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Atmospheric Transmittance/Radiance: Computer Code LOWTRAN 4

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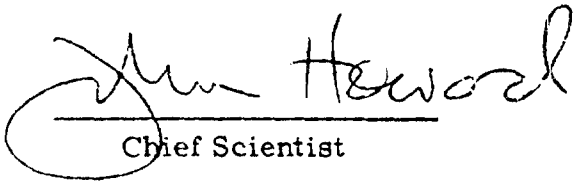

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This report describes a computer code for predicting atmospheric transmittance and the thermal radiation emitted by the atmosphere and earth in the wavelength range from 0.25 to 28.5 (μm) at a spectral resolution of 20 cm^{-1}. The program is based on the LOWTRAN 3B (1976) computer code and includes the same data package. The effect of aerosol radiance and nitric acid (HNO_3) transmittance and radiance is included. The computer code also contains six standard (geographical and seasonal) atmospheric models and four standard aerosol models with an option to replace either with non-standard or

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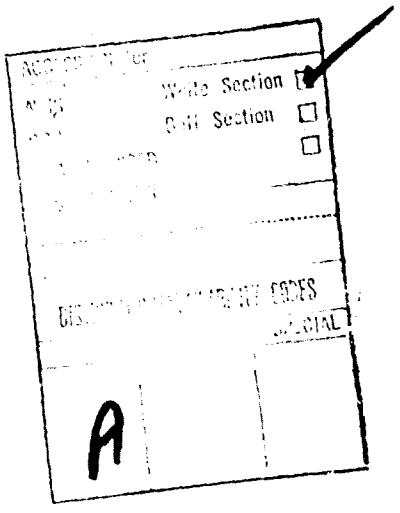
measured values. The program can be run in one of two modes, namely, to compute only atmospheric transmittance (as LOWTRAN 3B) or radiance and atmospheric transmittance for any given path geometry.



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1. INTRODUCTION

This report describes the development of a Fortran computer code LOWTRAN 4 designed to calculate atmospheric radiance and/or transmittance for a given atmospheric path at moderate spectral resolution. The present code is based on the current LOWTRAN atmospheric transmittance code, LOWTRAN 3B[1] (and its predecessors LOWTRAN 3,[2] LOWTRAN 2,[3] LOWTRAN 1[4]). All the capabilities of the LOWTRAN transmittance codes have been preserved in the conversion of the computer code to atmospheric radiance calculations. The LOWTRAN 4 program will perform either atmospheric transmittance or radiance calculations. The mode of the calculation is determined by a single input control parameter.

(Received for publication 27 February 1978)

1. 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.

2. 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.

3. 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.

4. Manley, O. P., Smith, H. J. P., Treve, Y. M., Carpenter, J. W., Degges, T. C., and Doan, L. R. (1971) OPTIR II, AFCRL-71-0528 (Vol. 2 & 3); (1973) OPTIR III, AFCRL-TR-73-0217 and 0491; and (1974) OPTIR IIIB, AFCRL-TR-74-0319.

Continuity with the LOWTRAN 3B transmittance code has been retained. Changes in the program required for radiance calculations have been minimized. Only two new subroutines have been added to the program. Although a new card sequencing has been established in the LOWTRAN 4 program, a comparison with the previous LOWTRAN 3B code has been provided (see Appendix A) to facilitate user conversion of this program to the radiance mode.

In this report, we will describe the changes made in the transmittance code. These include a discussion of the method used in the calculation of atmospheric radiance, the addition of HNO_3 as an atmospheric absorber, and the modification of the empirical transmittance functions for small absorber amounts. In addition, instructions for using LOWTRAN 4 are given in Section 6. A listing of the computer code and data is given in Appendix A (note data is the same as LOWTRAN 3B). A flow chart of the program is provided in Appendix B, and a definition of symbols in Appendix C. Sample output from the program is provided in Section 7. Examples of atmospheric radiance calculations from LOWTRAN 4 are presented in Section 8. Comparison with measurements are given in Section 9. Some comments on the program use are discussed in Section 10.

The latest errata sheet (September 1977) to the LOWTRAN 3B (1976) code has been reprinted in Appendix D. Users of the LOWTRAN 3B program should verify that the corrections listed in Appendix D have been made in their present codes and in the conversion of their codes to the radiance mode, as described in this report.

Users of the current LOWTRAN 3B transmittance code will find this report sufficient in itself for performing atmospheric radiance/transmittance calculations. For those unfamiliar with the LOWTRAN band model type calculations, more complete information is provided in the previous LOWTRAN[1-4] reports, as well as the Optical Properties of the Atmosphere Report.[5]

The computer code has been tested for atmospheric radiance calculations for various atmospheric paths. However, no attempt has been made at this time to optimize either the computer code or the execution time. If any discrepancies are encountered or problems occur in the use of the code, please notify F.X. Kneizys, AFGL/OPI, Hanscom AFB, MA 01731.

The LOWTRAN 4 card deck will be made available from the National Climatic Center, Federal Building, Asheville, NC 28801 for a charge of $20.00. (Please address requests to Mr. R. Davis.)

---

5. McClatchey, R.A., Fenn, R.W., Selby, J.E.A., Volz, F.E., and Garing, J.S. (1972) Optical Properties of the Atmosphere (Third Edition) AFCRL-72-0497.

2. ATMOSPHERIC RADIANCE

The LOWTRAN 3B transmittance program has been modified to calculate atmospheric and earth radiance. A numerical evaluation of the integral form of the equation of radiative transfer has been added to the program. The emission from aerosols and the treatment of aerosol and molecular scattering were considered only in the zeroth order. Additional contributions to atmospheric emission from radiation scattered one or more times has been neglected. Local thermodynamic equilibrium was assumed in the atmosphere.

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

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

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,

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

T_b = temperature of the boundary.

The emissivity of the boundary is assumed to be unity.

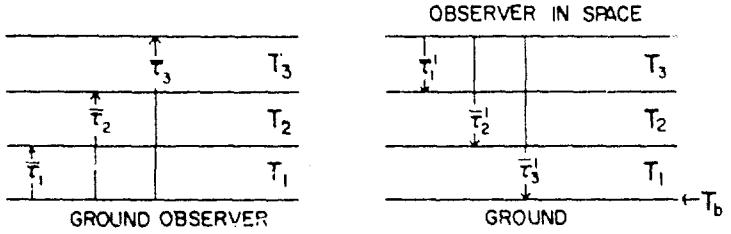
The LOWTRAN band model approach used here assumes that since the blackbody function is a slowly varying function of frequency we can represent the average value of the radiance in terms of the average values of the transmittance and the blackbody function. $\bar{\tau}_a$, $\bar{\tau}_s$, and $\bar{\tau}_t$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

The numerical analogue to Eq. (1) has been incorporated into the LOWTRAN 4 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

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

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. (1). 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 1. 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 1a). Figure 1b shows the corresponding case for an observer in space (distinguished by primed $\bar{\tau}$ values).



(a) (b)

Figure 1. Upward and Downward Atmospheric Radiance Through a Three-Layered Atmosphere

Then from Eq. (2) the total downward spectral radiance for an observer on the ground (looking upwards) is given by

$$I(\bar{\nu})\downarrow = (1-\bar{\tau}_1)B(\bar{\nu}, T_1) + (\bar{\tau}_1-\bar{\tau}_2)B(\bar{\nu}, T_2) + (\bar{\tau}_2-\bar{\tau}_3)B(\bar{\nu}, T_3) . \tag{3}$$

Similarly for an observer looking down from the top of the atmosphere (see Figure 1b), the total upward spectral radiance is given by

$$I(\bar{\nu})\uparrow = (1-\bar{\tau}_1')B(\bar{\nu}, T_3) + (\bar{\tau}_1'-\bar{\tau}_2')B(\bar{\nu}, T_2) + (\bar{\tau}_2'-\bar{\tau}_3')B(\bar{\nu}, T_1) + \bar{\tau}_3' B(\bar{\nu}, T_b). \tag{4}$$

A comparison of Eqs. (3) and (4) 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 4 radiance program, the position of the observer is always defined by the input parameter, H1 (see Section 6).

3. MODIFICATION OF TRANSMITTANCE FUNCTION

In the LOWTRAN 3/3B transmittance model,[1,2] the average transmittance $\bar{\tau}$ over a 20-cm^{-1} interval (due to molecular absorption) is represented by a single parameter model of the form

$$\bar{\tau} = f(C_\nu \omega^*) \tag{5}$$

where C_ν is a wavelength (or wavenumber) dependent absorption coefficient and ω^* is an "equivalent absorber amount" for the atmospheric path, which is defined in terms of the pressure P(z), temperature T(z), concentration of absorber ΔL, and an empirical constant n as follows

$$\omega^* = \Delta L \left\{ \frac{P(z)}{P_o} \sqrt{\frac{T_o}{T(z)}} \right\}^n . \tag{6}$$

If Eq. (6) is substituted in Eq. (5) and n is set to zero and unity, respectively, Eq. (5) 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. For sufficiently small values of the argument $C_\nu \omega^*$, the transmittance in LOWTRAN 3B and earlier models was set to unity.

Since the LOWTRAN 4 program now calculates radiance as well as transmittance, the transmittance functions, f, were modified for radiance calculations from atmospheric layers of small optical thickness. For cases where ($0.999 \leq \bar{\tau} \leq 1$) the transmittance functions now have the analytic form

$$\bar{\tau} = 1 - a(C_\nu \omega^*)^b \tag{7}$$

with a 0.033 and b 0.31 for H_2O and the uniformly mixed gases and a 0.055 and b 1.03 for ozone. This pseudo-linear approximation in Eq. (7) 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. (5).

4. NITRIC ACID

Measurements made from balloon flights[6], 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 LOWTRAN program as a separate atmospheric absorber.

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[7] by fitting their experimental results with the statistical band model approximation.

The concentration of atmospheric nitric acid varies with altitude and also appears to depend on latitude and season. Figure 2 shows the volume mixing ratio profile of atmospheric nitric acid as a function of altitude from the measurements of Evans, Kerr, and Wardle.[8] For the purpose of this report, we have chosen this profile to represent a mean nitric acid profile in the LOWTRAN program. This profile appears in a data statement in the main 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 main program.

The inclusion of nitric acid as an additional absorber will modify somewhat transmittances from those calculated with the LOWTRAN 3B (1976) code in the spectral regions described above. Differences in transmittance values will only be significant for long atmospheric limb paths passing through the peak of the nitric acid profile.

6. Murcray, D.G., Kyle, T.G., Murcray, F.H., and Williams, W.G. (1968) Nitric acid and nitric oxide in the lower stratosphere. Nature 218:78.

7. 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. 4:65.

8. 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.

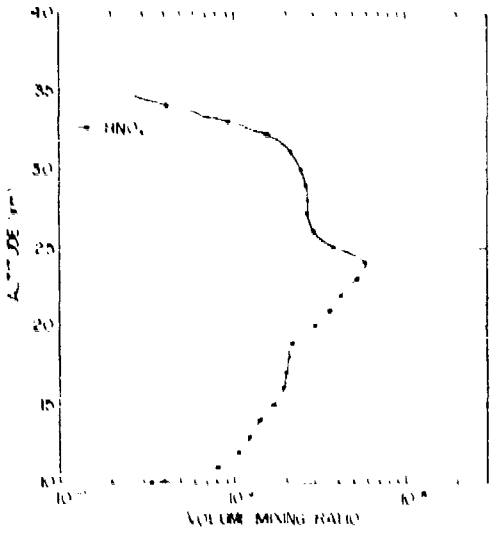


Figure 2. Volume Mixing Ratio of Atmospheric Nitric Acid as a Function of Altitude. See Reference 8

5. PROGRAM MODIFICATION

Program changes to the LOWTRAN 3/3B transmittance codes necessary for the conversion to a transmittance/radiance code were made in such a way as to preserve the logical flow in the original programs. Appendix A contains a listing of the FORTRAN computer code, LOWTRAN 4 together with the four subroutines, POINT, ANGLE, HNO3, and PATH. Although a new sequencing has been made in the code, the last column in the listing of Appendix A indicates the correspondence with the LOWTRAN 3B code. Changes in the code are indicated by the word, NEW, in the last column.

Two new subroutines have been added in the LOWTRAN 4 code. Subroutine PATH determines the cummulative absorber amounts through each of the layers intersected by the required atmospheric slant path. The amounts are stored in the matrix, WPATH, for each of the absorbing species. Subroutine HNO3 is called to find the nitric acid absorption coefficients as a function of frequency.

In the present program, a sample profile for the HNO_3 volume mixing ratio is provided in the data statement in the main program (DATA HMIX/..../). The altitudes of the mixing ratios correspond to those for the model atmosphere altitudes.

Only two new control parameters (IEMSCT, TRNEND) have been added to the program. These parameters, included on the first control card, will be fully explained in the instructions given in Section 6.

6. INSTRUCTIONS FOR USING LOWTRAN 4

The instructions for using LOWTRAN 4, with the exception of a change in a single control card, are essentially the same as those for the LOWTRAN 3, 3B transmittance codes. In an attempt to make the instructions as clear as possible and to provide sufficient information for utilization of the computer code in this report, Section 5 of the LOWTRAN 3[2] report has been repeated here in its entirety. Changes in the instructions required for radiance calculations are indicated by bars in the margins.

The input data for LOWTRAN 4 are given in Appendix A. In general, it is only necessary to change the last four cards (referred to here as No's. 1-4) in order to run the program for a given problem. The formats for the last four cards and their application will be discussed.

6.1 Input Data and Formats

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

CARD 1	MODEL, IHAZE, ITYPE, LEN, JP, IM, M1, M2, M3, ML, IEMISS, RO, TBOUND	FORMAT (11I3, 2F10.3)
CARD 2	H1, H2, ANGLE, RANGE, BETA, VIS	FORMAT (6F10.3)
CARD 3	V1, V2, DV	FORMAT (3F10.3)
CARD 4	IXY	FORMAT (I3)

Definitions of the above quantities will be discussed in Section 6.2.

If the quantity MODEL given in CARD 1 is set equal to 0 or 7 (which is the case if meteorological data are used input to the program), then the above card sequence (and format for CARD 2) is changed. These cases will be described in Section 6.3.

6.2 Basic Instructions

The various quantities to be specified on each of the four control cards (summarized in Section 6.1) will be discussed in this section.

CARD 1 MODTRN, IHAZE, ITYPE, LEN, IM, IMI, MI, M2, M3, MI, IEMISS, IRO, ITROUND

The parameter MODTRN selects one of the six geographical model atmospheres or specifies that meteorological data are to be used in place of the standard models. IHAZE specifies whether aerosol attenuation is to be included in the calculation or not. For any problem the atmospheric path must be specified as one of three types according to ITYPE and LEN. IEMISS and ITROUND are new control parameters for radiance calculations. The rest of the quantities given on CARD 1 (which can be left blank if not required) provide the user with options to suppress printing (IM), to intermix the six standard model atmospheres (MI, M2, M3) and to input a new model atmosphere (IMI, MI). The options for the above parameters and their uses are stated and described in detail below:

MODTRN = 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.

IHAZE = 0 means no aerosol attenuation included in the calculations.

IHAZE = 1 or 2 if aerosol attenuation is required (see also CARD 2).

If IHAZE is set equal to 1 or 2 and visual range (VIS) is not specified on CARD 2, then the program will automatically select visual ranges of 23 km or 5 km respectively.

IHAZE = 7 Read other aerosol model into the program.

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.

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† In these cases the format for Card 2 changes (see nonstandard conditions) Section 6.3.

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.

LEN = 0 for normal operation of program.

LEN = 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

JP = 1 to suppress printing of transmittance table/or radiance table

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

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

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 integral values between 0 and 6 and are used to modify or supplement the altitude profiles of temperature, water vapor, and ozone respectively, for any given atmospheric model specified by MODEL. For example:

M1 = 1 selects the TROPICAL temperature altitude profile

M1 = 2 selects the MIDLATITUDE SUMMER temperature altitude profile

M1 = 6 selects the 1962 U.S. STANDARD temperature altitude profile

M2 = 1 selects the TROPICAL water vapor altitude profile

M2 = 2 selects the MIDLATITUDE SUMMER water vapor altitude profile

M2 = 6 selects the 1962 U.S. STANDARD water vapor altitude profile

M3 = 1 selects the TROPICAL ozone altitude profile

M3 = 2 selects the MIDLATITUDE SUMMER ozone altitude profile

M3 = 6 selects the 1962 U.S. STANDARD ozone altitude profile.

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

IEMISS = 0 for program execution in transmittance mode

IEMISS = 1 for program execution in radiance mode.

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

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 mid-latitude 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 (°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.

In the case where MODTRN = 7, the new atmosphere (model or radiosonde data) is inserted between CARDS 1 and 2 (see Section 6.3).

CARD 2 H1, H2, ANGLE, RANGE, BETA, VIS

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 (IEMSS = 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)

VIS = sea level visual range (km).

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 and VIS only

(b) If nonstandard meteorological data are to be used, that is, if MODEL = 0 on CARD 1, then the following parameters must be specified on CARD 2: H1, P, T, DP, RH, WH, WO, VIS, RANGE according to FORMAT (3F10.3, 2F5.1, 2F10.3, 2F10.3), where P, T, DP, RH, WH, and WO are the pressure (mb), temperature (°C), dew point temperature (°C), relative humidity (%), H_2O density (gm m^{-3}) and ozone density (gm m^{-3}) respectively.

Note that it is necessary to specify all of the quantities underlined with a full line and one of the quantities underlined with a dashed line. If the ozone density (WO) is not known, a value can be chosen from one of the standard atmospheric models by using the parameter M3 on CARD 1.

(2) Slant Paths to Space (ITYPE 3)

(a) specify H1, ANGLE and VIS

(b) specify H1, HMIN and VIS (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 and VIS

(b) specify H1, ANGLE, RANGE and VIS

(c) specify H1, H2, RANGE and VIS

For cases (b) and (c), the program will calculate H2 and ANGLE respectively, assumming 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 and VIS. 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.

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.)

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.

6.3 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 reader 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 the latter. 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.

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

Z, P, T, DP, RH, WH, WO, AHAZE [FORMAT (3F10.3, 2F5.1, 2F10.3, 2F10.3)] where

Z	=	altitude (km)
P		pressure (mb)
T		ambient temperature (°C)
DP		dew point temperature (°C)
RH		relative humidity (%)
WH		water vapor density (gm m^{-3})
WO		ozone density (gm m^{-3})
AHAZE		aerosol number density (cm^{-3})

Note that it is only necessary to specify those quantities underlined with a full line and either 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.

If the aerosol number density was not measured as a function of altitude and the reader wishes to include aerosol attenuation in the calculation, set IHAZE = 1 on CARD 1. In this case (as with the M1, M2, and M3 options) LOWTRAN will use the aerosol models already contained in the program and interpolate to give aerosol number density values at the same altitudes as the radiosonde (or new model atmosphere) data. The program will then look for a sea level visual range (VIS) to be specified on CARD 2. If VIS is not specified, a 23 km sea level visual range will be assumed. If aerosol attenuation is not required, set IHAZE = 0 on CARD 1 as before.

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, VIS, RANGE [FORMAT (3, F10.3, 2F5.1, 2F10.3, 2F10.3)] 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}), visual range (km) 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.

7. EXAMPLE OF PROGRAM USE

7.1 Problem

Calculate the transmittance from 2350 to 2450 cm^{-1} in steps of 5 cm^{-1} for a slant path from 2.5 km to 8.5 km at a zenith angle of 65°, for a subarctic winter model atmosphere, and a 23 km visual range. Repeat the calculation for the same conditions executing the program in the radiance mode.

CARD 1 ␣␣5␣␣1␣␣2

CARD 2 ␣␣␣␣␣␣2.50␣␣␣␣␣␣8.50␣␣␣␣␣␣65.0

CARD 3 ␣␣␣␣2350.0␣␣␣␣2450.0␣␣␣␣␣␣5.0

CARD 4 ␣␣␣4

CARD 5 ␣␣5␣␣1␣␣2␣␣␣␣␣␣␣␣␣␣␣␣␣␣␣␣␣␣␣␣␣1 (column 33)

CARD 6 BLANK

(␣ represents a space on the card)

7.2 Output from LOWTRAN 4

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

The parameters defining the atmospheric path, model atmospheres and frequency range are next printed out. Following the heading HORIZONTAL PROFILES there are 13 columns. The first column gives a running integer associated with each level (level indicator). The second column gives the level altitude in km. The next 8 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), molecular scattering, aerosol extinction[1] and UV ozone, respectively. The next three columns give the mean refractive index modulus from that level to the level above, the equivalent absorber amounts per km for the water vapor continuum (4 μm) and for nitric acid.

A heading VERTICAL PROFILES is then printed followed by 15 columns. The first and second columns give the integer associated with the levels traversed by the path and the height of the level. Then follow 8 columns which give the integrated equivalent absorber amounts from the initial altitude to the level above (in the same order as indicated above). The next 4 columns are labelled PSI, PHI, BETA, and THETA, and correspond to the angles similar to ψ, ϕ, β, and θ described in LOWTRAN 3.[2] 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 θ_1 corresponding to that level and the angle of arrival at the level above, respectively. The accumulated slant range is printed out in the last column under RANGE.

The total equivalent absorber amounts for each absorber species are then summarized below in their appropriate units.

The second line in the total equivalent absorber amount table gives the water vapor continuum amount (4 μm) and the nitric acid amount.

A transmittance table, containing 12 columns, now follows. The first 3 columns give the frequency (cm^{-1}) wavelength (μm), and total transmittance. The next 7 columns show the individual transmittance due to water vapor, uniformly mixed gases, ozone, nitrogen (4 μm) continuum, total water vapor continuum, molecular scattering, and aerosol extinction. The last 2 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. Finally, the total integrated absorption from V1 to V2 is printed out (units are cm^{-1}) together with the average transmittance over the band.

---

[1] For all radiance calculations in this report, the average continental aerosol model was used.

Table 1. Typical Output of LOWTRAN 4

```
PROGRAM WILL BE EXECUTED IN THE TRANSMISSION MODE
 5  1  2  0  0  2  0  0  0  0  4        0.000      0.000
          2.500       8.500      65.000       0.000       0.000       0.000
     H1=  2.500KM,H2=  8.500KM,ANGLE= 65.0000GEOM. RANGE =  14.17KM,BETA=  .11557,VIS=   0.0
2350.000  2450.000      5.000

        SLANT PATH BETWEEN ALTITUDES H1 AND H2 WHERE H1 =  2.500 KM H2 =  8.500 KM,ZENITH ANGLE = 65.000 DEGREES

                MODEL ATMOSPHERE 5 = SUB-ARCTIC WINTER

                   HAZE MODEL 1 = 23 KM VISUAL RANGE

        FREQUENCY RANGE V1=  2350.0 CM-1 TO V2=  2450.0 CM-1 FOR DV =   5.0 CM-1   (  4.08 -  4.26 MICRONS )


        HORIZONTAL PROFILES

   1    0.0  .123E+00  .109E+01  .194E-02  .876E+00  .663E-03  .106E+01  .100E+01  .191E-02  .285E-03  .290E-01 0.
   2    1.0  .109E+00  .854E+00  .183E-02  .665E+00  .614E-03  .924E+00  .443E+00  .191E-02  .254E-03  .244E-01 0.
   3    2.0  .763E-01  .668E+00  .174E-02  .520E+00  .411E-03  .819E+00  .198E+00  .191E-02  .222E-03  .173E-01 0.
   4    3.0  .492E-01  .554E+00  .174E-02  .405E+00  .242E-03  .725E+00  .798E-01  .201E-02  .197E-03  .121E-01 0.
   5    4.0  .265E-01  .448E+00  .173E-02  .314E+00  .110E-03  .646E+00  .422E-01  .210E-02  .176E-03  .705E-02 0.
   6    5.0  .115E-01  .365E+00  .172E-02  .250E+00  .380E-04  .577E+00  .319E-01  .219E-02  .157E-03  .348E-02 0.
   7    6.0  .503E-02  .295E+00  .170E-02  .195E+00  .138E-04  .515E+00  .224E-01  .229E-02  .140E-03  .173E-02 0.
   8    7.0  .246E-02  .237E+00  .234E-02  .152E+00  .601E-05  .457E+00  .208E-01  .331E-02  .124E-03  .979E-03 0.
   9    8.0  .442E-03  .189E+00  .280E-02  .118E+00  .416E-06  .404E+00  .215E-01  .420E-02  .109E-03  .606E-03  .404E-04
  10    9.0  .295E-03  .147E+00  .469E-02  .890E-01  .833E-06  .351E+00  .206E-01  .747E-02  .936E-04  .147E-01  .351E-05
  11   10.0  .168E-03  .112E+00  .661E-02  .643E-01  .290E-06  .300E+00  .201E-01  .112E-01  .803E-04  .824E-04  .991E-05
  12   11.0  .101E-03  .849E-01  .828E-02  .470E-01  .168E-06  .257E+00  .188E-01  .149E-01  .684E-04  .467E-04  .259E-04
  13   12.0  .598E-04  .645E-01  .104E-01  .343E-01  .967E-07  .219E+00  .197E-01  .201E-01  .584E-04  .284E-04  .650E-04
  14   13.0  .360E-04  .490E-01  .107E-01  .251E-01  .566E-07  .187E+00  .182E-01  .219E-01  .500E-04  .168E-04  .262E-04
  15   14.0  .174E-04  .373E-01  .105E-01  .183E-01  .364E-07  .160E+00  .179E-01  .229E-01  .427E-04  .600E-05  .256E-04
  16   15.0  .115E-04  .283E-01  .113E-01  .134E-01  .171E-07  .137E+00  .166E-01  .251E-01  .365E-04  .519E-05  .249E-04
  17   16.0  .839E-05  .216E-01  .117E-01  .982E-02  .123E-07  .117E+00  .160E-01  .289E-01  .313E-04  .360E-05  .223E-04
  18   17.0  .638E-05  .165E-01  .110E-01  .720E-02  .920E-08  .101E+00  .158E-01  .289E-01  .268E-04  .269E-05  .201E-04
  19   18.0  .495E-05  .125E-01  .103E-01  .527E-02  .703E-08  .862E-01  .153E-01  .289E-01  .230E-04  .205E-05  .181E-04
  20   19.0  .421E-05  .954E-02  .941E-02  .386E-02  .592E-08  .738E-01  .128E-01  .281E-01  .197E-04  .191E-05  .174E-04
  21   20.0  .336E-05  .726E-02  .824E-02  .282E-02  .466E-08  .631E-01  .843E-02  .261E-01  .169E-04  .193E-05  .169E-04
  22   21.0  .330E-05  .551E-02  .705E-02  .206E-02  .457E-08  .540E-01  .684E-02  .236E-01  .144E-04  .150E-05  .200E-04
  23   22.0  .286E-05  .419E-02  .610E-02  .151E-02  .394E-08  .462E-01  .514E-02  .219E-01  .123E-04  .130E-05  .194E-04
  24   23.0  .263E-05  .316E-02  .524E-02  .110E-02  .362E-08  .395E-01  .394E-02  .201E-01  .105E-04  .126E-05  .206E-04
  25   24.0  .253E-05  .241E-02  .412E-02  .801E-03  .353E-08  .337E-01  .312E-02  .168E-01  .898E-05  .119E-05  .202E-04
  26   25.0  .245E-05  .183E-02  .343E-02  .584E-03  .348E-08  .288E-01  .263E-02  .149E-01  .597E-05  .112E-05  .164E-04
  27   30.0  .638E-06  .442E-03  .117E-02  .115E-03  .846E-09  .127E-01  .791E-03  .700E-02  .269E-05  .236E-06  .331E-05
  28   35.0  .959E-07  .110E-03  .522E-03  .235E-04  .111E-09  .570E-02  .208E-03  .429E-02  .113E-05  .274E-07  .126E-05
  29   40.0  .188E-07  .278E-04  .171E-03  .492E-05  .210E-10  .258E-02  .548E-04  .191E-02  .543E-06  .376E-08  .250E-06
  30   45.0  .432E-08  .761E-05  .406E-04  .112E-05  .431E-11  .122E-02  .144E-04  .807E-03  .262E-06  .619E-09 0.
  31   50.0  .769E-09  .222E-05  .102E-04  .276E-06  .722E-12  .595E-03  .381E-05  .201E-03  .910E-07  .814E-10 0.
  32   70.0  .160E-11  .229E-07  .711E-07  .147E-08  .112E-14  .441E-04  .196E-07  .401E-05  .539E-08  .259E-12 0.
  33  100.0  .150E-15  .540E-11  .518E-11  .104E-12  .104E-19  .385E-06  .696E-11  .201E-06  .553E-10  .230E-16 0.
  34******* 0.        0.        0.        0.        0.        0.        0.        0.        0.        0.       0.

FROM POINT1 HEIGHT=    2.5000 KM,N=  3,NP=  0,REF. INDEX ABOVE & BELOW X=  .2150E-03  .2284E-03,IP=  1
        EQUIV. ABSORBER AMOUNTS PER KM AT X=  .613E-01  .617E+00  .174E-02  .459E+00  .316E-03  .771E+00  .123E+00  .196E-02

FROM POINT1 HEIGHT=    8.5000 KM,N=  9,NP=  0,REF. INDEX ABOVE & BELOW X=  .1046E-03  .1122E-03,IP=  1
        EQUIV. ABSORBER AMOUNTS PER KM AT X=  .361E-03  .167E+00  .363E-02  .102E+00  .659E-06  .377E+00  .210E-01  .556E-02
```

Table 1. Typical Output of LOWTRAN 4 (Cont)

	VERTICAL PROFILES								PSI	PHI	BETA	THETA	RANGE
3	2.5	.651E-01	.692E+00	.206E-02	.510E+01	.328E-03	.895E+05	.1128E+00	.235E-02	-.0006	115.0697	.0017	66.0000	1.2
4	3.0	.152E+00	.187E+01	.616E-02	.136E+01	.724E-03	.250E+01	.258E+00	.720E-02	.0022	115.0268	.0090	66.9965	2.6
5	4.5	.194E+00	.283E+01	.102E-01	.203E+01	.884E-03	.395E+01	.344E+00	.123E-01	.0044	115.0434	.0062	66.9758	5.4
6	5.5	.213E+00	.561E+01	.143E-01	.255E+01	.941E-03	.524E+01	.408E+00	.176E-01	.0071	115.0604	.0075	66.9509	8.3
7	6.0	.221E+00	.423E+01	.190E-01	.296E+01	.963E-03	.638E+01	.459E+00	.241E-01	.0092	115.0775	.0068	66.9417	10.5
8	7.0	.224E+00	.473E+01	.250E-01	.328E+01	.969E-03	.740E+01	.509E+00	.329E-01	.0112	115.0948	.0151	66.9266	12.1
9	8.0	.224E+00	.494E+01	.288E-01	.341E+01	.970E-03	.786E+01	.534E+00	.387E-01	.0126	115.1036	.0156	66.9188	13.2

EQUIVALENT SEA LEVEL ABSORBER AMOUNTS

	WATER VAPOUR CM CM-2	CO2 ETC. KM	OZONE ATM CM	NITROGEN (CONT) KM	H2O (CONT) CM CM-2	MOL SCAT KM	AEROSOL KM	OZONE(U-V) ATM CM NITRIC ACID
MDL=8.=	.224E+00	.494E+01	.288E-01	.341E+01	.970E-03 .833E-01	.786E+01	.534E+00	.387E-01 .249E-01

FREQ CM-1	WAVELENGTH MICRONS	TOTAL TRANS	H2O TRANS	CO2* TRANS	OZONE TRANS	N2 CONT TRANS	H2O CONT TRANS	MOL SCAT TRANS	AEROSOL TRANS	AEROSOL ABS	INTEGRATED ABSORPTION
2350	4.2553	0.0000	.9969	0.0000	1.0000	.6576	1.0000	1.0000	.9967	.0033	2.5000
2355	4.2462	0.0000	.9970	0.0000	1.0000	.6666	.9988	1.0000	.9967	.0033	7.5000
2360	4.2373	0.0000	.9971	0.0000	1.0000	.6735	.9976	1.0000	.9967	.0033	12.5000
2365	4.2283	0.0000	.9974	0.0000	1.0000	.6781	.9955	1.0000	.9967	.0033	17.5000
2370	4.2194	0.0000	.9977	0.0000	1.0000	.6827	.9955	1.0000	.9967	.0033	22.5000
2375	4.2105	0.0000	.9976	0.0000	1.0000	.6827	.9944	1.0000	.9967	.0033	27.5000
2380	4.2017	.0015	.9981	.0022	1.0000	.6856	.9933	1.0000	.9967	.0033	32.4927
2385	4.1929	.0277	.9984	.0413	1.0000	.6856	.9921	1.0000	.9966	.0034	37.3584
2390	4.1841	.1111	.9988	.1653	1.0000	.6827	.9910	1.0000	.9966	.0034	42.2954
2395	4.1754	.2567	.9990	.3864	1.0000	.6781	.9899	1.0000	.9966	.0034	47.2019
2400	4.1667	.4559	.9991	.6847	1.0000	.6804	.9888	1.0000	.9965	.0035	52.0763
2405	4.1580	.6867	.9993	.8775	1.0000	.6827	.9890	1.0000	.9965	.0035	56.9165
2410	4.1494	.8656	.9995	.9851	1.0000	.6827	.9883	1.0000	.9964	.0036	61.7211
2415	4.1408	.9763	.9996	.9949	1.0000	.6945	.9895	1.0000	.9964	.0036	66.4884
2420	4.1322	.9966	.9996	.9988	1.0000	.7054	.9898	1.0000	.9963	.0037	71.2167
2425	4.1237	.9996	.9996	.9998	1.0000	.7236	.9904	1.0000	.9963	.0037	75.9044
2430	4.1152	.9961	.9996	.9813	1.0000	.7234	.9896	1.0000	.9962	.0038	80.5499
2435	4.1068	.7529	.9997	.9740	1.0000	.7359	.9905	1.0000	.9962	.0038	85.1516
2440	4.0984	.7080	.9998	.9630	1.0000	.7447	.9907	1.0000	.9962	.0038	89.7081
2445	4.0900	.7170	.9998	.9662	1.0000	.7562	.9909	1.0000	.9962	.0038	94.2182
2450	4.0816	.7295	.9998	.9845	1.0000	.7735	.9912	1.0000	.9962	.0038	98.6805

INTEGRATED ABSORPTION FROM 2350 TO 2450 CM-1 = 83.26, AVERAGE TRANSMITTANCE = .3674

Table 1. Typical Output of LOWTRAN 4 (Cont)

```
PROGRAM WILL BE EXECUTED IN THE EMISSION MODE
5 1 2 0 0 3 3 0 0 0 1      0.000      0.000

      SLANT PATH BETWEEN ALTITUDES H1 AND H2 WHERE H1 =  2.500 KM H2 =  8.500 KM,ZENITH ANGLE = 65.000 DEGREES

            MODEL ATMOSPHERE 5 = SUB-ARCTIC WINTER

               HAZE MODEL 1 = 23 KM VISUAL RANGE

      FREQUENCY RANGE V1=  2350.0 CM-1 TO V2=  2450.0 CM-1 FOR DV =   5.0 CM-1    ( 4.08 -  4.26 MICRONS )
```

HORIZONTAL PROFILES

1	0.0	.123E+00	.109E+01	.194E-02	.874E+00	.663E-03	.104E+01	.100E+01	.191E-02	.285E-03	.293E-01	0.
2	1.0	.103E+00	.854E+00	.183E-02	.665E+00	.614E-03	.924E+00	.440E+00	.191E-02	.250E-03	.244E-01	0.
3	2.0	.763E-01	.666E+00	.174E-02	.520E+00	.411E-03	.819E+00	.190E+00	.191E-02	.222E-03	.173E-01	0.
4	3.0	.492E-01	.554E+00	.174E-02	.405E+00	.242E-03	.725E+00	.798E-01	.201E-02	.197E-03	.121E-01	0.
5	4.0	.265E-01	.446E+00	.173E-02	.318E+00	.110E-03	.646E+00	.422E-01	.210E-02	.175E-03	.745E-02	0.
6	5.0	.115E-01	.365E+00	.172E-02	.250E+00	.380E-04	.577E+00	.318E-01	.219E-02	.157E-03	.346E-02	0.
7	6.0	.553E-02	.295E+00	.170E-02	.196E+00	.138E-04	.515E+00	.224E-01	.229E-02	.140E-03	.173E-02	0.
8	7.0	.246E-02	.237E+00	.234E-02	.152E+00	.601E-05	.457E+00	.206E-01	.331E-02	.124E-03	.473E-03	0.
9	8.0	.442E-03	.189E+00	.280E-02	.118E+00	.316E-05	.404E+00	.215E-01	.420E-02	[illegible]	.2[illegible]5E-03	.404E-04
10	9.0	.295E-03	.147E+00	.469E-02	.885E-01	.637E-06	.351E+00	.206E-01	.747E-02	.436E-04	.147E-03	.351E-04
11	10.0	.168E-03	.112E+01	.551E-02	.647E-01	.290E-06	.301E+00	.201E-01	.112E-01	[illegible]	[illegible]	.991E-04
12	11.0	.101E-03	.849E-01	.828E-02	.471E-01	.168E-06	.257E+00	.158E-01	.149E-01	[illegible]	.457E-04	.285E-04
13	12.0	.598E-04	.645E-01	.104E-01	.343E-01	.467E-07	.219E+00	.197E-01	.201E-01	.554E-04	[illegible]	.253E-04
14	13.0	.360E-04	.490E-01	.107E-01	.251E-01	.566E-07	.187E+00	.182E-01	.219E-01	[illegible]	.166E-04	[illegible]
15	14.0	.174E-04	.373E-01	.105E-01	.183E-01	.264E-07	[illegible]	.179E-01	.229E-01	.427E-04	[illegible]	.295E-04
16	15.0	.115E-04	.283E-01	.113E-01	.134E-01	.171E-07	.137E+00	.165E-01	.261E-01	.365E-04	.519E-05	[illegible]
17	16.0	.839E-05	.216E-01	.117E-01	.982E-02	.123E-07	.117E+00	.161E-01	.284E-01	.323E-04	.784E-05	.223E-04
18	17.0	.638E-05	.165E-01	.110E-01	.720E-02	.920E-08	.101E+00	.156E-01	.269E-01	.268E-04	[illegible]	[illegible]
19	18.0	.495E-05	.125E-01	.103E-01	.527E-02	.703E-08	.862E-01	.153E-01	[illegible]	[illegible]	.225E-05	[illegible]
20	19.0	.421E-05	.954E-02	.941E-02	.386E-02	.592E-08	.778E-01	.126E-01	[illegible]	.157E-04	.131E-05	.170E-04
21	20.0	.336E-05	.726E-02	.824E-02	.282E-02	.466E-08	.671E-01	.943E-02	.261E-01	[illegible]	.153E-05	[illegible]
22	21.0	.330E-05	.551E-02	.705E-02	.204E-02	.457E-08	.540E-01	.664E-02	.233E-01	.144E-04	.150E-05	.230E-04
23	22.0	.285E-05	.419E-02	.610E-02	.151E-02	.194E-08	.462E-01	.514E-02	.219E-01	[illegible]	.130E-05	[illegible]
24	23.0	.263E-05	.318E-02	.524E-02	.113E-02	.362E-08	.395E-01	.394E-02	.201E-01	.125E-04	[illegible]	[illegible]
25	24.0	.253E-05	.241E-02	.412E-02	.811E-03	.153E-08	.327E-01	.312E-02	.168E-01	.599E-05	.125E-05	.232E-04
26	25.0	.245E-05	.183E-02	.343E-02	.554E-03	.745E-08	.288E-01	.263E-02	.149E-01	.557E-05	.112E-05	.104E-04
27	30.0	.638E-06	.442E-03	.117E-02	.115E-03	.546E-09	.127E-01	.791E-03	.760E-02	.265E-05	[illegible]	.331E-05
28	35.0	.359E-07	.110E-03	.922E-03	.275E-04	.111E-09	.572E-02	[illegible]	.429E-02	.113E-05	.279E-07	.128E-06
29	40.0	.138E-07	.278E-04	.171E-03	.492E-05	.203E-10	.255E-02	.544E-04	.191E-02	.545E-06	.776E-08	.255E-06
30	45.0	.432E-08	.761E-05	.406E-04	.112E-05	.431E-11	.122E-02	.144E-04	.607E-03	.260E-06	.613E-09	0.
31	50.0	.759E-09	.222E-05	.107E-04	.275E-06	.722E-12	.595E-03	.381E-05	.201E-03	.918E-07	.814E-11	0.
32	70.0	.160E-11	.229E-07	.711E-07	.147E-08	.112E-14	.441E-04	.135E-07	.401E-05	.673E-09	.164E-12	0.
33	100.0	.150E-15	.540E-11	.516E-11	.134E-12	.534E-19	.365E-05	.696E-11	[illegible]	.553E-10	[illegible]	0.
34	******	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

```
FROM POINT: HEIGHT=    2.5000 KM,N=  3,NP= 3,REF. INDEX ABOVE & BELOW X=  .2150E-03  .2284E-03,IP=  1
      EQUIV. ABSORBER AMOUNTS PER KM AT X=  .613E-01  .617E+00  .174E-02  .450E+00  .316E-03  .771E+00  .123E+00  .196E-02

FROM POINT: HEIGHT=    8.5000 KM,N=  9,NP= 3,REF. INDEX ABOVE & BELOW X=  .1046E-03  .1122E-03,IP=  1
      EQUIV. ABSORBER AMOUNTS PER KM AT X=  .361E-03  .167E+00  .363E-02  .102E+00  .659E-06  .377E+00  .210E-01  .560E-02
```

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Table 1. Typical Output of LOWTRAN 4 (Cont)

VERTICAL PROFILES

										PSI	PHI	BETA	THETA	RANGE
3	2.5	.651E-31	.692E+00	.206E-02	.510E+31	.328E-03	.885E+00	.118E+00	.235E-02	-.0000	115.0197	.0397	85.0000	1.2
4	3.0	.152E+00	.187E+01	.616E-02	.136E+31	.724E-03	.250E+01	.258E+00	.720E-02	.0032	115.0268	.0234	84.9926	3.6
5	4.0	.194E+00	.283E+01	.102E-01	.203E+01	.884E-03	.395E+01	.344E+00	.123E-01	.0048	115.0434	.0432	84.9798	5.9
6	5.0	.213E+00	.361E+01	.143E-01	.255E+31	.941E-03	.524E+01	.428E+00	.176E-01	.0071	115.0600	.0675	84.9689	8.3
7	6.0	.221E+00	.423E+01	.190E-01	.296E+31	.963E-03	.638E+01	.459E+00	.241E-01	.0092	115.0775	.0868	84.9617	10.5
8	7.0	.224E+00	.473E+01	.253E-01	.328E+01	.969E-03	.740E+01	.509E+00	.329E-01	.0112	115.0948	.1060	84.9564	12.8
9	8.0	.224E+00	.494E+01	.288E-01	.341E+01	.970E-03	.786E+01	.534E+00	.387E-01	.0126	115.1030	.1166	84.9550	14.2

EQUIVALENT SEA LEVEL ABSORBER AMOUNTS

	WATER VAPOUR GM CM-2	CO2 ETC. KM	OZONE ATM CM	NITROGEN (CONT) KM	H2O (CONT) GM CM-2	MOL SCAT KM	AEROSOL KM	OZONE(U-V) ATM CM NITRIC ACID
W(1-8)=	.224E+00	.494E+01	.288E-01	.341E+01	.970E-03 .602E-01	.786E+01	.534E+00	.387E-01 .249E-31

3 8

CUMULATIVE ABSORBER AMOUNTS FOR THE ATMOSPHERIC PATH

	H2O	CO2*	O3	N2	H2O C	MOL S	AERO	O3 UV	H2O C		HNO3	TAVE
1	.651E-31	.692E+00	.206E-02	.510E+00	.328E-03	.885E+00	.118E+00	.235E-02	.158E-01	0.		254.300
2	.152E+00	.187E+01	.616E-02	.136E+01	.724E-03	.250E+01	.258E+00	.720E-02	.378E-01	0.		251.200
3	.194E+00	.283E+01	.102E-01	.203E+01	.884E-03	.395E+01	.344E+00	.123E-01	.488E-01	0.		244.300
4	.213E+00	.361E+01	.143E-01	.255E+01	.941E-03	.524E+01	.428E+00	.176E-01	.557E-01	0.		237.500
5	.221E+00	.423E+01	.190E-01	.296E+01	.963E-03	.638E+01	.459E+00	.241E-01	.588E-01	0.		230.700
6	.224E+00	.473E+01	.253E-01	.328E+01	.969E-03	.740E+01	.509E+00	.329E-01	.600E-01	0.		223.850
7	.224E+00	.494E+01	.288E-01	.341E+01	.970E-03	.786E+01	.534E+00	.387E-01	.602E-01		.249E-31	216.900

RADIANCE(WATTS/CM2-SR-MICRON)

FREQ(CM-1)	WVL(MICRON)	PER CM-1	PER MICRON	INTEGRAL	TRANS
2350.0	4.255319	.25963E-07	.14338E-04	.64907E-07	0.000000
2355.0	4.246285	.25400E-07	.14087E-04	.19191E-06	0.000001
2360.0	4.237288	.24849E-07	.13840E-04	.31615E-06	0.000001
2365.0	4.228333	.24310E-07	.13597E-04	.43770E-06	0.000001
2370.0	4.219409	.23779E-07	.13351E-04	.55655E-06	0.000000
2375.0	4.210526	.23159E-07	.13063E-04	.67235E-06	0.000000
2380.0	4.201681	.21955E-07	.12442E-04	.78217E-06	.001453
2385.0	4.192872	.19453E-07	.11066E-04	.87944E-06	.027733
2390.0	4.184100	.16113E-07	.92040E-05	.96000E-06	.111738
2395.0	4.175365	.12103E-07	.69424E-05	.10205E-05	.256694
2400.0	4.166667	.77927E-08	.44866E-05	.10595E-05	.455931
2405.0	4.158004	.53029E-08	.30672E-05	.10860E-05	.589[illegible]4
2410.0	4.149378	.39715E-08	.23067E-05	.11059E-05	.666477
2415.0	4.140787	.37388E-08	.21806E-05	.11246E-05	.676333
2420.0	4.132231	.35305E-08	.20676E-05	.11422E-05	.686569
2425.0	4.123711	.34011E-08	.20000E-05	.11592E-05	.690779
2430.0	4.115226	.32756E-08	.19342E-05	.11756E-05	.696025
2435.0	4.106776	.31329E-08	.18575E-05	.11913E-05	.702917
2440.0	4.098361	.30144E-08	.17947E-05	.12063E-05	.707968
2445.0	4.089980	.28492E-08	.17033E-05	.12206E-05	.717006
2450.0	4.081633	.26555E-08	.15940E-05	.12272E-05	.729462

RADMIN 2450.000 .26555E-08
RADMAX 2350.000 .25963E-07
INTEGRATED ABSORPTION FROM 2350 TO 2450 CM-1 = 83.26,AVERAGE TRANSMITTANCE = .3674
INTEGRATED RADIANCE = .12272E-05WATT CM -2 SR
8

The second case is now executed for the same conditions in the radiance mode. The output of the program is identical to the transmittance mode up to and including the printing of the equivalent sea level absorber amounts.

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 12 columns. The first column gives an integer associated with the layer traversal by the atmospheric slant path. The following 10 columns which 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, UV ozone, water vapor continuum (4 μm) and nitric acid. The last column is the average temperature of the layer.

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.

8. EXAMPLES OF RADIANCE SPECTRA

Some examples of radiance spectra obtained from LOWTRAN 4 are presented in Figures 3 through 9. Figures 3 and 4 show the atmospheric radiance as seen by an observer at the ground looking straight up to space (H1=0 km, zenith ANGLE=0°) for the six model atmospheres with a 23 km visual range. Figure 3 is for the spectral region from 400 to 2000 cm^{-1} a Figure 4 for the spectral region from 2000 to 3600 cm^{-1}.

Figures 5 and 6 show the atmospheric radiance as seen by an observer in space looking straight down to the ground (H1 = 100 km, zenith ANGL =180°) for the six model atmospheres with a 23 km visual range. The temperature of the ground for these plots is the appropriate boundary temperature of the first layer in the model atmosphere. Figure 5 is for the spectral region from 400 to 2000 cm^{-1} and Figure 6 for the spectral region from 2000 to 3600 cm^{-1}.

Figures 7 through 9 show atmospheric radiance spectra from 400 to 4000 cm^{-1} calculated using the U.S. Standard Atmosphere, 1962, with a 23 km visual range for three different types of atmospheric paths. Figure 7 shows the zenith radiance for an observer at altitudes of 0, 20, and 40 km. Figure 8 shows the atmospheric

radiance at a zenith angle of 45° as seen by an observer at altitudes of 0, 20, and 40 km. Figure 3 shows the comparisons of the limb radiance as seen from space for tangent heights of 0, 20, and 40 km.

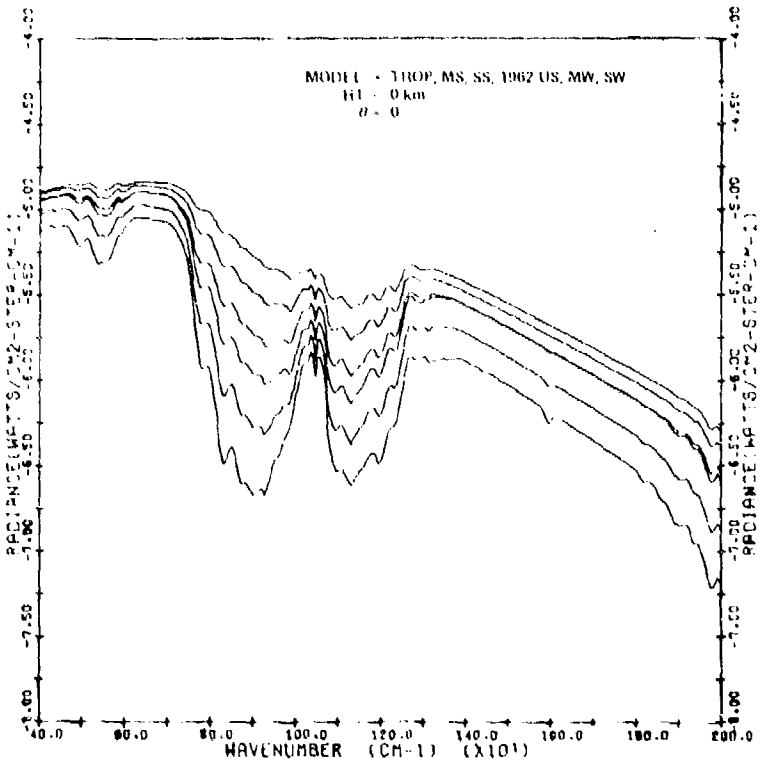

Figure 3. Atmospheric Radiance for a Vertical Path to Space from Ground Level for Six Model Atmospheres (400 to 2000 cm^{-1})

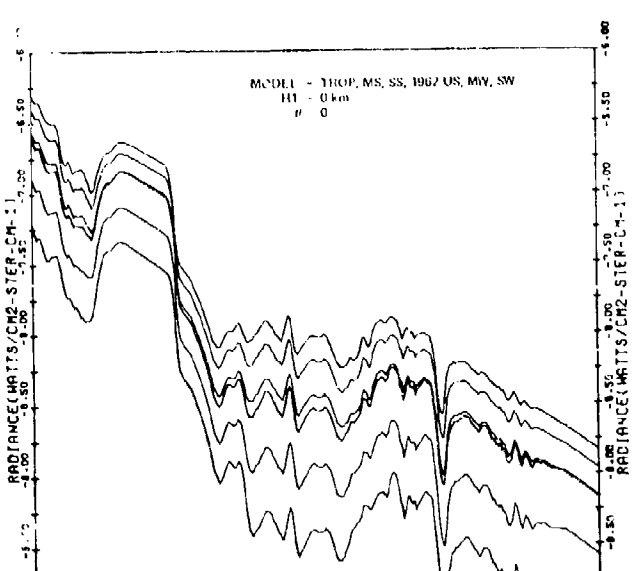

Figure 4. Atmospheric Radiance for a Vertical Path to Space from Ground Level for Six Model Atmospheres (2000 to 3600 cm^{-1})

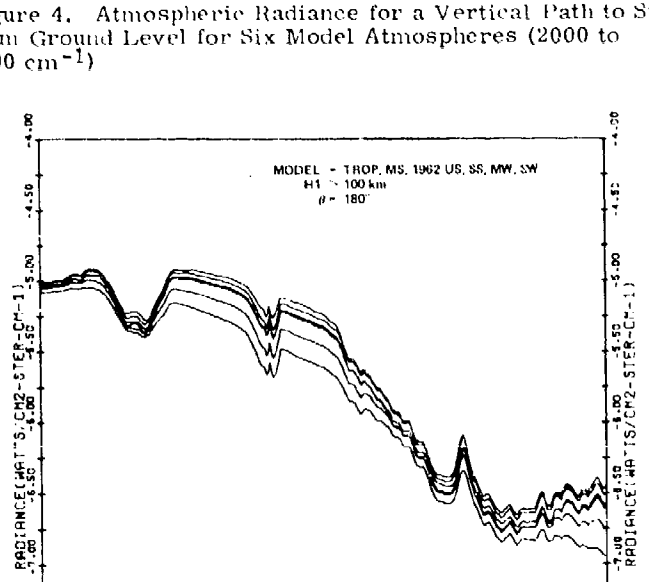

Figure 5. Atmospheric Radiance for a Vertical Path to Ground from Space for Six Model Atmospheres (400 to 2000 cm^{-1})

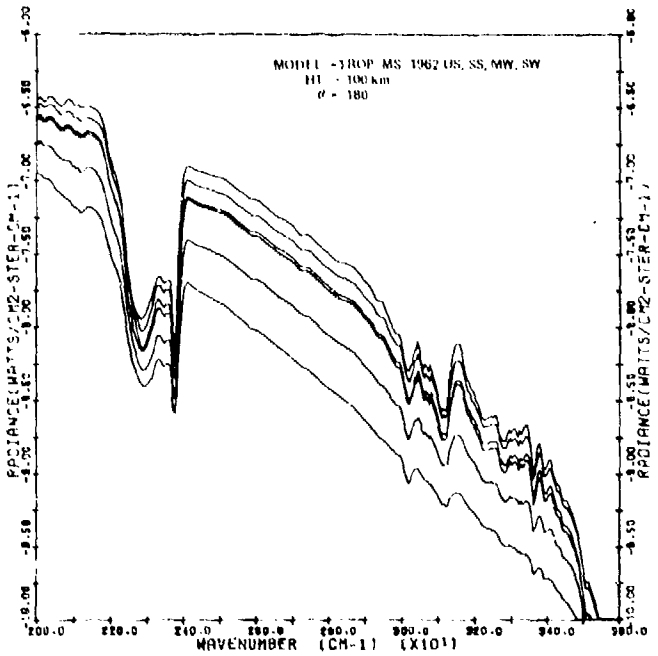

Figure 6. Atmospheric Radiance for a Vertical Path to Ground from Space for Six Model Atmospheres (2000 to 3600 cm^{-1})

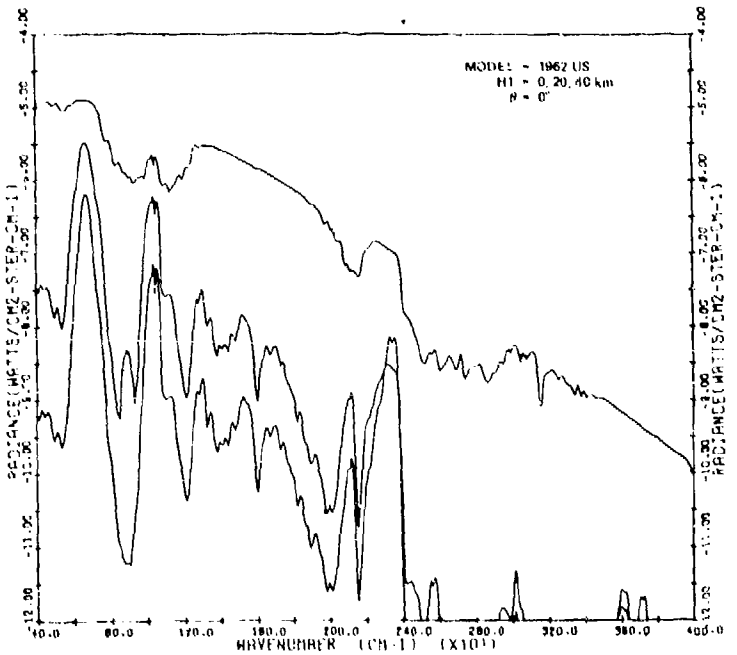

Figure 7. Variation of Atmospheric Radiance With Altitude for Vertical Paths to Space and the 1962 U.S. Standard Atmosphere

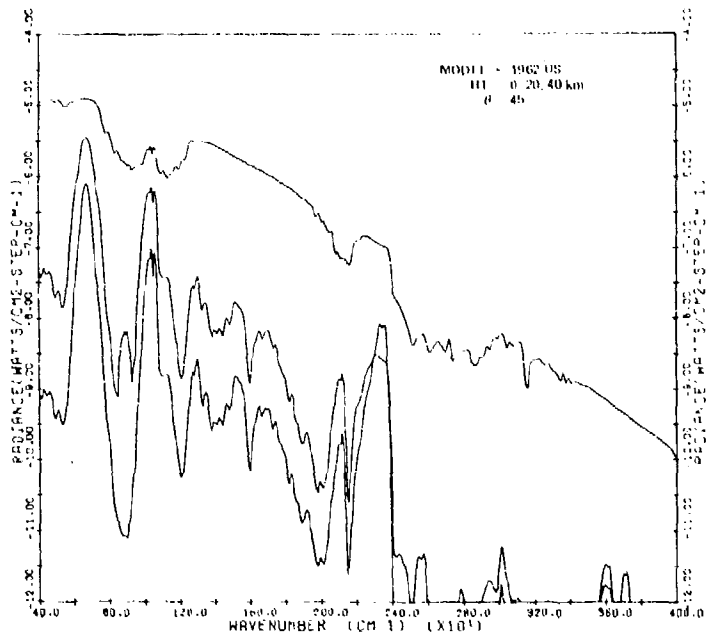

Figure 8. Variation of Atmospheric Radiance With Altitude for Slant Paths to Space (Zenith Angle = 45°) and the 1962 U.S. Standard Atmosphere

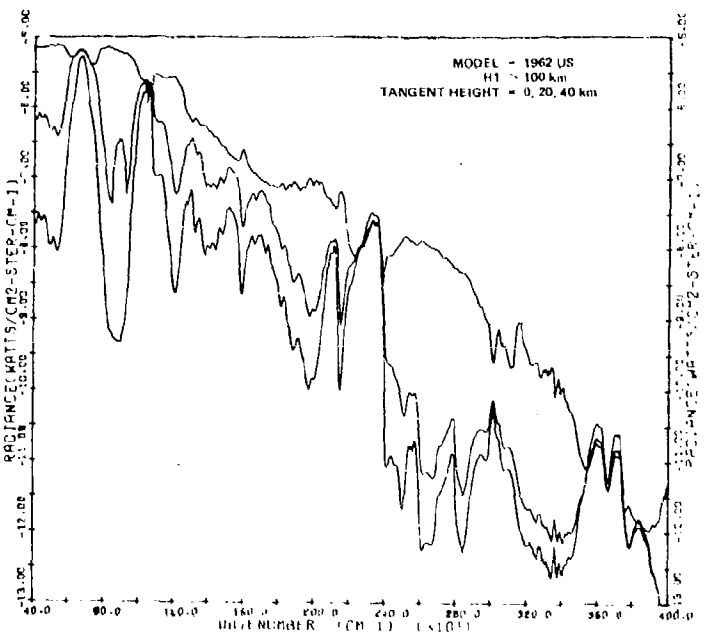

Figure 9. Variation of Atmospheric Limb Radiance With Tangent Height for the 1962 U.S. Standard Atmosphere

9. COMPARISONS WITH MEASUREMENTS

Figures 10 through 22 show some comparisons of LOWTRAN 4 calculations with measurements of atmospheric spectral radiance from both balloon and satellite platforms.

Figure 10 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.[9] 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 11 shows a comparison of an interferometer measurement made from the Nimbus 3 satellite[10] 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 11, 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 0KM in the model atmosphere as the boundary temperature.

Figure 12 shows the comparison of atmospheric radiance as seen from space between the LOWTRAN calculation and measurements from the Nimbus 4 satellite[11] 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[12] and a ground temperature of 190°K for the Antarctic comparison. All three calculations assumed a 23 km visual range for aerosols.

Figures 13 through 22 show a detailed comparison of calculated and observed atmospheric spectral radiance vs wavelength in both the 8 to 14 μm and the 18 to 27 μm spectral regions. The measurements were made on a balloon flight launched

9. Chaney, L.W. (1969) An Experimental Fourier Transform Asymmetrical Interferometer for Atmospheric Radiation Measurements, University of Michigan Technical Report 05863-18-T.

10. 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.

11. 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.

12. Valley, S.D., Ed. (1965) Handbook of Geophysics and Space Environments, AFCRL.

from Holloman AFB, New Mexico by Mureray et al,[13] University of Denver. The instrument used for these observations was a Lille 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, and 0.06 μm in the 18 to 27 μm region. The data in these figures are presented as a function of altitude and as a function of zenith angle. Figures 13 through 18 cover the 8 to 14 μm region and Figures 19 through 22, the 18 to 27 μm region. The LOWTRAN radiance calculation used the pressure, temperature, ozone, and nitric acid profiles from the Mureray report,[13] and the midlatitude winter water vapor profile contained in LOWTRAN.

The dominant spectral features in Figures 13 to 18 are the 9.0 and 9.6 μm ozone bands, the 11.3 μm band of nitric acid, and the carbon dioxide bands between 12 and 14 μm. In the long wavelength region, the spectral radiance is due primarily to water vapor rotational transitions. Because the resolution of the LOWTRAN radiance calculation is inferior to the measurements in this region, the comparisons here can only serve to verify the level of the calculated radiance.

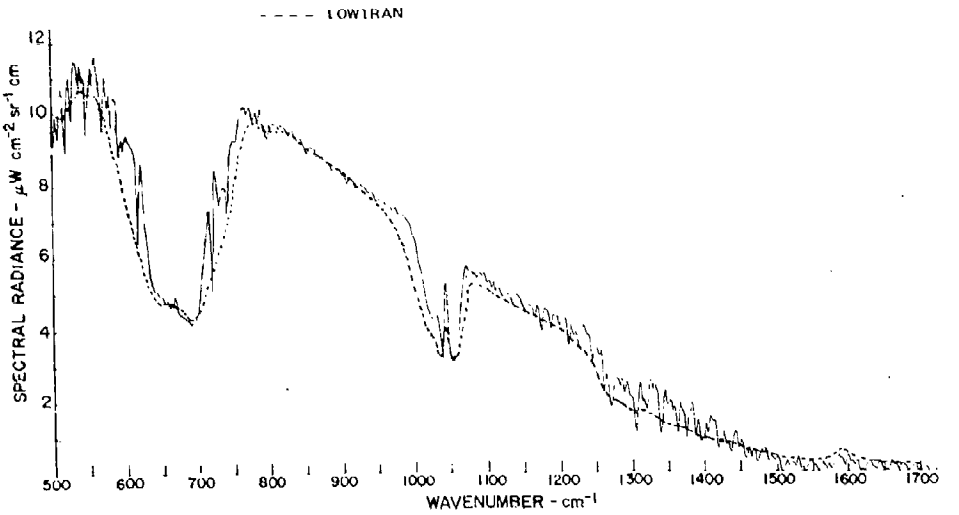

Figure 10. Comparison Between LOWTRAN Prediction and University of Michigan Balloon Measurement of Atmospheric Radiance Over Northern Nebraska

13. Mureray, 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.

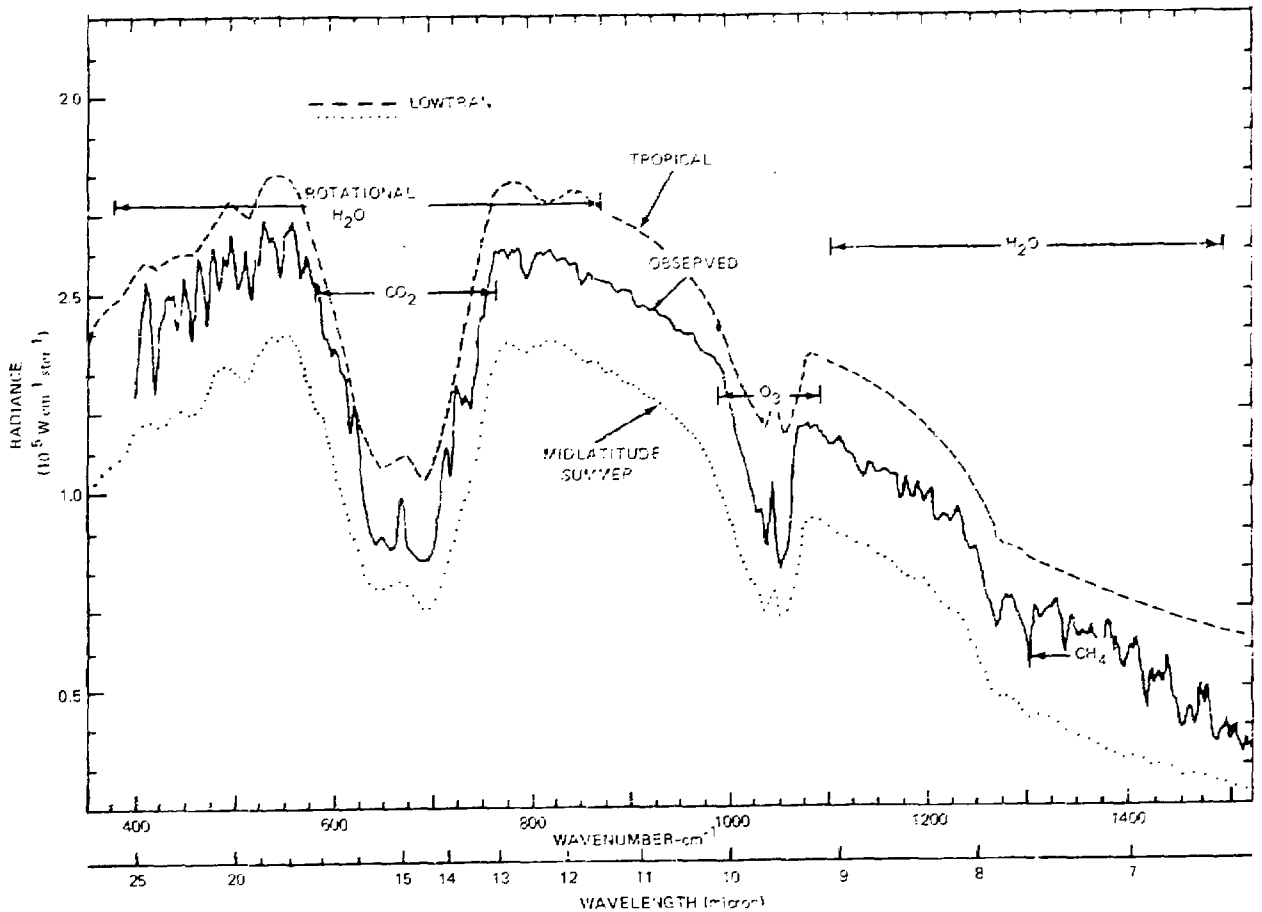

Figure 11. Comparison Between LOWTRAN Prediction and NIMBUS 3 Satellite Measurement of Atmospheric Radiance Over the Gulf of Mexico

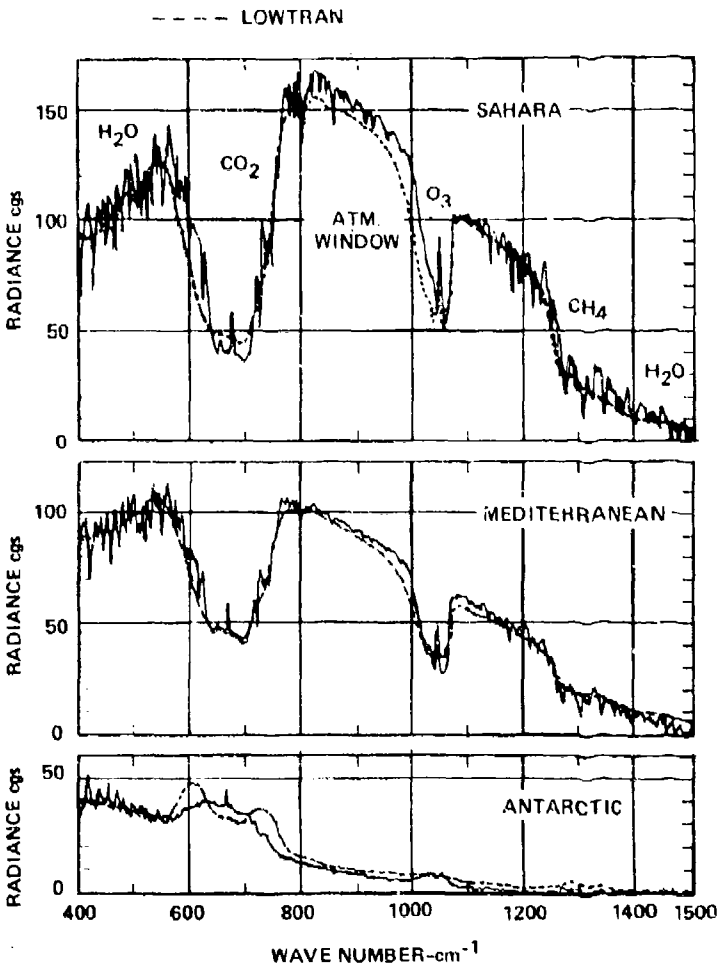

Figure 12. Comparison Between LOWTRAN Prediction and NIMBUS 4 Satellite Measurements of Atmospheric Radiance over the Sahara Desert, the Mediterranean, and the Antarctic

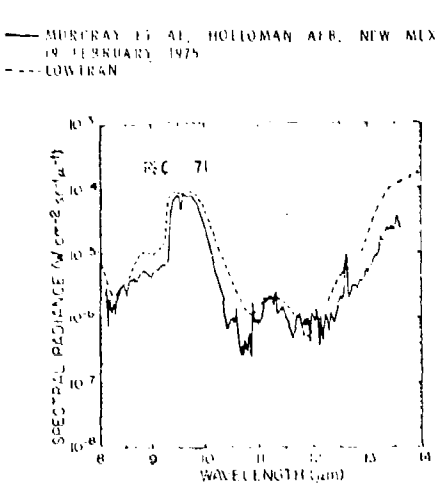

Figure 13. Sample Spectrum of Short Wavelength Region Observed at an Altitude of 9.5 km and a Zenith Angle of 63° on 19 February 1975, and LOWTRAN Comparison

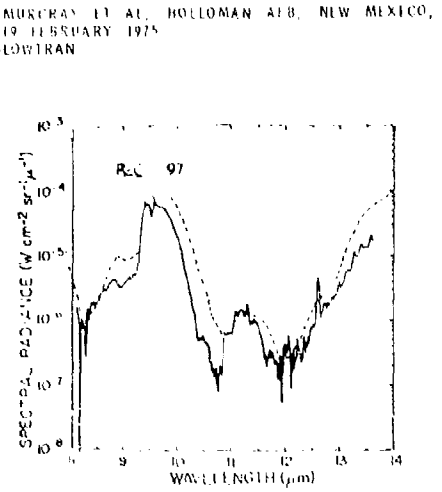

Figure 14. Sample Spectrum of Short Wavelength Region Observed at an Altitude of 13.5 km and a Zenith Angle of 63° on 19 February 1975, and LOWTRAN Comparison

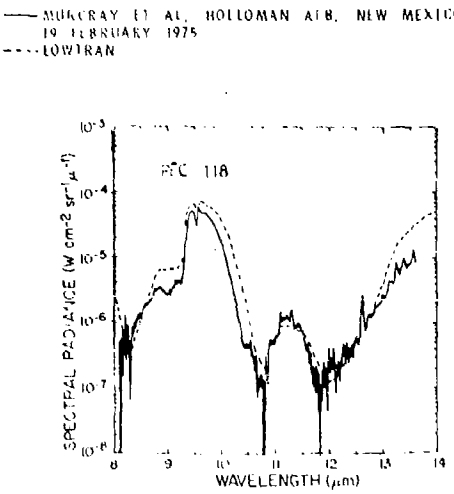

Figure 15. Sample Spectrum of Short Wavelength Region Observed at an Altitude of 18.0 km and a Zenith Angle of 63° on 19 February 1975, and LOWTRAN Comparison

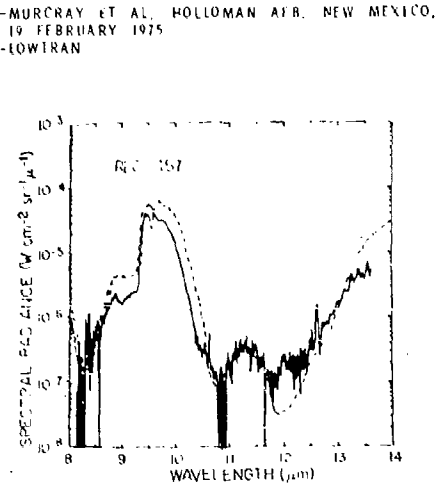

Figure 16. Sample Spectrum of Short Wavelength Region Observed at an Altitude of 24.0 km and a Zenith Angle of 63° on 19 February 1975, and LOWTRAN Comparison

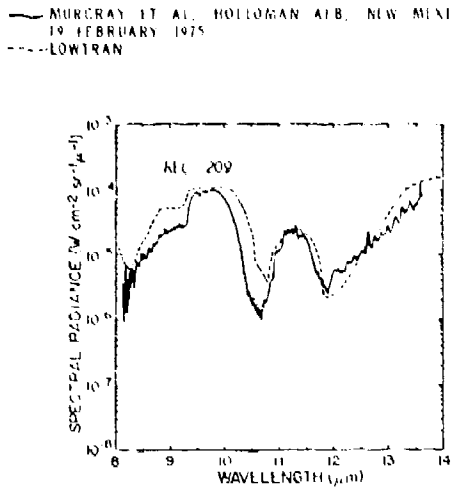

Figure 17. Sample Spectrum of Short Wavelength Region Observed at an Altitude of 29.1 km and a Zenith Angle of 93° on 19 February 1975, and LOWTRAN Comparison

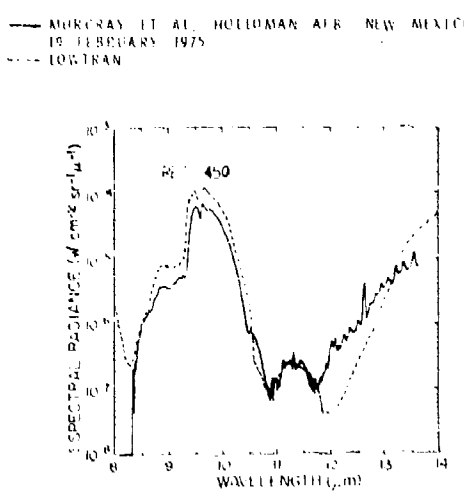

Figure 18. Sample Spectrum of Short Wavelength Region Observed at an Altitude of 29.1 km and a Zenith Angle of 81° on 19 February 1975, and LOWTRAN Comparison

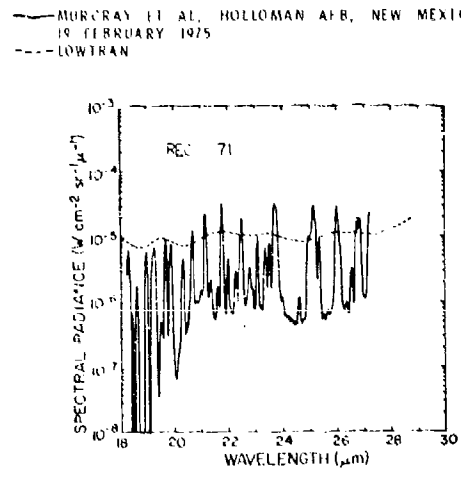

Figure 19. Sample Spectrum of Long Wavelength Region Observed at an Altitude of 9.5 km and a Zenith Angle of 63° on 19 February 1975, and LOWTRAN Comparison

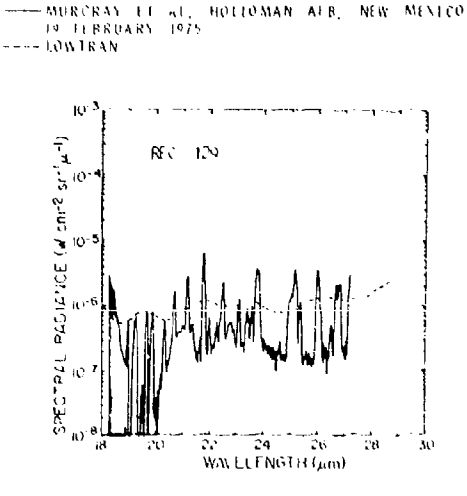

Figure 20. Sample Spectrum of Long Wavelength Region Observed at an Altitude of 20.0 km and a Zenith Angle of 63° on 19 February 1975, and LOWTRAN Comparison

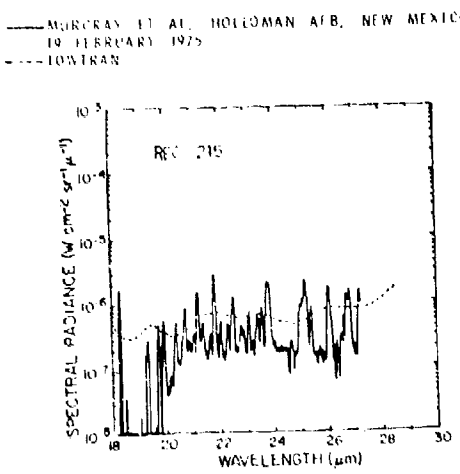

Figure 22. Sample Spectrum of Long Wavelength Region Observed at an Altitude of 29.1 km and a Zenith Angle of 81° on 19 February 1975, and LOWTRAN Comparison

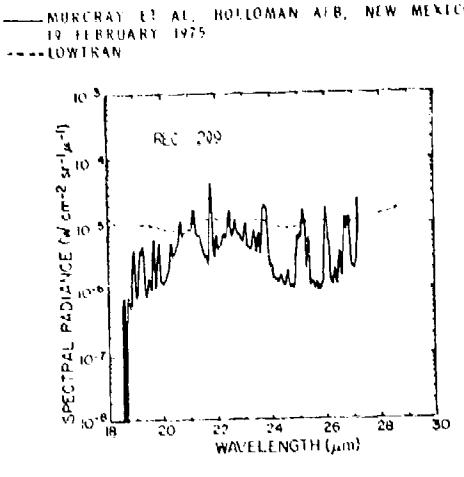

Figure 21. Sample Spectrum of Long Wavelength Region Observed at an Altitude of 29.1 km and a Zenith Angle of 93° on 19 February 1975, and LOWTRAN Comparison

10. COMMENTS

The LOWTRAN model was originally conceived as an atmospheric transmittance model. In the conversion to a radiance model, additional constraints on both the validity of the model as well as the range of applicability are introduced for atmospheric radiance calculations. It should be remembered that the digitized molecular absorption coefficients in LOWTRAN were obtained for conditions representative of moderate atmospheric paths and will tend to underestimate the transmittance for very long paths and overestimate the transmittance for very short paths. The modification of the transmittance function described in Section 3 was made to give some improvements to the radiance calculations for the short path cases. 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 ($\lesssim 5\ \mu m$), scattered solar radiation becomes an important source of background radiation. Since this has not been included in the LOWTRAN model, radiance calculations at the shorter wavelengths with a sunlit atmosphere should be made with caution.

With the obvious limitations in the LOWTRAN radiance code described above, the agreement between measurements and radiance calculations shown in Figures 10 through 22 is remarkably good for the cases considered. Further comparisons with measurements are planned for other spectral regions and other geometries to verify the radiance model.

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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References

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Appendix A

Listing of Program and Data

A listing of the Fortran program LOWTRAN 4 (PROGRAM LOWEM) is given in Table A1 together with the four subroutines PATH, HNO3, POINT, and ANGL. The input data for the program is given in Table A2. A general flow chart for the main program is presented in Appendix B, and definitions of the symbols used in the computer codes are summarized in Appendix C.

The subroutine POINT has a twofold purpose. When the subroutine is called for a given altitude X, it is used to determine the mean refractive index (1) and in the layer between X and the level above, TX(9), and (2) in the layer between X and the level below, YN. In addition, an interpolation scheme is used to determine the effective absorber amounts per km at altitude X for each absorber. When the parameter IP is set equal to zero, only the mean refractive index above and below altitude X is determined from POINT.

The subroutine ANGL is used solely for the purpose of calculating the initial zenith angle (θ_o or ANGL) by an iterative scheme taking into account refraction, given (1) the initial and final altitudes of the path (H1 and H2 respectively) and the angle subtended at the earth's center (β or BETA) by the trajectory, or (2) the initial altitude and tangent height (H1 and HMIN respectively). A more detailed explanation of subroutine ANGL is given in Appendix C of the LOWTRAN 3 report.[2]

PATH and HNO3 are new subroutines which have been added to the program. Subroutine PATH is used to determine and store the cumulative absorber amounts through the layers of the atmospheric slant path. Subroutine HNO3 is called to find the nitric acid absorption coefficients as a function of frequency.

The last column in the listing of the program in Table A1 is the corresponding listing of the LOWTRAN 3B computer code. Changes in the previous code are indicated by the word, NEW.

It should be noted that in the main program, card LOWE 7390, the temporary fog correction has been commented. The fog model should only be used for transmittance calculations as discussed in Appendix D. It should not be used for radiance calculations.

Table A1. Listing of Fortran Code LOWTRAN 4

```
      PROGRAM LOWTRN(INPUT,OUTPUT,TAPE5,TAPE6=OUTPUT,TAPE7)                    LOWE  10      NEW
      COMMON Z(34),P(7,34),T(7,34),FH(11,34),WH(7,34),M,NL,RE,GM,CO,PI         LOWE  20      NEW
      DIMENSION WO(7,34),HZ1(34),HZ2(6),AHAZE(34),AHZ2(20)                     LOWE  30    A    3*
      DIMENSION TR(67),EW(67),EO(67),HZ(2),TX(11),VH(11)                       LOWE  40      NEW
      DIMENSION HST0*(34)                                                      LOWE  50      NEW
      COMMON C1(2580),C2(1676),C3(640),C4(133),C5(15),C8(107)                  LOWE  60      NEW
      COMMON    VX(45),CZ(45),CZA(45)                                          LOWE  70      NEW
      DIMENSION HMIX(34),HLAY(34,11)                                           LOWE  80      NEW
       DIMENSION MPATH(68,11),TBBY(68)                                         LOWE  90      NEW
      COMMON /EMIZ/ IEMISS,KMAX,ANGLE,LEN,HMIN,IJ,J1,J2,JMIN,JEXTRA,ITYPE     LOWE 100      NEW
      COMMON /EM2Z/ IC,IRMAX  ,LENSTOR ,NLL,H(11),F(11)                        LOWE 110      NEW
      COMMON /EM3Z/ H1,H2,RH1 ,MODEL                                           LOWE 120      NEW
C HMIX(I)=RNCE VOLUME MIXING RATIOS TIMES E+09 FROM EVANS PROFILE              LOWE 130      NEW
      DATA HMIX/9*0.,0.1,0.35,0.8,1.2,1.4,1.6,1.8,1.9,2.0,2.1,2.3,3.0,3.5,LOWE 140      NEW
     17,4.2,5.2,6.0,5.8,2.6,0.22,6*0.0/                                        LOWE 150      NEW
      FF(T,V)=1.1909E-16*(V**5)/(EXP(1.4387*V/T)-1.)                           LOWE 160      NEW
C       WATTS, CM-2 SR-1 MICRON-1                                              LOWE 170      NEW
      F(A)=EXP(18.9766-14.9595*A-2.4388*A*A)*A                                 LOWE 180    A    5C
      DATA HZ(1)/5HKM ,HZ(2)/5H S KM/                                          LOWE 190    A    6
C*****************************************************************************LOWE 200    A    7
C     LOWTRAN      1 DEC 77                                                    LOWE 210      NEW
C                                                                              LOWE 220      NEW
*                AUTHORS                                                       LOWE 230      NEW
*                J.E.A. SELBY,                                                 LOWE 240      NEW
*                F.X.KNEIZYS,                                                  LOWE 250      NEW
*                J. H. CHETWYND JR.                                            LOWE 260      NEW
*                R. A. MCCLATCHEY                                              LOWE 270      NEW
C                                                                              LOWE 280      NEW
C     PROGRAM LOWTRAN  CALCULATES THE TRANSMITTANCE    AND/OR RADIANCE       LOWE 290      NEW
C     OF THE ATMOSPHERE                                                        LOWE 300      NEW
C     FROM 350 CM-1 TO 40000 CM-1 (.25 TO 28.57 MICRONS) AT 20 CM-1            LOWE 310    A    9
C     SPECTRAL RESOLUTION ON A LINEAR WAVENUMBER SCALE.                        LOWE 320    A   10
C     REFRACTION AND EARTH CURVATURE EFFECTS ARE INCLUDED.    ATMOSPHERELOWE 330    A   11
C     IS LAYERED IN ONE KM. INTERVALS BETWEEN 0 AND 25 KM., 5 KM. INTER-LOWE 340    A   12
C     VALS TO 50 KM., A TWENTY KM. INTERVAL TO 70 KM., AND A THIRTY KM. LOWE 350    A   13
C     INTERVAL TO 100 KM.                                                      LOWE 360    A   14
C*****************************************************************************LOWE 370    A   15
C     PROGRAM ACTIVATED BY SUBMISSION OF FOUR CARD SEQUENCE AS FOLLOWS         LOWE 380    A   16
C                                                                              LOWE 390    A   17
C   CARD 1 MODEL,IHAZE,ITYPE,LEN,JP,IM,M1,M2,M3,ML,IEMISS,PO,TBOUND            LOWE 400      NEW
C                                                  FORMAT(11I3,2F10.3)         LOWE 410      NEW
C   CARD 2 H1,H2,ANGLE,RANGE,BETA,VIS                    FORMAT(7F10.3)        LOWE 420    A   19
C   CARD 3 V1, V2, DV                                    FORMAT(3F10.3)        LOWE 430    A   20
C   CARD 4 IXX                                           FORMAT(I3)            LOWE 440    A   21
C                                                                              LOWE 450    A   22
C     MODEL=1,2,3,4,5 OR 6 SELECTS ONE OF THE FOLLOWING MODEL ATMOSPHERELOWE 460    A   23
C     TROPICAL,MIDLATITUDE SUMMER,MIDLATITUDE WINTER,SUBARCTIC SUMMER,  LOWE 470    A   24
C     SUBARCTIC WINTER,OR THE 1962 U.S.  STANDARD RESPECTIVELY         LOWE 480    A   25
C     MODEL=0 FOR HORIZ. PATH WHEN METEOROL. DATA USED INSTEAD OF CARD LOWE 490    A   26*
C     READ H1,P(MA),T(DEG C),DEW PT.TEMP(DEG C),%REL HUMIDITY,H2O DENSITLOWE 500    A   27*
```

Table A1. Listing of Fortran Code LOWTRAN 4 (Cont)

```
C     (GM.M-3),O3 DENSITY(GM.M-3), VIS(KM),RANGE(KM) WITH FORMAT 429.    LOWE 510    A  28*
C     MODEL=7 WHEN NEW MODEL ATMOSPHERE(E.G. RADIOSONDE DATA) USED.      LOWE 520    A  29A
C     DATA CARDS ARE READ IN BETWEEN CARDS 1 AND 2, AND SHOULD CONTAIN   LOWE 530    A  29B
C     ALTITUDE(KM,),PRESSURE,TEMP,DEW PT.TEMP,REL. HUMIDITY,H2O DENSITY,LOWE 540    A  29C
C     O3 DENSITY,AEROSOL NO. DENSITY(CM-3) ACCORDING TO FORMAT 429.      LOWE 550    A  29D
C     NOTE THAT EITHER DEW PT, TEMP,OR REL. HUMIDITY CAN BE USED.        LOWE 560    A  29E
C                                                                        LOWE 570    A  29F
C     M1,M2,M3, ARE USED TO CHANGE TEMP,H2O, AND O3 ALTITUDE PROFILES.   LOWE 580    A  29G
C        IEMISS=0=TRANSMISSION MODE / IEMISS=1=EMISSION MODE             LOWE 590       NEW
C        TBOUND=TEMPERATURE OF EARTH IN DEGREES KELVIN                   LOWE 600       NEW
C        IF TBOUND = ZERO, ASSUMES AIR TEMPERATURE OF MODEL ATMOS.       LOWE 610       NEW
C                                                                        LOWE 620    A  30
C     IF IHAZE=0 NO AEROSOL SCATTERING IS COMPUTED                       LOWE 630    A  31
C     IHAZE =1 IF AEROSOL ATTENUATION REQUIRED (THIS IS USED IN          LOWE 640    A  32
C     CONJUNCTION WITH VISUAL RANGE(SEE CARD 2))                         LOWE 650    A  33
C     IHAZE = 1 OR 2 ALSO GIVE AEROSOL ATTENUATION FOR 23KM AND 5KM VIS. LOWE 660    A  34
C     HAZE MODELS RESPECTIVELY IF VIS =0 ON CARD 2                       LOWE 670    A  35
C     IHAZE = 7 FOR OTHER AEROSOL MODELS (E.G, MARITIME ECT) WHICH       LOWE 680    A  35*
C     ARE READ INTO PROGRAM                                              LOWE 690    A  35*
C                                                                        LOWE 700    A  36
C     ITYPE=1,2  OR 3 INDICATES THE TYPE OF ATMOSPHERIC PATH             LOWE 710    A  37
C     ITYPE=3,VERTICAL OR SLANT PATH TO SPACE                            LOWE 720    A  38
C     ITYPE=2,VERTICAL OR SLANT PATH BETWEEN TWO ALTITUDES               LOWE 730    A  39
C     ITYPE=1, CORRESPONDS TO A HORIZONTAL (CONSTANT PRESSURE) PATH      LOWE 740    A  40
C                                                                        LOWE 750    A  41
C     H1=OBSERVER ALTITUDE (KM)                                          LOWE 760    A  42
C     H2=SOURCE  ALTITUDE (KM)                                           LOWE 770    A  43
C     ANGLE= ZENITH ANGLE AT H1 (DEGREES)                                LOWE 780    A  44
C     RANGE=PATH LENGTH (KM)                                             LOWE 790    A  45
C     BETA=EARTH CENTRE ANGLE                                            LOWE 800    A  46
C     VIS = VISUAL RANGE AT SEA LEVEL (KM)                               LOWE 810    A  47
C     (IF ITYPE=1 READ H1 AND RANGE;IF ITYPE=3 READ H1 AND ANGLE.        LOWE 820    A  48
C     IF ITYPE=2 READ H1 AND TWO OTHER PARAMETERS E.G. H2 AND ANGLE)     LOWE 830    A  49
C                                                                        LOWE 840    A  50
C     V1=INITIAL FREQUENCY (WAVENUMBER CM-1 ) INTEGER VALUE              LOWE 850    A  51
C     V2=FINAL FREQUENCY(WAVENUMBER CM-1 ) INTEGER VALUE                 LOWE 860    A  52
C     DV= FREQUENCY INTERVALS AT WHICH TRANSMITTANCE IS PRINTED          LOWE 870    A  53
C     NOTE: DV MUST BE A MULTIPLE OF 5 CM-1                              LOWE 880    A  54
C                                                                        LOWE 890    A  55
C     IXY=0  TO END DATA ,=1 FOR NEW V1,V2,DV ONLY , =2 TO CONTINUE DATALOWE 900    A  56
C     IXY=3 FOR NEW CARD 2 ONLY,=4 FOR NEW CARD 1 ONLY.                  LOWE 910    A  57A
C*************************************************************************LOWE 920    A  57B
      HMIX(9)=HMIX(29)=1.0 E+50                                          LOWE 930       NEW
      IXY=0                                                              LOWE 940    A  57C
      KMAX=11                                                            LOWE 950       NEW
      READ (5,400) IATM,NL                                               LOWE 960    A  58
      READ (5,401) (HZ1(I),I=1,NL)                                       LOWE 970    A  59
      READ (5,401) (HZ2(I),I=1,5)                                        LOWE 980    A  60
      HZ2(6)=HZ1(5)                                                      LOWE 990    A  60+
      DO 1 J=1,3                                                         LOWE1000    A  61
```

Table A1. Listing of Fortran Code LOWTRAN 4 (Cont)

```
      K2=2*J                                                          LOWE1010    A   62
      K1=K2-1                                                         LOWE1020    A   63
      DO 1 I=1,NL                                                     LOWE1030    A   64
1     READ (5,402) Z(I),(P(K,I),T(K,I),WH(K,I),WO(K,I),K=K1,K2)       LOWE1040    A   65
      READ (5,431) (VX(I),C7(I),C7A(I),I=1,44)                        LOWE1050    A   66*
      READ (5,403) (IR(I),FW(I),FO(I),I=1,67)                         LOWE1060    A   67
      READ (5,404) (C1(I),I=1,2580)                                   LOWE1070    A   68
      READ (5,404) (C2(I),I=1,1575)                                   LOWE1080    A   69
      READ (5,404) (C3(I),I=1,540)                                    LOWE1090    A   70
      READ (5,405) (C4(I),I=1,133)                                    LOWE1100    A   71
      READ (5,404) (C5(I),I=1,15)                                     LOWE1110    A   72
      READ (5,405) (C6(I),I=1,102)                                    LOWE1120    A   73

      JSTOR=0                                                         LOWE1140      NEW
      PI=2.0*ASIN(1.0)                                                LOWE1150    A   74*
      CA=PI/180.                                                      LOWE1160    A   75
      IP=0                                                            LOWE1170    A   76
2     CONTINUE                                                        LOWE1180    A   77
      RE=6371.23                                                      LOWE1190    A   78
      IFIRD=0                                                         LOWE1200    A   79
C     JP NE 0  SUPPESS PRINT                                          LOWE1210    A   79*
      READ 400,MODEL,IHAZE,ITYPE,LEN,JP,IM,M1,M2,M3,ML,IEMISS,RO,IBOUND LOWE1220      NEW
C  IEMISS=0=TRANSMISSION MODE / IEMISS=1=EMISSION MODE                  LOWE1230      NEW
      IF(IEMISS.EQ.1) PRINT 1171                                      LOWE1240      NEW
      IF(IEMISS.EQ.0) PRINT 1171                                      LOWE1250      NEW
      LENSTOR=LEN                                                     LOWE1260      NEW
      PRINT400,MODEL,IHAZE,ITYPE,LEN,JP,IM,M1,M2,M3,ML,IEMISS,RO,IBOUND LOWE1270    NEW
200   M=MODEL                                                         LOWE1280    A   82
      IF (M.EQ.1) RE=6378.39                                          LOWE1290    A   83
      IF (M.EQ.4) RE=6356.91                                          LOWE1300    A   84
      IF (M.EQ.5) RE=6356.91                                          LOWE1310    A   84A
       IF(IHAZE.NE.7) GO TO 250                                       LOWE1320    A   84B
      READ 431,(VX(I),C7(I),C7A(I),I=1,44)                            LOWE1330    A   84C
      PRINT 431,(VX(I),C7(I),C7A(I),I=1,44)                           LOWE1340    A   84D
      IHAZE=1                                                         LOWE1350    A   85
250   IF(RO.GT.0)RE=RO                                                LOWE1360    A   86
      IF(M.EQ.7.AND.IH.NE.0) GO TO 4                                  LOWE1370    A   86A
      IF(IXY.GT.3) GO TO 8                                            LOWE1380    A   86B
      IF (MODEL.EQ.0) GO TO 4                                         LOWE1390    A   87
300   READ 406, H1,H2,ANGLE,RANGE,BETA,VIS                            LOWE1400    A   87*
      PRINT 425, H1,H2,ANGLE,RANGE,BETA,VIS                           LOWE1410    A   88
      X1=RE+H1                                                        LOWE1420    A   89
      IF (ITYPE.EQ.3) GO TO 560                                       LOWE1430    A   90*
      IF (ITYPE.EQ.1) GO TO 8                                         LOWE1440    A   91
      X2=RE+H2                                                        LOWE1450    A   92
      IF (RANGE.EQ.0.) GO TO 5                                        LOWE1460    A   93
      PRINT 428, H1,H2,ANGLE,RANGE,BETA,VIS                           LOWE1470    A   94
      IF (H2.EQ.0.AND.ANGLE.NE.0) GO TO 3                             LOWE1480    A   95
      ANGLE=ACOS(0.5*((H2-H1)*(1.+X2/X1)/RANGE-RANGE/X1))/CA          LOWE1490    A   96
      GO TO 7                                                         LOWE1500    A   97
```

Table A1. Listing of Fortran Code LOWTRAN 4 (Cont)

```
3     X2=SQRT((X1/RANGE+RANGE/X1+2.0*COS(ANGLE*GA))*X1*RANGE)                  LOWE1510    A  98
      H2=X2-RE                                                                 LOWE1520    A  99
      GO TO 7                                                                  LOWE1530    A 100
4     CONTINUE                                                                 LOWE1540    A 101*
      IF(ML.LE.0)ML=1                                                          LOWE1550    A 102*
      DO 540 K=1,ML                                                            LOWE1560    A 103A
      AHAZE(K)=0.0                                                             LOWE1570    A 103B
      IF(M.EQ.0)READ 429,H1,P(7,1),TMP,DP,RH,WH(7,K),WO(7,K),VIS,RANGE         LOWE1580    A 103C
      IF(M.EQ.0)PRINT 430,H1,P(7,1),TMP,DP,RH,WH(7,K),WO(7,K),VIS,RANGE        LOWE1590    A 103D
      IF(M.GT.0)READ 429,Z(K),P(7,K),TMP,DP,RH,WH(7,K),WO(7,K),AHAZE(K)        LOWE1600    A 103E
      IF(M.EQ.0)Z(K)=H1                                                        LOWE1610    A*103F
      J=IFIX(Z(K)+1.0E-6)+1.                                                   LOWE1620    A*103G
      IF(Z(K).GE.25.0) J=(Z(K)-25.0)/5.0+26.                                   LOWE1630    A 103H
      IF(Z(K).GE.50.0) J=(Z(K)-50.0)/20.0+31.                                  LOWE1640    A 103I
      IF(Z(K).GE.70.0) J=(Z(K)-70.0)/30.0+32.                                  LOWE1650    A 103J
      IF(J.GT.33)J=33                                                          LOWE1660    A 103K
      FAC=Z(K)-FLOAT(J-1)                                                      LOWE1670    A 103L
      IF(J.LT.26) GO TO 500                                                    LOWE1680    A 103M
      FAC=(Z(K)-5.0*FLOAT(J-26)-25.)/5.                                        LOWE1690    A 103N
      IF(J.GE.31) FAC=(Z(K)-50.0)/20.                                          LOWE1700    A 103O
      IF(J.GE.32) FAC=(Z(K)-70.0)/30.                                          LOWE1710    A 103P
      IF(FAC.GT.1.0) FAC=1.0                                                   LOWE1720    A 103Q
500   L=J+1                                                                    LOWE1730    A 103R
      T(7,K)=TMP+273.15                                                        LOWE1740    A 103S
      IF(M1.GT.0)T(7,K)=T(M1,J)*(T(M1,L)/T(M1,J))**FAC                         LOWE1750    A 103T
      TT=273.15/T(7,K)                                                         LOWE1760    A 103U
      IF(RH.LE.0.0) TT=273.15/(273.15+DP)                                      LOWE1770    A 103V
      IF(WH(7,K).LE.0.0) WH(7,K)=E(TT)                                         LOWE1780    A 103W
      IF(M2.GT.0)WH(7,K)=WH(M2,J)*(WH(M2,L)/WH(M2,J))**FAC                     LOWE1790    A 103X
      IF(RH.GT.0.0) WH(7,K)=0.01*RH*WH(7,K)                                    LOWE1800    A 103Y
      IF(M3.GT.0)WO(7,K)=WO(M3,J)*(WO(M3,L)/WO(M3,J))**FAC                     LOWE1810    A 103Z
       HSTOR(K)=0.                                                             LOWE1820      NEW
      IF(HMIX(J).LE.0.) GO TO 522                                              LOWE1830      NEW
        HSTOR(K)=HMIX(J)*(HMIX(L)/HMIX(J))**FAC                                LOWE1840      NEW
522    CONTINUE                                                                LOWE1850      NEW
      IF(Z(K).GE.5.0)GO TO 520                                                 LOWE1860    A 104A
      IF(AHAZE(K).LE.0.0)AHAZE(K)=HZ2(J)*(HZ2(L)/HZ2(J))**FAC                  LOWE1870    A 104B
520   IF(AHAZE(K).EQ.0.0)AHAZE(K)=HZ1(J)*(HZ1(L)/HZ1(J))**FAC                  LOWE1880    A 104C
      IF(MODEL.EQ.0)GO TO 8                                                    LOWE1890    A 104D
      IF(K.EQ.1)PRINT 441                                                      LOWE1900    A 104E
      PRINT 429,Z(K),P(7,K),TMP,DP,RH,WH(7,K),WO(7,K),AHAZE(K)                 LOWE1910    A 104F
540   CONTINUE                                                                 LOWE1920    A 104G
      IH=0                                                                     LOWE1930    A 104H
      NL=ML                                                                    LOWE1940    A 104I
      M1=0                                                                     LOWE1950    A 104J
      M2=0                                                                     LOWE1960    A 104K
      M3=0                                                                     LOWE1970    A 104L
C     NOTE THAT Z(I) MAY NOT CORRESPOND TO THE VALUES GIVEN FOR STANDARD       LOWE1980    A 104M
C     MODEL ATMOSPHERES                                                        LOWE1990    A 104N
      IF(IXY.GT.3) GO TO 8                                                     LOWE2000      NEW
```

Table A1. Listing of Fortran Code LOWTRAN 4 (Cont)

```
      GO TO 300                                                          LOWE2010    A 1040
560   IF (RANGE.GT.0.0) GO TO 580                                        LOWE2020    A 1040
      IF (H2.GT.0.0.AND.H2.LT.H1) IFIND=1                                LOWE2030    A 1040
      GO TO 8                                                            LOWE2040    A 1040
580   ITYPE=2                                                            LOWE2050    A 1040
      BETA=ACOS(0.5*(RANGE*RANGE/(X1*X2)-X2/X1-X1/X2))/CA                LOWE2060    A 1041
5     IF (BETA.EQ.0.) GO TO 6                                            LOWE2070    A 105
      IFIND=1                                                            LOWE2080    A 106
      BET=CA*BETA                                                        LOWE2090    A 107
      X2=RE+H2                                                           LOWE2100    A 108
      ANGLE=ATAN(X2*SIN(BET)/(X2*COS(BET)-X1))/CA                        LOWE2110    A 109
      RANGE=X2*SIN(BET)/SIN(ANGLE*CA)                                    LOWE2120    A 110
      BET=BETA                                                           LOWE2130    A 111
      GO TO 8                                                            LOWE2140    A 112
6     RANGE=(X2/X1)**2-(SIN(ANGLE*CA))**2                                LOWE2150    A 113
      IF (RANGE.GE.0.0) RANGE=X1*(SQRT(RANGE)-ABS(COS(ANGLE*CA)))        LOWE2160    A 114
7     IF (ANGLE.90.1.,90.ANGLE.90.180.) BET=ASIN(RANGE*SIN(ANGLE*CA)/X2)LOWE2170    A 115
      IF (ANGLE.LT.0.) ANGLE=ANGLE+PI                                    LOWE2180    A 116
      IF (RANGE.LT.0.0) RANGE=-RANGE                                     LOWE2190    A 117
      BET=BET/CA                                                         LOWE2200    A 118
      PRINT 428, H1,H2,ANGLE,RANGE,BET,VIS                               LOWE2210    A 119
8     CONTINUE                                                           LOWE2220    A 1200
      DO 1002 I=1,34                                                     LOWE2230      NEW
      DO 1002 J=1,KMAX                                                   LOWE2240      NEW
1002  WLAY(I,J)=0.                                                       LOWE2250      NEW
      SUMA=0.                                                            LOWE2260    A 1200
      IF(IXY.LE.2) READ 406,V1,V2,DV                                     LOWE2270    A 121*
      IF(IXY.LE.2)PRINT 406,V1,V2,DV                                     LOWE2280    A 122*
      IF (ITYPE.EQ.1) PRINT 407, H1,RANGE                                LOWE2290    A 123
      IF (ITYPE.EQ.2) PRINT 408, H1,H2,ANGLE                             LOWE2300    A 124
      IF (ITYPE.EQ.3) PRINT 409, H1,ANGLE                                LOWE2310    A 125
      IF (MODEL.EQ.0) M=7                                                LOWE2320    A 126A
      IF (VIS.GT.0.0) PRINT 417,VIS                                      LOWE2330    A 1260
      IF(VIS.LT.2.0.AND.VIS.GT.0.0) PRINT 442                            LOWE2340    A 1260
      IF (M.EQ.1) PRINT 410, M                                           LOWE2350    A 127
      IF (M.EQ.2) PRINT 411, M                                           LOWE2360    A 128
      IF (M.EQ.3) PRINT 412, M                                           LOWE2370    A 129
      IF (M.EQ.4) PRINT 413, M                                           LOWE2380    A 130
      IF (M.EQ.5) PRINT 415, M                                           LOWE2390    A 131
      IF (M.EQ.6) PRINT 414, M                                           LOWE2400    A 132
      IF (IHAZE.EQ.0.) PRINT 426                                         LOWE2410    A 133
      IF (VIS.LE.0.0.AND.IHAZE.GT.0) PRINT 416,IHAZE,HZ(IHAZE)           LOWE2420    A 134*
      AVH=10000./V1                                                      LOWE2430    A 135
      ALAM=10000./V2                                                     LOWE2440    A 136
      RADMIN=1.0E+300 $RADMAX=0.  $  VKMIN=0.  $  VKMAX=0.               LOWE2450      NEW
      PRINT 418, V1,V2,DV,ALAM,AVH                                       LOWE2460    A 137
      AVH=0.5E-4*(V1+V2)                                                 LOWE2470    A 138
      AVH=AVH*AVH                                                        LOWE2480    A 139
      CO=77.46+.459*AVH                                                  LOWE2490    A 140
      CH=43.487-0.3473*AVH                                               LOWE2500    A 141
```

Table A1. Listing of Fortran Code LOWTRAN 4 (Cont)

```
      IF (IFIND.EQ.1) GO TO 15                                          LOWE2610    A 146
9     IF (IFIND.EQ.1) CALL ANGL (H1,H2,ANGLE,BETA,LEN,ML)               LOWE2620    A 147*
      IFIND=0                                                           LOWE2630    A 148
      IF (JP.EQ.0) PRINT 427                                            LOWE2640    A 149*
      IF (ITYPE.EQ.1) GO TO 15                                          LOWE2650    A 150
      DO 11 K=1,KMAX                                                    LOWE2660      NEW
      VH(K)=0.0                                                         LOWE2670    A 152
11    CONTINUE                                                          LOWE2680    A 153
      BETA=0.0                                                          LOWE2690    A 154-
      SR=0.0                                                            LOWE2700    A 155
      IP=0                                                              LOWE2710    A 156-
C**** NOW DEFINE CONSTANT PRESSURE PATH QUANTITIES  EH(1-6)             LOWE2720    A 157
      Y=CA*ANGLE                                                        LOWE2730    A 158
      SPHI=SIN(Y)                                                       LOWE2740    A 159
      R1=(RE+H1)*SPHI                                                   LOWE2750    A 160
      IF (H1.GT.Z(NL)) GO TO 13                                         LOWE2760    A 161
      GO TO 15                                                          LOWE2770    A 162
13    X=(RE+Z(NL))/(RE+H1)                                              LOWE2780    A 163
      IF (SPHI.GT.X) GO TO 14                                           LOWE2790    A 164
      H1=Z(NL)                                                          LOWE2800    A 165
      J1=NL                                                             LOWE2810    A 166
      SPHI=SPHI/X                                                       LOWE2820    A 167
      ANGLE=180.0-ASIN(SPHI)/CA                                         LOWE2830    A 168
      R1=(RE+H1)*SPHI                                                   LOWE2840    A 169
      GO TO 15                                                          LOWE2850    A 170
14    HMIN=R1-RE                                                        LOWE2860    A 171
      PRINT 433, HMIN                                                   LOWE2870    A 172
      GO TO 95                                                          LOWE2880    A 173
15    DO 17 I=1,NL                                                      LOWE2890    A 174
      PS=P(M,I)/1013.0                                                  LOWE2900    A 175
      TS=273.15/T(M,I)                                                  LOWE2910    A 176A
      IF(M1.GT.6.AND.M.LT.7)TS=273.15/T(M1,I)                           LOWE2920    A 176B
      X=PS*TS                                                           LOWE2930    A 177
      PT=PS*SQRT(TS)                                                    LOWE2940    A 178
      D=0.1*WH(M,I)                                                     LOWE2950    A 179
      IF(M2.GT.0.AND.M.LT.7) D=0.1*WH(M2,I)                             LOWE2960    A 180*
      EH(1,I)=D*PT**0.9                                                 LOWE2970    A 181*
      EH(2,I)=X*PT**0.75                                                LOWE2980    A 182*
      EH(4,I)=0.5*PT*X                                                  LOWE2990    A 183
      PPW=4.56E-5*D*273.15/TS                                           LOWE3000    A 184*
      TS1=(296.0/273.15)*TS                                             LOWE3010   *A 185A
      EH(5,I)=D*PPW*EXP(6.08*(TS1-1.0))+0.002*D*(PS-PPW)                LOWE3020   *A 185B
      EH(10,I)=D*(PPW+0.12*(PS-PPW))*EXP(4.56*(TS1-1.0))                LOWE3030   *A 185C
      EH(6,I)=X                                                         LOWE3040    A 186
      HAZE=HZ1(I)                                                       LOWE3050    A 187
      IF(M.EQ.7) HAZE=AHAZE(I)                                          LOWE3060    A 188*
      IF(Z(I).GE.5.0) GO TO 150                                         LOWE3070    A 189*
      IF(M.NE.7.AND.IHAZE.EQ.2) HAZE=HZ2(I)                             LOWE3080    A 190A
      IF(IHAZE.EQ.2.AND.M.EQ.7)HAZE=AHZ2(I)                             LOWE3090    A 190B
      IF(VIS.LE.0.0) GO TO 150                                          LOWE3100    A 190C
```

Table A1. Listing of Fortran Code LOWTRAN 4 (Cont)

```
      IF(M,NE,7) HAZE=6.309*(HZ2(I)-HZ1(I))/VIS*HZ1(I)/5.-HZ2(I)/23.)  LOWE3010    A 1900
      IF (M,NE,7) GO TO 150                                            LOWE3020    A 1906
      HAZE=6.309*((AHZ2(I)-AHAZE(I))/VIS*AHAZE(I)/5.0-AHZ2(I)/23.0)   LOWE3030    A 190F
150   IF(HAZE.LT.0.0) HAZE=0.0                                         LOWE3040    A 1906
      EH(7,I)=HAZE/HZ1(1)                                              LOWE3050    A 191A
      IF(MODEL.EQ.7) EH(7,I)=HAZE/AHAZE(1)                             LOWE3060    A 191H
      EH(8,I)=46.0667*WO(M,I)                                          LOWE3070    A 192
      IF(MS.GT.0.AND.M.LT.7) EH(8,I)=46.0667*WO(MS,I)                  LOWE3080    A 1926
      EH(3,I)=EH(8,I)*PT**0.6                                          LOWE3090    A 1938
C EH(11,I)=HNO3 ABSORBER AMOUNT (ATM-CM)/KM                            LOWE3100      NEW
      EH(11,I)=PS*TS*HMIX(I)*1.0E-04                                   LOWE3110      NEW
      IF(MODEL.EQ.0.OR.MODEL.EQ.7) EH(11,I)=PS*TS*HSTOR(I)*1.0 E-0*    LOWE3120      NEW
      EH(9,I)=1.0                                                      LOWE3130    A 1952
      REF=1.0E-6*(CO*X*1013.0/273.16-PPW*CW)                           LOWE3140    *A 1958
      IF (I.EQ.NL) GO TO 16                                            LOWE3150    A 196
      IF (MODEL.EQ.0.AND.I.GE.1) GO TO 26                              LOWE3160    A 196A
      I2=I(M,I+1)                                                      LOWE3170    A 196A
      H2=HH(M,I+1)                                                     LOWE3180    A 196C
      IF(M1.GT.0)I2=I(M1,I+1)                                          LOWE3190    A 196J
      IF(M2.GT.0)H2=HH(M2,I+1)                                         LOWE3200    A 196E
      PPW=4.56E-6*H2*12                                                LOWE3210    A 196*
      E(10,I)=0.5*(REF+1.0E-6*(CO*P(M,I+1)/I2-PPW*CW))                 LOWE3220    *A 197*
16    IF (I.EQ.NL) EH(3,I)=0.                                          LOWE3230    A 198*
      IF (H1.GE.Z(I)) J1=I                                             LOWE3240    A 199*
      IF (I.EQ.0.OR.JP.EQ.0) PRINT 434, I,Z(I),(E(K),I),K=1,KMAX)      LOWE3250      NEW
      EH(9,I)=EH(9,I)+1.0                                              LOWE3260    A 201
17    CONTINUE                                                         LOWE3270    A 202
170   IF (IFIND.EQ.1) GO TO 9                                          LOWE3280    A 203
      IP=1                                                             LOWE3290    A 204
      IK=0                                                             LOWE3300    A 205
      X1=H1                                                            LOWE3310    A 206
      CALL POINT (H1,YN,N,NP1,TX,IP)                                   LOWE3320    A 207
      J1=N                                                             LOWE3330    A 208
      TX1=TX(9)                                                        LOWE3340    A 209
      DO 18 K=1,KMAX                                                   LOWE3350      NEW
18    E(K)=TX(K)                                                       LOWE3360    A 211
      IF (ITYPE.EQ.1) GO TO 26                                         LOWE3370    A 212
      IF (ITYPE.EQ.3) H2=Z(NL)                                         LOWE3380    A 213
      IF (ANGLE.GT.90.0) GO TO 28                                      LOWE3390    A 214
19    IF (ANGLE.GT.90.0.AND.NP1.GT.0) J1=J1+1                          LOWE3400    A 215
      J2=NL                                                            LOWE3410    A 216
      IF (ITYPE.EQ.3) GO TO 20                                         LOWE3420    A 217
      CALL POINT (H2,YN,N,NP,TX,IP)                                    LOWE3430    A 218
      J2=N                                                             LOWE3440    A 219
      IF (NP.GT.0) J2=J2-1                                             LOWE3450    A 220
20    DO 21 K=1,KMAX                                                   LOWE3460      NEW
       IF(K.EQ.9) GO TO 21                                             LOWE3470    *A 2210
      EH(K,J1)=E(K)                                                    LOWE3480    A 222
      IF (ITYPE.EQ.3) GO TO 21                                         LOWE3490    A 223
      EH(K,J2+1)=TX(K)                                                 LOWE3500    A 224
```

Table A1. Listing of Fortran Code LOWTRAN 4 (Cont)

```
21    CONTINUE                                                    LOWE3510    A 225
      IF (J1.EQ.J2) TX1=TX1+YN-EH(9,J1)                           LOWE3520    A 226
C**** NOW DEFINE VERTICAL PATH QUANTITIES VH(1-8)                 LOWE3530    A 227
      IF (JP.EQ.0) PRINT 420                                      LOWE3540    A 228*
      DO 1020 K=1,KMAX                                            LOWE3550      NEW
 1020 W(K)=0.                                                     LOWE3560      NEW
      DO 25 I=J1,J2                                               LOWE3570    A 229
      X1=Z(I)                                                     LOWE3580    A 230
      X2=Z(I+1)                                                   LOWE3590    A 231
      IF (I.EQ.J1) X1=H1                                          LOWE3600    A 232
      IF (I.EQ.J2) X2=H2                                          LOWE3610    A 233
      DZ=X2-X1                                                    LOWE3620    A 234
      IF (I.EQ.NL) DZ=Z(I)-Z(I-1)                                 LOWE3630    A 235
      DS=DZ                                                       LOWE3640    A 236
C***** UPWARD TRAJECTORY                                          LOWE3650    A 237
      RX=(RE+X1)/(RE+X2)                                          LOWE3660    A 238
      THETA=ASIN(SPHI)/CA                                         LOWE3670    A 239
      PHI=ASIN(SPHI*RX)/CA                                        LOWE3680    A 240
      BET=THETA-PHI                                               LOWE3690    A 241
      SALP=RX*SPHI                                                LOWE3700    A 242
      IF (SPHI.GT.1.E-10) DS=(RE+X2)*SIN(BET*CA)/SPHI             LOWE3710    A 243
      BETA=BETA+BET                                               LOWE3720    A 244
      PSI=BETA+PHI-ANGLE                                          LOWE3730    A 245
      PHI=180.-PHI                                                LOWE3740    A 246
      SR=SR+DS                                                    LOWE3750    A 247
      JEXTRA=0                                                    LOWE3760      NEW
      DO 1024 K=1,KMAX                                            LOWE3770      NEW
      EV=DS*EH(K,I)                                               LOWE3780    A 249
      IF (I.EQ.NL) GO TO 22                                       LOWE3790    A 250
      IF (EH(K,I).EQ.0.0.OR.EH(K,I+1).EQ.0.0) GO TO 23            LOWE3800    A 251
      IF (EH(K,I).EQ.EH(K,I+1)) GO TO 24                          LOWE3810    A 252
      EV=DS*(EH(K,I)-EH(K,I+1))/ALOG(EH(K,I)/EH(K,I+1))           LOWE3820    A 253
      GO TO 24                                                    LOWE3830    A 254
22    IF (EH(K,I).EQ.0.0) GO TO 23                                LOWE3840    A 255
      IF (EH(K,I-1).EQ.0.0) GO TO 23                              LOWE3850    A 256
      IF (EH(K,I).EQ.EH(K,I-1)) GO TO 24                          LOWE3860    A 257
      EV=EV/ALOG(EH(K,I-1)/EH(K,I))                               LOWE3870    A 258
      GO TO 24                                                    LOWE3880    A 259
23    EV=0.                                                       LOWE3890    A 260
24    VH(K)=VH(K)+EV                                              LOWE3900    A 261
      IF(I.EQ.JSTOR) GO TO 1023                                   LOWE3910      NEW
 1022 WLAY(I,K)=EV+W(K)                                           LOWE3920      NEW
      W(K)=0.                                                     LOWE3930      NEW
      GO TO 1024                                                  LOWE3940      NEW
 1023 W(K)=EV                                                     LOWE3950      NEW
      IF(J1.NE.J2) GO TO 1024                                     LOWE3960      NEW
      WLAY(J2+1,K)=W(K)                                           LOWE3970      NEW
      W(K)=0.                                                     LOWE3980      NEW
      JEXTRA=1                                                    LOWE3990      NEW
 1024 CONTINUE                                                    LOWE4000      NEW
```

Table A1. Listing of Fortran Code LOWTRAN 4 (Cont)

```
      IF (JP.EQ.0) PRINT 435, I,X1,(VH(L),L=1,6),PSI,PHI,BETA,THETA,SR  LOWE4010   A 262*
      IF (I.GE.NL) GO TO 25                                            LOWE4020   A 263
      IF (I+1.EQ.J2) EH(9,I+1)=YN                                      LOWE4030   A 264
      IF (I.EQ.J1) EH(9,I)=TX1                                         LOWE4040   A 265
      RN=EH(9,I+1)/EH(9,I)                                             LOWE4050   A 266
      SPHI=SPHI*RX/RN                                                  LOWE4060   A 267
      IF (SALP.GE.RN) SPHI=SALP                                        LOWE4070   A 268
25    CONTINUE                                                         LOWE4080   A 269
      GO TO 47                                                         LOWE4090   A 270
C**** HORIZONTAL PATH                                                  LOWE4100   A 271
26    DO 27 K=1,KMAX                                                   LOWE4110     NEW
      W(K)=RANGE*EH(K,1)                                               LOWE4120   A 273*
      IF (MODEL.GT.0) W(K)=RANGE*TX(K)                                 LOWE4130   A 274*
      VH(K)=W(K)                                                       LOWE4140     NEW
27    CONTINUE                                                         LOWE4150   A 275
      GO TO 49                                                         LOWE4160   A 276
28    CONTINUE                                                         LOWE4170   A 277
C**** DOWNWARD TRAJECTORY                                              LOWE4180   A 278
      KP=0                                                             LOWE4190   A 279
      IF (NP1.EQ.1) J1=J1-1                                            LOWE4200   A 280
      J2=J1+1                                                          LOWE4210   A 281
      J=J1+1                                                           LOWE4220   A 283
      YN1=YN                                                           LOWE4230   A 282
      IF (H2.GT.Z(J1+1).OR.H1.EQ.H2) GO TO 30                          LOWE4240   A 284
      IF (NP1.EQ.1.AND.H2.GE.Z(J1+1)) GO TO 30                         LOWE4250   A 285
      CALL POINT (H2,YN,N,NP2,TX,IP)                                   LOWE4260   A 286
      DO 29 K=1,KMAX                                                   LOWE4270     NEW
29    W(K)=TX(K)                                                       LOWE4280   A 288
      TX2=TX(9)                                                        LOWE4290   A 289
      YN2=YN                                                           LOWE4300   A 290
      IF (H2.LT.H1) H=H2                                               LOWE4310   A 291
      J2=N                                                             LOWE4320   A 292
      IF (J1.EQ.J2) TX2=TX1+YN2-EH(9,N)                                LOWE4330   A 293
      IF (H2.GT.H1) TX1=TX2                                            LOWE4340   A 294
      IF (J1.EQ.J2.AND.H2.LT.H1) YN1=TX2                               LOWE4350   A 295
30    A0=(RE+H1)*SPHI*YN1                                              LOWE4360   A 296
      IF (H2.GE.H1) YN2=YN1                                            LOWE4370   A 297
      DO 31 I=1,J1                                                     LOWE4380   A 298
      HMIN=A0/EH(9,I)-RE                                               LOWE4390   A 299
      IF (I.EQ.J1) HMIN=A0/YN1-RE                                      LOWE4400   A 300
      JMIN=I                                                           LOWE4410   A 301
      IF (HMIN.LE.Z(I+1)) GO TO 32                                     LOWE4420   A 302
31    CONTINUE                                                         LOWE4430   A 303
32    X=HMIN                                                           LOWE4440   A 304
      IF (HMIN.LE.0) GO TO 34                                          LOWE4450   A 305
      CALL POINT (X,YN,N,NP,TX,IP)                                     LOWE4460   A 306
      JMIN=N                                                           LOWE4470   A 307
      TX3=TX(9)                                                        LOWE4480   A 308
      IF (J2.EQ.N.OR.J1.EQ.N) TX3=YN2+TX(9)-EH(9,N)                    LOWE4490   A 309
      IF(TX3.LT.0.0)TX3=TX(9)                                          LOWE4500   A 309*
```

Table A1. Listing of Fortran Code LOWTRAN 4 (Cont)

```
      IF (J1.EQ.N.AND.H2.GT.H1) GO TO 33                                LOWE4510    A 310
      HMIN=A0/TX3-RE                                                    LOWE4520    A 311
      IF (ABS(X-HMIN).GT.0.0001) GO TO 32                               LOWE4530    A 312
33    IF (J1.EQ.N.AND.H2.GE.H1) YN1=TX3                                 LOWE4540    A 313
      IF (J2.EQ.N.AND.J1.NE.J2) YN2=TX3                                 LOWE4550    A 314
      IF (H2.GE.H1) TX2=TX3                                             LOWE4560    A 315
      IF (H2.GE.H1) J2=N                                                LOWE4570    A 316
      IF (H2.GE.H1.OR.H2.LT.HMIN) H=HMIN                                LOWE4580    A 317
      PRINT 436, HMIN                                                   LOWE4590    A 318
      IF(H2.LT.HMIN)J2=N                                                LOWE4600    A 318*
      IF (H2.LT.HMIN) PRINT 440, HMIN                                   LOWE4610    A 319
      GO TO 36                                                          LOWE4620    A 320
34    PRINT 436, HMIN                                                   LOWE4630    A 321
      IF (H2.LT.H1) GO TO 35                                            LOWE4640    A 322
      IF (ITYPE.EQ.3.OR.H2.GE.H1) PRINT 437                             LOWE4650    A 323
      ITYPE=2                                                           LOWE4660    A 324
      TX2=EH(9,1)                                                       LOWE4670    A 325
      JMIN=0                                                            LOWE4680    A 326
      J2=1                                                              LOWE4690    A 327
      H2=0.0                                                            LOWE4700    A 328
      H=0.0                                                             LOWE4710    A 329
C**** NOW DEFINE VERTICAL PATH QUANTITIES VH(1-8)                       LOWE4720    A 330
35    IF (JF.EQ.0) PRINT 420                                            LOWE4730    A 331*
      JSTOR=J-1                                                         LOWE4740      NEW
      DO 40 I=1,NL                                                      LOWE4750    A 332
      J=J-1                                                             LOWE4760    A 333
      REF=EH(9,J)                                                       LOWE4770    A 334
      IF (I.EQ.1) REF=YN1                                               LOWE4780    A 335
      IF (I.EQ.1.AND.K2.EQ.1) REF=YN2                                   LOWE4790    A 336
      IF (J.EQ.J2.AND.K2.EQ.0) REF=TX2                                  LOWE4800    A 337
      IF (I.NE.1) X1=Z(J+1)                                             LOWE4810    A 338
      X2=Z(J)                                                           LOWE4820    A 339
      IF (J.EQ.J2.AND.K2.EQ.0) X2=H                                     LOWE4830    A 340
      IF (J.EQ.JMIN.AND.K2.EQ.1) X2=HMIN                                LOWE4840    A 341
      HM=(RE+X1)*SPHI-RE                                                LOWE4850    A 342
      IF (HM.GT.Z(J).AND.HM.GT.X2) X2=HM                                LOWE4860    A 343
      RX=(RE+X1)/(RE+X2)                                                LOWE4870    A 344
      DS=X1-X2                                                          LOWE4880    A 345
      ALP=90.0                                                          LOWE4890    A 346
      THET=ASIN(SPHI)/CA                                                LOWE4900    A 347
      SALP=RX*SPHI                                                      LOWE4910    A 348
      IF (ABS(X2-HM).GT.1.0E-5) ALP=ASIN(SALP)/CA                       LOWE4920    A 349
      BET=ALP-THET                                                      LOWE4930    A 350
      IF (SPHI.GT.1.0E-10) DS=(RE+X2)*SIN(BET*CA)/SPHI                  LOWE4940    A 351
      THETA=180.0-THET                                                  LOWE4950    A 352
      BETA=BETA+BET                                                     LOWE4960    A 353
      PSI=BETA-ALP-ANGLE+180.0                                          LOWE4970    A 354
      SR=SR+DS                                                          LOWE4980    A 355
      DO 1039 K=1,KMAX                                                  LOWE4990      NEW
      AJ=EH(K,J)                                                        LOWE5000    A 357
```

Table A1. Listing of Fortran Code LOWTRAN 4 (Cont)

```
      BJ=EH(K,J+1)                                                          LOWE5010    A 358
      IF (J.EQ.J1) BJ=E(K)                                                  LOWE5020    A 359
      IF (J.EQ.J2.AND.H2.LT.H1.AND.H2.GT.0.0) AJ=W(K)                       LOWE5030    A 360
      IF (J.EQ.JMIN.AND.H2.GE.H1) AJ=TX(K)                                  LOWE5040    A 361
      IF (J.EQ.JMIN.AND.ABS(H2-HM).LT.1.0E-5) AJ=TX(K)                      LOWE5050    A 362
      IF (K2.EQ.0) GO TO 36                                                 LOWE5060    A 363
      IF (J.EQ.J2) BJ=W(K)                                                  LOWE5070    A 364
      IF (J.EQ.JMIN) AJ=TX(K)                                               LOWE5080    A 365
36    IF (AJ.EQ.0.0.OR.BJ.EQ.0.0) GO TO 38                                  LOWE5090    A 366
      IF (AJ.EQ.BJ) GO TO 37                                                LOWE5100    A 367
      EV=DS*(AJ-BJ)/ALOG(AJ/BJ)                                             LOWE5110    A 368
      GO TO 39                                                              LOWE5120    A 369
37    EV=DS*AJ                                                              LOWE5130    A 370
      GO TO 39                                                              LOWE5140    A 371
38    EV=0.0                                                                LOWE5150    A 372
39    VH(K)=VH(K)+EV                                                        LOWE5160    A 373
10.39 HLAY(J,K)=EV                                                          LOWE5170      NEW
      IF (JP.EQ.0) PRINT 435, J,X1,(VH(L),L=1,8),PSI,ALP,BETA,THETA,SR      LOWE5180    A 374*
      IF (J.EQ.J2.AND.H2.GE.H1) GO TO 45                                    LOWE5190    A 375
      IF (J.EQ.JMIN.AND.K2.EQ.1) GO TO 43                                   LOWE5200    A 376
      IF (J.NE.1) RN=REF/EH(9,J-1)                                          LOWE5210    A 377
      IF (J.EQ.J2+1) RN=REF/TX2                                             LOWE5220    A 378
      IF (J.EQ.J2.AND.K2.EQ.0) RN=REF/YN2                                   LOWE5230    A 379
      IF (J.EQ.(JMIN+1).AND.K2.EQ.1) RN=REF/TX3                             LOWE5240    A 380
      IF (SALP.GE.RN) RN=1.0                                                LOWE5250    A 381
      SPHI=SALP*RN                                                          LOWE5260    A 382
      IF (J.EQ.J2.AND.K2.EQ.0) GO TO 41                                     LOWE5270    A 383
40    CONTINUE                                                              LOWE5280    A 384
41    IF (HMIN.LE.0) GO TO 47                                               LOWE5290    A 385
      IF (LEN.EQ.1) PRINT 438                                               LOWE5300    A 386
      IF (LEN.EQ.0) GO TO 47                                                LOWE5310    A 387
      IF (LEN.EQ.1) PRINT 439                                               LOWE5320    A 388
      K2=1                                                                  LOWE5330    A 389
      X1=X2                                                                 LOWE5340    A 390
      IF (ABS(X1-HMIN).LE.0.001) GO TO 47                                   LOWE5350    A 391
      H=HMIN                                                                LOWE5360    A 392
      J=J2+1                                                                LOWE5370    A 393
      IF (NP2.EQ.1) J=J-1                                                   LOWE5380    A 394
      B=BETA                                                                LOWE5390    A 395
      PH=180.0-ASIN(SPHI)/CA                                                LOWE5400    A 396
      TS=SR                                                                 LOWE5410    A 397
      PS=PSI                                                                LOWE5420    A 398
      DO 42 K=1,KMAX                                                        LOWE5430      NEW
42    E(K)=VH(K)                                                            LOWE5440    A 400
      GO TO 35                                                              LOWE5450    A 401
43    BETA=2.*BETA-B                                                        LOWE5460    A 402
      PSI=2.*PSI-PS                                                         LOWE5470    A 403
      SR=2.*SR-TS                                                           LOWE5480    A 404
C      LONG PATH  TAKEN                                                     LOWE5490    A 405
      PHI=PH                                                                LOWE5500    A 406
```

Table A1. Listing of Fortran Code LOWTRAN 4 (Cont)

```
      DO 44 K=1,KMAX                                                    LOWE5510      NEW
44    VH(K)=2.*VH(K)-T(K)                                               LOWE5520    A 408
      GO TO 47                                                          LOWE5530    A 409
45    DO 46 K=1,KMAX                                                    LOWE5540      NEW
46    VH(K)=2.0*VH(K)                                                   LOWE5550    A 411
      BETA=2.0*BETA                                                     LOWE5560    A 412
      SR=2.0*SR                                                         LOWE5570    A 413
      IF (H2.EQ.H1) GO TO 47                                            LOWE5580    A 414
      RN=IX1/XN1                                                        LOWE5590    A 415
      SPHI=SIN(ANGLE*CA)                                                LOWE5600    A 416
      IF (SPHI.LT.RN) SPHI=SPHI/RN                                      LOWE5610    A 417
      GO TO 19                                                          LOWE5620    A 418
47    CONTINUE                                                          LOWE5630    A 419
       IF(ANGLE.GT.90.0) PRINT 406,HH                                   LOWE5640    A 419A
      DO 48 K=1,KMAX                                                    LOWE5650      NEW
      W(K)=VH(K)                                                        LOWE5660    A 421
48    CONTINUE                                                          LOWE5670    A 422
49    WRITE (6,419)                                                     LOWE5680    A 423
      WRITE (6,1155)                                                    LOWE5690      NEW
      WRITE(6,421) (W(I),I=1,8),W(11),W(11)                             LOWE5700      NEW
      WRITE(7,3000) M,IHAZE,ITYPE,H1,ANGLE,HMIN,V1,V2,DV                LOWE5710      NEW
 3000 FORMAT(313,6F11.4)                                                LOWE5720      NEW
      I=1                                                               LOWE5730    A 425
      L=1                                                               LOWE5740    A 426
      IV1=V1/5.0                                                        LOWE5750    A 427
      IV2=V2/5.+.99                                                     LOWE5760    A 428
      IV1=5*IV1                                                         LOWE5770    A 429
      IV2=5*IV2                                                         LOWE5780    A 430
      IF (IV1.LT.350) IV1=350                                           LOWE5790    A 431
      IF (IV2.GT.50000) IV2=50000                                       LOWE5800    A 432
      IF (DV.LT.5.) DV=5.                                               LOWE5810    A 433
      IDV=DV                                                            LOWE5820    A 434
      IV=IV1-IDV                                                        LOWE5830    A 435
      ICOUNT=0                                                          LOWE5840    A 436
      IF(IEMISS.EQ.0) GO TO 50                                          LOWE5850      NEW
      RADSUM=0.0                                                        LOWE5860      NEW
      FACTOR=0.5                                                        LOWE5870      NEW
      CALL PATH(WLAY,WPATH,TBOY)                                        LOWE5880      NEW
      PRINT 1156                                                        LOWE5890      NEW
      PRINT 1157                                                        LOWE5900      NEW
      IF(IEMISS.EQ.0) IKMAX=IKLO                                        LOWE5910      NEW
C**** BEGINING OF TRANSMITTANCE CALCULATIONS                            LOWE5920    A 437
50    IV=IV+IDV                                                         LOWE5930    A 438A
      SUMV=0.                                                           LOWE5940      NEW
      TLOLD=1.      $  TSOLD=1.                                         LOWE5950      NEW
       IKLO=1                                                           LOWE5960      NEW
      IF(IEMISS.EQ.0) IKLO=IKMAX                                        LOWE5970      NEW
       DO 1050 IK=IKLO,IKMAX                                            LOWE5980      NEW
      IF(IEMISS.EQ.0) GO TO 1056                                        LOWE5990      NEW
       DO 1052 K=1,KMAX                                                 LOWE6000      NEW
```

Table A1. Listing of Fortran Code LOWTRAN 4 (Cont)

```
      W(K)=WPATH(IK,K)                                          LOWE6010      NEW
 1052 CONTINUE                                                  LOWE6020      NEW
1055  IJ=IK                                                     LOWE6030      NEW
      IF(JP.NE.0) GO TO 52                                      LOWE6040    A 438
      IF (ICOUNT.EQ.0) GO TO 51                                 LOWE6050    A 439
      IF (ICOUNT.EQ.50) GO TO 51                                LOWE6060    A 440
      GO TO 52                                                  LOWE6070    A 441
51    ICOUNT=0                                                  LOWE6080    A 442
      IF(ICMISS.EQ.0) PRINT 422                                 LOWE6090      NEW
52    DO 53 K=1,KMAX                                            LOWE6100      NEW
      TX(K)=0.0                                                 LOWE6110    A 445
      IF (K.LT.4) TX(K)=1.0                                     LOWE6120    A 446
53    CONTINUE                                                  LOWE6130    A 447
      ICOUNT=ICOUNT+1                                           LOWE6140    A 448
      SUM=0.0                                                   LOWE6150    A 449
      V=IV                                                      LOWE6160    A 450
      I=(IV-350)/5+1                                            LOWE6170    A 451
C   ********************  HNO3                                  LOWE6180      NEW
C     HNO3 ABSORPTION CALCULATION                               LOWE6190      NEW
      CALL HNO3 (V,HABS)                                        LOWE6200      NEW
      TX(11)=HABS*W(11)                                         LOWE6210      NEW
      SUM=SUM+TX(11)                                            LOWE6220      NEW
      IF(IV.LT.670) GO TO 72                                    LOWE6230   *A 452*
      IF(IV.LE.3000) GO TO 61                                   LOWE6240   *A 453*
C********   MOLECULAR SCATTERING                                LOWE6250    A 454
      C6=9.807E-21*(V**4.0117)                                  LOWE6260    A 455
      TX(6)=C6*W(6)                                             LOWE6270    A 456
      SUM=SUM+TX(6)                                             LOWE6280    A 457
      IF (IV.LT.9200) GO TO 72                                  LOWE6290    A 458
      IF (IV.LT.13000) GO TO 69                                 LOWE6300    A 459
C********  UV OZONE                                             LOWE6310    A 460
      IF (IV.LE.23400) GO TO 54                                 LOWE6320    A 461
      IF (IV.GE.27500) GO TO 55                                 LOWE6330    A 462
      GO TO 67                                                  LOWE6340    A 463
54    XX=200.0                                                  LOWE6350    A 464
      XI=(V-13000.0)/XX+1.0                                     LOWE6360    A 465
      L1=1                                                      LOWE6370    A 466
      L2=53                                                     LOWE6380    A 467
      GO TO 56                                                  LOWE6390    A 468
55    XX=500.0                                                  LOWE6400    A 469
      XI=(V-27500.0)/XX+57.0                                    LOWE6410    A 470
      L1=57                                                     LOWE6420    A 471
      L2=102                                                    LOWE6430    A 472
56    DO 57 N=L1,L2                                             LOWE6440    A 473
      XD=XI-FLOAT(N)                                            LOWE6450    A 474
      IF (XD) 59,58,57                                          LOWE6460    A 475
57    CONTINUE                                                  LOWE6470    A 476
58    TX(8)=W(8)*C8(N)                                          LOWE6480    A 477
      GO TO 60                                                  LOWE6490    A 478
59    TX(8)=C8(N)+XD*(C8(N)-C8(N-1))                            LOWE6500    A 479
```

Table A1. Listing of Fortran Code LOWTRAN 4 (Cont)

```
      TX(8)=W(8)*TX(8)                                                  LOWE6510     A 480
60    SUM=SUM+TX(8)                                                     LOWE6520     A 481
      IF(IV.GT.14500)GO TO 87                                           LOWE6530     A 482*
      GO TO 59                                                          LOWE6540     A 483
C********  WATER VAPOR CONTINUUM 10 MICRON REGION                       LOWE6550    *A 484
61    IF(IV.GT.1350) GO TO 62                                           LOWE6560    *A 485
      TX(5)=(4.18+5578.0*EXP(-7.87E-3*V))*W(5)                          LOWE6570    *A 486
      GO TO 66                                                          LOWE6580    *A 487
62    IF(IV.LT.2350) GO TO 68                                           LOWE6590    *A 488
C********  WATER VAPOR CONTINUUM 4 MICRON REGION                        LOWE6600    *A 489
      XI=(V-2350.0)/50.0+1.0                                            LOWE6610    *A 490
      NH=XI+1.001                                                       LOWE6620    *A 491
      XH=XI-FLOAT(NH)                                                   LOWE6630    *A 492
      TX(5)=C5(NH)                                                      LOWE6640    *A 493
64    TX(5)=TX(5)+XH*(C5(NH)-C5(NH-1))                                  LOWE6650    *A 496
65    TX(5)=TX(5)*W(10)                                                 LOWE6660    *A 497
66    SUM=SUM+TX(5)                                                     LOWE6670    *A 498
      IF(IV.LE.1350.OR.IV.GT.2740) GO TO 72                             LOWE6680    *A 499
C********  NITROGEN CONTINUUM                                           LOWE6690     A 500
68    IF (IV.LT.2080) GO TO 72                                          LOWE6700     A 501
      K4=I-346                                                          LOWE6710     A 502
      TX(4)=C4(K4)*W(4)                                                 LOWE6720     A 503
      SUM=SUM+TX(4)                                                     LOWE6730     A 504
      GO TO 72                                                          LOWE6740     A 505
C********  WATER VAPOUR                                                 LOWE6750     A 506
69    IF (IV.LT.12800.AND.IV.GE.9875) GO TO 70                          LOWE6760     A 507
      IF (IV.LE.14520.AND.IV.GE.13400) GO TO 71                         LOWE6770     A 508
      GO TO 76                                                          LOWE6780     A 509
70    I=I-135                                                           LOWE6790     A 510
      GO TO 72                                                          LOWE6800     A 511
71    I=I-255                                                           LOWE6810     A 512
72    K1=1                                                              LOWE6820     A 513
      IF (W(1).LT.1.01-20) GO TO 76                                     LOWE6830     A 514
      WS1=ALOG10(W(1))+C1(I)                                            LOWE6840     A 515
      IF (WS1.LT.-2.3468) TX(1)=1.-.087787*EXP(1.855595*WS1)            LOWE6850       NEW
      IF (WS1.LT.-2.3468) GO TO 76                                      LOWE6860     A 516
      IF (WS1.GT.3.9682) GO TO 75                                       LOWE6870     A 517
      IF (WS1.GT.2.0) K1=40                                             LOWE6880     A 518
      DO 73 K=K1,67                                                     LOWE6890     A 519
      IF (WS1.LE.FW(K)) GO TO 74                                        LOWE6900     A 520
73    CONTINUE                                                          LOWE6910     A 521
74    TX(1)=TR(K)+(TR(K-1)-TR(K))*(FW(K)-WS1)/(FW(K)-FW(K-1))           LOWE6920     A 522
      GO TO 76                                                          LOWE6930     A 523
75    TX(1)=0.0                                                         LOWE6940     A 524
76    CONTINUE                                                          LOWE6950     A 525
C********  UNIFORMLY MIXED GASES                                        LOWE6960     A 526
      IF (IV.LT.8060.AND.IV.GE.500) GO TO 77                            LOWE6970     A 527
      IF (IV.LT.13190.AND.IV.GT.12970) GO TO 78                         LOWE6980     A 528
      GO TO 83                                                          LOWE6990     A 529
77    J=I-30                                                            LOWE7000     A 530
```

Table A1. Listing of Fortran Code LOWTRAN 4 (Cont)

```
      GO TO 79                                                          LOWE7010    A 531
78    J=(IV-12950)/5+1516                                               LOWE7020    A 532
79    IF(W(2).LT.1.0E-20) GO TO 83                                      LOWE7030    A 533*
      K1=1                                                              LOWE7040    A 534
      WS2=ALOG10(W(2))+C2(J)                                            LOWE7050    A 535
      IF (WS2.LT.-2.3468) TX(2)=1.-.087747*EXP(1.855595*WS2)            LOWE7060      NEW
      IF (WS2.LT.-2.3468) GO TO 82                                      LOWE7070    A 536
      IF (WS2.GT.3.5682) GO TO 82                                       LOWE7080    A 537
      IF (WS2.GT.2.0) K1=40                                             LOWE7090    A 538
      DO 80 K=K1,67                                                     LOWE7100    A 539
      IF (WS2.LE.FW(K)) GO TO 81                                        LOWE7110    A 540
80    CONTINUE                                                          LOWE7120    A 541
81    TX(2)=TR(K)+(TR(K-1)-TR(K))*(FW(K)-WS2)/(FW(K)-FW(K-1))           LOWE7130    A 542
      GO TO 83                                                          LOWE7140    A 543
82    TX(2)=0.0                                                         LOWE7150    A 544
83    CONTINUE                                                          LOWE7160    A 545
C******** OZONE                                                         LOWE7170    A 546
      IF (IV.LT.575.OR.IV.GT.3270) GO TO 87                             LOWE7180    A 546*
      L=I-45                                                            LOWE7190    A 547
      K1=1                                                              LOWE7200    A 548
      IF (W(3).LT.1.0E-20) GO TO 87                                     LOWE7210    A 549
      WS3=ALOG10(W(3))+C3(L)                                            LOWE7220    A 550
      IF (WS3.LT.-1.6778) TX(3)=1.-.055194*EXP(2.367853*WS3)            LOWE7230      NEW
      IF (WS3.LT.-1.6778) GO TO 87                                      LOWE7240    A 551
      IF (WS3.GT.3.9345) GO TO 86                                       LOWE7250    A 552
      IF (WS3.GT.1.5) K1=36                                             LOWE7260    A 553
      DO 84 K=K1,67                                                     LOWE7270    A 554
      IF (WS3.LE.FO(K)) GO TO 85                                        LOWE7280    A 555
84    CONTINUE                                                          LOWE7290    A 556-
85    TX(3)=TR(K)-(TR(K)-TR(K-1))*(FO(K)-WS3)/(FO(K)-FO(K-1))           LOWE7300    A 558
      GO TO 87                                                          LOWE7310    A 559
86    TX(3)=0.0                                                         LOWE7320    A 560
87    CONTINUE                                                          LOWE7330    A 561
C******** AEROSOL EXTINCTION                                            LOWE7340    A 562
      ALAM=1.0E+4/V                                                     LOWE7350    A 563A
      XX=0.0                                                            LOWE7360    A 563B
      YY=0.0                                                            LOWE7370    A 563C
C******** TEMPORARY FOG CORRECTION FOR VIS BELOW 2 KM.                  LOWE7380    A 563D
C     IF(VIS.GT.0.0.AND.VIS.LT.2.0)  XX=0.168                           LOWE7390      NEW
C        TEMPORARY FOG SUPPRESSED                                       LOWE7400      NEW
      IF (IHAZE.EQ.0.OR.XX.GT.0.0)   GO TO 90                           LOWE7410    A 564*
      DO 88 N=1,44                                                      LOWE7420    A 565*
      XD=ALAM-VX(N)                                                     LOWE7430    A 566*
      IF(XD)89,88,88                                                    LOWE7440    A 567*
88    CONTINUE                                                          LOWE7450    A 568A
89    XX=(C7(N)-C7(N-1))*XD/(VX(N)-VX(N-1))+C7(N)                       LOWE7460    A 568B
      YY=(C7A(N)-C7A(N-1))*XD/(VX(N)-VX(N-1))+C7A(N)                    LOWE7470    A 568C
90    TX(10)=YY*W(7)                                                    LOWE7480    A 568D
      TX(7)=XX*W(7)                                                     LOWE7490    A 569*
      SUM=SUM+TX(7)                                                     LOWE7500    A 570
```

Table A1. Listing of Fortran Code LOWTRAN 4 (Cont)

```
      TX(9)=SUM                                                          LOWE7510     A 571
      DO 94 K=4,KMAX                                                     LOWE7520       NEW
      IF (TX(K).EQ.0.0) GO TO 92                                         LOWE7530     A 573
      IF (TX(K).LE.0.1) GO TO 91                                         LOWE7540     A 574
      IF (TX(K).GT.20.) GO TO 93                                         LOWE7550     A 575
      TX(K)=EXP(-TX(K))                                                  LOWE7560     A 576
      GO TO 94                                                           LOWE7570     A 577
91    TX(K)=1.0-TX(K)+0.5*TX(K)*TX(K)                                    LOWE7580     A 578
      GO TO 94                                                           LOWE7590     A 579
92    TX(K)=1.0                                                          LOWE7600     A 580
      GO TO 94                                                           LOWE7610     A 581
93    TX(K)=0.                                                           LOWE7620     A 582
94    CONTINUE                                                           LOWE7630     A 583
      TX(9)=TX(1)*TX(2)*TX(3)*TX(9)                                      LOWE7640     A 584
      IF (IV.GE.13000) TX(3)=TX(8)                                       LOWE7650     A 585
      IF(IEMISS.EQ.0) GO TO 1210                                         LOWE7660       NEW
      ALAM=1.0E+04/V                                                     LOWE7670       NEW
       BBIK =FF(TBBY(IK),V)                                              LOWE7680       NEW
      TLNEW    =(TX(9)*TX(10))/(TX(7)*TX(6))                             LOWE7690       NEW
      TSNEW     =(TX(7)*TX(6))/TX(10)                                    LOWE7700       NEW
       DTAU=TLOLD-TLNEW                                                  LOWE7710       NEW
      IF (DTAU.LT.1.0E-5.AND.TLNEW    .LT.1.0E-5) GO TO 1104             LOWE7720       NEW
      SUMV=SUMV+0.5*BBIK*DTAU*(TSOLD+TSNEW)                              LOWE7730       NEW
       TLOLD=TLNEW      $  TSOLD=TSNEW                                   LOWE7740       NEW
1050  CONTINUE                                                           LOWE7750       NEW
1104  CONTINUE                                                           LOWE7760       NEW
      TAUG=0                                                             LOWE7770       NEW
       IF(HMIN.LE.0.0.AND.IL.EQ.1) TAUG=TX(9)                            LOWE7780       NEW
      T1=T(M,1)                                                          LOWE7790       NEW
      IF(TBOUND.GT.0.0) T1=TBOUND                                        LOWE7800       NEW
      BBG=FF(T1,V)*TAUG                                                  LOWE7810       NEW
      IF (HMIN.LE.0) SUMV=SUMV+BBG                                       LOWE7820       NEW
      SUMVV=SUMV                                                         LOWE7830       NEW
      IF (IV.GT.IV1) FACTOR=1.0                                          LOWE7840       NEW
      IF (IV.GE.IV2) FACTOR=0.5                                          LOWE7850       NEW
      SUMV=(1.0E+04/V**2)*SUMV                                           LOWE7860       NEW
      RADSUM=RADSUM+DV*FACTOR*SUMV                                       LOWE7870       NEW
      IF(JP.EQ.0) PRINT 1160, V,ALAM,SUMV,SUMVV,RADSUM,TX(9)             LOWE7880       NEW
      IF(SUMV.GE.RADMAX) VRMAX=V                                         LOWE7890       NEW
      IF(SUMV.GE.RADMAX)  RADMAX=SUMV                                    LOWE7900       NEW
      IF(SUMV.LE.RADMIN) VRMIN=V                                         LOWE7910       NEW
      IF(SUMV.LE.RADMIN) RADMIN=SUMV                                     LOWE7920       NEW
       WRITE(7,3010) V,SUMV,SUMVV,RADSUM,TX(9),TX(1)                     LOWE7930       NEW
3010  FORMAT(F10.1,11F10.3)                                              LOWE7940       NEW
1210  TX(10)=1.-TX(10)                                                   LOWE7950       NEW
      AB=1.-TX(9)                                                        LOWE7960     A 5868
      IF(IV.EQ.IV1.OR.IV.EQ.IV2) AB=0.5*AB                               LOWE7970     A 5869
      SUMA=SUMA+AB*DV                                                    LOWE7980     A 5870
      IF(IEMISS.EQ.1) GO TO 1220                                         LOWE7990       NEW
      IF(JP.EQ.0) WRITE(6,423) IV,ALAM,TX(9),(TX(K),K=1,7),TX(10),SUMA   LOWE8000     A 5871
```

Table A1. Listing of Fortran Code LOWTRAN 4 (Cont)

```
 1220 CONTINUE                                                          LOWE8010      NEW
      IF (IV.GE.IV2) GO TO 95                                           LOWE8020    A 588
      GO TO 90                                                          LOWE8030    A 589
 95   READ 400, IXY                                                     LOWE8040    A 590
      IF(IEMISS.EQ.1)PRINT 1175,VRMIN,RADMIN,VRMAX,RADMAX               LOWE8050      NEW
 1175  FORMAT(* RADMIN * ,F12.3,E12.5,/,* RADMAX *,F12.3,F12.5)         LOWE8060      NEW
       ENDFILE 7                                                        LOWE8070      NEW
      JSTOR=0  $  IFIND=0                                               LOWE8080      NEW
      AB=1.0-SUMA/FLOAT(IV2-IV1)                                        LOWE8090      NEW
      PRINT 424, IV1,IV2,SUMA,AB                                        LOWE8100    A 591B
      IF(IEMISS.EQ.1) PRINT 443,RADSUM                                  LOWE8110      NEW
 443  FORMAT(* INTEGRATED RADIANCE =*,E12.5,*WATT CM -2  SR*)           LOWE8120      NEW
      PRINT 400,IXY                                                     LOWE8130    A 591C
      IF(IXY.EQ.0) GO TO 100                                            LOWE8140    A 591D
      GO TO 96,2,97,98,1001,IXY                                         LOWE8150    A 591E
 96   READ 406, V1,V2,DV                                                LOWE8160    A 592
      AVH=10000./V1                                                     LOWE8170    A 593
      ALAM=10000./V2                                                    LOWE8180    A 594
      PRINT 418, V1,V2,DV,ALAM,AVH                                      LOWE8190    A 595
      SUMA=0.0                                                          LOWE8200    A 596*
      GO TO 47                                                          LOWE8210      NEW
 97   IF(MODEL.EQ.0) GO TO 200                                          LOWE8220    A 598A
      GO TO 300                                                         LOWE8230    A 598B
 98   READ 400,MODEL,IHAZE,ITYPE,LEN,JP,IM,M1,M2,M3,ML,IEMISS,RO,TBOUND LOWE8240      NEW
      IF(IEMISS.EQ.1) PRINT 1170                                        LOWE8250      NEW
      IF(IEMISS.EQ.0) PRINT 1171                                        LOWE8260      NEW
      LENSTOR=LEN                                                       LOWE8270      NEW
      PRINT 400,MODEL,IHAZE,ITYPE,LEN,JP,IM,M1,M2,M3,ML,IEMISS,RO,TBOUND LOWE8280     NEW
      GO TO 200                                                         LOWE8290    A 598E
 100  STOP                                                              LOWE8300    A 599*
 400  FORMAT(11I3,2F10.3)                                               LOWE8310      NEW
 1170 FORMAT(*1 PROGRAM WILL BE EXECUTED IN THE EMISSION MODE*)         LOWE8320      NEW
 1171 FORMAT(*1 PROGRAM WILL BE EXECUTED IN THE TRANSMISSION MODE*)     LOWE8330      NEW
 401  FORMAT (8F10.3)                                                   LOWE8340    A 601
 402  FORMAT (F6.1,2(F10.3,F6.1,2E10.3))                                LOWE8350    A 602
 403  FORMAT (4(F6.3,2F7.4))                                            LOWE8360    A 603
 404  FORMAT (15F5.2)                                                   LOWE8370    A 604
 405  FORMAT (8E9.2)                                                    LOWE8380    A 605
 406  FORMAT (7F10.3)                                                   LOWE8390    A 606
 407  FORMAT (//10X,28H HORIZONTAL PATH, ALTITUDE =,F7.3,11H KM,RANGE =,LOWE8400    A 607
     1F7.3,3H KM)                                                       LOWE8410    A 608
 408  FORMAT (//10X,50H SLANT PATH BETWEEN ALTITUDES H1 AND H2 WHERE H1 LOWE8420    A 609
     1=,F7.3,8H KM H2 =,F7.3,18H KM,ZENITH ANGLE =,F7.3,8H DEGREES)     LOWE8430    A 610
 409  FORMAT (//10X,39H SLANT PATH TO SPACE FROM ALTITUDE H1 =,F7.3,19H LOWE8440    A 611
     1KM, ZENITH ANGLE =,F7.3,8H DEGREES)                               LOWE8450    A 612
 410  FORMAT (/20X,18H MODEL ATMOSPHERE ,I1,11H = TROPICAL)             LOWE8460    A 613
 411  FORMAT (/20X,18H MODEL ATMOSPHERE ,I1,21H = MIDLATITUDE SUMMER)   LOWE8470    A 614
 412  FORMAT (/20X,18H MODEL ATMOSPHERE ,I1,21H = MIDLATITUDE WINTER)   LOWE8480    A 615
 413  FORMAT (/20X,18H MODEL ATMOSPHERE ,I1,21H = SUB-ARCTIC SUMMER )   LOWE8490    A 616
 414  FORMAT (/20X,18H MODEL ATMOSPHERE ,I1,21H = 1962 US STANDARD  )   LOWE8500    A 617
```

Table A1. Listing of Fortran Code LOWTRAN 4 (Cont)

```
415   FORMAT (/20X,18H MODEL ATMOSPHERE ,I1,21H = SUB-ARCTIC WINTER )   LOWE8510    A 618
416   FORMAT (/20X,18H       HAZE MODEL ,I1,3H = ,A5,13H VISUAL RANGE)  LOWE8520    A 619
417   FORMAT (/25X*HAZE MODEL  =*,F5.1,* KM VISUAL RANGE AT SEA LEVEL*) LOWE8530    A 620
418   FORMAT (/10X,21H FREQUENCY RANGE V1= ,F7.1,13H CM-1 TO V2= ,F7.1,1LOWE8540    A 621
     14H CM-1 FOR DV =,F6.1,9H CM-1   (,F6.2,* - *,F6.2,* MICRONS )*)   LOWE8550    A 622
419   FORMAT (/10X,36H EQUIVALENT SEA LEVEL ABSORBER AMOUNTS//21X110HWATLOWE8560    A 623
     1ER VAPOUR     CO2 ETC.       OZONE    NITROGEN (CONT)  H2O (CONT) LOWE8570    A 624
     2    MOL  SCAT      AEROSOL      OZONE(V-V)/24X,7HGM CM-2,13X,2HKM,1LOWE8580    A 625
     30X,6HATM CM,10X,2HKM,9X,7HGM CM-2,10X,2HKM,13X,2HKM,10X,6HATM CM) LOWE8590    A 626
420   FORMAT (1H1,///10X,*  VERTICAL PROFILES  *,64X,*PSI*,6X,*PHI*,6X,*LOWE8600    A 627
     1BETA*,4X,*THETA     RANGE*)                                       LOWE8610    A 628
421   FORMAT (/10X,8H W(1-8)=8(E14.3)/ 74X,E14.3,28X,E14.3/)             LOWE8620      NEW
422   FORMAT (1H1,/10X,32H  FREQ WAVELENGTH  TOTAL      H2O,5X4HCO2+,6X,6LOWE8630    A 630*
     14HOZONE   N2 CONT   H2O CONT MOL SCAT  AEROSOL  AEROSOL   INTEGRATEDLOWE8640    A 631*
     2 /11X,14H CM-1   MICRONS,8(4X6HTRANS),4X,20H ABS      ABSORPTION )  LOWE8650    A 632*
  423 FORMAT(13X,I6,11F9.4      )                                         LOWE8660      NEW
424   FORMAT (* INTEGRATED ABSORPTION FROM*,I5,* TO*,I5,* CM-1 =*,F10.3,LOWE8670    A 633A
     1*,AVERAGE TRANSMITTANCE =*,F6.4)                                   LOWE8680    A 634A
425   FORMAT (10X,7E10.3)                                               LOWE8690    A 635
426   FORMAT (/20X,*AEROSOL SCATTERING NOT COMPUTED,IHAZE=0*)           LOWE8700    A 636
427   FORMAT (1H1,///10X,20H HORIZONTAL PROFILES/)                      LOWE8710    A 637
428   FORMAT (10X,* H1=*,F7.3,*KM,H2=*,F7.3,*KM,ANGLE=*,F6.4,*GEOM. RANGLOWE8720    A 638
     1E =*,F7.2,*KM,BETA=*,F8.5,*,VIS=*,F6.1)                          LOWE8730    A 639
429   FORMAT(3F10.3,2F5.1,2E10.3,2F10.3)                                LOWE8740    A 640*
430   FORMAT(10X,*INPUT METEOROLOGICAL DATA:*/10X,*Z=*,F7.2,* KM, P=*,F7LOWE8750    A 641*
     1.2,* MB,T=*,F5.1,* C, DEW PT. TEMP*,F5.1,* C, REL HUMIDITY=*,F5.1, LOWE8760    A 642*
     2* %, H2O DENSITY=*,1PE9.2,* GM M-3*/10X,* OZONE DENSITY=*,E9.2,* GLOWE8770    A 643*
     3M-3, VISUAL RANGE=*,0PF6.1,* KM,RANGE=*,F10.3,* KM *  )          LOWE8780    A 644*
431   FORMAT(6(F6.2,2F7.5))                                             LOWE8790    A 645*
432   FORMAT (* STARTING PARAMETERS H1 AND ANGLE HAVE BEEN REDEFINED:H1=LOWE8800    A 646
     1 *,F10.3,*ANGLE =*,F10.6)                                          LOWE8810    A 647
433   FORMAT (* TRAJECTORY MISSES EARTHS ATMOSPHERE, CLOSEST DISTANCE OFLOWE8820    A 648
     1 APPROACH IS*,F10.2,1X,/,1X,*END OF CALCULATION*)                  LOWE8830    A 649
434   FORMAT (10X,I4,F6.1,11(E10.3))                                    LOWE8840    A 650
435   FORMAT (I5,F7.1,8F10.3,4F9.4,F7.1)                                LOWE8850    A 651
436   FORMAT (* HMIN = *,F10.3)                                         LOWE8860    A 652
437   FORMAT (* PATH INTERSECTS EARTH - PATH CHANGED TO TYPE 2 WITH H2 =LOWE8870    A 653
     1 0.0 KM*)                                                          LOWE8880    A 654
438   FORMAT (* CHOICE OF TWO PATHS FOR THIS CASE -SHORTEST PATH TAKEN. LOWE8890    A 655
     1 FOR LONGER PATH SET LEN=1.*)                                      LOWE8900    A 656
439   FORMAT (* CHOICE OF TWO PATHS FOR THIS CASE -LONGEST PATH TAKEN.  LOWE8910    A 657
     1 FOR SHORT PATH SET LEN = 0 *)                                     LOWE8920    A 658
440   FORMAT (* H2 WAS SET LESS THAN HMIN AND HAS BEEN RESET EQUAL TO   LOWE8930    A 659
     1  HMIN I.E. H2 = *,F10.3)                                          LOWE8940    A 660
441   FORMAT(*  MODEL ATMOSPHERE NO. 7*,/ 4X,*Z (KM)*,3X,*P (MB)*,4X,  LOWE8950    A 661*
     1 *T (K) DEW PT %RH  H2O(GM.M-3) O3(GM.M-3) NO. DEN.*)              LOWE8960    A 662*
442   FORMAT(*  FOG CONDITIONS MAY EXIST AT SEA LEVEL FOR THIS VISUAL RALOWE8970    A 663*
     1NGE*,/,*  IF SO THEN ASSUME THE TRANSMITTANCE DUE TO FOG IS GIVEN LOWE8980    A 664*
     2BY THE TRANSMITTANCE AT 0.55 MICRONS*)                             LOWE8990    A 665*
1109  FORMAT (9I3)                                                      LOWE9000      NEW
```

Table A1. Listing of Fortran Code LOWTRAN 4 (Cont)

```
1155  FORMAT (118X,*NITRIC ACID*)                                          LOWE9010      NEW
1156  FORMAT (1H1,50X,*RADIANCE(WATTS/CM2-STER-XXX)*)                       LOWE9020      NEW
1157  FORMAT (30X,*FR(CM-1)   WVL(MICRON)      PER CM-1    PER MICRON*,*   LOWE9030      NEW
     1   INTEGRAL          TRANS*)                                         LOWE9040      NEW
 1160 FORMAT(30X,F8.1,F13.6,3E13.5,F13.6)                                   LOWE9050      NEW
      END                                                                   LOWE9060    A 666*
```

Table A1. Listing of Fortran Code LOWTRAN 4 (Cont)

```
      SUBROUTINE PATH(WLAY,WPATH,TBBY)                                  PATH  10      NEW
      COMMON Z(34),P(7,34),T(7,34),WH(11,34),WH(7,34),M,NL,RE,GM,CO,PI  PATH  20      NEW
      DIMENSION          WLAY(34,11),TBBY(68),WPATH(68,11)              PATH  30      NEW
      COMMON /EM1/ IEMISS,KMAX,ANGLE,LEN,HMIN,IJ,J1,J2,JMIN,JEXTRA,ITYPEPATH  40      NEW
      COMMON /EM2/ IL,IKMAX  ,LENSTOR ,NLL,W(11),E(11)                  PATH  50      NEW
      COMMON /EM3/ H1,H2,NP1 ,MODEL                                     PATH  60      NEW
       IF(ITYPE.EQ.1) GO TO 2000                                        PATH  70      NEW
      IF (ITYPE.EQ.2.AND.H1.EQ.H2) J2=J1                                PATH  80      NEW
      IF(H2.GT.H1.AND.ANGLE.GT.90..AND.NP1.EQ.1) J1=J1-1                PATH  90      NEW
      IF(JEXTRA.EQ.1) J2=J2+1                                           PATH 100      NEW
      IF((ITYPE.EQ.2).AND.(H1.GT.H2).AND.(LENSTOR.EQ.1))J2=J2-1         PATH 110      NEW
      IF(ITYPE.EQ.3) J2=NL                                              PATH 120      NEW
      PRINT 1109, J1,J2                                                 PATH 130      NEW
 1109 FORMAT(9I5)                                                       PATH 140      NEW
      PRINT 910                                                         PATH 150      NEW
  910   FORMAT    (//,23X,* CUMULATIVE ABSORBER AMOUNTS FOR THE ATMOSPHERPATH 160      NEW
     1IC PATH*,//                                                       PATH 170      NEW
     210X,*H2O*,6X,*CO2*,8X,*O3*,9X,*N2O*,8X,*H2O C*,6X,*MOL S*,7X,     PATH 180      NEW
     3 *AERO*,5X,*O3 UV*,7X,*H2O C*,7X,*HNO3*,5X,*TAVE*)                PATH 190      NEW
      DO 1057 IK=1,68                                                   PATH 200      NEW
       TBBY(IK)=0.                                                      PATH 210      NEW
      DO 1052 K=1,KMAX                                                  PATH 220      NEW
       WPATH(IK,K)=0.                                                   PATH 230      NEW
 1052 CONTINUE                                                          PATH 240      NEW
      LEN=0                                                             PATH 250      NEW
      NLL=NL-1                                                          PATH 260      NEW
      IL=J1+1                                                           PATH 270      NEW
      IJ=IL+NLL                                                         PATH 280      NEW
      DO 1060 K=1,KMAX                                                  PATH 290      NEW
      E(K)=0.                                                           PATH 300      NEW
 1060 CONTINUE                                                          PATH 310      NEW
      IF (ANGLE.GT.90.0) GO TO 1061                                     PATH 320      NEW
      LEN=1.                                                            PATH 330      NEW
      IL=J1-1                                                           PATH 340      NEW
      HMIN=1.0E-6                                                       PATH 350      NEW
      IJ=NLL                                                            PATH 360      NEW
 1061 CONTINUE                                                          PATH 370      NEW
      DO 1050 IK=1,68                                                   PATH 380      NEW
      IF (LEN.EQ.0) IL=IL-1                                             PATH 390      NEW
      IF (LEN.EQ.1) IL=IL+1                                             PATH 400      NEW
      IJ=IJ-1                                                           PATH 410      NEW
      IF(IL.EQ.0) GO TO 1050                                            PATH 420      NEW
      DO 1064 K=1,KMAX                                                  PATH 430      NEW
      W(K)=E(K)+WLAY(IL,K)                                              PATH 440      NEW
      WPATH(IK,K)=W(K)                                                  PATH 450      NEW
 1064 CONTINUE                                                          PATH 460      NEW
      IF(IL.LE.0.OR.IL.GE.NL) GO TO 1053                                PATH 470      NEW
      TBAR=(T(M,IL)+T(M,IL+1))*0.5                                      PATH 480      NEW
C      JEXTRA IS 1 ONLY WHEN PROGRAM NEVER LEAVES ONE LAYER             PATH 490      NEW
      IF(JEXTRA.EQ.1) TBAR=(T(M,J1)+T(M,J1+1))*0.5                      PATH 500      NEW
```

Table A1. Listing of Fortran Code LOWTRAN 4 (Cont)

```
 1053   CONTINUE                                                                PATH 510      NEW
       TBBY(IK)=TBAR                                                           PATH 520      NEW
       DO 1103 K=1,KMAX                                                        PATH 530      NEW
       E(K)=W(K)                                                               PATH 540      NEW
 1103  CONTINUE                                                                PATH 550      NEW
       IF (ANGLE.LE.90.0.AND.IL.EQ.NLL) GO TO 1104                             PATH 560      NEW
       IF (ITYPE.EQ.3.AND.ANGLE.LE.90.0) GO TO 1062                            PATH 570      NEW
       IF (ITYPE.EQ.3.AND.LEN.EQ.1.AND.IL.EQ.J2) GO TO 1104                    PATH 580      NEW
       IF (ITYPE.EQ.2.AND.LENSTOR.EQ.0.AND.IL.EQ.J2) GO TO 1104                PATH 590      NEW
       IF (IL.EQ.JMIN.AND.HMIN.GT.0) LEN=1                                     PATH 600      NEW
       IF (IL.EQ.1.AND.HMIN.LE.0.0) GO TO 1104                                 PATH 610      NEW
       IF (LEN.EQ.0) GO TO 1062                                                PATH 620      NEW
       IF (IL.EQ.JMIN.AND.IJ.EQ.IL+NLL) IL=IL-1                                PATH 630      NEW
       IF (ITYPE.EQ.2.AND.IL.EQ.J2) GO TO 1104                                 PATH 640      NEW
 1062  CONTINUE                                                                PATH 650      NEW
       PRINT900,IK,(WPATH(IK,K),K=1,8),WPATH(IK,10),WPATH(IK,11),TBBY(IK)PATH 660      NEW
 1050  CONTINUE                                                                PATH 670      NEW
       IKMAX=IK                                                                PATH 680      NEW
       LEN=LENSTOR                                                             PATH 690      NEW
        RETURN                                                                 PATH 700      NEW
 1104  CONTINUE                                                                PATH 710      NEW
       PRINT900,IK,(WPATH(IK,K),K=1,8),WPATH(IK,10),WPATH(IK,11),TBBY(IK)PATH 720      NEW
       IKMAX=IK                                                                PATH 730      NEW
       LEN=LENSTOR                                                             PATH 740      NEW
        RETURN                                                                 PATH 750      NEW
 2000  DO 2052 K=1,KMAX                                                        PATH 760      NEW
        WPATH(1,K)=W(K)                                                        PATH 770      NEW
 2052  CONTINUE                                                                PATH 780      NEW
        IF(MODEL.EQ.0) J1=1                                                    PATH 790      NEW
        J2=J1                                                                  PATH 800      NEW
       TBBY(1)=T(M,J1)                                                         PATH 810      NEW
        IKMAX=1                                                                PATH 820      NEW
       PRINT 1109, J1,J2                                                       PATH 830      NEW
        PRINT 910                                                              PATH 840      NEW
       IK=1                                                                    PATH 850      NEW
       PRINT900,IK,(WPATH(IK,K),K=1,8),WPATH(IK,10),WPATH(IK,11),TBBY(IK)PATH 860      NEW
        HMIN=1.0E-6                                                            PATH 870      NEW
       RETURN                                                                  PATH 880      NEW
  900  FORMAT(I5,10F11.3,F10.3)                                                PATH 890      NEW
       END                                                                     PATH 900      NEW
```

Table A1. Listing of Fortran Code LOWTRAN 4 (Cont)

```
      SUBROUTINE HNO3 (V,HABS)                                          HNO3  10      NEW
      DIMENSION H1(15), H2(16), H3(13)                                  HNO3  20      NEW
C ARRAY H1 CONTAINS HNO3 ABS, COEF(CM-1ATM-1) FROM  850 TO 920 CM-1     HNO3  30      NEW
      DATA H1/2.197,3.911,6.154,8.150,9.217,9.461,11.56,11.10,11.17,12.4HNO3  40      NEW
     10,10.49,7.509,6.136,4.899,2.866/                                  HNO3  50      NEW
C ARRAY H2 CONTAINS HNO3 ABS, COEF(CM-1ATM-1) FROM 1275 TO1350 CM-1     HNO3  60      NEW
      DATA H2/2.928,4.611,6.755,8.759,10.51,13.74,18.00,21.51,23.09,21.6HNO3  70      NEW
     18,21.32,16.82,16.42,17.67,14.86,8.716/                            HNO3  80      NEW
C ARRAY H3 CONTAINS HNO3 ABS, COEF(CM-1ATM-1) FROM 1675 TO1735 CM-1     HNO3  90      NEW
      DATA H3/5.003,8.803,14.12,19.83,23.31,23.58,23.22,21.09,26.99,25.8HNO3 100      NEW
     14,24.79,17.68,9.420/                                              HNO3 110      NEW
      HABS=0.                                                           HNO3 120      NEW
      IF (V.GE.850.0.AND.V.LE.920.0) GO TO 1000                         HNO3 130      NEW
      IF (V.GE.1275.0.AND.V.LE.1350.0) GO TO 1001                       HNO3 140      NEW
      IF (V.GE.1675.0.AND.V.LE.1735.0) GO TO 1002                       HNO3 150      NEW
      GO TO 1003                                                        HNO3 160      NEW
1000  I=(V-845.)/5.                                                     HNO3 170      NEW
      HABS=H1(I)                                                        HNO3 180      NEW
      GO TO 1003                                                        HNO3 190      NEW
1001  I=(V-1270.)/5.                                                    HNO3 200      NEW
      HABS=H2(I)                                                        HNO3 210      NEW
      GO TO 1003                                                        HNO3 220      NEW
1002  I=(V-1670.)/5.                                                    HNO3 230      NEW
      HABS=H3(I)                                                        HNO3 240      NEW
1003  RETURN                                                            HNO3 250      NEW
      END                                                               HNO3 260      NEW
```

Table A1. Listing of Fortran Code LOWTRAN 4 (Cont)

```
      SUBROUTINE POINT (X,YN,N,NP,TX,IP)                                POIN  10     B   1
      COMMON Z(34),P(7,34),T(7,34),EH(11,34),WH(7,34),M,NL,RE,CW,CO,PI  POIN  20       NEW
      COMMON /EM1/ IEMISS,KMAX                                          POIN  30       NEW
      DIMENSION TX(11)                                                  POIN  40       NEW
C*****************************************************************************POIN  50     B   4
C     SUBROUTINE POINT COMPUTES THE MEAN REFRATIVE INDEX ABOVE AND BELOWPOIN  60     B   5
C     A GIVEN ALTITUDE AND INTERPOLATES EXPONENTIALLY TO DETERMINE THE  POIN  70     B   6
C     EQUIVALENT ABSORBER AMOUNTS AT THAT ALTITUDE.                     POIN  80     B   7
C                                                                       POIN  90     B   8
C*****************************************************************************POIN 100     B   9
C                                                                       POIN 110     B  10
C      X IS THE HEIGHT IN QUESTION                                      POIN 120     B  11
C      TX(9) AND YN ARE THE MEAN REFRACTIVE INDICES ABOVE AND BELOW X   POIN 130     B  12
C      N IS THE LEVEL INTEGER CORRESPONDING TO X OR THE LEVEL BELOW X   POIN 140     B  13
C      NP =1 IF X COINCIDES WITH MODEL ATMOSPHERE LEVEL ,IF NOT NP = 0  POIN 150     B  14
C      TX(1-8) ARE ABSORBER  AMOUNTS PER KM AT HEIGHT X                 POIN 160     B  15
C*****************************************************************************POIN 170     B  16*
      N=NL                                                              POIN 180     B  17*
      NP=0                                                              POIN 190     B  18
      IF(X.LT.0.0) X=Z(1)                                               POIN 200     B  19A
      IF (X.GT.Z(NL)) GO TO 4                                           POIN 210     B  19B
      DO 1 I=1,NL                                                       POIN 220     B  20
      N=I                                                               POIN 230     B  21
      IF (X-Z(I)) 2,4,1                                                 POIN 240     B  22
1     CONTINUE                                                          POIN 250     B  23-
2     J2=N                                                              POIN 260     B  25
      N=N-1                                                             POIN 270     B  26
      FAC=(X-Z(N))/(Z(J2)-Z(N))                                         POIN 280     B  27
      PX1=P(M,N)*(P(M,J2)/P(M,N))**FAC                                  POIN 290     B  28
      TX1=T(M,N)*(T(M,J2)/T(M,N))**FAC                                  POIN 300     B  29
      WX1=WH(M,N)*(WH(M,J2)/WH(M,N))**FAC                               POIN 310     B  30
      TX(3)=CO*PX1/TX1-4.56E-6*WX1*TX1*CW                               POIN 320     B  31
      TX(2)=CO*P(M,J2)/T(M,J2)-4.56E-6*WH(M,J2)*T(M,J2)*CW              POIN 330     B  32
      TX(1)=CO*P(M,N)/T(M,N)-4.56E-6*WH(M,N)*T(M,N)*CW                  POIN 340     B  33
      TX(9)=0.5E-6*(TX(2)+TX(3))                                        POIN 350     B  34
      YN=0.5E-6*(TX(1)+TX(3))                                           POIN 360     B  35
      IF (IP.EQ.0) GO TO 9                                              POIN 370     B  36
      DO 3 K=1,KMAX                                                     POIN 380       NEW
      IF(K.EQ.9) GO TO 3                                                POIN 390    *B  37B
       TX(K)=0.0                                                        POIN 400    *B  37C
      IF (EH(K,N).EQ.0.0) GO TO 3                                       POIN 410     B  38
      IF (EH(K,N).GT.1000.0) GO TO 3                                    POIN 420     B  39
      TX(K)=EH(K,N)*(EH(K,J2)/EH(K,N))**FAC                             POIN 430     B  40
3     CONTINUE                                                          POIN 440     B  41
      GO TO 9                                                           POIN 450     B  42
4     NP=1                                                              POIN 460     B  43
      IF (IP.EQ.0) GO TO 6                                              POIN 470     B  44
      DO 5 K=1,KMAX                                                     POIN 480       NEW
5     TX(K)=EH(K,N)                                                     POIN 490     B  46
6     TX(9)=EH(9,N)-1.                                                  POIN 500     B  47
```

Table A1. Listing of Fortran Code LOWTRAN 4 (Cont)

```
      YN=0.0                                                            POIN 510    B  48
C*****  CARDS 8 24 AND 50 THROUGH 59 ARE NO LONGER REQUIRED             POIN 520    B  48+
      IF (N.GT.1) YN=EH(9,N-1)-1.0                                      POIN 530    B  49
9     CONTINUE                                                          POIN 540    B  60
      IF (IP.EQ.1) PRINT 400, X,N,NP,TX(9),YN,IP,(TX(K),K=1,8)          POIN 550    B  61
      TX(9)=TX(9)+1.                                                    POIN 560    B  62
      YN=YN+1.                                                          POIN 570    B  63
      RETURN                                                            POIN 580    B  64
C                                                                       POIN 590    B  65
400   FORMAT (/,* FROM POINT: HEIGHT=*,F10.4,* KM,N=*,I3,*,NP=*,I2,*,REFPOIN 600    B  66
     1, INDEX ABOVE & BELOW X=*,2F11.4,*,IP=*,I3,/,12X,*EQUIV. ABSORBER POIN 610    B  67
     2AMOUNTS PER KM AT X=*,8F10.3)                                     POIN 620    B  68
      END                                                               POIN 630    B  69
```

Table A1 Listing of Fortran Code LOWTRAN 4 (Cont)

```
      SUBROUTINE ANGL (H1,H2,ANGLE,B1,LEN,ML)                                ANGL  10    C   1*
      COMMON Z(34),P(7,34),T(7,34),EH(11,34),WH(7,34),M,NL,RE,CH,CO,PI       ANGL  20        NEW
      COMMON /EM1/ IEMISS,KMAX                                               ANGL  30        NEW
      DIMENSION TX(11)                                                       ANGL  40        NEW
C*****************************************************************         ANGL  50    C   4
C                                                                            ANGL  60    C   5
C     THIS SUBROUTINE CALCULATES THE INITIAL ZENITH ANGLE (ANGLE)            ANGL  70    C   6
C     TAKING INTO ACCOUNT REFRACTION EFFECTS GIVEN H1,H2, AND BETA           ANGL  80    C   7
C     (WHERE BETA IS THE EARTH CENTRE ANGLE SUBTENDED BY H1 AND H2 ),        ANGL  90    C   8
C     ASSUMING THE REFRACTIVE INDEX TO BE CONSTANT IN A GIVEN LAYER.         ANGL 100    C   9
C     FOR GREATER ACCURACY INCREASE THE NUMBER OF LEVELS IN THE MODEL        ANGL 110    C  10
C     ATMOSPHERE.                                                            ANGL 120    C  11
C                                                                            ANGL 130    C  12
C     THIS SUBROUTINE CAN BE REMOVED FROM THE PROGRAM IF NOT REQUIRED.       ANGL 140    C  13
C*****************************************************************         ANGL 150    C  14
      IP=99                                                                  ANGL 160    C  15
      CA=PI/180.                                                             ANGL 170    C  16
      X1=RE+H1                                                               ANGL 180    C  17
      X2=RE+H2                                                               ANGL 190    C  18
      LEN=0.                                                                 ANGL 200    C  19
      IT=0                                                                   ANGL 210    C  20
      B1=B1*CA                                                               ANGL 220    C  21

      TANG=X2*SIN(B1)/(X2*COS(B1)-X1)                                        ANGL 240    C  22
      THET=ATAN(TANG)                                                        ANGL 250    C  23
      IF (THET.LT.0.0) THET=THET+PI                                          ANGL 260    C  24
      SEMI=SIN(THET)                                                         ANGL 270    C  25
      ANG=THET/CA                                                            ANGL 280    C  26
C     PRINT 404, B1,ANG,TANG                                                 ANGL 290    C  27
      TN=THET                                                                ANGL 300    C  28
      TM=TN-0.5*CA                                                           ANGL 310    C  29
1     ANGLE=THET                                                             ANGL 320    C  30
      ERT=0.                                                                 ANGL 330    C  31
      BETA=0.                                                                ANGL 340    C  32
      BET1=0                                                                 ANGL 350    C  33
      BET2=0                                                                 ANGL 360    C  34
      FBT1=0                                                                 ANGL 370    C  35
      FBT2=0                                                                 ANGL 380    C  36
      FBT3=0.0                                                               ANGL 390    C  37
      IF(B1.LE.0.0) GO TO 2                                                  ANGL 400    C  37*
C     PRINT 400, IT                                                          ANGL 410    C  38
      Y=2.*THET                                                              ANGL 420    C  39
      IF (Y-PI.GT.1.0E-8) GO TO 9                                            ANGL 430    C  40
      IF (IP.EQ.100) GO TO 6                                                 ANGL 440    C  41
      XMIN=X2*COS(B1)-RE                                                     ANGL 450    C  42
      IF (XMIN-H1) 8,4,4                                                     ANGL 460    C  43
2     HMIN=H2                                                                ANGL 470    C  44A
      H2=H1                                                                  ANGL 480    C  44B
      H1=HMIN                                                                ANGL 490    C  44C
3     ANGLE=0.5*PI                                                           ANGL 500    C  44D
```

Table A1. Listing of Fortran Code LOWTRAN 4 (Cont)

```
      THET=ANGLE                                                        ANGL 510    C  65
      SPHI=1.0                                                          ANGL 520    C  66
      ANG=ANGLE/CA                                                      ANGL 530    C  67
C     PRINT 404, H1,ANG,SPHI                                            ANGL 540    C  68
4     IP=100                                                            ANGL 550    C  69
      CALL POINT (H1,YN,N,NP,TX,IP)                                     ANGL 560    C  70
      J1=N                                                              ANGL 570    C  71
      TX1=TX(9)                                                         ANGL 580    C  72
5     CALL POINT (H2,YN,N,NP,TX,IP)                                     ANGL 590    C  73
      IF (NP.EQ.1) N=N-1                                                ANGL 600    C  74
      J2=N                                                              ANGL 610    C  75
      IF (J1.EQ.J2) TX1=TX1*YN-EH(9,J1)                                 ANGL 620    C  76
6     DO 7 J=J1,J2                                                      ANGL 630    C  77
      X1=RE+Z(J)                                                        ANGL 640    C  78
      X2=RE+Z(J+1)                                                      ANGL 650    C  79
      IF (J.EQ.J1) X1=RE+H1                                             ANGL 660    C  80
      IF (J.EQ.J2) X2=RE+H2                                             ANGL 670    C  81
      SALP=X1*SPHI/X2                                                   ANGL 680    C  82
      ALP=ASIN(SALP)                                                    ANGL 690    C  83
      RN=EH(9,J+1)/EH(9,J)                                              ANGL 700    C  84
      IF ((J+1).EQ.J2) RN=YN/EH(9,J)                                    ANGL 710    C  85
      IF (J.EQ.J1) RN=EH(9,J+1)/TX1                                     ANGL 720    C  86
      IF ((J+1).EQ.J2.AND.J.EQ.J1) RN=YN/TX1                            ANGL 730    C  87
      BET=THET-ALP                                                      ANGL 740    C  88
      FB=-TAN(ALP)                                                      ANGL 750    C  89
      IF (J.NE.J1) FB=FB+TAN(THET)                                      ANGL 760    C  90
      FBT=FBT+FB                                                        ANGL 770    C  91
      BETA=BETA+BET                                                     ANGL 780    C  92
      TH1=THET/CA                                                       ANGL 790    C  93
      BE=BET/CA                                                         ANGL 800    C  94
      C=ALP/CA                                                          ANGL 810    C  95
C     PRINT 402, J,Z(J),THET,ALP,BET,BETA,FBT,FB,TH1,BE,C               ANGL 820    C  96
      IF (Y2.EQ.RE+H2) C=FT-ALP                                         ANGL 830    C  97
      IF (SALP.GE.RN) RN=1.                                             ANGL 840    C  98
      SPHI=SALP/RN                                                      ANGL 850    C  99
      THET=ASIN(SPHI)                                                   ANGL 860    C 100
7     CONTINUE                                                          ANGL 870    C 101
      IF(H1.LE.0.0) GO TO 29                                            ANGL 880    C 102
      GO TO 26                                                          ANGL 890    C 103
8     CONTINUE                                                          ANGL 900    C 104
      TANG=-TANG                                                        ANGL 910    C 105
      ANGLE=PI-ANGLE                                                    ANGL 920    C 106
      THET=ANGLE                                                        ANGL 930    C 107
      ANG=ANGLE/CA                                                      ANGL 940    C 108
C     PRINT 404, H1,ANG,TANG                                            ANGL 950    C 109
      IF (H1.LE.0.0) GO TO 3                                            ANGL 960    C 110
9     CONTINUE                                                          ANGL 970    C 111
      IP=101                                                            ANGL 980    C 112
      CALL POINT (H1,YN,N,NP1,TX,IP)                                    ANGL 990    C 113
      TX1=TX(9)                                                         ANGL1000
```

Table A1. Listing of Fortran Code LOWTRAN 4 (Cont)

```
      YN1=YN                                                            ANGL1010    C  94
      IF (NP1.EQ.1) N=N-1                                               ANGL1020    C  95
      J2=ML                                                             ANGL1030    C  96A
      IF (M.EQ.7) J2=ML                                                 ANGL1040    C  96B
      J1=N                                                              ANGL1050    C  97
      J=J1+1                                                            ANGL1060    C  98
      IF (H2.GE.H1) GO TO 13                                            ANGL1070    C  99
      CALL POINT (H2,YN,N,NF,TX,IP)                                     ANGL1080    C 100
      TX2=YX(9)                                                         ANGL1090    C 101
      YN2=YN                                                            ANGL1100    C 102
      J2=N                                                              ANGL1110    C 103
      IF (J1.EQ.J2) TX2=YN1*TX(9)-EH(9,J1)                              ANGL1120    C 104
10    J=J-1                                                             ANGL1130    C 105
      X1=RE+Z(J+1)                                                      ANGL1140    C 106
      X2=RE+Z(J)                                                        ANGL1150    C 107
      IF (J.EQ.J1) X1=RE+H1                                             ANGL1160    C 108
      IF (J.EQ.J2) X2=RE+H2                                             ANGL1170    C 109
      SALP=X1*SPHI/X2                                                   ANGL1180    C 110
      HMIN=X1*SPHI-RE                                                   ANGL1190    C 111
C     PRINT 402, J,X1,Z(J),SPHI,SALP,HMIN,RE                            ANGL1200    C 112
      IF (SALP.LE.1.0) GO TO 11                                         ANGL1210    C 113
      SALP=SPHI                                                         ANGL1220    C 114
      IF (HMIN.GT.H2) GO TO 18                                          ANGL1230    C 115
11    ALP=ASIN(SALP)                                                    ANGL1240    C 116
      THET=ASIN(SPHI)                                                   ANGL1250    C 117
      BET=ALP-THET                                                      ANGL1260    C 118
      BET1=BET1+BET                                                     ANGL1270    C 119
      FB=TAN(ALP)                                                       ANGL1280    C 120
      IF (J.NE.J1) FB=FB-TAN(THET)                                      ANGL1290    C 121
      FBI1=FBI1+FB                                                      ANGL1300    C 122
      TH1=THET/CA                                                       ANGL1310    C 123
      BE=BET/CA                                                         ANGL1320    C 124
      AL=ALP/CA                                                         ANGL1330    C 125
C     PRINT 402, J,X2,THET,ALP,BET1,BET,BMIN,HMIN,FBI1,TH1,BE,AL        ANGL1340    C 126
      IF (X2.EQ.RE+H2) G=FI-ALP                                         ANGL1350    C 127
      REF=EH(9,J)                                                       ANGL1360    C 128
      IF (J.EQ.J1) REF=YN1                                              ANGL1370    C 129
      IF (J.EQ.J2) REF=TX2                                              ANGL1380    C 130
      IF (J.EQ.1) GO TO 12                                              ANGL1390    C 131
      RN=EH(9,J)/EH(9,J-1)                                              ANGL1400    C 132
      IF (J.EQ.J1) RN=YN1/EH(9,J-1)                                     ANGL1410    C 133A
      IF(J.EQ.J2+1) RN=REF/TX2                                          ANGL1420    C 133B
      IF(J.EQ.J2) RN=REF/YN2                                            ANGL1430    C 133C
      IF (SALP.GT.RN) RN=1.                                             ANGL1440    C 134
      SPHI=SALP*RN                                                      ANGL1450    C 135
      IF (Z(J).LE.H2) GO TO 12                                          ANGL1460    C 136
      GO TO 10                                                          ANGL1470    C 137
12    X1=X2                                                             ANGL1480    C 138
      IF (ABS(Z(J)-H2).LT.1.0E-10.AND.J.NE.1) GO TO 13                  ANGL1490    C 139
      GO TO 14                                                          ANGL1500    C 140
```

Table A1. Listing of Fortran Code LOWTRAN 4 (Cont)

```
13    J=J-1                                                              ANGL1510    C 141
      X1=RE+Z(J+1)                                                       ANGL1520    C 142
      IF (J.EQ.J1) X1=RE+H1                                              ANGL1530    C 143
      IF (J.EQ.J2.AND.J.NE.J1) X1=RE+H2                                  ANGL1540    C 144
14    X2=RE+Z(J)                                                         ANGL1550    C 145
      HMIN=X1*SPHI-RE                                                    ANGL1560    C 146
      IF (HMIN.LE.0.0) GO TO 25                                          ANGL1570    C 147
      IF (Z(J).LT.HMIN) GO TO 18                                         ANGL1580    C 148
      REF=EH(9,J)                                                        ANGL1590    C 149
      IF (J.EQ.J2) REF=YN                                                ANGL1600    C 150
      SALP=X1*SPHI/X2                                                    ANGL1610    C 151
      ALP=ASIN(SALP)                                                     ANGL1620    C 152
      THET=ASIN(SPHI)                                                    ANGL1630    C 153
      BET=ALP-THET                                                       ANGL1640    C 154
      FB=TAN(ALP)-TAN(THET)                                              ANGL1650    C 155
      FBT2=FBT2+FB                                                       ANGL1660    C 156
      BET2=BET2+BET                                                      ANGL1670    C 157
      BMIN=BET1+BET2                                                     ANGL1680    C 158
      AL=ALP/CA                                                          ANGL1690    C 159
      TH1=THET/CA                                                        ANGL1700    C 160
C     PRINT 402, J,X2,THET,ALP,BET2,BET,BMIN,HMIN,FBT2,TH1,BE,AL         ANGL1710    C 161
      RN=REF/EH(9,J-1)                                                   ANGL1720    C 162
      IF (SALP.GE.RN) RN=1.0                                             ANGL1730    C 163
      SPHI=SALP*RN                                                       ANGL1740    C 164
      GO TO 13                                                           ANGL1750    C 165
17    TX3=YN1+TX(9)-EH(9,J1)                                             ANGL1760    C 166
      YN1=TX3                                                            ANGL1770    C 167
      IF (ABS(H2-Z(J+1)).LE.1.0E-5) YN1=TX(9)                            ANGL1780    C 168
      IF (ABS(H1-Z(J+1)).LE.1.0E-5) YN1=TX(9)                            ANGL1790    C 169
      PN=1.0                                                             ANGL1800    C 170
      GO TO 19                                                           ANGL1810    C 171
18    CALL POINT (HMIN,YN,N,NP,TX,IP)                                    ANGL1820    C 172
      IP=102                                                             ANGL1830    C 173
      TX3=TX(9)                                                          ANGL1840    C 174
      IF (J.EQ.J1.AND.H2.GE.H1) GO TO 17                                 ANGL1850    C 175
      IF (J.EQ.J1.OR.J.EQ.J2) TX3=YN2+TX(9)-EH(9,J)                      ANGL1860    C 176
      IF (HMIN.GT.H2) TX3=TX(9)                                          ANGL1870    C 177
      IF (J.EQ.J1.AND.HMIN.GT.H2) GO TO 17                               ANGL1880    C 178
      RN=REF/TX3                                                         ANGL1890    C 179
      IF (SALP.GE.RN) RN=1.                                              ANGL1900    C 180
      SPHI=SALP*RN                                                       ANGL1910    C 181
      X=X1*SPHI-RE                                                       ANGL1920    C 182
      DIF=ABS(HMIN-X)                                                    ANGL1930    C 183
      HMIN=X                                                             ANGL1940    C 184
      IF (DIF-1.0E-5) 19,19,18                                           ANGL1950    C 185
15    X2=RE+HMIN                                                         ANGL1960    C 186
C     PRINT 403, HMIN,DIF,RN                                             ANGL1970    C 187
      THET=ASIN(SPHI)                                                    ANGL1980    C 188
      IF(RN.EQ.1.0) FBT3=-TAN(THET)                                      ANGL1990    C 1888
      IF (RN.EQ.1) GO TO 20                                              ANGL2000    C 189
```

Table A1. Listing of Fortran Code LOWTRAN 4 (Cont)

```
      DNX=(TX3-1.0)*ALOG((TX3-1.0)/(REF-1.0))/(X2-X1)                    ANGL2010    C 190
      FBT3=-TAN(THET)*(1.0-1.0/(1.0+TX3/(X2*DNX)))                       ANGL2020    C 191
20    BET=0.5*PI-THET                                                    ANGL2030    C 192
      BET2=BET2+BET                                                      ANGL2040    C 193
      BMIN=BET1+BET2                                                     ANGL2050    C 194
      IF (H2.GE.H1) GO TO 23                                             ANGL2060    C 195
      BET=BET1+2.*BET2                                                   ANGL2070    C 196
      DB1=B1-BET1                                                        ANGL2080    C 197
      DB2=BET-B1                                                         ANGL2090    C 198
21      DB3=ABS(BMIN-B1)                                                 ANGL2100    C 199A
      IF(DB3.GT.DB1.AND.DB2.GT.DB1) GO TO 25                             ANGL2110    C 199B
      IF(DB2.GT.DB3) GO TO 22                                            ANGL2120    C 199C
      IF(DB2.GT.DB1)  GO TO 25                                           ANGL2130    C 200
      BETA=BET                                                           ANGL2140    C 201
      FBT=FBT1+2.0*(FBT2+FBT3)                                           ANGL2150    C 202
      LEN=1.                                                             ANGL2160    C 203
      GO TO 26                                                           ANGL2170    C 204
22    BETA=BET1+BET2                                                     ANGL2180    C 205
      FBT=FBT1+FBT2+FBT3                                                 ANGL2190    C 206
C     PRINT 401, J,BET ,FBT,FBT1,FBT2,FBT3,TX1,YN1                       ANGL2200    C 207
      GO TO 26                                                           ANGL2210    C 208
23    BETA=2.0*(BET1+BET2)                                               ANGL2220    C 209
      LEN=1.                                                             ANGL2230    C 210
      FBT=2.0*(FBT1+FBT2+FBT3)                                           ANGL2240    C 211
      PRINT 401, J,BETA,FBT,FBT1,FBT2,FBT3,TX1,YN1                       ANGL2250    C 212
      IF (H2.EQ.H1) GO TO 26                                             ANGL2260    C 213
      IP=103                                                             ANGL2270    C 214
      IF (NP1.EQ.1) J1=J1+1                                              ANGL2280    C 215
      SPHI=SIN(ANGLE)                                                    ANGL2290    C 216
      IF (Z(J1+1).LE.H2) GO TO 24                                        ANGL2300    C 217
      RN=TX1/YN1                                                         ANGL2310    C 218
      IF (SPHI.GT.RN) RN=1.                                              ANGL2320    C 219
      SPHI=SPHI/RN                                                       ANGL2330    C 220
      THET=ASIN(SPHI)                                                    ANGL2340    C 221
      GO TO 6                                                            ANGL2350    C 222
24    CALL POINT (H2,YN,N,NP,TX,IP)                                      ANGL2360    C 223
      TX1=TX1+YN-EH(9,J1)                                                ANGL2370    C 224
      RN=TX1/YN1                                                         ANGL2380    C 225
      J2=J1                                                              ANGL2390    C 226
      IF (SPHI.GE.RN) RN=1.                                              ANGL2400    C 227
      SPHI=SPHI/RN                                                       ANGL2410    C 228
      THET=ASIN(SPHI)                                                    ANGL2420    C 229
      GO TO 5                                                            ANGL2430    C 230
25    BETA=BET1                                                          ANGL2440    C 231
      LEN=0.                                                             ANGL2450    C 232
      FBT=FBT1                                                           ANGL2460    C 233
26    THET=ANGLE+(B1-BETA)/(1.+FBT/TANG)                                 ANGL2470    C 234
      DBETA=BETA/CA                                                      ANGL2480    C 235
      B=BET1/CA                                                          ANGL2490    C 236
      TH1=THET/CA                                                        ANGL2500    C 237
```

Table A1. Listing of Fortran Code LOWTRAN 4 (Cont)

```
      PRINT 404, BETA,OBETA,FBT,TH1,TANG                                    ANGL2510    C 238
      IF (THET.GT.TN.OR.THET.LT.TM) THET=(TN+TM)/2.                         ANGL2520    C 239
      TH1=THET/CA                                                           ANGL2530    C 240*
      PRINT 404, BET1,B,FBT,TH1                                             ANGL2540    C 241*
      TN1=TN/CA                                                             ANGL2550    C 242
      TM1=TM/CA                                                             ANGL2560    C 243
      PRINT 405, TN,TM,TN1,TM1                                              ANGL2570    C 244
      SPHI=SIN(THET)                                                        ANGL2580    C 245
      TANG=TAN(THET)                                                        ANGL2590    C 246
      IT=IT+1                                                               ANGL2600    C 247
      OBE=ABS(B1-BETA)                                                      ANGL2610    C 248
      OTH=ABS(ANGLE-THET)                                                   ANGL2620    C 249
      IF (IT.EQ.10)  THET=0.5*(ANGLE+THET)                                  ANGL2630    C 250*
      IF (IT.EQ.10) GO TO 28                                                ANGL2640    C 251
      IF (OBE.GT.1.0E-7.AND.OTH.GT.1.0E-7) GO TO 1                          ANGL2650    C 252
28    ANGLE=THET/CA                                                         ANGL2660    C 253
      PRINT 406, ANGLE,IT                                                   ANGL2670    C 254
      RETURN                                                                ANGL2680    C 255A
29    H1=H2                                                                 ANGL2690    C 255B
      ANGLE=0/CA                                                            ANGL2700    C 255C
      PRINT 406, ANGLE,IT                                                   ANGL2710    C 255D
      RETURN                                                                ANGL2720    C 255E
C                                                                           ANGL2730    C 256
400   FORMAT (///* ITTERATION NUMBER *,I3,//)                               ANGL2740    C 257
401   FORMAT (I6,F16.7,8F13.8)                                              ANGL2750    C 258
402   FORMAT (I4,F10.4,6E13.4,4F10.4/)                                      ANGL2760    C 259
403   FORMAT (*  HMIN=*,F14.6,*  DIF=*F14.6,*  PR=*,E16.8)                  ANGL2770    C 260
404   FORMAT (* TOTAL BETA = *,E14.6,F15.6,*,FBT = *,E14.6,* THET =*,F10    ANGL2780    C 261
     1.6,*TANG=*,F10.6)                                                     ANGL2790    C 262
405   FORMAT (5F12.6)                                                       ANGL2800    C 263
406   FORMAT (8X,/1H*,*ZENITH ANGLE =*,F7.3,* DEGREES #  RECOMPUTED         ANGL2810    C 264
     1 FROM SUBROUTINE ANGL (ITTERATION*,I3,*)*)                            ANGL2820    C 265
      END                                                                   ANGL2830    C 266
```

Table A2. Listing of Data for LOWTRAN 4

```
 6 34
2.830E+03 1.245E+03 5.374E+02 2.257E+02 1.193E+02 8.992E+01 6.341E+01 5.893E+01
6.073E+01 5.822E+01 5.679E+01 5.320E+01 5.589E+01 5.159E+01 5.052E+01 4.747E+01
4.514E+01 4.460E+01 4.317E+01 3.636E+01 2.669E+01 1.935E+01 1.456E+01 1.114E+01
8.831E+00 7.434E+00 2.239E+00 5.893E-01 1.551E-01 4.084E-02 1.078E-02 5.693E-03
1.970E-08-0.
1.379E+04 5.034E+03 1.845E+03 6.735E+02 2.454E+02
   0.0  1.013E+03 300.0    1.9E 01    5.6E-05 1.013E+03 294.0    1.4E 01    6.0E-05
   1.0  9.040E+02 294.0    1.3E+01    5.6E-05 9.020E+02 290.0    5.3E+00    6.0E-05
   2.0  8.050E+02 288.0    9.3E+00    5.4E-05 8.020E+02 285.0    5.9E+01    6.9E-05
   3.0  7.150E+02 284.0    4.7E+00    5.1E-05 7.100E+02 279.0    3.3E+00    5.2E-05
   4.0  6.330E+02 277.0    2.2E+00    4.7E-05 6.280E+02 273.0    1.9E+00    5.4E-05
   5.0  5.590E+02 270.0    1.9E+00    4.5E-05 5.540E+02 267.0    1.0E+00    6.6E-05
   6.0  4.920E+02 264.0    8.5E-01    4.3E-05 4.870E+02 261.0    6.1E-01    6.9E-05
   7.0  4.320E+02 257.0    4.7E-01    4.1E-05 4.260E+02 255.0    3.7E-01    7.5E-05
   8.0  3.780E+02 250.0    2.5E-01    3.9E-05 3.720E+02 248.0    2.1E-01    7.9E-05
   9.0  3.290E+02 244.0    1.2E-01    3.9E-05 3.240E+02 242.0    1.2E-01    9.6E-05
  10.0  2.860E+02 237.0    5.9E-02    3.9E-05 2.810E+02 235.0    6.4E-02    1.0E-04
  11.0  2.470E+02 230.0    1.7E-02    4.1E-05 2.430E+02 229.0    2.2E-02    1.1E-04
  12.0  2.130E+02 224.0    6.3E-03    4.3E-05 2.090E+02 222.0    6.0E-03    1.2E-04
  13.0  1.820E+02 217.0    1.8E-03    4.5E-05 1.790E+02 216.0    1.8E-03    1.5E-04
  14.0  1.560E+02 216.0    1.0E-03    4.5E-05 1.530E+02 216.0    1.0E-03    1.8E-04
  15.0  1.320E+02 204.0    7.6E-04    4.7E-05 1.300E+02 216.0    7.6E-04    1.9E-04
  16.0  1.110E+02 197.0    6.4E-04    4.7E-05 1.110E+02 216.0    6.4E-04    2.1E-04
  17.0  9.370E+01 195.0    5.6E-04    6.9E-05 9.500E+01 216.0    5.6E-04    2.4E-04
  18.0  7.890E+01 199.0    5.1E-04    9.0E-05 8.120E+01 216.0    5.0E-04    2.8E-04
  19.0  6.660E+01 203.0    4.9E-04    1.4E-04 6.950E+01 217.0    4.9E-04    3.2E-04
  20.0  5.650E+01 207.0    4.5E-04    1.9E-04 5.950E+01 218.0    4.5E-04    3.4E-04
  21.0  4.830E+01 211.0    5.1E-04    2.4E-04 5.100E+01 219.0    5.1E-04    3.6E-04
  22.0  4.090E+01 219.0    5.1E-04    2.8E-04 4.370E+01 220.0    5.1E-04    3.6E-04
  23.0  3.500E+01 217.0    5.4E-04    3.2E-04 3.760E+01 222.0    5.4E-04    3.6E-04
  24.0  3.000E+01 219.0    6.2E-04    3.4E-04 3.220E+01 223.0    6.0E-04    3.6E-04
  25.0  2.570E+01 221.0    6.7E-04    3.4E-04 2.770E+01 224.0    6.7E-04    3.6E-04
  30.0  1.220E+01 232.0    3.6E-04    2.4E-04 1.320E+01 234.0    3.6E-04    2.6E-04
  35.0  6.000E+00 243.0    1.1E-04    9.2E-05 6.520E+00 245.0    1.1E-04    9.2E-05
  40.0  3.050E+00 254.0    4.3E-05    4.1E-05 3.330E+00 258.0    4.3E-05    4.1E-05
  45.0  1.590E+00 265.0    1.9E-05    1.3E-05 1.760E+00 270.0    1.9E-05    1.3E-05
  50.0  8.540E-01 270.0    6.3E-06    4.3E-06 9.510E-01 276.0    6.3E-06    4.3E-06
  70.0  5.790E-02 219.0    1.4E-07    8.6E-08 6.710E-02 218.0    1.4E-07    8.6E-08
 100.0  3.000E-04 210.0    1.3E-09    4.3E-11 3.030E-04 210.0    1.0E-09    4.3E-11
99999.  0.000E+00 210.     0.0E-00    0.0E-00 0.000E 00 210.0    0.0E-00    1.0E-00
   0.0  1.018E+03 272.2    3.5E+00    6.0E-05 1.01JE+03 267.0    9.1E+00    4.9E-05
   1.0  8.973E+02 268.7    2.5E+00    5.4E-05 8.960E+02 262.0    6.0E+00    5.4E-05
   2.0  7.897E+02 265.2    1.6E+00    4.9E-05 7.929E+02 256.0    4.2E+00    5.0E-05
   3.0  6.938E+02 261.7    1.2E+00    4.9E-05 7.000E+02 251.0    2.7E+00    5.8E-05
   4.0  6.081E+02 255.7    6.6E-01    4.9E-05 6.160E+02 246.0    1.7E+00    6.0E-05
   5.0  5.313E+02 249.7    3.8E-01    5.8E-05 5.410E+02 240.0    1.0E+00    6.4E-05
   6.0  4.627E+02 243.7    2.1E-01    6.4E-05 4.730E+02 253.0    5.4E-01    7.1E-05
   7.0  4.016E+02 237.7    8.5E-02    7.7E-05 4.130E+02 246.0    2.9E-01    7.9E-05
   8.0  3.473E+02 231.7    3.5E-02    9.0E-05 3.590E+02 239.0    1.3E-01    7.9E-05
```

Table A2. Listing of Data for LOWTRAN 4 (Cont)

9.0	2.992E+02	225.7	1.6E-02	1.2E-04	3.107E+02	232.0	4.2E-02	1.1E-04
10.0	2.568E+02	219.7	7.5E-03	1.6E-04	2.677E+02	225.0	1.5E-02	1.3E-04
11.0	2.199E+02	219.2	6.9E-03	2.1E-04	2.300E+02	225.0	9.4E-03	1.8E-04
12.0	1.882E+02	218.7	6.0E-03	2.6E-04	1.977E+02	225.0	6.0E-03	2.1E-04
13.0	1.610E+02	218.2	1.8E-03	3.0E-04	1.700E+02	225.0	1.8E-03	2.6E-04
14.0	1.378E+02	217.7	1.0E-03	3.2E-04	1.460E+02	225.0	1.0E-03	2.8E-04
15.0	1.178E+02	217.2	7.6E-04	3.4E-04	1.250E+02	225.0	7.6E-04	3.2E-04
16.0	1.007E+02	216.7	6.4E-04	3.6E-04	1.080E+02	225.0	6.4E-04	3.4E-04
17.0	8.610E+01	216.2	5.6E-04	3.9E-04	9.280E+01	225.0	5.6E-04	3.9E-04
18.0	7.350E+01	215.7	5.0E-04	4.1E-04	7.980E+01	225.0	5.0E-04	4.1E-04
19.0	6.280E+01	215.2	4.9E-04	4.3E-04	6.860E+01	225.0	4.9E-04	4.1E-04
20.0	5.370E+01	215.2	4.5E-04	4.5E-04	5.890E+01	225.0	4.5E-04	3.9E-04
21.0	4.580E+01	215.2	5.1E-04	4.3E-04	5.070E+01	225.0	5.1E-04	3.6E-04
22.0	3.910E+01	215.2	5.1E-04	4.3E-04	4.360E+01	225.0	5.1E-04	3.2E-04
23.0	3.340E+01	215.2	5.4E-04	3.9E-04	3.750E+01	225.0	5.4E-04	3.0E-04
24.0	2.860E+01	215.2	6.0E-04	3.6E-04	3.227E+01	226.0	6.0E-04	2.8E-04
25.0	2.430E+01	215.2	6.7E-04	3.4E-04	2.780E+01	228.0	6.7E-04	2.6E-04
30.0	1.110E+01	217.4	3.6E-04	1.9E-04	1.340E+01	235.0	3.6E-04	1.4E-04
35.0	5.180E+00	227.8	1.1E-04	9.2E-05	6.610E+00	247.0	1.1E-04	9.2E-05
40.0	2.530E+00	243.2	4.3E-05	4.1E-05	3.400E+00	262.0	4.3E-05	4.1E-05
45.0	1.290E+00	258.5	1.9E-05	1.3E-05	1.810E+00	274.0	1.9E-05	1.3E-05
50.0	6.820E-01	265.7	6.3E-06	4.3E-06	9.870E-01	277.0	6.3E-06	4.3E-06
70.0	4.670E-02	230.7	1.4E-07	8.6E-08	7.070E-02	216.0	1.4E-07	8.6E-08
100.0	3.000E-04	210.2	1.0E-09	4.3E-11	3.000E-04	210.0	1.0E-09	4.3E-11
99999.	0.000E+00	210.	0.0E-00	0.0E-00	0.000E 00	210.0	0.0E-00	0.0E-00
0.0	1.013E+03	257.1	1.2E+00	4.1E-05	1.013E+03	288.1	5.9E+00	5.4E-05
1.0	8.878E+02	259.1	1.2E+00	4.1E-05	8.986E+02	281.6	4.2E+00	5.4E-05
2.0	7.775E+02	255.9	9.4E-01	4.1E-05	7.950E+02	275.1	2.9E+00	5.4E-05
3.0	6.798E+02	252.7	6.8E-01	4.3E-05	7.012E+02	268.7	1.8E+00	5.0E-05
4.0	5.932E+02	247.7	4.1E-01	4.5E-05	6.166E+02	262.2	1.1E+00	4.6E-05
5.0	5.158E+02	246.9	2.0E-01	4.7E-05	5.405E+02	255.7	6.4E-01	4.6E-05
6.0	4.467E+02	234.1	9.8E-02	4.9E-05	4.722E+02	249.2	3.8E-01	4.5E-05
7.0	3.853E+02	227.3	5.4E-02	7.1E-05	4.111E+02	242.7	2.1E-01	4.9E-05
8.0	3.308E+02	220.6	1.1E-02	9.0E-05	3.565E+02	236.2	1.2E-01	5.2E-05
9.0	2.829E+02	217.2	8.4E-03	1.6E-04	3.080E+02	229.7	4.6E-02	7.1E-05
10.0	2.418E+02	217.2	5.5E-03	2.4E-04	2.650E+02	223.2	1.8E-02	9.0E-05
11.0	2.067E+02	217.2	3.8E-03	3.2E-04	2.270E+02	216.8	8.2E-03	1.3E-04
12.0	1.766E+02	217.2	2.6E-03	4.3E-04	1.940E+02	216.6	3.7E-03	1.6E-04
13.0	1.510E+02	217.2	1.8E-03	4.7E-04	1.658E+02	216.6	1.8E-03	1.7E-04
14.0	1.291E+02	217.2	1.3E-03	4.9E-04	1.417E+02	216.6	8.4E-04	1.9E-04
15.0	1.103E+02	217.2	7.6E-04	5.6E-04	1.211E+02	216.6	7.2E-04	2.1E-04
16.0	9.431E+01	216.6	6.4E-04	6.2E-04	1.035E+02	216.6	6.1E-04	2.4E-04
17.0	8.058E+01	216.0	5.6E-04	6.2E-04	8.850E+01	216.6	5.2E-04	2.8E-04
18.0	6.882E+01	215.4	5.0E-04	6.2E-04	7.565E+01	216.6	4.4E-04	3.2E-04
19.0	5.875E+01	214.8	4.9E-04	6.0E-04	6.467E+01	216.6	4.4E-04	3.5E-04
20.0	5.014E+01	214.1	4.5E-04	5.6E-04	5.529E+01	216.6	4.4E-04	3.8E-04
21.0	4.277E+01	213.5	5.1E-04	5.1E-04	4.729E+01	217.6	4.8E-04	3.8E-04
22.0	3.647E+01	213.0	5.1E-04	4.7E-04	4.047E+01	218.6	5.2E-04	3.9E-04
23.0	3.109E+01	212.4	5.4E-04	4.3E-04	3.467E+01	219.6	5.7E-04	3.8E-04
24.0	2.649E+01	211.8	6.0E-04	3.6E-04	2.972E+01	220.6	6.1E-04	3.6E-04

MODEL ATMOSPHERES 3 & 4 continued

MODEL ATMOSPHERES 5 & 6

Table A2. Listing of Data for LOWTRAN 4 (Cont)

25.0	2.[illegible]6E+01	211.2	6.7E-04	3.2E-04	2.549E+01	221.6	6.6E-04	3.4E-04	
30.0	1.00.0E+01	216.0	3.6E-04	1.5E-04	1.197E+01	226.5	3.8E-04	2.0E-04	
35.0	4.701E+00	222.2	1.1E-04	9.2E-05	5.746E+00	236.5	1.6E-04	1.1E-04	
40.0	2.243E+00	234.7	4.3E-05	4.1E-05	2.871E+00	253.4	6.7E-05	4.9E-05	
45.0	1.113E+00	247.0	1.9E-05	1.3E-05	1.491E+00	264.2	3.2E-05	1.7E-05	
50.0	5.719E-01	259.3	6.3E-06	4.3E-06	7.978E-01	270.6	1.2E-05	4.0E-06	
70.0	4.016E-02	245.7	1.4E-07	8.6E-08	5.520E-02	219.7	1.5E-07	9.6E-08	
100.0	3.000E-04	210.0	1.0E-09	4.3E-11	3.008E-04	210.0	1.0E-09	4.3E-11	
99999.	0.000E+00	210.	0.0E-00	0.0E-00	0.000E 00	210.0	0.0E-00	0.0E-00	
.200	.38223	.07945	.250	.32 7	.03661	.300	.28640	.02110	.400	.22026	.01317
.488	.17989	.01114	.550	.15800	.01095	.694	.12064	.00968	.860	.09151	.01058
1.060	.07078	.01070	1.536	.04184	.00933	1.800	.03126	.00700	2.000	.02510	.00437
2.500	.02068	.00463	3.000	.01900	.00584	3.500	.01767	.00250	3.750	.01699	.00214
4.000	.01654	.00232	5.000	.01533	.00321	5.500	.01479	.00388	6.000	.01389	.00462
7.200	.01569	.00745	7.900	.01102	.00617	8.300	.01019	.00807	8.500	.01778	.01254
8.700	.01994	.01126	9.000	.02112	.01209	9.200	.02213	.01378	9.500	.01870	.01009
9.80	.01744	.00837	10.00	.01714	.00810	10.50	.01588	.00680	11.00	.01514	.00570
11.50	.01455	.00535	12.50	.01365	.00916	13.00	.01339	.00523	14.00	.01286	.00538
15.00	.01368	.00834	16.40	.01384	.00696	17.20	.01480	.00767	18.50	.01353	.00677
20.00	.01427	.00767	22.50	.01381	.00767	25.00	.01302	.00749	30.00	.01204	.00761
0.999	-2.3468	-1.6778	0.998	-2.0362	-1.3960	0.996	-1.6990	-1.1192	0.994	-1.4815	-0.9508
0.992	-1.3079	-0.8239	0.990	-1.2007	-0.7258	0.980	-0.7805	-0.4318	0.970	-0.5229	-0.2366
0.960	-0.3468	-0.1074	0.950	-0.1938	-0.	0.940	-0.0655	0.0969	0.930	0.0414	0.1761
0.920	0.1553	0.2304	0.910	0.2430	0.3010	0.900	0.3324	0.3522	0.880	0.4342	0.4624
0.860	0.6128	0.5563	0.840	0.7243	0.6439	0.820	0.8261	0.7243	0.800	0.8191	0.7924
0.780	1.0000	0.8573	0.760	1.0792	0.9191	0.740	1.1461	0.9731	0.720	1.2122	1.0253
0.700	1.2672	1.0719	0.680	1.3284	1.1173	0.660	1.3892	1.1614	0.640	1.4409	1.2095
0.620	1.4955	1.2486	0.600	1.5441	1.2900	0.580	1.5966	1.3263	0.560	1.6435	1.3617
0.540	1.6857	1.3979	0.520	1.7340	1.4393	0.500	1.7782	1.4698	0.480	1.8261	1.4983
0.460	1.8692	1.5314	0.440	1.9191	1.5682	0.420	1.9638	1.6021	0.400	2.0186	1.6335
0.380	2.0607	1.6721	0.360	2.1038	1.7076	0.340	2.1461	1.7482	0.320	2.1875	1.7924
0.300	2.2304	1.8325	0.280	2.2788	1.8865	0.260	2.3263	1.9395	0.240	2.3717	2.0000
0.220	2.4183	2.0607	0.200	2.4698	2.1206	0.180	2.5159	2.1903	0.160	2.5740	2.2552
0.140	2.6284	2.3385	0.120	2.6902	2.4313	0.100	2.7559	2.5195	0.080	2.8261	2.6435
0.060	2.9031	2.7853	0.040	3.0003	2.9777	0.030	3.0607	3.1072	0.020	3.1461	3.2553
0.015	3.2041	3.3617	0.010	3.2718	3.4771	0.008	3.3054	3.5563	0.006	3.3444	3.6233
0.004	3.3979	3.7076	0.002	3.4914	3.8325	0.001	3.5682	3.9345			
3.93	3.72	3.54	3.42	3.37	3.37	3.36	3.33	3.25	3.15	3.02	2.96	2.97	3.06	3.08	350
3.12	3.08	3.03	3.00	3.01	3.03	3.07	3.05	3.01	2.94	2.83	2.71	2.62	2.58	2.57	425
2.62	2.67	2.72	2.71	2.60	2.46	2.35	2.26	2.22	2.23	2.19	2.17	2.17	2.20	2.26	500
2.34	2.42	2.39	2.26	2.01	1.90	1.83	1.78	1.73	1.81	1.84	1.83	1.80	1.71	1.51	575
1.39	1.30	1.25	1.18	1.19	1.18	1.21	1.33	1.47	1.53	1.54	1.36	1.12	0.89	0.68	650
0.49	0.60	0.71	0.79	0.99	0.86	0.73	0.53	0.43	0.51	0.52	0.67	0.73	0.80	0.83	725
0.80	0.63	0.47	0.32	-0.08	-0.21	-0.29	-0.21	-0.01	0.08	0.16	0.09	-0.03	-0.21	-0.37	800
-0.35	-0.30	-0.31	-0.37	-0.42	-0.48	-0.42	-0.40	-0.39	-0.43	-0.77	-0.83	-0.83	-0.79	-0.60	875
-0.50	-0.42	-0.39	-0.38	-0.37	-0.40	-0.51	-0.67	-0.82	-0.58	-0.40	-0.32	-0.21	-0.09	-0.18	950
-0.16	-0.19	-0.28	-0.33	-0.35	-0.28	-0.22	-0.10	-0.05	-0.11	-0.13	-0.27	-0.27	-0.18	-0.06	1025
0.11	0.23	0.26	0.19	0.11	-0.00	-0.09	0.02	0.08	0.12	0.22	0.28	0.39	0.54	0.68	1100
0.75	0.79	0.79	0.71	0.69	0.76	0.88	1.01	1.16	1.18	1.14	1.09	1.02	1.11	1.23	1175
1.41	1.75	1.83	1.99	2.05	2.03	2.00	1.96	1.90	1.86	1.91	2.08	2.24	2.41	2.63	1250

AEROSOL SPECTRAL DATA

TRANSMITTANCE FUNCTION

SPECTRAL DATA

Table A2. Listing of Data for LOWTRAN 4 (Cont)

```
 2.68 2.67 2.73 2.79 2.81 2.91 2.93 3.02 3.16 3.23 3.30 3.34 3.43 3.57 3.59 1325
 3.59 3.58 3.57 3.61 3.71 3.71 3.69 3.64 3.60 3.68 3.80 3.95 4.05 4.05 4.02 1400
 3.99 3.96 4.01 4.13 4.22 4.35 4.49 4.58 4.62 4.63 4.61 4.57 4.56 4.56 4.53 1475
 4.49 4.46 4.40 4.28 4.14 3.92 3.63 3.35 3.15 3.10 3.24 3.47 3.66 3.80 3.93 1550
 4.00 4.04 4.15 4.23 4.31 4.35 4.31 4.23 4.20 4.24 4.28 4.35 4.42 4.42 4.44 1625
 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 1700
 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 1775
 3.21 3.14 3.10 3.06 3.11 2.98 2.88 2.78 2.74 2.76 2.72 2.76 2.82 2.89 2.86 1850
 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 1925
 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 2000
 1.38 1.07 0.91 0.87 0.92 1.04 1.01 0.92 0.84 0.92 0.97 1.01 1.06 1.10 1.06 2075
 1.01 0.91 0.79 0.55 0.47 0.41 0.39 0.38 0.34 0.33 0.36 0.43 0.48 0.45 0.38 2150
 0.27 0.21 0.22 0.29 0.37 0.38 0.37 0.29 0.19 0.13 0.11 0.03-0.05-0.12-0.24 2225
-0.31-0.39-0.43-0.50-0.59-0.68-0.73-0.80-0.92-1.06-1.14-1.22-1.27-1.28-1.33 2300
-1.32-1.43-1.51-1.63-1.74-1.82-1.96-2.09-2.21-2.21-2.24-2.27-2.36-2.51-2.65 2375
-2.70-2.63-2.57-2.56-2.59-2.67-2.69-2.67-2.68-2.62-2.52-2.42-2.29-2.14-2.00 2450
-1.87-1.71-1.51-1.39-1.27-1.12-1.01-0.89-0.75-0.68-0.57-0.47-0.42-0.32-0.27 2525
-0.26-0.19-0.15-0.11-0.01 0.05 0.08 0.17 0.25 0.31 0.41 0.43 0.44 0.43 0.36 2600
 0.35 0.31 0.25 0.25 0.22 0.21 0.33 0.49 0.65 0.76 0.71 0.51 0.30 0.13 0.10 2675
 0.17 0.24 0.31 0.38 0.45 0.51 0.56 0.60 0.63 0.62 0.63 0.64 0.66 0.69 0.76 2750
 0.75 0.74 0.70 0.62 0.53 0.46 0.39 0.38 0.37 0.38 0.42 0.47 0.50 0.58 0.69 2825
 0.67 0.62 0.64 0.66 0.76 0.90 1.11 1.13 1.10 0.97 0.98 1.17 1.38 1.52 1.70 2900
 1.76 1.84 1.92 1.90 1.87 1.91 2.02 2.13 2.10 2.18 2.22 2.25 2.03 2.01 1.77 2975
 1.93 2.19 2.28 2.14 2.15 2.22 2.01 2.14 2.26 2.30 2.51 2.46 2.73 2.68 2.69 3050
 2.64 2.22 1.95 1.61 1.11 0.88 0.83 0.89 1.20 1.62 1.82 1.99 2.01 2.14 2.16 3125
 2.21 2.30 2.33 2.42 2.50 2.51 2.49 2.46 2.42 2.37 2.37 2.33 2.31 2.43 2.56 3200
 2.61 2.63 2.60 2.50 2.38 2.41 2.34 2.31 2.32 2.40 2.27 2.32 2.22 2.09 2.08 3275
 2.17 2.41 2.77 2.66 2.49 2.29 2.23 2.42 2.61 2.58 2.49 2.40 2.39 2.51 2.66 3350
 2.68 2.68 2.70 2.82 2.83 2.82 2.81 2.84 2.86 2.91 2.96 3.03 3.08 3.21 3.30 3425
 3.40 3.52 3.49 3.46 3.51 3.54 3.56 3.55 3.57 3.61 3.71 3.80 3.92 3.99 4.06 3500
 4.02 4.06 4.12 4.26 4.36 4.22 4.32 4.42 4.53 4.64 4.55 4.40 4.28 4.32 4.36 3575
 4.37 4.24 4.13 4.14 4.20 4.25 4.32 4.35 4.31 4.27 4.25 4.27 4.31 4.36 4.41 3650
 4.52 4.59 4.71 4.79 4.81 4.73 4.61 4.42 4.28 4.08 4.00 3.88 3.86 3.92 3.98 3725
 4.12 4.18 4.31 4.37 4.42 4.50 4.53 4.58 4.59 4.61 4.61 4.59 4.53 4.49 4.44 3800
 4.41 4.40 4.34 4.30 4.26 4.09 3.96 3.87 3.78 3.77 3.79 3.75 3.72 3.62 3.56 3875
 3.51 3.48 3.32 3.18 3.07 2.96 2.87 2.80 2.68 2.58 2.59 2.61 2.59 2.57 2.50 3950
 2.42 2.32 2.20 2.12 2.00 1.92 1.79 1.63 1.60 1.69 1.78 2.04 2.00 1.81 1.70 4025
 1.63 1.61 1.60 1.49 1.14 1.35 1.64 1.69 1.70 1.59 1.45 1.29 1.19 1.08 1.02 4100
 1.04 1.10 1.16 1.20 1.23 1.22 1.08 1.08 1.06 0.89 0.93 0.73 0.58 0.54 0.77 4175
 0.81 0.74 0.71 0.57 0.49 0.43 0.38 0.12 0.10 0.20 0.41 0.37 0.31 0.11-0.13 4250
-0.21-0.32-0.36-0.39-0.33-0.39-0.45-0.50-0.55-0.62-0.68-0.77-0.84-0.91-1.00 4325
-1.11-1.19-1.20-1.31-1.39-1.43-1.48-1.52-1.57-1.60-1.61-1.60-1.58-1.51-1.42 4400
-1.32-1.26-1.16-1.06-0.83-0.71-0.61-0.52-0.43-0.36-0.30-0.21-0.19-0.17-0.15 4475
-0.13-0.17-0.19-0.12-0.06-0.01 0.00-0.11-0.23-0.32-0.44-0.51-0.48-0.47-0.42 4550
-0.40-0.40-0.39-0.37-0.35-0.48-0.75-1.13-1.58-1.80-1.66-1.52-1.36-1.19-1.02 4625
-0.88-0.66-0.65-0.63-0.62-0.66-0.73-0.79-0.88-0.84-0.70-0.59-0.43-0.39-0.50 4700
-0.61-0.74-0.79-0.76-0.69-0.62-0.59-0.52-0.48-0.48-0.42-0.39-0.38-0.33-0.29 4775
-0.26-0.23-0.22-0.28-0.37-0.50-0.60-0.60-0.51-0.46-0.42-0.43-0.45-0.35-0.24 4850
-0.14-0.08-0.08 0.00 0.11 0.32 0.43 0.42 0.32 0.23 0.22 0.28 0.45 0.55 0.62 4925
 0.65 0.71 0.75 0.80 0.83 0.85 0.87 0.90 0.93 1.00 1.04 1.15 1.22 1.32 1.31 5000
```

Table A2. Listing of Data for LOWTRAN 4 (Cont)

```
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 2.70 2.71 2.76 2.78 2.70 2.77 3.08 2.94 3.05 2.94 3.23 3.20 3.19 3.32 3.11 5150
 3.41 3.31 3.36 3.46 3.36 3.39 3.50 3.41 3.22 3.19 2.98 2.78 2.98 3.02 2.82 5225
 2.98 2.86 2.92 2.92 3.05 3.22 3.60 3.78 3.81 3.96 3.76 3.62 3.34 3.08 3.31 5300
 3.16 3.37 3.41 3.30 3.33 3.33 3.51 3.48 3.43 3.52 3.31 3.40 3.58 3.61 3.49 5375
 3.46 3.42 3.19 3.16 3.30 3.00 2.99 3.21 3.11 3.14 3.10 2.72 2.81 2.95 2.69 5450
 2.73 2.72 2.47 2.51 2.60 2.42 2.37 2.73 1.91 1.87 1.81 1.78 1.53 1.51 1.62 5525
 1.59 1.50 1.42 1.32 1.22 1.12 1.08 1.02 0.97 0.92 0.90 0.87 0.84 0.82 0.79 5600
 0.78 0.76 0.75 0.72 0.71 0.71 0.70 0.69 0.67 0.61 0.59 0.52 0.48 0.41 0.39 5675
 0.38 0.33 0.32 0.30 0.30 0.30 0.29 0.28 0.27 0.26 0.25 0.23 0.22 0.21 0.20 5750
 0.18 0.14 0.13 0.06 0.01-0.03-0.07-0.11-0.16-0.21-0.24-0.29-0.32-0.38-0.41 5825
-0.45-0.50-0.54-0.61-0.69-0.76-0.84-0.90-0.97-1.01-1.10-1.13-1.19-1.22-1.28 5900
-1.30-1.33-1.36-1.39-1.43-1.48-1.50-1.52-1.57-1.61-1.66-1.70-1.72-1.78-1.81 5975
-1.89-1.92-2.00-2.08-2.16-2.24-2.31-2.40-2.48-2.54-2.61-2.71-2.83-2.95-3.10 6050
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-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00 6200
-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00 6275
-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00 6350
-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00 6425
-3.78-3.33-3.01-2.82-2.68-2.49-2.30-2.13-2.00-1.81-1.60-1.41-1.13-0.90-0.79 6500
-0.63-0.48-0.36-0.28-0.16-0.06 0.08 0.20 0.29 0.41 0.54 0.69 0.80 0.92 1.04 6575
 1.19 1.19 1.01 0.98 1.02 1.19 1.29 1.30 1.29 1.38 1.19 1.39 1.42 1.43 1.70 6650
 1.62 1.54 1.41 1.53 1.86 1.96 1.97 2.02 2.01 1.94 1.94 1.83 2.03 2.21 2.42 6725
 2.30 2.16 2.02 2.02 2.02 2.13 1.90 1.71 2.01 1.56 1.56 1.51 1.30 1.63 1.64 6800
 1.67 1.70 2.22 2.32 2.38 2.30 1.93 2.39 2.49 2.52 2.57 2.21 2.18 2.40 2.41 6875
 2.45 2.51 2.23 2.49 2.30 2.61 2.72 2.52 2.63 2.56 2.51 2.70 2.62 2.62 2.80 6950
 2.74 2.79 2.74 2.70 2.88 2.81 2.72 2.76 2.84 2.92 2.98 2.88 2.88 3.02 3.08 7025
 3.26 3.03 3.14 3.28 3.03 3.11 3.15 3.30 3.31 3.22 3.00 3.06 3.34 3.40 3.37 7100
 3.32 3.08 3.09 3.09 3.01 3.07 3.07 3.31 3.21 3.31 3.67 3.58 3.79 3.70 3.49 7175
 3.39 3.11 3.13 3.01 3.10 3.01 3.18 3.32 3.43 3.35 3.40 3.39 3.39 3.51 3.54 7250
 3.42 3.50 3.67 3.59 3.63 3.66 3.48 3.39 3.29 3.31 3.41 3.23 3.32 3.12 2.91 7325
 2.91 2.75 2.78 2.72 2.62 2.58 2.32 2.22 2.00 1.97 1.68 1.62 1.64 1.53 1.56 7400
 1.51 1.52 1.48 1.42 1.42 1.40 1.41 1.43 1.56 1.52 1.51 1.52 1.39 1.38 1.30 7475
 1.09 1.16 1.21 1.20 1.22 1.20 1.18 1.20 1.19 1.17 1.10 1.10 1.09 1.10 1.11 7550
 1.04 0.98 0.90 0.86 0.90 0.90 0.90 0.88 0.71 0.79 0.70 0.71 0.67 0.62 0.53 7625
 0.42 0.31 0.20 0.01-0.08-0.17-0.26-0.35-0.44-0.53-0.63-0.73-0.83-0.93-1.04 7700
-1.14-1.24-1.34-1.44-1.54-1.64-1.74-1.84-1.94-2.04-2.14-2.24-2.34-2.44-2.54 7775
-2.64-2.74-2.84-2.94-3.04-3.14-3.24-3.34-3.44-3.54-3.64-3.74-3.84-3.94-4.04 7850
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-2.80-2.71-2.62-2.53-2.44-2.35-2.26-2.18-2.09-2.00-1.91-1.82-1.73-1.64-1.55 8375
-1.46-1.37-1.28-1.19-1.10-1.01-0.92-0.83-0.74-0.65-0.56-0.47-0.38-0.29-0.20 8450
-0.14-0.09-0.02 0.03 0.10 0.17 0.22 0.30 0.35 0.41 0.46 0.42 0.40 0.43 0.46 8525
 0.50 0.59 0.71 0.84 0.93 1.01 1.06 1.07 1.02 1.01 1.12 1.23 1.24 1.28 1.34 8600
 1.43 1.52 1.56 1.59 1.56 1.51 1.61 1.50 1.70 1.82 1.92 1.94 1.89 1.81 1.45 8675
 1.30 1.28 1.43 1.50 1.49 1.55 1.48 1.32 1.39 1.53 1.82 2.23 2.61 2.51 2.20 8750
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SPECTRAL DATA H_2O

Table A2. Listing of Data for LOWTRAN 4 (Cont)

```
 1.86 1.61 1.19 1.32 1.52 1.70 1.90 2.01 1.92 1.91 2.12 2.10 2.01 2.18 1.99 8875
 2.11 2.28 2.21 2.13 2.00 1.91 1.92 1.97 1.88 1.91 1.91 1.92 1.93 1.74 1.61 8900
 1.58 1.27 1.20 1.18 1.11 0.99 0.86 0.71 0.60 0.44 0.31 0.19 0.03-0.07-0.21 8975
-0.35-0.49-0.64-0.79-0.94-1.11-1.24-1.41-1.57-1.73-1.91-2.09-2.27-2.45-2.63 9050
-2.81-2.99-3.18-3.37-3.56-3.75-3.94-4.13-4.31-4.49-4.66-4.83-4.99-5.14-5.28 9125
-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-4.68-4.26-3.89-3.57-3.32-3.11-2.91 9875
-2.89-2.79-2.74-2.63-2.47-2.29-2.20-2.17-2.23-2.27-2.32-2.12-2.08-2.07-2.07 9950
-2.07-1.98-1.77-1.70-1.63-1.60-1.59-1.43-1.21-1.15-1.09-1.13-1.29-1.19-0.9810025
-0.93-0.87-0.91-0.88-0.71-0.62-0.59-0.58-0.63-0.58-0.39-0.22-0.14-0.06-0.0110100
-0.01-0.08-0.20-0.16-0.02 0.18 0.32 0.42 0.37 0.23 0.12 0.15 0.28 0.43 0.5910175
 0.58 0.53 0.44 0.39 0.38 0.35 0.23 0.26 0.19 0.08 0.10 0.18 0.27 0.38 0.4310250
 0.32 0.37 0.58 0.64 0.87 0.98 1.00 1.02 1.13 1.08 1.08 1.16 1.16 1.30 1.4110325
 1.40 1.32 1.32 1.37 1.42 1.50 1.42 1.38 1.36 1.38 1.49 1.63 1.62 1.62 1.7010400
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 1.62 1.63 1.71 1.72 1.70 1.70 1.67 1.62 1.66 1.70 1.67 1.56 1.49 1.42 1.3810550
 1.26 1.20 1.13 1.14 1.19 1.29 1.50 1.72 1.86 1.78 1.82 1.88 1.82 1.89 1.9910625
 2.00 2.14 2.04 2.02 2.02 1.98 1.90 1.83 1.71 1.72 1.69 1.59 1.50 1.36 1.2010700
 0.98 0.63 0.43 0.29 0.16 0.05 0.02 0.03 0.03 0.01-0.08-0.18-0.20-0.11-0.0610775
-0.03-0.14-0.21-0.08-0.06 0.10 0.18 0.11 0.32 0.42 0.44 0.38 0.20 0.42 0.4310850
 0.41 0.33 0.32 0.41 0.50 0.46 0.31 0.18 0.08 0.20 0.21 0.34 0.36 0.20 0.3510925
 0.39 0.42 0.38 0.32 0.30 0.16-0.01-0.23-0.41-0.52-0.48-0.58-0.61-0.48-0.2311000
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 0.59 0.55 0.50 0.32 0.26 0.11-0.08-0.10-0.16-0.43-0.62-0.88-1.09-1.16-1.3111150
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-1.83-1.82-1.71-1.59-1.49-1.46-1.46-1.49-1.49-1.25-1.24-1.08-0.90-1.06-0.9111825
-0.91-1.01-0.99-0.87-0.92-0.79-0.42-0.54-0.38-0.42-0.48-0.34-0.27-0.17-0.2811900
-0.38-0.22-0.30-0.08-0.01-0.20 0.06 0.10 0.06 0.14-0.12-0.02-0.02-0.13-0.1111975
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 0.09 0.06 0.08 0.16 0.21 0.13 0.32 0.35 0.51 0.60 0.51 0.51 0.40 0.40 0.4312200
 0.42 0.33 0.43 0.34 0.22 0.13-0.11-0.31-0.31-0.41-0.41-0.39-0.53-0.69-0.8412275
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-2.46-2.26-1.99-2.01-2.14-2.31-2.15-2.01-1.99-2.14-2.41-2.12-1.99-1.84-1.7913400
-1.71-1.78-1.72-1.68-1.78-1.52-1.38-1.29-1.22-0.91-0.90-1.31-0.76-0.90-0.9013475
-0.90-1.19-1.00-0.79-0.68-0.68-0.73-0.85-0.85-0.61-0.61-0.48-0.61-0.92-0.8313550
-0.61-0.41-0.29-0.29-0.61-0.74-0.19-0.18 0.   0.19-0.10 0.20 0.20 0.02  .2013625
-0.01 0.18 0.28 0.11 0.  -0.37-0.10 0.02 0.16 0.20 0.   0.09 0.09 0.09 0.0713700
 0.22 0.11 0.11 0.21 0.09 0.21 0.20 0.37 0.28 0.07 0.09-0.29-0.69-0.69-0.7413775
```

SPECIAL UNIT M.S

Table A2. Listing of Data for LOWTRAN 4 (Cont)

```
-0.88-1.01-0.86-0.54-0.19 0.19 0.23 0.21 0.29 0.28 0.29 0.52 0.54 0.51  .6013850
 0.40 0.49 0.48 0.46 0.49 0.27 0.06-0.33-0.81-1.17-1.11-1.37-1.52-1.54-1.9413925
-2.06-2.06-2.14-1.96-2.00-2.00-2.08-2.23-2.31-2.31-2.53-2.31-2.31-2.31-2.2814000
-2.34-2.34-1.91-1.82-1.69-1.56-1.84-1.91-1.75-1.83-1.76-1.54-1.98-1.80-1.6814075
-1.69-1.56-1.60-1.71-1.36-1.36-1.44-1.48-1.40-1.48-1.36-1.45-1.49-1.85-1.3914150
-1.23-1.18-1.18-1.34-1.36-1.23-1.23-1.37-1.30-1.40-1.28-1.27-1.37-1.32-1.3214225
-1.22-1.28-1.38-1.69-2.07-2.42-2.58-2.58-2.80-2.58-2.43-1.88-1.60-1.26-1.1614300
-1.23-1.10-1.23-1.10-0.83-0.80-0.80-0.80-0.98-0.97-0.97-0.91-0.92-1.13-1.2414375
-1.50-1.89-2.18-2.32-2.63-3.91-4.20-4.49-4.78-5.07-5.07-5.07-5.07-5.07-5.0714450
-4.25-3.70-3.20-2.75-1.90-1.73-1.51-1.29-1.11-0.91-0.71-0.51-0.30-0.06 0.22  500
 0.49 0.76 1.08 1.29 1.56 1.76 1.91 2.08 2.23 2.36 2.51 2.72 2.90 3.12 3.37  575
 3.56 3.69 3.79 3.86 3.88 3.86 3.73 3.58 3.38 3.17 2.86 2.73 2.52 2.31 2.17  650
 2.01 1.89 1.77 1.63 1.47 1.21 0.92 0.53 0.23-0.17-0.53-0.74-0.81-0.84-0.88  725
-1.00-1.16-1.42-1.61-1.86-2.10-2.29-2.51-2.72-2.91-3.14-5.00-5.00-5.00-5.00  800
-5.00-5.00-5.00-5.00-5.00-5.00-2.68-2.47-2.19-1.97-1.71-1.50-1.32-1.21-1.13  875
-1.09-1.11-1.10-1.09-1.01-1.01-1.11-1.33-1.66-2.13-2.51-2.83-2.71-2.39-2.09  950
-1.78-1.59-1.33-1.18-1.01-0.96-0.91-0.90-0.87-0.80-0.79-0.86-1.07-1.28-1.69 1025
-2.11-2.74-3.09-3.50-3.03-2.58-2.23-1.89-1.54-1.28-1.13-1.11-1.16-1.20-1.23 1100
-1.21-1.17-1.12-1.15-1.19-1.20-1.17-1.02-0.89-0.68-0.42-0.24-0.01 0.18 0.40 1175
 0.57 0.77 0.96 1.07 1.13 1.11 1.08 1.15 1.27 1.33 1.44 1.40 1.13 0.89 0.63 1250
 0.54 0.65 0.78 0.81 0.86 0.82 0.68 0.47 0.14-0.12-0.48-0.92-1.43-1.99 2.72 1325
-2.81-5.00-5.00-5.00-3.14-2.47-2.00-1.71-1.53-1.61-1.69-1.82-1.87-1.90-1.94 1400
-2.04-2.10-2.23-2.32-2.48-2.71-2.88-3.09-2.98-2.43-2.00-1.69-1.42-1.38-1.49 1475
-1.70-2.01-2.41-2.64-2.63-2.49-2.38-2.27-2.16-2.05-1.94-1.83-1.76-1.71-1.70 1550
-1.72-1.81-1.92-2.03-2.27-2.61-3.21-4.01-5.00-5.00-5.00-5.00-5.00-5.00-5.00 1625
-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00 1700
-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-4.30-3.42-3.17-2.98 1775
-2.83-2.71-2.67-2.67-2.68-2.58-2.33-2.01-1.64-1.32-0.97-0.76-0.63-0.59-0.60 1850
-0.63-0.69-0.87-1.08-1.26-1.53-1.87-1.91-1.93-2.02-2.21-2.48-2.80-3.08-3.11 1925
-3.09-2.93-2.76-2.39-2.01-1.69-1.36-0.99-0.63-0.28 0.00 0.08 0.11 0.12 0.12 2000
 0.07 0.01-0.08-0.23-0.40-0.51-0.53-0.57-0.60-0.61-0.73-0.81-0.95-1.05-1.02 2075
-0.91-0.68-0.41-0.09 0.16 0.41 0.76 1.00 1.18 1.39 1.51 1.58 1.68 1.71 1.80 2150
 1.91 2.02 2.18 2.32 2.50 2.61 2.69 2.81 2.89 2.96 3.04 3.14 3.27 3.41 3.55 2225
 3.72 3.90 4.03 4.22 4.42 4.61 4.71 4.73 4.65 4.63 4.72 4.78 4.79 4.50 3.62 2300
 3.24 2.79 2.30 1.86 1.35 0.52-0.24-1.69-2.18-2.01-1.79-1.53-1.32-1.20-1.15 2375
-1.12-1.18-1.25-1.26-1.20-1.17-1.20-1.32-1.54-1.84-2.16-2.30-2.26-2.01-1.71 2450
-1.36-1.06-0.81-0.61-0.49-0.45-0.47-0.49-0.46-0.37-0.31-0.34-0.49-0.75-1.11 2525
-1.43-2.01-2.60-2.89-2.87-2.74-2.51-2.42-2.38-2.39-2.42-2.46-2.48-2.49-2.43 2600
-2.43-2.46-2.53-2.68-2.74-2.82-2.87-2.83-2.82-2.79-2.71-2.66-2.49-2.40-2.32 2675
-2.26-2.23-2.20-2.09-2.02-1.96-1.88-1.84-1.86-1.86-1.87-1.83-1.79-1.73-1.68 2750
-1.64-1.69-1.74-1.79-1.87-1.78-1.63-1.50-1.37-1.21-1.00-0.83-0.69-0.53-0.41 2825
-0.30-0.19-0.09-0.04 0.02 0.10 0.16 0.18 0.23 0.26 0.27 0.26 0.24 0.22 0.17 2900
 0.12 0.07-0.01-0.07-0.09 0.32 0.72 0.91 1.12 1.03 0.67 0.18-0.11-0.38-0.29 2975
-0.17-0.08-0.00 0.09 0.13 0.18 0.24 0.27 0.29 0.31 0.29 0.26 0.23 0.21 0.13 3050
 0.09 0.02-0.04-0.18-0.32-0.51-0.72-0.98-1.18-1.50-1.62-1.81-2.04-2.29-2.49 3125
-2.62-2.87-3.03-3.21-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00 3200
-5.00-4.01-3.38-3.01-2.63-2.32-2.09-1.98-1.94-2.00-2.14-2.26-2.20-2.02-1.82 3275
-1.59-1.43-1.38-1.46-1.64-1.90-2.09-2.54-2.91-3.28-3.61-3.72-3.64-3.50-3.41 3350
-3.37-3.30-3.16-3.01-2.76-2.51-2.20-1.80-1.49-1.22-0.97-0.72-0.49-0.20 0.03 3425
 0.20 0.36 0.51 0.61 0.67 0.83 1.00 1.22 1.38 1.56 1.70 1.86 2.01 2.20 2.31 3500
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SPECTRAL DATA UNIFORM / MIXED GASES

Table A2. Listing of Data for LOWTRAN 4 (Cont)

```
 2.47 2.61 2.76 2.92 3.01 3.05 3.02 2.98 2.98 3.01 3.03 2.97 2.78 2.44 2.13 3575
 1.83 1.79 1.49 1.50 1.67 1.94 2.22 2.50 2.71 2.93 3.12 3.18 3.17 3.15 3.21 3650
 3.26 3.19 2.98 2.59 2.14 1.70 1.22 0.55-0.27-1.09-2.54-3.06-2.94-2.78-2.68 3725
-2.61-2.60-2.63-2.66-2.67-2.53-2.57-2.64-2.77-3.04-3.38-3.98-5.00-5.00-5.00 3800
-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00 3875
-5.00-4.00-3.73-3.62-3.59-3.53-3.56-3.57-3.53-3.51-3.45-3.37-3.26-3.21-3.18 3950
-3.27-3.36-3.60-3.96-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00 4025
-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-4.62 4100
-4.07-3.89-3.76-3.67-3.56-3.42-3.35-3.26-3.18-3.14-3.11-3.09-3.10-3.12-3.23 4175
-3.30-3.38-3.37-3.29-3.14-3.08-3.00-2.93-2.89-2.91-3.00-3.08-3.16-3.31-3.48 4250
-3.71-3.98-5.00-5.00-5.00-5.00-4.52-3.98-3.69-3.42-3.18-2.95-2.77-2.61-2.48 4325
-2.41-2.41-2.40-2.38-2.34-2.27-2.21-2.31-2.49-2.73-3.21-4.13-5.00-5.00-5.00 4400
-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00 4475
-5.00-5.00-4.13-4.02-3.99-3.96-3.87-3.73-3.51-3.29-3.13-2.99-2.84-2.73-2.69 4550
-2.68-2.69-2.65-2.62-2.59-2.57-2.62-2.61-3.04-3.21-3.39-3.42-3.36-3.21-3.03 4625
-2.93-2.80-2.64-2.52-2.37-2.28-2.20-2.13-2.07-2.02-1.96-1.88-1.78-1.63-1.44 4700
-1.31-1.20-1.08-0.98-0.94-0.86-0.76-0.52-0.31-0.00 0.13 0.30 0.37 0.36 0.36 4775
 0.35 0.35 0.39 0.46 0.48 0.41 0.23-0.08-0.38-0.67-0.88-0.96-0.98-0.87-0.67 4850
-0.36-0.12 0.14 0.44 0.68 0.90 1.11 1.19 1.24 1.25 1.26 1.27 1.51 1.59 1.50 4925
 1.28 0.71 0.11-0.28-0.67-1.32-1.61-1.58-1.42-1.18-0.91-0.59-0.27-0.06 0.29 5000
 0.57 0.73 0.92 0.91 0.73 0.79 0.91 1.01 1.03 0.88 0.72 0.63 0.38 0.12-0.21 5075
-0.47-0.67-1.23-1.67-2.31-2.76-3.24-3.49-3.51-3.47-3.39-3.37-3.43-3.53-3.58 5150
-3.36-3.18-3.07-2.96-3.08-3.14-3.12-3.23-3.07-2.83-2.47-2.23-2.07-1.91-1.78 5225
-1.63-1.46-1.27-1.23-1.26-1.40-1.57-1.98-2.28-2.87-3.74-5.00-5.00-5.00-5.00 5300
-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00 5375
-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00 5450
-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00 5525
-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00 5600
-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00 5675
-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00 5750
-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00 5825
-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-4.91-4.79-4.61 5900
-4.48-4.40-4.29-4.17-3.90-3.73-3.59-3.62-3.72-3.73-3.69-3.31-3.12-2.91-2.83 5975
-2.41-2.27-2.16-2.11-2.28-2.29-2.21-2.06-1.91-1.99-2.27-2.59-2.96-3.35-3.69 6050
-3.79-3.68-3.53-3.46-3.39-3.31-3.18-2.97-2.69-2.39-2.11-1.83-1.58-1.49-1.22 6125
-1.08-0.89-0.68-0.54-0.71-0.79-0.78-0.66-0.43-0.54-0.80-1.37-2.08-2.44-3.46 6200
-3.72-3.74-3.59-3.22-2.98-2.52-2.21-1.64-1.34-1.08-0.86-0.72-0.61-0.70-0.72 6275
-0.67-0.57-0.38-0.51-0.97-1.36-1.89-2.74-3.18-4.21-4.57-4.62-4.78-4.87-5.00 6350
-5.00-5.00-5.00-5.00-5.00-4.93-4.46-3.99-3.46-2.99-2.63-2.30-2.09-2.02-2.12 6425
-2.18-2.13-2.04-1.78-1.83-2.08-2.28-2.61-3.01-3.15-3.22-3.29-3.58-3.89-4.46 6500
-4.88-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00 6575
-4.81-4.52-4.11-3.69-3.09-2.99-2.91-2.89-3.19-3.20-3.36-3.62-3.89-3.92-3.73 6650
-3.53-3.37-3.19-3.02-2.79-2.52-2.36-2.24-2.19-2.32-2.41-2.29-2.00-2.00-2.18 6725
-2.47-2.91-3.57-4.89-5.00-5.00-5.00-5.00-5.00-4.61-4.18-3.89-3.57-3.50-3.92 6800
-2.74-2.51-2.20-1.98-1.73-1.57-1.38-1.21-1.11-0.98-0.87-0.78-0.60-0.37-0.18 6875
-0.04-0.04-0.06-0.16-0.18-0.19-0.23-0.45-1.02-1.97-2.70-3.71-4.01-4.20-4.35 6950
-4.58-4.73-4.81-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00 7025
-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00 7100
-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00 7175
-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00 7250
```

Table A2. Listing of Data for LOWTRAN 4 (cont)

```
-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00 7325
-5.00-5.00-5.00-4.71-4.31-3.99-3.66-3.50-3.34-3.22-3.23-3.25-3.24-3.18-3.10 7400
-3.07-3.18-3.41-3.67-4.12-4.68-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-4.51-4.16 7475
-3.73-3.48-3.17-2.96-2.73-2.63-2.58-2.59-2.57-2.49-2.42-2.38-2.48-2.62-3.02 7550
-3.49-4.16-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-4.87-4.50 7625
-4.21-3.90-3.66-3.56-3.51-3.51-3.51-3.49-3.41-3.34-3.34-3.47-3.60-3.87-4.23 7700
-4.59-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-4.93 7775
-4.51-4.10-3.78-3.32-3.03-2.74-2.43-2.08-1.83-1.59-1.29-1.02-0.81-0.70-0.73 7850
-0.90-1.08-1.19-1.35-1.47-1.57-1.66-1.80-1.91-2.04-2.18-2.33-2.47-2.61-2.78 7925
-2.97-3.10-3.28-3.44-3.63-3.81-3.98-4.15-4.32-4.61-4.71-4.80-5.00-5.00-5.00 8000
-5.00-5.00-5.00-5.00-4.32-3.24-2.59-2.12-1.82-1.57-1.35-1.15-1.02-0.82-0.64 2950
-0.48-0.33-0.14-0.00 0.08 0.21 0.39 0.52 0.61 0.72 0.85 0.96 1.02 1.12 1.18 3025
 1.21 1.17 1.08 0.98 0.90 0.97 1.13 1.27 1.58 1.74 1.70 1.48 1.13 0.73 0.22 3100
-0.51-1.57-3.48-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00 3175
-4.15-3.51-3.00-2.54-2.12-1.76-1.50-1.21-1.00-0.89-0.69-0.29-0.10 0.02 0.12 0.24  575
 0.32 0.43 0.52 0.58 0.65 0.72 0.79 0.76 0.72 0.68 0.64 0.68 0.79 0.83 0.83  650
 0.80 0.78 0.68 0.60 0.49 0.42 0.34 0.26 0.14 0.02-0.14-0.35-0.51-0.74-0.88  725
-1.17-1.40-1.58-2.11-2.47-2.83-3.24-3.59-3.94-5.00-5.00-5.00-5.00-5.00-5.0    800
-5.00-5.00-5.00-5.00-5.00-4.46-4.00-3.50-3.14-2.78-2.41-2.10-2.78-1.49-1.20  875
-0.70 0.15 0.35 0.57 0.78 0.95 1.20 1.40 1.65 1.80 1.97 2.10 2.21 2.31 2.38  950
 2.50 2.42 2.58 2.62 2.20 2.48 2.54 2.46 2.30 2.00 1.20 0.95 0.92 0.90 0.90 1025
 0.89 0.90 0.92 0.94 0.95 0.96 0.96 0.90 0.80 0.68 0.55 0.46 0.30 0.19 0.08 1100
-0.02-0.11-0.22-0.41-0.56-0.71-0.89-1.03-1.19-1.33-1.60-1.76-1.90-2.02-2.21 1175
-2.46-2.69-2.79-3.06-3.22-3.61-4.16-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00 1250
-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00 1325
-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00 1400
-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00 1475
-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-4.16-3.91-3.66-3.41-3.05-2.69 1550
-2.44-2.19-2.03-1.86-1.71-1.56-1.48-1.39-1.26-1.15-0.97-0.81-0.69-0.48-0.35 1625
-0.22-0.14-0.06-0.02-0.09-0.18-0.14 0.06 0.26-0.02-0.42-0.80-0.82-0.80-0.74 1700
-0.74-0.79-0.84-0.89-0.85-0.81-0.76-0.70-0.64-0.64-0.65-0.66-0.72-0.78-0.84 1775
-0.90-1.02-1.14-1.24-1.33-1.47-1.61-1.77-1.92-1.98-2.04-2.08-2.09-2.06-2.03 1850
-1.98-1.93-1.87-1.82-1.76-1.71-1.65-1.59-1.51-1.44-1.36-1.28-1.18-1.08-0.98 1925
-0.88-0.78-0.69-0.59-0.49-0.37-0.25-0.18-0.10 0.00 0.16 0.27 0.38 0.57 0.75 2000
 0.93 1.11 1.20 1.35 1.44 1.46 1.48 1.48 1.44 1.44 1.58 1.49 1.23 0.66 0.38 2.33 2075
-0.71-0.86-0.58-0.49-0.44-0.40-0.40-0.46-0.53-0.64-0.76-0.89-1.01-1.14-1.26 2150
-1.40-1.59-1.69-1.83-1.98-2.13-2.28-2.43-2.64-2.80-3.07-3.28-3.50-3.72-3.94 2225
-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00 2300
-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00 2375
-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00 2450
-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00 2525
-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-4.16-3.97-3.77-3.58-3.38-3.07-2.75 2600
-2.44-2.12-1.85-1.57-1.30-1.07-0.98-0.94-3.69-0.85-0.81-0.77-0.72-0.68-0.63 2675
-0.58-0.53-0.48-0.41-0.34-0.26-0.19-0.17-0.18-0.19-0.46-0.79-1.12-1.45-1.75 2750
-2.38-2.97-3.57-4.16-5.00-5.00-5.00-4.16-3.90-3.63-3.37-3.10-2.79-2.47-2.15 2825
-1.84-1.73-1.63-1.52-1.41-1.33-1.25-1.17-1.09-1.02-0.96-0.89-0.82-0.73-0.68 2900
-0.54-0.42-0.27-0.12 0.03 0.18 0.25 0.31 0.39 0.47 0.48 0.49 0.50 0.50 0.48 2975
 0.46 0.23 0.01-0.11-0.33-0.56-0.77-0.83-0.88-0.94-0.92-0.91-0.90-0.85-0.80 3050
-0.76-0.71-0.69-0.67-0.66-0.65-0.65-0.66-0.67-0.68-0.70-0.72-0.82-0.93-1.03 3125
-1.14-1.24-1.36-1.51-1.68-2.13-2.57-2.92-3.26-3.71-4.16-5.00-5.00-5.00-5.00 3200
```

Table A2. Listing of Data for LOWTRAN 4 (Cont)

```
2.93E-04 3.86E-04 5.09E-04 6.56E-04 8.85E-04 1.06E-03 1.31E-03 1.73E-03     2080
2.27E-03 2.73E-03 3.36E-03 3.95E-03 5.46E-03 7.13E-03 9.00E-03 1.13E-02     2120
1.36E-02 1.66E-02 1.96E-02 2.16E-02 2.36E-02 2.63E-02 2.90E-02 3.15E-02     2160
3.40E-02 3.66E-02 3.92E-02 4.26E-02 4.60E-02 4.96E-02 5.30E-02 5.65E-02     2200
6.00E-02 6.30E-02 6.60E-02 6.89E-02 7.18E-02 7.39E-02 7.60E-02 7.84E-02     2240
8.08E-02 8.39E-02 8.70E-02 9.13E-02 9.56E-02 1.08E-01 1.20E-01 1.36E-01     2280
1.52E-01 1.60E-01 1.69E-01 1.60E-01 1.51E-01 1.37E-01 1.23E-01 1.19E-01     2320
1.16E-01 1.14E-01 1.12E-01 1.12E-01 1.11E-01 1.11E-01 1.12E-01 1.14E-01     2360
1.13E-01 1.12E-01 1.09E-01 1.07E-01 1.02E-01 9.95E-02 9.50E-02 9.00E-02     2400
8.65E-02 8.20E-02 7.65E-02 7.05E-02 6.50E-02 6.10E-02 5.50E-02 4.95E-02     2440
4.50E-02 4.00E-02 3.75E-02 3.50E-02 3.10E-02 2.65E-02 2.50E-02 2.20E-02     2480
1.95E-02 1.75E-02 1.60E-02 1.40E-02 1.20E-02 1.05E-02 9.50E-03 9.00E-03     2520
8.00E-03 7.00E-03 6.50E-03 6.00E-03 5.50E-03 4.75E-03 4.00E-03 3.75E-03     2560
3.50E-03 3.00E-03 2.50E-03 2.25E-03 2.00E-03 1.85E-03 1.70E-03 1.60E-03     2600
1.50E-03 1.50E-03 1.54E-03 1.50E-03 1.47E-03 1.34E-03 1.25E-03 1.06E-03     2640
9.06E-04 7.53E-04 6.41E-04 5.09E-04 4.04E-04 3.30E-04 2.86E-04 2.32E-04     2680
1.94E-04 1.57E-04 1.31E-04 1.02E-04 8.07E-05                               2720
0.00 .187 .147 .117 .097 .087 .10  .120 .147 .174 .20  .24  .28  .33  .40   2350
4.50E-03 8.00E-03 1.07E-02 1.10E-02 1.27E-02 1.71E-02 2.00E-02 2.45E-02    13000
3.07E-02 3.84E-02 4.78E-02 5.67E-02 6.54E-02 7.62E-02 9.15E-02 1.00E-01    14600
1.09E-01 1.20E-01 1.28E-01 1.12E-01 1.11E-01 1.10E-01 1.19E-01 1.13E-01    16200
1.03E-01 9.24E-02 8.28E-02 7.57E-02 7.07E-02 6.58E-02 5.56E-02 4.77E-02    17800
4.06E-02 3.87E-02 3.82E-02 2.94E-02 2.09E-02 1.80E-02 1.91E-02 1.66E-02    19400
1.17E-02 7.70E-03 6.10E-03 8.50E-03 6.10E-03 3.70E-03 3.20E-03 3.10E-03    21000
2.55E-03 1.98E-03 1.40E-03 8.25E-04 2.50E-04 0.00E-04 0.00E-04 0.00E-04    22600
5.65E-04 2.04E-03 7.35E-03 2.03E-02 4.48E-02 1.18E-01 2.46E-01 5.18E-01    27800
1.02E+00 1.95E+00 3.79E+00 6.65E+00 1.24E+01 2.20E+01 3.67E+01 5.95E+01    31500
8.50E+01 1.26E+02 1.66E+02 2.06E+02 2.42E+02 2.71E+02 2.91E+02 3.02E+02    35930
3.03E+02 2.98E+02 2.77E+02 2.54E+02 2.26E+02 1.96E+02 1.68E+02 1.44E+02    39500
1.17E+02 9.75E+01 7.65E+01 6.04E+01 4.62E+01 3.46E+01 2.52E+01 2.00E+01    43500
1.57E+01 1.20E+01 1.00E+01 8.80E-00 8.30E-00 8.60E-00                      47500
 5  1  2
    2.500      8.500     65.000
 2350.000   2459.000      9.000
 2
 5  7  1  0  1
 .200 .20832 .02054  .250 .19518 .00864  .300 .18479 .00442  .400 .17030 .00243
 .488 .16213 .00193  .550 .15800 .00186  .604 .15001 .00155  .860 .14412 .00171
1.060 .13909 .00191 1.536 .12754 .00191 1.800 .12049 .00145 2.000 .11530 .00218
2.500 .09962 .00336 3.000 .10426 .05258 3.500 .09899 .00658 3.750 .09191 .00271
4.000 .08670 .00314 5.000 .07012 .00578 6.500 .05928 .00507 6.000 .05485 .00351
7.000 .04758 .00942 7.900 .04063 .00923 8.200 .03960 .01006 8.500 .04045 .01125
8.700 .04267 .01114 9.000 .04208 .01119 9.200 .03962 .01141 9.500 .03552 .01011
 9.80 .03257 .00983 10.00 .03051 .00987 10.69 .02582 .01089 11.00 .02470 .01330
11.50 .02556 .01663 12.50 .03085 .02354 13.00 .03339 .02575 14.00 .03688 .02827
15.00 .03888 .02948 16.40 .04021 .02964 17.00 .04121 .02936 18.50 .03951 .02769
20.00 .03648 .02537 22.50 .03232 .02263 25.00 .02901 .02053 30.00 .02420 .01775
 0.        0.        0.       10.
 1800.     20000.    5.
 2
```

Table A2. Listing of Data for LOWTRAN 4 (Cont)

```
 6  7  1  0  1
 .200 .31030 .10690   .250 .28410 .08649   .300 .25805 .07571   .400 .20867 .06376
 .488 .17631 .05674   .550 .15800 .05282   .694 .13601 .04528   .860 .10071 .04022
1.060 .08140 .03564 1.536 .05408 .02769 1.800 .04465 .02408 2.000 .03899 .02115
2.500 .03211 .01827 3.000 .02838 .01699 3.500 .02545 .01360 3.750 .02421 .01274
4.000 .02319 .01223 5.000 .02010 .01078 5.500 .01896 .01045 6.000 .01776 .01023
7.200 .01747 .01070 7.900 .01445 .00953 8.200 .01384 .01037 8.500 .01757 .01251
8.700 .01854 .01172 9.000 .01900 .01262 9.200 .01939 .01278 9.500 .01748 .01075
 9.80 .01669 .00973 10.00 .01644 .00954 10.59 .01955 .00868 11.00 .01499 .00796
11.50 .01452 .00765 12.50 .01373 .00727 13.00 .01347 .00721 14.00 .01248 .00707
15.00 .01315 .00843 16.40 .01297 .00751 17.20 .01333 .00776 18.50 .01245 .00712
20.00 .01262 .00741 22.50 .01209 .00719 25.00 .01143 .00691 30.00 .01050 .00668
 0.       0.       0.       10.
1820.     20000.    5.
2
 6  7  1  0  1
 .290 .38223 .07945   .250 .32979 .03661   .300 .28540 .02110   .400 .22035 .01317
 .488 .17989 .01114   .550 .15807 .01095   .694 .13064 .00968   .860 .09151 .01068
1.060 .07078 .01070 1.536 .04184 .00933 1.800 .03126 .00736 2.000 .02513 .00437
2.500 .02068 .00463 3.000 .01900 .00584 3.500 .01767 .00260 3.750 .01699 .00214
4.000 .01654 .00382 5.000 .01533 .00321 5.500 .01479 .00388 6.000 .01349 .00382
7.200 .01569 .00745 7.900 .01102 .00617 8.200 .01019 .00807 8.500 .01778 .01264
8.700 .01994 .01126 9.000 .02112 .01209 9.200 .02213 .01378 9.500 .01870 .01005
 9.80 .01744 .00832 10.00 .01714 .00810 10.59 .01588 .00680 11.00 .01514 .00570
11.50 .01455 .00539 12.50 .01365 .00516 13.00 .01339 .00523 14.00 .01296 .00538
15.00 .01368 .00834 16.40 .01384 .00696 17.20 .01480 .00767 18.50 .01353 .00677
20.00 .01427 .00767 22.50 .01381 .00767 25.00 .01307 .00749 30.00 .01204 .00761
 0.       0.       0.       10.
1820.     20000.    5.
2
 6  7  1  0  1
 .200 .40212 .08642   .250 .34565 .03451   .300 .29874 .01767   .400 .22935 .00971
 .488 .18187 .00772   .550 .15800 .00745   .694 .11722 .00619   .860 .08537 .00683
1.060 .06265 .00689 1.536 .03078 .00545 1.800 .01917 .00348 2.000 .01741 .00173
2.500 .00783 .00183 3.000 .00629 .00251 3.500 .00470 .00076 3.750 .00354 .00063
4.000 .00368 .00222 5.000 .00293 .00285 5.500 .00465 .00463 6.000 .00785 .00766
8.700 .00669 .00542 9.000 .00726 .00593 9.200 .00858 .00766 9.500 .00533 .00427
 9.80 .00377 .00311 10.00 .00359 .00299 10.59 .00272 .00228 11.00 .00212 .00175
11.50 .00191 .00162 12.50 .00177 .00157 13.00 .00180 .00164 14.00 .00182 .00170
15.00 .00382 .00379 16.40 .00246 .00239 17.20 .00264 .00249 18.50 .00221 .00212
20.00 .00251 .00242 22.50 .00252 .00245 25.00 .00250 .00246 30.00 .00276 .00274
 0.       0.       0.       10.
1820.     20000.    5.
 6  7  1  0  1
  .20 .28600 .09530   .25 .28000 .05660   .31 .26200 .02060   .34 .24500 .01450
  .49 .10500 .01050   .51 .17600 .01000   .63 .14600 .00914   .69 .13400 .00914
  .86 .10800 .01026 1.06 .08910 .01080 1.54 .05790 .00924 2.00 .03610 .00348
2.50 .02660 .00369 2.70 .02670 .00988 3.00 .02240 .00487 3.20 .02150 .00332
3.39 .02090 .00722 3.50 .02100 .00171 3.75 .01950 .00143 4.00 .01820 .00154
4.50 .01670 .00248 5.60 .01360 .00295 6.00 .01190 .00366 6.50 .01210 .00423
```

Table A2. Listing of Data for LOWTRAN 4 (Cont)

```
 7.20 .01330 .00629  7.90 .00784 .00504  8.20 .00809 .00702  8.50 .01530 .01160
 8.70 .02190 .01180  9.00 .02380 .01310  9.20 .02350 .01430  9.50 .01650 .00937
10.00 .01570 .00698 10.50 .01350 .00549 11.00 .01220 .00439 13.00 .00938 .00586
14.80 .00827 .01464 15.00 .01010 .00691 17.20 .01100 .00607 18.50 .00923 .00506
20.00 .01010 .00567 25.00 .00878 .00565 27.90 .00821 .00562 30.00 .00808 .00581
 0.       0.       0.       10.
1820.     20000.    5.
```

Appendix B

Basic Flow Chart for LOWTRAN 4

A general flow chart for LOWTRAN 4 is given in Figure B1 which shows the overall mode of operation of the program. More detailed flow charts are also given for the main blocks in the program, that is, where the equivalent absorber amounts and refraction calculations are made (Figure B2), the transmittance/radiance loop (Figure B3), and the transmittance calculations (Figure B4).

The notation used in the flow charts is as follows:

(1) If a condition stated within a given block is fulfilled, then the direction of flow is sideways as indicated by the direction in which the block points (for example → for the following block ▭>).

(2) If the condition stated within a block is not fulfilled, the flow is downwards.

The numbers appearing on the flow charts correspond to the statement numbers given in the main program (see Table A1).

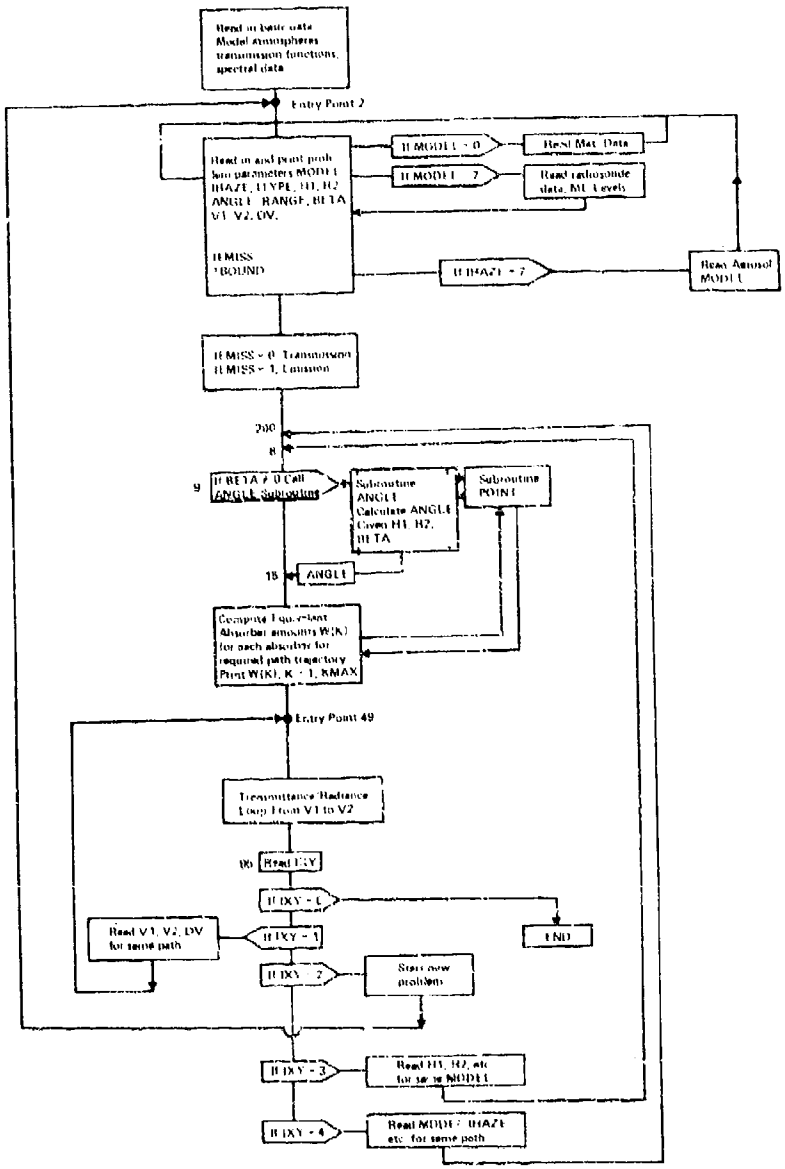

Figure B1. General Flow Chart for LOWTRAN 4

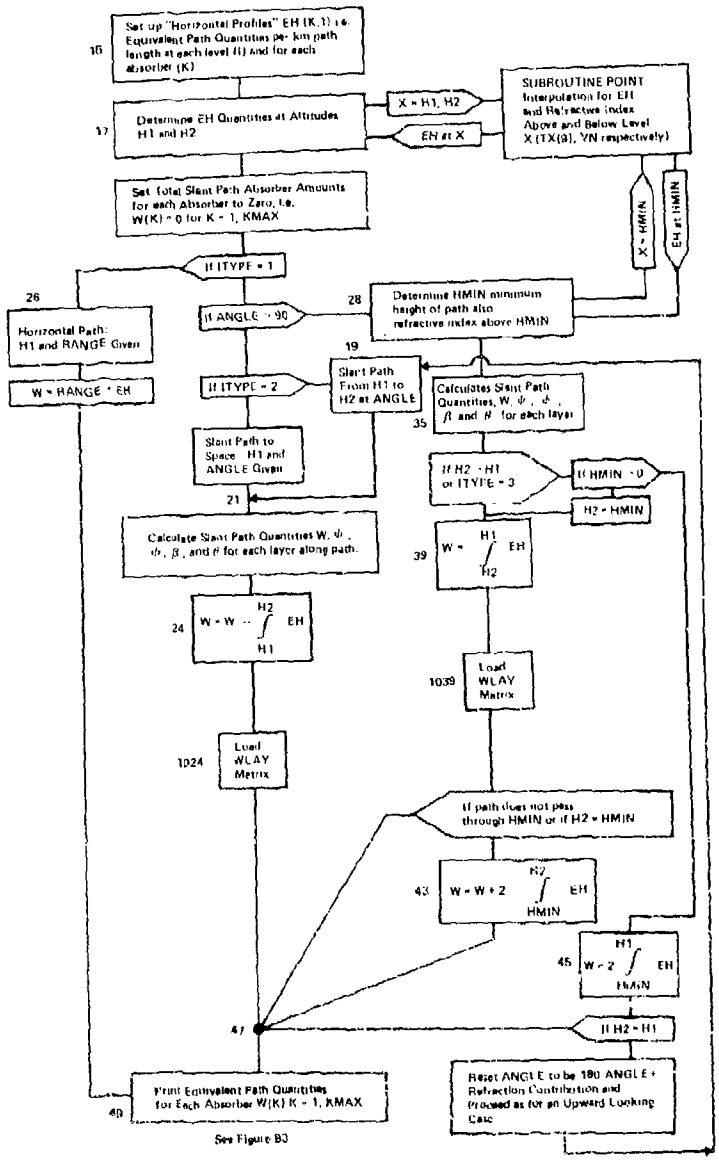

Figure B2. Flow Chart for Calculation of Equivalent Path Quantities

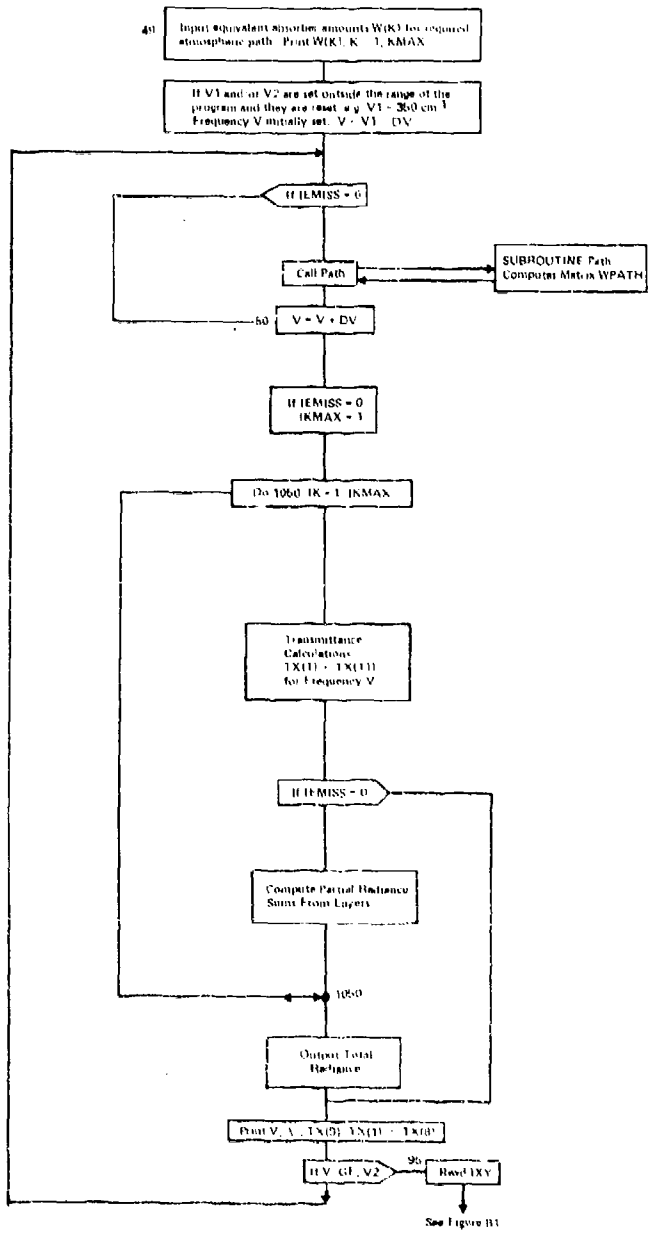

Figure B3. Flow Chart for Transmittance/Radiance Loop

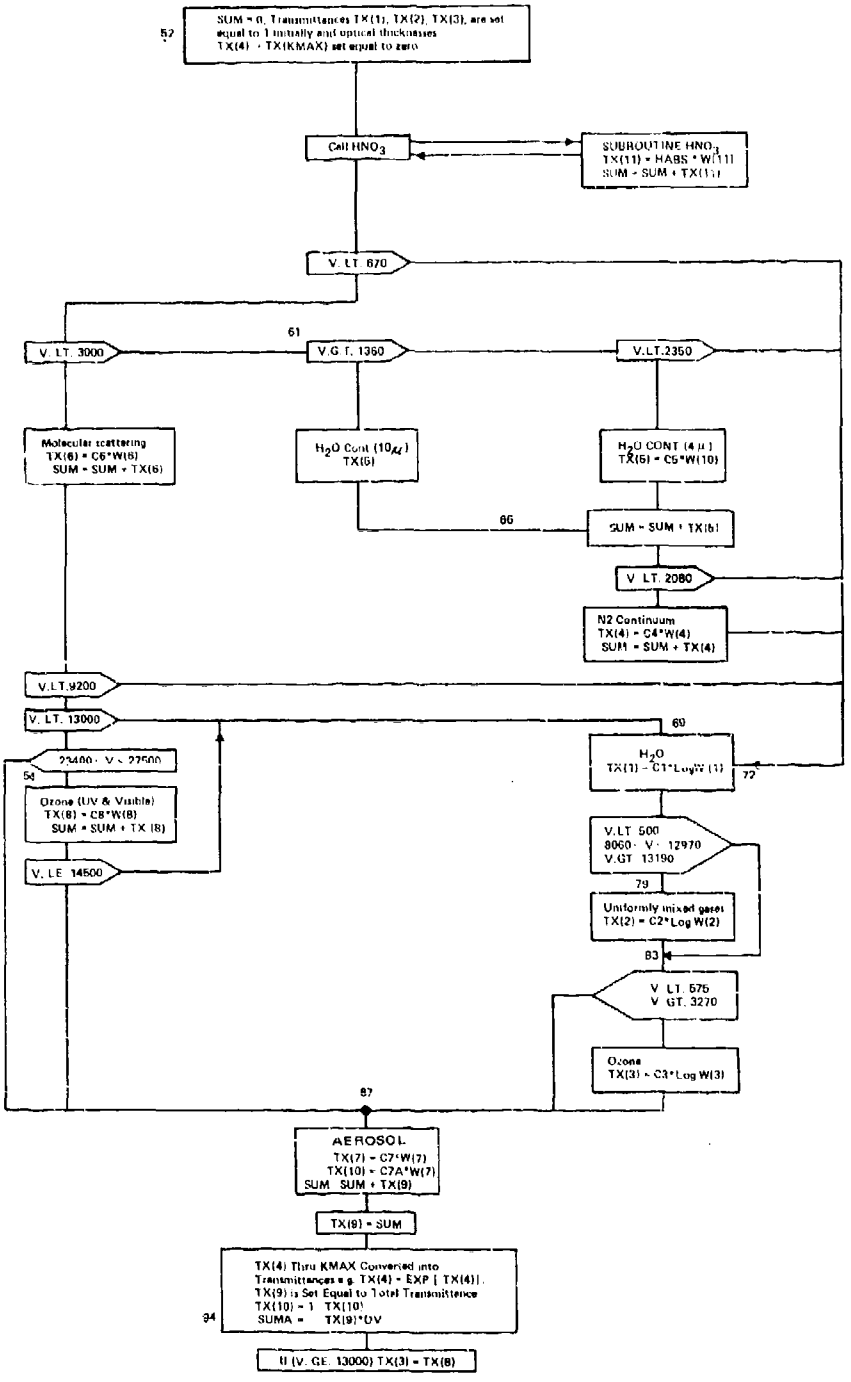

Figure B4. Flow Chart for Transmittance Calculations

Appendix C

Symbols and Definitions

AB	Absorption at frequency V; also average transmittance
AHAZE	Aerosol number density for MODEL = 7
AHZ2	Aerosol number density for MODEL = 7
AJ	Equivalent absorber amount per km at level J
ALAM	Wavelength (μm)
ALP	Angle of arrival at adjacent level
ANGLE	Input zenith angle (degrees)
AO	Constant $A = (R_o + H1)n_o \sin\theta_o$
AVW	Average wavelength used in refractive index expression
B	Storage parameter for BETA
BBG	Black body function of boundary times the total transmittance along the path
BBIK	Black body function of the IK layer and the frequency V
BET	Angle subtended at the earth's center as path traverses adjacent levels
BETA	Total angle subtended by path at earth's center
BJ	Equivalent absorber amount per km at level J + 1
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
C1	Log absorption coefficient for water vapor
C2	Log absorption coefficient for uniformly mixed gases
C3	Log absorption coefficient for ozone

C4	Absorption coefficient for nitrogen (~ 4 μm)
C5	Absorption coefficient for water vapor continuum (~ 10 μm)
C6	Extinction coefficient for molecular scattering
C7	Extinction coefficient for aerosol models
C7A	Aerosol absorption coefficient
C8	Absorption coefficient for ozone (UV and visible regions)
D	Water vapor amount (pr. cm/km) at level I
DTAU	Differential transmittance (due to absorption) across the IK layer
DP	Dew point temperature (°C)
DS	Path length from level I to level I + 1
DV	Wavenumber increment at which transmittance is calculated
DZ	Height increment from level I to level I + 1
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 extinction at 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)
EV	Integrated absorber amount from level I to level I + 1
F	Function for determining saturation vapor density of water (gm m^{-3})
FF	Black body function (W/cm^2-ster-μm)
FAC	Interpolation parameter
FACTOR	Integration weighting parameter
FO	Transmission function logarithmic absorber amount scale for O_3
FW	Transmission function logarithmic absorber amount scale for H_2O and the uniformly mixed gases
H	Altitude dependent control parameter
H1	Initial altitude (km)
H2	Final altitude (km)
HABS	Nitric acid absorption coefficient

HAZE	Aerosol number density (no. cm^{-3})
HH	Estimated tangent height (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 visibili:
HZ1	Aerosol number density (no. cm^{-3}) for 23 km visual range
HZ2	Aerosol number density (no. cm^{-3}) for 5 km visual range
I	Running integer used as altitude (level) indicator and frequency indicator
IATM	Number of model atmospheres
ICOUNT	Output page counter
IDV	Frequency increment (cm^{-1})
IEMISS	Input control parameter determining mode of program execution (=0 for transmittance, =1 for radiance mode)
IFIND	Indicator for using subroutine ANGL
IHAZE	Aerosol model indicator
IJ	Equals IK
IK	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
IP	Indicator for using subroutine POINT to calculate refractive index only (IP = 0) or equivalent absorber amounts also (IP ≠ 0)
ITYPE	Indicator for type of atmospheric path
IV	Frequency at which transmittance is calculated
IV1	Starting frequency (equivalent to V1)
IV2	Last frequency (equivalent to V2)
IXY	Parameter for terminating program and cycling indicator
J	Running integer for altitude identification
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
JSTOR	Integer indicator used when vertical profile changes from downward to upward path
J1	Level indicator for altitude H1
J2	Level indicator for altitude H2
K	Absorber indicator, K = 1, 2, 3, etc., corresponds to H_2O uniformly mixed gases, O_3 etc, respectively

KMAX	Upper limit of absorber amount loops (= 11)
K1	Integer used in reading two model atmospheres on one card
K2	Integer used in reading two model atmospheres on one card and cycling parameter for downward looking paths
K4	Frequency indicator for nitrogen continuum transmittance calculation
L	Frequency indicator for ozone transmittance calculation
LEN	Parameter used for defining longest of two paths
LENSTOR	Integer storage for parameter LEN, needed for cases run in succession
L1	Frequency identifier for UV and visible ozone transmittance calculation
L2	Frequency identifier for UV and visible ozone transmittance calculation
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 H_2O altitude profile for (M=M1)
M2	Integer for selecting temperature altitude profile for (M=M2)
M3	Integer for selecting O_3 altitude profile for (M=M3)
N	Indicator for level below given input altitude used in POINT subroutine; also as frequency indicator in UV and visible ozone transmittance calculation
NH	Frequency indicator for water vapor continuum transmittance calculation
NL	Number of levels in model atmosphere data
NLL	Equals NL-1
NP	Indicator for determining whether H1 or H2 coincide with levels in the model atmosphere
NP1	Value of NP for altitude H1
NP2	Value of NP for altitude H2
P(M, I)	Pressure (mb) at level I for model atmosphere M
PH	$180° - PHI$
PHI	Angle of arrival at H2
PI	3.141592654 that is (π)
PPW	Partial pressure of water vapor (in atmospheres)
PS	Total pressure in atmospheres
PSI	Angular deviation of path from initial direction
PT	Product of total pressure (atm) and the square root of 273/T(M, I)
RADMAX	Maximum value of radiance
RADMIN	Minimum value of radiance
RADSUM	Integrated radiance (W/cm^2-ster)
RANGE	Path length (km)
RE	Earth radius (km)

REF	Refractive index of air at level I
RH	Relative humidity (%)
RN	Ratio of refractive indices of air above and below a given level
RO	Earth radius (km) read in as input (=RE)
RX	Ratio of earth center distances between adjacent levels
R1	The product of the sine of the initial zenith angle and the earth center distance to starting altitude
SALP	Sine of angle of arrival at adjacent level (cf sin α)
SPHI	Sine of the local zenith angle at a given level (cf sin θ)
SR	Slant range (km)
SUM	Sum of the optical thicknesses of absorbers 4 through 11
SUMA	Accumulated integrated absorption
SUMV	Radiance (W/cm^2-ster-cm^{-1})
SUMVV	Radiance (W/cm^2-ster-μm)
T(M,I)	Temperature (°K) for model atmosphere M at level I
TAUG	Total transmittance to the boundary
TBBY(IK)	Average temperature of the IK layer
TBOUND	Input temperature of the boundary in °K
THET	Zenith angle at a given level (in radians)
THETA	Zenith angle at a given level (in degrees)
TMP	Ambient temperature (°C)
TR	Transmittance scales for transmission functions
TS	Ratio of standard temperature (273.0°K) to temperature at Level I
TSNEW	Transmittance (due to scattering) to the far boundary of the IK layer
TSOLD	Transmittance (due to scattering) to the near boundary of the IK layer
TS1	Ratio of 296°K to ambient temperature (°K)
TT	Ratio 273.15/(TMP+273.15)
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
TX1	Refractive index of layer above initial altitude H1
TX2	Refractive index of layer above final altitude H2
TX3	Refractive index of layer above minimum altitude HMIN
T1	Temperature of the boundary (°K)
T2	Temperature of the I+1 boundary used in index of refraction calculation
V	Running frequency (cm^{-1})
VH(K)	Integral of the equivalent absorber amounts from H1 to level I
VIS	Visual range (km) at sea level

VRMAX	Frequency of the maximum radiance (cm^{-1})
VRMIN	Frequency of the minimum radiance (cm^{-1})
VX	Wavelength at which aerosol coefficients are read in (μm)
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(IK, K)	The cumulative absorber amount of the species, K, for the IK layer along the atmospheric slant path
WS1	Transmission function scaling factor for H_2O at given wavelength
WS2	Transmission function scaling factor for CO_2, etc., at given wavelength
WS3	Transmission function scaling factor for O_3 at given wavelength
W2	Water vapor density for atmospheric model M at level I + 1 ($gm\ m^{-3}$)
X	Input height to POINT subroutine
XD	Wavenumber interpolation parameter in UV ozone transmittance calculation
XH	Wavenumber interpolation parameters in H_2O continuum calculation
XI	Wavenumber interpolation parameter
XX	Wavenumber identification parameter for UV ozone transmittance calculation
X1	Earth center distance of level I
X2	Earth center distance of level I + 1
Y	Input zenith angle in radians
YN	Refractive index of layer below input height from POINT subroutine
YN1	Refractive index of layer below initial altitude H1
YN2	Refractive index of layer below final altitude H2
YY	Aerosol absorption coefficient at frequency V
Z(I)	Altitude at level I in km

Appendix D

Errata Sheet No. 2 (September 1977), Atmospheric Transmittance From 0.25 to 28.5 μm: Supplement LOWTRAN 3B(1976), AFGL-TR-0158, 1 November 1976, Environmental Research Papers, No. 587

1. Page 52 - Line A 3M should read A 3*
2. Page 53 - The second line A 81 should be removed
3. Page 54 - Reverse the order of statements A 103F and A 103G and relabel them:

   i.e., IF (M.EQ.0) Z(K) = H1 A* 103F
   J = IFIX (Z(K) + 1.0E-6) + 1 A* 103G

4. Page 56 - Line *A 185B should read:

   EH(5,I) = D*PPW*EXP (6.08*(TS1-1.0)) + 0.002*D(PS-PPW) *A 185B

5. Page 56 - Line A 204 is correct, i.e. IP=-1
6. Page 63 - Line A 586A should be removed.
7. Page 64 - Replace UALENTVENT by EQUIVALENT in line A 623
8. Page 78 - The 9th and 10th cards from the bottom of page 78 should be interchanged. The wavenumber identifications for these cards are 17800 and 19400 (see extreme right hand side of card).
9. Cautionary Note: When standard radiosonde data are used (MODEL-7 option), insert a card for sea level even though the required transmittance path does not extend to sea level. The reason for inserting the sea level altitude card is to correctly interpolate the aerosol number densities at the required altitudes for a given sea level visual range. However the above does not apply if the user is inserting his own aerosol extinction data for a given starting altitude.

10. Example: On page 79 a set of input data for LOWTRAN 3B is given. The first example (represented by the first three cards) is to calculate the transmittance for a 65° zenith angle slant path from altitudes 2.5 km to 8.5 km for a 23 km visual range (rural aerosol) subarctic winter atmosphere covering the wavenumber range from 2350 to 2450 cm^{-1} (i.e. 4.08 - 4.27μm).

The four examples which follow are to calculate the average transmittance from 1820 to 20,000 cm^{-1} (i.e. from 0.5 to 5.5 μm) for a 10 km horizontal path at sea level (using the 1962 U.S. Standard Atmosphere) for four different aerosol models, namely, Maritime, Urban, Rural, and Tropospheric respectively.

It is recommended that the various aerosol model data sets be labelled and stored for further use.

The extinction coefficients for the Average Continental aerosol model originally contained in LOWTRAN 3 are included as an additional data set at the end of LOWTRAN 3B (1976) card deck available from the National Climatic Center, Federal Building, Asheville, No. Carolina 28801 for a charge of $20.00. (Please address requests to Mr. R. Davis.)

11. Page 25 - delete the last three lines on this page.

12. Page 26 - Delete lines *A 494 and *A 495, and change line *A 491 to read:

NH = XI + 1.001

13. Page 33 - Lines A 85G and A 85H should be interchanged to be consistent with page 53.

14. Page 54 - Insert - IF(IXY.GT.3) GO TO 8 after A 104N.

15. Page 62 - A 563 should be

IF(VIS.GT.0.0.AND.VIS.LT.2.0) XX=0.158

Cautionary Note: The temporary fog correction will scale aerosol extinction regardless of atmospheric path. As presently coded, it probably should be restricted to horizontal paths (ITYPE=1) under 1 km in altitude.

16. Page 66 - Delete card C 21B in ANGL.†

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†NEW ERRATUM

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