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Atmospheric Transmittance From 0.25 to 28.5μm: Supplement LOWTRAN 3B (1976)

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This technical report has been reviewed and is approved for publication.

FOR THE COMMANDER

John Howard

Chief Scientist

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This supplement provides several additions and updates to the LOWTRAN 3 computer code, which can be used to calculate the transmittance of the atmosphere from the ultraviolet to the middle infrared portion of the spectrum (0.25 to 28.5 µm) at a spectral resolution of 20/cm^{-1}. The major additions are the inclusion of water vapor continuum attenuation in the 3.5 to 4.2 µm region, and a temperature dependence to the H_2O continuum attenuation coefficient in both the 4 µm and 10 µm regions. The contribution of foreign

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20. Abstract (Continued)

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gas broadening in the 8-14 µm region has also been reduced. Four aerosol models are included in this supplement. These include three boundary layer aerosol models for maritime, urban, and rural conditions in the lower 2 km of the atmosphere, and a tropospheric model for use mainly above 1 or 2 km altitude. The rural model is a replacement for the average continental model presently in LOWTRAN 3. A temporary provision is also given to accommodate fog conditions when the visual range falls below 2 km.

Preface

There has been some confusion in parts of the scientific community concerning the use and distinction between the LOWTRAN and HITRAN computer codes. In this preface, we will briefly describe both codes in terms of their applications and limitations.

The HITRAN and LOWTRAN codes are atmospheric propagation models relating to high and low spectral resolution, respectively. The word HITRAN generally refers to one or more line-by-line computer codes which are used in conjunction with a compilation of atmospheric absorption line parameters, to calculate synthetic molecular absorption spectra mainly at high resolution for laser applications. However, the HITRAN technique can be used to calculate molecular absorption spectra at any spectral resolution. Although there is no resolution restriction with the HITRAN technique, computation times become excessive for low resolution applications, which was one of the major reasons for developing the LOWTRAN computer code with a fixed (20 cm^{-1}) resolution capability.

It should be emphasized that molecular absorption is only one process which limits atmospheric propagation and molecular scattering and "continuum" absorption (due to nitrogen and water vapor primarily); and aerosol extinction should also be included in a complete HITRAN code just as they are in the LOWTRAN code.

The wavelength range over which the HITRAN code can be applied is currently from 0 to 1500 cm^{-1} (that is, for all wavelengths greater than 0.69 μm), whereas LOWTRAN covers the range from 0.25 to 28.5 μm. The lower wavelength limit for HITRAN corresponds to the shortest wavelength for which we have molecular line parameters documented on the AFGL compilation of atmospheric line parameters. We do plan to extend the line parameters compilation to the visible and ultraviolet region of the spectrum. HITRAN techniques can be applied to any low spectral resolution requirements where a particularly high accuracy is required and where it is felt that the limitations imposed in the interest of computational efficiency are not too great. This is not to say that HITRAN does not have its own limitations. Its limitations are related to the uncertainties in the fundamental line parameters and particularly in line shapes. In the wings of absorption lines it is known that most lines do not generally follow a Lorentz line shape, but adequate information is simply not available for all molecules of atmospheric interest in all portions of the spectrum. For most atmospheric paths at moderate spectral resolution (say, 20 cm^{-1}), we expect that HITRAN will generally give results to ±1-2 percent in transmittance with an increase in accuracy as we approach 100 percent. There are limited spectral regions, near the edges of strong absorption bands and window regions, where line shape uncertainties will lead to greater transmittance errors. One major HITRAN limitation has already been stated; namely, that the computation time (especially for low spectral resolution problems) is enormous and generally impractical for systems applications. Another limitation at this time is that HITRAN has not been developed into a flexible system oriented code in the same way that LOWTRAN has.

In order to deal with these computational limitations of HITRAN, the LOWTRAN concept was developed and is similar to a number of previous "band model" concepts. The LOWTRAN concept is applicable to low spectral resolution (20 cm^{-1} or poorer) and in any case cannot be applied to high spectral resolution or laser propagation problems.[†] In the LOWTRAN "single-parameter" model, the molecular abundance and pressure dependence of absorption are clumped together and the temperature dependence is ignored. This reduction in the number of independent variables leads to some decrease in computational accuracy and we place the accuracy at about ±5 percent in transmittance. The transmittance accuracy must improve as 100 percent is approached, but the percentage accuracy in absorption is expected to decrease for very transparent paths. Thus, the application of LOWTRAN to the computation of window background radiance levels will be somewhat limited. There will be situations, particularly in spectral regions where the actual temperature dependence is large, where larger uncertainties may exist due to the omission of the temperature dependence in LOWTRAN.

[†] This statement applies to the molecular absorption part of LOWTRAN. The parts of LOWTRAN which determine the transmittance loss due to molecular scattering, molecular continuum absorption, and aerosol extinction are common to both high and low resolution applications, since these loss mechanisms have no fine line structure.

Both HITRAN and LOWTRAN must depend on the introduction of continuum extinction (due to water vapor, nitrogen, and aerosols) as an addition to the line absorption in atmospheric window regions. In these regions, the accuracy of both codes is dependent on the accuracy of the laboratory measurements involved in the determination of the continuum coefficients due to molecular absorption, and on the indices of refraction and description of aerosol models in relation to the real atmosphere in the case of aerosols. The largest uncertainty in the atmospheric window is the variability of aerosols and the relationship of any particular atmospheric situation to the aerosol models available. We are working to improve the aerosol models by creating a greater number of models and providing more user guidance on the selection of the most appropriate aerosol model for a given application.

The work of deriving the aerosol extinction coefficients and the various aerosol models contained in LOWTRAN 3B was carried out by Eric P. Shettle. Questions relating to aerosol models should therefore be addressed to him.

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1. INTRODUCTION

The LOWTRAN 3 computer code[1] (and its predecessors LOWTRAN 1 and LOWTRAN 2)[2] has been widely used for making atmospheric transmittance predictions covering the 0.25-28.5 μm region. This supplement is intended to provide an update to the LOWTRAN 3 computer code[1] and also the LOWTRAN 3A[†] version. It contains two modifications which affect the transmittance due to the water vapor continuum in the 3.5-4.2 μm and 8-14 μm regions. Also contained in this supplement are four new aerosol models and a temporary provision for handling fog situations.

The data provided here should be regarded as our best estimates at this time, based on available measurements. As further measurements become available, additional updates to LOWTRAN 3B will be made.

(Received for Publication 1 November 1976)

[†] The LOWTRAN 3A modification was given a limited distribution only, and did not contain any formal documentation besides that given in Appendix A.

1. 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.
2. Selby, J.E.A., and McClatchey, R.A. (1972) Atmospheric Transmittance From 0.25 to 28.5 μm: Computer Code LOWTRAN 2, AFCRL-72-0745.

Included in this supplement (see Appendix B) is an updated errata sheet for LOWTRAN 3 (Errata Sheet No. 3) and a full listing of the LOWTRAN 3B computer code (see Appendix D).

We will first review the changes that have been incorporated into LOWTRAN 3A and 3B, and then discuss the impact which these changes have on the transmittance for some specific atmospheric paths. Several comparisons will be given between LOWTRAN 3 and LOWTRAN 3A and 3B predictions together with some measurements.

2. THEORY

Attenuation due to molecular absorption occurs as a result of collision interactions between molecules; that is, collisions between two H_2O molecules and those of other gases (principally H_2O:N_2 collisions, since nitrogen comprises approximately 80 percent of the air).

The attenuation due to the water vapor continuum still eludes a complete theoretical explanation. At present, we believe that it results from the accumulated attenuations of the distant wings of H_2O absorption lines, emanating principally in the far infrared part of the spectrum. Other postulates, such that the phenomenon is caused by other absorption mechanisms involving H_2O dimers, remain possibilities yet to be proved.

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

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

$$\tau(\nu) = e^{-k(\nu)\times \text{RANGE}}$$

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

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

or (1)

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

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

Values for C_S and C_N/C_S have been obtained empirically from laboratory measurements. In the study presented here, as with LOWTRAN 1 through LOWTRAN 3, the quantity C_N/C_S is assumed to remain constant over a given wavelength interval. However, one major addition has been to account for the temperature dependence of C_S and this will be discussed in Sections 3 and 4.

In the recent LOWTRAN 3A modification, the term involving C_N/C_S was omitted completely in the 8-14 μm region because of the large uncertainty in the measurements available. However, (as will be seen in Appendix C), although the uncertainty in the available measurements still exists there does appear to be a trend in the measurements towards a small but finite value for C_N/C_S in this spectral region. Consequently, a further change has been included in this version of LOWTRAN which distinguishes it from the previous LOWTRAN 3A version.

3. 8-14 μm H_2O CONTINUUM

Two major modifications have been made to LOWTRAN 3 in the 8-14 μm region. The first of these is the addition of a temperature dependence to the water vapor continuum absorption coefficient (the self broadened coefficient), which was determined empirically from the measurements of Burch.[3] The second major modification is a 60 percent reduction in the nitrogen broadened water vapor absorption coefficient (see Section 3.2 and Appendix C).

3.1 Temperature Dependence

Recently, a review of available water vapor continuum experimental measurements was made by Roberts et al[4] in the 10 μm region in order to update the attenuation coefficients currently used in the LOWTRAN 3 model. These workers found that an empirical expression of the form given in Eq. (2) (below), provided a good fit to the wavelength dependence of the measured water vapor continuum attenuation coefficients at 296 K. It was found that the more recent results did

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3. Burch, D.E. (1971) Semiannual Technical Report: Investigation of the Absorption of Infrared Radiation by Atmospheric Gases, Aeronutronic Report U-4784, ASTIA (AD 702117).

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

not deviate significantly from those previously reported by Selby and McClatchey[1, 2] in LOWTRAN 3 and LOWTRAN 2, as can be seen in Figure 1. However, the water vapor continuum attenuation coefficient has been found to have a significant temperature dependence, which was not accounted for in the previous LOWTRAN computer codes. Based on the laboratory measurements of Burch[3] using samples of water vapor at elevated temperatures, an approximate empirical expression was obtained by Roberts et al[4] for the temperature dependence which is given in Eq. (3) below. It was found that the attenuation coefficient due to the water vapor continuum increases as the temperature decreases. That is, for a fixed amount of water vapor in a given path, one would expect more absorption at colder temperatures and less absorption at warmer temperatures. This is a somewhat unusual phenomenon. In practice one finds less water vapor in the atmosphere under cold conditions, therefore, the effect of temperature on the attenuation in the 8-14 μm region plays two competing roles, through the total water content of the path and the attenuation coefficient.

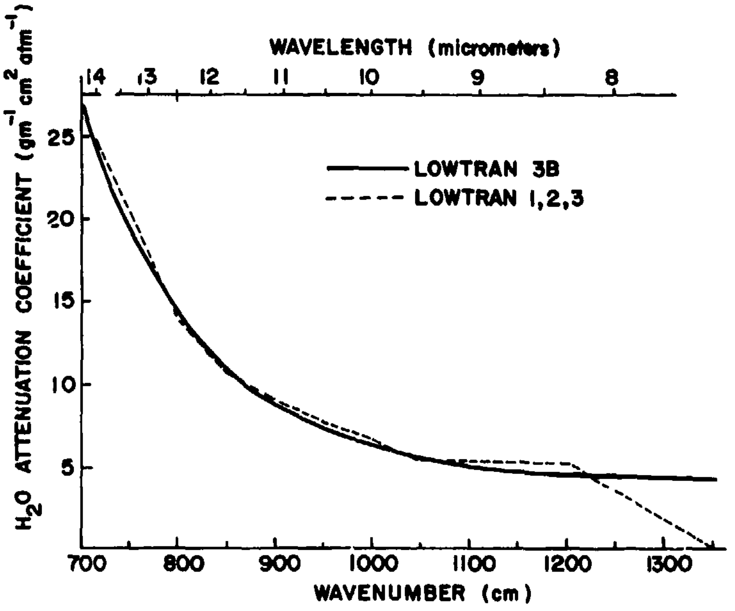

Figure 1. Comparison of H_2O Continuum Self Broadening Coefficients Used in LOWTRAN 3 and LOWTRAN 3B

The empirical fits to the wavelength and temperature dependence of the water vapor continuum described in Roberts et al[4] have been used in LOWTRAN 3B with the appropriate conversion of units, as follows:

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

$$C_s(\nu, 296) = 4.18 + 5578 \exp(-7.87 \times 10^{-3}\ \nu) \tag{2}$$

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

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

$$C_s(\nu, T) = C_s(\nu, 296) \exp\left[1800\left(\frac{1}{T} - \frac{1}{296}\right)\right] \tag{3}$$

where T is the temperature in degrees Kelvin.

Equation 3 can be rewritten as follows:

$$C_s(\nu, T) = C_s(\nu, 296) \exp\left[6.08\left(\frac{296}{T} - 1\right)\right] \quad . \tag{4}$$

3.2 Nitrogen Broadened Coefficient

The second term in Eq. (1), defined as C_N/C_S, represents the ratio of the foreign (nitrogen) broadening coefficient to the self broadening coefficient.

For the 8-14 μm region, we have used a value of 0.005 for this parameter in LOWTRAN 1 through LOWTRAN 3, based on the measurements of McCoy and Rensch.[5] Several questions have arisen recently concerned with the uncertainty of those measurements, and a summary and review of more recent measurements are given in Appendix C.

As a result of the uncertainty in the above value ($C_N/C_S = 0.005$), a modification had been made to the LOWTRAN computer code incorporating the temperature term discussed in Section 3.1 but omitting the C_N/C_S term completely. This constituted the LOWTRAN 3A supplement (see Appendix A), which is now superceded by this report.

In LOWTRAN 3B, we are using a value of 0.002 for the parameter C_N/C_S based on the review of the measurements presented in Appendix C.

In LOWTRAN 3B, we have assumed that C_N/C_S (at 296 K) does not vary with temperature (since no supporting measurements are available).

Thus, further measurements are needed to determine more accurately the magnitude of the parameter C_N/C_S and its temperature and wavelength dependence.

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[5] McCoy, J.H., Rensch, D.B., and Long, R.K. (1969) Appl. Opt. **8**:1471.

3.3 Transmittance Calculations

The transmittance due to the water vapor continuum in the 8-14 μm region, is calculated for a horizontal path of length RANGE (km) at altitude z using the following expression in LOWTRAN 3B:

$$\tau(\nu) = \exp\left[-C_s(\nu, 296)W(z)\,\mathrm{RANGE}\right] \tag{5}$$

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

The quantity W(z) is given by:

$$W(z) = w(z)\left\{p_{H_2O}\exp\left[6.08\left(\frac{296}{T(z)} - 1\right)\right] + 0.002\left(P_T - p_{H_2O}\right)\right\} \tag{6}$$

where

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

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

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

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

Note that the temperature dependence of the attenuation coefficient $C_s(\nu, T)$ given in Eq. (4) has been incorporated into the expression for W in Eq. (6). The reason for this is so that the temperature variation over a given atmospheric slant path is weighted equally with the water content along the path.

---

† Note that if temperature T(K) and relative humidity RH (%) are known, then w and p_{H_2O} can be determined as follows:

$$w = 0.001 \times RH \times \rho(T)\ (\mathrm{gm\ cm^{-2}/km}) \tag{a}$$

$$p_{H_2O} = 4.56 \times 10^{-5}\ w\ T\ (\mathrm{atm}) \tag{b}$$

where $\rho(T)$ is the saturation vapor density of water (gm m^{-3}) at ambient temperature T, which can be obtained from standard meteorological tables (for example, List[6]) or from the following expression:

$$\rho(T) = A \exp(18.9766 - 14.9595A - 2.4388A^2) \tag{c}$$

where $A = 273.15/T$

Equation (c) is the empirical equation used in LOWTRAN 3 (see page 9 of Selby and McClatchey[1]).

6. List, R.J. (Editor) (1963) Smithsonian Meteorological Tables, 6th Revised Edition, Smithsonian Institute, Washington, D.C.

It may be worth contrasting Eq. (6) with the corresponding expression which has been used in LOWTRAN 1 through LOWTRAN 3, that is:

$$W(z) = w(z) \left[p_{H_2O} + 0.005 \left(p_T - p_{H_2O} \right) \right] . \tag{7}$$

4. 3.5-4.2 μm H_2O CONTINUUM

Using the laboratory measurements of Burch et al,[7] an empirical expression was obtained for the temperature dependence of the attenuation coefficients in the 3-5 μm region. The measurements reported in Burch et al were for samples of pure water vapor made at elevated temperatures, and have been confirmed independently by White et al.[8]

It was found that

$$C_s(\nu, T) = C_s(\nu, 296) \exp \left[4.56 \left(\frac{296}{T} - 1 \right) \right] \tag{8}$$

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

The attenuation coefficients at 296 K used in LOWTRAN 3B for the 3.5-4.2 μm region have been digitized directly from the extrapolations reported by Burch et al.[7]

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

4.1 Foreign Gas Broadening

A value for the nitrogen broadening coefficient of 0.12 was obtained by Burch et al[7] for a temperature of 428 K. Since no other measurements are available at the time of writing, this value will be used in LOWTRAN 3B (see Section 4.2) with the same temperature correction which is applied to the self broadening term (see Eq. (8)).

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[7] Burch, D.E., Gryvnak, D.A., and Pembroke, J.D. (1971) Philco Ford Corp. Aeronutronic Report U-4897, ASTIA (AD 882876).

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

4.2 Transmittance Calculations

As for the 8-14 μm region, the transmittance for a horizontal path of length RANGE (km) can be calculated using Eq. (5) (Section 3.3), where the parameter W(z) is now given by the following expression for the 3.5-4.2 μm region:

$$W(z) = w(z) \left[p_{H_2O} + 0.12(P_T - p_{H_2O}) \right] \exp \left[4.56 \left(\frac{296}{T(z)} - 1 \right) \right] . \qquad (9)$$

As in Section 3, the temperature dependence of the attenuation coefficient has been incorporated into Eq. (9). It will be noted that the nitrogen broadening coefficient in the 4 μm region (see second term in Eq. (12)) is more significant relative to the self broadening term than in the 10 μm region. Again it should be emphasized that the above expressions are approximate and further measurements are required to determine the temperature dependence of the nitrogen broadening coefficient, as well as more accurate values for the wavelength dependence of the self broadening coefficient at ambient temperatures (for example, 296 K) and its temperature dependence.

5. COMPARISON OF LOWTRAN 3, 3A AND 3B PREDICTIONS

The effect of the changes described in this supplement on the transmittance for (1) a 10 km horizontal path at sea level, and (2) a vertical path to space from sea level for three extreme atmospheric models (tropical, 1962 U.S. Standard and Subarctic winter) are shown in Figures 2 and 3 respectively for the 3.5-5.5 μm regions and 7-15 μm regions.

In all cases, the LOWTRAN 3B predictions (dashed curves in Figures 2 and 3) lead to greater attenuation in the 3-5 μm region, by as much as 20 percent in the worst case shown in Figure 2. However, in the 8-14 μm region LOWTRAN 3B appears more optimistic than LOWTRAN 3 by up to a factor of 2 for the worst case given in Figure 2.

Figures 4-6 show some comparisons of LOWTRAN 3 and 3B with measurements of Gebbie et al[9] and Yates and Taylor.[10] In general, LOWTRAN 3B provides better agreement with both sets of measurements. However, the statements previously made in Selby and McClatchey[1, 2] with regard to the measurements of Yates and Taylor, still apply, namely that these measurements should not be used as a standard to compare LOWTRAN or any other model against.

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[9] Gebbie, H.A., Harding, W.R., Hilsum, C., Pryce, A.W., and Roberts, V. (1951) Proc. Roy. Soc. 206A:87.

[10] Yates, H.W., and Taylor, J.H. (1960) Infrared Transmission of the Atmosphere, NR Report 5453, U.S. Naval Research Laboratory, Washington, D.C.

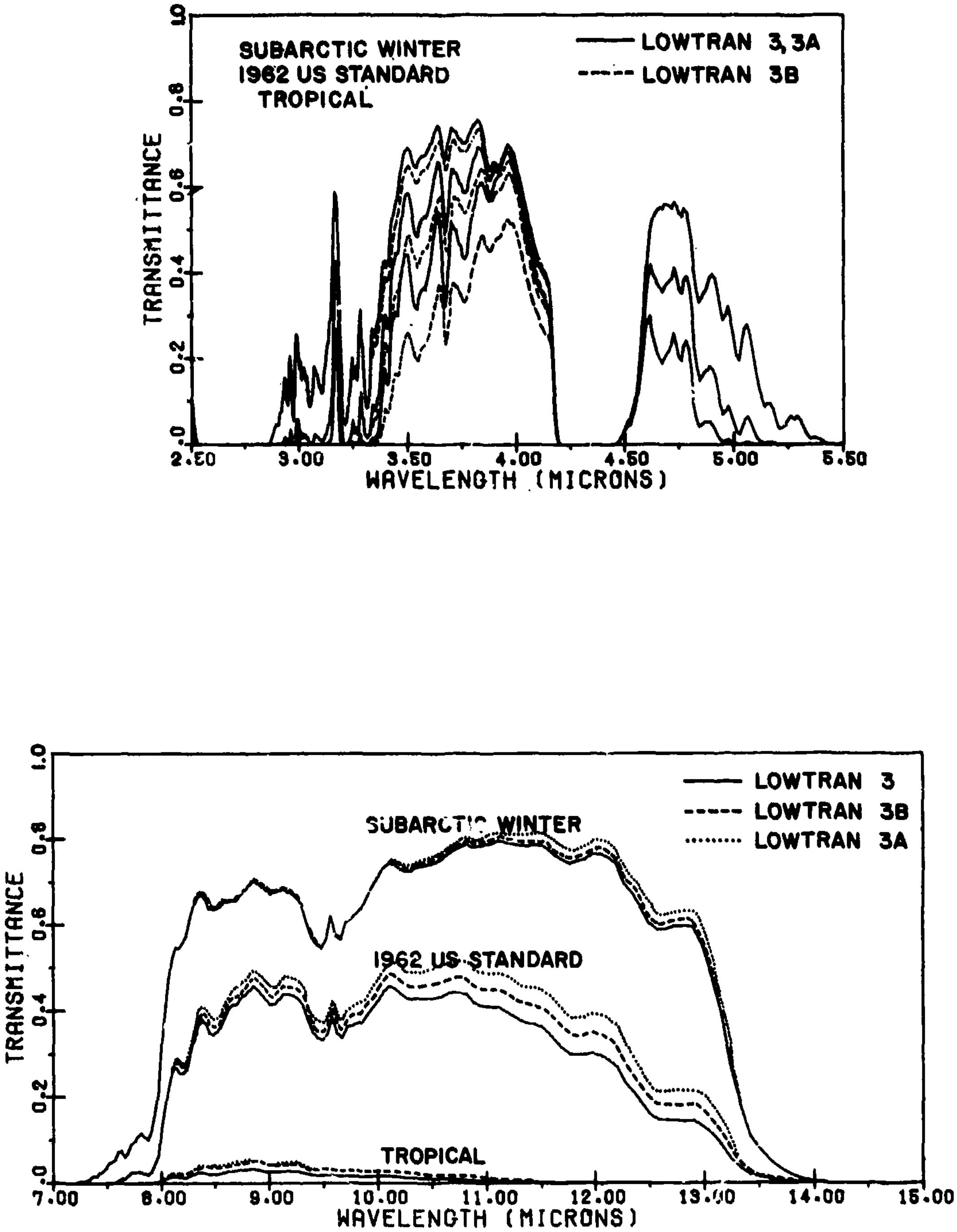


Figure 2. Transmittance for a 10 km Path at Sea Level for Three Atmospheric Models (Comparison of LOWTRAN 3, 3A, and 3B)

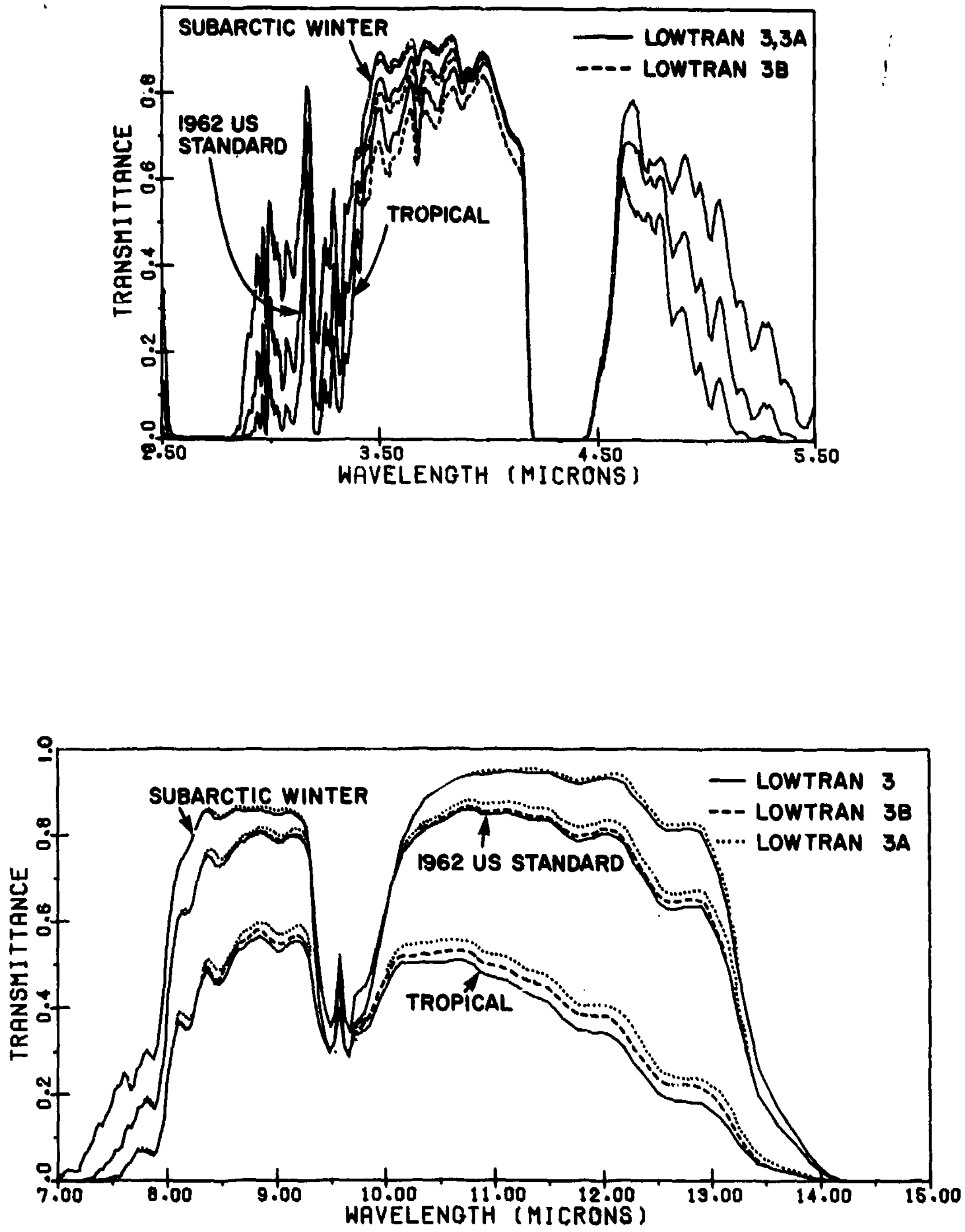
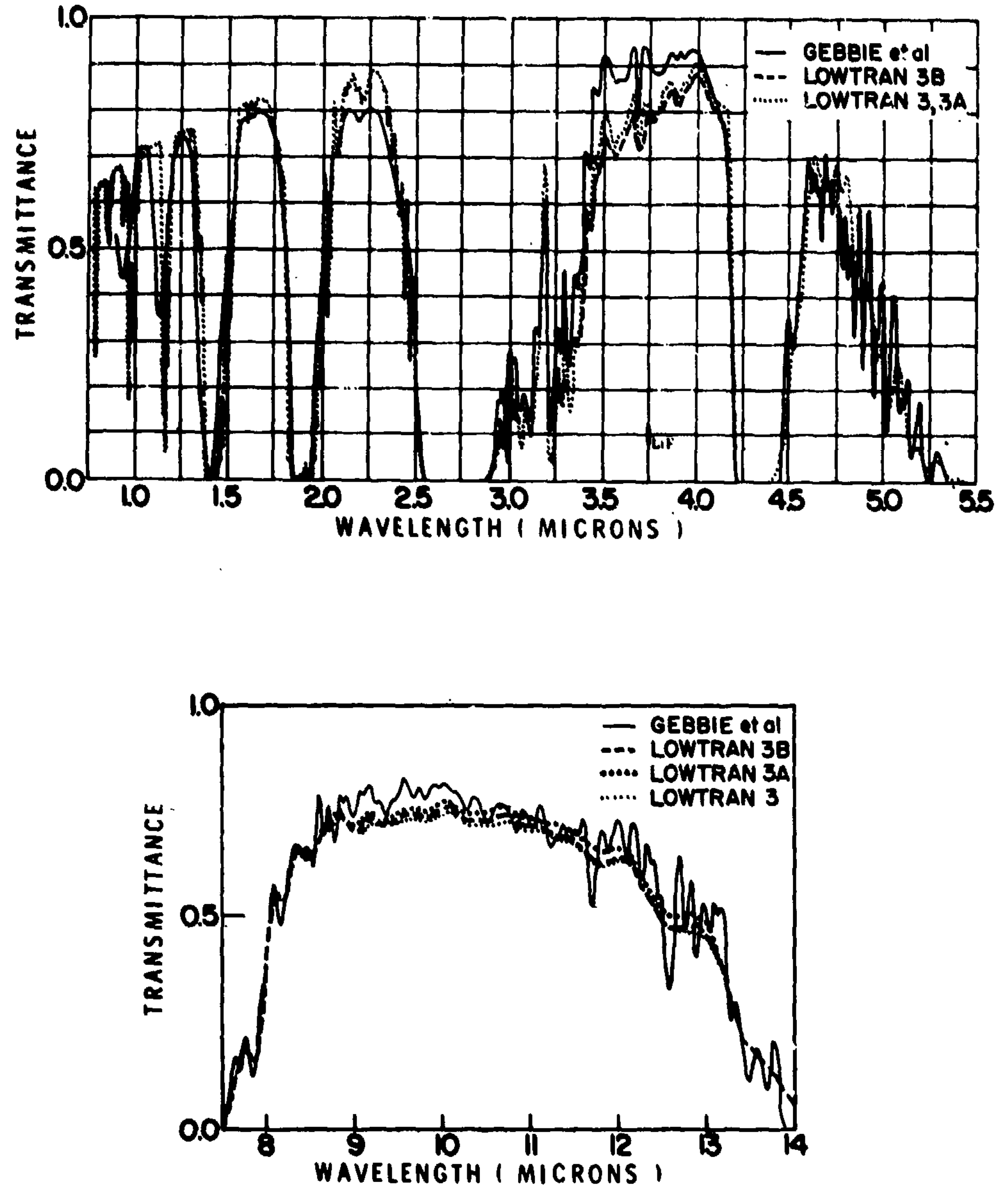


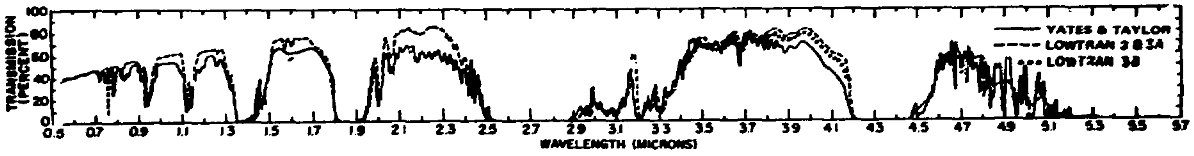
Figure 3. Transmittance for a Vertical Path to Space for Three Atmospheric Models (Comparison of LOWTRAN 3, 3A, and 3B)



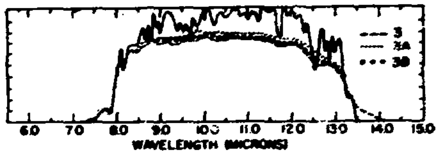
ATMOSPHERIC TRANSMITTANCE FOR A 1 NAUTICAL MILE PATH

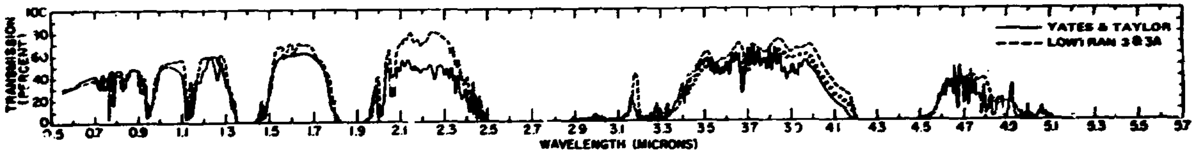
(WATER CONTENT 1.7 pr. cm.)

Figure 4. Comparison of LOWTRAN 3B Predictions With Measurements of Gebbie et al[8]



Path Length	5.5 km	Relative Humidity	68%
Time		H_2O in Path	2.2 cm
Temperature	38°F	Transmittance at 0.55 μm	40%
		LOWTRAN 3 visual range	23.5 km





Path Length	16.25 km	Relative Humidity	41%
Time		H_2O in Path	6.5 - 6.9 cm
Temperature	53°F	Transmittance at 0.55 μm	29%
		LOWTRAN 3 visual range	51 km

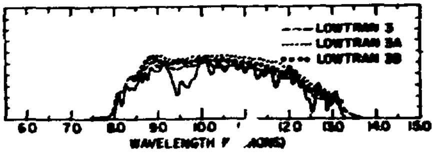
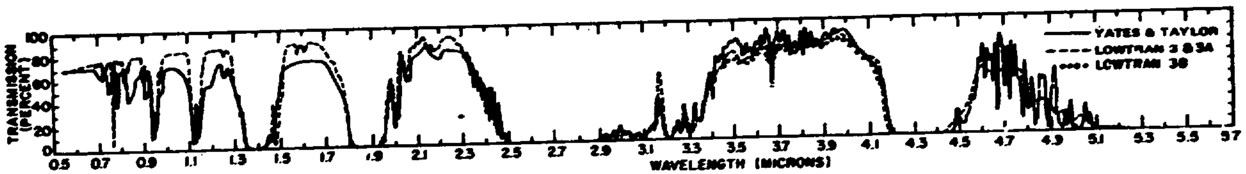
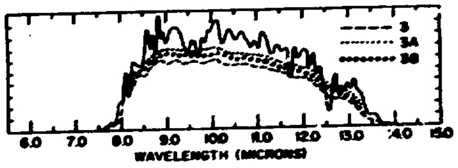
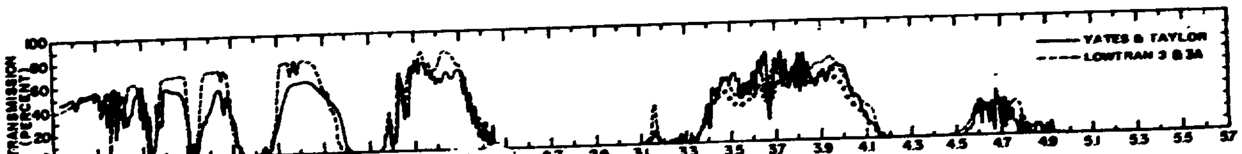


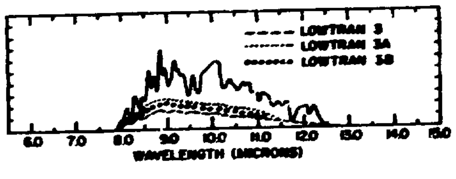
Figure 5. Comparison of LOWTRAN 3B Predictions With Measurements in Chesapeake Bay Area on 19 April 1956





Path Length	5.5 km	Relative Humidity	51%
Time	2100 hr	H_2O in Path	4.18 cm
Temperature	64°F	Transmittance at 0.55 μm	70%
		LOWTRAN 3 visual range	60 km





Path Length	16.25 km	Relative Humidity	53%
Time	1600 hr	H_2O in Path	15 1 cm
Temperature	68.7°F	Transmittance at 0.55 μm	43%
		LOWTRAN 3 visual range	75 km

Figure 6. Comparison of LOWTRAN 3B Predictions With Measurements in Chesapeake Bay Area on 19 June 1956

6. LOWTRAN 3B H_2O CONTINUUM COMPUTER CODE CHANGES

The computer code modifications necessary to update LOWTRAN 3 to LOWTRAN 3B are discussed below and are treated separately from the errata sheet given in Appendix B, and from the aerosol model changes given in Sections 7 and 8.

The code modifications necessary to incorporate the 3.5-4.2 μm and 8-14 μm water vapor continuum additions are not trivial unless one treats the changes separately. Because of the different formulations given in Eqs. (6) and (8), it is necessary to treat the water vapor continuum in the two spectral regions as though they were different absorbing species. This means that separate arrays need to be set up for the horizontal and vertical profiles. Because of this, the reader will be given two options. The first is the change necessary to run either the 8-14 μm region (see Section 6.1) or the 3-5 μm region (see Section 6.2) but not both together. The second change (see Section 6.3) will enable both regions to be run with one submission of the program and this change is recommended for permanent conversion to LOWTRAN 3B (see Appendix E). Note that changes 6.1(b) and 6.2(b), (c), and (d) are compatible. That is, after effecting the changes 6.1(b), 6.2(b), (c), and (d), the computer code can be run with either change 6.1(a) for 10 μm region or change 6.2(a) for the 4 μm region. If the computer code is only going to be run for the 8-14 μm region, then only changes 6.1(a) and (b) need be affected and vice versa.

6.1 8-14 μm Region Change Only

(a) Page 70 - Replace line A 185A by the following:

```
TSI = (296.0/273.15)*TS                                        *A 185A
EH(5,I) = D*PPW*EXP(6.08*(TSI - 1.0)) + 0.002*D*(PS-PPW)       *A 185B
```

(b) Page 75 - Delete line A 486 and insert the following:

```
C******** 10 MICRON H20 CONTINUUM CHANGE
TX(5) = 4.18 + 5578.0*EXP(-7.87E-3*V)                          *A 486A
GO TO 67                                                       *A 486B
```

6.2 3.5-4.2 μm Region Change Only

(a) Page 70 - Replace line A 185 by the following:

```
TSI = (296.0/273.15)*TS                                        *A 185A
EH(5,I) = D*(PPW+0.12*(PS-PPW))*EXP(4.56*(TSI - 1.0))          *A 185 C
```

(b) Page 74 - Replace line A 453 by the following:

```
IF (IV.LT.2080) GO TO 72                                     *A 453A
IF (IV.LE.3000) GO TO 62                                     *A 453B
```

(c) Page 75 - Delete lines A 486, A 487, A 495, and A 496

```
C******** 4 MICRON H20 CONTINUUM CHANGE
62  IF (IV.LT.2350) GO TO 68                                 *A 486
    XI = (V - 2350.0)/50.0 + 1.0                             *A 487
    IF (IV.LE.1350.OR.IV.GT.2740) GO TO 72                   *A 499
```

(d) Page 92 - Replace the 10 μm attenuation coefficients on the 17th line from the bottom of page 92 (identified by 700 in the last column on the right of the line) by the following:

(Format 15F5.3)

```
▽0.00▽.187▽.147▽.117▽.097▽.087▽.100▽.120▽.147▽.174▽.200▽.240▽.280▽.330▽.000▽2350
```

where the symbol ▽ here refers to a space.

Note that the 4 μm water vapor continuum data given above occupy the same storage locations previously occupied by the 10 μm continuum data, which is now replaced by an empirical equation (see Eq. (2)).

6.3 Complete Changes for Both 4 μm and 10 μm Regions

Page 70: 1. Replace line A 185 by:

```
TS1 = (296.0/273.15)*TS                                      *A 185A
EH(5,I) = D*PPW*EXP(6.08*(TS1 -1.0)) + 0.002*D*(PS-PPW)      *A 185B
EH(10,I) = D*(PPW + 0.12*(PS-PPW))*EXP(4.56*(TS1-1.0))       *A 185C
```

2. Line A 193D, Replace EH(10,I) by REF
3. Line A 197*, Replace EH(10,I) by REF
4. Replace line A 200 by:

```
IF(IFIND.EQ.0.OR.JP.EQ.0)PRINT 434,I,Z(I),(EH(K,I),K=1,10),REF *A 200*
```

5. Replace line A 210 by: `DO 18 K = 1,10` *A 210
6. After line A 220 add: `EH(10,J1) = E(10)` *A 220+
7. After line A 225 add:

```
IF(ITYPE.NE.3)EH(10,J2+1) = TX(10)                           *A 225+
```

Page 71: Replace line A 248 by: `DO 24 K = 1, 10` *A 248

Replace line A 272* by: `26 DO 27 K = 1, 10` *A 272*

Replace line A 287 by: `DO 29 K = 1, 10` *A 287

Page 73: Replace line A 356 by: `DO 39 K = 1, 10` *A 357

Replace line A 399 by: `DO 42 K = 1, 10` *A 399

Replace line A 407 by: `DO 44 K = 1, 10` *A 407

Page 74: Replace line A 424 by: `WRITE(6, 421)(W(I), I=1, 8), W(10)`

Replace lines A 452 and A 453 by the following:

```
IF(IV.LT.670) GO TO 72                                   *A 452
IF(IV.LE.3000) GO TO 61                                  *A 453
```

Page 75: Replace statements A 484 through A 499 by the following:

```
C******** WATER VAPOR CONTINUUM 10 MICRON REGION          *A 484
61   IF (IV.GT.1350) GO TO 62                             *A 485
     TX(5) = (4.18 + 5578.0*EXP(-7.87E - 3*V))*W(5)       *A 486
     GO TO 66                                             *A 487
62   IF (IV.LT.2350) GO TO 68                             *A 488
C******** WATER VAPOR CONTINUUM 4 MICRON REGION           *A 489
     XI = (V - 2350.0)/50.0 + 1.0                         *A 490
     DO 63 NH = 1, 15                                     *A 491
     XH = XI - FLOAT (NH)                                 *A 492
     TX(5) = C5(NH)                                       *A 493
     IF (XH) 64, 65, 63                                   *A 494
63   CONTINUE                                             *A 495
64   TX(5) = TX(5) + XH*(C5(NH) - C5(NH - 1))             *A 496
65   TX(5) = TX(5)*W(10)                                  *A 497
66   SUM = SUM + TX(5)                                    *A 498
     IF (IV.LE.1350.OR.IV.GT.2740) GO TO 72               *A 499
```

Page 77 - Line A 629 modify format statement as follows:

```
421  FORMAT (/10X,8H W(1-8)=8(E14.3)/74X,E14.3/)         *A 629
```

Page 79 - Relabel line B 37B by B 37D and replace line B 37A by the following:

```
DO 3 K = 1, 10                                          *B 37A
IF(K.EQ.9) GO TO 3                                      *B 37B
```

Page 79 - Replace line B 45 by the following:

```
DO 5 K = 1, 10                                          *B 45
```

Page 92 - Replace the 10 μm attenuation coefficients on the 17th line from the bottom of page 92 (identified by 700 in the last column on the right of the line) by the following:

(Format 15F5.3)

```
▽0.00▽.187▽.147▽.117▽.097▽.087▽.100▽.120▽.147▽.174▽.200▽.240▽.280▽.330▽.000▽2350
```

where the symbol ▽ here refers to a space.

Note that the 4 μm water vapor continuum data given above occupy the same storage locations previously occupied by the 10 μm continuum data which is now replaced by an empirical equation (see Eq. (2)).

7. ATTENUATION FOR MARITIME, URBAN, RURAL, AND TROPOSPHERIC AEROSOL MODELS

Four new aerosol models are shown in Table 1 below which can be read into the LOWTRAN 3B program as data, when required. The wavelengths (μm) and the extinction and absorption coefficients (km^{-1}) for these aerosols have been digitized directly from the work of Shettle and Fenn,[11] and are given below in the same format (that is 4(F6.2, 2F7.5)) as the average continental aerosol data already contained in LOWTRAN 3 (for a visual range of 23 km). The Rural Model is intended to replace the present LOWTRAN 3 Aerosol Model, which was a preliminary version of the Rural Model.

The Maritime, Urban, Rural and Average Continental Aerosol Models are all strictly speaking, boundary layer models; that is, they apply to the first few kilometers of the atmosphere. The Tropospheric Model, on the other hand, was developed primarily for use in the troposphere above the boundary layer. However, it can be used for transmittance calculations near ground level for

---

[11] Shettle, E.P., and Fenn, R.W. (1976) Models of the atmospheric aerosols and their optical properties in AGARD Conference Proceedings No. 183, Optical Propagation in the Atmosphere, pages 2.1-2.16, presented at the Electromagnetic Wave Propagation Panel Symposium, Lyngby, Denmark, 27-31 October 1975. (Available from NTIS, Acc. No. N76-29817.)

Table 1. Maritime, Rural, Urban, and Tropospheric Models

Rural Model

.200	.38223	.07945	.250	.32979	.03661	.300	.28540	.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	8.200	.01019	.00807	8.500	.01778	.01254
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	.00535	12.50	.01365	.00516	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

Maritime Model

.200	.20832	.02054	.250	.19518	.00864	.300	.18479	.00442	.400	.17032	.00243
.488	.16213	.00193	.550	.15800	.00186	.694	.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	5.500	.05928	.00507	6.000	.05485	.02351
7.200	.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	10.59	.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	17.20	.04121	.02936	18.50	.03951	.02769
20.00	.03648	.02537	22.50	.03232	.02263	25.00	.02901	.02053	30.00	.02420	.01775

Urban Model

.200	.31030	.10692	.250	.28416	.08649	.300	.25805	.07571	.400	.20867	.06376
.488	.17631	.05674	.550	.15800	.05282	.694	.12601	.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	.01072	7.900	.01445	.00953	8.200	.01384	.01037	8.500	.01757	.01251
8.700	.01854	.01172	9.000	.01900	.01202	9.200	.01939	.01278	9.500	.01748	.01075
9.80	.01669	.00973	10.00	.01644	.00954	10.59	.01555	.00868	11.00	.01499	.00796
11.50	.01452	.00765	12.50	.01373	.00727	13.00	.01347	.00721	14.00	.01294	.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

Tropospheric Model

.200	.40212	.08042	.250	.34505	.03451	.300	.29674	.01767	.400	.22585	.00971
.488	.18187	.00772	.550	.15800	.00745	.694	.11722	.00619	.860	.08537	.00683
1.060	.06265	.00685	1.536	.03078	.00545	1.800	.01912	.00348	2.000	.01241	.00173
2.500	.00783	.00183	3.000	.00629	.00251	3.500	.00420	.00076	3.750	.00354	.00063
4.000	.00316	.00069	5.000	.00233	.00098	5.500	.00224	.00127	6.000	.00234	.00171
7.200	.00368	.00322	7.900	.00293	.00285	8.200	.00465	.00463	8.500	.00785	.00766
8.700	.00664	.00540	9.000	.00726	.00593	9.200	.00858	.00760	9.500	.00503	.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	.00375	16.40	.00246	.00235	17.20	.00264	.00249	18.50	.00221	.00212
20.00	.00251	.00242	22.50	.00252	.00245	25.00	.00250	.00246	30.00	.00276	.00274

particularly clear and calm conditions (in pollution free areas and with visibilities greater than 30-40 km), where there has been very little turbulent mixing for a period of one or two days, permitting the larger particles to have settled out without being replaced.

The altitude variation of the aerosol number densities is the same as that used in the previous LOWTRAN programs, based on Elterman's[12] measured extinction coefficients at 0.55 μm. The size distributions for the Maritime and Rural Aerosol Models are shown in Figure 7 (taken from Figures 2 and 3 of Shettle and Fenn[11]). The Urban Model is assumed to have the same size distribution as the Rural Model.

The Tropospheric Aerosol Model is the same as the small particle portion of the Rural and Urban Models, that is, $n_1(r)$ in Figure 7a. The larger particles are lost at a higher rate than the small ones, and above the boundary layer they are not replaced by turbulent mixing from the surface. The continental component of the Maritime Model also is the same as the small particle portion of the Rural Aerosol Model for analogous reasons. For comparison, the earlier LOWTRAN 3 Aerosol Model is the curve labeled Modified Haze C in Figure 7a.

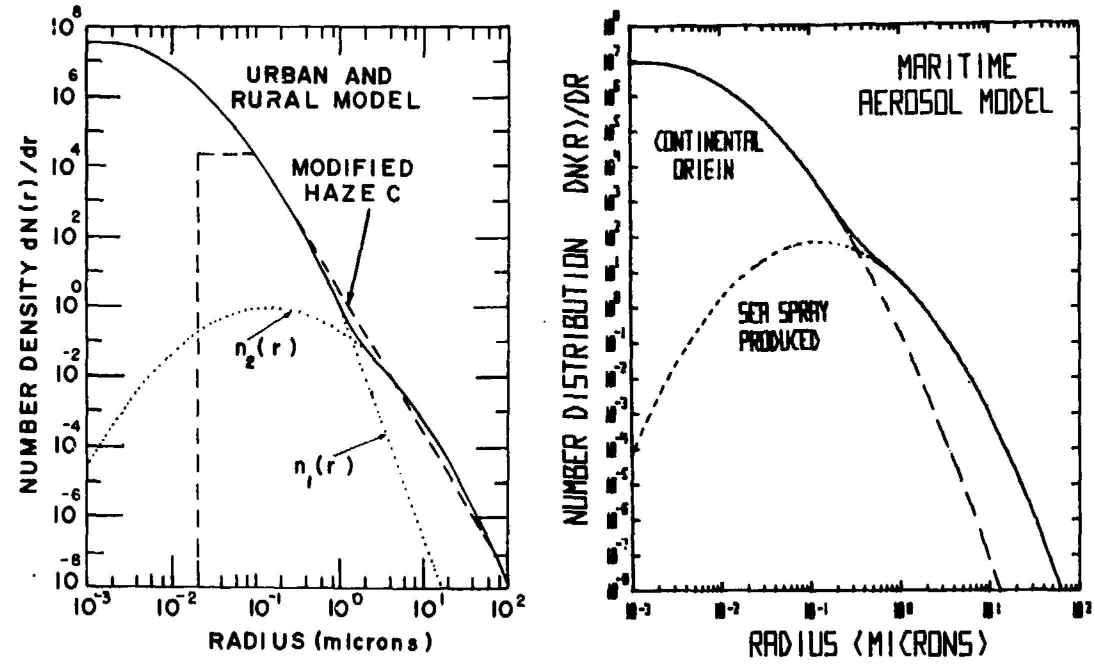


Figure 7. Size Distributions for Aerosol Models Used in LOWTRAN 3B

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12. Elterman, L. (1968) UV, Visible, and IR Attenuation for Altitudes to 50 km, 1968; Tech. Report AFCRL-68-0153, April 1968.

The aerosol models also differ in their composition and the corresponding variation of refractive index with wavelength. The Rural Model is assumed to be a mixture of 70 percent water soluble aerosols and 30 percent dust-like aerosol.

The Maritime Model is composed of a mixture of aerosols of oceanic and continental origins. The oceanic aerosols are produced primarily by the sea spray and are assumed to be a solution of sea salts in water. The continental component has the same composition as the Rural Model. While the proportions and nature of the two components of the Maritime Aerosol will vary geographically, there is insufficient data to meanfully model these variations. For simplicity, the oceanic component is taken as contributing 75 percent of the extinction at 0.55 μm, which yields a model which is consistent with measurements in a number of different maritime locations.

The Urban Model is similar to the Rural Model, but with an addition of soot-like aerosols such that the mixture is 35 percent soot-like aerosols and 65 percent Rural Aerosols. The Tropospheric Model is assumed to have the same composition as the Rural Aerosols. The refractive index data used is tabulated in Appendix D.

The characteristics of the different aerosol models, for the lower atmosphere, are summarized in Table 2. The size distributions are represented by one or the sum of two log-normal distributions:

$$\frac{dN(r)}{dr} = \sum_{i=1}^{2} \left(\frac{N_i}{\ln (10) \cdot r \cdot \sigma_i \sqrt{2\pi}} \right) \exp \left[- \frac{(\log r - \log r_i)^2}{2\, \sigma_i^2} \right] . \qquad (10)$$

The choices of N_o in Table 2 correspond to 1 particle/cm^3. The actual size distributions are renormalized to give the correct extinction coefficients for the altitude and visibility model being used.

The wavelength variation of the extinction coefficients for the aerosol models is shown in Figure 8 (taken from Figure 4 of Shettle and Fenn[11]) for a visual range of 23 km. It will be noted that the extinction coefficients for the average continental, Rural and Urban Models do not differ significantly.† The Maritime Aerosol extinction coefficients and those of the Tropospheric Model show contrasting features which bracket the remaining three models.

The effect which these various aerosol models have on the atmospheric transmittance for a 10 km path at sea level is shown in Fi[illegible] for the 1962 U.S. Standard Atmosphere and a visual range of 23 km. The strong attenuation of the Maritime Aerosol Model relative to the other aerosol models is apparent.

---

†The absorption properties of the Urban Model, however, are appreciably different from those of the other models.[11]

Table 2. Characteristics of the Aerosol Models of the Lower Atmosphere

Aerosol Model		Size Distribution			Type
	i	N_i	r_i	σ_i	
Rural	1	0.9999975	0.005 μm	0.475	Water-Solubles and Dust-Like
	2	0.0000025	0.5 μm	0.475	
Urban	1	0.9999975	0.005 μm	0.475	Rural Aerosol Mixture and Soot-Like
	2	0.0000025	0.5 μm	0.475	
Maritime					
Continental Origin		1.0	0.005 μm	0.475	Rural Aerosol Mixture
Marine Origin		1.0	0.3 μm	0.4	Sea Salt Solution in Water
Tropospheric		1.0	0.005 μm	0.475	Rural Aerosol Mixture

The parameters defining the size distribution, correspond to the N_i, r_i, and σ_i in Eq. (10). Note that the r_i values are the mode radii of the distributions on a plot at dN/dr vs r.

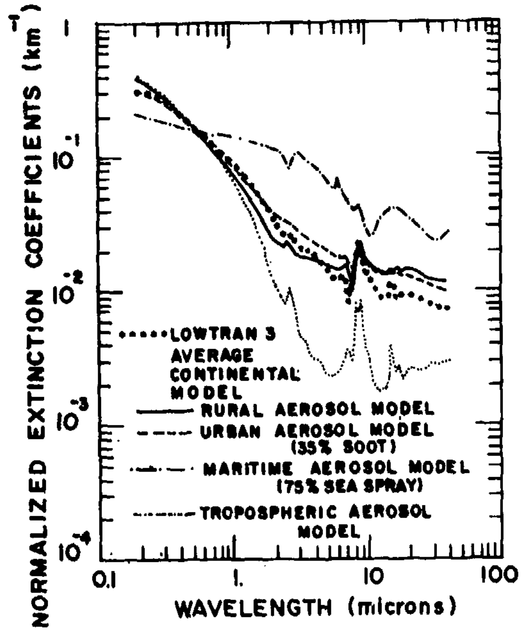

Figure 8. Extinction Coefficient for New Aerosol Models Used in LOWTRAN 3B

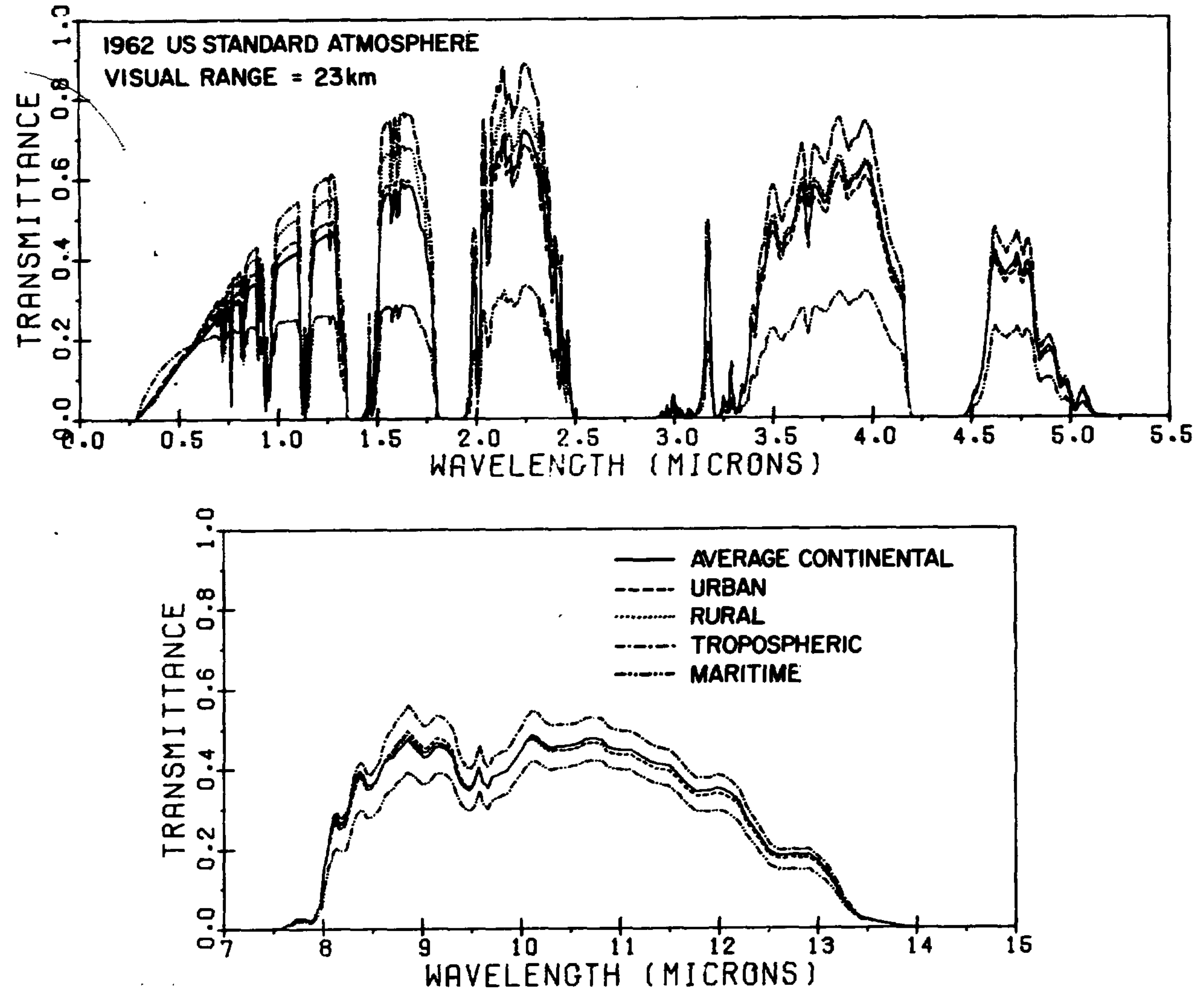

Figure 9. Transmittance for a 10 km Path at Sea Level for Three Aerosol Models

It is recommended that the Tropospheric Model be used for air-to-air applications and the other models for near surface applications.

Further work is proceeding to incorporate stratospheric aerosol models[11] and a procedure for including the altitude variation of aerosol properties for more accurate slant path calculations. The effect of increased humidity on the growth of aerosol particles and the effect which these changes have on the attenuation as a function of wavelength is also being investigated. Many of the effects of changing humidity are handled by normalizing the extinction coefficients to the visibility as is done by LOWTRAN. This can be seen by examining the wavelength dependence of attenuation coefficients as a function of humidity in the Hodges[13] or Barnhardt and Street[14] models.

7.1 Computer Code Changes for Including Aerosol Models

In order to use the aerosol models described in the previous section, it is necessary to make the following card changes in LOWTRAN 3.

Page 67 - Replace lines A 85B through A 85D by the following:

```
IF(IHAZE.NE.7) GO TO 250                                  A 85B
READ 431, (VX(I), C7(I), C7A(I), I=1,44)                  A 85C
PRINT 431, (VX(I), C7(I), C7A(I), I=1,44)                 A 85D
IHAZE = 1                                                 A 85E
250 IF(RO.NE.0 ) RE=RO                                    A 85F
    IF(IXY.GT.3) GO TO 8                                  A 85G
    IF(M.EQ.7.AND.IM.NE.0 ) GO TO 4                       A 85H
```

Page 86 - Replace the AEROSOL SPECTRAL DATA (between 3 and 13 lines from the bottom of the page) with the corresponding 11 cards for the Rural Model presented above.

Note that the above changes simply replace the Average Continental Aerosol extinction coefficient arrays by those for the Rural Model, and permit any of the other three Aerosol Models described above to be read-in with the control data cards when IHAZE is set equal to 7. The same altitude variation of aerosol number density and visual range interpolation/extrapolation scheme is used for determining the aerosol transmittance.

---

13. Hodges, John A. (1972) Aerosol extinction contribution to atmospheric attenuation in infrared wavelengths, Appl. Opt. 11:2304-2310.

14. Barnhardt, E.A., and Street, J.L. (1970) A method for predicting atmospheric aerosol scattering coefficients in the infrared, Appl. Opt. 9:1337-1344.

7.2 Example of Use of New Aerosol Data

Suppose that we wish to compute the transmittance for a 10 km path at sea level for a midlatitude winter model atmosphere for both Rural Aerosol and a Maritime Aerosol condition where the visual range is 15 km. Let the wavelength range be 2 to 5 μm (that is, 2000-5000 cm^{-1}).

The control cards necessary for executing this problem are as follows (using the same parameters and card formats as specified in Section 5 of the LOWTRAN 3 report[1]).

```
CARD 1    **3**1**1
CARD 2    *****0.000************************10.000**************15.00
CARD 3    **2000.000**5000.000*****5.000
CARD 4    **4
CARD 5    **3**7**1
CARD 6      .200 .20832 .02054 ......................  .400 .17032 .00243
CARD 7      .488 .16213 .00193 ......................  .860  14412 .00171
CARD 8     1.060 .13909 .00191 ...................... 2.000 .11530 .00218
CARD 9     2.500 .09962 .00336 ...................... 3.750 .09191 .00271
CARD 10    4.000 .08670 .00314 ...................... 6.000 .05485 .02351
CARD 11    7.200 .04758 .00942 ...................... 8.500 .04045 .01125
CARD 12    8.700 .04267 .01114 .....................  9.500 .03552 .01011
CARD 13    9.800 .03257 .00983 .....................11.000 .02470 .01330
CARD 14   11.500 .02556 .01663 .....................14.000 .03688 .02827
CARD 15   15.000 .03888 .02948 .....................18.500 .03951 .02769
CARD 16   20.000 .03648 .02537 .....................30.000 .02420 .01775
CARD 17   ***
```

where the symbol * refers to a space.

The card sequence can be continued after CARD 16 if further calculations are required with one submission of the program (see Example 5 on page 30 of Selby and McClatchey[1]). In such a case, however, it should be noted that the subsequent calculations will also use the Maritime Model, for the example given here. Thus, all calculations involving the Average Continental Model (or the Rural Model replacement) should be set up first.

8. FOG ATTENUATION

In LOWTRAN 3B, we have not added attenuation coefficients for fog models; such additions will be included in subsequent updates. However, the following update is included as a temporary measure.

```
IF(VIS.GT.0.0.AND.VIS.LT.2.0) XX = 3.91/VIS                          A 563D
IF(IHAZE.EQ.0.OR.XX.GT.0.0) GO TO 90                                 A 564*
```

The above statements will set the infrared transmittance equal to visible transmittance, as is suggested by the studies of transmittance by fogs of Ruppersberg et al,[15] when the input visual range is less than 2 km. Alternately, the reader could omit the above changes and use the Maritime Aerosol Model described in Section 7 for moderate fog situations. This would provide a more optimistic value for the infrared extinction for a given visibility in fog.

Work is currently proceeding at AFGL to develop representative fog models.

9. SUMMARY AND CONCLUSIONS

The reason for designating this supplement as LOWTRAN 3B is to distinguish it from an earlier supplement called LOWTRAN 3A (see Appendix A).

In this supplement, we have attempted to review the available measurements and theory for the water vapor continuum attenuation in both the 8-14 μm and the 3.5-4.2 μm regions. These results have been included as updates to the LOWTRAN 3 computer code.[1] These updates include the addition of water vapor continuum attenuation in the 3.5-4.2 μm region, as well as the incorporation of a temperature dependence to the attenuation coefficients in both the 4 μm and 10 μm spectral regions. The contribution of foreign gas broadening to the 10 μm H_2O continuum attenuation has also been reduced by 60 percent (the latter contribution was reduced by 100 percent in LOWTRAN 3A).

Also included are a Rural Aerosol Model to replace the LOWTRAN 3 Average Continental Aerosol and three additional Aerosol Models which are representative of Maritime or Urban conditions and the Tropospheric above the boundary layer. A temporary provision has been made for handling fog situations, whereby the infrared attenuation is set equal to the visible attenuation (at 0.55 μm) when the visual range is less than 2 km. The latter provision could overestimate the attenuation at 10.6 μm by a factor of 2 under the best propagation conditions.

Several examples have been presented here which demonstrate the effect which the above additions have on the transmittance for representative atmospheric paths. In general, LOWTRAN 3B predicts higher transmittance values in the 8-14 μm region and lower transmittance values in the 3-5 μm regions than LOWTRAN 3, due solely to the water vapor continuum additions. LOWTRAN 3A was more optimistic in the 10 μm region than LOWTRAN 3B, due to the omission

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[15] Ruppersberg, G.H., Schellhase, R., and Schuster, M. (1975) Calculations about the transmittance window of clouds and fog at about 10.5 μm wavelengths, Atmos. Environ. 9:723-730.

of the foreign gas contribution to the attenuation coefficient. Also for similar sea level visibilities, the Maritime Aerosol Model predicts more attenuation generally throughout the infrared portion of the spectrum and less attenuation at wavelengths shorter than 0.55 μm, than the continental Aerosol Models.

It must be remembered that the results presented here reflect our best estimates at this time based on the limited experimental results currently available. As more accurate measurements become available, further refinements and improvements will be made to the LOWTRAN 3B computer code.

Work is proceeding to investigate further the effects of molecular line absorption in the window regions, and also the effect of high relative humidities on the size distribution of aerosols and their attenuation properties.

The next publication of LOWTRAN will include a provision for calculating atmospheric and earth spectral background signatures.

References

1. 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.
2. Selby, J. E. A., and McClatchey, R. A. (1972) Atmospheric Transmittance From 0.25 to 28.5 μm: Computer Code LOWTRAN 2, AFCRL-72-0745.
3. Burch, D. E. (1971) Semiannual Technical Report: Investigation of the Absorption of Infrared Radiation by Atmospheric Gases, Aeronutronic Report U-4784, ASTIA (AD 702117).
4. Roberts, R. E., Selby, J. E. A., and Biberman, L. M. (1976) Infrared continuum absorption by atmospheric water vapor in the 8-12 μm window Applied Optics 14:2085.
5. McCoy, J. H., Rensch, D. B., and Long, R. K. (1969) Appl. Opt. 8:1471.
6. List, R. J. (Editor) (1963) Smithsonian Meteorological Tables, 6th Revised Edition, Smithsonian Institute, Washington, D. C.
7. Burch, D. E., Gryvnak, D. A., and Pembroke, J. D. (1971) Philco Ford Corp. Aeronutronic Report U-4897, ASTIA (AD 882876).
8. White, K. O., Watkins, W. R., Tuer, T. W., Smith, F. G., and Meredith, R. F. (1975) J. Opt. Soc. Amer. 65:1201.
9. Gebbie, H. A., Harding, W. R., Hilsum, C., Pryce, A. W., and Roberts, V. (1951) Proc. Roy. Soc. 206A:87.
10. Yates, H.W., and Taylor, J.H. (1960) Infrared Transmission of the Atmosphere, NRL Report 5453, U.S. Naval Res Lab, Washington, D. C. ASTIA (AD240188).
11. Shettle, E. P., and Fenn, R. W. (1976) Models of the atmospheric aerosols and their optical properties in AGARD Conference Proceedings No. 183, Optical Propagation in the Atmosphere, pages 2.1-2.16, presented at the Electromagnetic Wave Propagation Panel Symposium, Lyngby, Denmark, 27-31 October 1975.
12. Elterman, L. (1968) UV, Visible, and IR Attenuation for Altitudes to 50 km, 1968; Tech. Report AFCRL-68-0153, April 1968.

13. Hodges, John A. (1972) Aerosol extinction contribution to atmospheric attenuation in infrared wavelengths, Appl. Opt. **11**:2304-2310.

14. Barnhardt, E.A., and Street, J.L. (1970) A method for predicting atmospheric aerosol scattering coefficients in the infrared, Appl. Opt. **9**:1337-1344.

15. Ruppersberg, G.H., Schellhase, R., and Schuster, M. (1975) Calculations about the transmittance window of clouds and fog at about 10.5 μm wavelengths, Atmos. Environ. **9**:723-730.

Appendix A

LOWTRAN 3A Supplement

The following modification applies to the 8-14 μm region:

1. Replace line A 185 by the following:

   ```
   EH(5,I) = 1.67*D*PPW*EXP(6.58*(TS-1.0))                    A 185A
   ```

2. Delete lines A 486 through A 496 and insert:

   ```
   TX(5) = (4.18 + 5578.0*EXP(-7.87E-3*V))*W(5)                A 486*
   ```

The above supplement received only a limited distribution and is now superceded by LOWTRAN 3B.

Appendix B

LOWTRAN 3 Errata Sheet No. 3

The errata sheet (No. 3) for the LOWTRAN 3 report (Selby and McClatchey[1]) is given in this section. So far as the running of the computer code is concerned, the following comments may be useful with respect to the significance of the errata presented here.

Errata numbers 2, 8, 9, 10, 12, 15, 17, 24 are important for the general running of the LOWTRAN 3 (and LOWTRAN 3B) computer codes, without using the MODEL = 7 option (see pages 27 and 33 of Selby and McClatchey[1]).

Errata numbers 20 through 23 are important in certain cases when the MODEL = 7 option is used (that is, when the reader is inputting his own radiosonde data). In the latter case, if the reader is inserting more than 20 altitude levels in the first 5 km of the atmosphere, he is advised to change the dimension of the quantity AHZ2(20) correspondingly, in line A 3*. If in doubt, change the dimension to AHZ2(34).

Errata numbers 7, 11, 13, 14, 16 are for bookkeeping purposes and will not affect the running of the program.

---

[1] 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.

AFCRL-TR-75-0255
7 MAY 1975
ENVIRONMENTAL RESEARCH PAPERS, NO. 513

ATMOSPHERIC TRANSMITTANCE FROM 0.25 TO 28.5 μm: COMPUTER CODE LOWTRAN 3

J.E.A. Selby
R.A. McClatchey

Errata Sheet No. 3 (April 1976)

1. Pages 38 through 44 - The transmittance curves presented in Figures 5 through 11 should be terminated at 0.25 μm. The figures show an increase in transmittance due to ozone absorption as the wavelength approaches 0.2 μm. However, absorption due to oxygen becomes important below 0.25 μm and has not been taken into account in LOWTRAN 3.

2. Page 69 - Line number A 126B and A 134* should read as follows:

```
IF (VIS.GT.0.0) PRINT 417, VIS                              A 126B
IF (VIS. LE.0.0. AND .IHAZE.GT.0) PRINT 416, IHAZE,HZ(IHAZE)    A 134*
```

3. Page 11 (para. 2) - Delete ' and 4 μm' from the end of the first line. Note that the 4 μm water vapor continuum was omitted in the first edition of LOWTRAN 3. The 4 μm H_2O continuum is included in the second edition of LOWTRAN 3 (LOWTRAN 3A) together with an updated version of the 10 μm H_2O continuum.

4. Page 12 - The left hand scale of Figure 1 should read:

ATTENUATION COEFFICIENT (km^{-1})

5. Page 14 - The 2nd Equation should read: $N(z) = \frac{a(z)}{VIS} + b(z)$

6. Page 42 - The transmittance curve for 30 km to space was not reproduced on the upper part of Figure 9.

7. Page 67 - The second A 81 line should be deleted and line numbers A 80 through A 82 should read A 80*, A 81* and A 82*.

8. Page 70 - Line numbers A 203 and A 204 should read as follows:

```
170 IF (IFIND.EQ.1) GO TO 9                     A 203
    IP = -1                                     A 204
```

9. Page 72 - Lines following A 309 and A 318 were omitted and should read:

```
IF (TX3.LT.0.0) TX3 = TX(9)                     A 309+
IF (H2.LT.HMIN) J2 = N                          A 318+
```

10. Page 75 - Line A 517 should preceed line A 518.

11. Page 76 - Line A 586A can be deleted.

12. Page 77 - Line A 591A should read:

```
      AB = 1.0 - SUMA/(IV2-IV1)                                  A 591A
```

13. Page 82 - The sequence number C 197 for the last line on this page was accidently printed at the top of page 83.

14. Page 83 - Although the card sequence on this page is correct the card identification numbers C 240 and C 241 should be interchanged and marked with an *.

15. Page 84 - At the end of format 404 (line number C 262) delete the ,* preceeding the closed parenthesis.

16. Page 88 - The first ten lines should be followed by *.

17. Page 92 - The 12th and 13th cards from the bottom of page 92 should be interchanged. The wavenumber identifications for these cards are 17800 and 19400.

18. Page 93 - In the title for Appendix B, LOWTRAN 2 should be changed to LOWTRAN 3.

19. Page 62 - Figure 29 (lower figure); The radiance scale should be multiplied by 10^{-2}.

20. Page 66 - Line A 3*; change HZ2(5) to HZ2(6) in the dimension statement.

21. Page 67 - After line A 60 insert the following card:

```
      HZ2(6) = HZ1(6)                                            A  60+
```

22. Page 70 - Lines A 190A and A 190D should read as follows:

```
              IF(M.NE.7.AND.IHAZE.EQ.2) HAZE=HZ2(I)                      A 190A
              IF(M.NE.7)HAZE=6.389*((HZ2(I)-HZ1(I)/VIS + HZ1(I)/5.-HZ2(I)/23.) A 190D
```

23. Page 70 - After line A 191 insert the following card:

```
              IF(MODEL.EQ.7) EH(7,I) = HAZE/AHAZE(1)                     A 191+
```

24. Page 80 - Line C 44C should read: H1 = HMIN

25. Page 99 - Replace LOWTRAN 2 by LOWTRAN 3 in the third line of the last paragraph.

26. Page 48 - The identifications shown in Fig. 15 should be reversed. The solid curve refers to Gebbie et al and the dotted curve to LOWTRAN 3.

Appendix C

8-14 μm H_2O Continuum (Nitrogen Broadening Effects)

As stated in Section 3, one major dilemma in the 8-14 μm region is how to account for the H_2O attenuation due to the effect of both self and foreign gas broadening and the temperature dependence of both. Because we do not fully understand molecular line shape theory as it relates to the far wings of absorption lines, we have to resort to accounting for such effects empirically. Also the influence of H_2O dimers (or other absorption mechanisms) on the attenuation in the 8-14 μm region is still an open question.

However, from laboratory measurements[1, 2] it appears that the water vapor attenuation in the 10 μm window does follow the expression given in Eq. (1).

From the laboratory measurements of pure water samples at various temperatures, it seems as though we are able to give a fairly reliable value to C_S at 10.6 μm and 296 K.

A summary of the 10.6 μm attenuation measurements obtained at Ohio State University up to the time of writing this paper, was kindly provided by Long[2] and are reproduced in Table C1, together with the experimental conditions.

Unfortunately, the temperature was not precisely recorded for these measurements; the temperatures quoted in Table C1 are estimated values.

---

1. Burch, D.E. (1971) Semiannual Technical Report: Investigation of the Absorption of Infrared Radiation by Atmospheric Gases, Aeronutronic Report U-4784, ASTIA (AD 702117).
2. Long, R.K. (1976) Private Communication.

Table C1. H_2O Continuum Nitrogen Broadening Coefficient at 10.6 μm. Water vapor absorption coefficients for the P(20) 00^01-10^00 line of the CO_2 laser (λ = 10.591 μm) measured in the laboratory at the Ohio State University. Temperature is approximately 296 K for all measurements. Broadening gas was 80-20 nitrogen oxygen for McCoy measurements and 100 nitrogen for the remainder (Long[2])

Partial Pressure (torr)	Total Pressure (torr)	Absorption Coefficient km^{-1}	Date	Notes
5.1	760	0.038	4/74	Mills
5.64	760	0.022-0.034*	4/74	Mills
6.0	760	0.06-0.083*	11/74	Thomas
7.6	760	0.07	4/74	Mills
8.5	700	0.086	5/68	McCoy†
9.17	760	0.111	4/74	Mills
10.	760	0.118	4/74	Mills
10.3	700	0.121-0.125#	5/68	McCoy†
10.8	700	0.129	5/68	McCoy†
11.7	760	0.16-0.179	11/74	Thomas
12	760	0.186-0.191	4/74	Mills
12.8	700	0.198	5/68	McCoy†
14	700	0.205	5/68	McCoy†
14	760	0.216	4/74	Mills
14.3	760	0.231	8/74	Mills
15	760	0.216-0.240*	11/74	Thomas
15	760	0.241-0.260	4/74	Mills
15.1	760	0.245	10/74	Mills
15.3	700	0.220	5/68	McCoy†
15.6	760	0.256	4/74	Mills

Notes: * One water sample, two backgrounds.

#Two separate measurements.

† Measurements over temperature range 22 to 26°C.

An attempt is made here to determine the quantity C_N/C_S (from 296 K) the above measurements assuming a fixed value for C_S.

The attenuation coefficient $k(\nu)$ can be written as follows in the same notation given in Sections 2 and 3, that is

$$k(\nu) = C_S(\nu) \left[p_{H_2O} + \left(\frac{C_N}{C_S} \right) (P_T - p_{H_2O} \right] w \qquad \text{(C1)}$$

where p_{H_2O} and P_T refer to the partial pressure of water vapor and the total pressure (atm), $C_S(\nu)$ is given in gm^{-1} cm^2 atm^{-1} at 296 K, and w is of the quantity of water vapor in the path in gm cm^{-2} km^{-1}. If we assume a value for C_S, we can rewrite Eq. (C1) in terms of the quantity C_N/C_S as follows:

$$\frac{C_N}{C_S} = \left[\frac{k(\nu)}{C_S w} - p_{H_2O}\right] \Big/ (p_T - p_{H_2O}) \quad . \qquad \text{(C2)}$$

Alternatively Eq. (C2) can be rewritten as:

$$\frac{C_N}{C_S} = \left[\frac{k(\nu)}{C_S w p_{H_2O}} - 1\right]\left(\frac{p_{H_2O}}{p_T - p_{H_2O}}\right) \quad . \qquad \text{(C3)}$$

The quantity w can be calculated from p_{H_2O} and temperature T using Eq. (b) of the footnote in Section 3.3, that is

$$w = p_{H_2O}/(4.56 \times 10^{-5}T) \ \text{gm cm}^{-2}/\text{km} \qquad \text{(C4)}$$

where p_{H_2O} and T are given in atm and degrees Kelvin respectively.

Using the experimental measurements of k at 10.6 μm given in Table C1, values of C_N/C_S were calculated using Eq. (C3). It was assumed that $C_S = 7.48$ gm cm^{-2} atm at 296 K based on Eq. (C3), which is consistent with reported measurements.[1,3,2] The results were plotted against water vapor partial pressure p_{H_2O} for convenience and are shown in Figure C1. The large spread in the data points will be apparent, with values of C_N/C_S ranging from -0.004 to 0.01. The horizontal bars shown in Figure C1 indicate the spread in a given data point due to the uncertainty in temperature. Note that the temperature affects both C_S (through Eq. (3)) and w (through Eq. (C4)).

A least square fit through the data points given in Figure C1 yields a value of approximately 0.002 for the ratio C_N/C_S, which forms the basis for the value used in LOWTRAN 3B.

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

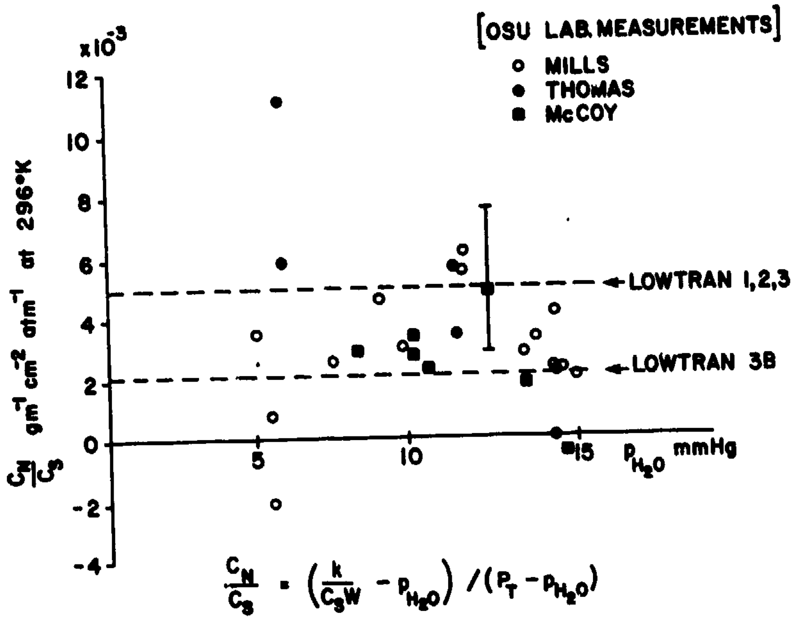

Figure C1. Water Vapor Absorption Coefficients for P(20) Line of the 10.6 μm CO_2 Laser

Appendix D

Aerosol Refractive Index Data

The refractive indices of the different types of aerosols used in the models are a function of the comparison of the aerosols. The basic for choosing the different aerosol types used for the models is discussed by Shettle and Fenn,[1] along with a discussion of the different sources of the refractive index data which is presented in Table D1.

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[1] Shettle, E.P., and Fenn, R.W. (1976) Models of the atmospheric aerosols and their optical properties in AGARD Conference Proceedings No. 183, Optical Propagation in the Atmosphere, pages 2.1-2.16, presented at the Electromagnetic Wave Propagation Panel Symposium, Lyngby, Denmark, 27-31 October 1975 (NTIS N76-29817).

Table D1. Refractive Indices for the Different Aerosol Types

WAVELENGTH	H2O-SOLBLE		DUST-LIKE		SOOT		CCEANIC	
.2000	1.530	-7.00E-02	1.530	-7.00E-02	1.500	-.350	1.429	-2.87E-05
.2500	1.530	-3.00E-02	1.530	-3.00E-02	1.620	-.450	1.404	-1.45E-06
.3000	1.530	-8.00E-03	1.530	-8.00E-03	1.740	-.470	1.395	-5.83E-07
.3371	1.530	-5.00E-03	1.530	-8.00E-03	1.750	-.470	1.392	-1.20E-07
.4000	1.530	-5.00E-03	1.530	-8.00E-03	1.750	-.460	1.385	-9.90E-09
.4880	1.530	-5.00E-03	1.530	-8.00E-03	1.750	-.450	1.382	-6.41E-09
.5145	1.530	-5.00E-03	1.530	-8.00E-03	1.750	-.450	1.381	-3.70E-09
.5500	1.530	-6.00E-03	1.530	-8.00E-03	1.750	-.440	1.381	-4.26E-09
.6328	1.530	-6.00E-03	1.530	-8.00E-03	1.750	-.430	1.377	-1.62E-08
.6943	1.530	-7.00E-03	1.530	-8.00E-03	1.750	-.430	1.376	-5.04E-08
.8600	1.520	-1.20E-02	1.520	-8.00E-03	1.750	-.430	1.372	-1.09E-06
1.0600	1.520	-1.70E-02	1.520	-8.00E-03	1.750	-.440	1.367	-6.01E-05
1.3000	1.510	-2.00E-02	1.460	-8.00E-03	1.760	-.450	1.365	-1.41E-04
1.5360	1.510	-2.30E-02	1.400	-8.00E-03	1.770	-.460	1.359	-2.43E-04
1.8000	1.460	-1.70E-02	1.330	-8.00E-03	1.790	-.480	1.351	-3.11E-04
2.0000	1.420	-8.00E-03	1.260	-8.00E-03	1.800	-.490	1.347	-1.07E-03
2.2500	1.420	-1.00E-02	1.220	-9.00E-03	1.810	-.500	1.334	-8.50E-04
2.5000	1.420	-1.20E-02	1.180	-9.00E-03	1.820	-.510	1.309	-2.39E-03
2.7000	1.400	-5.50E-02	1.180	-1.30E-02	1.830	-.520	1.249	-1.56E-02
3.0000	1.420	-2.20E-02	1.160	-1.20E-02	1.840	-.540	1.439	-.197
3.2000	1.430	-8.00E-03	1.220	-1.00E-02	1.860	-.540	1.481	-6.69E-02
3.3923	1.430	-7.00E-03	1.260	-1.30E-02	1.870	-.550	1.439	-1.51E-02
3.5000	1.450	-5.00E-03	1.280	-1.10E-02	1.880	-.560	1.423	-7.17E-03
3.7500	1.452	-4.00E-03	1.270	-1.10E-02	1.900	-.570	1.398	-2.90E-03
4.0000	1.455	-5.00E-03	1.260	-1.20E-02	1.920	-.580	1.388	-3.69E-03
4.5000	1.460	-1.30E-02	1.260	-1.40E-02	1.940	-.590	1.377	-9.97E-03
5.0000	1.450	-1.20E-02	1.250	-1.60E-02	1.970	-.600	1.366	-9.57E-03
5.5000	1.440	-1.80E-02	1.220	-2.10E-02	1.990	-.610	1.333	-9.31E-03
6.0000	1.410	-2.30E-02	1.150	-3.70E-02	2.020	-.620	1.306	-7.96E-02
6.2000	1.430	-2.70E-02	1.140	-3.90E-02	2.030	-.625	1.431	-6.91E-02
6.5000	1.460	-3.30E-02	1.130	-4.20E-02	2.040	-.630	1.374	-2.94E-02
7.2000	1.400	-7.00E-02	1.400	-5.50E-02	2.060	-.650	1.343	-2.49E-02
7.9000	1.200	-6.50E-02	1.150	-4.00E-02	2.120	-.670	1.324	-2.79E-02
8.2000	1.010	-.100	1.130	-7.40E-02	2.130	-.680	1.324	-3.08E-02
8.5000	1.300	-.215	1.300	-9.00E-02	2.150	-.690	1.336	-3.36E-02
8.7000	2.400	-.290	1.400	-.100	2.160	-.690	1.366	-3.56E-02
9.0000	2.560	-.370	1.700	-.140	2.170	-.700	1.373	-3.65E-02
9.2000	2.200	-.420	1.720	-.150	2.180	-.700	1.356	-3.71E-02
9.5000	1.950	-.160	1.730	-.162	2.190	-.710	1.339	-3.68E-02
9.8000	1.870	-9.50E-02	1.740	-.162	2.200	-.715	1.324	-3.88E-02
10.0000	1.820	-9.00E-02	1.750	-.162	2.210	-.720	1.310	-4.06E-02
10.5910	1.760	-7.00E-02	1.620	-.120	2.220	-.730	1.271	-5.22E-02
11.0000	1.720	-5.00E-02	1.620	-.105	2.230	-.730	1.246	-7.31E-02
11.5000	1.670	-4.70E-	1.590	-.100	2.240	-.740	1.227	-.105
12.5000	1.620	-5.30E-02	1.510	-9.00E-02	2.270	-.750	1.208	-.190
13.0000	1.620	-5.50E-02	1.470	-.100	2.280	-.760	1.221	-.223
14.0000	1.560	-7.30E-02	1.520	-8.50E-02	2.310	-.775	1.267	-.271
14.8000	1.440	-.100	1.570	-.100	2.330	-.790	1.307	-.292
15.0000	1.420	-.200	1.570	-.100	2.330	-.790	1.321	-.297
16.4000	1.750	-.160	1.600	-.100	2.360	-.810	1.407	-.331
17.2000	2.080	-.240	1.630	-.100	2.380	-.820	1.487	-.341
18.0000	1.980	-.180	1.640	-.115	2.400	-.825	1.525	-.341
18.5000	1.850	-.170	1.640	-.120	2.410	-.830	1.536	-.339
20.0000	2.120	-.220	1.680	-.220	2.450	-.850	1.560	-.324
21.3000	2.060	-.230	1.770	-.280	2.460	-.860	1.568	-.318
22.5000	2.000	-.240	1.900	-.280	2.480	-.870	1.579	-.316
25.0000	1.880	-.280	1.970	-.240	2.510	-.890	1.596	-.313
27.9000	1.840	-.290	1.890	-.320	2.540	-.910	1.612	-.320
30.0000	1.820	-.300	1.800	-.420	2.570	-.930	1.614	-.320
35.0000	1.920	-.400	1.900	-.500	2.630	-.970	1.597	-.383
40.0000	1.860	-.500	2.100	-.600	2.690	-1.000	1.582	-.561

Appendix E

List of Program and Data

A listing of the Fortran program LOWTRAN 3B (1976) is given in Table E1 together with the two subroutines POINT and ANGL. The input data for the program is given in Table E2.

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) 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). Examples of two typical problems involving the use of the subroutine ANGL are given in Sections 6.6 and 6.7.

The changes necessary to update LOWTRAN 2 to LOWTRAN 3 are indicated by the symbols *, +, A, B, C etc. against the card sequence numbers in Table E1. The - symbol indicates that the following card (in LOWTRAN 2) has been removed. The recent water vapor continuum changes are also characterized by an "*" preceeding the card identification.

Table E1. Listing of LOWTRAN 3B Computer Code

```
      PROGRAM LT3B(INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT)               A   1*
      COMMON Z(34),P(7,34),T(7,34),EH(10,34),WH(7,34),M,NL,RE,CW,CO,PI  A   2*
      DIMENSION WO(7,34),HZ1(34),HZ2(6),AHAZE(34),AHZ2(20)              A   3M
      DIMENSION TR(67),FW(67),FO(67),HZ(2),TX(10),VH(10),W(10),E(10)    A   4
      DIMENSION C1(2580), C2(1575), C3(540), C4(133), C5(15), C8(102)   A   5A
      DIMENSION VX(45),C7(45),C7A(45)                                   A   5B
      F(A)=EXP(18.9766-14.9595*A-2.43882*A*A)*A                         A   5C
      DATA HZ(1)/5H23 KM/,HZ(2)/5H 5 KM/                                A   6
C*********************************************************************  A   7
C        LOWTRAN III B  JUNE 76                                        *A   7+
C     PROGRAM LOWTRAN3 CALCULATES THE TRANSMITTANCE OF THE ATMOSPHERE   A   8
C     FROM 350 CM-1 TO 40000 CM-1 (0.25 TO 28.57 MICRONS) AT 20 CM-1    A   9
C     SPECTRAL RESOLUTION ON A LINEAR WAVENUMBER SCALE.                 A  10
C     REFFACTION AND EARTH CURVATURE EFFECTS ARE INCLUDED.   ATMOSPHERE A  11
C     IS LAYERED IN ONE KM. INTERVALS BETWEEN 0 AND 25 KM., 5 KM. INTER- A  12
C     VALS TO 50 KM., A TWENTY KM. INTERVAL TO 70 KM., AND A THIRTY KM. A  13
C     INTERVAL TO 100 KM.                                               A  14
C*********************************************************************  A  15
C     PROGRAM ACTIVATED BY SUBMISSION OF FOUR CARD SEQUENCE AS FOLLOWS  A  16
C                                                                       A  17
C   CARD 1 MODEL,IHAZE,ITYPE,LEN,JP,IM,M1,M2,M3,ML,RO  FORMAT(10I3,F10.3) A  18*
C   CARD 2 H1,H2,ANGLE,RANGE,BETA,VIS                  FORMAT(7F10.3)   A  19
C   CARD 3 V1, V2, DV                                  FORMAT(7F10.3)   A  20
C   CARD 4 IXY                                         FORMAT(I3)       A  21
C                                                                       A  22
C     MODEL=1,2,3,4,5 OR 6 SELECTS ONE OF THE FOLLOWING MODEL ATMOSPHERE A  23
C     TROPICAL,MIDLATITUDE SUMMER,MIDLATITUDE WINTER,SUBARCTIC SUMMER,  A  24
C     SUBARCTIC WINTER,OR THE 1962 U.S.  STANDARD RESPECTIVELY          A  25
C     MODEL=0 FOR HORIZ. PATH WHEN METEOROL. DATA USED:INSTEAD OF CARD 2 A  26*
C     READ H1,P(MB),T(DEG C),DEW PT.TEMP(DEG C),%REL HUMIDITY,H2O DENSITY A  27*
C     (GM.M-3),O3 DENSITY(GM.M-3), VIS(KM),RANGE(KM) WITH FORMAT 429.   A  28*
C     MODEL=7 WHEN NEW MODEL ATMOSPHERE(E.G. RADICSONDE DATA) USED.     A  29A
C     DATA CARDS ARE READ IN BETWEEN CARDS 1 AND 2, AND SHOULD CONTAIN: A  29B
C     ALTITUDE(KM.),PRESSURE,TEMP,DEW PT.TEMP,REL. HUMIDITY,H2O DENSITY, A  29C
C     O3 DENSITY,AEROSOL NO. DENSITY(CM-3) ACCORDING TO FORMAT 429.     A  29D
C     NOTE THAT EITHER DEW PT. TEMP.OR REL. HUMIDITY CAN BE USED.       A  29E
C                                                                       A  29F
C     M1,M2,M3, ARE USED TO CHANGE TEMP,H2O, AND O3 ALTITUDE PROFILES.  A  29G
C                                                                       A  30
C     IF IHAZE=0 NO AEROSOL SCATTERING IS COMPUTED                      A  31
C     IHAZE =1 IF AEROSOL ATTENUATION REQUIRED (THIS IS USED IN         A  32
C     CONJUNCTION WITH VISUAL RANGE(SEE CARD 2))                        A  33
C     IHAZE = 1 OR 2 ALSO GIVE AEROSOL ATTENUATION FOR 23KM AND 5KM VIS. A  34
C     HAZE MODELS RESPECTIVELY IF VIS =0 ON CARD 2                      A  35
C     IHAZE = 7 FOR OTHER AEROSOL MODELS (E.G. MARITIME ECT) WHICH      A  35+
C     ARE READ INTO PROGRAM                                             A  35+
C                                                                       A  36
C     ITYPE=1,2  OR 3 INDICATES THE TYPE OF ATMOSPHERIC PATH            A  37
C     ITYPE=3,VERTICAL OR SLANT PATH TO SPACE                           A  38
C     ITYPE=2,VERTICAL OR SLANT PATH BETWEEN TWO ALTITUDES              A  39
C     ITYPE=1, CORRESPONDS TO A HORIZONTAL (CONSTANT PRESSURE) PATH     A  40
C                                                                       A  41
C     H1=OBSERVER ALTITUDE (KM)                                         A  42
C     H2=SOURCE  ALTITUDE (KM)                                          A  43
C     ANGLE= ZENITH ANGLE AT H1 (DEGREES)                               A  44
C     RANGE=PATH LENGTH (KM)                                            A  45
C     BETA=EARTH CENTRE ANGLE                                           A  46
C     VIS = VISUAL RANGE AT SEA LEVEL (KM)                              A  47
C     (IF ITYPE=1 READ H1 AND RANGE:IF ITYPE=3 READ H1 AND ANGLE.       A  48
```

Table E1. Listing of LOWTRAN 3B Computer Code (Cont.)

```
C     IF ITYPE=2 READ H1 AND TWO OTHER PARAMETERS E.G. H2 AND ANGLE)
C
C     V1=INITIAL FREQUENCY (WAVENUMBER CM-1 ) INTEGER VALUE
C     V2=FINAL FREQUENCY(WAVENUMBER CM-1 ) INTEGER VALUE
C     DV= FREQUENCY INTERVALS AT WHICH TRANSMITTANCE IS PRINTED
C     NOTE: DV MUST BE A MULTIPLE OF 5 CM-1
C
C     IXY=0  TO END DATA ,=1 FOR NEW V1,V2,DV ONLY , =2 TO CONTINUE DATA
C     IXY=3 FOR NEW CARD 2 ONLY,=4 FOR NEW CARD 1 ONLY.
C*****************************************************************
      IXY=0
      READ (5,400) IATM,ML
      READ (5,401) (HZ1(I),I=1,NL)
      READ (5,401) (HZ2(I),I=1,5)
      HZ2(6)=HZ1(6)
      DO 1 J=1,3
      K2=2*J
      K1=K2-1
      DO 1 I=1,NL
1     READ (5,402) Z(I),(P(K,I),T(K,I),WH(K,I),WO(K,I),K=K1,K2)
      READ (5,431) (VX(I),C7(I),C7A(I),I=1,44)
      READ (5,403) (TR(I),FW(I),FO(I),I=1,67)
      READ (5,404) (C1(I),I=1,2580)
      READ (5,404) (C2(I),I=1,1575)
      READ (5,404) (C3(I),I=1,540)
      READ (5,405) (C4(I),I=1,133)
      READ (5,404) (C5(I),I=1,15)
      READ (5,405) (C8(I),I=1,102)
      PI=2.0*ASIN(1.0)
      CA=PI/180.
      IP=0
2     CONTINUE
      RE=6371.23
      IFIND=0
C     JP NE 0  SUPRESS PRINT
      READ 400,MODEL,IHAZE,ITYPE,LEN,JP,IM,M1,M2,M3,ML,RO
      PRINT400,MODEL,IHAZE,ITYPE,LEN,JP,IM,M1,M2,M3,ML,RO
C     PRINT 424, MODEL,IHAZE,ITYPE,LEN
200   M=MODEL
      IF (M.EQ.1) RE=6378.39
      IF (M.EQ.4) RE=6356.91
      IF (M.EQ.5) RE=6356.91
       IF(IHAZE.NE.7) GO TO 250
      READ 431,(VX(I),C7(I),C7A(I),I=1,44)
      PRINT 431,(VX(I),C7(I),C7A(I),I=1,44)
      IHAZE=1
250   IF(RO.GT.0)RE=RO
      IF(M.EQ.7.AND.IM.NE.0) GO TO 4
      IF(IXY.GT.3) GO TO 8
      IF (MODEL.EQ.0) GO TO 4
300   READ 406, H1,H2,ANGLE,RANGE,BETA,VIS
      PRINT 425, H1,H2,ANGLE,RANGE,BETA,VIS
      X1=RE+H1
      IF (ITYPE.EQ.3) GO TO 560
      IF (ITYPE.EQ.1) GO TO 8
      X2=RE+H2
      IF (RANGE.EQ.0.) GO TO 5
      PRINT 428, H1,H2,ANGLE,RANGE,BETA,VIS
      IF (H2.EQ.0.AND.ANGLE.NE.0) GO TO 3
      ANGLE=ACOS(0.5*((H2-H1)*(1.+X2/X1)/RANGE-RANGE/X1))/CA
```

Table E1. Listing of LOWTRAN 3B Computer Code (Cont.)

```
      GO TO 7                                                           A  97
3     X2=SQRT((X1/RANGE+RANGE/X1+2.0*COS(ANGLE*CA))*X1*RANGE)           A  98
      H2=X2-RE                                                          A  99
      GO TO 7                                                           A 100
4     CONTINUE                                                          A 101*
      IF(ML.LE.0)ML=1                                                   A 102*
      DO 540 K=1,ML                                                     A 103A
      AHAZE(K)=0.0                                                      A 103B
      IF(M.EQ.0)READ 429,H1,P(7,1),TMP,DP,RH,WH(7,K),WO(7,K),VIS,RANGE  A 103C
      IF(M.EQ.0)PRINT 430,H1,P(7,1),TMP,DP,RH,WH(7,K),WO(7,K),VIS,RANGE A 103D
      IF(M.GT.0)READ 429,Z(K),P(7,K),TMP,DP,RH,WH(7,K),WO(7,K),AHAZE(K) A 103E
      J=IFIX(Z(K)+1.0E-6)+1.                                            A 103F
      IF(M.EQ.0)Z(K)=H1                                                 A 103G
      IF(Z(K).GE.25.0) J=(Z(K)-25.0)/5.0+26.                            A 103H
      IF(Z(K).GE.50.0) J=(Z(K)-50.0)/20.0+31.                           A 103I
      IF(Z(K).GE.70.0) J=(Z(K)-70.0)/30.0+32.                           A 103J
      IF(J.GT.33)J=33                                                   A 103K
      FAC=Z(K)-FLOAT(J-1)                                               A 103L
      IF(J.LT.26) GO TO 500                                             A 103M
      FAC=(Z(K)-5.0*FLOAT(J-26)-25.)/5.                                 A 103N
      IF(J.GE.31) FAC=(Z(K)-50.0)/20.                                   A 103O
      IF(J.GE.32) FAC=(Z(K)-70.0)/30.                                   A 103P
      IF(FAC.GT.1.0) FAC=1.0                                            A 103Q
500   L=J+1                                                             A 103R
      T(7,K)=TMP+273.15                                                 A 103S
      IF(M1.GT.0)T(7,K)=T(M1,J)*(T(M1,L)/T(M1,J))**FAC                  A 103T
      TT=273.15/T(7,K)                                                  A 103U
      IF(RH.LE.0.0) TT=273.15/(273.15+DP)                               A 103V
      IF(WH(7,K).LE.0.0) WH(7,K)=F(TT)                                  A 103W
      IF(M2.GT.0)WH(7,K)=WH(M2,J)*(WH(M2,L)/WH(M2,J))**FAC              A 103X
      IF(RH.GT.0.0) WH(7,K)=0.01*RH*WH(7,K)                             A 103Y
      IF(M3.GT.0)WO(7,K)=WO(M3,J)*(WO(M3,L)/WO(M3,J))**FAC              A 103Z
      IF(Z(K).GE.5.0)GO TO 520                                          A 104A
      IF(AHAZE(K).EQ.0.0)AHZ2(K)=HZ2(J)*(HZ2(L)/HZ2(J))**FAC            A 104B
520   IF(AHAZE(K).EQ.0.0)AHAZE(K)=HZ1(J)*(HZ1(L)/HZ1(J))**FAC           A 104C
      IF(MODEL.EQ.0)GO TO 8                                             A 104D
      IF(K.EQ.1)PRINT 441                                               A 104E
      PRINT 429,Z(K),P(7,K),TMP,DP,RH,WH(7,K),WO(7,K),AHAZE(K)          A 104F
540   CONTINUE                                                          A 104G
      IM=0                                                              A 104H
      NL=ML                                                             A 104I
      M1=0                                                              A 104J
      M2=0                                                              A 104K
      M3=0                                                              A 104L
C     NOTE THAT Z(I) MAY NOT CORRESPOND TO THE VALUES GIVEN FOR STANDARD A 104M
C     MODEL ATMOSPHERES                                                 A 104N
      GO TO 300                                                         A 104O
560   IF (RANGE.GT.0.0) GO TO 580                                       A 104P
      IF (H2.GT.0.0.AND.H2.LT.H1) IFIND=1                               A 104Q
      GO TO 8                                                           A 104R
580   ITYPE=2                                                           A 104S
      BETA=ACOS(0.5*(RANGE*RANGE/(X1*X2)-X2/X1-X1/X2))/CA               A 104T
5     IF (BETA.EQ.0.) GO TO 6                                           A 105
      IFIND=1                                                           A 106
      BET=CA*BETA                                                       A 107
      X2=RE+H2                                                          A 108
      ANGLE=ATAN(X2*SIN(BET)/(X2*COS(BET)-X1))/CA                       A 109
      RANGE=X2*SIN(BET)/SIN(ANGLE*CA)                                   A 110
      BET=BETA                                                          A 111
      GO TO 8                                                           A 112
```

Table E1. Listing of LOWTRAN 3B Computer Code (Cont.)

```
6       RANGE=(X2/X1)**2-(SIN(ANGLE*CA))**2                                  A 113
        IF (RANGE.GE.0.0) RANGE=X1*(SQRT(RANGE)-ABS(COS(ANGLE*CA)))          A 114
7       IF (ANGLE.NE.0..OR.ANGLE.NE.180.) BET=ASIN(RANGE*SIN(ANGLE*CA)/X2)   A 115
        IF (ANGLE.LT.0.) ANGLE=ANGLE+PI                                      A 116
        IF (RANGE.LT.0.0) RANGE=-RANGE                                       A 117
        BET=BET/CA                                                           A 118
        PRINT 428, H1,H2,ANGLE,RANGE,BET,VIS                                 A 119
8       CONTINUE                                                             A 120A
        SUMA=0.                                                              A 120B
        IF(IXY.LE.2) READ 406,V1,V2,DV                                       A 121*
        IF(IXY.LE.2)PRINT 406,V1,V2,DV                                       A 122*
        IF (ITYPE.EQ.1) PRINT 407, H1,RANGE                                  A 123
        IF (ITYPE.EQ.2) PRINT 408, H1,H2,ANGLE                               A 124
        IF (ITYPE.EQ.3) PRINT 409, H1,ANGLE                                  A 125
        IF (MODEL.EQ.0) M=7                                                  A 126A
        IF (VIS.GT.0.0) PRINT 417,VIS                                        A 126B
        IF(VIS.LT.2.0.AND.VIS.GT.0.0) PRINT 442                              A 126C
        IF (M.EQ.1) PRINT 410, M                                             A 127
        IF (M.EQ.2) PRINT 411, M                                             A 128
        IF (M.EQ.3) PRINT 412, M                                             A 129
        IF (M.EQ.4) PRINT 413, M                                             A 130
        IF (M.EQ.5) PRINT 415, M                                             A 131
        IF (M.EQ.6) PRINT 414, M                                             A 132
        IF (IHAZE.EQ.0.) PRINT 426                                           A 133
        IF (VIS.LE.0.0.AND.IHAZE.GT.0) PRINT 416,IHAZE,HZ(IHAZE)             A 134*
        AVW=10000./V1                                                        A 135
        ALAM=10000./V2                                                       A 136
        PRINT 418, V1,V2,DV,ALAM,AVW                                         A 137
        AVW=0.5E-4*(V1+V2)                                                   A 138
        AVW=AVW*AVW                                                          A 139
        CO=77.46+.459*AVW                                                    A 140
        CW=43.487-0.3473*AVW                                                 A 141
        IF (IFIND.EQ.1) GO TO 15                                             A 142
9       IF (IFIND.EQ.1) CALL ANGL (H1,H2,ANGLE,BETA,LEN,ML)                  A 143*
        IFIND=0                                                              A 144
        IF (JP.EQ.0) PRINT 427                                               A 146*
        IF (ITYPE.EQ.1) GO TO 15                                             A 147
        DO 11 K=1,10                                                         A 148
        VH(K)=0.0                                                            A 149
11      CONTINUE                                                             A 150
        BETA=0.0                                                             A 151-
        SR=0.0                                                               A 153
        IP=0                                                                 A 154-
C****    NOW DEFINE CONSTANT PRESSURE PATH QUANTITES  EH(1-8)                A 156
        Y=CA*ANGLE                                                           A 157
        SPHI=SIN(Y)                                                          A 158
        R1=(RE+H1)*SPHI                                                      A 159
        IF (H1.GT.Z(NL)) GO TO 13                                            A 160
        GO TO 15                                                             A 161
13      X=(RE+Z(NL))/(RE+H1)                                                 A 162
        IF (SPHI.GT.X) GO TO 14                                              A 163
        H1=Z(NL)                                                             A 164
        J1=NL                                                                A 165
        SPHI=SPHI/X                                                          A 166
        ANGLE=180.0-ASIN(SPHI)/CA                                            A 167
        R1=(RE+H1)*SPHI                                                      A 168
        GO TO 15                                                             A 170
14      HMIN=R1-RE                                                           A 171
        PRINT 433, HMIN                                                      A 172
        GO TO 95                                                             A 173
```

Table E1. Listing of LOWTRAN 3B Computer Code (Cont.)

```
15     DO 17 I=1,NL                                                     A 174
       PS=P(M,I)/1013.0                                                 A 175
       TS=273.15/T(M,I)                                                 A 176A
       IF(M1.GT.0.AND.M.LT.7)TS=273.15/T(M1,I)                          A 176B
       X=PS*TS                                                          A 177
       PT=PS*SQRT(TS)                                                   A 178
       D=0.1*WH(M,I)                                                    A 179
       IF(M2.GT.0.AND.M.LT.7) D=0.1*WH(M2,I)                            A 180*
       EH(1,I)=D*PT**0.9                                                A 181*
       EH(2,I)=X*PT**0.75                                               A 182*
       EH(4,I)=0.8*PT*X                                                 A 183
       PPW=4.56E-5*D*273.15/TS                                          A 184*
       TS1=(296.0/273.15)*TS                                           *A 185A
       EH(5,I)=D*PPW*EXP(6.08*(TS1-1.0))+0.002*D(PS-PPW)               *A 185B
       EH(10,I)=D*(PPW+0.12*(PS-PPW))*EXP(4.56*(TS1-1.0))              *A 185C
       EH(6,I)=X                                                        A 186
       HAZE=HZ1(I)                                                      A 187
       IF(M.EQ.7) HAZE=AHAZE(I)                                         A 188*
       IF(Z(I).GE.5.0) GO TO 150                                        A 189*
       IF(M.NE.7.AND.IHAZE.EQ.2) HAZE=HZ2(I)                            A 190A
       IF(IHAZE.EQ.2.AND.M.EQ.7)HAZE=AHZ2(I)                            A 190B
       IF(VIS.LE.0.0) GO TO 150                                         A 190C
       IF(M.NE.7) HAZE=6.389*((HZ2(I)-HZ1(I))/VIS+HZ1(I)/5.-HZ2(I)/23.) A 190D
       IF (M.NE.7) GO TO 150                                            A 190E
       HAZE=6.389*((AHZ2(I)-AHAZE(I))/VIS+AHAZE(I)/5.0-AHZ2(I)/23.0)    A 190F
150    IF(HAZE.LT.0.0) HAZE=0.0                                         A 190G
       EH(7,I)=HAZE/HZ1(1)                                              A 191A
       IF(MODEL.EQ.7) EH(7,I)=HAZE/AHAZE(1)                             A 191B
       EH(8,I)=46.6667*WO(M,I)                                          A 192
       IF(M3.GT.0.AND.M.LT.7) EH(8,I)=46.667*WO(M3,I)                   A 193A
       EH(3,I)=EH(8,I)*PT**0.4                                          A 193B
       EH(9,I)=1.0                                                      A 193C
       REF=1.0E-6*(CO*X*1013.0/273.15-PPW*CW)                          *A 193D
       IF (I.EQ.NL) GO TO 16                                            A 194
       IF (MODEL.EQ.0.AND.I.GE.1) GO TO 26                              A 195A
       T2=T(M,I+1)                                                      A 195B
       W2=WH(M,I+1)                                                     A 195C
       IF(M1.GT.0)T2=T(M1,I+1)                                          A 195D
       IF(M2.GT.0)W2=WH(M2,I+1)                                         A 195E
       PPW=4.56E-6*W2*T2                                                A 196*
       EH(9,I)=0.5*(REF+1.0E-6*(CO*P(M,I+1)/T2-PPW*CW))                *A 197*
16     IF (I.EQ.NL) EH(9,I)=0.                                          A 198*
       IF (H1.GE.Z(I)) J1=I                                             A 199*
       IF(IFIND.EQ.0.OR.JP.EQ.0) PRINT 434, I,Z(I),(EH(K,I),K=1,10),REF *A 200
       EH(9,I)=EH(9,I)+1.0                                              A 201
17     CONTINUE                                                         A 202
170    IF (IFIND.EQ.1) GO TO 9                                          A 203
       IP=-1                                                            A 204
       IK=0                                                             A 205
       X1=+1                                                            A 206
       CALL POINT (H1,YN,N,NP1,TX,IP)                                   A 207
       J1=N                                                             A 208
       TX1=TX(9)                                                        A 209
       DO 18 K=1,10                                                    *A 210
18     E(K)=TX(K)                                                       A 211
       IF (ITYPE.EQ.1) GO TO 26                                         A 212
       IF (ITYPE.EQ.3) H2=Z(NL)                                         A 213
       IF (ANGLE.GT.90.0) GO TO 28                                      A 214
19     IF (ANGLE.GT.90.0.AND.NP1.GT.0) J1=J1+1                          A 215
       J2=NL                                                            A 216
```

Table E1. Listing of LOWTRAN 3B Computer Code (Cont.)

```
      IF (ITYPE.EQ.3) GO TO 20                                          A 217
      CALL POINT (H2,YN,N,NP,TX,IP)                                     A 218
      J2=N                                                              A 219
      IF (NP.GT.0) J2=J2-1                                              A 220
20    DO 21 K=1,10                                                     *A 221A
       IF(K.EQ.9) GO TO 21                                             *A 221B
      EH(K,J1)=E(K)                                                     A 222
      IF (ITYPE.EQ.3) GO TO 21                                          A 223
      EH(K,J2+1)=TX(K)                                                  A 224
21    CONTINUE                                                          A 225
      IF (J1.EQ.J2) TX1=TX1+YN-EH(9,J1)                                 A 226
C****  NOW DEFINE VERTICAL PATH QUANTITIES VH(1-8)                      A 227
      IF (JP.EQ.0) PRINT 420                                            A 228*
      DO 25 I=J1,J2                                                     A 229
      X1=Z(I)                                                           A 230
      X2=Z(I+1)                                                         A 231
      IF (I.EQ.J1) X1=H1                                                A 232
      IF (I.EQ.J2) X2=H2                                                A 233
      DZ=X2-X1                                                          A 234
      IF (I.EQ.NL) DZ=Z(I)-Z(I-1)                                       A 235
      DS=DZ                                                             A 236
C*****  UPWARD TRAJECTORY                                               A 237
      RX=(RE+X1)/(RE+X2)                                                A 238
      THETA=ASIN(SPHI)/CA                                               A 239
      PHI=ASIN(SPHI*RX)/CA                                              A 240
      BET=THETA-PHI                                                     A 241
      SALP=RX*SPHI                                                      A 242
      IF (SPHI.GT.1.E-10) DS=(RE+X2)*SIN(BET*CA)/SPHI                   A 243
      BETA=BETA+BET                                                     A 244
      PSI=BETA+PHI-ANGLE                                                A 245
      PHI=180.-PHI                                                      A 246
      SR=SR+DS                                                          A 247
      DO 24 K=1,10                                                     *A 248
      EV=DS*EH(K,I)                                                     A 249
      IF (I.EQ.NL) GO TO 22                                             A 250
      IF (EH(K,I).EQ.0.0.OR.EH(K,I+1).EQ.0.0) GO TO 23                  A 251
      IF (EH(K,I).EQ.EH(K,I+1)) GO TO 24                                A 252
      EV=DS*(EH(K,I)-EH(K,I+1))/ALOG(EH(K,I)/EH(K,I+1))                 A 253
      GO TO 24                                                          A 254
22    IF (EH(K,I).EQ.0.0) GO TO 23                                      A 255
      IF (EH(K,I-1).EQ.0.0) GO TO 23                                    A 256
      IF (EH(K,I).EQ.EH(K,I-1)) GO TO 24                                A 257
      EV=EV/ALOG(EH(K,I-1)/EH(K,I))                                     A 258
      GO TO 24                                                          A 259
23    EV=0.                                                             A 260
24    VH(K)=VH(K)+EV                                                    A 261
      IF (JP.EQ.0) PRINT 435, I,X1,(VH(L),L=1,8),PSI,PHI,BETA,THETA,SR  A 262*
      IF (I.GE.NL) GO TO 25                                             A 263
      IF (I+1.EQ.J2) EH(9,I+1)=YN                                       A 264
      IF (I.EQ.J1) EH(9,I)=TX1                                          A 265
      RN=EH(9,I+1)/EH(9,I)                                              A 266
      SPHI=SPHI*RX/RN                                                   A 267
      IF (SALP.GE.RN) SPHI=SALP                                         A 268
25    CONTINUE                                                          A 269
      GO TO 47                                                          A 270
C**** HORIZONTAL PATH                                                   A 271
26    DO 27 K=1,10                                                     *A 272
      W(K)=RANGE*EH(K,1)                                                A 273*
      IF (MODEL.GT.0) W(K)=RANGE*TX(K)                                  A 274*
27    CONTINUE                                                          A 275
```

Table E1. Listing of LOWTRAN 3B Computer Code (Cont.)

```
      GO TO 49
28    CONTINUE
C****   DOWNWARD TRAJECTORY
      K2=0
      IF (NP1.EQ.1) J1=J1-1
      J2=J1+1
      J=J1+1
      YN1=YN
      IF (H2.GT.Z(J1+1).OR.H1.EQ.H2) GO TO 30
      IF (NP1.EQ.1.AND.H2.GE.Z(J1+1)) GO TO 30
      CALL POINT (H2,YN,N,NP2,TX,IP)
      DO 29 K=1,10
29    W(K)=TX(K)
      TX2=TX(9)
      YN2=YN
      IF (H2.LT.H1) H=H2
      J2=N
      IF (J1.EQ.J2) TX2=TX1+YN2-EH(9,N)
      IF (H2.GT.H1) TX1=TX2
      IF (J1.EQ.J2.AND.H2.LT.H1) YN1=TX2
30    A0=(RE+H1)*SPHI*YN1
      IF (H2.GE.H1) YN2=YN1
      DO 31 I=1,J1
      HMIN=A0/EH(9,I)-RE
      IF (I.EQ.J1) HMIN=A0/YN1-RE
      JMIN=I
      IF (HMIN.LE.Z(I+1)) GO TO 32
31    CONTINUE
32    X=HMIN
      IF (HMIN.LE.0) GO TO 34
      CALL POINT (X,YN,N,NP,TX,IP)
      JMIN=N
      TX3=TX(9)
      IF (J2.EQ.N.OR.J1.EQ.N) TX3=YN2+TX(9)-EH(9,N)
      IF(TX3.LT.0.0)TX3=TX(9)
      IF (J1.EQ.N.AND.H2.GE.H1) GO TO 33
      HMIN=A0/TX3-RE
      IF (ABS(X-HMIN).GT.0.0001) GO TO 32
33    IF (J1.EQ.N.AND.H2.GE.H1) YN1=TX3
      IF (J2.EQ.N.AND.J1.NE.J2) YN2=TX3
      IF (H2.GE.H1) TX2=TX3
      IF (H2.GE.H1) J2=N
      IF (H2.GE.H1.OR.H2.LT.HMIN) H=HMIN
      PRINT 436, HMIN
      IF(H2.LT.HMIN)J2=N
      IF (H2.LT.HMIN) PRINT 440, HMIN
      GO TO 35
34    PRINT 436, HMIN
      IF (H2.LT.H1) GO TO 35
      IF (ITYPE.EQ.3.OR.H2.GE.H1) PRINT 437
      ITYPE=2
      TX2=FH(9,1)
      JMIN=0
      J2=1
      H2=0.0
      H=0.0
C****   NOW DEFINE VERTICAL PATH QUANTITIES VH(1-8)
35    IF (JP.EQ.0) PRINT 420
      DO 40 I=1,NL
      J=J-1
```

Table E1. Listing of LOWTRAN 3B Computer Code (Cont.)

```
      REF=EH(9,J)                                                       A 334
      IF (I.EQ.1) REF=YN1                                               A 335
      IF (I.EQ.1.AND.K2.EQ.1) REF=YN2                                   A 336
      IF (J.EQ.J2.AND.K2.EQ.0) REF=TX2                                  A 337
      IF (I.NE.1) X1=Z(J+1)                                             A 338
      X2=Z(J)                                                           A 339
      IF (J.EQ.J2.AND.K2.EQ.0) X2=H                                     A 340
      IF (J.EQ.JMIN.AND.K2.EQ.1) X2=HMIN                                A 341
      HM=(RE+X1)*SPHI-RE                                                A 342
      IF (HM.GT.Z(J).AND.HM.GT.X2) X2=HM                                A 343
      RX=(RE+X1)/(RE+X2)                                                A 344
      DS=X1-X2                                                          A 345
      ALP=90.0                                                          A 346
      THET=ASIN(SPHI)/CA                                                A 347
      SALP=RX*SPHI                                                      A 348
      IF (ABS(X2-HM).GT.1.0E-5) ALP=ASIN(SALP)/CA                       A 349
      BET=ALP-THET                                                      A 350
      IF (SPHI.GT.1.0E-10) DS=(RE+X2)*SIN(BET*CA)/SPHI                  A 351
      THETA=180.0-THET                                                  A 352
      BETA=BETA+BET                                                     A 353
      PSI=BETA-ALP-ANGLE+180.0                                          A 354
      SR=SR+DS                                                          A 355
      DO 39 K=1,10                                                     *A 356
      AJ=EH(K,J)                                                        A 357
      BJ=EH(K,J+1)                                                      A 358
      IF (J.EQ.J1) BJ=E(K)                                              A 359
      IF (J.EQ.J2.AND.H2.LT.H1.AND.H2.GT.0.0) AJ=W(K)                   A 360
      IF (J.EQ.JMIN.AND.H2.GE.H1) AJ=TX(K)                              A 361
      IF (J.EQ.JMIN.AND.ABS(H2-HM).LT.1.0E-5) AJ=TX(K)                  A 362
      IF (K2.EQ.0) GO TO 36                                             A 363
      IF (J.EQ.J2) BJ=W(K)                                              A 364
      IF (J.EQ.JMIN) AJ=TX(K)                                           A 365
36    IF (AJ.EQ.0.0.OR.BJ.EQ.0.0) GO TO 38                              A 366
      IF (AJ.EQ.BJ) GO TO 37                                            A 367
      EV=DS*(AJ-BJ)/ALOG(AJ/BJ)                                         A 368
      GO TO 39                                                          A 369
37    EV=DS*AJ                                                          A 370
      GO TO 39                                                          A 371
38    EV=0.0                                                            A 372
39    VH(K)=VH(K)+EV                                                    A 373
      IF (JP.EQ.0) PRINT 435, J,X1,(VH(L),L=1,8),PSI,ALP,BETA,THETA,SR  A 374*
      IF (J.EQ.J2.AND.H2.GE.H1) GO TO 45                                A 375
      IF (J.EQ.JMIN.AND.K2.EQ.1) GO TO 43                               A 376
      IF (J.NE.1) RN=REF/EH(9,J-1)                                      A 377
      IF (J.EQ.J2+1) RN=REF/TX2                                         A 378
      IF (J.EQ.J2.AND.K2.EQ.0) RN=REF/YN2                               A 379
      IF (J.EQ.(JMIN+1).AND.K2.EQ.1) RN=REF/TX3                         A 380
      IF (SALP.GE.RN) RN=1.0                                            A 381
      SPHI=SALP*RN                                                      A 382
      IF (J.EQ.J2.AND.K2.EQ.0) GO TO 41                                 A 383
40    CONTINUE                                                          A 384
41    IF (HMIN.LE.0) GO TO 47                                           A 385
      IF (LEN.EQ.0) PRINT 438                                           A 386
      IF (LEN.EQ.0) GO TO 47                                            A 387
      IF (LEN.EQ.1) PRINT 439                                           A 388
      K2=1                                                              A 389
      X1=X2                                                             A 390
      IF (ABS(X1-HMIN).LE.0.001) GO TO 47                               A 391
      H=HMIN                                                            A 392
      J=J2+1                                                            A 393
```

Table E1. Listing of LOWTRAN 3B Computer Code (Cont.)

```
      IF (NP2.EQ.1) J=J-1                                                A 394
      B=BETA                                                             A 395
      PH=180.0-ASIN(SPHI)/CA                                             A 396
      TS=SR                                                              A 397
      PS=PSI                                                             A 398
      DO 42 K=1,10                                                      *A 399
42    E(K)=VH(K)                                                         A 400
      GO TO 35                                                           A 401
43    BETA=2.*BETA-B                                                     A 402
      PSI=2.*PSI-PS                                                      A 403
      SR=2.*SR-TS                                                        A 404
C      LONG PATH  TAKEN                                                  A 405
      PHI=PH                                                             A 406
      DO 44 K=1,10                                                      *A 407
44    VH(K)=2.*VH(K)-E(K)                                                A 408
      GO TO 47                                                           A 409
45    DO 46 K=1,10                                                      *A 410
46    VH(K)=2.0*VH(K)                                                    A 411
      BETA=2.0*BETA                                                      A 412
      SR=2.0*SR                                                          A 413
      IF (H2.EQ.H1) GO TO 47                                             A 414
      RN=TX1/YN1                                                         A 415
      SPHI=SIN(ANGLE*CA)                                                 A 416
      IF (SPHI.LT.RN) SPHI=SPHI/RN                                       A 417
      GO TO 19                                                           A 418
47    CONTINUE                                                           A 419
       IF(ANGLE.GT.90.0) PRINT 406,HM                                    A 419+
      DO 48 K=1,10                                                      *A 420
      W(K)=VH(K)                                                         A 421
48    CONTINUE                                                           A 422
49    WRITE (6,419)                                                      A 423
      WRITE(6,421) (W(I),I=1,8),W(10)                                   *A 424
      I=1                                                                A 425
      L=1                                                                A 426
      IV1=V1/5.0                                                         A 427
      IV2=V2/5.+.99                                                      A 428
      IV1=5*IV1                                                          A 429
      IV2=5*IV2                                                          A 430
      IF (IV1.LT.350) IV1=350                                            A 431
      IF (IV2.GT.50000) IV2=50000                                        A 432
      IF (DV.LT.5.) DV=5.                                                A 433
      IDV=DV                                                             A 434
      IV=IV1-IDV                                                         A 435
      ICOUNT=0                                                           A 436
C****  BEGINING OF TRANSMITTANCE CALCULATIONS                            A 437
50    IV=IV+IDV                                                          A 438A
      IF(JP.NE.0) GO TO 52                                               A 438B
      IF (ICOUNT.EQ.0) GO TO 51                                          A 439
      IF (ICOUNT.EQ.50) GO TO 51                                         A 440
      GO TO 52                                                           A 441
51    ICOUNT=0                                                           A 442
      PRINT 422                                                          A 443
52    DO 53 K=1,10                                                       A 444*
      TX(K)=0.0                                                          A 445
      IF (K.LT.4) TX(K)=1.0                                              A 446
53    CONTINUE                                                           A 447
      ICOUNT=ICOUNT+1                                                    A 448
      SUM=0.0                                                            A 449
      V=IV                                                               A 450
      I=(IV-350)/5+1                                                     A 451
```

Table E1. Listing of LOWTRAN 3B Computer Code (Cont.)

```
      IF(IV.LT.670) GO TO 72                                            *A 452
      IF(IV.LE.3000) GO TO 61                                           *A 453
C********   MOLECULAR SCATTFRING                                         A 454
      C6=9.807E-20*(V**4.0117)                                           A 455
      TX(6)=C6*W(6)                                                      A 456
      SUM=SUM+TX(6)                                                      A 457
      IF (IV.LT.9200) GO TO 72                                           A 458
      IF (IV.LT.13000) GO TO 69                                          A 459
C********  UV OZONE                                                       A 460
      IF (IV.LE.23400) GO TO 54                                          A 461
      IF (IV.GE.27500) GO TO 55                                          A 462
      GO TO 87                                                           A 463
54    XX=200.0                                                           A 464
      XI=(V-13000.0)/XX+1.0                                              A 465
      L1=1                                                               A 466
      L2=53                                                              A 467
      GO TO 56                                                           A 468
55    XX=500.0                                                           A 469
      XI=(V-27500.0)/XX+57.0                                             A 470
      L1=57                                                              A 471
      L2=102                                                             A 472
56    DO 57 N=L1,L2                                                      A 473
      XD=XI-FLOAT(N)                                                     A 474
      IF (XD) 59,58,57                                                   A 475
57    CONTINUE                                                           A 476
58    TX(8)=W(8)*C8(N)                                                   A 477
      GO TO 60                                                           A 478
59    TX(8)=C8(N)+XD*(C8(N)-C8(N-1))                                     A 479
      TX(8)=W(8)*TX(8)                                                   A 480
60    SUM=SUM+TX(8)                                                      A 481
      IF(IV.GT.14500)GO TO 87                                            A 482*
      GO TO 69                                                           A 483
C********  WATER VAPOR CONTINUUM 10 MICRON REGION                        *A 484
61    IF(IV.GT.1350) GO TO 62                                           *A 485
      TX(5)=(4.18+5578.0*EXP(-7.87E-3*V))*W(5)                          *A 486
      GO TO 66                                                          *A 487
62    IF(IV.LT.2350) GO TO 68                                           *A 488
C********  WATER VAPOR CONTINUUM 4 MICRON REGION                         *A 489
      XI=(V-2350.0)/50.0+1.0                                            *A 490
      NH=XI+1.001                                                       *A 491
      XH=XI-FLOAT(NH)                                                   *A 492
      TX(5)=C5(NH)                                                      *A 493
64    TX(5)=TX(5)+XH*(C5(NH)-C5(NH-1))                                  *A 496
65    TX(5)=TX(5)*W(10)                                                 *A 497
66    SUM=SUM+TX(5)                                                     *A 498
      IF(IV.LE.1350.OR.IV.GT.2740) GO TO 72                             *A 499
C********   NITROGEN CONTINUUM                                           A 500
68    IF (IV.LT.2080) GO TO 72                                           A 501
      K4=I-346                                                           A 502
      TX(4)=C4(K4)*W(4)                                                  A 503
      SUM=SUM+TX(4)                                                      A 504
      GO TO 72                                                           A 505
C********  WATER VAPOUR                                                   A 506
69    IF (IV.LT.12800.AND.IV.GE.9875) GO TO 70                           A 507
      IF (IV.LE.14520.AND.IV.GE.13400) GO TO 71                          A 508
      GO TO 76                                                           A 509
70    I=I-135                                                            A 510
      GO TO 72                                                           A 511
71    I=I-255                                                            A 512
72    K1=1                                                               A 513
```

Table E1. Listing of LOWTRAN 3B Computer Code (Cont.)

```
      IF (W(1).LT.1.0E-20) GO TO 76                                     A 514
      WS1=ALOG10(W(1))+C1(I)                                            A 515
      IF (WS1.LT.-2.3468) GO TO 76                                      A 516
      IF (WS1.GT.3.5682) GO TO 75                                       A 517
      IF (WS1.GT.2.0) K1=40                                             A 518
      DO 73 K=K1,67                                                     A 519
      IF (WS1.LE.FW(K)) GO TO 74                                        A 520
73    CONTINUE                                                          A 521
74    TX(1)=TR(K)+(TR(K-1)-TR(K))*(FW(K)-WS1)/(FW(K)-FW(K-1))           A 522
      GO TO 76                                                          A 523
75    TX(1)=0.0                                                         A 524
76    CONTINUE                                                          A 525
C********  UNIFORMLY MIXED GASES                                        A 526
      IF (IV.LT.8060.AND.IV.GE.500) GO TO 77                            A 527
      IF (IV.LT.13190.AND.IV.GT.12970) GO TO 78                         A 528
      GO TO 83                                                          A 529
77    J=I-30                                                            A 530
      GO TO 79                                                          A 531
78    J=(IV-12970)/5+1516                                               A 532
79    IF(W(2).LT.1.0E-20) GO TO 83                                      A 533*
      K1=1                                                              A 534
      WS2=ALOG10(W(2))+C2(J)                                            A 535
      IF (WS2.LT.-2.3468) GO TO 83                                      A 536
      IF (WS2.GT.3.5682) GO TO 82                                       A 537
      IF (WS2.GT.2.0) K1=40                                             A 538
      DO 80 K=K1,67                                                     A 539
      IF (WS2.LE.FW(K)) GO TO 81                                        A 540
80    CONTINUE                                                          A 541
81    TX(2)=TR(K)+(TR(K-1)-TR(K))*(FW(K)-WS2)/(FW(K)-FW(K-1))           A 542
      GO TO 83                                                          A 543
82    TX(2)=0.0                                                         A 544
83    CONTINUE                                                          A 545
C********  OZONE                                                        A 546
      IF (IV.LT.575.OR.IV.GT.3270) GO TO 87                             A 546+
      L=I-45                                                            A 547
      K1=1                                                              A 548
      IF (W(3).LT.1.0E-20) GO TO 87                                     A 549
      WS3=ALOG10(W(3))+C3(L)                                            A 550
      IF (WS3.LT.-1.6778) GO TO 87                                      A 551
      IF (WS3.GT.3.9345) GO TO 86                                       A 552
      IF (WS3.GT.1.5) K1=36                                             A 553
      DO 84 K=K1,67                                                     A 554
      IF (WS3.LE.FO(K)) GO TO 85                                        A 555
84    CONTINUE                                                          A 556-
85    TX(3)=TR(K)-(TR(K)-TR(K-1))*(FO(K)-WS3)/(FO(K)-FO(K-1))           A 558
      GO TO 87                                                          A 559
86    TX(3)=0.0                                                         A 560
87    CONTINUE                                                          A 561
C********  AEROSOL EXTINCTION                                           A 562
      ALAM=1.0E+4/V                                                     A 563A
      XX=0.0                                                            A 563B
      YY=0.0                                                            A 563C
C********  TEMPORARY FOG CORRECTION FOR VIS BELOW 2 KM.                 A 563D
      IF(VIS.GT.0.0.AND.VIS.LT.2.0)  XX=3.91/VIS                        A 563E
      IF(IHAZE.EQ.0.OR.XX.GT.0.0) GO TO 90                              A 564*
      DO 88 N=1,44                                                      A 565*
      XD=ALAM-VX(N)                                                     A 566*
      IF(XD)89,88,88                                                    A 567*
88    CONTINUE                                                          A 568A
89    XX=(C7(N)-C7(N-1))*XD/(VX(N)-VX(N-1))+C7(N)                       A 568B
```

Table E1. Listing of LOWTRAN 3B Computer Code (Cont.)

```
      YY=(C7A(N)-C7A(N-1))*XD/(VX(N)-VX(N-1))+C7A(N)
90    TX(10)=YY*W(7)
      TX(7)=XX*W(7)
      SUM=SUM+TX(7)
      TX(9)=SUM
      DO 94 K=4,10
      IF (TX(K).EQ.0.0) GO TO 92
      IF (TX(K).LE.0.1) GO TO 91
      IF (TX(K).GT.20.) GO TO 93
      TX(K)=EXP(-TX(K))
      GO TO 94
91    TX(K)=1.0-TX(K)+0.5*TX(K)*TX(K)
      GO TO 94
92    TX(K)=1.0
      GO TO 94
93    TX(K)=0.
94    CONTINUE
      TX(10)=1.0-TX(10)
      TX(9)=TX(1)*TX(2)*TX(3)*TX(9)
      IF (IV.GE.13000) TK(3)=TX(8)
      IF(JP.EQ.3)TX(9)=TX(7)
      AB=1.-TX(9)
      IF(IV.EQ.IV1.OR.IV.EQ.IV2) AB=0.5*AB
      SUMA=SUMA+AB*DV
      IF(JP.EQ.0) WRITE(6,423) IV,ALAM,TX(9),(TX(K),K=1,7),TX(10),SUMA
      IF (IV.GE.IV2) GO TO 95
      GO TO 50
95    READ 400, IXY
      AB=1.0-SUMA/FLOAT(IV2-IV1)
      PRINT 424, IV1,IV2,SUMA,AB
      PRINT 400,IXY
      IF(IXY.EQ.0) GO TO 100
      GO TO (96,2,97,98,100),IXY
96    READ 406, V1,V2,DV
      AVW=10000./V1
      ALAM=10000./V2
      PRINT 418, V1,V2,DV,ALAM,AVW
      SUMA=0.0
      GO TO 49
97    IF(MODEL.EQ.0) GO TO 200
      GO TO 300
98    READ 400,MODEL,IHAZE,ITYPE,LEN,JP,IM,M1,M2,M3,ML,RO
      PRINT 400,MODEL,IHAZE,ITYPE,LEN,JP,IM,M1,M2,M3,ML,RO
      GO TO 200
100   STOP
400   FORMAT(10I3,F10.3)
401   FORMAT (8E10.3)
402   FORMAT (F6.1,2(E10.3,F6.1,2E10.3))
403   FORMAT (4(F6.3,2F7.4))
404   FORMAT (15F5.2)
405   FORMAT (8E9.2)
406   FORMAT (7F10.3)
407   FORMAT (//10X,28H HORIZONTAL PATH, ALTITUDE =,F7.3,11H KM,RANGE =,
     1F7.3,3H KM)
408   FORMAT (//10X,50H SLANT PATH BETWEEN ALTITUDES H1 AND H2 WHERE H1
     1=,F7.3,8H KM H2 =,F7.3,18H KM,ZENITH ANGLE =,F7.3,8H DEGREES)
409   FORMAT (//10X,39H SLANT PATH TO SPACE FROM ALTITUDE H1 =,F7.3,19H
     1KM, ZENITH ANGLE =,F7.3,8H DEGREES)
410   FORMAT (/20X,18H MODEL ATMOSPHERE ,I1,11H = TROPICAL)
411   FORMAT (/20X,18H MODEL ATMOSPHERE ,I1,21H = MIDLATITUDE SUMMER)
```

Table E1. Listing of LOWTRAN 3B Computer Code (Cont.)

```
412   FORMAT (/20X,18H MODEL ATMOSPHERE ,I1,21H = MIDLATITUDE WINTER)       A 615
413   FORMAT (/20X,18H MODEL ATMOSPHERE ,I1,21H = SUB-ARCTIC SUMMER )       A 616
414   FORMAT (/20X,18H MODEL ATMOSPHERE ,I1,21H = 1962 US STANDARD  )       A 617
415   FORMAT (/20X,18H MODEL ATMOSPHERE ,I1,21H = SUB-ARCTIC WINTER )       A 618
416   FORMAT (/20X,18H       HAZE MODEL ,I1,3H = ,A5,13H VISUAL RANGE)      A 619
417   FORMAT (/25X*HAZE MODEL  =*,F5.1,* KM VISUAL RANGE AT SEA LEVEL*)     A 620
418   FORMAT (/10X,21H FREQUENCY RANGE V1= ,F7.1,13H CM-1 TO V2= ,F7.1,1    A 621
     14H CM-1 FOR DV =,F6.1,9H CM-1   (,F6.2,* - *,F5.2,* MICRONS )*)      A 622
419   FORMAT (/10X,38H UALENTVENT SEA LEVEL ABSORBER AMOUNTS//21X113HWAT    A 623
     1ER VAPOUR     CO2 ETC.       OZONE    NITROGEN (CONT)  H2O (CONT)    A 624
     2    MOL  SCAT       AEROSOL     OZONE(U-#)/24X,7HGM CM-2,10X,2HKM,1  A 625
     30X,6HATM CM,10X,2HKM,9X,7HGM CM-2,10X,2HKM,13X,2HKM,10X,6HATM CM)    A 626
420   FORMAT (1H1,///10X,*  VERTICAL PROFILES  *,64X,*PSI*,6X,*PHI*,6X,*    A 627
     1BETA*,4X,*THETA     RANGE*)                                          A 628
421   FORMAT(/10X,8H W(1-8)= 8E(14.3)/74X,E14.3/)                          *A 629
422   FORMAT (1H1,/10X,32H  FREQ WAVELENGTH  TOTAL      H2O,5X4HCO2+,5X,6   A 630*
     14HOZONE  N2 CONT  H2O CONT MOL SCAT  AEROSOL  AEROSOL   INTEGRATED   A 631*
     2 /11X,14H CM-1  MICRONS,8(4X5HTRANS),4X,20H ABS      ABSORPTION )    A 632*
423   FORMAT (10X,I6,10F9.4,F12.2)                                          A 633*
424   FORMAT (* INTEGRATED ABSORPTION FROM*,I5,* TO*,I5,* CM-1 =*,F10.2,    A 634A
     1*,AVERAGE TRANSMITTANCE =*,F6.4)                                     A 634B
425   FORMAT (10X,7F10.3)                                                   A 635
426   FORMAT (/20X,*AEROSOL SCATTERING NOT COMPUTED,IHAZE=0*)               A 636
427   FORMAT (1H1,///10X,20H HORIZONTAL PROFILES/)                          A 637
428   FORMAT (10X,* H1=*,F7.3,*KM,H2=*,F7.3,*KM,ANGLE=*,F8.4,*GEOM. RANG    A 638
     1E =*,F7.2,*KM,BETA=*,F8.5,*,VIS=*,F6.1)                              A 639
429   FORMAT(3F10.3,2F5.1,2E10.3,2F10.3)                                    A 640*
430   FORMAT(10X,*INPUT METEOROLOGICAL DATA:*/10X,*Z=*,F7.2,* KM, P=*,F7    A 641*
     1.2,* MB,T=*,F5.1,* C, DEW PT.TEMP*,F5.1,* C, REL HUMIDITY=*,F5.1,    A 642*
     2* %, H2O DENSITY=*,1PE9.2,* GM M-3*/10X,* OZONE DENSITY=*,E9.2,* G   A 643*
     3M-3, VISUAL RANGE=*,0PF6.1,* KM,RANGE=*,F10.3,* KM *  )              A 644*
431   FORMAT(4(F6.2,2F7.5))                                                 A 645*
432   FORMAT (* STARTING PARAMETERS H1 AND ANGLE HAVE BEEN REDEFINED:H1=    A 646
     1 *,F10.3,*ANGLE =*,F10.6)                                            A 647
433   FORMAT (* TRAJECTORY MISSES EARTHS ATMOSPHERE. CLOSEST DISTANCE OF    A 648
     1 APPROACH IS*,F10.2,1X,/,1X,*END OF CALCULATION*)                    A 649
434   FORMAT (10X,I4,F6.1,11(E10.3))                                        A 650
435   FORMAT (I5,F7.1,8E10.3,4F9.4,F7.1)                                    A 651
436   FORMAT (* HMIN = *,F10.3)                                             A 652
437   FORMAT (* PATH INTERSECTS EARTH - PATH CHANGED TO TYPE 2 WITH H2 =    A 653
     1 0.0 KM*)                                                            A 654
438   FORMAT (* CHOICE OF TWO PATHS FOR THIS CASE -SHORTEST PATH TAKEN.     A 655
     1 FOR LONGER PATH SET LEN=1.*)                                        A 656
439   FORMAT (* CHOICE OF TWO PATHS FOR THIS CASE -LONGEST PATH TAKEN.      A 657
     1 FOR SHORT PATH SET LEN = 0 *)                                       A 658
440   FORMAT (* H2 WAS SET LESS THAN HMIN AND HAS BEEN RESET EQUAL TO       A 659
     1  HMIN I.E. H2 = *,F10.3)                                            A 660
441   FORMAT(*  MODEL ATMOSPHERE NO. 7*,/ 4X,*Z (KM)*,3X,*P (MB)*,4X,       A 661*
     1 *T (C) DEW PT %RH  H2O(GM.M-3) O3(GM.M-3) NO. DEN.*)                A 662*
442   FORMAT(*  FOG CONDITIONS MAY EXIST AT SEA LEVEL FOR THIS VISUAL RA    A 663*
     1NGE*,/,*  IF SO THEN ASSUME THE TRANSMITTANCE DUE TO FOG IS GIVEN    A 644*
     2BY THE TRANSMITTANCE AT 0.55 MICRONS*)                               A 665*
      END                                                                  A 666*
```

Table E1. Listing of LOWTRAN 3B Computer Code (Cont.)

```
      SUBROUTINE POINT (X,YN,N,NP,TX,IP)                                 B   1
      COMMON Z(34),P(7,34),T(7,34),EH(10,34),WH(7,34),M,NL,RE,CW,CO,PI   B   2*
      DIMENSION TX(10)                                                   B   3
C*********************************************************************** B   4
C     SUBROUTINE POINT COMPUTES THE MEAN REFRATIVE INDEX ABOVE AND BELOW B   5
C     A GIVEN ALTITUDE AND INTERPOLATES EXPONENTIALLY TO DETERMINE THE   B   6
C     EQUIVALENT ABSORBER AMOUNTS AT THAT ALTITUDE.                      B   7
C                                                                        B   8
C*********************************************************************** B   9
C                                                                        B  10
C      X IS THE HEIGHT IN QUESTION                                       B  11
C      TX(9) AND YN ARE THE MEAN REFRACTIVE INDICES ABOVE AND BELOW X    B  12
C      N IS THE LEVEL INTEGER CORRESPONDING TO X OR THE LEVEL BELOW X    B  13
C      NP =1 IF X COINCIDES WITH MODEL ATMOSPHERE LEVEL ,IF NOT NP = 0   B  14
C      TX(1-8) ARE ABSORBER  AMOUNTS PER KM AT HEIGHT X                  B  15
C*********************************************************************** B  16*
      N=NL                                                               B  17*
      NP=0                                                               B  18
      IF(X.LT.0.0) X=Z(1)                                                B  19A
      IF (X.GT.Z(NL)) GO TO 4                                            B  19B
      DO 1 I=1,NL                                                        B  20
      N=I                                                                B  21
      IF (X-Z(I)) 2,4,1                                                  B  22
1     CONTINUE                                                           B  23-
2     J2=N                                                               B  25
      N=N-1                                                              B  26
      FAC=(X-Z(N))/(Z(J2)-Z(N))                                          B  27
      PX1=P(M,N)*(P(M,J2)/P(M,N))**FAC                                   B  28
      TX1=T(M,N)*(T(M,J2)/T(M,N))**FAC                                   B  29
      WX1=WH(M,N)*(WH(M,J2)/WH(M,N))**FAC                                B  30
      TX(3)=CO*PX1/TX1-4.56E-6*WX1*TX1*CW                                B  31
      TX(2)=CO*P(M,J2)/T(M,J2)-4.56E-6*WH(M,J2)*T(M,J2)*CW               B  32
      TX(1)=CO*P(M,N)/T(M,N)-4.56E-6*WH(M,N)*T(M,N)*CW                   B  33
      TX(9)=0.5E-6*(TX(2)+TX(3))                                         B  34
      YN=0.5E-6*(TX(1)+TX(3))                                            B  35
      IF (IP.EQ.0) GO TO 9                                               B  36
      DO 3 K=1,10                                                       *B  37A
      IF(K.EQ.9) GO TO 3                                                *B  37B
       TX(K)=0.0                                                        *B  37C
      IF (EH(K,N).EQ.0.0) GO TO 3                                        B  38
      IF (EH(K,N).GT.1000.0) GO TO 3                                     B  39
      TX(K)=EH(K,N)*(EH(K,J2)/EH(K,N))**FAC                              B  40
3     CONTINUE                                                           B  41
      GO TO 9                                                            B  42
4     NP=1                                                               B  43
      IF (IP.EQ.0) GO TO 6                                               B  44
      DO 5 K=1,10                                                       *B  45
5     TX(K)=EH(K,N)                                                      B  46
6     TX(9)=EH(9,N)-1.                                                   B  47
      YN=0.0                                                             B  48
C*****  CARDS B 24 AND 50 THROUGH 59 ARE NO LONGER REQUIRED              B  48+
      IF (N.GT.1) YN=EH(9,N-1)-1.0                                       B  49
9     CONTINUE                                                           B  60
      IF (IP.EQ.1) PRINT 400, X,N,NP,TX(9),YN,IP,(TX(K),K=1,8)           B  61
      TX(9)=TX(9)+1.                                                     B  62
      YN=YN+1.                                                           B  63
      RETURN                                                             B  64
C                                                                        B  65
400   FORMAT (/,* FROM POINT: HEIGHT=*,F10.4,* KM,N=*,I3,*,NP=*,I2,*,REF B  66
     1. INDEX ABOVE & BELOW X=*,2E11.4,*,IP=*,I3,/,12X,*EQUIV. ABSORBER  B  67
```

Table E1. Listing of LOWTRAN 3B Computer Code (Cont.)

```
     2AMOLNTS PER KM AT X=*,8E10.3)
      END



      SUBFOUTINE ANGL (H1,H2,ANGLE,B1,LEN,ML)
      COMMON Z(34),P(7,34),T(7,34),EH(10,34),WH(7,34),M,NL,RE,CW,CO,PI
      DIMENSION TX(10)
C*****************************************************************
C
C     THIS SUBROUTINE CALCULATES THE INITIAL ZENITH ANGLE (ANGLE)
C     TAKING INTO ACCOUNT REFRACTION EFFECTS GIVEN H1,H2, AND BETA
C     (WHERE BETA IS THE EARTH CENTRE ANGLE SUBTENDED BY H1 AND H2 ),
C     ASSUMING THE REFRACTIVE INDEX TO BE CONSTANT IN A GIVEN LAYER.
C     FOR GREATER ACCURACY INCREASE THE NUMBER OF LEVELS IN THE MODEL
C     ATMOSPHERE.
C
C     THIS SUBROUTINE CAN BE REMOVED FROM THE PROGRAM IF NOT REQUIRED.
C*****************************************************************
      IP=99
      CA=PI/180.
      X1=RE+H1
      X2=RE+H2
      LEN=0.
      IT=0
      B1=B1*CA
      IF(B1.EQ.0.0) B1=ACOS(X2/X1)
      TANG=X2*SIN(B1)/(X2*COS(B1)-X1)
      THET=ATAN(TANG)
      IF (THET.LT.0.0) THET=THET+PI
      SPHI=SIN(THET)
      ANG=THET/CA
C     PRINT 404, B1,ANG,TANG
      TN=THET
      TM=TN-0.5*CA
1     ANGLE=THET
      FBT=0.
      BETA=0.
      BET1=0
      BET2=0
      FBT1=0
      FBT2=0
      FBT3=0.0
      IF(B1.LE.0.0) GO TO 2
C     PRINT 400, IT
      Y=2.*THET
      IF (Y-PI.GT.1.0E-8) GO TO 9
      IF (IP.EQ.100) GO TO 6
      XMIN=X2*COS(B1)-RE
      IF (XMIN-H1) 8,4,4
2     HMIN=H2
      H2=H1
      H1=HMIN
3     ANGLE=0.5*PI
      THET=ANGLE
      SPHI=1.0
      ANG=ANGLE/CA
```

Table E1. Listing of LOWTRAN 3B Computer Code (Cont.)

```
C     PRINT 404, B1,ANG,SPHI
4     IP=100
      CALL POINT (H1,YN,N,NP,TX,IP)
      J1=N
      TX1=TX(9)
5     CALL POINT (H2,YN,N,NP,TX,IP)
      IF (NP.EQ.1) N=N-1
      J2=N
      IF (J1.EQ.J2) TX1=TX1+YN-EH(9,J1)
6     DO 7 J=J1,J2
      X1=RE+Z(J)
      X2=RE+Z(J+1)
      IF (J.EQ.J1) X1=RE+H1
      IF (J.EQ.J2) X2=RE+H2
      SALP=X1*SPHI/X2
      ALP=ASIN(SALP)
      RN=EH(9,J+1)/EH(9,J)
      IF ((J+1).EQ.J2) RN=YN/EH(9,J)
      IF (J.EQ.J1) RN=EH(9,J+1)/TX1
      IF ((J+1).EQ.J2.AND.J.EQ.J1) RN=YN/TX1
      BET=THET-ALP
      FB=-TAN(ALP)
      IF (J.NE.J1) FB=FB+TAN(THET)
      FBT=FBT+FB
      BETA=BETA+BET
      TH1=THET/CA
      BE=BET/CA
      C=ALP/CA
C     PRINT 402, J,Z(J),THET,ALP,BET,BETA,FBT,FB,TH1,BE,C
      IF (X2.EQ.RE+H2) C=PI-ALP
      IF (SALP.GE.RN) RN=1.
      SPHI=SALP/RN
      THET=ASIN(SPHI)
7     CONTINUE
      IF(B1.LE.0.0) GO TO 29
      GO TO 26
8     CONTINUE
      TANG=-TANG
      ANGLE=PI-ANGLE
      TN=ANGLE
      ANG=ANGLE/CA
C     PRINT 404, B1,ANG,TANG
      IF (H1.LE.0.0) GO TO 3
9     CONTINUE
      IP=101
      CALL POINT (H1,YN,N,NP1,TX,IP)
      TX1=TX(9)
      YN1=YN
      IF (NP1.EQ.1) N=N-1
      J2=ML
      IF (N.EQ.7) J2=ML
      J1=N
      J=J1+1
      IF (H2.GE.H1) GO TO 13
      CALL POINT (H2,YN,N,NP,TX,IP)
      TX2=TX(9)
      YN2=YN
      J2=N
```

Table E1. Listing of LOWTRAN 3B Computer Code (Cont.)

```
      IF (J1.EQ.J2) TX2=YN1+TX(9)-EH(9,J1)                            C 104
10    J=J-1                                                           C 105
      X1=RE+Z(J+1)                                                    C 106
      X2=RE+Z(J)                                                      C 107
      IF (J.EQ.J1) X1=RE+H1                                           C 108
      IF (J.EQ.J2) X2=RE+H2                                           C 109
      SALF=X1*SPHI/X2                                                 C 110
      HMIN=X1*SPHI-RE                                                 C 111
C     PRINT 402, J,X1,Z(J),SPHI,SALP,HMIN,RE                          C 112
      IF (SALP.LE.1.0) GO TO 11                                       C 113
      SALF=SPHI                                                       C 114
      IF (HMIN.GT.H2) GO TO 18                                        C 115
11    ALP=ASIN(SALP)                                                  C 116
      THET=ASIN(SPHI)                                                 C 117
      BET=ALP-THET                                                    C 118
      BET1=BET1+BET                                                   C 119
      FB=TAN(ALP)                                                     C 120
      IF (J.NE.J1) FB=FB-TAN(THET)                                    C 121
      FBT1=FBT1+FB                                                    C 122
      TH1=THET/CA                                                     C 123
      BE=EET/CA                                                       C 124
      AL=ALP/CA                                                       C 125
C     PRINT 402, J,X2,THET,ALP,BET1,BET,BMIN,HMIN,FBT1,TH1,BE,AL      C 126
      IF (X2.EQ.RE+H2) C=PI-ALP                                       C 127
      REF=EH(9,J)                                                     C 128
      IF (J.EQ.J1) REF=YN1                                            C 129
      IF (J.EQ.J2) REF=TX2                                            C 130
      IF (J.EQ.1) GO TO 12                                            C 131
      RN=EH(9,J)/EH(9,J-1)                                            C 132
      IF (J.EQ.J1) RN=YN1/EH(9,J-1)                                   C 133A
      IF(J.EQ.J2+1) RN=REF/TX2                                        C 133B
      IF(J.EQ.J2) RN=REF/YN2                                          C 133C
      IF (SALP.GE.RN) RN=1.                                           C 134
      SPHI=SALP*RN                                                    C 135
      IF (Z(J).LE.H2) GO TO 12                                        C 136
      GO TO 10                                                        C 137
12    X1=X2                                                           C 138
      IF (ABS(Z(J)-H2).LT.1.0E-10.AND.J.NE.1) GO TO 13                C 139
      GO TO 14                                                        C 140
13    J=J-1                                                           C 141
      X1=RE+Z(J+1)                                                    C 142
      IF (J.EQ.J1) X1=RE+H1                                           C 143
      IF (J.EQ.J2.AND.J.NE.J1) X1=RE+H2                               C 144
14    X2=RE+Z(J)                                                      C 145
      HMIN=X1*SPHI-RE                                                 C 146
      IF (HMIN.LE.0.0) GO TO 25                                       C 147

      HMIN=X1*SPHI-RE                                                 C 146
      IF (HMIN.LE.0.0) GO TO 25                                       C 147
      IF (Z(J).LT.HMIN) GO TO 18                                      C 148
      REF=EH(9,J)                                                     C 149
      IF (J.EQ.J2) REF=YN                                             C 150
      SALF=X1*SPHI/X2                                                 C 151
      ALP=ASIN(SALP)                                                  C 152
      THET=ASIN(SPHI)                                                 C 153
      BET=ALP-THET                                                    C 154
      FB=TAN(ALP)-TAN(THET)                                           C 155
      FBT2=FBT2+FB                                                    C 156
      BET2=BET2+BET                                                   C 157
      BMIN=BET1+BET2                                                  C 158
```

Table E1. Listing of LOWTRAN 3B Computer Code (Cont.)

```
      AL=ALP/CA
      TH1=THET/CA
C     PRINT 402, J,X2,THET,ALP,BET2,BET,BMIN,HMIN,FBT2,TH1,BE,AL
      RN=REF/EH(9,J-1)
      IF (SALP.GE.RN) RN=1.0
      SPHI=SALP*RN
      GO TO 13
17    TX3=YN1+TX(9)-EH(9,J1)
      YN1=TX3
      IF (ABS(H2-Z(J+1)).LE.1.0E-5) YN1=TX(9)
      IF (ABS(H1-Z(J+1)).LE.1.0E-5) YN1=TX(9)
      RN=1.0
      GO TO 19
18    CALL POINT (HMIN,YN,N,NP,TX,IP)
      IP=102
      TX3=TX(9)
      IF (J.EQ.J1.AND.H2.GE.H1) GO TO 17
      IF (J.EQ.J1.OR.J.EQ.J2) TX3=YN2+TX(9)-EH(9,J)
      IF (HMIN.GT.H2) TX3=TX(9)
      IF (J.EQ.J1.AND.HMIN.GT.H2) GO TO 17
      RN=REF/TX3
      IF (SALP.GE.RN) RN=1.
      SPHI=SALP*RN
      X=X1*SPHI-RE
      DIF=ABS(HMIN-X)
      HMIN=X
      IF (DIF-1.0E-5) 19,19,18
19    X2=RE+HMIN
C     PRINT 403, HMIN,DIF,RN
      THET=ASIN(SPHI)
      IF(RN.EQ.1.0) FBT3=-TAN(THET)
      IF (RN.EQ.1) GO TO 20
      DNX=(TX3-1.0)*ALOG((TX3-1.0)/(REF-1.0))/(X2-X1)
      FBT3=-TAN(THET)*(1.0-1.0/(1.0+TX3/(X2*DNX)))
20    BET=0.5*PI-THET
      BET2=BET2+BET
      BMIN=BET1+BET2
      IF (H2.GE.H1) GO TO 23
      BET=BET1+2.*BET2
      DB1=B1-BET1
      DB2=BET-B1
21      DB3=ABS(BMIN-B1)
      IF(DB3.GT.DB1.AND.DB2.GT.DB1) GO TO 25
      IF(DB2.GT.DB3) GO TO 22
      IF(DB2.GT.DB1)  GO TO 25
      BETA=BET
      FBT=FBT1+2.0*(FBT2+FBT3)
      LEN=1.
      GO TO 26
22    BETA=BET1+BET2
      FBT=FBT1+FBT2+FBT3
C     PRINT 401, J,BETA,FBT,FBT1,FBT2,FBT3,TX1,YN1
      GO TO 26
23    BETA=2.0*(BET1+BET2)
      LEN=1.
      FBT=2.0*(FBT1+FBT2+FBT3)
      PRINT 401, J,BETA,FBT,FBT1,FBT2,FBT3,TX1,YN1
      IF (H2.EQ.H1) GO TO 26
      IP=103
```

Table E1. Listing of LOWTRAN 3B Computer Code (Cont.)

```
      IF (NP1.EQ.1) J1=J1+1
      SPHI=SIN(ANGLE)
      IF (Z(J1+1).LE.H2) GO TO 24
      RN=TX1/YN1
      IF (SPHI.GE.RN) RN=1.
      SPHI=SPHI/RN
      THET=ASIN(SPHI)
      GO TO 5
24    CALL POINT (H2,YN,W,NP,TX,IP)
      TX1=TX1+YN-EH(9,J1)
      RN=TX1/YN1
      J2=J1
      IF (SPHI.GE.RN) RN=1.
      SPHI=SPHI/RN
      THET=ASIN(SPHI)
      GO TO 5
25    BETA=BET1
      LEN=0.
      FBT=FBT1
26    THET=ANGLE+(B1-BETA)/(1.+FBT/TANG)
      DBETA=BETA/CA
      B=BET1/CA
      TH1=THET/CA
      PRINT 404, BETA,DBETA,FBT,TH1,TANG
      IF (THET.GT.TN.OR.THET.LT.TM) THET=(TN+TM)/2.
      TH1=THET/CA
      PRINT 404, BET1,B,FBT,TH1
      TN1=TN/CA
      TM1=TM/CA
      PRINT 405, TN,TM,TN1,TM1
      SPHI=SIN(THET)
      TANG=TAN(THET)
      IT=IT+1
      DBE=ABS(B1-BETA)
      DTH=ABS(ANGLE-THET)
      IF (IT.EQ.10)  THET=0.5*(ANGLE+THET)
      IF (IT.EQ.10) GO TO 28
      IF (DBE.GT.1.0E-7.AND.DTH.GT.1.0E-7) GO TO 1
28    ANGLE=THET/CA
      PRINT 406, ANGLE,IT
      RETURN
29    H1=H2
      ANGLE=C/CA
      PRINT 406, ANGLE,IT
      RETURN
C
400   FORMAT (//* ITTERATION NUMBER *,I3,//)
401   FORMAT (I6,E16.7,8F13.8)
402   FORMAT (I4,F10.4,6E13.4,4F10.4/)
403   FORMAT (*  HMIN=*,F14.6,*  DIF=*E14.6,*  PR=*,E16.8)
404   FORMAT (* TOTAL BETA = *,E14.6,F15.6,*,FBT = *,E14.6,* THET =*,F10
     1.6,*TANG=*,F10.6)
405   FORMAT (5F12.6)
406   FORMAT (8X,/1H*,*ZENITH ANGLE =*,F7.3,* DEGREES :  RECOMPUTED
     1 FROM SUBROUTINE ANGL (ITTERATION*,I3,*)*)
      END
```

Table E2. Listing of Data for LOWTRAN 3B

```
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 5.553E-05
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    9.3E+00    6.0E-05
>  2.0 8.050E+02 288.0    9.3E+00    5.4E-05 8.020E+02 285.0    5.9E+00    6.0E-05
   3.0 7.150E+02 284.0    4.7E+00    5.1E-05 7.100E+02 279.0    3.3E+00    6.2E-05
   4.0 6.330E+02 277.0    2.2E+00    4.7E-05 6.280E+02 273.0    1.9E+00    6.4E-05
   5.0 5.590E+02 270.0    1.5E+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    8.6E-05
  10.0 2.860E+02 237.0    5.0E-02    3.9E-05 2.810E+02 235.0    6.4E-02    9.0E-05
  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    6.0E-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+02 210.0    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    5.0E-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 4.800E+01 211.0    5.1E-04    2.4E-04 5.100E+01 219.0    5.1E-04    3.6E-04
  22.0 4.090E+01 215.0    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    3.4E-04
  24.0 3.000E+01 219.0    6.0E-04    3.4E-04 3.220E+01 223.0    6.0E-04    3.2E-04
  25.0 2.570E+01 221.0    6.7E-04    3.4E-04 2.770E+01 224.0    6.7E-04    3.0E-04
  30.0 1.220E+01 232.0    3.6E-04    2.4E-04 1.320E+01 234.0    3.6E-04    2.0E-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    1.0E-09    4.3E-11 3.000E-04 210.0    1.0E-09    4.3E-11
99999. 0.000E+00  30.     0.0E-00    0.0E-00 0.000E 00 19[illegible]  0.0E-00    0.0E-00
   0.0 1.018E+03 272.2    3.5E+00    6.0E-05 1.010E+03 26[illegible]    9.1E+00    4.9E-05
   1.0 8.973E+02 268.7    2.5E+00    5.4E-05 8.960E+02 282.0    6.0E+00    5.4E-05
   2.0 7.897E+02 265.2    1.8E+00    4.9E-05 7.929E+02 276.0    4.2E+00    5.6E-05
   3.0 6.938E+02 261.7    1.2E+00    4.9E-05 7.000E+02 271.0    2.7E+00    5.8E-05
   4.0 6.081E+02 255.7    6.6E-01    4.9E-05 6.160E+02 266.0    1.7E+00    6.0E-05
   5.0 5.313E+02 249.7    3.8E-01    5.8E-05 5.410E+02 260.0    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    7.5E-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
   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    [illegible].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.[illegible]    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
```

HAZE MODELS

MODEL ATMOSPHERES 1 & 2

MODEL ATMOSPHERES 3 & 4

Table E2. Listing of Data for LOWTRAN 3B (Cont.)

MODEL ATMOSPHERES 3 & 4 continued

```
  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+00 190.    0.0E-00   0.0E-00 0.000E 00 190.0   0.0E-00   0.0E-00
```

MODEL ATMOSPHERES 5 & 6

```
   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+02 240.9   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   1.0E-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 8.059E+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+01 213.6   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
  25.0 2.256E+01 211.2   6.7E-04   3.2E-04 2.549E+01 221.6   6.6E-04   3.4E-04
  30.0 1.020E+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   8.6E-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+00 190.    0.0E-00   0.0E-00 0.000E 00 190.0   0.0E-00   0.0E-00
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AEROSOL SPECTRA DATA

```
 .200 .38223 .07945  .250 .32979 .03661  .300 .28540 .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 .0190  .00584 3.500 .01767 .00250 3.750 .01699 .00214
4.000 .01654 .00232 5.000 .0153  .00321 5.500 .01479 .00388 6.000 .01389 .00462
7.200 .01569 .00745 7.900 .01102 .00617 8.200 .01119 .00807 8.500 .01778 .01254
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 .00535 12.50 .01365 .00516 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 0.998-2.0362-1.3981 0.996-1.6990-1.1192 0.994-1.4815-0.9508
```

Table E2. Listing of Data for LOWTRAN 3B (Cont.)

TRANSMITTANCE FUNCTIONS

```
0.992-1.3279-0.8239 0.990-1.2007-0.7258 0.980-0.7825-0.4318 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 0.6435 0.820 0.8261 0.7243 0.800 0.9191 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 1.2480 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 2.0086 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 2.5185 0.080 2.8261 2.6435
0.060 2.9031 2.7853 0.040 3.0000 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
```

SPECTRAL DATA H_2O

```
 3.93 3.72 3.54 3.42 3.37 3.37 3.36 3.33 3.25 3.13 3.02 2.96 2.97 3.00 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 2.20 2.01 1.92 1.83 1.78 1.79 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 0.69  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
-0.35-0.30-0.31-0.37-0.42-0.48-0.42-0.40-0.39-0.43-0.77-0.83-0.88-0.79-0.60  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 1.05 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
 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 3.16 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 3.08 3.11 2.98 2.88 2.78 2.74 2.76 2.72 2.76 2.82 2.85 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
-1.32-1.43-1.51-1.63-1.74-1.82-1.98-2.09-2.21-2.21-2.24-2.27-2.36-2.51-2.65 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
-0.26-0.19-0.13-0.11-0.01 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 0.68 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 2.36 2.51 2.66 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 2.68 2.49 2.29 2.23 2.42 2.61 2.58 2.49 2.40 2.39 2.51 2.60 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 4.28 4.30 4.22 4.32 4.42 4.53 4.64 4.55 4.40 4.28 4.32 4.38 3575
```

Table E2. Listing of Data for LOWTRAN 3B (Cont.)

```
 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 3.90 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 3.98 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 2.51 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
-0.21-0.32-0.36-0.39-0.33-0.39-0.45-0.50-0.56-0.62-0.68-0.77-0.84-0.91-1.00 4325
-1.11-1.19-1.28-1.31-1.39-1.43-1.48-1.52-1.57-1.60-1.61-1.60-1.58-1.51-1.42 4400
-1.32-1.26-1.16-1.00-0.83-0.71-0.61-0.52-0.43-0.36-0.30-0.21-0.19-0.17-0.15 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
-0.40-0.40-0.39-0.37-0.35-0.48-0.75-1.13-1.58-1.80-1.66-1.52-1.35-1.19-1.02 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
 1.32 1.33 1.48 1.78 1.87 2.01 1.92 1.86 1.89 1.92 1.98 2.03 2.39 2.31 2.48 5075
 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 3.18 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
-0.45-0.50-0.54-0.61-0.69-0.76-0.84-0.90-0.97-1.01-1.10-1.13-1.19-1.22-1.26 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
-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 6125
-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 0.28 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 2.39 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 1.39 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 0.86 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
-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 7925
-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 8000
-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 8075
```

Table E2. Listing of Data for Lowtran 3B (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 8150
-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 8225
-4.15-4.06-3.97-3.88-3.79-3.70-3.61-3.52-3.43-3.34-3.25-3.16-3.07-2.98-2.89 8300
-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 0.45 0.42 0.40 0.43 0.46 8525
 0.59 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
 1.86 1.61 1.17 1.32 1.52 1.70 1.90 2.01 1.92 1.91 2.12 2.13 2.01 2.18 1.99 8825
 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
-2.07-1.90-1.77-1.70-1.63-1.60-1.59-1.43-1.21-1.15-1.09-1.13-1.29-1.19-0.9810025
-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
-0.01-0.01-0.20-0.16-0.02 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
 1.68 1.60 1.56 1.56 1.63 1.64 1.56 1.49 1.49 1.52 1.58 1.62 1.62 1.61 1.6110475
 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 1.81 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
-0.07-0.14-0.21-0.08-0.06 0.10 0.18 0.11 0.32 0.42 0.44 0.38 0.28 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 0.28 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
-0.03 0.21 0.36 0.39 0.47 0.44 0.40 0.51 0.59 0.53 0.69 0.57 0.48 0.52 0.6211075
 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
-1.45-1.49-1.78-1.91-2.01-1.97-1.97-1.97-1.97-2.26-2.20-2.01-1.99-2.00-2.0411225
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-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00 5.00-5.00-5.00-5.00-5.00-5.00-5.0011600
-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.0011675
-3.71-3.56-3.40-3.21-3.06-2.90-2.74-2.60-2.46-2.32-2.17-2.03-1.87-1.79-1.7411750
-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
-0.10-0.06-0.05-0.04-0.10-0.04-0.06-0.21-0.38-0.61-0.40-0.31-0.42-0.58-0.5712050
-0.54-0.24 0.11 0.51 0.81 0.79 0.62 0.26-0.31-0.67-0.80-0.88-0.50-0.39-0.1012125
 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
-0.88-1.01-1.10-1.19-1.29-1.45-1.49-1.67-1.67-1.51-1.66-1.60-1.69-1.83-1.5112350
-1.42-1.40-1.24-1.38-1.31-1.30-1.30-1.28-1.39-1.33-1.40-1.35-1.37-1.39-1.4112425
-1.49-1.48-1.56-1.47-1.46-1.41-1.42-1.48-1.41-1.31-1.15-1.13-1.20-1.41-1.8812500
-2.08-2.08-2.22-2.35-2.35-1.98-1.92-1.78-1.57-1.69-1.70-1.70-1.66-1.84-1.5012575
-1.56-1.42-1.29-1.38-1.28-1.48-1.58-1.44-1.53-1.48-1.48-1.58-1.58-1.69-1.7912650
-2.09-2.16-1.99-2.23-2.04-2.04-2.39-2.74-3.09-3.44-3.79-4.14-4.49-4.84-5.1912725
-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
-1.71-1.78-1.72-1.68-1.78-1.52-1.38-1.29-1.22-0.91-0.90-1.01-0.76-0.90-0.9013475
-0.90-1.19-1.00-0.79-0.68-0.68-0.73-0.85-0.35-0.61-0.61-0.48-0.51-0.92-0.8313550
-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
-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
```

SPECTRAL DATA H_2O

Table E2. Listing of Data for LOWTRAN 3B (Cont.)

```
 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
-1.69-1.56-1.60-1.71-1.36-1.36-1.44-1.48-1.48-1.48-1.36-1.45-1.49-1.85-1.3914150
-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
-1.00-1.18-1.42-1.61-1.86-2.10-2.29-2.51-2.72-2.91-3.14-5.00-5.00-5.00-5.00   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 0.14-0.12-0.48-0.92-1.43-1.89-2.32  1325
-2.81-5.00-5.00-5.00-3.14-2.47-2.00-1.71-1.59-1.61-1.69-1.82-1.87-1.90-1.94  1400
-2.04-2.10-2.23-2.32-2.49-2.71-2.88-3.09-2.99-2.43-2.00-1.69-1.42-1.38-1.49  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
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-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 0.18 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
 3.28 2.79 2.30 1.86 1.35 0.62-0.24-1.69-2.18-2.01-1.79-1.53-1.32-1.20-1.15  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 0.30 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
-5.00-4.01-3.39-3.01-2.63-2.32-2.09-1.98-1.94-2.00-2.14-2.26-2.20-2.02-1.82  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
 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 1.59 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 0.55-0.27-1.09-2.54-3.00-2.94-2.78-2.68  3725
-2.61-2.60-2.63-2.60-2.57-2.53-2.57-2.64-2.77-3.04-3.38-3.98-5.00-5.00-5.00  3800
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-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
-3.30-3.31-3.37-3.29-3.14-3.08-3.00-2.93-2.89-2.91-3.00-3.08-3.16-3.31-3.48  4250
-3.71-3.98-5.00-5.00-5.00-5.08-4.52-3.98-3.69-3.42-3.18-2.95-2.77-2.61-2.48  4325
```

SPECTRAL DATA H_2O

SPECTRAL DATA: UNIFORMLY MIXED GASES

Table E2. Listing of Data for LOWTRAN 3B (Cont.)

```
-2.41-2.41-2.40-2.38-2.34-2.27-2.21-2.31-2.48-2.73-3.21-4.13-5.00-5.00-5.00 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
-2.68-2.69-2.65-2.62-2.59-2.57-2.62-2.81-3.04-3.21-3.39-3.42-3.36-3.21-3.03 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
-1.31-1.20-1.08-0.98-0.94-0.85-0.76-0.52-0.31-0.08 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 0.81 0.73 0.79 0.91 1.01 1.03 0.88 0.72 0.63 0.38 0.12-0.21 5075
-0.47-0.67-1.23-1.67-2.31-2.76-3.24-3.49-3.51-3.47-3.39-3.37-3.43-3.53-3.50 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
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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 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
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-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-4.91-4.79-4.61 5900
-4.48-4.40-4.29-4.17-3.90-3.73-3.59-3.62-3.72-3.73-3.69-3.31-3.12-2.91-2.63 5975
-2.41-2.27-2.16-2.11-2.28-2.29-2.21-2.06-1.91-1.99-2.27-2.59-2.98-3.35-3.69 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
-1.08-0.89-0.68-0.54-0.71-0.79-0.78-0.66-0.49-0.54-0.86-1.37-2.08-2.44-3.46 6200
-3.72-3.74-3.59-3.22-2.98-2.52-2.21-1.64-1.34-1.08-0.96-0.72-0.61-0.70-0.72 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
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-2.18-2.13-2.04-1.78-1.83-2.08-2.28-2.81-3.01-3.15-3.22-3.29-3.58-3.89-4.46 6500
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-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
-3.53-3.37-3.19-3.02-2.79-2.52-2.36-2.24-2.19-2.32-2.41-2.29-2.06-2.00-2.18 6725
-2.47-2.91-3.57-4.89-5.00-5.00-5.00-5.00-5.00-4.61-4.18-3.89-3.57-3.30-3.02 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
-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
-5.00-5.00-5.00-4.71-4.31-3.99-3.68-3.50-3.34-3.22-3.23-3.25-3.24-3.18-3.10 7400
-3.07-3.18-3.41-3.67-4.12-4.68-5.00-5.00-5.00-5.00-5.00-5.00-5.00-4.51-4.18 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
-0.93-1.08-1.19-1.35-1.47-1.57-1.66-1.80-1.91-2.04-2.18-2.33-2.47-2.61-2.78 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
-5.00-5.00-5.00-5.00-4.32-3.24-2.59-2.12-1.82-1.57-1.34-1.16-1.02-0.82-0.6412950
-0.48-0.33-0.14-0.06 0.08 0.21 0.39 0.52 0.61 0.72 0.85 0.95 1.02 1.12 1.1813025
 1.21 1.17 1.08 0.98 0.90 0.97 1.13 1.37 1.58 1.74 1.70 1.48 1.13 0.73 0.2213100
-0.51-1.57-3.48-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.0013175
-4.15-3.51-3.00-2.54-2.12-1.76-1.50-1.21-0.86-0.49-0.23-0.10 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 0.56 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
-5.00-5.00-5.00-5.00-5.00-4.46-4.00-3.50-3.14-2.78-2.41-2.10-1.78-1.49-1.20  875
-0.20 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
 2.40 2.42 2.58 2.52 2.20 2.48 2.54 2.45 2.30 2.00 1.20 0.95 0.92 0.90 0.90 1025
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SPECTRAL DATA: UNIFORMLY MIXED GASES

SPECTRAL DATA: OZONE

Table E2. Listing of Data for LOWTRAN 3B (Cont.)

```
 0.89 0.90 0.92 0.94 0.95 0.96 0.95 0.90 0.80 0.68 0.55 0.40 0.30 0.19 0.08 1100
-0.02-0.11-0.22-0.41-0.56-0.71-0.89-1.03-1.18-1.33-1.60-1.76-1.90-2.02-2.21 1175
-2.46-2.59-2.79-3.00-3.22-3.61-4.16-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00 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
-2.44-2.19-2.03-1.86-1.71-1.56-1.48-1.39-1.26-1.13-0.97-0.81-0.65-0.48-0.35 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
-0.74-0.79-0.84-0.89-0.85-0.81-0.76-0.70-0.68-0.64-0.65-0.65-0.72-0.78-0.84 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 1.33 1.44 1.46 1.48 1.48 1.64 1.58 1.43 1.23 0.66 0.38-0.33 2075
-0.71-0.66-0.58-0.49-0.44-0.40-0.40-0.46-0.53-0.64-0.76-0.89-1.01-1.14-1.26 2150
-1.40-1.55-1.69-1.83-1.98-2.13-2.28-2.43-2.64-2.86-3.07-3.28-3.50-3.72-3.94 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
-2.44-2.12-1.85-1.57-1.30-1.07-0.98-0.94-0.89-0.85-0.81-0.77-0.72-0.68-0.63 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
-1.84-1.73-1.63-1.52-1.41-1.33-1.25-1.17-1.09-1.02-0.96-0.89-0.82-0.73-0.66 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 0.01-0.11-0.33-0.55-0.77-0.83-0.88-0.94-0.92-0.91-0.90-0.85-0.80 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
-1.14-1.24-1.34-1.51-1.68-2.13-2.57-2.92-3.26-3.71-4.16-5.00-5.00-5.00-5.00 3200
 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 7.19E-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 4.95E-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 7.94E-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 9.90E-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 3.36E-04 2.86E-04 2.32E-04     2680
 1.94E-04 1.57E-04 1.31E-04 1.02E-04 8.07E-05                                2720
 0.23 .187 .147 .117 .097 .087 .10  .120 .147 .174 .20  .24  .28  .33  .00  2350 H2O
 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 1.16E-01 1.19E-01 1.13E-01    16200
 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
 1.03E-01 9.24E-02 8.28E-02 7.57E-02 7.07E-02 6.58E-02 5.56E-02 4.77E-02    17800
 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 4.98E-02 1.18E-01 2.46E-01 5.18E-01    27500
 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 1.68E+02 2.06E+02 2.42E+02 2.71E+02 2.91E+02 3.02E+02    35500
 3.03E+02 2.94E+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 8.65E-00                      47500
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SPECTRAL DATA: OZONE

N_2 CONTINUUM

OZONE UV & VISIBLE

Table E2. Listing of Data for LOWTRAN 3B (Cont.)

```
 5  1  2
   2.500      8.500     65.000
 2350.000  2450.000      5.000
 2
 6  7  1  0  1
 .200 .20832 .02054  .250 .19518 .00864  .300 .13479 .00442  .400 .17032 .00243
 .488 .16213 .00193  .550 .15800 .00186  .694 .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 5.500 .05928 .00507 6.000 .05485 .02351
7.200 .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 10.59 .02582 .01089 11.00 .02470 .01330
11.50 .02556 .01663 12.50 .03085 .02354 13.00 .03339 .02575 14.00 .03688 .02927
15.00 .03888 .02948 16.40 .04021 .02964 17.20 .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.
 1820.     20000.    5.
 2
 6  7  1  0  1
 .200 .31030 .10692  .250 .28416 .08649  .300 .25805 .07571  .400 .20867 .06376
 .488 .17631 .05674  .550 .15800 .05282  .694 .12601 .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 .01072 7.900 .01445 .00953 8.200 .01384 .01037 8.500 .01757 .01251
8.700 .01854 .01172 9.000 .01900 .01202 9.200 .01939 .01278 9.500 .01748 .01075
 9.80 .01669 .00973 10.00 .01644 .00954 10.59 .01555 .00868 11.00 .01499 .00795
11.50 .01452 .00765 12.50 .01373 .00727 13.00 .01347 .00721 14.00 .01294 .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
 .200 .38223 .07945  .250 .32979 .03661  .300 .28540 .02110  .400 .22026 .01317
 .488 .17989 .01114  .550 .15800 .01095  .694 .12164 .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 .01639 .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 8.200 .01019 .00807 8.500 .01778 .01254
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 .00535 12.50 .01365 .00516 13.00 .01339 .00523 14.00 .01286 .00536
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.        0.        0.        10.
 1820.     20000.    5.
 2
 6  7  1  0  1
 .200 .40212 .08042  .250 .34505 .03451  .300 .23674 .01767  .400 .22505 .00971
 .488 .18187 .00772  .550 .15800 .00745  .694 .11722 .00619  .860 .08537 .00683
1.060 .06265 .00685 1.536 .03078 .00545 1.800 .01912 .00348 2.000 .01241 .00173
2.500 .00783 .00183 3.000 .00629 .00251 3.500 .00420 .00076 3.750 .00354 .00063
4.000 .00316 .00069 5.000 .00233 .00098 5.500 .00224 .00127 6.000 .00234 .00171
7.200 .00358 .00322 7.900 .00293 .00285 8.200 .00465 .00463 8.500 .00785 .00766
8.700 .00664 .00540 9.000 .00726 .00593 9.200 .00858 .00760 9.500 .00507 .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 .00375 16.40 .00246 .00235 17.20 .00264 .00249 18.50 .00221 .00212
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