG 1000
   J=J1+1                                                    ANG 1010
   IF (H2.GE.H1) GO TO 65                                    ANG 1020
   CALL POINT (H2,YN,N,NP,IP)                                ANG 1030
   TX2=TX(9)                                                 ANG 1040
   YN2=YN                                                    ANG 1050
   J2=N                                                      ANG 1060
   IF (J1.EQ.J2) TX2=YN1+TX(9)-EH(9,J1)                      ANG 1070
50 J=J-1                                                     ANG 1080
   X1=RE+Z(J+1)                                              ANG 1090
   X2=RE+Z(J)                                                ANG 1100
   IF (J.EQ.J1) X1=RE+H1                                     ANG 1110
   IF (J.EQ.J2) X2=RE+H2                                     ANG 1120
   SALP=X1*SPHI/X2                                           ANG 1130
   HMIN=X1*SPHI-RE                                           ANG 1140
   IF (SALP.LE.1.0) GO TO 55                                 ANG 1150
   SALP=SPHI                                                 ANG 1160
   IF (HMIN.GT.H2) GO TO 80                                  ANG 1170
55 ALP=ASIN(SALP)                                            ANG 1180
   THET=ASIN(SPHI)                                           ANG 1190
                                                             ANG 1200
```

Table A1. Listing of Fortran Code LOWTRAN 5 (Cont.)

```
      BET=ALP-THET                                                      ANG 1210
      BET1=BET1+BET                                                     ANG 1220
      FB=TAN(ALP)                                                       ANG 1230
      IF (J.NE.J1) FB=FB-TAN(THET)                                      ANG 1240
      FBT1=FBT1+FB                                                      ANG 1250
      TH1=THET/CA                                                       ANG 1260
      BE=BET/CA                                                         ANG 1270
      AL=ALP/CA                                                         ANG 1280
      IF (X2.EQ.RE+H2) C=PI-ALP                                         ANG 1290
      REF=EH(9,J)                                                       ANG 1300
      IF (J.EQ.J1) REF=YN1                                              ANG 1310
      IF (J.EQ.J2) REF=TX2                                              ANG 1320
      IF (J.EQ.1) GO TO 60                                              ANG 1330
      RN=EH(9,J)/EH(9,J-1)                                              ANG 1340
      IF (J.EQ.J1) RN=YN1/EH(9,J-1)                                     ANG 1350
      IF (J.EQ.J2+1) RN=REF/TX2                                         ANG 1360
      IF (J.EQ.J2) RN=REF/YN2                                           ANG 1370
      IF (SALP.GE.RN) RN=1.                                             ANG 1380
      SPHI=SALP*RN                                                      ANG 1390
      IF (Z(J).LE.H2) GO TO 60                                          ANG 1400
      GO TO 50                                                          ANG 1410
   60 X1=X2                                                             ANG 1420
      IF (ABS(Z(J)-H2).LT.1.0E-10.AND.J.NE.1) GO TO 65                  ANG 1430
      GO TO 70                                                          ANG 1440
   65 J=J-1                                                             ANG 1450
      X1=RE+Z(J+1)                                                      ANG 1460
      IF (J.EQ.J1) X1=RE+H1                                             ANG 1470
      IF (J.EQ.J2.AND.J.NE.J1) X1=RE+H2                                 ANG 1480
   70 X2=RE+Z(J)                                                        ANG 1490
      HMIN=X1*SPHI-RE                                                   ANG 1500
      IF (HMIN.LE.0.0) GO TO 110                                        ANG 1510
      IF (Z(J).LT.HMIN) GO TO 80                                        ANG 1520
      REF=EH(9,J)                                                       ANG 1530
      IF (J.EQ.J2) REF=YN                                               ANG 1540
      SALP=X1*SPHI/X2                                                   ANG 1550
      ALP=ASIN(SALP)                                                    ANG 1560
      THET=ASIN(SPHI)                                                   ANG 1570
      BET=ALP-THET                                                      ANG 1580
      FB=TAN(ALP)-TAN(THET)                                             ANG 1590
      FBT2=FBT2+FB                                                      ANG 1600
      BET2=BET2+BET                                                     ANG 1610
      BMIN=BET1+BET2                                                    ANG 1620
      AL=ALP/CA                                                         ANG 1630
      TH1=THET/CA                                                       ANG 1640
      RN=REF/EH(9,J-1)                                                  ANG 1650
      IF (SALP.GE.RN) RN=1.0                                            ANG 1660
      SPHI=SALP*RN                                                      ANG 1670
      GO TO 65                                                          ANG 1680
   75 TX3=YN1+TX(9)-EH(9,J1)                                            ANG 1690
      YN1=TX3                                                           ANG 1700
      IF (ABS(H2-Z(J+1)).LE.1.0E-5) YN1=TX(9)                           ANG 1710
      IF (ABS(H1-Z(J+1)).LE.1.0E-5) YN1=TX(9)                           ANG 1720
      RN=1.0                                                            ANG 1730
      GO TO 65                                                          ANG 1740
   80 CALL POINT (HMIN,YN,N,NF,IP)                                      ANG 1750
      IP=102                                                            ANG 1760
      TX3=TX(9)                                                         ANG 1770
      IF (J.EQ.J1.AND.H2.GE.H1) GO TO 75                                ANG 1780
      IF (J.EQ.J1.OR.J.EQ.J2) TX3=YN2+TX(9)-EH(9,J)                     ANG 1790
      IF (HMIN.GT.H2) TX3=TX(9)                                         ANG 1800
```

Table A1. Listing of Fortran Code LOWTRAN 5 (Cont.)

```
      IF (J.EQ.J1.AND.HMIN.GT.H2) GO TO 75                              ANG 1810
      RN=REF/TX3                                                        ANG 1820
      IF (SALP.GE.RN) RN=1.                                             ANG 1830
      SPHI=SALP*RN                                                      ANG 1840
      X=X1*SPHI-RE                                                      ANG 1850
      DIF=ABS(HMIN-X)                                                   ANG 1860
      HMIN=X                                                            ANG 1870
      IF (DIF-1.0E-5) 85,85,80                                          ANG 1880
   85 X2=RE+HMIN                                                        ANG 1890
      THET=ASIN(SPHI)                                                   ANG 1900
      IF (RN.EQ.1.0) FBT3=-TAN(THET)                                    ANG 1910
      IF (RN.EQ.1.0) GO TO 90                                           ANG 1920
      DNX=(TX3-1.0)*ALOG((TX3-1.0)/(REF-1.0))/(X2-X1)                   ANG 1930
      FBT3=-TAN(THET)*(1.0-1.0/(1.0+TX3/(X2*DNX)))                      ANG 1940
   90 BET=0.5*PI-THET                                                   ANG 1950
      BET2=BET2+BET                                                     ANG 1960
      BMIN=BET1+BET2                                                    ANG 1970
      IF (H2.GE.H1) GO TO 100                                           ANG 1980
      BET=BET1+2.*BET2                                                  ANG 1990
      DB1=B1-BET1                                                       ANG 2000
      DB2=BET-B1                                                        ANG 2010
      DB3=ABS(BMIN-B1)                                                  ANG 2020
      IF (DB3.GT.DB1.AND.DB2.GT.DB1) GO TO 110                          ANG 2030
      IF (DB2.GT.DB3) GO TO 95                                          ANG 2040
      IF (DB2.GT.DB1) GO TO 110                                         ANG 2050
      BETA=BET                                                          ANG 2060
      FBT=FBT1+2.0*(FBT2+FBT3)                                          ANG 2070
      LEN=1.                                                            ANG 2080
      GO TO 115                                                         ANG 2090
   95 BETA=BET1+BET2                                                    ANG 2100
      FBT=FBT1+FBT2+FBT3                                                ANG 2110
      GO TO 115                                                         ANG 2120
  100 BETA=2.0*(BET1+BET2)                                              ANG 2130
      LEN=1.                                                            ANG 2140
      FBT=2.0*(FBT1+FBT2+FBT3)                                          ANG 2150
      PRINT 130, J,BETA,FBT,FBT1,FBT2,FBT3,TX1,YN1                      ANG 2160
      IF (H2.EQ.H1) GO TO 115                                           ANG 2170
      IP=103                                                            ANG 2180
      IF (NP1.EQ.1) J1=J1+1                                             ANG 2190
      SPHI=SIN(ANGLE)                                                   ANG 2200
      IF (Z(J1+1).LE.H2) GO TO 105                                      ANG 2210
      RN=TX1/YN1                                                        ANG 2220
      IF (SPHI.GE.RN) RN=1.                                             ANG 2230
      SPHI=SPHI/RN                                                      ANG 2240
      THET=ASIN(SPHI)                                                   ANG 2250
      GO TO 25                                                          ANG 2260
  105 CALL POINT (H2,YN,N,NP,IP)                                        ANG 2270
      TX1=TX1+YN-EH(9,J1)                                               ANG 2280
      RN=TX1/YN1                                                        ANG 2290
      J2=J1                                                             ANG 2300
      IF (SPHI.GE.RN) RN=1.                                             ANG 2310
      SPHI=SPHI/RN                                                      ANG 2320
      THET=ASIN(SPHI)                                                   ANG 2330
      GO TO 25                                                          ANG 2340
  110 BETA=BET1                                                         ANG 2350
      LEN=0.                                                            ANG 2360
      FBT=FBT1                                                          ANG 2370
  115 THET=ANGLE+(B1-BETA)/(1.+FBT/TANG)                                ANG 2380
      DBETA=BETA/CA                                                     ANG 2390
      B=BET1/CA                                                         ANG 2400
```

Table A1. Listing of Fortran Code LOWTRAN 5 (Cont.)

```
      TH1=THET/CA                                                       ANG 2410
      PRINT 135, BETA,DBETA,FBT,TH1,TANG                                ANG 2420
      IF (THET.GT.TN.OR.THET.LT.TM) THET=(TN+TM)/2.                     ANG 2430
      TH1=THET/CA                                                       ANG 2440
      PRINT 135, BET1,B,FBT,TH1                                         ANG 2450
      TN1=TN/CA                                                         ANG 2460
      TM1=TM/CA                                                         ANG 2470
      PRINT 140, TN,TM,TN1,TM1                                          ANG 2480
      SPHI=SIN(THET)                                                    ANG 2490
      TANG=TAN(THET)                                                    ANG 2500
      IT=IT+1                                                           ANG 2510
      DBE=ABS(B1-BETA)                                                  ANG 2520
      DTH=ABS(ANGLE-THET)                                               ANG 2530
      IF (IT.EQ.10) THET=0.5*(ANGLE+THET)                               ANG 2540
      IF (IT.EQ.10) GO TO 120                                           ANG 2550
      IF (DBE.GT.1.0E-7.AND.DTH.GT.1.0E-7) GO TO 5                      ANG 2560
  120 ANGLE=THET/CA                                                     ANG 2570
      PRINT 145, ANGLE,IT                                               ANG 2580
      RETURN                                                            ANG 2590
  125 H1=H2                                                             ANG 2600
      ANGLE=C/CA                                                        ANG 2610
      PRINT 145, ANGLE,IT                                               ANG 2620
      RETURN                                                            ANG 2630
C                                                                       ANG 2640
  130 FORMAT (I6,F16.7,4F13.8)                                          ANG 2650
  135 FORMAT (14H TOTAL BETA = ,E14.6,F15.6,7H,FBT = ,E14.6,7H THET =,F1ANG 2660
     10.6,5HTANG=,F10.6)                                                ANG 2670
  140 FORMAT (5F12.6)                                                   ANG 2660
  145 FORMAT (8X,/1H*,14HZENITH ANGLE =,F7.3,60H DEGREES \  RECOMPUTED  ANG 2690
     1    FROM SUBROUTINE ANGL (ITTERATION,I3,1H))                      ANG 2700
      END                                                               ANG 2710
```

Table A1. Listing of Fortran Code LOWTRAN 5 (Cont.)

```
      SUBROUTINE POINT (X,YN,N,NP,IP)
C                                           REVISED 12 DEC 79
      COMMON /CARD1/ MODEL,IHAZE,ITYPE,LEN,JP,IM,M1,M2,M3,ML,IEMISS,RO
     1 ,TBOUND,ISEASN,IVULCN,VIS
      COMMON /CARD2/ H1,H2,ANGLE,RANGE,BETA,HMIN,RE
      COMMON /CARD3/ V1,V2,DV,AVW,CO,CW,W(15),E(15),CA,PI
      COMMON /CNTRL/ LENST,KMAX,M,IJ,J1,JL,JMIN,JEXTRA,IL,IKMAX,NLL,NP1
     1,IFIND,NL,IKLO
      COMMON /MDATA/ Z(34),P(7,34),T(7,34),WH(7,34),WO(7,34)
     1 ,SEASN(2),VULCN(5),VSB(9),HZ(15),HMIX(34)
      COMMON RELHUM(34),HSTOR(34),EH(15,34),ICH(4),VH(15),TX(15)
      COMMON WLAY(34,15),WPATH(68,15),TBBY(68)
      COMMON ABSC(4,40),EXTC(4,40),VX2(40)
C     ******************************************************************
C     SUBROUTINE POINT COMPUTES THE MEAN REFR. INDEX ABOVE AND BELOW
C     A GIVEN ALTITUDE AND INTERPOLATES EXPONENTIALLY TO DETERMINE THE
C     EQUIVALENT ABSORBER AMOUNTS AT THAT ALTITUDE.
C
C     ******************************************************************
C
C      X IS THE HEIGHT IN QUESTION
C      TX(9) AND YN ARE THE MEAN REFRACTIVE INDICES ABOVE AND BELOW X
C      N IS THE LEVEL INTEGER CORRESPONDING TO X OR THE LEVEL BELOW X
C      NP =1 IF X COINCIDES WITH MODEL ATMOSPHERE LEVEL ,IF NOT NP = 0
C      TX(1-8) ARE ABSORBER  AMOUNTS PER KM AT HEIGHT X
C     ******************************************************************
      N=NL
      NP=0
      IF (X.LT.0.0) X=Z(1)
      IF (X.GT.Z(NL)) GO TO 20
      DO 5 I=1,NL
      N=I
      IF (X-Z(I)) 10,20,5
    5 CONTINUE
   10 J2=N
      N=N-1
      MM1=M
      IF(M1.GT.0.AND.M.LT.7) MM1=M1
      MM2=M
      IF(M2.GT.0.AND.M.LT.7) MM2=M2
      FAC=(X-Z(N))/(Z(J2)-Z(N))
      PX1=P(MM1,N)*(P(MM1,J2)/P(MM1,N))**FAC
      TX1=T(MM1,N)*(T(MM1,J2)/T(MM1,N))**FAC
      WX1=WH(MM2,N)*(WH(MM2,J2)/WH(MM2,N))**FAC
      TX(3)=CO*PX1/TX1-4.56E-6*WX1*TX1*CW
      TX(2)=CO*P(MM1,J2)/T(MM1,J2)-4.56E-6*WH(MM2,J2)*T(MM1,J2)*CW
      TX(1)=CO*P(MM1,N)/T(MM1,N)-4.56E-6*WH(MM2,N)*T(MM1,N)*CW
      TX(9)=0.5E-6*(TX(2)+TX(3))
      YN=0.5E-6*(TX(1)+TX(3))
      IF (IP.EQ.0) GO TO 25
      DO 15 K=1,KMAX
      IF (K.EQ.9) GO TO 15
      TX(K)=0.0
      IF (EH(K,N).GT.1000.0) GO TO 15
      IF (X.LE.100.0) TX(K)=EH(K,N)+FAC*(EH(K,J2)-EH(K,N))
      IF (EH(K,N).EQ.0.0.OR.EH(K,J2).EQ.0.0) GO TO 15
      TX(K)=EH(K,N)*(EH(K,J2)/EH(K,N))**FAC
   15 CONTINUE
      GO TO 25
   20 NP=1
```

Table A1. Listing of Fortran Code LOWTRAN 5 (Cont.)

```
      IF (IP.EQ.0) GO TO 30                                             POI  610
      DO 25 K=1,KMAX                                                    POI  620
   25 TX(K)=EH(K,N)                                                     POI  630
   30 TX(9)=EH(9,N)-1.                                                  POI  640
      YN=0.0                                                            POI  650
C        CARDS P 24 AND 50 THROUGH 59 ARE NO LONGER REQUIRED            POI  660
      IF (N.GT.1) YN=EH(9,N-1)-1.0                                      POI  670
   35 CONTINUE                                                          POI  680
      IF (IP.EQ.1) PRINT 45, X,N,NP,TX(9),YN,IP,(TX(K),K=1,8)           POI  690
      IF (IP.EQ.1) PRINT 40, (TX(K),K=12,14)                            POI  700
      TX(9)=TX(9)+1.                                                    POI  710
      YN=YN+1.                                                          POI  720
      RETURN                                                            POI  730
C                                                                       POI  740
   40 FORMAT (//5X,11H TX(12-14)=,3E10.3/)                              POI  750
   45 FORMAT (/,20H FROM POINT\ HEIGHT=,F10.4,6H KM,N=,I3,4H,NP=,I2,28H,POI  760
     1REF. INDEX ABOVE & BELOW X=,2E11.4,4H,IP=,I3,/,12X,36HEQUIV. ABSORPOI  770
     2BER AMOUNTS PER KM AT X=,3E10.3)                                  POI  780
      END                                                               POI  790
```

Table A1. Listing of Fortran Code LOWTRAN 5 (Cont.)

```
      SUBROUTINE EXABIN
C
C      LOADS EXTINCTION AND ABSORPTION COEFFICIENTS FOR THE FOUR
C        AEROSOL ALTITUDE REGIONS
C
      COMMON /CARD1/ MODEL,IHAZE,ITYPE,LEN,JP,IM,M1,M2,M3,ML,IEMISS,RO
     1 ,TBOUND,ISEASN,IVULCN,VIS
      COMMON /CARD2/ H1,H2,ANGLE,RANGE,BETA,HMIN,RE
      COMMON /CARD3/ V1,V2,DV,AVW,CO,CW,W(15),E(15),CA,PI
      COMMON /CNTRL/ LENST,KMAX,MD,IJ,J1,J2,JMIN,JEXTRA,IL,IKMAX,NLL,NP1
     1,IFIND,NL,IKLO
      COMMON /MDATA/ Z(34),P(7,34),T(7,34),WH(7,34),WO(7,34)
     1 ,SEASN(2),VULCN(5),VSB(9),HZ(15),HMIX(34)
      COMMON RELHUM(34),HSTOR(34),EH(15,34),ICH(4),VH(15),TX(15)
      COMMON WLAY(34,15),WPATH(68,15),TBBY(68)
      COMMON ABSC(4,40),EXTC(4,40),VX0(40)
      COMMON /EXTDTA/  VX2(40),RUREXT(40,4),RURABS(40,4),URBEXT(40,4),
     1URBABS(40,4),OCNEXT(40,4),OCNABS(40,4),TROEXT(40,4),TROABS(40,4),
     2FG1EXT(40),FG1ABS(40),FG2EXT(40),FG2ABS(40)
     3,BSTEXT(40),BSTABS(40),AVOEXT(40),AVOABS(40),FVOEXT(40
     4),FVOABS(40),DMEEXT(40),DMEABS(40)
      DIMENSION RHZONE(4)
      DATA (RHZONE(I),I=1,4)/0.,70.,80.,99./
      PRINT 90, (ICH(I),I=1,4)
      CALL EXTDTA
      DO 5 I=1,40
    5 VX0(I)=VX2(I)
      I1=1
      IF (IHAZE.EQ.7) I1=2
      DO 85 M=I1,4
      ITA=ICH(M)
      ITC=ICH(M)-7
      WRH=W(15)
      IF (ICH(M).EQ.6.AND.M.NE.1) WRH=70.
C     THIS CODING  DOES NOT ALLOW TROP RH DEPENDENT  ABOVE EH(7,I)
C     DEFAULTS TO TROPOSPHERIC AT 70. PERCENT
      DO 10 I=2,4
      IF (WRH.LT.RHZONE(I)) GO TO 15
   10 CONTINUE
      I=4
   15 II=I-1
      IF(WRH.GT.0.0.AND.WRH.LT.99.) X=ALOG(100.0-WRH)
      X1=ALOG(100.0-RHZONE(II))
      X2=ALOG(100.0-RHZONE(I))
      IF (WRH.GE.99.0) X=X2
      IF (WRH.LE.0.0) X=X1
      DO 80 N=1,40
      ABSC(M,N)=0.
      EXTC(M,N)=0.
      IF(ITA.GT.6) GO TO 45
      IF(ITA.LE.0) GO TO 80
C     RH DEPENDENT AEROSOLS
      GO TO (20,20,25,25,30,35), ITA
   20 Y2=ALOG(RUREXT(N,I))
      Y1=ALOG(RUREXT(N,II))
      Z2=ALOG(RURABS(N,I))
      Z1=ALOG(RURABS(N,II))
      GO TO 40
   25 Y2=ALOG(OCNEXT(N,I))
      Y1=ALOG(OCNEXT(N,II))
```

Table A1. Listing of Fortran Code LOWTRAN 5 (Cont.)

```
      Z2=ALOG(OCNABS(N,I))                                              EXA  610
      Z1=ALOG(OCNABS(N,II))                                             EXA  620
      GO TO 40                                                          EXA  630
   30 Y2=ALOG(URBEXT(N,I))                                              EXA  640
      Y1=ALOG(URBEXT(N,II))                                             EXA  650
      Z2=ALOG(URBABS(N,I))                                              EXA  660
      Z1=ALOG(URBABS(N,II))                                             EXA  670
      GO TO 40                                                          EXA  680
   35 Y2=ALOG(TROEXT(N,I))                                              EXA  690
      Y1=ALOG(TROEXT(N,II))                                             EXA  700
      Z2=ALOG(TROABS(N,I))                                              EXA  710
      Z1=ALOG(TROABS(N,II))                                             EXA  720
   40 Y=Y1+(Y2-Y1)*(X-X1)/(X2-X1)                                       EXA  730
      ZK=Z1+(Z2-Z1)*(X-X1)/(X2-X1)                                      EXA  740
      ABSC(M,N)=EXP(ZK)                                                 EXA  750
      EXTC(M,N)=EXP(Y)                                                  EXA  760
      GO TO 80                                                          EXA  770
   45 IF (ITA.GT.14) GO TO 75                                           EXA  780
      IF (ITC.LT.1) GO TO 80                                            EXA  790
      GO TO (50,55,60,65,70,65,70), ITC                                 EXA  800
   50 ABSC(M,N)=FG1ABS(N)                                               EXA  810
      EXTC(M,N)=FG1EXT(N)                                               EXA  820
      GO TO 80                                                          EXA  830
   55 ABSC(M,N)=FG2ABS(N)                                               EXA  840
      EXTC(M,N)=FG2EXT(N)                                               EXA  850
      GO TO 80                                                          EXA  860
   60 ABSC(M,N)=BSTABS(N)                                               EXA  870
      EXTC(M,N)=BSTEXT(N)                                               EXA  880
      GO TO 80                                                          EXA  890
   65 ABSC(M,N)=AVOABS(N)                                               EXA  900
      EXTC(M,N)=AVOEXT(N)                                               EXA  910
      GO TO 80                                                          EXA  920
   70 ABSC(M,N)=FVOABS(N)                                               EXA  930
      EXTC(M,N)=FVOEXT(N)                                               EXA  940
      GO TO 80                                                          EXA  950
   75 ABSC(M,N)=DMEABS(N)                                               EXA  960
      EXTC(M,N)=DMEEXT(N)                                               EXA  970
   80 CONTINUE                                                          EXA  980
   85 CONTINUE                                                          EXA  990
      PRINT 95                                                          EXA 1000
C     PRINT 100, (VX2(N),(EXTC(M,N),ABSC(M,N),M=1,4),N=1,40)            EXA 1010
      RETURN                                                            EXA 1020
C                                                                       EXA 1030
   90 FORMAT (7H  ICH  ,4I5)                                            EXA 1040
   95 FORMAT (40H  EXTINCTION AND ABSORPTION COEFFICIENTS)              EXA 1050
  100 FORMAT (F10.4,8F10.5)                                             EXA 1060
      END                                                               EXA 1070
```

Table A1. Listing of Fortran Code LOWTRAN 5 (Cont.)

```
      SUBROUTINE EXTDTA
C
C     AEROSOL EXTINCTION AND ABSORPTION DATA
C
      COMMON /EXTDTA/VX2(40),RUREXT(40,4),RURABS(40,4),URBEXT(40,4),
     1URBABS(40,4),OCNEXT(40,4),OCNABS(40,4),TROEXT(40,4),TROABS(40,4),
     2FG1EXT(40),FG1ABS(40),FG2EXT(40),FG2ABS(40)
     3,   BSTEXT(40),BSTABS(40),AVOEXT(40),AVOABS(40),FVOEXT(40
     4),FVOABS(40),DMEEXT(40),DMEABS(40)
      DATA (VX2(I),I=    1,   40)/
     *    .2000,    .3000,    .3371,    .5500,    .6943,   1.0600,   1.5360,
     *   2.0000,   2.2500,   2.5000,   2.7000,   3.0000,   3.3923,   3.7500,
     *   4.5000,   5.0000,   5.5000,   6.0000,   6.2000,   6.5000,   7.2000,
     *   7.9000,   8.2000,   8.7000,   9.0000,   9.2000,  10.0000,  10.5910,
     *  11.0000,  11.5000,  12.5000,  14.8000,  15.0000,  16.4000,  17.2000,
     *  18.5000,  21.3000,  25.0000,  30.0000,  40.0000/
      DATA (RUREXT(I,1) ,I=1, 40)/
     1 2.09291, 1.74582, 1.60500, 1.00000,  .75203,  .41943,  .24070,
     2  .14709,  .13304,  .12234,  .13247,  .11196,  .10437,  .09956,
     3  .09199,  .08449,  .07861,  .07025,  .07089,  .07196,  .07791,
     4  .04481,  .04399,  .12184,  .12658,  .12829,  .09152,  .08076,
     5  .07456,  .06880,  .06032,  .04949,  .05854,  .06000,  .06962,
     6  .05722,  .06051,  .05177,  .04589,  .04304/
      DATA (RUREXT(I,2) ,I=1, 40)/
     1 2.09544, 1.74165, 1.59981, 1.00000,  .75316,  .42171,  .24323,
     2  .15108,  .13608,  .12430,  .13222,  .13823,  .11076,  .10323,
     3  .09475,  .08728,  .08075,  .07639,  .07797,  .07576,  .07943,
     4  .04899,  .04525,  .12165,  .12741,  .12778,  .09032,  .07962,
     5  .07380,  .06880,  .06329,  .05791,  .06646,  .06539,  .07443,
     6  .06304,  .06443,  .05539,  .04867,  .04519/
      DATA (RUREXT(I,3) ,I=1, 40)/
     1 2.07082, 1.71456, 1.57962, 1.00000,  .76095,  .43228,  .25348,
     2  .16456,  .14677,  .13234,  .13405,  .20316,  .12873,  .11506,
     3  .10481,  .09709,  .08919,  .09380,  .09709,  .08791,  .08601,
     4  .06247,  .05601,  .11905,  .12595,  .12348,  .08741,  .07703,
     5  .07266,  .07044,  .07443,  .08146,  .08810,  .08563,  .08962,
     6  .08051,  .07677,  .06658,  .05747,  .05184/
      DATA (RUREXT(I,4) ,I=1, 40)/
     1 1.66076, 1.47886, 1.40139, 1.00000,  .80652,  .50595,  .32259,
     2  .23468,  .20772,  .18532,  .17348,  .35114,  .20006,  .17386,
     3  .16139,  .15424,  .14557,  .16215,  .16766,  .14994,  .14032,
     4  .12968,  .12601,  .13551,  .13582,  .13228,  .11070,  .09994,
     5  .09873,  .10418,  .13241,  .15924,  .16139,  .15949,  .15778,
     6  .15184,  .13848,  .12563,  .11076,  .09601/
      DATA (RURABS(I,1) ,I=1, 40)/
     1  .67196,  .11937,  .08505,  .05930,  .05152,  .05816,  .05006,
     2  .01968,  .02070,  .02101,  .05652,  .02785,  .01316,  .00867,
     3  .01462,  .01310,  .01627,  .02013,  .02165,  .02367,  .03538,
     4  .02823,  .03962,  .06779,  .07285,  .08120,  .04032,  .03177,
     5  .02557,  .02342,  .02177,  .02627,  .03943,  .03114,  .03696,
     6  .02956,  .03500,  .03241,  .03297,  .03380/
      DATA (RURABS(I,2) ,I=1, 40)/
     1  .62968,  .10816,  .07671,  .05380,  .04684,  .05335,  .04614,
     2  .01829,  .01899,  .01962,  .05525,  .06816,  .01652,  .00867,
     3  .01546,  .01373,  .01677,  .02892,  .02829,  .02532,  .03487,
     4  .07835,  .03854,  .06684,  .07272,  .08038,  .03987,  .03247,
     5  .02816,  .02816,  .03101,  .03741,  .04829,  .04032,  .04399,
     6  .03734,  .03956,  .03601,  .03525,  .03563/
      DATA (RURABS(I,3) ,I=1, 40)/
     1  .51899,  .08278,  .05815,  .04082,  .03570,  .04158,  .03620,
```

Table A1. Listing of Fortran Code LOWTRAN 5 (Cont.)

```
2  .01513,  .01481,  .01633,  .05278,  .13690,  .02494,  .00886,    EXT  610
3  .01804,  .01582,  .01677,  .04816,  .04367,  .03013,  .03443,    EXT  620
4  .02930,  .03677,  .06209,  .06911,  .07475,  .03892,  .03494,    EXT  630
5  .03513,  .03968,  .05152,  .06241,  .06937,  .06203,  .06215,    EXT  640
6  .05614,  .05209,  .04608,  .04196,  .04095/                      EXT  650
 DATA (RURABS(I,4) ,I=1, 40)/                                       EXT  660
1  .21943,  .02848,  .01943,  .01342,  .01171,  .01437,  .01323,    EXT  670
2  .01152,  .00696,  .01329,  .06108,  .24690,  .05323,  .01430,    EXT  680
3  .03361,  .02949,  .02652,  .09437,  .08506,  .05348,  .04627,    EXT  690
4  .04363,  .04557,  .05383,  .05715,  .05899,  .04861,  .05253,    EXT  700
5  .06171,  .07437,  .10152,  .12019,  .12190,  .11734,  .11411,    EXT  710
6  .10766,  .09487,  .08430,  .07348,  .06861/                      EXT  720
 DATA (URBEXT(I,1) ,I=1, 40)/                                       EXT  730
1 1.88815, 1.63316, 1.51867, 1.00000,  .77785,  .47095,  .30006,    EXT  740
2  .21392,  .19405,  .17886,  .18127,  .16133,  .14785,  .14000,    EXT  750
3  .12715,  .11880,  .11234,  .10601,  .10500,  .10361,  .10342,    EXT  760
4  .08766,  .08652,  .11937,  .12139,  .12297,  .09757,  .09057,    EXT  770
5  .08595,  .08196,  .07563,  .06696,  .07209,  .06842,  .07177,    EXT  780
6  .05354,  .06177,  .05373,  .04728,  .04051/                      EXT  790
 DATA (URBEXT(I,2) ,I=1, 40)/                                       EXT  800
1 1.95582, 1.64994, 1.53070, 1.00000,  .77614,  .46639,  .29487,    EXT  810
2  .21051,  .18943,  .17285,  .17209,  .21418,  .15354,  .14051,    EXT  820
3  .12728,  .11861,  .11083,  .11329,  .11323,  .10563,  .10247,    EXT  830
4  .08696,  .08361,  .12013,  .12418,  .12304,  .09614,  .08842,    EXT  840
5  .08487,  .08285,  .08361,  .08430,  .08880,  .08449,  .08601,    EXT  850
6  .07835,  .07323,  .06367,  .05500,  .04747/                      EXT  860
 DATA (URBEXT(I,3) ,I=1, 40)/                                       EXT  870
1 1.96430, 1.64032, 1.52392, 1.00000,  .77709,  .46253,  .20690,    EXT  880
2  .20310,  .17981,  .16101,  .15614,  .26475,  .15456,  .13563,    EXT  890
3  .12215,  .11361,  .10500,  .11715,  .11753,  .10392,  .09766,    EXT  900
4  .08443,  .08057,  .10943,  .11342,  .11063,  .08703,  .08025,    EXT  910
5  .07886,  .08032,  .09101,  .10070,  .10386,  .09943,  .09886,    EXT  920
6  .09152,  .08247,  .07152,  .06089,  .05253/                      EXT  930
 DATA (URBEXT(I,4) ,I=1, 40)/                                       EXT  940
1 1.41266, 1.33816, 1.29114, 1.00000,  .83646,  .55025,  .35342,    EXT  950
2  .25285,  .21576,  .18310,  .16215,  .27854,  .20494,  .16665,    EXT  960
3  .14778,  .13842,  .12943,  .15575,  .15709,  .13513,  .12481,    EXT  970
4  .11759,  .11494,  .11487,  .11329,  .11108,  .09911,  .09209,    EXT  980
5  .09342,  .10120,  .13177,  .15696,  .15766,  .15513,  .15203,    EXT  990
6  .14532,  .13038,  .11785,  .10411,  .09101/                      EXT 1000
 DATA (URBABS(I,1) ,I=1, 40)/                                       EXT 1010
1  .78437,  .58975,  .54285,  .36184,  .29222,  .20886,  .15658,    EXT 1020
2  .12329,  .11462,  .10747,  .11797,  .10025,  .08759,  .08184,    EXT 1030
3  .07506,  .07006,  .06741,  .06601,  .06544,  .06449,  .06665,    EXT 1040
4  .06276,  .06949,  .07316,  .07462,  .08101,  .05753,  .05272,    EXT 1050
5  .04899,  .04734,  .04494,  .04447,  .05133,  .04348,  .04443,    EXT 1060
6  .03994,  .03981,  .03633,  .03468,  .03146/                      EXT 1070
 DATA (URBABS(I,2) ,I=1, 40)/                                       EXT 1080
1  .69032,  .49367,  .45165,  .29741,  .24070,  .17399,  .13146,    EXT 1090
2  .10354,  .07589,  .09025,  .10411,  .15101,  .07880,  .06949,    EXT 1100
3  .06170,  .06095,  .05829,  .07171,  .06797,  .05975,  .06113,    EXT 1110
4  .05589,  .06051,  .07139,  .07454,  .07956,  .05525,  .05184,    EXT 1120
5  .05083,  .05291,  .05885,  .06380,  .06880,  .06127,  .06019,    EXT 1130
6  .05525,  .05070,  .04500,  .04076,  .03741/                      EXT 1140
 DATA (URBABS(I,3) ,I=1, 40)/                                       EXT 1150
1  .54848,  .37101,  .33134,  .21949,  .17785,  .12968,  .09354,    EXT 1160
2  .07804,  .07165,  .06791,  .08563,  .18639,  .06722,  .05316,    EXT 1170
3  .05316,  .04816,  .04620,  .07570,  .06899,  .05291,  .05101,    EXT 1180
4  .04734,  .05025,  .06171,  .06570,  .06854,  .04892,  .04797,    EXT 1190
5  .05057,  .05665   .07127,  .08095,  .08411,  .07728,  .07475,    EXT 1200
```

Table A1. Listing of Fortran Code LOWTRAN 5 (Cont.)

```
6  .06886,  .06019,  .05222,  .04538,  .04171/                       EXT 1210
 DATA (URBABS(I,4) ,I=1, 40)/                                        EXT 1220
1  .15975,  .10000,  .09013,  .05785,  .04671,  .03424,  .02633,     EXT 1230
2  .02525,  .01975,  .02354,  .06241,  .26690,  .05810,  .02285,     EXT 1240
3  .03810,  .03386,  .03044,  .09627,  .08557,  .05465,  .04576,     EXT 1250
4  .04392,  .04474,  .04671,  .04791,  .04861,  .04654,  .05177,     EXT 1260
5  .06159,  .07475,  .10342,  .12146,  .12177,  .11734,  .11325,     EXT 1270
6  .10608,  .09171,  .08063,  .06968,  .06475/                       EXT 1280
 DATA (OCNEXT(I,1) ,I=1, 40)/                                        EXT 1290
1 1.47576, 1.32614, 1.26171, 1.00000,  .88133,  .70257,  .56487,     EXT 1300
2  .46006,  .42044,  .38310,  .35076,  .42266,  .32278,  .28810,     EXT 1310
3  .24905,  .21184,  .16734,  .14791,  .21532,  .15076,  .12057,     EXT 1320
4  .10038,  .10703,  .15070,  .15665,  .14639,  .10228,  .08367,     EXT 1330
5  .07373,  .06829,  .05044,  .04373,  .04962,  .06158,  .07703,     EXT 1340
6  .07234,  .06297,  .05481,  .05329,  .08741/                       EXT 1350
 DATA (OCNEXT(I,2) ,I=1, 40)/                                        EXT 1360
1 1.36924, 1.25443, 1.20835, 1.00000,  .91367,  .77089,  .64987,     EXT 1370
2  .54886,  .50247,  .45038,  .38209,  .50589,  .43766,  .38076,     EXT 1380
3  .31658,  .27475,  .22215,  .21019,  .27570,  .23057,  .16949,     EXT 1390
4  .14209,  .14215,  .16956,  .17082,  .16025,  .11665,  .09759,     EXT 1400
5  .09215,  .09373,  .10532,  .12570,  .13000,  .13633,  .14291,     EXT 1410
6  .13596,  .11475,  .09658,  .08291,  .10348/                       EXT 1420
 DATA (OCNEXT(I,3) ,I=1, 40)/                                        EXT 1430
1 1.22259, 1.14627, 1.11842, 1.00000,  .94766,  .87538,  .80418,     EXT 1440
2  .72939,  .68592,  .62165,  .49962,  .67949,  .66468,  .59253,     EXT 1450
3  .49551,  .44671,  .37886,  .35924,  .43367,  .37019,  .30842,     EXT 1460
4  .26437,  .25228,  .24905,  .23975,  .22766,  .17804,  .15316,     EXT 1470
5  .15373,  .16791,  .22361,  .28348,  .28677,  .29082,  .29038,     EXT 1480
6  .27819,  .23867,  .20209,  .16430,  .14943/                       EXT 1490
 DATA (OCNEXT(I,4) ,I=1, 40)/                                        EXT 1500
1 1.09133, 1.06601, 1.05620, 1.00000,  .97506,  .94791,  .94203,     EXT 1510
2  .93671,  .92867,  .90411,  .80253,  .89222,  .94462,  .92146,     EXT 1520
3  .85797,  .82596,  .76747,  .68646,  .78209,  .75266,  .68658,     EXT 1530
4  .62722,  .60228,  .56335,  .53728,  .51861,  .47449,  .37196,     EXT 1540
5  .35899,  .37316,  .46854,  .58234,  .58690,  .60348,  .60563,     EXT 1550
6  .60009,  .55392,  .50367,  .43576,  .35949/                       EXT 1560
 DATA (OCNABS(I,1) ,I=1, 40)/                                        EXT 1570
1  .30987,  .04354,  .02880,  .01797,  .01468,  .01766,  .01582,     EXT 1580
2  .00816,  .01146,  .01677,  .03310,  .03380,  .00715,  .00443,     EXT 1590
3  .00500,  .00601,  .00753,  .01595,  .02943,  .00994,  .01367,     EXT 1600
4  .0167 ,  .02538,  .03481,  .03405,  .03601,  .01608,  .01310,     EXT 1610
5  .01152,  .01082,  .01070,  .01563,  .02063,  .03171,  .03810,     EXT 1620
6  .03741,  .03804,  .03763,  .04209,  .07892/                       EXT 1630
 DATA (OCNABS(I,2) ,I=1, 40)/                                        EXT 1640
1  .23367,  .03127,  .02070,  .01297,  .01063,  .01285,  .01190,     EXT 1650
2  .00937,  .00911,  .01575,  .05576,  .23487,  .03949,  .00905,     EXT 1660
3  .02057,  .01816,  .01665,  .06025,  .08044,  .03677,  .03139,     EXT 1670
4  .03190,  .03766,  .04532,  .04544,  .04715,  .03405,  .03614,     EXT 1680
5  .04329,  .05424,  .07823,  .09728,  .10057,  .10247,  .10222,     EXT 1690
6  .09551,  .08241,  .07158,  .06506,  .09203/                       EXT 1700
 DATA (OCNABS(I,3) ,I=1, 40)/                                        EXT 1710
1  .13025,  .01557,  .01013,  .00646,  .00532,  .00665,  .00722,     EXT 1720
2  .01335,  .00728,  .01810,  .09835,  .37329,  .05703,  .01968,     EXT 1730
3  .05114,  .04342,  .03709,  .17456,  .16468,  .08785,  .06800,     EXT 1740
4  .06589,  .06791,  .07247,  .07329,  .07449,  .07025,  .07962,     EXT 1750
5  .09899,  .12481,  .17867,  .22019,  .22228,  .22051,  .21595,     EXT 1760
6  .20335,  .17279,  .14677,  .12171,  .12430/                       EXT 1770
 DATA (OCNABS(I,4) ,I=1, 40)/                                        EXT 1780
1  .03506,  .00323,  .00215,  .00139,  .00114,  .00171,  .00542,     EXT 1790
2  .03082,  .01101,  .03741,  .20101,  .47608,  .21165,  .05234,     EXT 1800
```

Table A1. Listing of Fortran Code LOWTRAN 5 (Cont.)

```
3  .12886,   .11215,   .09684,   .32810,   .31778,   .20513,   .16658,    EXT 1810
4  .15956,   .15842,   .15905,   .15968,   .16051,   .16506,   .18323,    EXT 1820
5  .21709,   .25652,   .33222,   .39639,   .39854,   .40297,   .40025,    EXT 1830
6  .39025,   .35468,   .32005,   .27715,   .25348/                        EXT 1840
 DATA (TROEXT(I,1) ,I=1, 40)/                                             EXT 1850
1 2.21222, 1.82753, 1.67032, 1.00000,   .72424,   .35272,   .15234,    EXT 1860
2  .05165,   .03861,   .02994,   .04671,   .02467,   .01538,   .01146,    EXT 1870
3  .01032,   .00816,   .00861,   .00994,   .01057,   .01139,   .01747,    EXT 1880
4  .01494,   .02418,   .03165,   .03386,   .04247,   .01601,   .01215,    EXT 1890
5  .00977,   .00861,   .00823,   .01139,   .01924,   .01234,   .01348,    EXT 1900
6  .01114,   .01297,   .01266,   .01418,   .01487/                        EXT 1910
 DATA (TROEXT(I,2) ,I=1, 40)/                                             EXT 1920
1 2.21519, 1.82266, 1.66557, 1.00000,   .72525,   .35481,   .15449,    EXT 1930
2  .05475,   .04044,   .03082,   .04620,   .05272,   .01867,   .01266,    EXT 1940
3  .01127,   .00886,   .00885,   .01449,   .01399,   .01228,   .01728,    EXT 1950
4  .01475,   .02285,   .03215,   .03494,   .04285,   .01652,   .01304,    EXT 1960
5  .01101,   .01120,   .01297,   .01753,   .02468,   .01741,   .01766,    EXT 1970
6  .01513,   .01557,   .01456,   .01532,   .01582/                        EXT 1980
 DATA (TROEXT(I,3) ,I=1, 40)/                                             EXT 1990
1 2.19082, 1.79462, 1.64456, 1.00000,   .73297,   .36443,   .16278,    EXT 2000
2  .06468,   .04658,   .03799,   .04538,   .11892,   .02835,   .01646,    EXT 2010
3  .01386,   .01076,   .00968,   .02551,   .02222,   .01468,   .01690,    EXT 2020
4  .01437,   .01994,   .03127,   .03513,   .04076,   .01722,   .01513,    EXT 2030
5  .01519,   .01791,   .02538,   .03272,   .03816,   .03038,   .02886,    EXT 2040
6  .02551,   .02228,   .01937,   .01804,   .01791/                        EXT 2050
 DATA (TROEXT(I,4) ,I=1, 40)/                                             EXT 2060
1 1.75696, 1.54829, 1.45962, 1.00000,   .77816,   .43139,   .21778,    EXT 2070
2  .11329,   .08101,   .05506,   .04943,   .25291,   .06816,   .03703,    EXT 2080
3  .02601,   .01968,   .01468,   .04962,   .04247,   .02234,   .01797,    EXT 2090
4  .01532,   .01633,   .02259,   .02487,   .02595,   .01728,   .01892,    EXT 2100
5  .02399,   .03247,   .05285,   .06462,   .06608,   .05930,   .05525,    EXT 2110
6  .04861,   .03753,   .02968,   .02348,   .02165/                        EXT 2120
 DATA (TROABS(I,1) ,I=1, 40)/                                             EXT 2130
1  .69671,   .09906,   .06563,   .04101,   .03354,   .03627,   .02810,    EXT 2140
2  .00873,   .00918,   .00930,   .03215,   .01285,   .00513,   .00316,    EXT 2150
3  .00557,   .00494,   .00646,   .00867,   .00937,   .01025,   .01646,    EXT 2160
4  .01481,   .02418,   .02885,   .03070,   .04032,   .01494,   . 1139,    EXT 2170
5  .00873,   .00816,   .00797,   .01133,   .01911,   .01215,   .01329,    EXT 2180
6  .01101,   .01291,   .01266,   .01418,   .01487/                        EXT 2190
 DATA (TROABS(I,2) ,I=1, 40)/                                             EXT 2200
1  .65000,   .08791,   .05816,   .03652,   .02994,   .03278,   .02557,    EXT 2210
2  .00810,   .00842,   .00867,   .03139,   .03949,   .00646,   .00316,    EXT 2220
3  .00595,   .00519,   .00646,   .01304,   .01247,   .01095,   .01620,    EXT 2230
4  .01449,   .02278,   .02930,   .03184,   .04063,   .01544,   .01234,    EXT 2240
5  .01044,   .01076,   .01272,   .01741,   .02462,   .01722,   .01747,    EXT 2250
6  .01506,   .01551,   .01456,   .01532,   .01582/                        EXT 2260
 DATA (TROABS(I,3) ,I=1, 40)/                                             EXT 2270
1  .52804,   .06367,   .04158,   .02633,   .02184,   .02443,   .01937,    EXT 2280
2  .00658,   .00646,   .00709,   .02949,   .10013,   .00968,   .00310,    EXT 2290
3  .00677,   .00582,   .00646,   .02361,   .01994,   .01266,   .01544,    EXT 2300
4  .01386,   .01968,   .02648,   .03203,   .03854,   .01620,   .01449,    EXT 2310
5  .01462,   .01747,   .02513,   .03253,   .03797,   .03019,   .02861,    EXT 2320
6  .02538,   .02215,   .01933,   .01797,   .01791/                        EXT 2330
 DATA (TROABS(I,4) ,I=1, 40)/                                             EXT 2340
1  .19879,   .01842,   .01215,   .00791,   .00665,   .00778,   .00652,    EXT 2350
2  .00361,   .00253,   .00393,   .02570,   .20690,   .01715,   .00316,    EXT 2360
3  .00873,   .00778,   .00658,   .04481,   .03525,   .01646,   .01405,    EXT 2370
4  .01310,   .01468,   .01955,   .02184,   .02367,   .01608,   .01816,    EXT 2380
5  .02342,   .03203,   .05234,   .06399.   .06538,   .05867,   .05456,    EXT 2390
6  .04810,   .03715,   .02949,   .02335,   .02158/                        EXT 2400
```

Table A1. Listing of Fortran Code LOWTRAN 5 (Cont.)

```
 DATA(FG1EXT(I),I=1, 40)/                                           EXT 2410
1  .98519,  .99158,  .99089, 1.00000, 1.00576, 1.01747, 1.03177,    EXT 2420
2 1.04146, 1.04696, 1.05323, 1.05886, 1.04899, 1.06823, 1.07804,    EXT 2430
3 1.09272, 1.10367, 1.11684, 1.10430, 1.11367, 1.12899, 1.14987,    EXT 2440
4 1.17209, 1.18278, 1.20133, 1.21266, 1.21949, 1.22677, 1.15589,    EXT 2450
5 1.05684,  .98291, 1.01120, 1.10911, 1.11462, 1.14671, 1.16247,    EXT 2460
6 1.18544, 1.21582, 1.24614, 1.26842, 1.20500/                      EXT 2470
 DATA(FG1ABS(I),I=1, 40)/                                           EXT 2480
1  .00013, 0.00000, 0.00000, 0.00000, 0.00000,  .00095,  .01513,    EXT 2490
2  .10861,  .03892,  .13272,  .47133,  .49696,  .45785,  .17910,    EXT 2500
3  .37373,  .34601,  .31867,  .55190,  .55025,  .49987,  .46342,    EXT 2510
4  .45943,  .45918,  .46083,  .46241,  .46386,  .47196,  .48905,    EXT 2520
5  .51468,  .57101,  .55266,  .58665,  .58899,  .60367,  .61158,    EXT 2530
6  .62335,  .64120,  .65627,  .66278,  .66392/                      EXT 2540
 DATA(FG2EXT(I),I=1, 40)/                                           EXT 2550
1  .94791,  .96215,  .97063, 1.00000, 1.00937, 1.05177, 1.12519,    EXT 2560
2 1.29570, 1.39203, 1.41120, 1.04715, 1.10816, 1.43285, 1.45272,    EXT 2570
3 1.18709, 1.04367,  .82354,  .71747,  .92405,  .79342,  .60266,    EXT 2580
4  .47677,  .43171,  .36734,  .33259,  .31184,  .24139,  .21601,    EXT 2590
5  .24006,  .28815,  .42671,  .56861,  .57266,  .58089,  .57165,    EXT 2600
6  .54247,  .47981,  .34475,  .24905,  .19291/                      EXT 2610
 DATA(FG2ABS(I),I=1, 40)/                                           EXT 2620
1 0.00000, 0.00000, 0.00000, 0.00000, 0.00000,  .00013,  .00247,    EXT 2630
2  .01987,  .00620,  .02323,  .17209,  .57930,  .19810,  .03475,    EXT 2640
3  .09639,  .08000,  .06582,  .34589,  .32703,  .17025,  .12633,    EXT 2650
4  .11316,  .11627,  .11513,  .11538,  .11601,  .12329,  .14468,    EXT 2660
5  .18633,  .24057,  .35411,  .44886,  .45095,  .45215,  .44278,    EXT 2670
6  .41779,  .34430,  .27823,  .21063,  .17857/                      EXT 2680
 DATA(BSTEXT(I),I=1, 40)/                                           EXT 2690
1 1.48671, 1.55462, 1.51506, 1.00000,  .70633,  .28867,  .09994,    EXT 2700
2  .04184,  .02728,  .01848,  .01335,  .05513,  .08930,  .06532,    EXT 2710
3  .04766,  .04278,  .05811,  .05367,  .04392,  .03342,  .04456,    EXT 2720
4  .11867,  .14799,  .17734,  .09291,  .08778,  .05013,  .04070,    EXT 2730
5  .05734,  .03576,  .01975,  .01892,  .01956,  .03665,  .04152,    EXT 2740
6  .01715,  .01620,  .00835,  .00633,  .00589/                      EXT 2750
 DATA(BSTABS(I),I=1, 40)/                                           EXT 2760
1 0.00000, 0.00000, 0.00000, 0.00000, 0.00000, 0.00000,  .00019,    EXT 2770
2  .00127,  .00158,  .00291,  .00405,  .05880,  .06297,  .06019,    EXT 2780
3  .04519,  .04133,  .05703,  .05266,  .04304,  .03265,  .04437,    EXT 2790
4  .11816,  .14633,  .12639,  .09215,  .08722,  .04968,  .04044,    EXT 2800
5  .05709,  .03551,  .01952,  .01892,  .01949,  .03655,  .04146,    EXT 2810
6  .01709,  .01620,  .00835,  .00633,  .00589/                      EXT 2820
 DATA(AVOEXT(I),I=1, 40)/                                           EXT 2830
1 1.14880, 1.19171, 1.18013, 1.00000,  .84873,  .57019,  .27968,    EXT 2840
2  .14551,  .11070,  .08633,  .07184,  .06076,  .04506,  .03399,    EXT 2850
3  .02095,  .01538,  .01266,  .01019,  .00994,  .01044,  .01361,    EXT 2860
4  .01791.  .02278,  .02918,  .03108,  .03234,  .03456,  .03184,    EXT 2870
5  .02772,  .02475,  .01715,  .01563,  .01665,  .01646,  .01734,    EXT 2880
6  .01772,  .01076,  .01051,  .01133,  .01329/                      EXT 2890
 DATA(AVOABS(I),I=1, 40)/                                           EXT 2900
1  .44816,  .11259,  .08500,  .05272,  .04082,  .02449,  .01487.    EXT 2910
2  .01019,  .00867,  .00842,  .00842,  .00949,  .00741,  .00487,    EXT 2920
3  .00316,  .00335,  .00333,  .00449,  .00525,  .00665,  .01114,    EXT 2930
4  .01652,  .02177,  .02437,  .02506,  .02658,  .03006,  .02861,    EXT 2940
5  .02513,  .02285,  .01620,  .01532,  .01633,  .01620,  .01709,    EXT 2950
6  .01741,  .01057,  .01038,  .01127,  .01329/                      EXT 2960
 DATA(FVOEXT(I),I=1, 40)/                                           EXT 2970
1  .68715,  .92532,  .94013, 1.00000, 1.03013, 1.05975, 1.01171,    EXT 2980
2  .88677,  .82538,  .76361,  .71563,  .67424,  .60589,  .55057,    EXT 2990
3  .45222,  .37646,  .32316,  .25519,  .22728,  .20525,  .17810,    EXT 3000
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Table A1. Listing of Fortran Code LOWTRAN 5 (Cont.)

```
     4  .14481,  .14152,  .37633,  .44551,  .44405,  .42222,  .36462,    EXT 3010
     5  .32551,  .27519,  .16728,  .10627,  .10861,  .10885,  .11665,    EXT 3020
     6  .13127,  .10108,  .08557,  .06411,  .05741/                      EXT 3030
      DATA(FVOABS(I),I=1, 40)/                                           EXT 3040
     1  .41582,  .22892,  .19108,  .14468,  .12475,  .09158,  .06601,    EXT 3050
     2  .04943,  .04367,  .04342,  .04399,  .05076,  .04133,  .02829,    EXT 3060
     3  .01924,  .01981,  .02297,  .02475,  .02778,  .03411,  .05335,    EXT 3070
     4 -.07133,  .08816,  .15342,  .18506,  .19354,  .20791,  .18449,    EXT 3080
     5  .16101,  .13759,  .08455,  .06886,  .07278,  .07367,  .07956,    EXT 3090
     6  .08785,  .06032,  .05747,  .05133,  .05323/                      EXT 3100
      DATA(DMEEXT(I),I=1, 40)/                                           EXT 3110
     1 1.05019, 1.05880, 1.05259, 1.00000,  .94949,  .81456,  .66051,    EXT 3120
     2  .54380,  .49133,  .44677,  .41671,  .38063,  .34778,  .32804,    EXT 3130
     3  .29722,  .27506,  .25082,  .22620,  .21652,  .20253,  .17266,    EXT 3140
     4  .14905,  .14234,  .14082,  .15057,  .16399,  .23608,  .24481,    EXT 3150
     5  .27791,  .29076,  .15272,  .09601,  .09456,  .14576,  .12373,    EXT 3160
     6  .18348,  .12150,  .12924,  .08538,  .04108/                      EXT 3170
      DATA(DMEABS(I),I=1, 40)/                                           EXT 3180
     1  .00063,  .00152,  .00184,  .00506,  .00791,  .01829,  .03728,    EXT 3190
     2  .06158,  .07538,  .08943,  .10051,  .11614,  .13310,  .14348,    EXT 3200
     3  .14633,  .13728,  .12462,  .11184,  .10709,  .10076,  .09006,    EXT 3210
     4  .08734,  .09000,  .10304,  .11905,  .13437,  .19551,  .20095,    EXT 3220
     5  .22494,  .18418,  .09235,  .06665,  .06823,  .12329,  .10551,    EXT 3230
     6  .16184,  .09835,  .10582,  .06759,  .03247/                      EXT 3240
      RETURN                                                             EXT 3250
CCC                                                                      EXT 3260
CCC   ALTITUDE REGIONS FOR AEROSOL EXTINCTION COEFFICIENTS               EXT 3270
CCC                                                                      EXT 3280
CCC                                                                      EXT 3290
CCC           0-2KM                                                      EXT 3300
CCC             RUREXT=RURAL EXTINCTION   RURABS=RURAL ABSORPTION        EXT 3310
CCC             URBEXT=URBAN EXTINCTION   URBABS=URBAN ABSORPTION        EXT 3320
CCC             OCNEXT=MARITIME EXTINCTION  OCNABS=MARITIME ABSORPTION   EXT 3330
CCC             TROEXT=TROPSPHER EXTINCTION  TROABS=TROPOSPHER ABSORPTION EXT 3340
CCC             FG1EXT=FOG1 .2KM VIS EXTINCTION  FG1ABS=FOG1 ABSORPTION  EXT 3350
CCC             FG2EXT=FOG2 .5KM VIS EXTINCTION  FG2ABS=FOG2 ABSORPTION  EXT 3360
CCC           >2-9KM                                                     EXT 3370
CCC             TROEXT=TROPOSPHER EXTINCTION  TROABS=TROPOSPHER ABSORPTIONEXT 3380
CCC           >9-30KM                                                    EXT 3390
CCC             BSTEXT=BACKGROUND STRATOSPHERIC EXTINCTION               EXT 3400
CCC             BSTABS=BACKGROUND STRATOSPHERIC ABSORPTION               EXT 3410
CCC             AVOEXT=AGED VOLCANIC EXTINCTION                          EXT 3420
CCC             AVOABS=AGED VOLCANIC ABSORPTION                          EXT 3430
CCC             FVOEXT=FRESH VOLCANIC EXTINCTION                         EXT 3440
CCC             FVOABS=FRESH VOLCANIC ABSORPTION                         EXT 3450
CCC           >30-100KM                                                  EXT 3460
CCC             DMEEXT=METEORIC DUST EXTINCTION                          EXT 3470
CCC             DMEABS=METEORIC DUST ABSORPTION                          EXT 3480
      END                                                                EXT 3490
```

Table A1. Listing of Fortran Code LOWTRAN 5 (Cont.)

```
      SUBROUTINE PATH
C                                            REVISED 12 DEC 79
C     LOADS CUMULATIVE ABSORBER AMOUNTS INTO THE MATRIX WPATH FROM WLAY
C        FOR THE ATMOSPHERIC SLANT PATH
C     USED FOR RADIANCE CALCULATIONS
C
      COMMON /CARD1/ MODEL,IHAZE,ITYPE,LEN,JP,IM,M1,M2,M3,ML,IEMISS,RO
     1 ,TBOUND,ISEASN,IVULCN,VIS
      COMMON /CARD2/ H1,H2,ANGLE,RANGE,BETA,HMIN,RE
      COMMON /CARD3/ V1,V2,DV,AVW,CO,CW,W(15),E(15),CA,FI
      COMMON /CNTRL/ LENST,KMAX,M,IJ,J1,J2,JMIN,JEXTRA,IL,IKMAX,NLL,NP1
     1,IFIND,NL,IKLO
      COMMON /MDATA/ Z(34),P(7,34),T(7,34),WH(7,34),WO(7,34)
     1 ,SEASN(2),VULCN(5),VSB(9),HZ(15),HMIX(34)
      COMMON RELHUM(34),HSTOR(34),EH(15,34),ICH(4),VH(15),TX(15)
      COMMON WLAY(34,15),WPATH(68,15),TBBY(68)
      COMMON ABSC(4,40),EXTC(4,40),VX2(40)
      IF (ITYPE.EQ.1) GO TO 60
      IF (J1.EQ.J2.AND.J1.EQ.JMIN) GO TO 60
      IF (ITYPE.EQ.2.AND.H1.EQ.H2) J2=J1
      IF (H2.GT.H1.AND.ANGLE.GT.90..AND.NP1.EQ.1) J1=J1-1
      IF (JEXTRA.EQ.1) J2=J2+1
      IF ((ITYPE.EQ.2).AND.(H1.GT.H2).AND.(LENST.EQ.1)) J2=J2-1
      IF (ITYPE.EQ.3) J2=NL
      IF(JP.EQ.0) PRINT 70, J1,J2
      IF(JP.EQ.0) PRINT 75
      DO 5 IK=1,68
      TBBY(IK)=0.
      DO 5 K=1,KMAX
      WPATH(IK,K)=0.
    5 CONTINUE
      LEN=0
      NLL=NL-1
      IL=J1+1
      IJ=IL+NLL
      DO 10 K=1,KMAX
      E(K)=0.
   10 CONTINUE
      IF (ANGLE.GT.90.0) GO TO 15
      LEN=1.
      IL=J1-1
      HMIN=1.0E-6
      IJ=NLL
   15 CONTINUE
      DO 40 IK=1,68
      IF (LEN.EQ.0) IL=IL-1
      IF (LEN.EQ.1) IL=IL+1
      IJ=IJ-1
      IF (IL.EQ.0) GO TO 40
      DO 20 K=1,KMAX
      W(K)=E(K)+WLAY(IL,K)
      WPATH(IK,K)=W(K)
   20 CONTINUE
      IF (IL.LE.0.OR.IL.GE.NL) GO TO 25
      TBAR=(T(M,IL)+T(M,IL+1))*0.5
      IF(M1.GT.0.AND.M.LT.7) TBAR=(T(M1,IL)+T(M1,IL+1))*0.5
C
C      IF (JEXTRA.EQ.1) TBAR=(T(M,J1)+T(M,J1+1))*0.5
   25 CONTINUE
      TBBY(IK)=TBAR
```

Table A1. Listing of Fortran Code LOWTRAN 5 (Cont.)

```
      DO 30 K=1,KMAX
      E(K)=W(K)
   30 CONTINUE
      IF (ANGLE.LE.90.0.AND.IL.EQ.NLL) GO TO 50
      IF (ITYPE.EQ.3.AND.ANGLE.LE.90.0) GO TO 35
      IF (ITYPE.EQ.3.AND.LEN.EQ.1.AND.IL.EQ.J2) GO TO 50
      IF (ITYPE.EQ.2.AND.LENST.EQ.0.AND.IL.EQ.J2) GO TO 50
      IF (IL.EQ.JMIN.AND.HMIN.GT.0.0) LEN=1
      IF (IL.EQ.1.AND.HMIN.LE.0.0) GO TO 50
      IF (LEN.EQ.0) GO TO 35
      IF (IL.EQ.JMIN.AND.IJ.EQ.IL+NLL) IL=IL-1
      IF (ITYPE.EQ.2.AND.IL.EQ.J2) GO TO 50
   35 CONTINUE
      IF(JP.EQ.0)PRINT 80, IK,(WPATH(IK,K),K=1,8), WPATH(IK,10),
     1WPATH(IK,11),TBBY(IK)
   40 CONTINUE
      IKMAX=68
      LEN=LENST
      IF(JP.NE.0) RETURN
      PRINT 85
      DO 45 IK=1,IKMAX
   45 PRINT 80, IK,(WPATH(IK,K),K=12,14)
      RETURN
   50 CONTINUE
      IF(JP.EQ.0) PRINT 80, IK,(WPATH(IK,K),K=1,8),WPATH(IK,10)
     1 ,WPATH(IK,11),TBBY(IK)
      IKMAX=IK
      LEN=LENST
      IF(JP.NE.0) RETURN
      PRINT 85
      DO 55 IK=1,IKMAX
   55 PRINT 80, IK,(WPATH(IK,K), K=12,14)
      RETURN
   60 DO 65 K=1,KMAX
      WPATH(1,K)=W(K)
   65 CONTINUE
      IF (M.EQ.0) J1=1
      J2=J1
      TBBY(1)=T(M,J1)
      IF(M1.GT.0.AND.M.LT.7) TBBY(1)=T(M1,J1)
      IKMAX=1
      IF(JP.EQ.0) PRINT 70, J1,J2
      IF(JP.EQ.0) PRINT 75
      IK=1
      IKMAX=IK
      IF(JP.EQ.0) PRINT 80, IK,(WPATH(IK,K),K=1,8),WPATH(IK,10),
     1 WPATH(IK,11),TBBY(IK)
      HMIN=1.0E-6
      IF(JP.NE.0) RETURN
      PRINT 85
      PRINT 80, IK,(WPATH(IK,K),K=12,14)
      RETURN
C
   70 FORMAT (9I3)
   75 FORMAT (//,20X,53H CUMULATIVE ABSORBER AMOUNTS FOR THE ATMOSPHERIC
     1 PATH,//10X,3HH2O,6X,4HCO2+,8X,2HO3,9X,2HN2,8X,5HH2O C,6X,5HMOL S,
     27X,4HAER1,6X,5HO3 UV,7X,5HH2O C,7X,4HHNO3,5X,4HTAVE)
   80 FORMAT (I5,1P10E11.3,0PF10.3)
   85 FORMAT (//,2X,2HIK,4X,4HAER2,7X,4HAER3,7X,4HAER4)
      END
```

Table A1. Listing of Fortran Code LOWTRAN 5 (Cont.)

```
      SUBROUTINE TRANS
C                                                     REVISED 16 JAN 1980
C     CALCULATES TRANSMITTANCE AND RADIANCE VALUES BETWEEN V1 AND V2
C        FOR A GIVEN ATMOSPHERIC SLANT PATH
C
      COMMON /CARD1/ MODEL,IHAZE,ITYPE,LEN,JP,IM,M1,M2,M3,ML,IEMISS,RO
     1 ,TBOUND,ISEASN,IVULCN,VIS
      COMMON /CARD2/ H1,H2,ANGLE,RANGE,BETA,HMIN,RE
      COMMON /CARD3/ V1,V2,DV,AVW,CO,CW,H(15),C(15),CA,FI
      COMMON /CNTRL/ LENST,KMAX,M,IJ,J1,J2,JMIN,JEXTRA,IL,IKMAX,NLL,NP1
     1,IFIND,NL,IKLO
      COMMON /MDATA/ Z(34),P(7,34),T(7,34),WH(7,34),WO(7,34)
     1 ,SEASN(2),VULCN(5),VSB(9),HZ(15),HMIX(34)
      COMMON RELHUM(34),HSTOR(34),EH(15,34),ICH(4),VH(15),TX(15)
      COMMON WLAY(34,15),WPATH(68,15),TBBY(68)
      COMMON ABSC(4,40),EXTC(4,40),VX2(40)
      COMMON /TRFWFO/ TR(67),FW(67),FO(67)
      COMMON /C4C5C8/ C4(133),C5(15),C8(102)
      COMMON /AER/ XX1,XX2,XX3,XX4,YY1,YY2,YY3,YY4
      DIMENSION ABS(15)
      FF(T,V)=1.190956E-16*(V**5)/(EXP(1.43879*V/T)-1.)
C       WATTS. CM-2 ST-1 MICRON-1
      RADMIN=1.0E+300
      RADMAX=0.
      VRMIN=0.
      VRMAX=0.
      SUMA=0.
      RADSUM=0.
      FACTOR=0.5
      CALL C4DTA
      CALL TRFN
      IV1=V1/5.
      IV2=V2/5.+.99
      IV1=IV1*5
      IV2=IV2*5
      IF (IV1.LT.350) IV1=350
      IF (IV2.GT.50000) IV2=50000
      IF (DV.LT.5) DV=5
      IDV=DV
      IV=IV1-IDV
      ICOUNT=0
C       BEGINING OF TRANSMITTANCE CALCULATIONS
    5 IV=IV+IDV
      SUMV=0.
      TLOLD=1.
      TSOLD=1.
      IKLO=1
      IF (IEMISS.EQ.0) IKMAX=IKLO
      DO 10 JK=1,11
      ABS(JK)=0.
      IF (JK.LE.3) ABS(JK)=-5.
   10 CONTINUE
      IF (JP.NE.0) GO TO 20
      IF (ICOUNT.EQ.0) GO TO 15
      IF (ICOUNT.EQ.50) GO TO 15
      GO TO 20
   15 ICOUNT=0
      IF (IEMISS.EQ.0) PRINT 255
   20 DO 25 K=1,KMAX
      TX(K)=0.0
```

Table A1. Listing of Fortran Code LOWTRAN 5 (Cont.)

```
      IF (K.LT.4) TX(K)=1.0                                             TRA  610
   25 CONTINUE                                                          TRA  620
      ICOUNT=ICOUNT+1                                                   TRA  630
      SUM=0.0                                                           TRA  640
      V=IV                                                              TRA  650
      I=(IV-350)/5+1                                                    TRA  660
C     ******************  HNO3                                          TRA  670
C     HNO3 ABSORPTION CALCULATION                                       TRA  680
      CALL HNO3 (V,ABS(11))                                             TRA  690
      IF (IV.LT.670) GO TO 80                                           TRA  700
      IF (IV.LE.3000) GO TO 45                                          TRA  710
C     ***   MOLECULAR SCATTERING                                        TRA  720
      ABS(6)=V**4/(9.26799E+18-1.07123E+09*V**2)                        TRA  730
      IF (IV.LT.9200) GO TO 80                                          TRA  740
      IF (IV.LT.13000) GO TO 65                                         TRA  750
C     ***  UV OZONE                                                     TRA  760
      IF (IV.LE.23400) GO TO 30                                         TRA  770
      IF (IV.GE.27500) GO TO 35                                         TRA  780
      GO TO 110                                                         TRA  790
   30 XI=(V-13000.0)/200.0+1.                                           TRA  800
      GO TO 40                                                          TRA  810
   35 XI=(V-27500.0)/500.+57.                                           TRA  820
   40 N=XI+1.001                                                        TRA  830
      XD=XI-FLOAT(N)                                                    TRA  840
      ABS(8)=C8(N)+XD*(C8(N)-C8(N-1))                                   TRA  850
      IF (IV.GT.14500) GO TO 110                                        TRA  860
      GO TO 65                                                          TRA  870
C     ***  WATER VAPOR CONTINUUM 10 MICRON REGION                       TRA  880
   45 IF (IV.GT.1350) GO TO 50                                          TRA  890
      ABS(5)=(4.18+5578.0*EXP(-7.87E-3*V))                              TRA  900
      GO TO 55                                                          TRA  910
   50 IF (IV.LT.2350) GO TO 60                                          TRA  920
C     ***  WATER VAPOR CONTINUUM 4 MICRON REGION                        TRA  930
      XI=(V-2350.0)/50.0+1.0                                            TRA  940
      NH=XI+1.001                                                       TRA  950
      XH=XI-FLOAT(NH)                                                   TRA  960
      ABS(10)=C5(NH)+XH*(C5(NH)-C5(NH-1))                               TRA  970
   55 CONTINUE                                                          TRA  980
      IF (IV.LE.1350.OR.IV.GT.2740) GO TO 80                            TRA  990
C     ***   NITROGEN CONTINUUM                                          TRA 1000
   60 IF (IV.LT.2080) GO TO 80                                          TRA 1010
      K4=I-346                                                          TRA 1020
      ABS(4)=C4(K4)                                                     TRA 1030
      GO TO 80                                                          TRA 1040
C     ***  WATER VAPOUR                                                 TRA 1050
   65 IF (IV.LT.12800.AND.IV.GE.9875) GO TO 70                          TRA 1060
      IF (IV.LE.14520.AND.IV.GE.13400) GO TO 75                         TRA 1070
      GO TO 85                                                          TRA 1080
   70 I=I-135                                                           TRA 1090
      GO TO 80                                                          TRA 1100
   75 I=I-255                                                           TRA 1110
   80 CALL C1DTA (ABS(1),T)                                             TRA 1120
   85 CONTINUE                                                          TRA 1130
C     ***   UNIFORMLY MIXED GASES                                       TRA 1140
      IF (IV.LT.8060.AND.IV.GE.500) GO TO 90                            TRA 1150
      IF (IV.LT.13190.AND.IV.GT.12970) GO TO 95                         TRA 1160
      GO TO 105                                                         TRA 1170
   90 J=I-30                                                            TRA 1180
      GO TO 100                                                         TRA 1190
   95 J=(IV-12950)/5+1516                                               TRA 1200
```

Table A1. Listing of Fortran Code LOWTRAN 5 (Cont.)

```
100 CALL C2DTA (ABS(2),J)                                            TRA 1210
105 CONTINUE                                                         TRA 1220
    ***  OZONE                                                       TRA 1230
    IF (IV.LT.575.OR.IV.GT.3270) GO TO 110                           TRA 1240
    L=I-45                                                           TRA 1250
    CALL C3DTA (ABS(3),L)                                            TRA 1260
110 CONTINUE                                                         TRA 1270
    CALL AEREXT (V)                                                  TRA 1280
    DO 210 IK=IKLO,IKMAX                                             TRA 1290
    IF (IEMISS.EQ.0) GO TO 120                                       TRA 1300
    DO 115 K=1,KMAX                                                  TRA 1310
    W(K)=WPATH(IK,K)                                                 TRA 1320
115 CONTINUE                                                         TRA 1330
120 CONTINUE                                                         TRA 1340
    SUM=0.                                                           TRA 1350
    DO 125 JK=4,11                                                   TRA 1360
    TX(JK)=ABS(JK)*W(JK)                                             TRA 1370
125 SUM=SUM+TX(JK)                                                   TRA 1380
    TX(5)=TX(5)+TX(10)                                               TRA 1390
    TX(1)=1.0                                                        TRA 1400
    K1=1                                                             TRA 1410
    IF (W(1).LT.1.0E-20) GO TO 145                                   TRA 1420
    IF (ABS(1).LE.-5.0) GO TO 145                                    TRA 1430
    WS1=ALOG10(W(1))+ABS(1)                                          TRA 1440
    IF (WS1.LT.-2.3468) TX(1)=1.-.087787*EXP(1.855595*WS1)           TRA 1450
    IF (WS1.LT.-2.3468) GO TO 145                                    TRA 1460
    IF (WS1.GT.3.5682) GO TO 140                                     TRA 1470
    IF (WS1.GT.2.0) K1=40                                            TRA 1480
    DO 130 K=K1,67                                                   TRA 1490
    IF (WS1.LE.FW(K)) GO TO 135                                      TRA 1500
130 CONTINUE                                                         TRA 1510
135 TX(1)=TR(K)+(TR(K-1)-TR(K))*(FW(K)-WS1)/(FW(K)-FW(K-1))          TRA 1520
    GO TO 145                                                        TRA 1530
140 TX(1)=0.0                                                        TRA 1540
145 CONTINUE                                                         TRA 1550
    TX(2)=1.0                                                        TRA 1560
    K1=1                                                             TRA 1570
    IF (W(2).LT.1.0E-20) GO TO 165                                   TRA 1580
    IF (ABS(2).LE.-5.0) GO TO 165                                    TRA 1590
    WS2=ALOG10(W(2))+ABS(2)                                          TRA 1600
    IF (WS2.LT.-2.3468) TX(2)=1.-.087787*EXP(1.855595*WS2)           TRA 1610
    IF (WS2.LT.-2.3468) GO TO 165                                    TRA 1620
    IF (WS2.GT.3.5682) GO TO 160                                     TRA 1630
    IF (WS2.GT.2.0) K1=40                                            TRA 1640
    DO 150 K=K1,67                                                   TRA 1650
    IF (WS2.LE.FW(K)) GO TO 155                                      TRA 1660
150 CONTINUE                                                         TRA 1670
155 TX(2)=TR(K)+(TR(K-1)-TR(K))*(FW(K)-WS2)/(FW(K)-FW(K-1))          TRA 1680
    GO TO 165                                                        TRA 1690
160 TX(2)=0.0                                                        TRA 1700
165 CONTINUE                                                         TRA 1710
    TX(3)=1.                                                         TRA 1720
    K1=1                                                             TRA 1730
    IF (W(3).LT.1.0E-20) GO TO 185                                   TRA 1740
    IF (ABS(3).LE.-5.0) GO TO 185                                    TRA 1750
    WS3=ALOG10(W(3))+ABS(3)                                          TRA 1760
    IF (WS3.LT.-1.6778) TX(3)=1.-.055194*EXP(2.367853*WS3)           TRA 1770
    IF (WS3.LT.-1.6778) GO TO 185                                    TRA 1780
    IF (WS3.GT.3.9345) GO TO 180                                     TRA 1790
    IF (WS3.GT.1.5) K1=36                                            TRA 1800
```

Table A1. Listing of Fortran Code LOWTRAN 5 (Cont.)

```
      DO 170 K=K1,67                                                    TRA 1810
      IF (WS3.LE.FO(K)) GO TO 175                                       TRA 1820
  170 CONTINUE                                                          TRA 1830
  175 TX(3)=TR(K)-(TR(K)-TR(K-1))*(FO(K)-WS3)/(FO(K)-FO(K-1))          TRA 1840
      GO TO 185                                                         TRA 1850
  180 TX(3)=0.0                                                         TRA 1860
  185 CONTINUE                                                          TRA 1870
      TX(10)=YY1*H(7)+YY2*H(12)+YY3*H(13)+YY4*H(14)                     TRA 1880
      TX(7)=XX1*H(7)+XX2*H(12)+XX3*H(13)+XX4*H(14)                      TRA 1890
      SUM=SUM+TX(7)                                                     TRA 1900
      TX(9)=SUM                                                         TRA 1910
      DO 205 K=4,KMAX                                                   TRA 1920
      IF (TX(K).EQ.0.0) GO TO 195                                       TRA 1930
      IF (TX(K).LE.0.1) GO TO 190                                       TRA 1940
      IF (TX(K).GT.20.) GO TO 200                                       TRA 1950
      TX(K)=EXP(-TX(K))                                                 TRA 1960
      GO TO 205                                                         TRA 1970
  190 TX(K)=1.0-TX(K)+0.5*TX(K)*TX(K)                                   TRA 1980
      GO TO 205                                                         TRA 1990
  195 TX(K)=1.0                                                         TRA 2000
      GO TO 205                                                         TRA 2010
  200 TX(K)=0.                                                          TRA 2020
  205 CONTINUE                                                          TRA 2030
      TX(9)=TX(1)*TX(2)*TX(3)*TX(9)                                     TRA 2040
      IF (IV.GE.13000) TX(3)=TX(8)                                      TRA 2050
      ALAM=1.0E+04/V                                                    TRA 2060
      IF (IEMISS.EQ.0) GO TO 220                                        TRA 2070
      BBIK=FF(TBBY(IK),V)                                               TRA 2080
      TLNEW=(TX(9)*TX(10))/(TX(7)*TX(6))                                TRA 2090
      TSNEW=(TX(7)*TX(6))/TX(10)                                        TRA 2100
      DTAU=TLOLD-TLNEW                                                  TRA 2110
      IF (DTAU.LT.1.0E-5.AND.TLNEW.LT.1.0E-5) GO TO 215                 TRA 2120
      SUMV=SUMV+0.5*BBIK*DTAU*(TSOLD+TSNEW)                             TRA 2130
      TLOLD=TLNEW                                                       TRA 2140
      TSOLD=TSNEW                                                       TRA 2150
  210 CONTINUE                                                          TRA 2160
  215 CONTINUE                                                          TRA 2170
      TAUG=0                                                            TRA 2180
      IF (HMIN.LE.0.0.AND.IL.EQ.1) TAUG=TX(9)                           TRA 2190
      T1=TBOUND                                                         TRA 2200
      BBG=FF(T1,V)*TAUG                                                 TRA 2210
      IF (HMIN.LE.0.0) SUMV=SUMV+BBG                                    TRA 2220
      SUMVV=SUMV                                                        TRA 2230
      IF (IV.GT.IV1) FACTOR=1.0                                         TRA 2240
      IF (IV.GE.IV2) FACTOR=0.5                                         TRA 2250
      SUMV=(1.0E+04/V**2)*SUMV                                          TRA 2260
      RADSUM=RADSUM+DV*FACTOR*SUMV                                      TRA 2270
      IF (JP.EQ.0) PRINT 265, V,ALAM,SUMV,SUMVV,RADSUM,TX(9)            TRA 2280
      IF (SUMV.GE.RADMAX) VRMAX=V                                       TRA 2290
      IF (SUMV.GE.RADMAX) RADMAX=SUMV                                   TRA 2300
      IF (SUMV.LE.RADMIN) VRMIN=V                                       TRA 2310
      IF (SUMV.LE.RADMIN) RADMIN=SUMV                                   TRA 2320
      WRITE (7,235) V,ALAM,SUMV,SUMVV,RADSUM,TX(9)                      TRA 2330
  220 TX(10)=1.-TX(10)                                                  TRA 2340
      AB=1.-TX(9)                                                       TRA 2350
      IF (IV.EQ.IV1.OR.IV.EQ.IV2) AB=0.5*AB                             TRA 2360
      SUMA=SUMA+AB*DV                                                   TRA 2370
      IF (IEMISS.EQ.1) GO TO 225                                        TRA 2380
      IF (JP.EQ.0) WRITE (6,260) IV,ALAM,TX(9),(TX(K),K=1,7),TX(10),SUMATRA 2390
     1,TX(11)                                                           TRA 2400
```

Table A1. Listing of Fortran Code LOWTRAN 5 (Cont.)

```
C      IF(JP.EQ.0)WRITE (6,483) IV,ALAM,EXTINC,ABSORB                    TRA 2410
       WRITE (7,240) IV,ALAM,TX(9),(TX(K),K=1,7),TX(10),TX(11)           TRA 2420
   225 CONTINUE                                                          TRA 2430
       IF (IV.GE.IV2) GO TO 230                                          TRA 2440
       GO TO 5                                                           TRA 2450
   230 AB=1.0-SUMA/FLOAT(IV-TV1)                                         TRA 2460
       PRINT 245, IV1,TV,SUMA,AB                                         TRA 2470
       IF (IEMISS.EQ.1) PRINT 250, RADSUM,VRMIN,RADMIN,VRMAX,RADMAX      TRA 2480
       RETURN                                                            TRA 2490
C                                                                        TRA 2500
   235 FORMAT (F8.1,F13.5,3E13.5,F13.6)                                  TRA 2510
   240 FORMAT(I6,11F9.4,5X,F9.4)                                         TRA 2520
   245 FORMAT (27H INTEGRATED ABSORPTION FROM,I5,3H TO,I5,7H CM-1 =,F10.2TRA 2530
      1,23HAVERAGE TRANSMITTANCE =,F6.4)                                 TRA 2540
   250 FORMAT (22H INTEGRATED RADIANCE =,E12.5,13HWATT CM -2 SR,/7H RADMITRA 2550
      1N,F12.3,E12.5,/,8H RADMAX ,F12.3,E12.5)                           TRA 2560
   255 FORMAT (1H1,/10X,32H  FREQ WAVELENGTH  TOTAL     H2O,5X,4HCO2+,5X,TRA 2570
      164HOZONE  N2 CONT  H2O CONT MOL SCAT  AEROSOL  AEROSOL   INTEGRATETRA 2580
      2D,12H NITRIC ACID/11X,14H CM-1  MICRONS,8(4X,5HTRANS),4X,20H ABS  TRA 2590
      3   ABSORPTION ,4X,5HTRANS)                                        TRA 2600
   260 FORMAT (10X,I6,10F9.4,F14.4,F9.4)                                 TRA 2610
   265 FORMAT (30X,F8.1,F13.5,3E13.5,F13.6)                              TRA 2620
       END                                                               TRA 2630
```

Table A1. Listing of Fortran Code LOWTRAN 5 (Cont.)

```
      SUBROUTINE TRFN
C     LOWTRAN TRANSMITTANCE FUNCTIONS
      COMMON /TRFWFO/ TR(67),FW(67),FO(67)
      DATA(TR(I),I=1, 67)/
     1  .9990,  .9980,  .9960,  .9940,  .9920,  .9900,  .9800,  .9700,
     2  .9600,  .9500,  .9400,  .9300,  .9200,  .9100,  .9000,  .8800,
     3  .8600,  .8400,  .8200,  .8000,  .7800,  .7600,  .7400,  .7200,
     4  .7000,  .6800,  .6600,  .6400,  .6200,  .6000,  .5800,  .5600,
     5  .5400,  .5200,  .5000,  .4800,  .4600,  .4400,  .4200,  .4000,
     6  .3800,  .3600,  .3400,  .3200,  .3000,  .2800,  .2600,  .2400,
     7  .2200,  .2000,  .1800,  .1600,  .1400,  .1200,  .1000,  .0800,
     8  .0600,  .0400,  .0300,  .0200,  .0150,  .0100,  .0080,  .0060,
     9  .0040,  .0020,  .0010/
      DATA(FW(I),I=1, 67)/
     1-2.3468,-2.0362,-1.6990,-1.4815,-1.3279,-1.2007, -.7825, -.5229,
     2 -.3468, -.1938, -.0655,  .0414,  .1553,  .2430,  .3324,  .4038,
     3  .6128,  .7243,  .8261,  .9191, 1.0000, 1.0792, 1.1461, 1.2122,
     4 1.2672, 1.3284, 1.3892, 1.4409, 1.4955, 1.5441, 1.5966, 1.6435,
     5 1.6857, 1.7340, 1.7782, 1.8261, 1.8692, 1.9191, 1.9638, 2.0086,
     6 2.0607, 2.1038, 2.1461, 2.1875, 2.2304, 2.2788, 2.3263, 2.3717,
     7 2.4183, 2.4698, 2.5159, 2.5740, 2.6284, 2.6902, 2.7559, 2.8261,
     8 2.9031, 3.0000, 3.0607, 3.1461, 3.2041, 3.2718, 3.3054, 3.3444,
     9 3.3979, 3.4914, 3.5682/
      DATA(FO(I),I=1, 67)/
     1-1.6778,-1.3980,-1.1192, -.9508, -.8239, -.7258, -.4318, -.2366,
     2 -.1074, 0.0000,  .0969,  .1761,  .2304,  .3010,  .3522,  .4624,
     3  .5563,  .6435,  .7243,  .7924,  .8573,  .9191,  .9731, 1.0253,
     4 1.0719, 1.1173, 1.1614, 1.2095, 1.2480, 1.2900, 1.3263, 1.3617,
     5 1.3979, 1.4393, 1.4698, 1.4983, 1.5314, 1.5682, 1.6021, 1.6335,
     6 1.6721, 1.7076, 1.7482, 1.7924, 1.8325, 1.8865, 1.9395, 2.0000,
     7 2.0607, 2.1206, 2.1903, 2.2552, 2.3385, 2.4313, 2.5185, 2.6435,
     8 2.7853, 2.9777, 3.1072, 3.2553, 3.3617, 3.4771, 3.5563, 3.6233,
     9 3.7076, 3.8325, 3.9345/
      RETURN
      END
```

Table A1. Listing of Fortran Code LOWTRAN 5 (Cont.)

```
      SUBROUTINE AEREXT (V)
C
C     INTERPOLATES AEROSOL EXTINCTION AND ABSORPTION COEFFICIENT
C        FOR THE WAVENUMBER, V.
C
      COMMON /CARD1/ MODEL,IHAZE,ITYPE,LEN,JP,IM,M1,M2,M3,ML,IEMISS,RO
     1 ,IBOUND,ISEASN,IVULCN,VIS
      COMMON /CARD2/ H1,H2,ANGLE,RANGE,BETA,HMIN,RE
      COMMON /CARD3/ V1,V2,DV,AVW,CO,CW,W(15),E(15),CA,PI
      COMMON /CNTRL/ LENST,KMAX,M,IJ,J1,J2,JMIN,JEXTRA,IL,IKMAX,NLL,NP1
     1,IFIND,NL,IKLO
      COMMON /MDATA/ Z(34),P(7,34),T(7,34),WH(7,34),WO(7,34)
     1 ,SEASN(2),VULCN(5),VSB(9),HZ(15),HMIX(34)
      COMMON RELHUM(34),HSTOR(34),EH(15,34),ICH(4),VH(15),TX(15)
      COMMON WLAY(34,15),WPATH(68,15),TBBY(68)
      COMMON ABSC(4,40),EXTC(4,40),VX2(40)
      COMMON /AER/ EXTV(4),ABSV(4)
      DO 5 I=1,4
      EXTV(I)=0.
      ABSV(I)=0.
    5 CONTINUE
      IF (IHAZE.EQ.0) RETURN
      ALAM=1.0E+4/V
      DO 10 N=1,40
      XD=ALAM-VX2(N)
      IF (XD) 15,15,10
   10 CONTINUE
      N=40
   15 VXD=VX2(N)-VX2(N-1)
      DO 20 I=1,4
      EXTV(I)=(EXTC(I,N)-EXTC(I,N-1))*XD/VXD+EXTC(I,N)
      ABSV(I)=(ABSC(I,N)-ABSC(I,N-1))*XD/VXD+ABSC(I,N)
   20 CONTINUE
      RETURN
      END
```

Table A1. Listing of Fortran Code LOWTRAN 5 (Cont.)

```
      SUBROUTINE HNO3 (V,HABS)
C
C     HNO3  STATISTICAL BAND PARAMETERS
C
      DIMENSION H1(15), H2(16), H3(13)
C     ARRAY H1 CONTAINS HNO3 ABS, COEF(CM-1ATM-1) FROM  850 TO 920 CM-1
      DATA H1/2.197,3.911,6.154,8.150,9.217,9.461,11.56,11.10,11.17,12.4
     10,10.49,7.509,6.136,4.899,2.866/
C     ARRAY H2 CONTAINS HNO3 ABS, COEF(CM-1ATM-1) FROM 1275 TO1350 CM-1
      DATA H2/2.828,4.611,6.755,8.759,10.51,13.74,18.00,21.51,23.09,21.6
     18,21.32,16.82,16.42,17.87,14.86,8.716/
C     ARRAY H3 CONTAINS HNO3 ABS, COEF(CM-1ATM-1) FROM 1675 TO1735 CM-1
      DATA H3/5.003,8.803,14.12,19.83,23.31,23.58,23.22,21.09,26.99,25.8
     14,24.79,17.68,9.420/
      HABS=0.
      IF (V.GE.850.0.AND.V.LE.920.0) GO TO 5
      IF (V.GE.1275.0.AND.V.LE.1350.0) GO TO 10
      IF (V.GE.1675.0.AND.V.LE.1735.0) GO TO 15
      RETURN
    5 I=(V-845.)/5.
      HABS=H1(I)
      RETURN
   10 I=(V-1270.)/5.
      HABS=H2(I)
      RETURN
   15 I=(V-1670.)/5.
      HABS=H3(I)
      RETURN
      END
```

Table A1. Listing of Fortran Code LOWTRAN 5 (Cont.)

```
      SUBROUTINE C1DTA (C1L,L)
C          WATER VAPOR
C     C1 LOCATION  1    V =  350  CM-1
C     C1 LOCATION  1770 V =  9195  CM-1
C     C1 LOCATION  1771 V =  9875  CM-1
C     C1 LOCATION  2355 V =  12795  CM-1
C     C1 LOCATION  2356 V =  12350  CM-1
C     C1 LOCATION  2580 V =  14520  CM-1
      COMMON /C1/C1(2580)
      DATA(C1(I),I=    1, 190)/
     1 3.93, 3.72, 3.54, 3.42, 3.37, 3.37, 3.36, 3.33, 3.25, 3.13,
     2 3.02, 2.96, 2.97, 3.00, 3.08, 3.12, 3.08, 3.03, 3.00, 3.01,
     3 3.03, 3.07, 3.05, 3.01, 2.94, 2.83, 2.71, 2.62, 2.58, 2.57,
     4 2.62, 2.67, 2.72, 2.71, 2.60, 2.46, 2.35, 2.26, 2.22, 2.23,
     5 2.19, 2.17, 2.17, 2.20, 2.26, 2.34, 2.42, 2.39, 2.20, 2.01,
     6 1.92, 1.83, 1.78, 1.79, 1.81, 1.84, 1.83, 1.80, 1.71, 1.51,
     7 1.39, 1.30, 1.25, 1.18, 1.19, 1.18, 1.21, 1.33, 1.47, 1.53,
     8 1.54, 1.36, 1.12,  .89,  .69,  .49,  .60,  .71,  .79,  .99,
     9  .86,  .73,  .53,  .43,  .51,  .52,  .67,  .73,  .80,  .83,
     $  .80,  .63,  .47,  .32, -.08, -.21, -.29, -.21, -.01,  .08,
     $  .16,  .09, -.03, -.21, -.37, -.35, -.30, -.31, -.37, -.42,
     $ -.48, -.42, -.40, -.39, -.43, -.77, -.83, -.88, -.79, -.60,
     $ -.50, -.42, -.39, -.38, -.37, -.40, -.51, -.67, -.82, -.58,
     $ -.40, -.32, -.21, -.09, -.18, -.16, -.19, -.28, -.33, -.35,
     $ -.28, -.22, -.10, -.05, -.11, -.13, -.27, -.27, -.18, -.06,
     $  .11,  .23,  .26,  .19,  .11, 0.00, -.09,  .02,  .08,  .12,
     $  .22,  .28,  .39,  .54,  .68,  .75,  .79,  .79,  .71,  .69,
     $  .76,  .88, 1.01, 1.16, 1.18, 1.14, 1.05, 1.02, 1.11, 1.23,
     $ 1.41, 1.75, 1.83, 1.99, 2.05, 3.03, 2.00, 1.96, 1.90, 1.86/
      DATA(C1(I),I= 191, 380)/
     1 1.91, 2.08, 2.24, 2.41, 2.63, 2.68, 2.67, 2.73, 2.79, 2.81,
     2 2.91, 2.93, 3.02, 3.16, 3.23, 3.30, 3.34, 3.43, 3.57, 3.59,
     3 3.59, 3.58, 3.57, 3.61, 3.71, 3.71, 3.69, 3.64, 3.60, 3.68,
     4 3.80, 3.95, 4.05, 4.05, 4.02, 3.99, 3.96, 4.01, 4.13, 4.22,
     5 4.35, 4.49, 4.58, 4.62, 4.63, 4.61, 4.57, 4.56, 4.56, 4.53,
     6 4.49, 4.46, 4.40, 4.28, 4.14, 3.92, 3.63, 3.35, 3.16, 3.10,
     7 3.24, 3.47, 3.66, 3.80, 3.93, 4.00, 4.04, 4.15, 4.23, 4.31,
     8 4.35, 4.31, 4.23, 4.20, 4.24, 4.28, 4.35, 4.42, 4.42, 4.44,
     9 4.46, 4.40, 4.30, 4.22, 4.13, 4.07, 4.12, 4.19, 4.22, 4.23,
     $ 4.16, 4.04, 3.99, 3.94, 3.93, 3.91, 3.86, 3.83, 3.80, 3.78,
     $ 3.70, 3.54, 3.40, 3.30, 3.31, 3.42, 3.52, 3.52, 3.49, 3.41,
     $ 3.21, 3.14, 3.10, 3.08, 3.11, 2.98, 2.88, 2.78, 2.74, 2.76,
     $ 2.77, 2.76, 2.82, 2.85, 2.86, 2.75, 2.64, 2.60, 2.61, 2.64,
     $ 2.56, 2.49, 2.37, 2.25, 2.14, 2.08, 2.11, 2.20, 2.31, 2.28,
     $ 2.15, 2.06, 1.98, 2.03, 2.05, 1.96, 1.84, 1.72, 1.64, 1.59,
     $ 1.57, 1.57, 1.60, 1.63, 1.51, 1.38, 1.07,  .91,  .87,  .92,
     $ 1.04, 1.01,  .92,  .84,  .92,  .97, 1.01, 1.06, 1.10, 1.06,
     $ 1.01,  .91,  .79,  .55,  .47,  .41,  .39,  .38,  .34,  .33,
     $  .36,  .43,  .48,  .45,  .38,  .27,  .21,  .22,  .29,  .37/
      DATA(C1(I),I= 381, 570)/
     1  .38,  .37,  .29,  .19,  .13,  .11,  .03, -.05, -.12, -.24,
     2 -.31, -.39, -.43, -.50, -.59, -.68, -.73, -.80, -.92,-1.06,
     3-1.14,-1.22,-1.27,-1.28,-1.33,-1.32,-1.43,-1.51,-1.63,-1.74,
     4-1.82,-1.98,-2.09,-2.21,-2.21,-2.24,-2.27,-2.36,-2.51,-2.65,
     5-2.70,-2.63,-2.57,-2.56,-2.59,-2.67,-2.69,-2.67,-2.68,-2.62,
     6-2.52,-2.42,-2.29,-2.14,-2.00,-1.87,-1.71,-1.51,-1.39,-1.27,
     7-1.12,-1.01, -.89, -.75, -.68, -.57, -.47, -.42, -.32, -.27,
     8 -.26, -.19, -.13, -.11, -.01,  .05,  .08,  .17,  .25,  .31,
     9  .41,  .43,  .44,  .43,  .36,  .35,  .31,  .25,  .25,  .22,
     $  .21,  .33,  .49,  .65,  .76,  .71,  .51,  .30,  .13,  .10,
```

Table A1. Listing of Fortran Code LOWTRAN 5 (Cont.)

```
$   .17,  .24,  .31,  .38,  .45,  .51,  .56,  .60,  .63,  .62,       C10  610
$   .63,  .64,  .66,  .69,  .76,  .75,  .74,  .70,  .62,  .53,       C10  620
$   .46,  .39,  .30,  .37,  .38,  .42,  .47,  .50,  .58,  .69,       C10  630
$   .67,  .62,  .64,  .68,  .76,  .90, 1.11, 1.13, 1.10,  .97,       C10  640
$   .98, 1.17, 1.38, 1.52, 1.70, 1.76, 1.84, 1.92, 1.90, 1.87,       C10  650
$  1.91, 2.02, 2.13, 2.10, 2.18, 2.22, 2.25, 2.03, 2.01, 1.77,       C10  660
$  1.93, 2.19, 2.28, 2.14, 2.15, 2.22, 2.01, 2.14, 2.26, 2.36,       C10  670
$  2.51, 2.66, 2.73, 2.68, 2.69, 2.64, 2.22, 1.95, 1.61, 1.11,       C10  680
$   .88,  .83,  .89, 1.20, 1.62, 1.82, 1.99, 2.01, 2.14, 2.16/       C10  690
 DATA(C1(I),I= 571, 760)/                                            C10  700
1  2.21, 2.30, 2.38, 2.42, 2.50, 2.51, 2.49, 2.46, 2.42, 2.37,       C10  710
2  2.37, 2.33, 2.31, 2.43, 2.56, 2.61, 2.63, 2.60, 2.50, 2.38,       C10  720
3  2.41, 2.34, 2.31, 2.32, 2.40, 2.27, 2.32, 2.22, 2.09, 2.08,       C10  730
4  2.17, 2.41, 2.77, 2.68, 2.49, 2.29, 2.23, 2.42, 2.61, 2.58,       C10  740
5  2.49, 2.40, 2.39, 2.51, 2.60, 2.68, 2.68, 2.70, 2.82, 2.83,       C10  750
6  2.82, 2.81, 2.84, 2.86, 2.91, 2.96, 3.03, 3.08, 3.21, 3.30,       C10  760
7  3.40, 3.52, 3.49, 3.46, 3.51, 3.54, 3.56, 3.55, 3.57, 3.61,       C10  770
8  3.71, 3.80, 3.92, 3.99, 4.06, 4.02, 4.06, 4.12, 4.28, 4.30,       C10  780
9  4.22, 4.32, 4.42, 4.53, 4.64, 4.55, 4.40, 4.28, 4.32, 4.38,       C10  790
$  4.37, 4.24, 4.13, 4.14, 4.20, 4.25, 4.32, 4.35, 4.31, 4.27,       C10  800
$  4.25, 4.27, 4.31, 4.36, 4.41, 4.52, 4.59, 4.71, 4.79, 4.81,       C10  810
$  4.73, 4.61, 4.42, 4.28, 4.08, 4.00, 3.88, 3.86, 3.92, 3.98,       C10  820
$  4.12, 4.18, 4.31, 4.37, 4.42, 4.50, 4.53, 4.56, 4.59, 4.61,       C10  830
$  4.61, 4.59, 4.53, 4.49, 4.44, 4.41, 4.40, 4.34, 4.30, 4.26,       C10  840
$  4.09, 3.98, 3.87, 3.78, 3.77, 3.79, 3.75, 3.72, 3.62, 3.56,       C10  850
$  3.51, 3.48, 3.32, 3.18, 3.07, 2.96, 2.87, 2.80, 2.68, 2.58,       C10  860
$  2.59, 2.51, 2.59, 2.57, 2.50, 2.42, 2.32, 2.20, 2.12, 2.00,       C10  870
$  1.92, 1.79, 1.63, 1.60, 1.69, 1.78, 2.04, 2.00, 1.81, 1.70,       C10  880
$  1.63, 1.61, 1.60, 1.49, 1.14, 1.35, 1.64, 1.69, 1.70, 1.59/       C10  890
 DATA(C1(I),I= 761, 950)/                                            C10  900
1  1.45, 1.29, 1.19, 1.08, 1.02, 1.04, 1.10, 1.16, 1.20, 1.23,       C10  910
2  1.22, 1.08, 1.08, 1.06,  .89,  .93,  .73,  .58,  .54,  .77,       C10  920
3   .81,  .74,  .71,  .57,  .49,  .43,  .38,  .12,  .10,  .20,       C10  930
4   .41,  .37,  .31,  .11, -.13, -.21, -.32, -.36, -.39, -.33,       C10  940
5  -.39, -.45, -.50, -.56, -.62, -.68, -.77, -.84, -.91,-1.00,       C10  950
6-1.11,-1.19,-1.28,-1.31,-1.39,-1.43,-1.48,-1.52,-1.57,-1.60,        C10  960
7-1.61,-1.60,-1.58,-1.51,-1.42,-1.32,-1.26,-1.16,-1.00, -.83,        C10  970
8  -.71, -.61, -.57, -.43, -.36, -.30, -.21, -.19, -.17, -.15,       C10  980
9  -.13, -.17, -.19, -.12, -.06, -.01, 0.00, -.11, -.23, -.32,       C10  990
$  -.44, -.51, -.48, -.47, -.42, -.40, -.40, -.39, -.37, -.35,       C10 1000
$  -.48, -.75,-1.13,-1.58,-1.80,-1.66,-1.52,-1.35,-1.19,-1.02,       C10 1010
$  -.88, -.66, -.65, -.63, -.62, -.66, -.73, -.79, -.88, -.84,       C10 1020
$  -.70, -.59, -.43, -.39, -.50, -.61, -.74, -.79, -.76, -.69,       C10 1030
$  -.62, -.59, -.52, -.48, -.48, -.42, -.39, -.38, -.33, -.29,       C10 1040
$  -.26, -.23, -.22, -.28, -.37, -.50, -.60, -.60, -.51, -.46,       C10 1050
$  -.42, -.43, -.45, -.35, -.24, -.14, -.08, -.08, 0.00,  .11,       C10 1060
$   .32,  .43,  .42,  .32,  .23,  .22,  .28,  .45,  .55,  .62,       C10 1070
$   .65,  .71,  .75,  .80,  .83,  .85,  .87,  .90,  .93, 1.00,       C10 1080
$  1.04, 1.15, 1.22, 1.32, 1.31, 1.32, 1.33, 1.48, 1.78, 1.87/       C10 1090
 DATA(C1(I),I= 951,1140)/                                            C10 1100
1  2.01, 1.92, 1.86, 1.89, 1.92, 1.98, 2.03, 2.39, 2.31, 2.48,       C10 1110
2  2.70, 2.71, 2.76, 2.78, 2.70, 2.77, 3.08, 2.94, 3.05, 2.94,       C10 1120
3  3.23, 3.20, 3.19, 3.32, 3.11, 3.41, 3.31, 3.36, 3.46, 3.36,       C10 1130
4  3.39, 3.57, 3.41, 3.22, 3.19, 2.98, 2.78, 2.98, 3.02, 2.82,       C10 1140
5  2.98, 2.86, 2.92, 2.92, 3.05, 3.22, 3.60, 3.78, 3.81, 3.96,       C10 1150
6  3.76, 3.62, 3.34, 3.08, 3.31, 3.16, 3.37, 3.41, 3.30, 3.33,       C10 1160
7  3.33, 3.51, 3.48, 3.43, 3.52, 3.31, 3.40, 3.58, 3.61, 3.49,       C10 1170
8  3.46, 3.42, 3.19, 3.18, 3.30, 3.00, 2.99, 3.21, 3.11, 3.14,       C10 1180
9  3.10, 2.72, 2.81, 2.95, 2.69, 2.73, 2.72, 2.47, 2.51, 2.60,       C10 1190
$  2.42, 2.37, 2.73, 1.91, 1.87, 1.81, 1.78, 1.53, 1.51, 1.62,       C10 1200
```

Table A1. Listing of Fortran Code LOWTRAN 5 (Cont.)

```
$ 1.59, 1.50, 1.42, 1.32, 1.22, 1.12, 1.08, 1.02,  .97,  .92,        C1D 1210
$  .90,  .87,  .84,  .82,  .79,  .78,  .76,  .75,  .72,  .71,        C1D 1220
$  .71,  .70,  .69,  .67,  .61,  .59,  .52,  .48,  .41,  .39,        C1D 1230
$  .38,  .33,  .32,  .30,  .30,  .30,  .29,  .28,  .27,  .26,        C1D 1240
$  .25,  .23,  .22,  .21,  .20,  .18,  .14,  .13,  .06,  .01,        C1D 1250
$ -.03, -.07, -.11, -.16, -.21, -.24, -.29, -.32, -.38, -.41,        C1D 1260
$ -.45, -.50, -.54, -.61, -.69, -.76, -.84, -.90, -.97,-1.01,        C1D 1270
$-1.10,-1.13,-1.19,-1.22,-1.28,-1.30,-1.33,-1.36,-1.39,-1.43,        C1D 1280
$-1.48,-1.50,-1.52,-1.57,-1.61,-1.66,-1.70,-1.72,-1.78,-1.81/        C1D 1290
 DATA(C1(I),I=1141,1330)/                                            C1D 1300
1-1.89,-1.92,-2.00,-2.08,-2.16,-2.24,-2.31,-2.40,-2.48,-2.54,        C1D 1310
2-2.61,-2.71,-2.83,-2.95,-3.10,-5.00,-5.00,-5.00,-5.00,-5.00,        C1D 1320
3-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,        C1D 1330
4-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,        C1D 1340
5-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,        C1D 1350
6-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,        C1D 1360
7-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,        C1D 1370
8-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,        C1D 1380
9-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,        C1D 1390
$-3.78,-3.33,-3.01,-2.82,-2.68,-2.49,-2.30,-2.13,-2.00,-1.81,        C1D 1400
$-1.60,-1.41,-1.13, -.90, -.79, -.63, -.48, -.36, -.28, -.16,        C1D 1410
$ -.06,  .08,  .20,  .28,  .41,  .54,  .69,  .80,  .92, 1.04,        C1D 1420
$ 1.19, 1.19, 1.01,  .98, 1.02, 1.19, 1.29, 1.30, 1.29, 1.38,        C1D 1430
$ 1.19, 1.39, 1.42, 1.43, 1.70, 1.62, 1.54, 1.41, 1.53, 1.86,        C1D 1440
$ 1.96, 1.97, 2.02, 2.01, 1.94, 1.94, 1.83, 2.03, 2.21, 2.42,        C1D 1450
$ 2.30, 2.16, 2.02, 2.02, 2.02, 2.13, 1.90, 1.71, 2.01, 1.56,        C1D 1460
$ 1.56, 1.51, 1.30, 1.63, 1.64, 1.67, 1.70, 2.22, 2.39, 2.38,        C1D 1470
$ 2.30, 1.93, 2.39, 2.49, 2.52, 2.57, 2.21, 2.18, 2.40, 2.41,        C1D 1480
$ 2.45, 2.51, 2.23, 2.49, 2.30, 2.61, 2.72, 2.52, 2.63, 2.56/        C1D 1490
 DATA(C1(I),I=1331,1520)/                                            C1D 1500
1 2.51, 2.70, 2.62, 2.52, 2.80, 2.74, 2.79, 2.74, 2.70, 2.88,        C1D 1510
2 2.81, 2.72, 2.76, 2.84, 2.92, 2.98, 2.88, 2.88, 3.02, 3.08,        C1D 1520
3 3.26, 3.03, 3.14, 3.28, 3.03, 3.11, 3.15, 3.30, 3.31, 3.22,        C1D 1530
4 3.00, 3.06, 3.34, 3.40, 3.37, 3.32, 3.08, 3.09, 3.09, 3.61,        C1D 1540
5 3.07, 3.07, 3.31, 3.21, 3.31, 3.67, 3.58, 3.79, 3.70, 3.49,        C1D 1550
6 3.39, 3.11, 3.13, 3.01, 3.10, 3.01, 3.18, 3.32, 3.43, 3.35,        C1D 1560
7 3.40, 3.39, 3.39, 3.51, 3.54, 3.42, 3.50, 3.67, 3.59, 3.63,        C1D 1570
8 3.66, 3.48, 3.39, 3.29, 3.31, 3.41, 3.23, 3.32, 3.12, 2.91,        C1D 1580
9 2.91, 2.75, 2.78, 2.72, 2.62, 2.58, 2.32, 2.22, 2.00, 1.97,        C1D 1590
$ 1.68, 1.62, 1.64, 1.53, 1.56, 1.51, 1.52, 1.48, 1.42, 1.42,        C1D 1600
$ 1.40, 1.41, 1.43, 1.56, 1.52, 1.51, 1.52, 1.39, 1.39, 1.30,        C1D 1610
$ 1.09, 1.16, 1.21, 1.20, 1.22, 1.20, 1.18, 1.20, 1.19, 1.17,        C1D 1620
$ 1.10, 1.10, 1.09, 1.10, 1.11, 1.04,  .98,  .90,  .86,  .90,        C1D 1630
$  .90,  .90,  .86,  .71,  .79,  .70,  .71,  .67,  .62,  .53,        C1D 1640
$  .42,  .31,  .20,  .01, -.08, -.17, -.26, -.35, -.44, -.53,        C1D 1650
$ -.63, -.73, -.83, -.93,-1.04,-1.14,-1.24,-1.34,-1.44,-1.54,        C1D 1660
$-1.64,-1.74,-1.84,-1.94,-2.04,-2.14,-2.24,-2.34,-2.44,-2.54,        C1D 1670
$-2.64,-2.74,-2.84,-2.94,-3.04,-3.14,-3.24,-3.34,-3.44,-3.54,        C1D 1680
$-3.64,-3.74,-3.84,-3.94,-4.04,-5.00,-5.00,-5.00,-5.00,-5.00/        C1D 1690
 DATA(C1(I),I=1521,1710)/                                            C1D 1700
1-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,        C1D 1710
2-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,        C1D 1720
3-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,        C1D 1730
4-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,        C1D 1740
5-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,        C1D 1750
6-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,        C1D 1760
7-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,        C1D 1770
8-4.15,-4.06,-3.97,-3.88,-3.79,-3.70,-3.61,-3.52,-3.43,-3.34,        C1D 1780
9-3.25,-3.16,-3.07,-2.98,-2.89,-2.80,-2.71,-2.62,-2.53,-2.44,        C1D 1790
$-2.35,-2.26,-2.18,-2.09,-2.00,-1.91,-1.82,-1.73,-1.64,-1.55,        C1D 1800
```

Table A1. Listing of Fortran Code LOWTRAN 5 (Cont.)

```
$-1.46,-1.37,-1.28,-1.19,-1.10,-1.01, -.92, -.83, -.74, -.65,          C1D 1810
$ -.56, -.47, -.38, -.29, -.20, -.14, -.09, -.02,  .03,  .10,          C1D 1820
$  .17,  .22,  .30,  .35,  .41,  .45,  .42,  .40,  .43,  .46,          C1D 1830
$  .50.  .59,  .71,  .84,  .93, 1.01, 1.06, 1.07, 1.02, 1.01,          C1D 1840
$ 1.12, 1.23, 1.24, 1.28, 1.34, 1.43, 1.32, 1.56, 1.59, 1.56,          C1D 1850
$ 1.51, 1.61, 1.50, 1.70, 1.82, 1.92, 1.94, 1.89, 1.81, 1.45,          C1D 1860
$ 1.30, 1.28, 1.43, 1.50, 1.49, 1.55, 1.48, 1.32, 1.39, 1.53,          C1D 1870
$ 1.82, 2.23, 2.61, 2.51, 2.20, 1.86, 1.61, 1.19, 1.32, 1.52,          C1D 1880
$ 1.70, 1.90, 2.01, 1.92, 1.91, 2.12, 2.10  2.   , 2.18, 1.99/          C1D 1890
 DATA(C1(I),I=1711,1900)/                                              C1D 1900
1 2.11, 2.28, 2.21, 2.13, 2.00, 1.91, 1.92, 1.97, 1.88, 1.91,          C1D 1910
2 1.91, 1.92, 1.93, 1.74, 1.61, 1.58, 1.27, 1.20, 1.18, 1.11,          C1D 1920
3  .99,  .86,  .71,  .60,  .44,  .31,  .19,  .03, -.07, -.21,          C1D 1930
4 -.35, -.49, -.64, -.79, -.94,-1.11,-1.24,-1.41,-1.57,-1.73,          C1D 1940
5-1.91,-2.09,-2.27,-2.45,-2.63,-2.81,-2.99,-3.18,-3.37,-3.56,          C1D 1950
6-3.75,-3.94,-4.13,-4.31,-4.49,-4.66,-4.83,-4.99,-5.14,-5.28,          C1D 1960
7-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-4.68,-4.26,          C1D 1970
8-3.89,-3.57,-3.32,-3.11,-2.91,-2.89,-2.79,-2.74,-2.63,-2.47,          C1D 1980
9-2.29,-2.20,-2.17,-2.23,-2.27,-2.32,-2.12,-2.08,-2.07,-2.07,          C1D 1990
$-2.07,-1.98,-1.77,-1.70,-1.63,-1.60,-1.59,-1.43,-1.21,-1.15,          C1D 2000
$-1.09,-1.13,-1.29,-1.19, -.98, -.93, -.87, -.91, -.88, -.71,          C1D 2010
$ -.62, -.59, -.58, -.63, -.58, -.39, -.22, -.14, -.06, -.01,          C1D 2020
$ -.01, -.08, -.20, -.16, -.02,  .18,  .32,  .42,  .37,  .23,          C1D 2030
$  .12,  .15,  .28,  .43,  .59,  .58,  .53,  .44,  .39,  .38,          C1D 2040
$  .35,  .23,  .26,  .19,  .08,  .10,  .18,  .27,  .38,  .43,          C1D 2050
$  .32,  .37,  .58,  .64,  .87,  .98, 1.00, 1.02, 1.13, 1.08,          C1D 2060
$ 1.08, 1.16, 1.16, 1.30, 1.41, 1.40, 1.32, 1.32, 1.37, 1.42,          C1D 2070
$ 1.50, 1.42, 1.38, 1.36, 1.38, 1.49, 1.63, 1.62, 1.62, 1.70,          C1D 2080
$ 1.68, 1.60, 1.56, 1.56, 1.63, 1.64, 1.56, 1.49, 1.49, 1.52/          C1D 2090
 DATA(C1(I),I=1901,2090)/                                              C1D 2100
1 1.58, 1.62, 1.62, 1.61, 1.61, 1.62, 1.63, 1.71, 1.72, 1.70,          C1D 2110
2 1.70, 1.67, 1.62, 1.66, 1.70, 1.67, 1.56, 1.49, 1.42, 1.38,          C1D 2120
3 1.26, 1.20, 1.13, 1.14, 1.19, 1.29, 1.50, 1.72, 1.86, 1.78,          C1D 2130
4 1.82, 1.88, 1.82, 1.89, 1.99, 2.00, 2.14, 2.04, 2.02, 2.02,          C1D 2140
5 1.98, 1.90, 1.83, 1.81, 1.72, 1.69, 1.59, 1.50, 1.36, 1.20,          C1D 2150
6  .98,  .63,  .43,  .29,  .16,  .05,  .02,  .03,  .03,  .01,          C1D 2160
7 -.08, -.18, -.20, -.11, -.06, -.03, -.14, -.21, -.08, -.06,          C1D 2170
8  .10,  .18,  .11,  .72,  .42,  .44,  .38,  .28,  .42,  .43,          C1D 2180
9  .41,  .33,  .32,  .41,  .50,  .46,  .31,  .18,  .08,  .20,          C1D 2190
$  .21,  .34,  .36,  .28,  .35,  .39,  .42,  .38,  .32,  .30,          C1D 2200
$  .16, -.01, -.23, -.41, -.52, -.48, -.58, -.61, -.48, -.23,          C1D 2210
$ -.03,  .21,  .36,  .39,  .47,  .44,  .40,  .51,  .59,  .53,          C1D 2220
$  .69,  .57,  .48,  .52,  .62,  .59,  .55,  .50,  .32,  .26,          C1D 2230
$  .11, -.08, -.10, -.16, -.43, -.62, -.88,-1.09,-1.16,-1.31,          C1D 2240
$-1.45,-1.49,-1.78,-1.91,-2.01,-1.97,-1.97,-1.97,-1.97,-2.26,          C1D 2250
$-2.20,-2.01,-1.99,-2.00,-2.04,-2.37,-2.49,-2.44,-2.36,-2.32,          C1D 2260
$-2.19,-2.10,-2.25,-2.16,-2.36,-2.44,-2.40,-2.49,-2.48,-2.43,          C1D 2270
$-2.40,-2.36,-2.40,-2.49,-2.59,-2.68,-2.89,-3.28,-3.51,-3.74,          C1D 2280
$-3.97,-4.20,-4.43,-4.66,-4.89,-5.00,-5.00,-5.00,-5.00,-5.00/          C1D 2290
 DATA(C1(I),I=2091,2280)/                                              C1D 2300
1-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,          C1D 2310
2-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,          C1D 2320
3-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,          C1D 2330
4-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,          C1D 2340
5-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,          C1D 2350
6-5.00,-5.00,-5.00,-5.00,-5.00,-3.71,-3.56,-3.40,-3.21,-3.06,          C1D 2360
7-2.90,-2.74,-2.60,-2.46,-2.32,-2.17,-2.03,-1.87,-1.79,-1.74,          C1D 2370
8-1.83,-1.82,-1.71,-1.59,-1.49,-1.46,-1.46,-1.49,-1.49,-1.25,          C1D 2380
9-1.24,-1.08, -.90,-1.05, -.91, -.91,-1.01, -.99, -.87, -.92,          C1D 2390
$ -.79, -.42, -.54, -.38, -.42, -.48, -.34, -.27, -.17, -.28,          C1D 2400
```

Table A1. Listing of Fortran Code LOWTRAN 5 (Cont.)

```
$ -.38, -.22, -.30, -.08, -.01, -.20,  .06,  .10,  .06,  .14,        C10 2410
$ -.12, -.02, -.07, -.13, -.11, -.10, -.06, -.05, -.04, -.10,        C10 2420
$ -.04, -.06, -.21, -.38, -.61, -.40, -.31, -.42, -.58, -.57,        C10 2430
$ -.54, -.24,  .11,  .51,  .81,  .79,  .62,  .26, -.31, -.67,        C10 2440
$ -.80, -.88, -.50, -.39, -.10,  .09,  .06,  .08,  .16,  .21,        C10 2450
$  .13,  .32,  .35,  .51,  .60,  .51,  .51,  .40,  .40,  .43,        C10 2460
$  .42,  .33,  .43,  .34,  .22,  .13, -.11, -.31, -.31, -.41,        C10 2470
$ -.41, -.39, -.53, -.69, -.84, -.88,-1.01,-1.10,-1.19,-1.29,        C10 2480
$-1.45,-1.49,-1.67,-1.67,-1.51,-1.56,-1.60,-1.69,-1.83,-1.51/        C10 2490
 DATA(C1(I),I=2281,2470)/                                            C10 2500
1-1.42,-1.40,-1.24,-1.38,-1.31,-1.30,-1.30,-1.28,-1.39,-1.33,        C10 2510
2-1.40,-1.35,-1.37,-1.39,-1.41,-1.49,-1.48,-1.56,-1.47,-1.46,        C10 2520
3-1.41,-1.42,-1.48,-1.41,-1.31,-1.15,-1.13,-1.20,-1.41,-1.88,        C10 2530
4-2.08,-2.08,-2.22,-2.35,-2.35,-1.98,-1.92,-1.78,-1.57,-1.69,        C10 2540
5-1.70,-1.70,-1.66,-1.94,-1.50,-1.56,-1.42,-1.29,-1.38,-1.28,        C10 2550
6-1.48,-1.58,-1.44,-1.53,-1.48,-1.48,-1.58,-1.58,-1.69,-1.79,        C10 2560
7-2.00,-2.16,-1.99,-2.23,-2.04,-2.04,-2.39,-2.74,-3.09,-3.44,        C10 2570
8-3.79,-4.14,-4.49,-4.84,-5.19,-2.46,-2.26,-1.99,-2.01,-2.14,        C10 2580
9-2.31,-2.15,-2.01,-1.99,-2.14,-2.41,-2.12,-1.99,-1.84,-1.79,        C10 2590
$-1.71,-1.78,-1.72,-1.68,-1.78,-1.52,-1.38,-1.29,-1.22, -.91,        C10 2600
$ -.90,-1.01, -.76, -.90, -.90, -.90,-1.19,-1.00, -.79, -.68,        C10 2610
$ -.68, -.73, -.85, -.85, -.61, -.61, -.48, -.51, -.92, -.83,        C10 2620
$ -.61, -.41, -.29, -.29, -.61, -.74, -.19, -.18, 0.00,  .19,        C10 2630
$ -.10,  .20,  .20,  .02,  .20, -.01,  .18,  .28,  .11, 0.00,        C10 2640
$ -.37, -.10,  .02,  .16,  .20, 0.00,  .09,  .09,  .09,  .07,        C10 2650
$  .22,  .11,  .11,  .21,  .09,  .21,  .20,  .37,  .28,  .07,        C10 2660
$  .09, -.29, -.60, -.69, -.74, -.88,-1.01, -.86, -.54, -.19,        C10 2670
$  .19,  .27,  .21,  .29,  .28,  .29,  .52,  .54,  .51,  .60,        C10 2680
$  .40,  .49,  .48,  .46,  .49,  .27,  .06, -.33, -.81,-1.17/        C10 2690
 DATA(C1(I),I=2471,2580)/                                            C10 2700
1-1.11,-1.37,-1.52,-1.54,-1.94,-2.06,-2.06,-2.14,-1.96,-2.00,        C10 2710
2-2.00,-2.08,-2.23,-2.31,-2.31,-2.53,-2.31,-2.31,-2.31,-2.28,        C10 2720
3-2.34,-2.34,-1.91,-1.82,-1.69,-1.56,-1.84,-1.91,-1.75,-1.83,        C10 2730
4-1.76,-1.54,-1.98,-1.80,-1.68,-1.69,-1.56,-1.60,-1.71,-1.36,        C10 2740
5-1.36,-1.44,-1.48,-1.40,-1.48,-1.36,-1.45,-1.49,-1.85,-1.39,        C10 2750
6-1.23,-1.19,-1.18,-1.34,-1.36,-1.23,-1.23,-1.37,-1.30,-1.40,        C10 2760
7-1.28,-1.27,-1.37,-1.32,-1.32,-1.22,-1.28,-1.38,-1.69,-2.07,        C10 2770
8-2.42,-2.58,-2.58,-2.80,-2.58,-2.47,-1.88,-1.60,-1.26,-1.16,        C10 2780
9-1.23,-1.10,-1.23,-1.10, -.83, -.80, -.80, -.80, -.98, -.97,        C10 2790
$ -.97, -.91, -.92,-1.13,-1.24,-1.50,-1.89,-2.18,-2.32,-2.63,        C10 2800
$-3.91,-4.20,-4.49,-4.78,-5.07,-5.07,-5.07,-5.07,-5.07,-5.07/        C10 2810
  C1L=C1(L)                                                          C10 2820
  RETURN                                                             C10 2830
  END                                                                C10 2840
```

Table A1. Listing of Fortran Code LOWTRAN 5 (Cont.)

```
      SUBROUTINE C2DTA (C2L,L)                                          C2D   10
C        UNIFORMLY MIXED GASES                                          C2D   20
C     C2 LOCATION  1    V =  500    CM-1                                C2D   30
C     C2 LOCATION  1515 V =  8070    CM-1                               C2D   40
C     C2 LOCATION  1516 V =  12950    CM-1                              C2D   50
C     C2 LOCATION  1575 V =  13245  CM-1                                C2D   60
      COMMON/C2/ C2(1575)                                               C2D   70
      DATA(C2(I),I=   1, 190)/                                          C2D   80
     1-4.25,-3.70,-3.20,-2.75,-1.90,-1.73,-1.51,-1.29,-1.11, -.91,      C2D   90
     2 -.71, -.51, -.30, -.36,  .22,  .49,  .76, 1.08, 1.29, 1.56,      C2D  100
     3 1.76, 1.91, 2.08, 2.23, 2.36, 2.51, 2.72, 2.90, 3.12, 3.37,      C2D  110
     4 3.56, 3.69, 3.79, 3.86, 3.88, 3.86, 3.73, 3.58, 3.38, 3.17,      C2D  120
     5 2.86, 2.73, 2.52, 2.31, 2.17, 2.01, 1.89, 1.77, 1.63, 1.47,      C2D  130
     6 1.21,  .92,  .53,  .23, -.17, -.53, -.74, -.81, -.84, -.88,      C2D  140
     7-1.00,-1.18,-1.42,-1.61,-1.86,-2.10,-2.29,-2.51,-2.72,-2.91,      C2D  150
     8-3.14,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,      C2D  160
     9-5.00,-2.68,-2.47,-2.19,-1.97,-1.71,-1.50,-1.32,-1.21,-1.13,      C2D  170
     $-1.09,-1.11,-1.10,-1.09,-1.01,-1.01,-1.11,-1.33,-1.66,-2.13,      C2D  180
     $-2.51,-2.62,-2.71,-2.39,-2.09,-1.78,-1.59,-1.33,-1.18,-1.01,      C2D  190
     $ -.96, -.91, -.90, -.87, -.80, -.79, -.86,-1.07,-1.28,-1.69,      C2D  200
     $-2.11,-2.74,-3.09,-3.50,-3.03,-2.58,-2.23,-1.89,-1.54,-1.28,      C2D  210
     $-1.13,-1.11,-1.16,-1.20,-1.23,-1.21,-1.17,-1.12,-1.15,-1.19,      C2D  220
     $-1.20,-1.17,-1.02, -.89, -.68, -.42, -.24, -.01,  .18,  .40,      C2D  230
     $  .57,  .77,  .96, 1.07, 1.13, 1.11, 1.08, 1.15, 1.27, 1.33,      C2D  240
     $ 1.44, 1.40, 1.13,  .89,  .63,  .54,  .65,  .78,  .81,  .86,      C2D  250
     $  .87,  .68,  .47,  .14, -.12, -.48, -.92,-1.43,-1.89,-2.32,      C2D  260
     $-2.81,-5.00,-5.00,-5.00,-3.14,-2.47,-2.00,-1.71,-1.59,-1.61/      C2D  270
      DATA(C2(I),I= 191, 380)/                                          C2D  280
     1-1.69,-1.82,-1.87,-1.90,-1.94,-2.04,-2.10,-2.23,-2.32,-2.48,      C2D  290
     2-2.71,-2.88,-3.09,-2.99,-2.43,-2.00,-1.69,-1.42,-1.38,-1.49,      C2D  300
     3-1.70,-2.01,-2.41,-2.64,-2.63,-2.49,-2.38,-2.27,-2.16,-2.05,      C2D  310
     4-1.94,-1.83,-1.76,-1.71,-1.70,-1.72,-1.81,-1.92,-2.03,-2.27,      C2D  320
     5-2.61,-3.21,-4.01,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,      C2D  330
     6-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,      C2D  340
     7-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,      C2D  350
     8-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-4.30,-3.42,-3.17,-2.98,      C2D  360
     9-2.83,-2.71,-2.67,-2.67,-2.68,-2.58,-2.33,-2.01,-1.64,-1.32,      C2D  370
     $ -.97, -.76, -.63, -.59, -.60, -.63, -.69, -.87,-1.08,-1.26,      C2D  380
     $-1.53,-1.87,-1.91,-1.93,-2.02,-2.21,-2.48,-2.80,-3.08,-3.11,      C2D  390
     $-3.09,-2.93,-2.76,-2.39,-2.01,-1.69,-1.36, -.99, -.63, -.28,      C2D  400
     $ 0.00,  .08,  .11,  .12,  .12,  .07,  .01, -.08, -.23, -.40,      C2D  410
     $ -.51, -.53, -.57, -.60, -.61, -.73, -.81, -.95,-1.05,-1.02,      C2D  420
     $ -.91, -.68, -.41, -.09,  .18,  .41,  .76, 1.00, 1.18, 1.39,      C2D  430
     $ 1.51, 1.58, 1.68, 1.71, 1.8 , 1.91, 2.02, 2.18, 2.32, 2.50,      C2D  440
     $ 2.61, 2.69, 2.81, 2.89, 2.96, 3.04, 3.14, 3.27, 3.41, 3.55,      C2D  450
     $ 3.72, 3.90, 4.03, 4.22, 4.42, 4.61, 4.71, 4.73, 4.65, 4.63,      C2D  460
     $ 4.72, 4.78, 4.79, 4.50, 3.62, 3.28, 2.79, 2.30, 1.86, 1.35/      C2D  470
      DATA(C2(I),I= 381, 570)/                                          C2D  480
     1  .62, -.24,-1.69,-2.18,-2.01,-1.79,-1.53,-1.32,-1.20,-1.15,      C2D  490
     2-1.12,-1.18,-1.25,-1.26,-1.20,-1.17,-1.20,-1.32,-1.54,-1.84,      C2D  500
     3-2.16,-2.30,-2.26,-2.01,-1.71,-1.36,-1.06, -.81, -.61, -.49,      C2D  510
     4 -.45, -.47, -.49, -.46, -.37, -.31, -.34, -.49, -.75,-1.11,      C2D  520
     5-1.43,-2.01,-2.60,-2.89,-2.87,-2.74,-2.51,-2.42,-2.38,-2.39,      C2D  530
     6-2.42,-2.40,-2.48,-2.49,-2.43,-2.43,-2.46,-2.53,-2.68,-2.74,      C2D  540
     7-2.82,-2.87,-2.83,-2.82,-2.79,-2.71,-2.66,-2.49,-2.40,-2.32,      C2D  550
     8-2.26,-2.23,-2.20,-2.09,-2.02,-1.96,-1.88,-1.84,-1.86,-1.86,      C2D  560
     9-1.87,-1.83,-1.79,-1.73,-1.68,-1.64,-1.69,-1.74,-1.79,-1.87,      C2D  570
     $-1.78,-1.63,-1.50,-1.37,-1.21,-1.00, -.83, -.69, -.53, -.41,      C2D  580
     $ -.30, -.19, -.09, -.04,  .02,  .10,  .16,  .18,  .23,  .26,      C2D  590
     $  .27,  .26,  .24,  .22,  .17,  .12,  .07, -.01, -.07, -.09,      C2D  600
```

Table A1. Listing of Fortran Code LOWTRAN 5 (Cont.)

```
$  .32,  .72,  .91, 1.12, 1.03,  .67,  .16, -.11, -.38, -.29,     C2D  610
$ -.17, -.08, 0.00,  .09,  .13,  .18,  .24,  .27,  .29,  .30,     C2D  620
$  .29,  .26,  .23,  .21,  .13,  .09,  .02, -.04, -.18, -.32,     C2D  630
$ -.51, -.72, -.98,-1.18,-1.50,-1.62,-1.81,-2.04,-2.29,-2.49,     C2D  640
$-2.62,-2.87,-3.03,-3.21,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,     C2D  650
$-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-4.01,-3.38,-3.01,-2.63,     C2D  660
$-2.32,-2.09,-1.98,-1.94,-2.00,-2.14,-2.26,-2.20,-2.02,-1.82/     C2D  670
 DATA(C2(I),I= 571, 760)/                                         C2D  680
1-1.59,-1.43,-1.38,-1.46,-1.64,-1.90,-2.09,-2.54,-2.91,-3.28,     C2D  690
2-3.61,-3.72,-3.64,-3.50,-3.41,-3.37,-3.30,-3.16,-3.01,-2.76,     C2D  700
3-2.51,-2.20,-1.80,-1.49,-1.22, -.97, -.72, -.49, -.20,  .03,     C2D  710
4  .20,  .36,  .51,  .61,  .67,  .83, 1.00, 1.22, 1.38, 1.56,     C2D  720
5 1.70, 1.86, 2.01, 2.20, 2.31, 2.47, 2.61, 2.76, 2.92, 3.01,     C2D  730
6 3.05, 3.02, 2.98, 2.98, 3.01, 3.03, 2.97, 2.78, 2.44, 2.13,     C2D  740
7 1.83, 1.59, 1.49, 1.50, 1.67, 1.94, 2.22, 2.50, 2.71, 2.93,     C2D  750
8 3.12, 3.18, 3.17, 3.15, 3.21, 3.26, 3.19, 2.98, 2.69, 2.14,     C2D  760
9 1.70, 1.22,  .55, -.27,-1.09,-2.54,-3.00,-2.94,-2.78,-2.65,     C2D  770
$-2.61,-2.60,-2.63,-2.60,-2.57,-2.53,-2.57,-2.64,-2.77,-3.04,     C2D  780
$-3.38,-3.98,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,     C2D  790
$-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,     C2D  800
$-5.00,-4.00,-3.73,-3.62,-3.59,-3.53,-3.56,-3.57,-3.53,-3.51,     C2D  810
$-3.45,-3.37,-3.26,-3.21,-3.18,-3.27,-3.36,-3.60,-3.96,-5.00,     C2D  820
$-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,     C2D  830
$-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,     C2D  840
$-5.00,-5.00,-5.00,-5.00,-4.62,-4.07,-3.89,-3.76,-3.67,-3.56,     C2D  850
$-3.42,-3.35,-3.26,-3.18,-3.14,-3.11,-3.09,-3.10,-3.12,-3.23,     C2D  860
$-3.30,-3.38,-3.37,-3.29,-3.14,-3.08,-3.00,-2.93,-2.89,-2.91/     C2D  870
 DATA(C2(I),I= 761, 950)/                                         C2D  880
1-3.00,-3.08,-3.16,-3.31,-3.48,-3.71,-3.98,-5.00,-5.00,-5.00,     C2D  890
2-5.00,-4.52,-3.98,-3.69,-3.42,-3.18,-2.95,-2.77,-2.51,-2.48,     C2D  900
3-2.41,-2.41,-2.40,-2.38,-2.34,-2.27,-2.21,-2.31,-2.48,-2.73,     C2D  910
4-3.21,-4.13,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,     C2D  920
5-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,     C2D  930
6-5.00,-5.00,-4.13,-4.02,-3.99,-3.96,-3.87,-3.73,-3.51,-3.29,     C2D  940
7-3.15,-2.99,-2.84,-2.73,-2.69,-2.68,-2.69,-2.65,-2.62,-2.59,     C2D  950
8-2.57,-2.62,-2.81,-3.04,-3.21,-3.39,-3.42,-3.36,-3.21,-3.03,     C2D  960
9-2.93,-2.80,-2.64,-2.52,-2.37,-2.28,-2.20,-2.13,-2.07,-2.02,     C2D  970
$-1.96,-1.88,-1.78,-1.63,-1.44,-1.31,-1.20,-1.08, -.98, -.94,     C2D  980
$ -.86, -.76, -.57, -.31, -.08,  .13,  .30,  .37,  .36,  .36,     C2D  990
$  .35,  .35,  .39,  .46,  .48,  .41,  .23, -.08, -.38, -.67,     C2D 1000
$ -.88, -.96, -.98, -.87, -.67, -.36, -.12,  .14,  .44,  .68,     C2D 1010
$  .90, 1.11, 1.19, 1.24, 1.25, 1.26, 1.27, 1.51, 1.59, 1.50,     C2D 1020
$ 1.28,  .71,  .11, -.28, -.67,-1.32,-1.61,-1.58,-1.42,-1.18,     C2D 1030
$ -.91, -.59, -.27, -.06,  .29,  .57,  .73,  .92,  .81,  .73,     C2D 1040
$  .79,  .91, 1.01, 1.03,  .88,  .72,  .63,  .38,  .12, -.21,     C2D 1050
$ -.47, -.67,-1.23,-1.67,-2.31,-2.76,-3.24,-3.49,-3.51,-3.47,     C2D 1060
$-3.39,-3.37,-3.43,-3.53,-3.50,-3.36,-3.18,-3.07,-2.96,-3.08/     C2D 1070
 DATA(C2(I),I= 951,1140)/                                         C2D 1080
1-3.14,-3.12,-3.23,-3.07,-2.83,-2.47,-2.23,-2.07,-1.91,-1.78,     C2D 1090
2-1.63,-1.46,-1.27,-1.23,-1.26,-1.40,-1.57,-1.98,-2.28,-2.87,     C2D 1100
3-3.74,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,     C2D 1110
4-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,     C2D 1120
5-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,     C2D 1130
6-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,     C2D 1140
7-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,     C2D 1150
8-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,     C2D 1160
9-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,     C2D 1170
$-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,     C2D 1180
$-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,     C2D 1190
$-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,     C2D 1200
```

Table A1. Listing of Fortran Code LOWTRAN 5 (Cont.)

```
$-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,       C2D 1210
$-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,       C2D 1220
$-5.00,-5.00,-4.91,-4.79,-4.61,-4.49,-4.40,-4.29,-4.17,-3.90,       C2D 1230
$-3.73,-3.59,-3.62,-3.72,-3.73,-3.69,-3.31,-3.12,-2.91,-2.63,       C2D 1240
$-2.41,-2.27,-2.16,-2.11,-2.28,-2.29,-2.21,-2.06,-1.91,-1.99,       C2D 1250
$-2.27,-2.59,-2.98,-3.35,-3.69,-3.79,-3.68,-3.53,-3.46,-3.39,       C2D 1260
$-3.31,-3.18,-2.97,-2.69,-2.39,-2.11,-1.83,-1.58,-1.49,-1.22/       C2D 1270
 DATA(C2(I),I=1141,1330)/                                           C2D 1280
1-1.08, -.89, -.68, -.54, -.71, -.79, -.78, -.66, -.49, -.54,       C2D 1290
2 -.86,-1.77,-2.08,-2.44,-3.46,-3.72,-3.74,-3.59,-3.22,-2.98,       C2D 1300
3-2.52,-2.21,-1.64,-1.34,-1.08, -.86, -.72, -.61, -.70, -.72,       C2D 1310
4 -.67, -.57, -.38, -.51, -.97,-1.36,-1.89,-2.74,-3.18,-4.21,       C2D 1320
5-4.57,-4.62,-4.78,-4.87,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,       C2D 1330
6-4.93,-4.46,-3.99,-3.45,-2.99,-2.63,-2.30,-2.09,-2.02,-2.12,       C2D 1340
7-2.18,-2.13,-2.04,-1.78,-1.83,-2.08,-2.28,-2.81,-3.01,-3.15,       C2D 1350
8-3.22,-3.29,-3.58,-3.99,-4.46,-4.88,-5.00,-5.00,-5.00,-5.00,       C2D 1360
9-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,       C2D 1370
$-4.81,-4.52,-4.11,-3.69,-3.09,-2.99,-2.91,-2.89,-3.19,-3.20,       C2D 1380
$-3.36,-3.62,-3.89,-3.92,-3.73,-3.53,-3.37,-3.19,-3.02,-2.79,       C2D 1390
$-2.52,-2.36,-2.24,-2.19,-2.32,-2.41,-2.29,-2.06,-2.00,-2.18,       C2D 1400
$-2.47,-2.91,-3.57,-4.89,-5.00,-5.00,-5.00,-5.00,-5.00,-4.61,       C2D 1410
$-4.19,-3.89,-3.57,-3.30,-3.02,-2.74,-2.51,-2.20,-1.98,-1.73,       C2D 1420
$-1.57,-1.38,-1.21,-1.11, -.98, -.87, -.78, -.60, -.37, -.18,       C2D 1430
$ -.04, -.04, -.06, -.16, -.18, -.19, -.23, -.45,-1.02,-1.97,       C2D 1440
$-2.79,-3.71,-4.01,-4.20,-4.35,-4.58,-4.73,-4.81,-5.00,-5.00,       C2D 1450
$-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,       C2D 1460
$-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00/       C2D 1470
 DATA(C2(I),I=1331,1520)/                                           C2D 1480
1-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,       C2D 1490
2-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,       C2D 1500
3-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,       C2D 1510
4-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,       C2D 1520
5-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,       C2D 1530
6-5.00,-5.00,-5.00,-4.71,-4.31,-3.99,-3.68,-3.50,-3.34,-3.22,       C2D 1540
7-3.23,-3.25,-3.24,-3.18,-3.10,-3.07,-3.18,-3.41,-3.67,-4.12,       C2D 1550
8-4.68,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-4.51,-4.18,       C2D 1560
9-3.73,-3.48,-3.17,-2.96,-2.73,-2.63,-2.58,-2.59,-2.57,-2.49,       C2D 1570
$-2.42,-2.38,-2.48,-2.62,-3.02,-3.49,-4.16,-5.00,-5.00,-5.00,       C2D 1580
$-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-4.87,-4.50,       C2D 1590
$-4.21,-3.90,-3.66,-3.56,-3.51,-3.51,-3.51,-3.49,-3.41,-3.34,       C2D 1600
$-3.34,-3.47,-3.60,-3.87,-4.23,-4.59,-5.00,-5.00,-5.00,-5.00,       C2D 1610
$-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-4.93,       C2D 1620
$-4.51,-4.10,-3.78,-3.32,-3.03,-2.74,-2.43,-2.08,-1.83,-1.59,       C2D 1630
$-1.29,-1.07, -.81, -.70, -.73, -.90,-1.08,-1.19,-1.35,-1.47,       C2D 1640
$-1.57,-1.66,-1.80,-1.91,-2.04,-2.18,-2.33,-2.47,-2.61,-2.78,       C2D 1650
$-2.97,-3.10,-3.28,-3.44,-3.63,-3.81,-3.98,-4.15,-4.32,-4.61,       C2D 1660
$-4.71,-4.80,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-4.32/       C2D 1670
 DATA(C2(I),I=1521,1575)/                                           C2D 1680
1-3.24,-2.59,-2.12,-1.82,-1.57,-1.34,-1.16,-1.02, -.82, -.64,       C2D 1690
2 -.48, -.33, -.19, -.06,  .08,  .21,  .39,  .52,  .61,  .72,       C2D 1700
3  .85,  .96, 1.02, 1.12, 1.18, 1.21, 1.17, 1.08,  .98,  .90,       C2D 1710
4  .97, 1.13, 1.37, 1.58, 1.74, 1.70, 1.48, 1.13,  .73,  .22,       C2D 1720
5 -.51,-1.57,-3.48,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,       C2D 1730
6-5.00,-5.00,-5.00,-5.00,-5.00/                                     C2D 1740
 C2L=C2(L)                                                          C2D 1750
 RETURN                                                             C2D 1760
 END                                                                C2D 1770
```

Table A1. Listing of Fortran Code LOWTRAN 5 (Cont.)

```
      SUBROUTINE C3DTA (C3L,L)                                          C3D   10
C         OZONE                                                         C3D   20
C     C3 LOCATION  1     V =   575    CM-1                              C3D   30
C     C3 LOCATION  510   V =   3270 CM-1                                C3D   40
      COMMON /C3/ C3(540)                                               C3D   50
      DATA(C3(I),I=   1, 190)/                                          C3D   60
     1-4.15,-3.51,-3.00,-2.54,-2.12,-1.76,-1.50,-1.21, -.88, -.49,      C3D   70
     2 -.29, -.10,  .07,  .12,  .24,  .32,  .43,  .52,  .58,  .65,      C3D   80
     3  .72,  .79,  .76,  .72,  .68,  .64,  .68,  .79,  .83,  .83,      C3D   90
     4  .80,  .78,  .68,  .56,  .49,  .42,  .34,  .26,  .14,  .02,      C3D  100
     5 -.14, -.35, -.51, -.74, -.88,-1.17,-1.40,-1.58,-2.11,-2.47,      C3D  110
     6-2.83,-3.24,-3.59,-3.94,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,      C3D  120
     7-5.00,-5.00,-5.00,-5.00,-5.00,-4.46,-4.00,-3.50,-3.14,-2.78,      C3D  130
     8-2.41,-2.10,-1.78,-1.49,-1.20, -.20,  .15,  .35,  .57,  .78,      C3D  140
     9  .95, 1.20, 1.40, 1.65, 1.80, 1.97, 2.10, 2.21, 2.31, 2.38,      C3D  150
     $ 2.40, 2.42, 2.58, 2.52, 2.20, 2.48, 2.54, 2.45, 2.20, 2.00,      C3D  160
     $ 1.20,  .95,  .92,  .90,  .90,  .89,  .90,  .92,  .94,  .95,      C3D  170
     $  .96,  .95,  .90,  .80,  .68,  .55,  .40,  .30,  .19,  .08,      C3D  180
     $ -.02, -.11, -.22, -.41, -.56, -.71, -.89,-1.03,-1.18,-1.33,      C3D  190
     $-1.60,-1.76,-1.90,-2.02,-2.21,-2.46,-2.59,-2.79,-3.00,-3.22,      C3D  200
     $-3.61,-4.16,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,      C3D  210
     $-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,      C3D  220
     $-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,      C3D  230
     $-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,      C3D  240
     $-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00/      C3D  250
      DATA(C3(I),I= 191, 380)/                                          C3D  260
     1-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,      C3D  270
     2-5.00,-5.00,-5.00,-5.00,-4.16,-3.91,-3.66,-3.41,-3.05,-2.69,      C3D  280
     3-2.44,-2.19,-2.03,-1.86,-1.71,-1.56,-1.48,-1.39,-1.26,-1.13,      C3D  290
     4 -.97, -.81, -.65, -.48, -.35, -.22, -.14, -.06, -.02, -.09,      C3D  300
     5  .18, -.14,  .06,  .26, -.02, -.42, -.80, -.82, -.80, -.74,      C3D  310
     6 -.74, -.79, -.84, -.89, -.85, -.81, -.76, -.70  -.68, -.64,      C3D  320
     7 -.65, -.66, -.72, -.78, -.84, -.90,-1.02,-1.14,-1.24,-1.33,      C3D  330
     8-1.47,-1.61,-1.77,-1.92,-1.98,-2.04,-2.08,-2.09,-2.06,-2.03,      C3D  340
     9-1.98,-1.93,-1.87,-1.82,-1.76,-1.71,-1.65,-1.59,-1.51,-1.44,      C3D  350
     $-1.36,-1.28,-1.18,-1.08, -.98, -.88, -.78, -.69, -.59, -.49,      C3D  360
     $ -.37, -.25, -.18, -.10, 0.00,  .16,  .27,  .38,  .57,  .75,      C3D  370
     $  .93, 1.11, 1.20, 1.33, 1.44, 1.46, 1.48, 1.48, 1.64, 1.58,      C3D  380
     $ 1.49, 1.23,  .66,  .38, -.33, -.71, -.66, -.58, -.49, -.41,      C3D  390
     $ -.40, -.40, -.46, -.53, -.64, -.76, -.89,-1.01,-1.14,-1.26,      C3D  400
     $-1.40,-1.55,-1.69.-1.83,-1.98,-2.13,-2.28,-2.43,-2.64,-2.86,      C3D  410
     $-3.07,-3.28,-3.50,-3.72,-3.94,-5.00,-5.00,-5.00,-5.00,-5.00,      C3D  420
     $-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,      C3D  430
     $-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,      C3D  440
     $-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00/      C3D  450
      DATA(C3(I),I= 381, 540)/                                          C3D  460
     1-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,      C3D  470
     2-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,      C3D  480
     3-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,      C3D  490
     4-5.00,-5.00,-5.00,-4.16,-3.97,-3.77,-3.58,-3.38,-3.07,-2.75,      C3D  500
     5-2.44,-2.12,-1.85,-1.57,-1.30,-1.07, -.98, -.94, -.89, -.85,      C3D  510
     6 -.81, -.77, -.72, -.68, -.63, -.58, -.53, -.48, -.41, -.34,      C3D  520
     7 -.26, -.19, -.17, -.18, -.19, -.46, -.79,-1.12,-1.45,-1.75,      C3D  530
     8-2.38,-2.97,-3.57,-4.16,-5.00,-5.00,-5.00,-4.16,-3.90,-3.63,      C3D  540
     9-3.37,-3.10,-2.79,-2.47,-2.15,-1.84,-1.73,-1.63,-1.52,-1.41,      C3D  550
     $-1.33,-1.25,-1.17,-1.09,-1.02, -.96, -.89, -.82, -.73, -.68,      C3D  560
     $ -.54, -.47, -.27, -.12,  .03,  .18,  .25,  .31,  .39,  .47,      C3D  570
     $  .48,  .49,  .50,  .50,  .48,  .46,  .23,  .01, -.11, -.33,      C3D  580
     $ -.55, -.77, -.83, -.88, -.94, -.92, -.91, -.90, -.85, -.80,      C3D  590
     $ -.76, -.71, -.69, -.67, -.66, -.65, -.65, -.66, -.67, -.68,      C3D  600
     $ -.70, -.72, -.82, -.93,-1.03,-1.14,-1.24,-1.37,-1.51,-1.68,      C3D  610
     $-2.13,-2.57,-2.92,-3.26,-3.71,-4.16,-5.00,-5.00,-5.00,-5.00/      C3D  620
      C3L=C3(L)                                                         C3D  630
      RETURN                                                            C3D  640
      END                                                               C3D  650
```

Table A1. Listing of Fortran Code LOWTRAN 5 (Cont.)

```
      SUBROUTINE C4DTA
      COMMON /C4C5C8/ C4(133),C5(15),C8(102)
C        N2 CONTINUUM
C      C4 LOCATION  1     V =  2050 CM-1
C      C4 LOCATION  133   V =  2740 CM-1
      DATA(C4(I),I=   1, 114)/
     1 2.93E-04, 3.86E-04, 5.09E-04, 6.56E-04, 8.85E-04, 1.06E-03,
     2 1.31E-03, 1.73E-03, 2.27E-03, 2.73E-03, 3.36E-03, 3.95E-03,
     3 5.46E-03, 7.19E-03, 9.00E-03, 1.13E-02, 1.36E-02, 1.66E-02,
     4 1.96E-02, 2.16E-02, 2.36E-02, 2.63E-02, 2.90E-02, 3.15E-02,
     5 3.40E-02, 3.66E-02, 3.92E-02, 4.26E-02, 4.60E-02, 4.95E-02,
     6 5.30E-02, 5.65E-02, 6.00E-02, 6.30E-02, 6.60E-02, 6.89E-02,
     7 7.18E-02, 7.39E-02, 7.60E-02, 7.84E-02, 8.08E-02, 8.39E-02,
     8 8.70E-02, 9.13E-02, 9.56E-02, 1.08E-01, 1.20E-01, 1.36E-01,
     9 1.52E-01, 1.60E-01, 1.69E-01, 1.60E-01, 1.51E-01, 1.37E-01,
     $ 1.23E-01, 1.19E-01, 1.16E-01, 1.14E-01, 1.12E-01, 1.12E-01,
     $ 1.11E-01, 1.11E-01, 1.12E-01, 1.14E-01, 1.13E-01, 1.12E-01,
     $ 1.09E-01, 1.07E-01, 1.02E-01, 9.90E-02, 9.50E-02, 9.00E-02,
     $ 8.65E-02, 8.20E-02, 7.65E-02, 7.05E-02, 6.50E-02, 6.10E-02,
     $ 5.50E-02, 4.95E-02, 4.50E-02, 4.00E-02, 3.75E-02, 3.50E-02,
     $ 3.10E-02, 2.65E-02. 2.50E-02, 2.20E-02, 1.95E-02, 1.75E-02,
     $ 1.60E-02, 1.40E-02, 1.20E-02, 1.05E-02, 9.50E-03, 9.00E-03,
     $ 8.00E-03, 7.00E-03, 6.50E-03, 6.00E-03, 5.50E-03, 4.75E-03,
     $ 4.00E-03, 3.75E-03, 3.50E-03, 3.00E-03, 2.50E-03, 2.25E-03,
     $ 2.00E-03, 1.85E-03, 1.70E-03, 1.60E-03, 1.50E-03, 1.50E-03/
      DATA(C4(I),I= 115, 133)/
     1 1.54E-03, 1.50E-03, 1.47E-03, 1.34E-03, 1.25E-03, 1.06E-03,
     2 9.06E-04, 7.53E-04, 6.41E-04, 5.09E-04  4.04E-04, 3.36E-04,
     3 2.86E-04, 2.32E-04, 1.94E-04, 1.57E-04, 1.31E-04, 1.02E-04,
     4 8.07E-05/
C        4M  H2O CONTINUUM
C      C5 LOCATION  1     V =  2350   CM-1
C      C5 LOCATION  15    V =  2420   CM-1
      DATA(C5(I),I=   1,  15)/
     1 0.00,  .19,  .15,  .12,  .10,  .09,  .10,  .12,  .15,  .17,
     2  .20,  .24,  .28,  .33, 0.00/
C        OZONE U.V. + VISIBLE
C      C8 LOCATION  1     V =  13000  CM-1
C      C8 LOCATION  56    V =  24200  CM-1
C        DV = 200  CM-1
C      C8 LOCATION  57    V =  27500  CM-1
C      C8 LOCATION  102   V =  50000  CM-1
C        DV = 500  CM-1
      DATA(C8(I),I=   1, 102)/
     1 4.50E-03, 8.00E-03, 1.07E-02, 1.10E-02, 1.27E-02, 1.71E-02,
     2 2.00E-02, 2.45E-02, 3.07E-02, 3.84E-02, 4.78E-02, 5.67E-02,
     3 6.54E-02, 7.62E-02, 9.15E-02, 1.00E-01, 1.09E-01, 1.20E-01,
     4 1.28E-01, 1.12E-01, 1.11E-01, 1.16E-01, 1.19E-01, 1.13E-01,
     5 1.03E-01, 9.24E-02, 8.28E-02, 7.57E-02, 7.07E-02, 6.58E-02,
     6 5.56E-02, 4.77E-02, 4.06E-02, 3.87E-02, 3.82E-02, 2.94E-02,
     7 2.09E-02, 1.80E-02, 1.91E-02, 1.66E-02, 1.17E-02, 7.70E-03,
     8 6.10E-03, 8.50E-03, 6.10E-03, 3.70E-03, 3.20E-03, 3.10E-03,
     9 2.55E-03, 1.98E-03, 1.40E-03, 8.25E-04, 2.50E-04, 0.       ,
     $ 0.       , 0.       , 5.65E-04, 2.04E-03, 7.35E-03, 2.03E-02,
     $ 4.98E-02, 1.18E-01, 2.46E-01, 5.18E-01, 1.02E+00, 1.95E+00,
     $ 3.79E+00, 6.65E+00, 1.24E+01, 2.20E+01, 3.67E+01, 5.95E+01,
     $ 8.50E+01, 1.26E+02, 1.68E+02, 2.06E+02, 2.42E+02, 2.71E+02,
     $ 2.91E+02, 3.02E+02, 3.03E+02, 2.94E+02, 2.77E+02, 2.54E+02,
     $ 2.26E+02, 1.96E+02, 1.68E+02, 1.44E+02, 1.17E+02, 9.75E+01,
     $ 7.65E+01, 6.04E+01, 4.62E+01, 3.46E+01, 2.52E+01, 2.00E+01,
     $ 1.57E+01, 1.20E+01, 1.00E+01, 8.80E+00, 8.30E+00, 8.60E+00/
      RETURN
      END
```

Table A2. Description of LOWTRAN Subroutines

LOWEM	Main driver program. Reads control cards.
MDTA	Contains the data for the six model atmospheres and HNO_3 profile.
NSMDL	For user defined model atmospheres or aerosols.
HPROF	Sets up horizontal profiles of attenuator densities in LOWTRAN units.
AERPRF	Sets up appropriate aerosol horizontal profiles for model selected.
PRFDTA	Contains the different aerosol model vertical distributions.
GEO	Calculates the absorber amounts along the atmospheric slant path.
ANGL	Calculates the initial zenith angle for the slant path when H1, H2 and BETA are given.
POINT	Computes mean refractive index above and below a given altitude and finds equivalent absorber densities at the altitude.
EXABIN	Loads the aerosol extinction and absorption coefficients for the appropriate models and boundary layer relative humidity.
EXTDTA	Contains all the aerosol attenuation coefficients.
PATH	For radiance calculations, saves cumulative absorber amounts along slant path.
TRANS	Calculates transmittances and radiances for slant path.
TRFN	Contains transmittance functions.
AEREXT	Interpolates aerosol attenuation coefficients for values at wavenumber ν.
HNO3	Determines nitric acid absorption coefficient at ν.
C1DTA	Contains water vapor absorption coefficients.
C2DTA	Contains uniformly mixed gases absorption coefficients.
C3DTA	Contains IR ozone absorption coefficients.
C4DTA	Contains absorption data for nitrogen continuum, 4-μm water continuum and ozone UV and visible data.

Appendix B

LOWEM Symbols and Definitions

ABSC	Aerosol absorption coefficient
ALAM	Wavelength (μm)
ANGLE	Input zenith angle (degrees)
AVW	Average wavelength used in refractive index expression
BET	Angle subtended at the earth's center as path traverses adjacent levels
BETA	Total angle subtended by path at earth's center
CA	Conversion factor from degrees to radians
CO	Wavelength dependent coefficient used in refractive index expression
CW	Wavelength dependent coefficient used in refractive index expression
DUMMY	Used when IHAZE = 7
DV	Wavenumber increment at which transmittance is calculated
E(K)	Equivalent absorber amounts per km at height H1
EH(1, I)	Equivalent absorber amount per km for H_2O at level Z(I)
EH(2, I)	Equivalent absorber amount per km for CO_2 + N_2O etc. at level Z(I)
EH(3, I)	Equivalent absorber amount per km for O_3 at level Z(I)
EH(4, I)	Equivalent absorber amount per km for N_2 at level Z(I)
EH(5, I)	Equivalent absorber amount per km for H_2O continuum at level Z(I), (10 μm)

EH(6, I)	Equivalent absorber amount per km for molecular scattering at level Z(I)
EH(7, I)	Equivalent absorber amount per km for aerosol 1 (0 to 2 km) at the level Z(I)
EH(8, I)	Equivalent absorber amount per km for ozone (UV and visible) at level Z(I)
EH(9, I)	Mean refractive index of layer above level Z(I)
EH(10, I)	Equivalent absorber amount per km for H_2O continuum at level Z(I), (4 μm)
EH(11, I)	Equivalent absorber amount per km for nitric acid at level Z(I)
EH(12, I)	Equivalent absorber amount per km for aerosol 2 (2 to 10 km region) at the level Z(I)
EH(13, I)	Equivalent absorber amount per km for aerosol 3 (10 to 30 km) at the level Z(I)
EH(14, I)	Equivalent absorber amount per km for aerosol 4 (30 to 100 km) at the level Z(I)
EH(15, I)	Relative humidity * EH(7, I)
EXTC	Aerosol extinction coefficient
H1	Initial altitude (km)
H2	Final altitude (km)
HMIN	Minimum altitude of path trajectory (km)
HMIX(I)	Nitric acid volume mixing ratio (times 1.0 E+09) at the level Z(I)
HSTOR(I)	Interpolated nitric acid volume mixing ratios
HZ(I)	Hollerith titles for visibility
I	Running integer used as altitude (level) indicator and frequency indicator
ICH	Array used to select the correct aerosol extinction/absorption coefficients from EXABIN
IEMISS	Input control parameter determining mode of program execution (=0 for transmittance, =1 for radiance mode)
IFIND	Indicator for using subroutine ANGL
IHAZE	Boundary layer aerosol model parameter (0 to 2 km)
IJ	Running integer used as layer indicator along the atmospheric path
IKLO	Lower limit of layer loop (=1)
IKMAX	Upper limit of layer loop
IL	Integer indicator used to determine if the atmospheric path intersects the earth
IM	Parameter used when reading in a new atmospheric model
ISEASN	Parameter for seasonal dependence of aerosol profile
ITYPE	Indicator for type of atmospheric path
IVULCN	Volcanic aerosol model parameter (10 to 30 km)
IXY	Parameter for terminating program and cycling indicator

JEXTRA	Integer indicator used when H1, H2, and HMIN are in the same layer (ITYPE=2)
JMIN	Altitude indicator for minimum height of path
JP	Print option parameter
J1	Level indicator for altitude H1
J2	Level indicator for altitude H2
KMAX	Upper limit of absorber amount loops (=15)
LEN	Parameter used for defining longest of two paths
LENST	Integer storage for parameter LEN, needed for cases run in succession
M	Integer used to identify required model atmosphere
ML	Number of levels in radiosonde data input (MODEL=7)
MODEL	Integer used to identify required model atmosphere
M1	Integer for selecting temperature altitude profile for (M=M1)
M2	Integer for selecting H_2O altitude profile for (M=M2)
M3	Integer for selecting O_3 altitude profile for (M=M3)
NL	Number of levels in model atmosphere data
NL1	Equals NL-1
NP1	Value of NP for altitude H1
P(M, I)	Pressure (mb) at level I for model atmosphere M
PI	3.141592654 that is (π)
RANGE	Path length (km)
RE	Earth radius (km)
RELHUM(I)	Relative humidity (percent) at the level Z(I)
RO	Earth radius (km) read in as input (=RE)
SEASN(ISEASN)	Hollerith titles for the season for the 2 to 30 km region
T(M, I)	Temperature (^{O}K) for model atmosphere M at level I
TBBY(IJ)	Average temperature of the IJ layer
TBOUND	Input temperature of the boundary in ^{O}K
TX(K)	Equivalent absorber amounts per km at a given altitude obtained from POINT; also transmittance values at a given wavelength for each absorber type (K = 1, KMAX)
TX(9)	Total transmittance at frequency V
TX(10)	Absorption due to aerosol only at frequency V
VH(K)	Integral of the equivalent absorber amounts from H1 to level I
VIS	Meteorological range (km) at sea level
VSB(IHAZE)	Default meteorological range for the boundary layer aerosol model IHAZE
VULCN	Hollerith titles for the volcanic aerosol model (10 to 30 km)
VX2	Wavelength array associated with EXTC and ABCS
V1	Initial frequency for transmittance calculation, cm^{-1}
V2	Final frequency for transmittance calculation, cm^{-1}

W(K)	Total equivalent absorber amount for entire path
WH(M, I)	Water vapor density for atmospheric model M at level I (gm m^{-3})
WLAY(I, K)	The absorber amount for the species, K, and the atmospheric layer, I
WO(M, I)	Ozone density for atmospheric model M at level I (gm m^{-3})
WPATH(IJ, K)	The cumulative absorber amount of the species, K, for the IJ layer along the atmospheric slant path
X1	Earth center distance of level I
X2	Earth center distance of level I + 1
Z(I)	Altitude at level I in km

Appendix C

LOWTRAN 5 Segmented Loader Map, AFGL CDC 6600

Table C1. Listing of Segmented Load

```
LOAD MAP - SEGMENTED LOAD.                          CYBER LOADER 1.5-498       12/11/79  15.10.34.      PAGE     1

SEGLOAD DIRECTIVES.1

LOWTRAN TREE LOWEM-(NSMDL,HPROF,GEO,EXABIN,PATH,XTRANS)
LOWEM GLOBAL CARD1,CARD2,CARD7,CNTRL,MDATA
NSMDL INCLUDE NSMDL,AERPRF,PRFDTA
HPROF INCLUDE HPROF,AERPRF,PRFDTA
GEO INCLUDE GEO,POINT,ANGL
EXABIN INCLUDE EXABIN,EXTDTA
XTRANS TREE TRANS-(HNO3,C1DTA,C2DTA,C3DTA)
TRANS INCLUDE TRANS,AEREXT,C4DTA
      END LOWEM

TREE DIAGRAM.

*LOWEM
 ?
 ?_NSMDL
 ?
 ?_HPROF
 ?
 ?_GEO
 ?
 ?_EXABIN
 ?
 ?_PATH
 ?
 ?_TRANS
   ?
   ?_HNO3
   ?
   ?_C1DTA
   ?
   ?_C2DTA
   ?
   ?_C3DTA

FWA OF THE LOAD             1025
LWA+1 OF THE LOAD          10765
CM BLANK COMMON FWA        23757

WRITTEN TO FILE      APS

TRANSFER ADDRESS -- LOWEM             4324


-------- SEGMENT - LOWEM


PROGRAM AND BLOCK ASSIGNMENTS.

BLOCK          ADDRESS   LENGTH    FILE      DATE      PROCSSR VER LEVEL  HARDWARE   COMMENTS

(LOWEM)          1026         6
/CARD1/    G     1034        20
/CARD2/    G     1054         7
/CARD_/    G     1063        46
/CNTRL/    G     1131        17
/MDATA/    G     1150      2033
/Q8.IO./         3203       101
/FCL.C./         3304        26
/STP.END/        3332         1
/FCL=ENT/        3333        40
/FCL.COM/        3373        14
LOWEM            3407      2304     LGO     12/11/79 FTN      4.7 476    666X I     PROGRAM    OPT=1
MDTA             5713        11     LGO     12/11/79 FTN      4.7 476    666X I     SUBROUTINEOPT=1
ACOSIN.          5724        63 SL-FORTRAN  12/04/78 COMPASS  3.6 485               COMPUTE THE INVERSE SINE OR COSINE OF X.
ALOG.            6007        63 SL-FORTRAN  12/04/78 COMPASS  3.6 485               COMPUTE COMMON AND NATURAL LOGARITHMS. OPT=ALL
ATAN.            6072        60 SL-FORTRAN  12/04/78 COMPASS  3.6 485               COMPUTE THE INVERSE TANGENT FUNCTION. OPT=ALL.
EXP.             6152        72 SL-FORTRAN  12/04/78 COMPASS  3.6 485               EXPONENTIAL FUNCTION. E TO POWER X. OPT=ALL.
EXP.MSG          6244        16 SL-FORTRAN  12/04/78 COMPASS  3.6 485               COMMON ERROR MESSAGES FOR EXPONENTIATION.
SINCOS.          6262        60 SL-FORTRAN  12/04/78 COMPASS  3.6 485               TRIGONOMETRIC SINE OR COSINE OF X. OPT=ALL.
SQRT.            6342        42 SL-FORTRAN  12/04/78 COMPASS  3.6 485               COMPUTE THE SQUARE ROOT OF X. OPT=ALL.
```

Table C1. Listing of Segmented Load (Cont.)

```
LOAD MAP - SEGMENTED LOAD.                              CYBER LOADER 1.5-498      12/11/79  15.10.34.       PAGE      2

BLOCK          ADDRESS   LENGTH     FILE       DATE       PROCSSR VER LEVEL  HARDWARE   COMMENTS

SYS=1ST           6374       63  SL-FORTRAN   12/04/78  COMPASS 3.6 485               MATH LIBRARY LINK TO ERROR MESSAGE PROCESSOR.
FECMSK=           6457       41  SL-FORTRAN   12/04/78  COMPASS 3.6 485               INITIALIZE CONSTANTS.
FLTIN=            6520      156  SL-FORTRAN   12/04/78  COMPASS 3.6 485               COMMON FLOATING INPUT CONVERTER.
FMTAP=            6676      357  SL-FORTRAN   12/04/78  COMPASS 3.6 485               CRACK APLIST AND FORMAT FOR KODER/KRAKER.
FCRUTL=           7255       46  SL-FORTRAN   12/04/78  COMPASS 3.6 485               FCL MISC. UTILITIES.
GETFIT=           7323       57  SL-FORTRAN   12/04/78  COMPASS 3.6 485               LOCATE AN FIT GIVEN A FILE NAME
KRAKER=           7402      375  SL-FORTRAN   12/04/78  COMPASS 3.6 485               PROCESS FORMATTED FORTRAN INPUT.
OUTC=             7777      150  SL-FORTRAN   12/04/78  COMPASS 3.6 485               FORMATTED WRITE FORTRAN RECORD.
SYSAID=          10147        1  SL-FORTRAN   12/04/78  COMPASS 3.6 485               LINK BETWEEN SYS=AID AND INITIALIZATION CODE.
SYS=AID          10150        7  SL-FORTRAN   12/04/78  COMPASS 3.6 485               AUXILIARY MATH LIBRARY LINK FOR ERRORS.
XTOY.            10157       31  SL-FORTRAN   12/04/78  COMPASS 3.6 485               REAL BASE TO REAL POWER. OPT=ALL.
Q2NTRY=          10210        0  SL-FORTRAN   12/04/78  COMPASS 3.6 485               FCL INITIALIZATION ROUTINE.
COMIO=           10210       33  SL-FORTRAN   12/04/78  COMPASS 3.6 485               COMMON CODED I/O ROUTINES AND CONSTANTS.
ENDFIL=          10243       31  SL-FORTRAN   12/04/78  COMPASS 3.6 485               WRITE END OF LOGICAL FILE MARK.
FCL=FDL          10274       40  SL-FORTRAN   12/04/78  COMPASS 3.6 485               FCL CAPSULE LOADING
FEIFST=          10334        3  SL-FORTRAN   12/04/78  COMPASS 3.6 485                CONVERTED DATA STORAGE
FLTOUT=          10337      311  SL-FORTRAN   12/04/78  COMPASS 3.6 485               COMMON FLOATING OUTPUT CODE
FCRSYS=          10650      301  SL-FORTRAN   12/04/78  COMPASS 3.6 485               FORTRAN OBJECT LIBRARY UTILITIES.
INCOM=           11151      145  SL-FORTRAN   12/04/78  COMPASS 3.6 485               COMMON INPUT FORMATTING CODE
INPC=            11316      207  SL-FORTRAN   12/04/78  COMPASS 3.6 485               FORMATTED READ FORTRAN RECORD.
KODER=           11525      451  SL-FORTRAN   12/04/78  COMPASS 3.6 485               OUTPUT FORMAT INTERPRETER.
OUTCOM=          12176      154  SL-FORTRAN   12/04/78  COMPASS 3.6 485               COMMON OUTPUT CODE
SPA=             12352       11  SL-FORTRAN   12/04/78  COMPASS 3.6 485               SPA= - SUBSTITUTE PARAMETER ADDRESSES.
GCTOER=          12363       14  SL-FORTRAN   12/04/78  COMPASS 3.6 485               COMPLETED GO TO ERROR PROCESSOR.
CTL$RM           12377      433  SL-SYSLIB    09/21/79  COMPASS 3.5 476               CRM CONTROLLING ROUTINE.
CTL$WR           13032       32  SL-SYSLIB    09/21/79  COMPASS 3.5 476               CRM CONTROLLER - RECX, REWIND
EPR$RH           13064       25  SL-SYSLIB    09/21/79  COMPASS 3.5 476               CRM ERROR PROCESSOR ENTRY
LIST$RM          13111       67  SL-SYSLIB    09/21/79  COMPASS 3.5 476               CRM - ALLOCATE SPACE FOR LIST OF FILES
CMF.ALF          13200      160  SL-SYSLIB    11/15/79  COMPASS 3.6 498               CMM V1.1 - ALLOCATE FIXED.
CMF.CSF          13360        6  SL-SYSLIB    11/15/79  COMPASS 3.6 498               CMM V1.1 - CHANGE SPECS FIXED.
CMM.FFA          13366       14  SL-SYSLIB    11/15/79  COMPASS 3.6 498               CMM V1.1 - FIXED FREE ALGORITHM.
CMF.FRF          13402       35  SL-SYSLIB    11/15/79  COMPASS 3.6 498               CMM V1.1 - FREE FIXED.
CMM.MEM          13437        7  SL-SYSLIB    11/15/79  COMPASS 3.6 498
CMM.P            13446      205  SL-SYSLIB    11/15/79  COMPASS 3.6 498               CMM V1.1 - RESIDENT SUBROUTINES.
CMF.SLF          13653       22  SL-SYSLIB    11/15/79  COMPASS 3.6 498               CMM V1.1 - SHRINK AT LWA FIXED.
CPU.SYS          13675       40  SL-SYSLIB    11/15/79  COMPASS 3.5 476               PROCESS SYSTEM REQUEST.
FDL.RES          13735      211  SL-SYSLIB    11/19/79  COMPASS 3.6 498               FAST DYNAMIC LOADER RESIDENT.
FCL.MMI          14146      222  SL-SYSLIB    11/19/79  COMPASS 3.6 496               FCL MEMORY MANAGER INTERFACE.
CMF.SDA          14370       47  SL-SYSLIB    11/15/79  COMPASS 3.6 498               CMM V1.1 - SCT CABA.


-------- SEGMENT - NSMDL


         PROGRAM AND BLOCK ASSIGNMENTS.

         BLOCK          ADDRESS   LENGTH     FILE       DATE       PROCSSR VER LEVEL  HARDWARE   COMMENTS

         /CARD1/    S     1034       20
         /CARD2/    S     1054        7
         /CARD3/    S     1063       46
         /CNTRL/    S     1131       17
         /MDATA/    S     1150     2033
         (NSMDL)         14440
         /PRFDTA/        14440     1354
         NSMDL           16014     1033  LGO        12/11/79 FTN        4.7 476    666X I     SUBROUTINEOPT=1
         AERPRF          17047      243  LGO        12/11/79 FTN        4.7 476    666X I     SUBROUTINEOPT=1
         PRFDTA          17312        3  LGO        12/11/79 FTN        4.7 476    666X I     SUBROUTINEOPT=1


-------- SEGMENT - MPROF


         PROGRAM AND BLOCK ASSIGNMENTS.

         BLOCK          ADDRESS   LENGTH     FILE       DATE       PROCSSR VER LEVEL  HARDWARE   COMMENTS

         /CARD1/    S     1034       20
         /CARD2/    S     1054        7
```

Table C1. Listing of Segmented Load (Cont.)

```
LOAD MAP - SEGMENTED LOAD.                                 CYBER LOADER 1.5-498       12/11/79  15.1..34.       PAGE     3

BLOCK            ADDRESS   LENGTH     FILE      DATE        PROCSSR VER LEVEL  HARDWARE   COMMENTS

/CARD3/     S       1063       45
/CNTRL/     S       1131       17
/MDATA/     S       1150     2033
(HPROF)            14440        0
/PRFDTA/           14440     1354
HPROF              15014      641     LGO       12/11/79 FTN       4.7 476     666X I     SUBROUTINEOPT=1
AERPOF             16655      243     LGO       12/11/79 FTN       4.7 476     666X I     SUBROUTINEOPT=1
PRFDTA             17120        3     LGO       12/11/79 FTN       4.7 476     666X I     SUBROUTINEOPT=1

-------- SEGMENT - GEO

         PROGRAM AND BLOCK ASSIGNMENTS
         BLOCK            ADDRESS   LENGTH     FILE      DATE        PROCSSR VER LEVEL  HARDWARE   COMMENTS

         /CARD1/     S       1034       20
         /CARD2/     S       1054        7
         /CARD3/     S       1063       45
         /CNTRL/     S       1131       17
         /MDATA/     S       1150     2033
         (GEO)              14440        0
         GEO                14440     1740     LGO       12/11/79 FTN       4.7 476     666X I     SUBROUTINEOPT=1
         POINT              15400      273     LGO       12/11/79 FTN       4.7 476     666X I     SUBROUTINEOPT=1
         ANGL               16673     1315     LGO       12/11/79 FTN       4.7 476     666X I     SUBROUTINEOPT=1
         TAN.               20210       75 SL-FORTRAN    12/04/78 COMPASS   3.6 485                TRIGONOMETRIC TANGENT. OPT=ALL.

-------- SEGMENT - EXABIN

         PROGRAM AND BLOCK ASSIGNMENTS.
         BLOCK            ADDRESS   LENGTH     FILE      DATE        PROCSSR VER LEVEL  HARDWARE   COMMENTS

         /CARD1/     S       1034       20
         /CARD2/     S       1054        7
         /CARD3/     S       1063       45
         /CNTRL/     S       1131       17
         /MDATA/     S       1150     2033
         (EXABIN)           14440        0
         /EXTDTA/           14440     3413
         EXABIN             23050      372     LGO       12/11/79 FTN       4.7 476     666X I     SUBROUTINEOPT=1
         EXTDTA             23442        3     LGO       12/11/79 FTN       4.7 476     666X I     SUBROUTINEOPT=1

-------- SEGMENT - PATH

         PROGRAM AND BLOCK ASSIGNMENTS
         BLOCK            ADDRESS   LENGTH     FILE      DATE        PROCSSR VER LEVEL  HARDWARE   COMMENTS

         /CARD1/     S       1034       20
         /CARD2/     S       1054        7
         /CARD3/     S       1063       45
         /CNTRL/     S       1131       17
         /MDATA/     S       1150     2033
         (PATH)             14440        0
         PATH               14440      621     LGO       12/11/79 FTN       4.7 476     666X I     SUBROUTINEOPT=1

-------- SEGMENT - TRANS
```

Table C1. Listing of Segmented Load (Cont.)

```
LOAD MAP - SEGMENTED LOAD.                         CYBER LOADER 1.5-498       12/11/79  15.10.34.        PAGE     4

PROGRAM AND BLOCK ASSIGNMENTS
BLOCK           ADDRESS   LENGTH     FILE      DATE       PROCSSR VER LEVEL  HARDWARE     COMMENTS

/CARD1/     S      1024       30
/CARD2/     S      1054        7
/CARD3/     S      1063       46
/CNTRL/     S      1131       17
/MDATA/     S      1150    13270
(TRANS)           14440        4
/TREMFO/          14444      311
/CALCSC/          14755      372
/AERO/            15347       10
TRANS             15357     1253     LGO       12/11/79 FTN       4.7 476      666X I       SUBROUTINEOPT=1
AEREXT            16632       57     LGO       12/11/79 FTN       4.7 476      666X I       SUBROUTINEOPT=1
CALCTA            16711        3     LGO       12/11/79 FTN       4.7 476      666X I       SUBROUTINEOPT=1
TREN              16714        3     LGO       12/11/79 FTN       4.7 476      666X I       SUBROUTINEOPT=1


-------- SEGMENT - HNO3

          PROGRAM AND BLOCK ASSIGNMENTS
          BLOCK           ADDRESS   LENGTH     FILE      DATE       PROCSSR VER LEVEL  HARDWARE     COMMENTS

          (HNO3)           15717        0
          HNO3             15717      132     LGO       12/11/79 FTN       4.7 476      666X I       SUBROUTINEOPT=1


-------- SEGMENT - C1DTA

          PROGRAM AND BLOCK ASSIGNMENTS.
          BLOCK           ADDRESS   LENGTH     FILE      DATE       PROCSSR VER LEVEL  HARDWARE     COMMENTS

          (C1DTA)          16717        0
          /C1/             16717     5024
          C1DTA            23743       10     LGO       12/11/79 FTN       4.7 476      666X I       SUBROUTINEOPT=1


-------- SEGMENT - C2DTA

          PROGRAM AND BLOCK ASSIGNMENTS.
          BLOCK           ADDRESS   LENGTH     FILE      DATE       PROCSSR VER LEVEL  HARDWARE     COMMENTS

          (C2DTA)          16717        0
          /C2/             16717     3047
          C2DTA            21766       10     LGO       12/11/79 FTN       4.7 476      666X I       SUBROUTINEOPT=1


-------- SEGMENT - C3DTA

          PROGRAM AND BLOCK ASSIGNMENTS.
          BLOCK           ADDRESS   LENGTH     FILE      DATE       PROCSSR VER LEVEL  HARDWARE     COMMENTS

          (C3DTA)          16717        0
          /C3/             16717     1034
          C3DTA            17753       13     LGO       12/11/79 FTN       4.7 476      666X I       SUBROUTINEOPT=1


          LOAD MAP - SEGMENTED LOAD.                         CYBER LOADER 1.5-498       12/11/79  15.10.34.        PAGE     5

               2.337 CP SECONDS              215008 CM STORAGE USED                   11 TABLE MOVES
```

Appendix D

Water Vapor Density and Relative Humidity in LOWTRAN

LOWTRAN requires both the water vapor density, used in calculating the molecular and continuum absorption, and the relative humidity, needed for interpolating the relative humidity dependent aerosol extinction coefficients. The user is given a choice of meteorological parameters with which to specify these quantities. The possible choices are the ambient temperature and any one of the following: relative humidity, dew-point temperature, or water vapor density. From any one of these three combinations, the program will supply the missing values of water vapor density and/or relative humidity as described in the next section.

The percent relative humidity, RH, is defined as 100 times the ratio of the ambient mass mixing ratio m to the saturation mixing ratio, m_s. The mixing ratio is defined as the ratio of the density of water vapor ρ_v to the density of the dry air ρ_d.

Therefore

$$\frac{RH}{100} = \frac{m}{m_s} = \frac{\rho_v/\rho_d}{\rho_s/\rho_{ds}}$$

where ρ_s is the saturation density of water vapor at ambient temperature and ρ_{ds} is the density of the dry air at saturation. The saturation water vapor density at a given temperature T is given by the following empirical expression.[D1]

$$\rho_s(t) = A \exp(18.9766 - 14.9595A - 2.4388A^2) \text{ gm m}^{-3}$$

where $A = T_o/(T_o + t)$, $T_o = 273.15$K, and t is in °C. This expression was found to give a good fit to published values of saturation water vapor density over water to better than 1 percent for temperatures between -50°C to 50°C.[D2]

The following section describes the equation used to supply the missing values of water vapor density and/or relative humidity.

1. Given: ambient temperature t in °C and relative humidity RH; find ρ_v.

$$\rho_v = \rho_s(t) \times \frac{RH}{100} \times \left[1 - \left(1 - \frac{RH}{100}\right) \frac{\rho_s(t)\, R_v\, T}{P}\right]^{-1}$$

where R_v is the gas constant for water vapor (4.6150×10^{-3} mb gm m^{-3} K^{-1}), $T = T_o + t$ and P is the total pressure in mb. If the ratio of ρ_d/ρ_{ds} were to be neglected in the equation for RH, then ρ_v is given simply by

$$\rho_v = \rho_s(t) \times \frac{RH}{100}$$

2. Given: ambient temperature t and dew-point temperature t_D, both in °C; find ρ_v and RH.

The dew-point temperature t_D is defined as that temperature at which the ambient water vapor pressure would just saturate the air. This condition gives

$$\rho_v = \frac{T_D}{T}\, \rho_s(t_D)$$

where T and T_D are the ambient and dew-point temperature in K.

The relative humidity is given by

$$\frac{RH}{100} = \frac{\rho_v}{\rho_s(t)}\; \frac{\rho^* - \rho_s(t)}{\rho^* - \rho_v}$$

D1. Selby, J.E.A., and McClatchey, R.A. (1975) Atmospheric Transmittance From 0.25 to 28.5 Microns: Computer Code Lowtran 3, AFCRL-TR-75-0255, AD A017 734.

D2. List, R.J. (1968) Smithsonian Meteorological Tables (6th revised edition). Smithsonian Institute Press, Washington.

where $\rho^* = P/(R_V T)$.

3. Given: t and ρ_V; find RH

RH is calculated in the same way as in 2.

Appendix E

Subroutine DRYSTR

Subroutine DRYSTR, listed in Table E1, can be used in LOWTRAN to generate "dry" stratospheric water vapor profiles. The subroutine uses a constant mass mixing ratio for water vapor above 15 km based on a recent analysis of field measurement data by Penndorf.[E1] In order to use this subroutine, the user should insert a call statement in the main program (PROGRAM LOWEM) immediately after line LOW1240, as follows

```
CALL DRYSTR                                                   LOW 1245
```

A message will be printed on the output file whenever this subroutine is called giving the value of the mass mixing ratio used to generate the modified water vapor profiles.

Figures E1a and E1b show the "dry" stratospheric water vapor profiles vs altitude from 0 to 100 km and expanded profiles from 0 to 30 km calculated from subroutine DRYSTR. A mass mixing ratio of 2.6 ppmm was used.

E1. Penndorf, R. (1978) Analysis of Ozone and Water Vapor Field Measurement Data, Federal Aviation Administration, Washington, D.C., Report FAA-EE-78-29.

Table E1. Listing of Subroutine DRYSTR

```
      CALL DRYSTR                                                     LCM 1245

      SUBROUTINE DRYSTR
C
C     THIS SUBROUTINE REPLACES THE STRATOSPHERIC (16 KM AND ABOVE)
C     WATER VAPOR PROFILE STORED IN MDLATM WITH
C     A "DRY" WATER VAPOR PROFILE CORRESPONDING TO
C     A CONSTANT MASS MIXING RATIO OF DRYMIX (DRYMIX=2.6 PPMM
C     FROM R. PENNDORF 1978 ANALYSIS OF OZONE AND WATER VAPOR
C     FIELD MEASUREMENT DATA FAA-EE-78-29)
C
      COMMON /CARD1/ MODEL,IHAZE,ITYPE,LEN,JP,IM,M1,M2,M3,ML,IEMISS,RO
     1 ,TBOUND,ISEASN,IVULCN,VIS
      COMMON /CARD2/ H1,H2,ANGLE,RANGE,BETA,HMIN,RE
      COMMON /CARD3/ V1,V2,DV,AVW,CO,CW,W(15),E(15),CA,PI
      COMMON /CNTRL/ LENST,KMAX,M,IJ,J1,J2,JMIN,JEXTRA,IL,IKMAX,NLL,NP1
     1,IFIND,NL,IKLO
      COMMON /MODTA/ Z(34),P(7,34),T(7,34),WH(7,34),WO(7,34)
     1 ,SEASN(2),VULCN(5),VSB(9),HZ(15),HMIX(34)
      COMMON RELHUM(34),HSTOR(34),FH(15,34),ICH(4),VH(15),TX(15)
      COMMON WLAY(34,15),WPATH(68,15),TBBY(68)
      COMMON ABSC(4,40),EXTC(4,40),VX2(40)
      DATA DRYMIX /2.6E-6/,RV /2.8705E-3/
      DO 10 N=1,6
      DO 10 I=17,33
10    WH(N,I)=DRYMIX*P(N,I)/(RV*T(N,I))
      PRINT 900,DRYMIX
900   FORMAT(* WATER VAPOR PROFILE HAS BEEN REPLACED BY A*,/,
     X* DRY WATER VAPOR PROFILE CORRESPONDING TO A MASS MIXING RATIO OF*
     X,1PE10.1)
      RETURN
      END
```

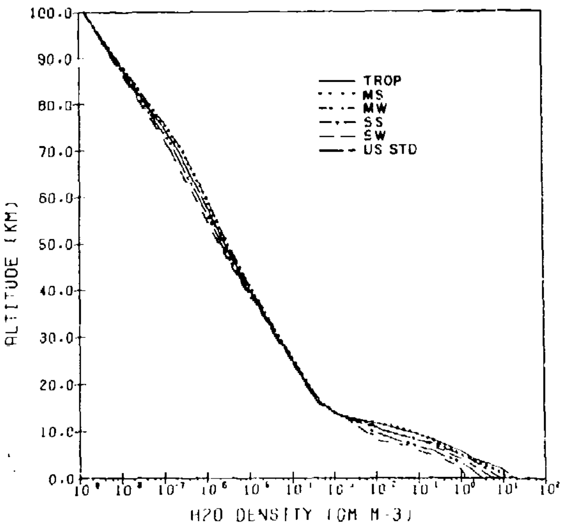

Figure E1a. Water Vapor Density Profiles vs Altitude for a "Dry" Stratosphere for the Six Model Atmospheres

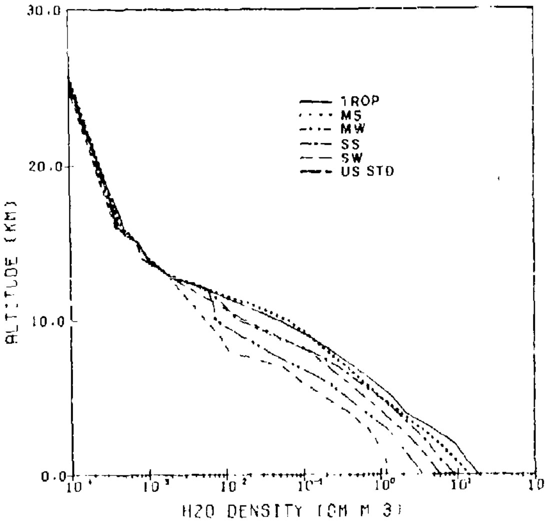

Figure E1b. Water Vapor Density Profiles vs Altitude for a "Dry" Stratosphere for the Six Model Atmospheres with the Region from 0 to 30 km Expanded

Appendix F

Comparisons of LOWTRAN with Measurements

Comparisons of LOWTRAN with measurements from previous LOWTRAN reports[F1, F2, F3] are presented here for ready reference. These earlier comparisons used either the rural or average continental extinction coefficients for the aerosol models.

Figures F1 and F2 show transmittance comparisions of LOWTRAN with laboratory measurements of Burch et al[F4] for some important water vapor and carbon dioxide bands. It will be seen that the LOWTRAN calculations agree closely with the measured spectral transmittance.

Figure F3 shows a transmittance comparison with a sea-level measurement by Ashley et al[F5] (General Dynamics). The measurement, made with an

---

F1. Selby, J.E.A., Kneizys, F.X., Chetwynd Jr., J.H., and McClatchey, R.A. (1978) Atmospheric Transmittance/Radiance: Computer Code LOWTRAN 4, AFGL-TR-78-0053, AD A058 643.

F2. Selby, J.E.A., Shettle, E.P., and McClatchey, R.A. (1976) Atmospheric Transmittance from 0.25 to 28.5 μm: Supplement LOWTRAN 3B, AFGL-TR-76-0258, AD A040 701.

F3. Selby, J.E.A., and McClatchey, R.A. (1975) Atmospheric Transmittance from 0.25 to 28.5 μm: Computer Code LOWTRAN 3, AFCRL-TR-75-0255, AD A017 734.

F4. Burch, D.E., Gryvnak, D., Singleton, E.B., France, W.L., and Williams, D. (1962) Infrared Absorption by Carbon Dioxide, Water Vapor, and Minor Atmospheric Constituents, AFCRL-62-698.

F5. Ashley, G.W., Gastineau, L., and Blay, D. (1973) Private Communication.

interferometer of ~ 4-cm^{-1} resolution from 1.8 to 5.4μm, is for a 1.3-km sea-level horizontal path.

Figure F4 shows a comparison of the calculated upward atmospheric radiance with an interferometer measurement from a balloon flight over northern Nebraska by Chaney at the University of Michigan.[F6] The measurement was taken at a float altitude of 111,700 ft. The calculated radiance used the midlatitude winter model, with a 23-km visual range, and a ground temperature of 280°K.

Figure F5 shows a comparison of an interferometer measurement made from the Nimbus 3 satellite[F7] looking down over the Gulf of Mexico with the calculated atmospheric radiance. The resolution of the interferometer was 5 cm^{-1} as compared to the 20 cm^{-1} resolution of LOWTRAN. Two theoretical models, the tropical and midlatitude summer, were used for comparison, as shown in Figure F7 and are displaced two divisions above and below the measured radiance for clarity. Both models assumed a 23-km visual range and used the temperature at 0 KM in the model atmosphere as the boundary temperature.

Figure F6 shows the comparison of atmospheric radiance as seen from space between the LOWTRAN calculation and measurements from the Nimbus 4 satellite[F8] for three different geographic locations. The spectra, obtained with a Michelson interferometer of resolution 2.8 cm^{-1}, were measured over the Sahara Desert, the Mediterranean, and the Antarctic. The calculated LOWTRAN radiances used the midlatitude winter model and a ground temperature of 320°K for the Sahara; the midlatitude winter model and a ground temperature of 285°K for the Mediterranean; and an arctic winter cold model taken from the AFCRL Handbook of Geophysics and Space Environments and a ground temperature of 190°K for the Antarctic comparison. All three calculations assumed a 23-km visual range for aerosols.

Figures F7 through F10 show comparisons of calculated and observed atmospheric spectral radiance vs wavelength in the 8- to 14-μm spectral region. The measurements were made on a balloon flight launched from Holloman AFB, New Mexico by Murcray et al,[F10] University of Denver. The instrument used for these observations was a LHe grating spectrometer, operated in the first and second order of the grating. The resolution was 0.03 μm in the 8- to 14-μm region. The data in these figures are presented as a function of altitude and as a function of zenith angle. The LOWTRAN radiance calculation used the pressure, temperature, ozone, and nitric acid profiles from the Murcray report,[F10] and the midlatitude winter water vapor profile contained in LOWTRAN.

Because of the large number of references cited above, they will not be listed here. See References, page 233.

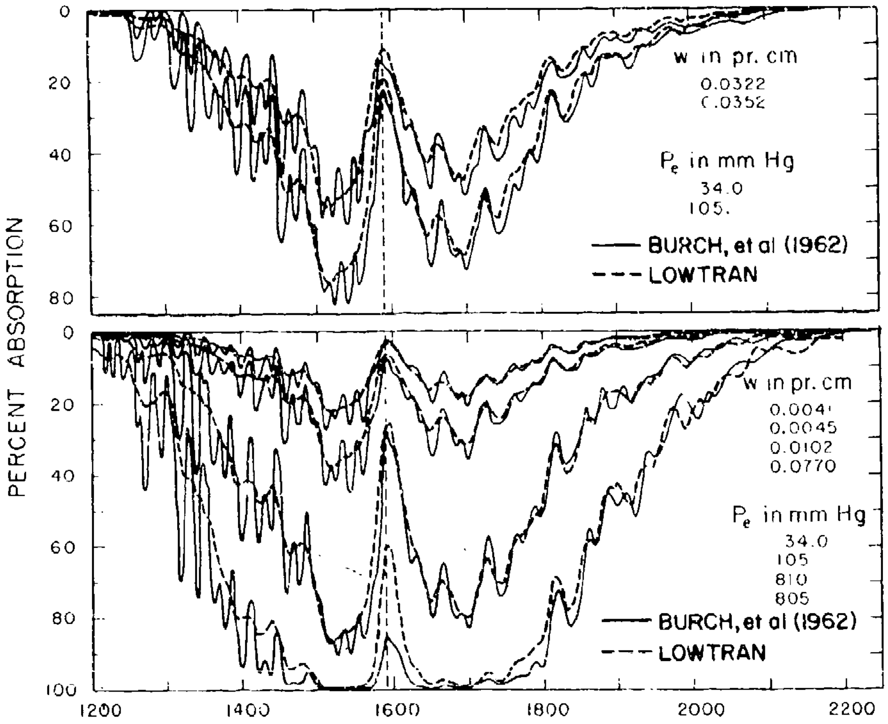

Figure F1. Representative Absorption Curves for the 6.3-μm H_2O Band

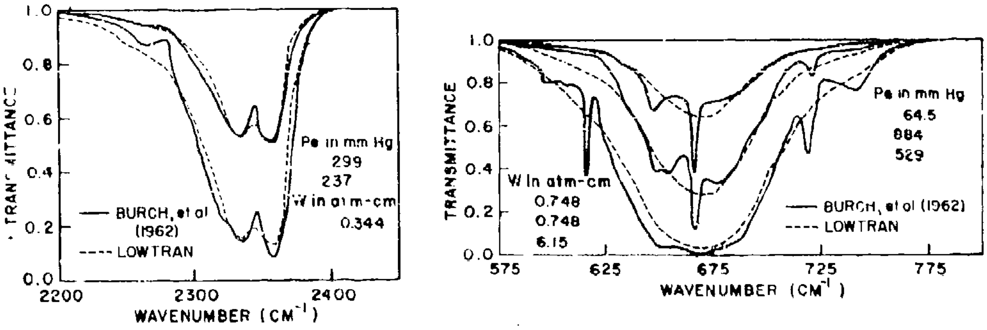

Figure F2. Comparison of LOWTRAN Calculations and Burch et al[F4] Calculations for CO_2 Bands at 4.3 μm and 15 μm

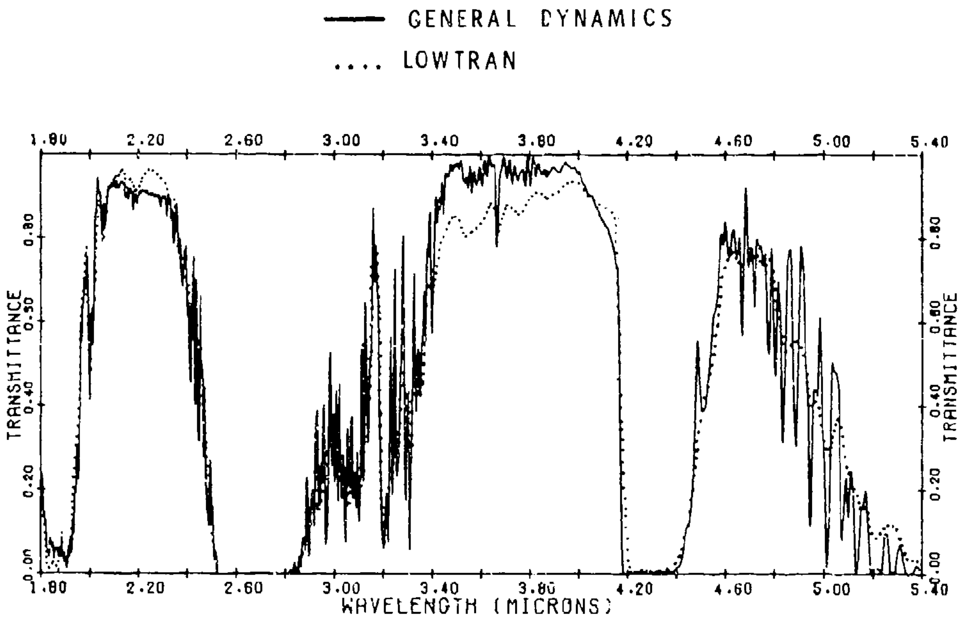

Figure F3. Comparison Between LOWTRAN and General Dynamics Measurements; Range = 1.3 km at Sea Level

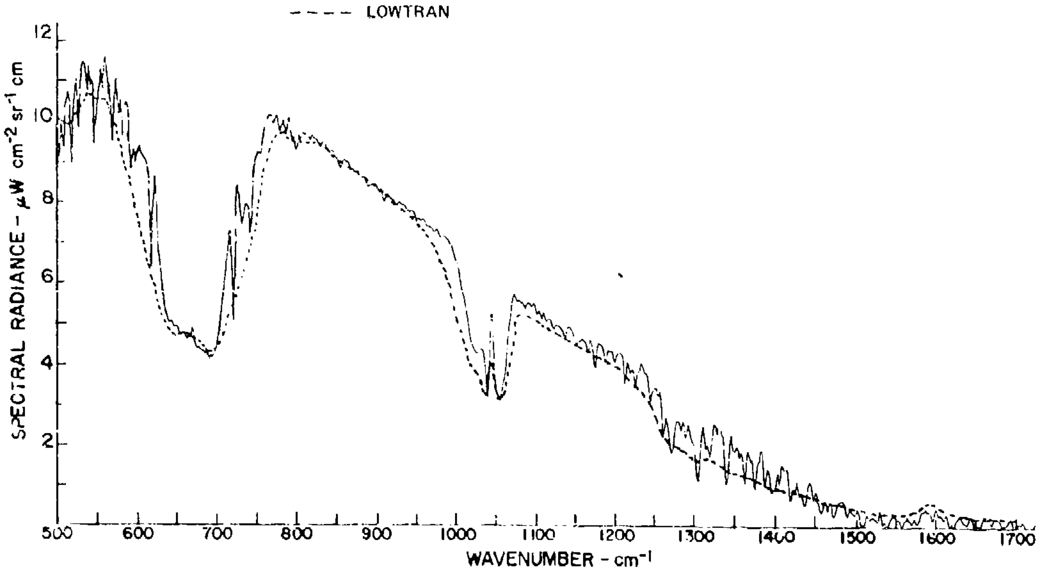

Figure F4. Comparison Between LOWTRAN Predication and University of Michigan Balloon Measurement of Atmospheric Radiance over Northern Nebraska

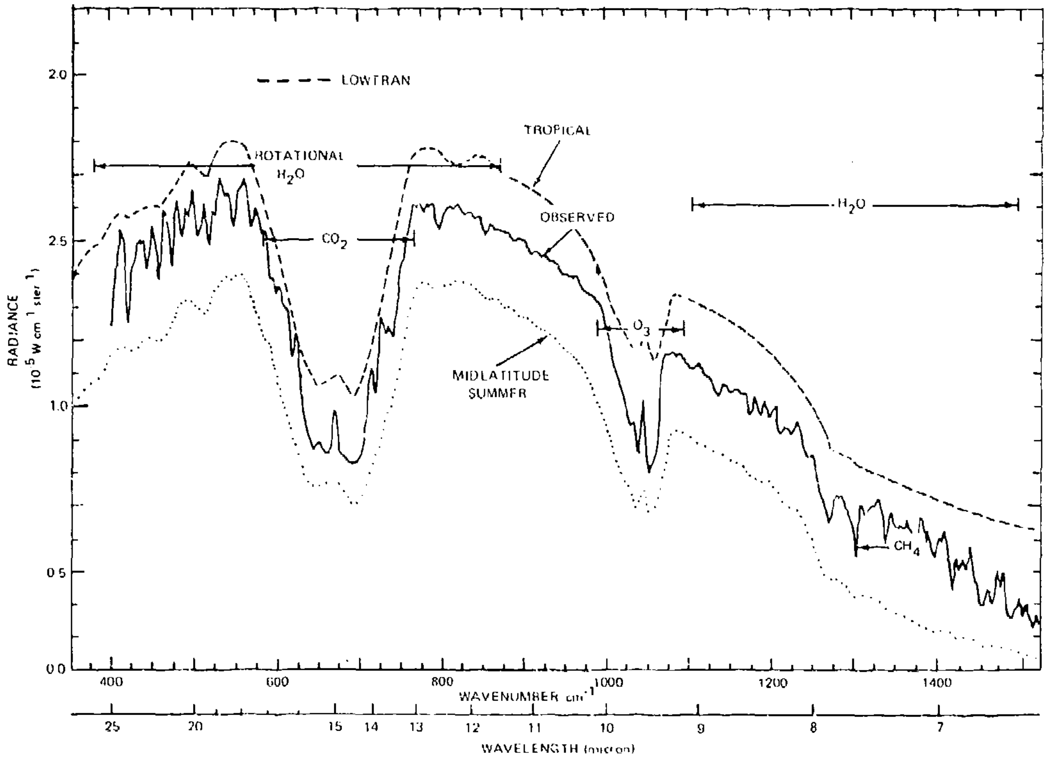

Figure F5. Comparison Between LOWTRAN Prediction and NIMBUS 3 Satellite Measurement of Atmospheric Radiance over the Gulf of Mexico

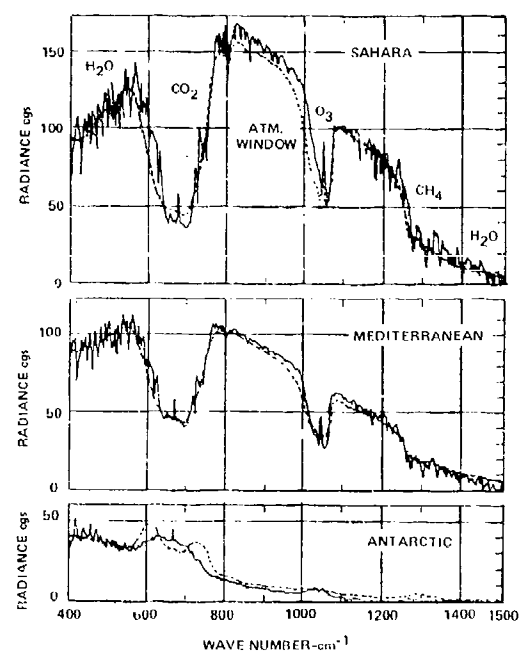

Figure F6. Comparison Between LOWTRAN Predictions and NIMBUS 4 Satellite Measurements of Atmospheric Radiance over the Sahara Desert, the Mediterranean, and the Antarctic

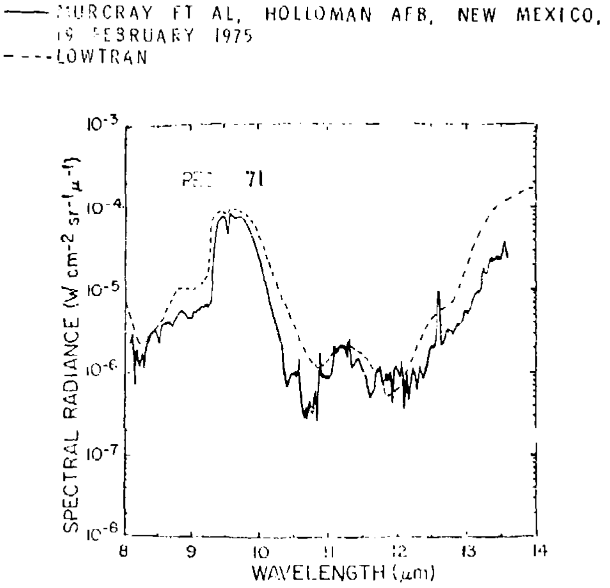

Figure F7. Sample Spectrum of Short Wavelength Region Observed at an Altitude of 9.5 km and a Zenith Angle of 63° on 19 February 1975, and LOWTRAN Comparison

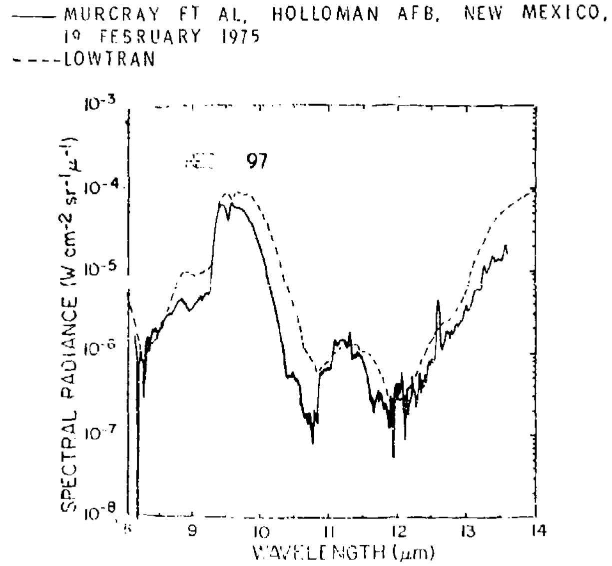

Figure F8. Sample Spectrum of Short Wavelength Region Observed at an Altitude of 13.5 km and a Zenith Angle of 63° on 19 February 1975, and LOWTRAN Comparison

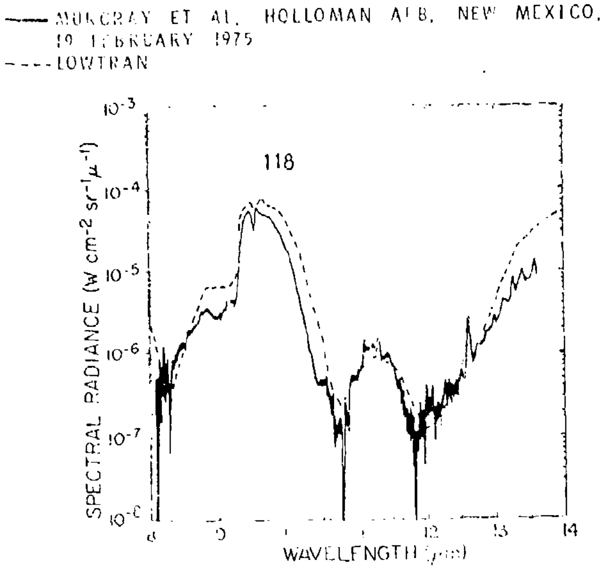

Figure F9. Sample Spectrum of Short Wavelength Region Observed at an Altitude of 18.0 km and a Zenith Angle of 63° on 19 February 1975, and LOWTRAN Comparison

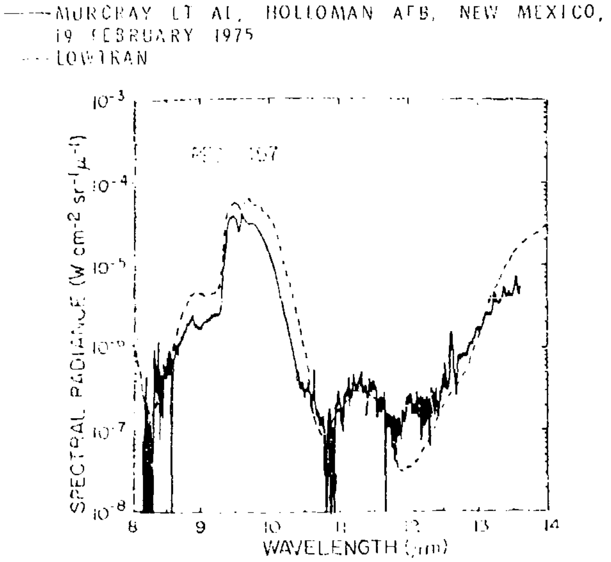

Figure F10. Sample Spectrum of Short Wavelength Region Observed at an Altitude of 24.0 km and a Zenith Angle of 63° on 19 February 1975, and LOWTRAN Comparison

References

F1. Selby, J.E.A., Kneizys, F.X., Chetwynd Jr., J.H., and McClatchey, R.A. (1978) Atmospheric Transmittance/Radiance: Computer Code LOWTRAN 4, AFGL-TR-78-0053, AD A058 643.

F2. Selby, J.E.A., Shettle, E.P., and McClatchey, R.A. (1976) Atmospheric Transmittance from 0.25 to 28.5 μm: Supplement LOWTRAN 3B, AFGL-TR-76-0258, AD A040 701.

F3. Selby, J.E.A., and McClatchey, R.A. (1975) Atmospheric Transmittance from 0.25 to 28.5 μm: Computer Code LOWTRAN 3, AFCRL-TR-75-0255, AD A017 734.

F4. Burch, D.E., Gryvnak, D., Singleton, E.B., France, W.L., and Williams, D. (1962) Infrared Absorption by Carbon Dioxide, Water Vapor, and Minor Atmospheric Constituents, AFCRL-62-698.

F5. Ashley, G.W., Gastineau, L., and Blay, D. (1973) Private Communication.

F6. Chaney, L.W. (1969) An Experimental Fourier Transform Asymmetrical Interferometer for Atmospheric Radiation Measurements, University of Michigan Technical Report 05863-18-T.

F7. Conrath, B.J., Hanel, R.A., Kunde, V.G., and Prabhakara, C. (1970) The Infrared Interferometer Experiment on Nimbus 3, Goddard Space Flight Center, Greenbelt, Maryland, Report X-620-70-213.

F8. Hanel, R.A., and Conrath, B.J. (1970) Thermal Emission Spectra of the Earth and Atmosphere Obtained from the Nimbus 4 Michelson Interferometer Experiment, Goddard Space Flight Center, Greenbelt, Maryland, Report X-620-70-244.

F9. Valley, S.D., Ed. (1965) Handbook of Geophysics and Space Environments, AFCRL.

F10. Murcray, D.G., Brooks, J.N., Goldman, A., Kosters, J.J., and Williams, W.J. (1977) Water Vapor Nitric Acid and Ozone Mixing Ratio Height Profiles Derived from Spectral Radiometric Measurements, University of Denver, Denver, Colorado 80208, Contract Report No. 332.

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