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# Atmospheric Transmittance From 0.25 to 28.5 $\mu$ m: Supplement LOWTRAN 3B (1976)

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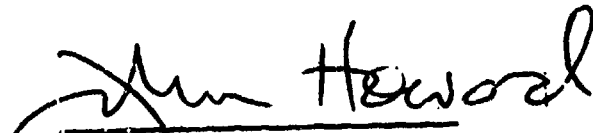
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20. Abstract (Continued)

gas broadening in the 8-14 <sup>micrometers</sup>  $\mu\text{m}$  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.

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## 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 ( $20 \text{ cm}^{-1}$ ) 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  $\infty$  to  $1500 \text{ cm}^{-1}$  (that is, for all wavelengths greater than  $0.69 \mu\text{m}$ ), whereas LOWTRAN covers the range from  $0.25$  to  $28.5 \mu\text{m}$ . 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,  $20 \text{ cm}^{-1}$ ), we expect that HITRAN will generally give results to  $\pm 1-2$  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 ( $20 \text{ cm}^{-1}$  or poorer) and in any case cannot be applied to high spectral resolution or laser propagation problems.<sup>†</sup> 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  $\pm 5$  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.

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<sup>†</sup>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.

## Contents

1. INTRODUCTION	11
2. THEORY	12
3. 8-14 $\mu\text{m}$ $\text{H}_2\text{O}$ CONTINUUM	13
3.1 Temperature Dependence	13
3.2 Nitrogen Broadened Coefficient	15
3.3 Transmittance Calculations	16
4. 3.5-4.2 $\mu\text{m}$ $\text{H}_2\text{O}$ CONTINUUM	17
4.1 Foreign Gas Broadening	17
4.2 Transmittance Calculations	18
5. COMPARISON OF LOWTRAN 3, 3A AND 3B PREDICTIONS	18
6. LOWTRAN 3B $\text{H}_2\text{O}$ CONTINUUM COMPUTER CODE CHANGES	24
6.1 8-14 $\mu\text{m}$ Region Change Only	24
6.2 3.5-4.2 $\mu\text{m}$ Region Change Only	24
6.3 Complete Changes for Both 4 $\mu\text{m}$ and 10 $\mu\text{m}$ Regions	25
7. ATTENUATION FOR MARITIME, URBAN, RURAL, AND TROPOSPHERIC AEROSOL MODELS	27
7.1 Computer Code Changes for Including Aerosol Models	33
7.2 Example of use of New Aerosol Data	34
8. FOG ATTENUATION	34
9. SUMMARY CONCLUSIONS	35
REFERENCES	37



## Contents

APPENDIX A: LOWTRAN 3A Supplement	39
APPENDIX B: LOWTRAN 3 Errata Sheet No. 3	41
APPENDIX C: 8-14 $\mu\text{m}$ $\text{H}_2\text{O}$ Continuum (Nitrogen Broadening Effects)	45
APPENDIX D: Aerosol Refractive Index Data	49
APPENDIX E: List of Program and Data	51

## Illustrations

1. Comparison of $\text{H}_2\text{O}$ Continuum Self Broadening Coefficients Used in LOWTRAN 3 and LOWTRAN 3B	14
2. Transmittance for a 10 km Path at Sea Level for Three Atmospheric Models (Comparison of LOWTRAN 3, 3A, and 3B)	19
3. Transmittance for a Vertical Path to Space for Three Atmospheric Models (Comparison of LOWTRAN 3, 3A, and 3B)	20
4. Comparison of LOWTRAN 3B Predictions With Measurements of Gebbie et al <sup>9</sup>	21
5. Comparison of LOWTRAN 3B Predictions With Measurements in Chesapeake Bay Area on 19 April 1956	22
6. Comparison of LOWTRAN 3B Predictions With Measurements in Chesapeake Bay Area on 19 June 1956	23
7. Size Distributions for Aerosol Models Used in LOWTRAN 3B	29
8. Extinction Coefficient for New Aerosol Models Used in LOWTRAN 3B	31
9. Transmittance for a 10 km Path at Sea Level for Three Aerosol Models	32
C1. Water Vapor Absorption Coefficients for P(20) Line of the 10.6 $\mu\text{m}$ $\text{CO}_2$ Laser	48

## Tables

1. Maritime, Rural, Urban and Tropospheric Models	28
2. Characteristics of the Aerosol Models of the Lower Atmosphere	31
C1. $\text{H}_2\text{O}$ Continuum Nitrogen Broadening Coefficient at 10.6 $\mu\text{m}$	46

## Tables

D1. Refractive Indices for the Different Aerosol Types	50
E1. Listing of LOWTRAN 3B Computer Code	52
E2. Listing of Data for LOWTRAN 3B	71

## Atmospheric Transmittance From 0.25 to 28.5 $\mu\text{m}$ : Supplement LOWTRAN 3B (1976)

### I. INTRODUCTION

The LOWTRAN 3 computer code<sup>1</sup> (and its predecessors LOWTRAN 1 and LOWTRAN 2)<sup>2</sup> has been widely used for making atmospheric transmittance predictions covering the 0.25-28.5  $\mu\text{m}$  region. This supplement is intended to provide an update to the LOWTRAN 3 computer code<sup>1</sup> and also the LOWTRAN 3A<sup>†</sup> version. It contains two modifications which affect the transmittance due to the water vapor continuum in the 3.5-4.2  $\mu\text{m}$  and 8-14  $\mu\text{m}$  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.

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(Received for Publication 1 November 1976)

<sup>†</sup>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  $\mu\text{m}$ : 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  $\mu\text{m}$ : Computer Code LOWTRAN 2, AFCRL-72-0745.

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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<sub>2</sub>O molecules and those of other gases (principally H<sub>2</sub>O:N<sub>2</sub> 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<sub>2</sub>O 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<sub>2</sub>O 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

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

(1)

where  $p_{\text{H}_2\text{O}}$  and  $P_T$  refer to the water vapor partial pressure and the ambient pressure respectively (atm), and  $\omega$  defines the quantity of water vapor per unit path length ( $\text{gm cm}^{-2} \text{ km}^{-1}$ ). 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  $\mu\text{m}$  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 $\mu\text{m}$ H<sub>2</sub>O CONTINUUM

Two major modifications have been made to LOWTRAN 3 in the 8-14  $\mu\text{m}$  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.<sup>3</sup> 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<sup>4</sup> in the 10  $\mu\text{m}$  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  $\mu\text{m}$  window Applied Optics 14:2085.

not deviate significantly from those previously reported by Selby and McClatchey<sup>1, 2</sup> 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<sup>3</sup> using samples of water vapor at elevated temperatures, an approximate empirical expression was obtained by Roberts et al<sup>4</sup> 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  $\mu\text{m}$  region plays two competing roles, through the total water content of the path and the attenuation coefficient.

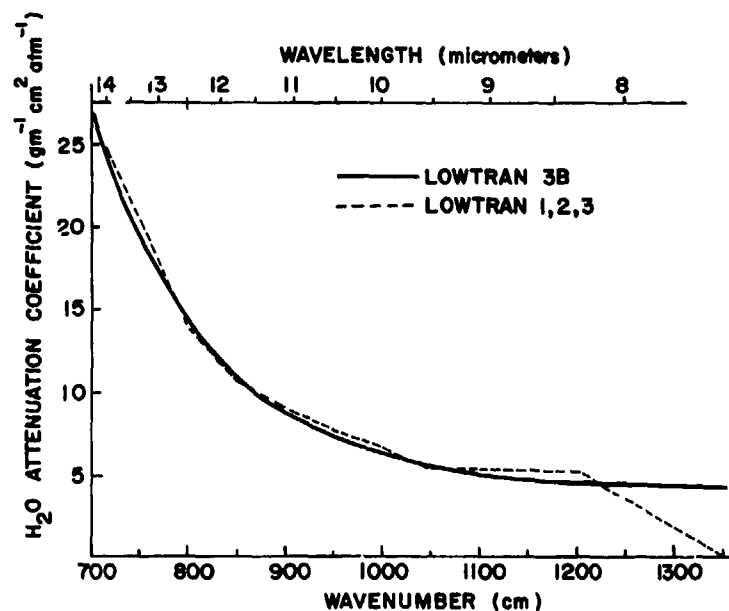


Figure 1. Comparison of  $\text{H}_2\text{O}$  Continuum Self Broadening Coefficients Used in LOWTRAN 3 and LOWTRAN 3B

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

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

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

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

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

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

where T is the temperature in degrees Kelvin.

Equation 3 can be rewritten as follows:

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

### 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  $\mu\text{m}$  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.<sup>5</sup> 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 superseded 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.

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  $\mu\text{m}$  region, is calculated for a horizontal path of length RANGE (km) at altitude  $z$  using the following expression in LOWTRAN 3B:

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

where  $W(z)$  is the effective  $\text{H}_2\text{O}$  absorber amount per unit path length (in  $\text{gm cm}^{-2}$  atm  $\text{km}^{-1}$ ) 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:

$$W(z) = w(z) \left\{ P_{\text{H}_2\text{O}} \exp \left[ 6.08 \left( \frac{296}{T(z)} - 1 \right) \right] + 0.002 \left( P_T - P_{\text{H}_2\text{O}} \right) \right\} \quad (6)$$

where

$w(z)$  =  $\text{gm cm}^{-2}/\text{km}$  of  $\text{H}_2\text{O}$  in the path at temperature  $T$ ,<sup>†</sup>

$P_{\text{H}_2\text{O}}$  =  $\text{H}_2\text{O}$  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.

<sup>†</sup>Note that if temperature  $T(\text{K})$  and relative humidity  $\text{RH}(\%)$  are known, then  $w$  and  $P_{\text{H}_2\text{O}}$  can be determined as follows:

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

$$P_{\text{H}_2\text{O}} = 4.56 \times 10^{-5} w T \text{ (atm)} \quad (b)$$

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

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

where  $A = 273.15/T$

Equation (c) is the empirical equation used in LOWTRAN 3 (see page 9 of Selby and McClatchey<sup>1</sup>).

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:

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

#### 4. 3.5-4.2 $\mu\text{m}$ $\text{H}_2\text{O}$ CONTINUUM

Using the laboratory measurements of Burch et al,<sup>7</sup> an empirical expression was obtained for the temperature dependence of the attenuation coefficients in the 3-5  $\mu\text{m}$  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.<sup>8</sup>

It was found that

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

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  $\mu\text{m}$  region have been digitized directly from the extrapolations reported by Burch et al.<sup>7</sup>

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  $\mu\text{m}$  region is not as strong as that in the 8-14  $\mu\text{m}$  region.

##### 4.1 Foreign Gas Broadening

A value for the nitrogen broadening coefficient of 0.12 was obtained by Burch et al<sup>7</sup> 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)).

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  $\mu\text{m}$  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  $\mu\text{m}$  region:

$$W(z) = w(z) \left[ P_{\text{H}_2\text{O}} + 0.12(P_T - P_{\text{H}_2\text{O}}) \right] \exp \left[ 4.56 \left( \frac{296}{T(z)} - 1 \right) \right] \quad (9)$$

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  $\mu\text{m}$  region (see second term in Eq. (12)) is more significant relative to the self broadening term than in the 10  $\mu\text{m}$  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  $\mu\text{m}$  regions and 7-15  $\mu\text{m}$  regions.

In all cases, the LOWTRAN 3B predictions (dashed curves in Figures 2 and 3) lead to greater attenuation in the 3-5  $\mu\text{m}$  region, by as much as 20 percent in the worst case shown in Figure 2. However, in the 8-14  $\mu\text{m}$  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.<sup>9</sup> and Yates and Taylor.<sup>10</sup> In general, LOWTRAN 3B provides better agreement with both sets of measurements. However, the statements previously made in Selby and McClatchey<sup>1, 2</sup> 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.

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.

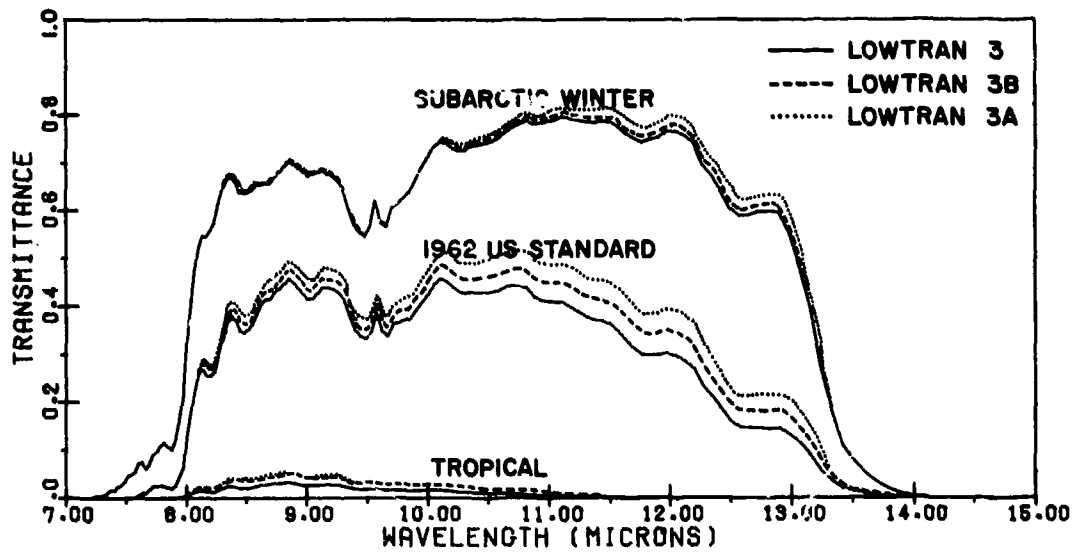
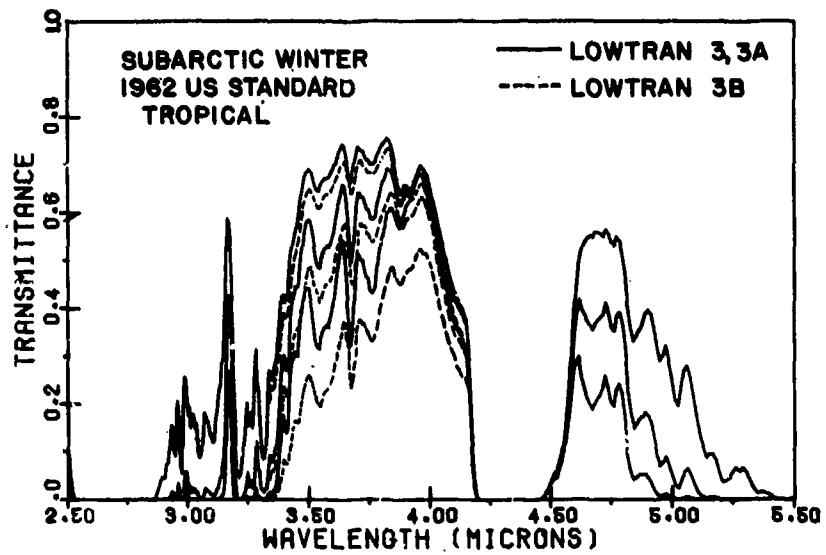


Figure 2. Transmittance for a 10 km Path at Sea Level for Three Atmospheric Models (Comparison of LOWTRAN 3, 3A, and 3B)

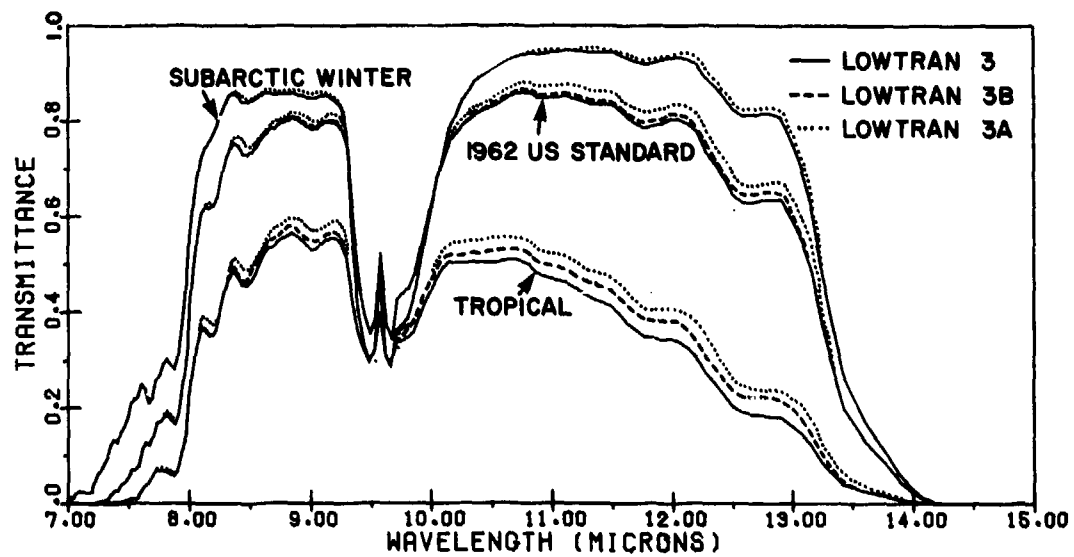
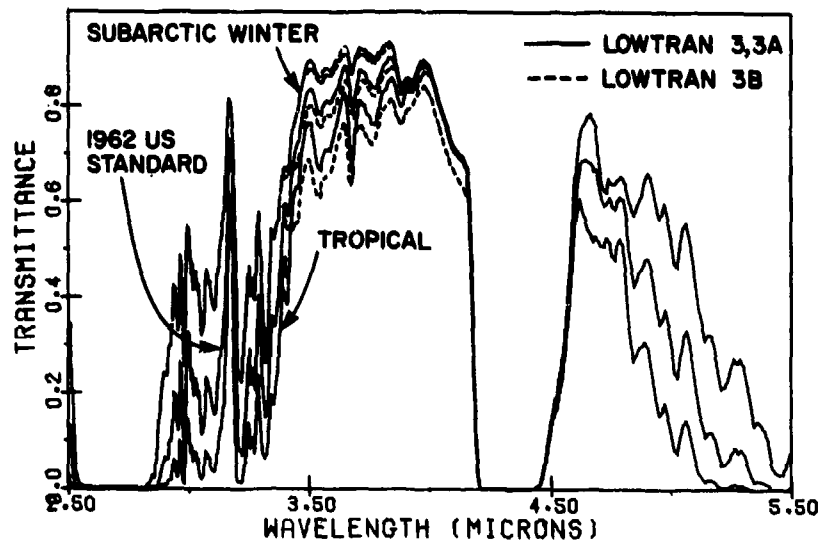
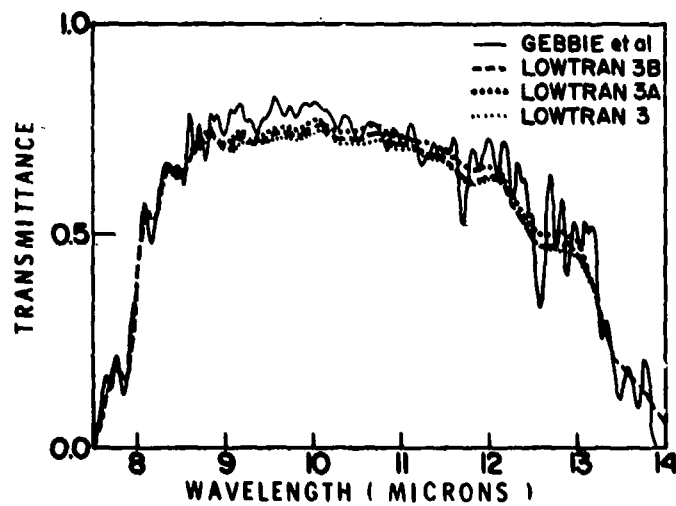
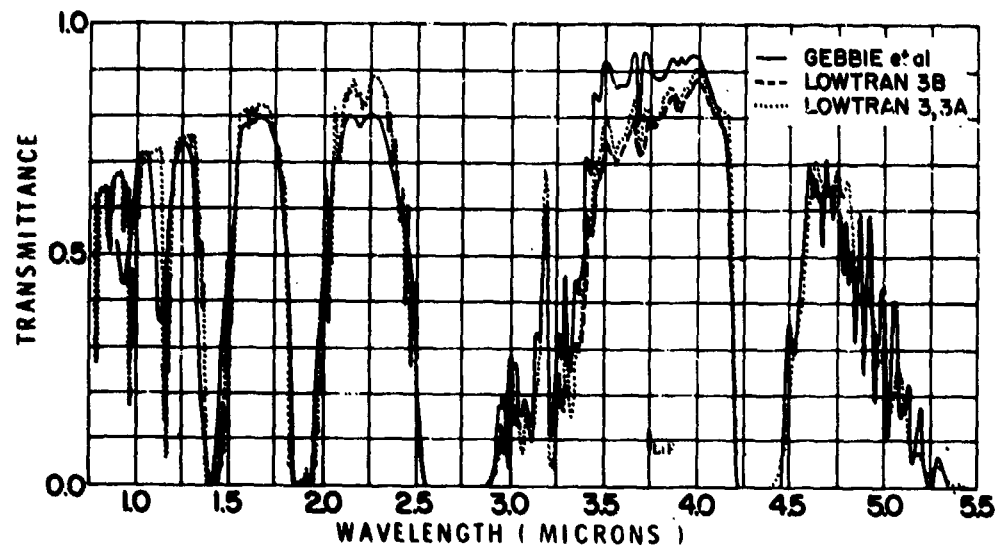
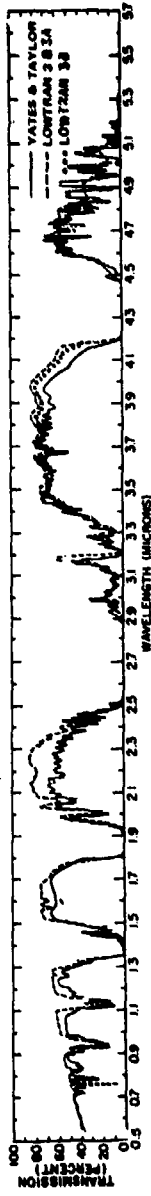


Figure 3. Transmittance for a Vertical Path to Space for Three Atmospheric Models (Comparison of LOWTRAN 3, 3A, and 3B)

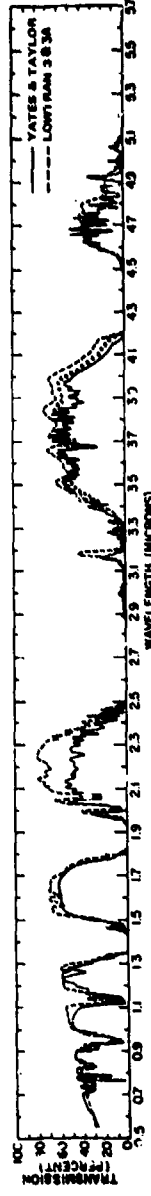
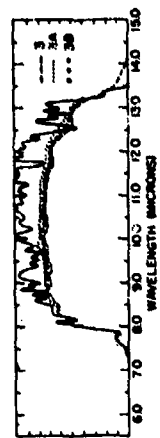


ATMOSPHERIC TRANSMITTANCE FOR A 1 NAUTICAL MILE PATH  
 ( WATER CONTENT 1.7 pr. cm. )

Figure 4. Comparison of LOWTRAN 3B Predictions With Measurements of GEBBIE et al<sup>8</sup>



Path Length 5.5 km  
 Temperature 38°F  
 Relative Humidity 66%  
 H<sub>2</sub>O in Path 2.2 cm  
 Transmittance at 0.55 μm 40%  
 LOWTRAN 3 visual range 23.5 km



Path Length 16.25 km  
 Temperature 53°F  
 Relative Humidity 41%  
 H<sub>2</sub>O in Path 6.5 - 8.9 cm  
 Transmittance at 0.55 μm 29%  
 LOWTRAN 3 visual range 51 km

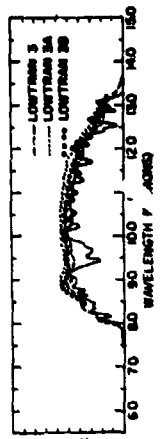
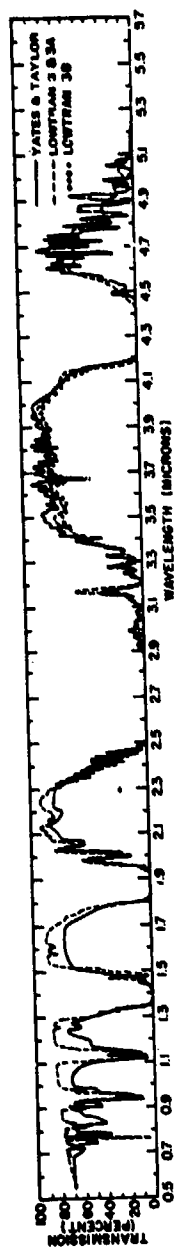
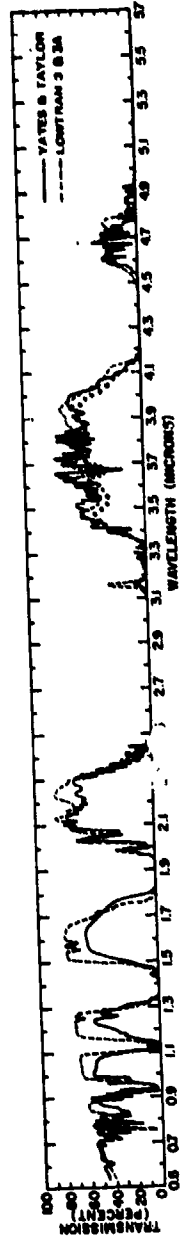
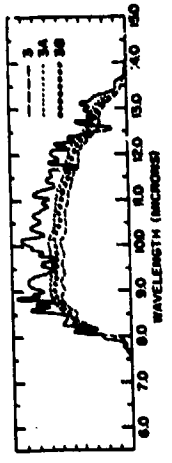


Figure 5. Comparison of LOWTRAN 3B Predictions With Measurements in Chesapeake Bay Area on 19 April 1956



Path Length 5.5 km  
 Time 2100 hr  
 Temperature 64°F  
 Relative Humidity 51%  
 H<sub>2</sub>O in Path 4.18 cm  
 Transmittance at 0.55 μm 70%  
 LOWTRAN 3 visual range 60 km



Path Length 16.25 km  
 Time 1600 hr  
 Temperature 68.7°F  
 Relative Humidity 53%  
 H<sub>2</sub>O in Path 15.1 cm  
 Transmittance at 0.55 μm 45%  
 LOWTRAN 3 visual range 75 km

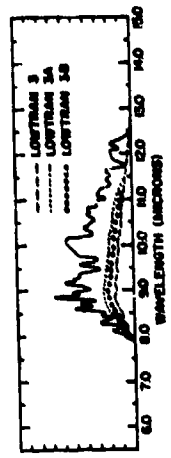


Figure 6. Comparison of LOWTRAN 3B Predictions With Measurements in Chesapeake Bay Area on 19 June 1956

## 6. LOWTRAN 3B H<sub>2</sub>O 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  $\mu\text{m}$  and 8-14  $\mu\text{m}$  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  $\mu\text{m}$  region (see Section 6.1) or the 3-5  $\mu\text{m}$  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  $\mu\text{m}$  region or change 6.2(a) for the 4  $\mu\text{m}$  region. If the computer code is only going to be run for the 8-14  $\mu\text{m}$  region, then only changes 6.1(a) and (b) need be affected and vice versa.

### 6.1 8-14 $\mu\text{m}$ 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 H2O 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 $\mu\text{m}$ 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 62 \*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 H2O 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  $\mu$ m 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)

$\nabla$ 0.00 $\nabla$ .187 $\nabla$ .147 $\nabla$ .117 $\nabla$ .097 $\nabla$ .087 $\nabla$ .100 $\nabla$ .120 $\nabla$ .147 $\nabla$ .174 $\nabla$ .200 $\nabla$ .240 $\nabla$ .280 $\nabla$ .330 $\nabla$ .000 $\nabla$ 2350

where the symbol  $\nabla$  here refers to a space.

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

### 6.3 Complete Changes for Both 4 $\mu$ m and 10 $\mu$ m 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  $\mu\text{m}$  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  $\nabla$  here refers to a space.

Note that the 4  $\mu\text{m}$  water vapor continuum data given above occupy the same storage locations previously occupied by the 10  $\mu\text{m}$  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 ( $\mu\text{m}$ ) and the extinction and absorption coefficients ( $\text{km}^{-1}$ ) for these aerosols have been digitized directly from the work of Shettle and Fenn,<sup>11</sup> and are given below in the same format (that is 4(F6.2, 2F<sup>..</sup>.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	.11479	.00388	6.000	.01389	.00462
7.200	.01569	.00775	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	.00689	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	.02754	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	.00613	.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	.00245	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<sup>12</sup> measured extinction coefficients at 0.55  $\mu\text{m}$ . 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<sup>11</sup>). 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.

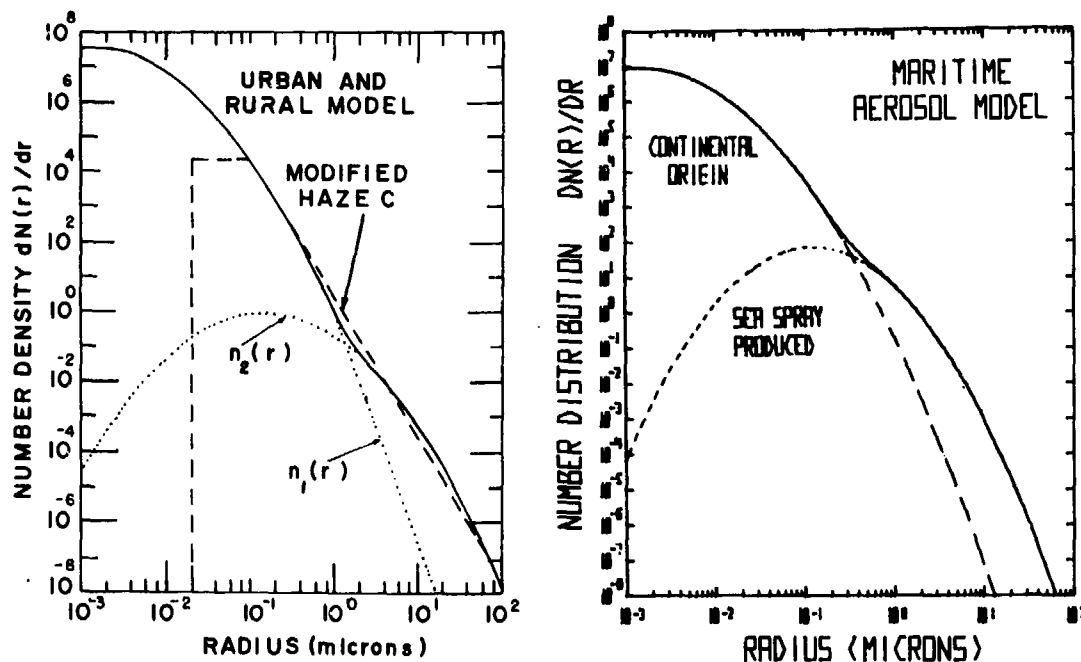


Figure 7. Size Distributions for Aerosol Models Used in LOWTRAN 3B

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 meaningfully model these variations. For simplicity, the oceanic component is taken as contributing 75 percent of the extinction at 0.55  $\mu\text{m}$ , 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:

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

The choices of  $N_0$  in Table 2 correspond to 1 particle/cm<sup>3</sup>. 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<sup>11</sup>) 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 Figure 9 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.<sup>11</sup>

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

Aerosol Model	Size Distribution			Type
	$i$	$N_i$	$r_i$	
Rural	1	0.9999975	0.005 $\mu\text{m}$	Water-Solubles and Dust-Like
	2	0.0000025	0.5 $\mu\text{m}$	
Urban	1	0.9999975	0.005 $\mu\text{m}$	Rural Aerosol Mixture and Soot-Like
	2	0.0000025	0.5 $\mu\text{m}$	
Maritime				
Continental Origin		1.0	0.005 $\mu\text{m}$	Rural Aerosol Mixture
Marine Origin		1.0	0.3 $\mu\text{m}$	Sea Salt Solution in Water
Tropospheric		1.0	0.005 $\mu\text{m}$	Rural Aerosol Mixture

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

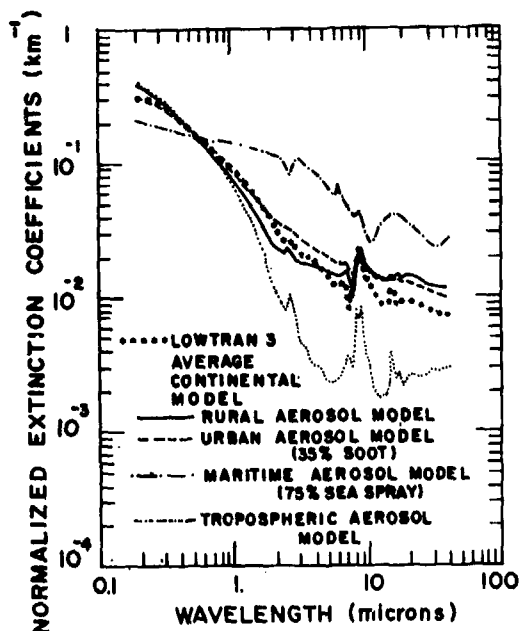


Figure 8. Extinction Coefficient for New Aerosol Models Used in LOWTRAN 3B

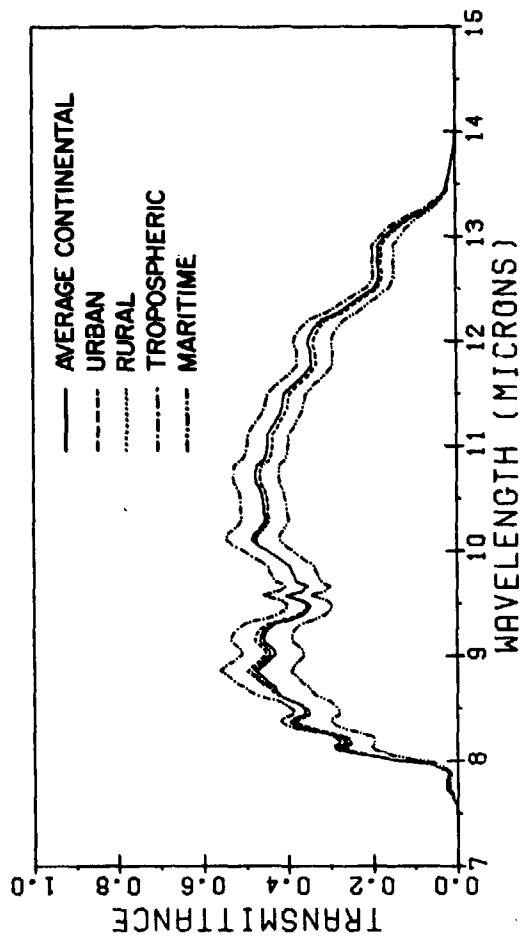
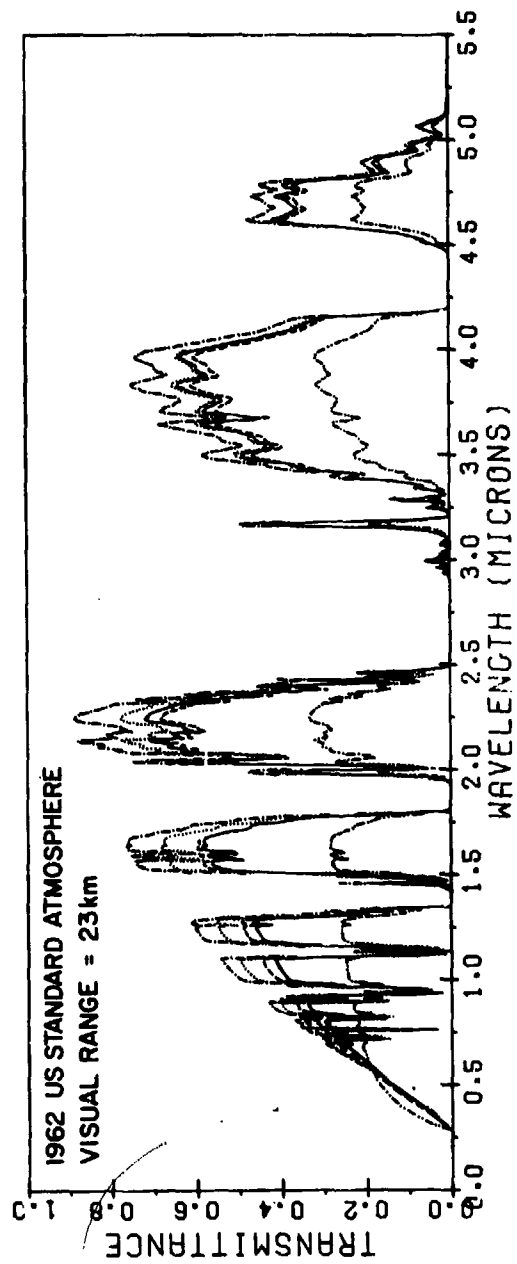


Figure 9. Transmittance for a 10 km Path at Sea Level for Three Aerosol Models



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<sup>11</sup> 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<sup>13</sup> or Barnhardt and Street<sup>14</sup> 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  $\mu\text{m}$  (that is, 2000-5000  $\text{cm}^{-1}$ ).

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<sup>1</sup>).

```
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 ***
```

w' = 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<sup>1</sup>). 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 Ruppertsberg et al,<sup>15</sup> 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  $\mu\text{m}$  and the 3.5-4.2  $\mu\text{m}$  regions. These results have been included as updates to the LOWTRAN 3 computer code.<sup>1</sup> These updates include the addition of water vapor continuum attenuation in the 3.5-4.2  $\mu\text{m}$  region, as well as the incorporation of a temperature dependence to the attenuation coefficients in both the 4  $\mu\text{m}$  and 10  $\mu\text{m}$  spectral regions. The contribution of foreign gas broadening to the 10  $\mu\text{m}$  H<sub>2</sub>O 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  $\mu\text{m}$ ) when the visual range is less than 2 km. The latter provision could overestimate the attenuation at 10.6  $\mu\text{m}$  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  $\mu\text{m}$  region and lower transmittance values in the 3-5  $\mu\text{m}$  regions than LOWTRAN 3, due solely to the water vapor continuum additions. LOWTRAN 3A was more optimistic in the 10  $\mu\text{m}$  region than LOWTRAN 3B, due to the omission

15. Ruppertsberg, G.H., Schellhase, R., and Schuster, M. (1975) Calculations about the transmittance window of clouds and fog at about 10.5  $\mu\text{m}$  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  $0.55 \mu\text{m}$ , 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  $\mu\text{m}$ : 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  $\mu\text{m}$ : 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  $\mu\text{m}$  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. 68:1201.
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. Ruppertsberg, G. H., Schellhase, R., and Schuster, M. (1975) Calculations about the transmittance window of clouds and fog at about 10.5  $\mu\text{m}$  wavelengths, Atmos. Environ. 9:723-730.

## Appendix A

### LOWTRAN 3A Supplement

The following modification applies to the 8-14  $\mu\text{m}$  region:

1. Replace line A 185 by the following:

$$\text{EH}(5, \text{I}) = 1.67 * \text{D} * \text{PPW} * \text{EXP}(6.58 * (\text{TS} - 1.0)) \quad \text{A 185A}$$

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

$$\text{TX}(5) = (4.18 + 5578.0 * \text{EXP}(-7.87\text{E}-3 * \text{V})) * \text{W}(5) \quad \text{A 486*}$$

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<sup>1</sup>) 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<sup>1</sup>).

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  $\mu\text{m}$ : Computer Code LOWTRAN 3, AFCRL-TR-75-0255.





ATMOSPHERIC TRANSMITTANCE FROM  
0.25 TO 28.5  $\mu\text{m}$ : 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  $\mu\text{m}$ . The figures show an increase in transmittance due to ozone absorption as the wavelength approaches 0.2  $\mu\text{m}$ . However, absorption due to oxygen becomes important below 0.25  $\mu\text{m}$  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.O.O) PRINT 417, VIS	A 126B
IF (VIS. LE.O.O. AND .IHAZE.GT.O) PRINT 416, IHAZE,HZ(IHAZE)	A 134*
3. Page 11 (para. 2) - Delete ' and 4  $\mu\text{m}$ ' from the end of the first line. Note that the 4  $\mu\text{m}$  water vapor continuum was omitted in the first edition of LOWTRAN 3. The 4  $\mu\text{m}$  H<sub>2</sub>O continuum is included in the second edition of LOWTRAN 3 (LOWTRAN 3A) together with an updated version of the 10  $\mu\text{m}$  H<sub>2</sub>O continuum.
4. Page 12 - The left hand scale of Figure 1 should read:  

ATTENUATION COEFFICIENT ( $\text{km}^{-1}$ )
5. Page 14 - The 2nd Equation should read:  $N(z) = \frac{a(z)}{\text{VIS}} + b(z)$
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.O.O) TX3 = TX(9)	A 309+
IF (H2.LT.HMIN) J2 = N	A 318+
10. Page 75 - Line A 517 should precede 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 accidentally 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 ,\* preceding 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 $\mu\text{m}$ $\text{H}_2\text{O}$ Continuum (Nitrogen Broadening Effects)

As stated in Section 3, one major dilemma in the 8-14  $\mu\text{m}$  region is how to account for the  $\text{H}_2\text{O}$  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  $\text{H}_2\text{O}$  dimers (or other absorption mechanisms) on the attenuation in the 8-14  $\mu\text{m}$  region is still an open question.

However, from laboratory measurements<sup>1, 2</sup> it appears that the water vapor attenuation in the 10  $\mu\text{m}$  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  $\mu\text{m}$  and 296 K.

A summary of the 10.6  $\mu\text{m}$  attenuation measurements obtained at Ohio State University up to the time of writing this paper, was kindly provided by Long<sup>2</sup> 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<sub>2</sub>O Continuum Nitrogen Broadening Coefficient at 10.6 μm. Water vapor absorption coefficients for the P(20) 00<sup>0</sup>1-10<sup>0</sup>0 line of the CO<sub>2</sub> 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<sup>2</sup>)

Partial Pressure (torr)	Total Pressure (torr)	Absorption Coefficient km <sup>-1</sup>	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

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

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:

$$\frac{C_N}{C_S} = \left[ \frac{k(\nu)}{C_S w} - P_{H_2O} \right] / (P_T - P_{H_2O}) \quad (C2)$$

Alternatively Eq. (C2) can be rewritten as:

$$\frac{C_N}{C_S} = \left[ \frac{k(\nu)}{C_S w P_{H_2O}} - 1 \right] \left( \frac{P_{H_2O}}{P_T - P_{H_2O}} \right) \quad (C3)$$

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

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

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

Using the experimental measurements of  $k$  at  $10.6 \mu\text{m}$  given in Table C1, values of  $C_N/C_S$  were calculated using Eq. (C3). It was assumed that  $C_S = 7.48 \text{ gm cm}^{-2} \text{ atm}$  at  $296 \text{ K}$  based on Eq. (C3), which is consistent with reported measurements.<sup>1, 3, 2</sup> 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.

3. Roberts, R. E., Selby, J. E. A., and Biberman, L. M. (1976) Infrared continuum absorption by atmospheric water vapor in the  $8\text{-}12 \mu\text{m}$  window Applied Optics 14:2085.

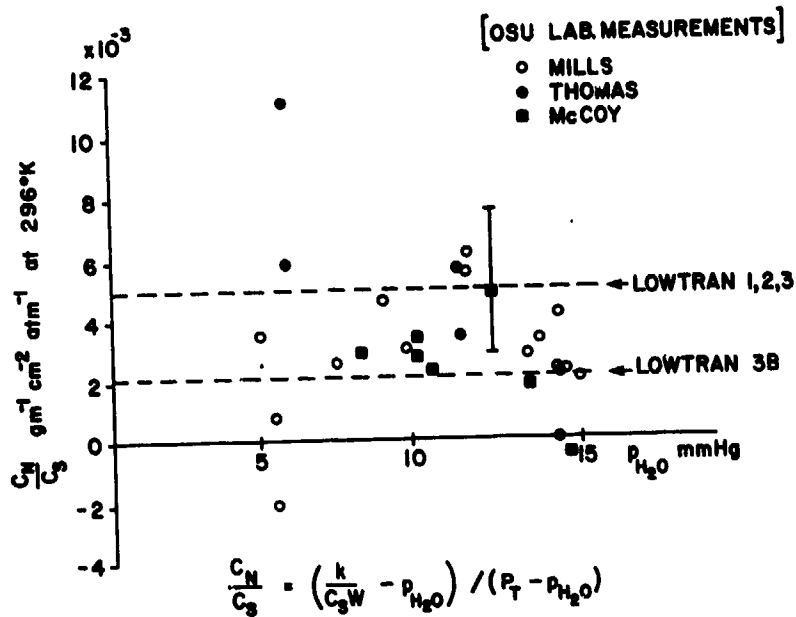


Figure C1. Water Vapor Absorption Coefficients for P(20) Line of the 10.6  $\mu\text{m}$   $\text{CO}_2$  Laser

## 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,<sup>1</sup> along with a discussion of the different sources of the refractive index data which is presented in Table D1.

- 
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-SOLUBLE	DUST-LIKE	SOOT	OCEANIC
.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 -1.00E-02	1.750 -.162	2.210 -.720	1.310 -4.06E-02
10.5910	1.750 -7.00E-02	1.620 -.120	2.220 -.730	1.271 -5.22E-02
11.0000	1.750 -5.00E-02	1.620 -.105	2.230 -.730	1.246 -7.31E-02
11.5000	1.870 -4.70E-02	1.590 -.100	2.240 -.740	1.227 -.105
12.5000	1.820 -5.30E-02	1.510 -9.00E-02	2.270 -.750	1.208 -.190
13.0000	1.820 -5.50E-02	1.470 -.100	2.280 -.760	1.221 -.223
14.0000	1.500 -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	1.467 -.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	1.800 -.280	2.480 -.870	1.579 -.316
25.0000	1.880 -.280	1.800 -.240	2.510 -.890	1.596 -.313
27.9000	1.840 -.290	1.800 -.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 ( $\theta_0$  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 ( $\beta$  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 "\*" preceding 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),F(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(2500),C2(1575),C3(540),C4(133),C5(15),C6(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  REFRACTION 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  CARD 1 MODEL, IHAZE, ITYPE, LEN, JP, IM, M1, M2, M3, ML, RO  FORMAT(10I3,F10.3)  A 17*
C  CARD 2 H1, H2, ANGLE, RANGE, BETA, VIS  FORMAT(7F10.2)  A 19
C  CARD 3 V1, V2, DV  FORMAT(7F10.3)  A 20
C  CARD 4 IXY  FORMAT(I3)  A 21
C  MODEL=1,2,3,4,5 OR 6 SELECTS ONE OF THE FOLLOWING MODEL ATMOSPHERE  A 22
C  TROPICAL, MIDLATITUDE SUMMER, MIDLATITUDE WINTER, SUBARCTIC SUMMER,  A 23
C  SUBARCTIC WINTER, OR THE 1962 U.S. STANDARD RESPECTIVELY  A 24
C  MODEL=0 FOR HORIZ. PATH WHEN METEOROL. DATA USED INSTEAD OF CARD 2  A 25
C  READ H1, P(MB), T(DEG C), DEW PT. TEMP(DEG C), XREL HUMIDITY, H2O DENSITY  A 26*
C  (GM,M-3), O3 DENSITY(GM,M-3), VIS(KM), RANGE(KM) WITH FORMAT 429.  A 27*
C  MODEL=7 WHEN NEW MODEL ATMOSPHERE (E.G. RADICSONDE DATA) USED.  A 28A
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  M1, M2, M3, ARE USED TO CHANGE TEMP, H2O, AND O3 ALTITUDE PROFILES.  A 29F
C  IF IHAZE=0 NO AEROSOL SCATTERING IS COMPUTED  A 30
C  IHAZE =1 IF AEROSOL ATTENUATION REQUIRED (THIS IS USED IN  A 31
C  CONJUNCTION WITH VISUAL RANGE(SEE CARD 2))  A 32
C  IHAZE = 1 OR 2 ALSO GIVE AEROSOL ATTENUATION FOR 23KM AND 5KM VIS.  A 33
C  HAZE MODELS RESPECTIVELY IF VIS =0 ON CARD 2  A 34
C  IHAZE = 7 FOR OTHER AEROSOL MODELS (E.G. MARITIME ECT) WHICH  A 35+
C  ARE READ INTO PROGRAM  A 35+
C  ITYPE=1,2 OR 3 INDICATES THE TYPE OF ATMOSPHERIC PATH  A 36
C  ITYPE=3, VERTICAL OR SLANT PATH TO SPACE  A 37
C  ITYPE=2, VERTICAL OR SLANT PATH BETWEEN TWO ALTITUDES  A 38
C  ITYPE=1, CORRESPONDS TO A HORIZONTAL (CONSTANT PRESSURE) PATH  A 39
C  H1=OBSERVER ALTITUDE (KM)  A 40
C  H2=SOURCE ALTITUDE (KM)  A 41
C  ANGLE= ZENITH ANGLE AT H1 (DEGREES)  A 42
C  RANGE=PATH LENGTH (KM)  A 43
C  BETA=EARTH CENTRE ANGLE  A 44
C  VIS = VISUAL RANGE AT SEA LEVEL (KM)  A 45
C  (IF ITYPE=1 READ H1 AND RANGE; IF ITYPE=3 READ H1 AND ANGLE.  A 46

```

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

C	IF ITYPE=2 READ H1 AND TWO OTHER PARAMETERS E.G. H2 AND ANGLE)	A	49
C		A	50
C	V1=INITIAL FREQUENCY (WAVENUMBER CM-1 ) INTEGER VALUE	A	51
C	V2=FINAL FREQUENCY(WAVENUMBER CM-1 ) INTEGER VALUE	A	52
C	OV= FREQUENCY INTERVALS AT WHICH TRANSMITTANCE IS PRINTED	A	53
C	NOTE: OV MUST BE A MULTIPLE OF 5 CM-1	A	54
C		A	55
C	IXY=0 TO END DATA ,=1 FOR NEW V1,V2,OV ONLY , =2 TO CONTINUE DATA	A	56
C	IXY=3 FOR NEW CARD 2 ONLY,=4 FOR NEW CARD 1 ONLY.	A	57A
C	*****	A	57B
	IXY=0	A	57C
	READ (5,400) IATH,NL	A	58
	READ (5,401) (HZ1(I),I=1,NL)	A	59
	READ (5,401) (HZ2(I),I=1,5)	A	60
	HZ2(6)=HZ1(6)	A	60+
	DO 1 J=1,3	A	61
	K2=2*J	A	62
	K1=K2-1	A	63
	DO 1 I=1,NL	A	64
1	READ (5,402) Z(I),(P(K,I),T(K,I),WH(K,I),WO(K,I),K=K1,K2)	A	65
	READ (5,431) (VX(I),C7(I),C7A(I),I=1,44)	A	66*
	READ (5,403) (TR(I),FN(I),FO(I),I=1,67)	A	67
	READ (5,404) (C1(I),I=1,2500)	A	68
	READ (5,404) (C2(I),I=1,1575)	A	69
	READ (5,404) (C3(I),I=1,540)	A	70
	READ (5,405) (C4(I),I=1,133)	A	71
	READ (5,404) (C5(I),I=1,15)	A	72
	READ (5,405) (C8(I),I=1,102)	A	73
	PI=2.0*ASIN(1.0)	A	74*
	CA=PI/180.	A	75
	IP=0	A	76
2	CONTINUE	A	77
	RE=6371.23	A	78
	IFIND=0	A	79
C	JP NE 0 SUPPRESS PRINT	A	79+
	READ 400,MODEL,IMAZE,ITYPE,LEN,JP,IM,H1,H2,H3,ML,RO	A	80
	PRINT 400,MODEL,IMAZE,ITYPE,LEN,JP,IM,H1,H2,H3,ML,RO	A	81
C	PRINT 424, MODEL,IMAZE,ITYPE,LEN	A	81
200	M=MODEL	A	82
	IF (M.EQ.1) RE=6378.79	A	83
	IF (M.EQ.4) RE=6356.91	A	84
	IF (M.EQ.5) RE=6356.91	A	85A
	IF (IMAZE.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
	IMAZE=1	A	85E
250	IF (RO.GT.0) RE=RO	A	85F
	IF (M.EQ.7.AND.IM.NE.0) GO TO 4	A	85G
	IF (IXY.GT.3) GO TO 8	A	85H
	IF (MODEL.EQ.0) GO TO 4	A	86
300	READ 406, H1,H2,ANGLE,RANGE,BETA,VIS	A	87*
	PRINT 425, H1,H2,ANGLE,RANGE,BETA,VIS	A	88
	X1=RE+H1	A	89
	IF (ITYPE.EQ.3) GO TO 560	A	90*
	IF (ITYPE.EQ.1) GO TO 8	A	91
	X2=RE+H2	A	92
	IF (RANGE.EQ.0.) GO TO 5	A	93
	PRINT 428, H1,H2,ANGLE,RANGE,BETA,VIS	A	94
	IF (H2.EQ.0.AND.ANGLE.NE.0) GO TO 3	A	95
	ANGLE=ACOS(0.5*((H2-H1)*(1.+X2/X1)/RANGE-RANGE/X1))/CA	A	96

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 (P.EQ.0) READ 429,M1,P(7,1),TMP,DP,RH,WH(7,K),WO(7,K),VIS,RANGE	A 103C
	IF (M.EQ.0) PRINT 430,M1,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 (P.EQ.0) Z(K)=M1	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) AHZ1(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=PL	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 (M2.GT.0.0.AND.M2.LT.M1) 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=XE+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,OV	A 121*
	IF (IXY.LE.2) PRINT 406,V1,V2,OV	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 (HAZE.EQ.0.) PRINT 426	A 133
	IF (VIS.LE.0.0.AND.IHAZE.GT.0) PRINT 416,IHAZE,HZ(IHAZE)	A 134*
	AVM=10000./V1	A 135
	ALAM=10000./V2	A 136
	PRINT 418, V1,V2,OV,ALAM,AVM	A 137
	AVM=0.5E-4*(V1+V2)	A 138
	AVM=AVM*AVM	A 139
	CO=77.46+.459*AVM	A 140
	CM=43.487-0.3473*AVM	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 (JIP.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.	A 149
11	CONTINUE	A 150
	BETA=0.0	A 151-
	SR=0.0	A 153
	IP=0	A 154-
C***	NOM DEFINE CONSTANT PRESSURE PATH QUANTITIES 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+7(NL))/(RE+H1)	A 162
	IF (SPHI.GT.X) GO TO 14	A 163
	H1=7(NL)	A 164
	J1=PL	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=F(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=MZ1(I)	A 187
	IF (P.EQ.7) HAZE=AHAZE(I)	A 188*
	IF (Z(I).GE.5.0) GO TO 150	A 189*
	IF (P.NE.7.AND.IHAZE.EQ.2) HAZE=MZ2(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)-AHZ1(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/MZ1(I)	A 191A
	IF (MODEL.EQ.7) EH(7,I)=HAZE/AHAZE(I)	A 191B
	EH(8,I)=46.6667*W0(M,I)	A 192
	IF (M.GT.0.AND.M.LT.7) EH(8,I)=46.667*W0(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 (M1.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 (M1,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=+L	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,IX,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=M1	A 232
	IF (I.EQ.J2) X2=M2	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.)

		A 276
		A 277
28	CONTINUE	A 278
C****	DCWNWARD TRAJECTORY	A 279
	K2=0	A 280
	IF (NP1.EQ.1) J1=J1-1	A 281
	J2=J1+1	A 283
	J=J1+1	A 282
	YN1=YN	A 284
	IF (H2.GT.Z(J1+1).OR.H1.EQ.H2) GO TO 30	A 285
	IF (NP1.EQ.1.AND.H2.GE.Z(J1+1)) GO TO 30	A 286
	CALL POINT (H2,YN,N,NP2,TX,IP)	A 287
	OO 29 K=1,10	A 288
29	W(K)=TX(K)	A 289
	TX2=TX(9)	A 290
	YN2=YN	A 291
	IF (H2.LT.H1) H=H2	A 292
	J2=N	A 293
	IF (J1.EQ.J2) TX2=TX1+YN2-EH(9,N)	A 294
	IF (H2.GT.H1) TX1=TX2	A 295
	IF (J1.EQ.J2.AND.H2.LT.H1) YN1=TX2	A 296
30	A0=(RE+H1)*SPHI*YNI	A 297
	IF (H2.GE.H1) YN2=YN1	A 298
	DO 31 I=1,J1	A 299
	HMIN=A0/EH(9,I)-RE	A 300
	IF (I.EQ.J1) HMIN=A0/YN1-RE	A 301
	JMIN=I	A 302
	IF (HMIN.LE.Z(I+1)) GO TO 32	A 303
31	CONTINUE	A 304
32	X=HMIN	A 305
	IF (HMIN.LE.0) GO TO 34	A 306
	CALL POINT (X,YN,N,NP,TX,IP)	A 307
	JMIA=N	A 308
	TX3=TX(9)	A 309
	IF (J2.EQ.N.OR.J1.EQ.N) TX3=YN2+TX(9)-EH(9,N)	A 309+
	IF (TX3.LT.0.0) TX3=TX(9)	A 310
	IF (J1.EQ.N.AND.H2.GE.H1) GO TO 33	A 311
	HMIN=A0/TX3-RE	A 312
	IF (ABS(X-HMIN).GT.0.0001) GO TO 32	A 313
33	IF (J1.EQ.N.AND.H2.GE.H1) YN1=TX3	A 314
	IF (J2.EQ.N.AND.J1.NE.J2) YN2=TX3	A 315
	IF (H2.GE.H1) TX2=TX3	A 316
	IF (H2.GE.H1) J2=N	A 317
	IF (H2.GE.H1.OR.H2.LT.HMIN) H=HMIN	A 318
	PRINT 436, HMIN	A 318+
	IF (H2.LT.HMIN) J2=N	A 319
	IF (H2.LT.HMIN) PRINT 440, HMIN	A 320
	GO TO 35	A 321
34	PRINT 436, HMIN	A 322
	IF (H2.LT.H1) GO TO 35	A 323
	IF (ITYPE.EQ.3.OR.H2.GE.H1) PRINT 437	A 324
	ITYFE=2	A 325
	TX2=EH(9,1)	A 326
	JMIN=0	A 327
	J2=1	A 328
	H2=0.0	A 329
	H=0.0	A 330
C****	NO+ DEFINE VERTICAL PATH QUANTITIES VH(1-8)	A 331+
35	IF (JP.EQ.0) PRINT 420	A 332
	OO 40 I=1,NL	A 333
	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=PI*TA+BET	A 353
	PSI=BETA-ALP-ANGLE+190.0	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.W2.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.0) 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 75	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 (M2.EQ.M1) GO TO 47	A 414
	PN=TX1/YN1	A 415
	SPHI=SIN(ANGLE*CA)	A 416
	IF (SPHI.LT.RN) SPMI=SPHI/RN	A 417
	GO TO 19	A 418
47	CONTINUE	A 419
	IF (ANGLE.GT.90.0) PRINT 406,MM	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=I\	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 SCATTERING	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 87	A 529
77	J=I-30	A 530
	GO TO 79	A 531
78	J=(IV-12050)/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
	ALAP=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 (HAZE.EQ.0.OR.XX.GT.0.0) GO TO 90	A 564*
	CO 88 N=1,44	A 565*
	XO=ALAM-VX(N)	A 566*
	IF (XO) 89,88,88	A 567*
88	CONTINUE	A 568A
89	XX=(C7(N)-C7(N-1))*XO/(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)	A 566C
90	TX(10)=YY*W(7)	A 568D
	TX(7)=XX*W(7)	A 569*
	SUM=SUM+TX(7)	A 570
	TX(9)=SUM	A 571
	DO 94 K=4,10	A 572*
	IF (TX(K).EQ.0.0) GO TO 92	A 573
	IF (TX(K).LE.0.1) GO TO 91	A 574
	IF (TX(K).GT.20.) GO TO 93	A 575
	TX(K)=EXP(-TX(K))	A 576
	GO TO 94	A 577
91	TX(K)=1.0-TX(K)+0.5*TX(K)*TX(K)	A 578
	GO TO 94	A 579
92	TX(K)=1.0	A 580
	GO TO 94	A 581
93	TX(K)=0.	A 582
94	CONTINUE	A 583
	TX(10)=1.0-TX(10)	A 583+
	TX(9)=TX(1)*TX(2)*TX(3)*TX(9)	A 584
	IF (IV.GE.13000) TX(3)=TX(8)	A 585
	IF (JP.EQ.3) TX(9)=TX(7)	A 586A
	AB=1.-TX(9)	A 586B
	IF (IV.EQ.IV1.OR.IV.EQ.IV2) AB=0.5*AB	A 586C
	SUMA=SUMA+AB*DV	A 586D
	IF (JP.EQ.0) WRITE(6,423) IV,ALAM,IXY,(TX(K),K=1,7),TX(10),SUMA	A 587*
	IF (IV.GE.IV2) GO TO 95	A 588
	GO TO 50	A 589
95	REAC 400, IXY	A 590
	AB=1.0-SUMA/FLOAT(IV2-IV1)	A 591A
	PRINT 424, IV1,IV2,SUMA,AB	A 591B
	PRINT 400,IXY	A 591C
	IF (IXY.EQ.0) GO TO 100	A 591D
	GO TO (95,2,97,98,100),IXY	A 591E
96	REAC 406, V1,V2,DV	A 592
	AVM=10000./V1	A 593
	ALAM=10000./V2	A 594
	PRINT 418, V1,V2,DV,ALAM,AVM	A 595
	SUMA=0.0	A 596*
	GO TO 49	A 597
97	IF (MODEL.EQ.0) GO TO 200	A 598A
	GO TO 300	A 598B
98	READ 400,MODEL,IHAZE,ITYPE,LEN,JP,IM,M1,M2,M3,ML,RO	A 598C
	PRINT 400,MODEL,IHAZE,ITYPE,LEN,JP,IM,M1,M2,M3,ML,RO	A 598D
	GO TO 200	A 598E
100	STOP	A 599*
400	FORMAT(10I3,F10.3)	A 600*
401	FORMAT (8E10.3)	A 601
402	FORMAT (F6.1,2(E10.3,F6.1,2E10.3))	A 602
403	FORMAT (4(F6.3,2F7.4))	A 603
404	FORMAT (15F5.2)	A 604
405	FORMAT (8E9.2)	A 605
406	FORMAT (7F10.3)	A 606
407	FORMAT (//10X,26H HORIZONTAL PATH, ALTITUDE =,F7.3,11H KM,RANGE =, 1F7.3,3H KM)	A 607
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)	A 609
409	FORMAT (//10X,39H SLANT PATH TO SPACE FROM ALTITUDE H1 =,F7.3,19H 1KM, ZENITH ANGLE =,F7.3,8H DEGREES)	A 610
410	FORMAT (/20X,18H MODEL ATMOSPHERE ,I1,11H = TROPICAL)	A 611
411	FORMAT (/20X,18H MODEL ATMOSPHERE ,I1,21H = MIDLATITUDE SUMMER)	A 612
		A 613
		A 614

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

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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
41F 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 FORPAT (/10X,21H FREQUENCY RANGE V1= ,F7.1,13H CM-1 TO V2= ,F7.1,1,1
14H CM-1 FOR DV =,F6.1,9H CM-1 (,F6.2,* - *,F5.2,* MICRONS I*) A 621
419 FORPAT (/10X,38H VALENTVENT SEA LEVEL ABSORBER AMOUNTS//21X11JHWAT 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 FORPAT (1H1,///10X,* VERTICAL PROFILES *,64X,*PSI*,6X,*PHI*,6X,* A 627
1BETA*,4X,*THETA RANGE*) A 628
421 FORPAT (/10X,8H W(1-8) = 8E(14.3)/74X,E14.3/) *A 629
422 FORPAT (1H1,/10X,32H FREQ WAVELENGTH TOTAL H2O,5X4HCO2*,5X,6 A 630*
14HOZONE H2O 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 FORPAT (10X,I6,10F9.4,F12.2) A 633*
424 FORPAT (* INTEGRATED ABSORPTION FROM*,I6,* TO*,I5,* CM-1 =*,F10.2, A 634A
1*,AVERAGE TRANSMITTANCE =*,F6.4) A 634B
425 FORPAT (10X,7F10.3) A 635
426 FORPAT (/20X,*AEROSOL SCATTERING NOT COMPUTED,1HAZE=0*) A 636
427 FORPAT (1H1,///10X,20H HORIZONTAL PROFILES/) A 637
428 FORPAT (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 FORPAT(3F10.3,2F5.1,2E10.3,2F10.3) A 640*
430 FORPAT(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 FORPAT(4(F6.2,2F7.5)) A 645*
432 FORPAT (* STARTING PARAMETERS H1 AND ANGLE HAVE BEEN REDEFINED:H1= A 646
1 *,F10.3,*ANGLE =*,F10.6) A 647
433 FORPAT (* TRAJECTORY MISSES EARTHS ATMOSPHERE. CLOSEST DISTANCE OF A 648
1 APPROACH IS*,F10.2,1X,/,1X,*END OF CALCULATION*) A 649
434 FORPAT (10X,I4,F6.4,11(E10.3)) A 650
435 FORPAT (I5,F7.1,8E10.3,4F9.4,F7.1) A 651
436 FORPAT (* HMIN = *,F10.3) A 652
437 FORPAT (* PATH INTERSECTS EARTH - PATH CHANGED TO TYPE 2 WITH H2 = A 653
1 0.0 KM*) A 654
438 FORPAT (* CHOICE OF TWO PATHS FOR THIS CASE -SHORTEST PATH TAKEN. A 655
1 FOR LONGER PATH SET LEN=1.*) A 656
439 FORPAT (* CHOICE OF TWO PATHS FOR THIS CASE -LONGEST PATH TAKEN. A 657
1 FOR SHORT PATH SET LEN = 0 *) A 658
440 FORPAT (* H2 WAS SET LESS THAN HMIN AND HAS BEEN RESET EQUAL TO A 659
1 HMIN I.E. H2 = *,F10.3) A 660
441 FORPAT(* MODEL ATMOSPHERE NO. 7*,/ 4X,*Z (KM)*,3X,*P (MB)*,4X, A 661*
1 *T (C) DEW PT XRM H2O(GM.M-3) O3(GM.M-3) NO. DEN.*) A 662*
442 FORPAT(* 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 664*
2BY THE TRANSMITTANCE AT 0.55 MICRONS*) A 665*
END A 666*

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

```

SUBROUTINE POINT (X,YN,N,NP,TX,P)
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 SUBROUTINE POINT COMPUTES THE MEAN REFRACTIVE INDEX ABOVE AND BELOW
C A GIVEN ALTITUDE AND INTERPOLATES EXPONENTIALLY TO DETERMINE THE
C EQUIVALENT ABSORBER AMOUNTS AT THAT ALTITUDE.
C
C*****
C X IS THE HEIGHT IN QUESTION
C TX(9) AND YN ARE THE MEAN REFRACTIVE INDICES ABOVE AND BELOW X
C N IS THE LEVEL INTEGER CORRESPONDING TO X OR THE LEVEL BELOW X
C NP =1 IF X COINCIDES WITH MODEL ATMOSPHERE LEVEL ,IF NOT NP = 0
C TX(1-8) ARE ABSORBER AMOUNTS PER KM AT HEIGHT X
C*****
      N=NL
      NP=N
      IF (X.LT.0.0) X=Z(1)
      IF (X.GT.Z(NL)) GO TO 4
      DO 1 I=1,NL
      N=I
      IF (X-Z(I)) 2,4,1
1  CONTINUE
2  J2=N
      N=N-1
      FAC=(X-Z(N))/(Z(J2)-Z(N))
      PX1=P(M,N)*(P(M,J2)/P(M,N))*FAC
      TX1=T(M,N)*(T(M,J2)/T(M,N))*FAC
      WX1=WH(M,N)*(WH(M,J2)/WH(M,N))*FAC
      TX(3)=CO*PX1/TX1-4.56E-6*WX1*TX1*CW
      TX(2)=CO*P(M,J2)/T(M,J2)-4.56E-6*WH(M,J2)*T(M,J2)*CW
      TX(1)=CO*P(M,N)/T(M,N)-4.56E-6*WH(M,N)*T(M,N)*CW
      TX(5)=0.5E-6*(TX(2)+TX(3))
      YN=(.5E-6*(TX(1)+TX(3)))
      IF (IP.EQ.0) GO TO 9
      DO 3 K=1,10
      IF (K.EQ.9) GO TO 3
      TX(K)=0.0
      IF (EH(K,N).EQ.0.0) GO TO 3
      IF (EH(K,N).GT.1000.0) GO TO 3
      TX(K)=EH(K,N)*(EH(K,J2)/EH(K,N))*FAC
3  CONTINUE
      GO TO 9
4  NP=1
      IF (IP.EQ.0) GO TO 6
      DO 5 K=1,10
      TX(K)=EH(K,N)
5  TX(5)=EH(9,N)-1.
6  YN=0.0
C***** CARDS B 24 AND 50 THROUGH 59 ARE NO LONGER REQUIRED
      IF (N.GT.1) YN=EH(9,N-1)-1.0
9  CONTINUE
      IF (IP.EQ.1) PRINT 400, X,N,NP,TX(9),YN,IP,(TX(K),K=1,8)
      TX(5)=TX(9)+1.
      YN=YN+1.
      RETURN
C
400 FORMAT (/,* FROM POINT: HEIGHT=*,F10.4,* KM,N=*,I3,* ,NP=*,I2,* ,REF
1. INDEX ABOVE & BELOW X=*,ZE11.4,* ,IP=*,I3,/,12X,*EQUIV. ABSORBER

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

```

2AMOUNTS PER KM AT X=* ,8E10.3)      B 68
END                                     B 69

SUBROUTINE ANGL (H1,H2,ANGLE,B1,LEN,NL)  C 1*
COMMON Z(34),P(7,34),T(7,34),EH(10,34),WH(7,34),M,NL,RE,CW,CO,PI  C 2*
DIMENSION TX(10)                       C 3
C*****                               C 4
C                                       C 5
C THIS SUBROUTINE CALCULATES THE INITIAL ZENITH ANGLE (ANGLE)  C 6
C TAKING INTO ACCOUNT REFRACTION EFFECTS GIVEN H1,H2, AND BETA  C 7
C (WHERE BETA IS THE EARTH CENTRE ANGLE SUBTENDED BY H1 AND H2 ),  C 8
C ASSUMING THE REFRACTIVE INDEX TO BE CONSTANT IN A GIVEN LAYER.  C 9
C FOR GREATER ACCURACY INCREASE THE NUMBER OF LEVELS IN THE MODEL  C 10
C ATMOSPHERE.                               C 11
C                                           C 12
C THIS SUBROUTINE CAN BE REMOVED FROM THE PROGRAM IF NOT REQUIRED.  C 13
C*****                               C 14
IP=99                                    C 15
CA=PI/180.                                C 16
X1=RE+H1                                    C 17
X2=RE+H2                                    C 18
LEN=0.                                       C 19
IT=0                                         C 20
B1=B1*CA                                    C 21
IF (E1.EQ.0.0) R1=ACOS(X2/X1)               C 21B
TAN(=X2*SIN(B1)/(X2*COS(B1)-X1)             C 22
THET=ATAN(TANG)                             C 23
IF (THET.LT.0.0) THET=THET+PI              C 24
SPHI=SIN(THET)                              C 25
ANG=THET/CA                                  C 26
C PRINT 404, B1,ANG,TANG                     C 27
TN=THET                                       C 28
TM=TN-0.5*CA                                  C 29
1 ANGLE=THET                                  C 30
FPT=0.                                       C 31
BETA=0.                                       C 32
RET1=0                                       C 33
RET2=0                                       C 34
FRT1=0                                       C 35
FRT2=0                                       C 36
FBT2=0.0                                     C 37
IF (E1.LE.0.0) GO TO 2                       C 37+
C PRINT 400, IT                               C 38
Y=2.*THET                                    C 39
IF (Y-PI.GT.1.0E-8) GO TO 9                 C 40
IF (IP.EQ.100) GO TO 6                      C 41
XMIN=X2*COS(B1)-RE                          C 42
IF (XMIN-H1) 8,4,4                          C 43
2 HMIN=H2                                     C 44A
H2=H1                                       C 44B
M1=HMIN                                     C 44C
3 ANGLE=0.5*PI                               C 44D
THET=ANGLE                                  C 45
SPHI=1.0                                    C 46
ANG=ANGLE/CA                                C 47

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

C	PRINT 404, B1,ANG,SPHI	C	48
4	IP=100	C	49
	CALL POINT (H1,YN,N,NP,TX,IP)	C	50
	J1=N	C	51
	TX1=TX(9)	C	52
5	CALL POINT (H2,YN,N,NP,TX,IP)	C	53
	IF (NP.EQ.1) N=N-1	C	54
	J2=N	C	55
	IF (J1.EQ.J2) TX1=TX1+YN-EH(9,J1)	C	56
6	DO 7 J=J1,J2	C	57
	X1=RE+7(J)	C	58
	X2=RE+7(J+1)	C	59
	IF (J.EQ.J1) X1=RE+H1	C	60
	IF (J.EQ.J2) X2=RE+H2	C	61
	SALP=X1*SPHI/X2	C	62
	ALP=ASIN(SALP)	C	63
	RN=EH(9,J+1)/EH(9,J)	C	64
	IF ((J+1).EQ.J2) RN=YN/EH(9,J)	C	65
	IF (J.EQ.J1) RN=EH(9,J+1)/TX1	C	66
	IF ((J+1).EQ.J2.AND.J.EQ.J1) RN=YN/TX1	C	67
	BET=THET-ALP	C	68
	FB=-TAN(ALP)	C	69
	IF (J.NE.J1) FB=FB+TAN(THET)	C	70
	FBT=FBT+FB	C	71
	BETA=BETA+FBT	C	72
	TH1=THET/CA	C	73
	BE=BET/CA	C	74
	C=ALP/CA	C	75
C	PRINT 402, J,Z(J),THET,ALP,BET,BETA,FBT,FB,TH1,BE,C	C	76
	IF (X2.EQ.RE+H2) C=PI-ALP	C	77
	IF (SALP.GE.RN) RN=1.	C	78
	SPHI=SALP/RN	C	79
	THET=ASIN(SPHI)	C	80
7	CONTINUE	C	81
	IF (P1.LE.0.0) GO TO 29	C	81+
	GO TO 26	C	82
8	CONTINUE	C	83
	TANG=-TANG	C	84
	ANGLE=PI-ANGLE	C	85
	TN=ANGLE	C	86
	ANG=ANGLE/CA	C	87
C	PRINT 404, B1,ANG,TANG	C	88
	IF (H1.LE.0.0) GO TO 3	C	89
9	CONTINUE	C	90
	IP=101	C	91
	CALL POINT (H1,YN,N,NP1,TX,IP)	C	92
	TX1=TX(9)	C	93
	YN1=YN	C	94
	IF (NP1.EQ.1) N=N-1	C	95
	J2=1L	C	96A
	IF (M.EQ.7) J2=ML	C	96B
	J1=N	C	97
	J=J1+1	C	98
	IF (H2.GE.H1) GO TO 13	C	99
	CALL POINT (H2,YN,N,NP,TX,IP)	C	100
	TX2=TX(9)	C	101
	YN2=YN	C	102
	J2=N	C	103

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+7(J+1)	C 106
	X2=RE+7(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 10	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
	IF (Z(J).LT.HMIN) GO TO 10	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	C 159
	TH1=THET/CA	C 160
C	PRINT 402, J, X2, THET, ALP, BET2, BET, BMIN, HMIN, FBT2, TH1, BE, AL	C 161
	RN=REF/EH(9, J-1)	C 162
	IF (SALP.GE.RN) RN=1.0	C 163
	SPHJ=SALP*RN	C 164
	GO TO 13	C 165
17	TX3=YN1+TX(9)-EH(9, J1)	C 166
	YN1=TX3	C 167
	IF (ABS(H2-Z(J+1)).LE.1.0E-5) YN1=TX(9)	C 168
	IF (ABS(H1-Z(J+1)).LE.1.0E-5) YN1=TX(9)	C 169
	RN=1.0	C 170
	GO TO 19	C 171
18	CALL POINT (HMIN, YN, N, NP, TX, IP)	C 172
	IP=102	C 173
	TX3=TX(9)	C 174
	IF (J.EQ.J1.AND.H2.GE.H1) GO TO 17	C 175
	IF (J.EQ.J1.OR.J.EQ.J2) TX3=YN2+TX(9)-EH(9, J)	C 176
	IF (HMIN.GT.H2) TX3=TX(9)	C 177
	IF (J.EQ.J1.AND.HMIN.GT.H2) GO TO 17	C 178
	RN=REF/TX3	C 179
	IF (SALP.GE.RN) RN=1.	C 180
	SPHI=SALP*RN	C 181
	X=X1*SPHI-RE	C 182
	DIF=ABS(HMIN-X)	C 183
	HMIN=X	C 184
	IF (DIF-1.0E-5) 19, 19, 18	C 185
19	X2=RE+HMIN	C 186
C	PRINT 403, HMIN, DIF, RN	C 187
	THET=ASIN(SPHI)	C 188
	IF (RN.EQ.1.0) FBT3=-TAN(THET)	C 188B
	IF (RN.EQ.1) GO TO 20	C 189
	DNX=(TX3-1.0)*ALOG((TX3-1.0)/(REF-1.0))/(X2-X1)	C 190
	FBT3=-TAN(THET)*(1.0-1.0/(1.0+TX3/(X2*DNX)))	C 191
20	BET=0.5*PI-THET	C 192
	BET2=BET2+BET	C 193
	BMIN=BET1+BET2	C 194
	IF (H2.GE.H1) GO TO 23	C 195
	BET=BET1+2.*BET2	C 196
	DB1=B1-BET1	C 197
	DB2=BET-B1	C 198
21	DB3=ABS(RMIN-B1)	C 199A
	IF (DB3.GT.DB1.AND.DB2.GT.DB1) GO TO 25	C 199B
	IF (DB2.GT.DB3) GO TO 22	C 199C
	IF (DB2.GT.DB1) GO TO 25	C 200
	BETA=BET	C 201
	FBT=FBT1+2.0*(FBT2+FBT3)	C 202
	LEN=1.	C 203
	GO TO 26	C 204
22	BETA=BET1+BET2	C 205
	FBT=FBT1+FBT2+FBT3	C 206
C	PRINT 401, J, BETA, FBT, FBT1, FBT2, FBT3, TX1, YN1	C 207
	GO TO 26	C 208
23	BETA=2.0*(BET1+BET2)	C 209
	LEN=1.	C 210
	FBT=2.0*(FBT1+FBT2+FBT3)	C 211
	PRINT 401, J, BETA, FBT, FBT1, FBT2, FBT3, TX1, YN1	C 212
	IF (H2.EQ.H1) GO TO 26	C 213
	IP=103	C 214

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

	IF (NP1.EQ.1) J1=J1+1	C 215
	SPHI=SIN(ANGLE)	C 216
	IF (7(J1+1).LE.H2; GO TO 24	C 217
	RN=TX1/YN1	C 218
	IF (SPHI.GE.RN) RN=1.	C 219
	SPHI=SPHI/RN	C 220
	THET=ASIN(SPHI)	C 221
	GO TO 5	C 222
24	CALL POINT (H2,YN,W,NP,TX,IP)	C 223
	TX1=TX1+YN-FH(9,J1)	C 224
	RN=TX1/YN1	C 225
	J2=J1	C 226
	IF (SPHI.GE.RN) RN=1.	C 227
	SPHI=SPHI/RN	C 228
	THET=ASIN(SPHI)	C 229
	GO TO *	C 230
25	BETA=BET1	C 231
	LEN=0.	C 232
	FBT=FBT1	C 233
26	THET=ANGLE+(B1-BETA)/(1.+FBT/TANG)	C 234
	OBETA=BETA/CA	C 235
	B=BET1/CA	C 236
	TH1=THET/CA	C 237
	PRINT 404, BETA,OBETA,FBT,TH1,TANG	C 238
	IF (THET.GT.TN.OR.THET.LT.TM) THET=(TN+TM)/2.	C 239
	TH1=THET/CA	C 241
	PRINT 404, BET1,B,FBT,TH1	C 240
	TN1=TN/CA	C 242
	TM1=TM/CA	C 243
	PRINT 405, TN, TM, TN1, TM1	C 244
	SPHI=SIN(THET)	C 245
	TANG=TAN(THET)	C 246
	IT=IT+1	C 247
	OBE=ABS(B1-BETA)	C 248
	DTH=ARS(ANGLE-THET)	C 249
	IF (IT.EQ.10) THET=0.5*(ANGLE+THET)	C 250*
	IF (IT.EQ.10) GO TO 28	C 251
	IF (OBE.GT.1.0E-7.AND.DTH.GT.1.0E-7) GO TO 1	C 252
28	ANGLE=THET/CA	C 253
	PRINT 406, ANGLE,IT	C 254
	RETRN	C 255A
29	H1=+2	C 255B
	ANGLE=C/CA	C 255C
	PRINT 406, ANGLE,IT	C 255D
	RETRN	C 255E
C		C 256
400	FORMAT (// * ITERATION NUMBER *,I3,//)	C 257
401	FORMAT (I6,E16.7,8F13.8)	C 258
402	FORMAT (I4,F10.4,6E13.4,4F10.4/)	C 259
403	FORMAT (* HMIN=*,F14.6,* DIF=*E14.6,* PR=*E16.8)	C 260
404	FORMAT (* TOTAL BETA = *,E14.6,F15.6,* FBT = *,E14.6,* THET =*,F10	C 261
	1.6,*TANG=*,F10.6)	C 262
405	FORMAT (5F12.6)	C 263
406	FORMAT (8X, /1H*, *ZENITH ANGLE =*,F7.3,* DEGREES : RECOMPUTED	C 264
	1 FROM SUBROUTINE ANGL (ITERATION*,I3,*))	C 265
	END	C 266

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+01	6.0E-05
2.0	8.050E+02	288.0	9.7E+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	9.6E-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	216.0	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.	0.0E-00	0.0E-00
0.0	1.016E+03	272.2	3.5E+00	6.0E-05	1.010E+03	267.0	9.1E+00	4.9E-05
1.0	8.573E+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	1.4E-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	216.0	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.)

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	4.366E+01	225.0	5.1E-04	3.2E-04			
23.0	3.240E+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	1.190E+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			
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	8.678E+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	8.053E+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	3.000E-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			
0.200	.38223	.07945	.250	.32079	.03651	.300	.28540	.02110	.400	.22026	.01317
0.400	.17989	.01114	.559	.15800	.01095	1.000	.12064	.00968	2.000	.09451	.01050
1.000	.07078	.01070	1.536	.04184	.00933	3.000	.03126	.00700	5.000	.02510	.00437
2.000	.02068	.00463	3.000	.01960	.00584	5.000	.01767	.00250	7.000	.01699	.00214
4.000	.01654	.00232	5.000	.01530	.00321	7.000	.01479	.00388	9.000	.01389	.00462
7.000	.01569	.00745	7.000	.01102	.00617	9.000	.01119	.00607	11.000	.01178	.00555
9.000	.01494	.01126	9.000	.02112	.01209	11.000	.02213	.01378	13.000	.01870	.01000
11.000	.01744	.00832	10.000	.01714	.00810	13.000	.01588	.00680	15.000	.01514	.00570
13.000	.01455	.00535	12.500	.01365	.00516	15.000	.01339	.00523	17.000	.01286	.00538
15.000	.01368	.00834	16.000	.01384	.00696	17.000	.01480	.00767	19.000	.01353	.00677
20.000	.01427	.00767	22.500	.01381	.00767	25.000	.01302	.00749	30.000	.01284	.00761

MODEL ATMOSPHERES 3 & 4 continued

MODEL ATMOSPHERES 5 & 6

AEROSOL SPECTRA DATA

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.)

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 3.0414 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	
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	0.08 800
-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 1.87 0.91 0.87	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

TRANSMITTANCE FUNCTIONS

SPECTRAL DATA H<sub>2</sub>O

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	3.98	3.86	3.92	3.98	3725
4.12	4.18	4.31	4.37	4.42	4.50	4.53	4.58	4.59	4.61	4.61	4.59	4.53	4.49	4.44	3800
4.41	4.40	4.34	4.30	4.26	4.09	3.98	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	2.87	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	3.13	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	-1.19	-1.13	-1.19	-1.22	-1.28	5900
-1.30	-1.33	-1.36	-1.39	-1.43	-1.48	-1.50	-1.52	-1.57	-1.61	-1.66	-1.70	-1.72	-1.78	-1.81	5975
-1.89	-1.92	-2.00	-2.08	-2.16	-2.24	-2.31	-2.40	-2.48	-2.54	-2.61	-2.71	-2.83	-2.95	-3.10	6050
-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	-1.63	-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	1.63	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

SPECTRAL DATA H<sub>2</sub>O



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	-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	-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	-2.80	-2.71	-2.62	-2.53	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	-1.46	-1.37	-1.28	-1.19	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	-0.14	-0.09	-0.02	0.03	8450		
0.03	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	0.59	0.55	0.71	0.84	8525		
0.93	1.01	1.06	1.07	1.02	1.01	1.12	1.23	1.24	1.28	1.34	1.43	1.52	1.59	1.65	1.43	1.52	1.56	1.51	8600		
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	1.86	1.61	1.17	1.32	8750		
1.52	1.70	1.90	2.01	1.92	1.91	2.12	2.11	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	1.58	1.27	1.20	1.18	8900		
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	-2.81	-2.99	-3.18	-3.37	9050		
-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	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	9200	
-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	9275						
-2.07	-1.91	-1.77	-1.70	-1.63	-1.60	-1.59	-1.43	-1.21	-1.15	-1.09	-1.13	-1.29	-1.19	-0.98	9350						
-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	-0.01	10100						
-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	0.59	10175						
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	0.43	10250						
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	1.41	10325						
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	1.61	1.61	10400					
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	1.61	10475						
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	1.38	10550						
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	1.99	10625						
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	1.20	10700						
0.98	0.63	0.43	0.29	0.16	0.05	0.02	0.03	0.03	0.01	0.08	-0.18	-0.21	-0.11	-0.06	10775						
-0.03	-0.14	-0.21	-0.08	-0.06	0.10	0.18	0.11	0.32	0.42	0.44	0.38	0.28	0.42	0.43	10850						
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	0.35	10925						
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	-0.23	11000						
-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	0.62	11075						
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	-1.31	11150						
-1.45	-1.48	-1.75	-1.91	-2.01	-1.97	-1.97	-1.97	-1.97	-2.26	-2.26	-2.01	-1.99	-2.00	-2.04	11225						
-2.37	-2.45	-2.44	-2.36	-2.32	-2.19	-2.10	-2.25	-2.16	-2.36	-2.44	-2.41	-2.49	-2.48	-2.43	11300						
-2.40	-2.36	-2.40	-2.49	-2.59	-2.68	-2.89	-3.28	-3.51	-3.74	-3.97	-4.20	-4.43	-4.66	-4.89	11375						
-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	11450	
-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	11525	
-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	11600	
-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	11675	
-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	-1.74	11750						
-1.83	-1.81	-1.71	-1.59	-1.49	-1.46	-1.46	-1.49	-1.49	-1.25	-1.24	-1.08	-0.90	-1.06	-0.91	11825						
-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	-0.28	11900						
-0.78	-0.21	-0.30	-0.08	-0.01	-0.20	0.06	0.10	0.06	0.14	-0.12	-0.02	-0.02	-0.13	-0.11	11975						
-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	-0.57	12050						
-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	-0.10	12125						
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	0.43	12200						
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	-0.84	12275						
-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	-1.51	12350						
-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	-1.41	12425						
-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	-1.88	12500						
-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	-1.50	12575						
-1.56	-1.41	-1.29	-1.38	-1.28	-1.48	-1.58	-1.44	-1.53	-1.48	-1.48	-1.58	-1.58	-1.69	-1.79	12650						
-2.00	-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	-5.19	12725						
-2.46	-2.26	-1.99	-2.01	-2.14	-2.31	-2.15	-2.81	-1.99	-2.14	-2.41	-2.12	-1.99	-1.84	-1.79	12800						
-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	-0.90	12875						
-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	-0.83	12950						
-0.61	-0.41	-0.29	-0.29	-0.61	-0.74	-0.19	0.18	0.19	0.10	0.20	0.20	0.02	0.20	0.13	12975						
-0.01	0.18	0.28	0.11	0.00	-0.37	-0.10	0.02	0.16	0.20	0.00	0.09	0.09	0.09	0.09	13000						
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	-0.74	13075						
-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	0.60	13150						

SPECTRAL DATA H<sub>2</sub>O

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

0.40	0.44	0.48	0.46	0.49	0.27	0.06	0.33	0.81	-1.17	-1.11	-1.37	-1.52	-1.54	-1.94	13925
-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	-2.28	14000
-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	-1.68	14075
-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	-1.39	14150
-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	-1.32	14225
-1.22	-1.28	-1.38	-1.69	-2.07	-2.42	-2.58	-2.58	-2.80	-2.58	-2.43	-1.88	-1.68	-1.26	-1.16	14300
-1.23	-1.11	-1.23	-1.10	-0.83	-0.80	-0.80	-0.80	-0.98	-0.97	-0.97	-0.91	-0.92	-1.13	-1.24	14375
-1.50	-1.85	-2.18	-2.32	-2.63	-3.91	-4.20	-4.49	-4.78	-5.07	-5.07	-5.07	-5.07	-5.07	-5.07	14450
-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	3.65	3.79	3.88	3.88	3.86	3.73	3.58	3.38	3.17	2.86	2.73	2.52	2.31	2.17	650
2.91	1.85	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
-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-4.31	-3.42	-3.17	-2.98	1775
-2.83	-2.71	-2.67	-2.67	-2.68	-2.58	-2.33	-2.01	-1.64	-1.32	-0.97	-0.76	-0.63	-0.59	-0.60	1850
-0.63	-0.65	-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	2.75	2.30	1.86	1.35	0.62	-0.24	-1.69	-2.16	-2.01	-1.79	-1.53	-1.32	-1.20	-1.15	2375
-1.12	-1.18	-1.25	-1.26	-1.28	-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	-2.48	-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
-0.39	-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	-1.42	-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	-1.88	-1.49	-1.22	-0.97	-0.72	-0.49	-0.20	0.03	3425
0.20	0.38	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
-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	3875
-5.00	-4.00	-3.73	-3.62	-3.59	-3.53	-3.56	-3.57	-3.53	-3.51	-3.45	-3.37	-3.26	-3.21	-3.18	3950
-3.27	-3.36	-3.60	-3.96	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	4025
-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	4100
-4.07	-3.85	-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	-5.00	-4.52	-3.98	-3.69	-3.42	-3.18	-2.95	-2.77	-2.61	-2.48	4325

SPECTRAL DATA H<sub>2</sub>O

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
-2.93-2.80-2.64-2.52-2.37-2.28-2.20-2.13-2.07-2.02-1.96-1.98-1.78-1.63-1.44	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
-1.63-1.46-1.27-1.23-1.26-1.40-1.57-1.73-1.98-2.28-2.87-3.74-5.00-5.00-5.00	5300
-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00	5375
-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00	5450
-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00	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	5600
-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00	5675
-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00	5750
-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00	5825
-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
-5.00-5.00-5.00-5.00-5.00-5.00-4.93-4.46-3.99-3.45-2.99-2.63-2.30-2.09-2.02-2.12	6425
-2.18-2.13-2.04-1.78-1.83-2.08-2.28-2.81-3.01-3.15-3.22-3.29-3.58-3.89-4.46	6500
-4.88-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00	6575
-4.81-4.52-4.11-3.69-3.09-2.99-2.91-2.89-3.19-3.20-3.36-3.62-3.89-3.92-3.73	6650
-3.53-3.37-3.19-3.02-2.79-2.52-2.36-2.24-2.19-2.32-2.41-2.29-2.06-2.00-2.18	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
-5.00-5.00-5.00-4.71-4.31-3.99-3.68-3.50-3.34-3.22-3.23-3.25-3.24-3.13-3.10	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
-4.59-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-4.93 7775	
-4.51-4.10-3.78-3.32-3.03-2.74-2.43-2.08-1.83-1.59-1.29-1.02-0.81-0.70-0.73	7850
-0.90-1.08-1.19-1.35-1.47-1.57-1.66-1.80-1.91-2.04-2.18-2.33-2.47-2.61-2.78	7925
-2.97-3.10-3.28-3.44-3.63-3.81-3.98-4.15-4.32-4.61-4.71-4.80-5.00-5.00-5.00	8000
-5.00-5.00-5.00-5.00-4.32-3.24-2.59-2.12-1.82-1.57-1.34-1.16-1.02-0.82-0.64	12950
-0.48-0.33-0.14-0.06 0.08 0.21 0.39 0.52 0.61 0.72 0.85 0.96 1.02 1.12 1.18	13025
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 0.23	13100
-0.51-1.57-3.48-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00	13175
-4.15-3.51-3.00-2.54-2.12-1.76-1.50-1.21-0.86-0.49-0.29-0.10 0.92 0.12 0.24	675
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
-1.17-1.40-1.58-2.11-2.47-2.83-3.24-3.59-3.94-5.00-5.00-5.00-5.00-5.00-5.00	600
-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	675
-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

SPECTRAL DATA: UNIFORMLY MIXED GASES

SPECTRAL DATA: OZONE

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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	-1.75	-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	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	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	-0.66	-0.72	-0.78	-0.84	1775	
-0.90	-1.02	-1.14	-1.24	-1.33	-1.47	-1.61	-1.77	-1.92	-1.98	-2.04	-2.08	-2.09	-2.06	-2.03	1850	
-1.98	-1.93	-1.87	-1.82	-1.76	-1.71	-1.65	-1.59	-1.51	-1.44	-1.36	-1.28	-1.18	-1.08	-0.98	1925	
-0.88	-0.78	-0.69	-0.59	-0.49	-0.37	-0.25	-0.18	-0.10	0.00	0.16	0.27	0.38	0.57	0.75	2000	
0.93	1.11	1.20	1.33	1.44	1.46	1.48	1.48	1.64	1.58	1.43	1.23	0.66	0.39	-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	-3.17	-3.26	-3.50	-3.72	-3.34	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	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	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	-0.68	2900	
-0.54	-0.42	-0.27	-0.12	0.03	0.18	0.25	0.31	0.39	0.47	0.48	0.49	0.50	0.50	0.48	2975	
0.46	0.23	0.01	-0.11	-0.33	-0.55	-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	2.00E-03	2.45E-03	3.00E-03	3.70E-03	4.50E-03	5.50E-03	6.80E-03	2000	
2.27E-03	2.73E-03	3.36E-03	3.95E-03	5.46E-03	7.19E-03	9.00E-03	1.13E-02	1.41E-02	1.73E-02	2.10E-02	2.50E-02	2.90E-02	3.30E-02	3.70E-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	3.40E-02	3.65E-02	3.90E-02	4.15E-02	4.40E-02	4.65E-02	4.90E-02	2150	
3.40E-02	3.66E-02	3.92E-02	4.26E-02	4.60E-02	4.95E-02	5.30E-02	5.65E-02	6.00E-02	6.35E-02	6.70E-02	7.05E-02	7.40E-02	7.75E-02	8.10E-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	8.28E-02	8.62E-02	8.96E-02	9.30E-02	9.64E-02	9.98E-02	1.03E-01	2240	
8.08E-02	8.39E-02	8.70E-02	9.13E-02	9.56E-02	1.09E-01	1.20E-01	1.36E-01	1.52E-01	1.68E-01	1.84E-01	2.00E-01	2.16E-01	2.32E-01	2.48E-01	2260	
1.52E-01	1.60E-01	1.69E-01	1.60E-01	1.51E-01	1.37E-01	1.23E-01	1.19E-01	1.15E-01	1.11E-01	1.07E-01	1.03E-01	9.90E-02	9.50E-02	9.10E-02	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	1.16E-01	1.18E-01	1.20E-01	1.22E-01	1.24E-01	1.26E-01	1.28E-01	2360	
1.13E-01	1.12E-01	1.09E-01	1.07E-01	1.02E-01	9.90E-02	9.50E-02	9.10E-02	8.70E-02	8.30E-02	7.90E-02	7.50E-02	7.10E-02	6.70E-02	6.30E-02	2400	
8.65E-02	8.20E-02	7.65E-02	7.05E-02	6.50E-02	6.10E-02	5.50E-02	5.10E-02	4.70E-02	4.30E-02	3.90E-02	3.50E-02	3.10E-02	2.70E-02	2.30E-02	2440	
4.50E-02	4.00E-02	3.75E-02	3.50E-02	3.10E-02	2.65E-02	2.50E-02	2.50E-02	2.50E-02	2.50E-02	2.50E-02	2.50E-02	2.50E-02	2.50E-02	2.50E-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	8.50E-03	8.00E-03	7.50E-03	7.00E-03	6.50E-03	6.00E-03	5.50E-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	3.50E-03	3.25E-03	3.00E-03	2.75E-03	2.50E-03	2.25E-03	2.00E-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	1.50E-03	1.40E-03	1.30E-03	1.20E-03	1.10E-03	1.00E-03	9.00E-04	2600	
1.50E-03	1.50E-03	1.54E-03	1.50E-03	1.47E-03	1.34E-03	1.25E-03	1.16E-03	1.07E-03	9.80E-04	8.90E-04	8.00E-04	7.10E-04	6.20E-04	5.30E-04	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	1.82E-04	1.32E-04	8.20E-05	3.20E-05	-1.80E-05	-6.80E-05	-1.30E-04	2680	
1.94E-04	1.57E-04	1.31E-04	1.02E-04	8.07E-05	6.07E-05	4.07E-05	2.07E-05	1.07E-05	0.07E-05	-0.93E-05	-2.93E-05	-5.93E-05	-8.93E-05	-1.19E-04	2720	
0.23	.187	.147	.117	.097	.087	.10	.120	.147	.174	.20	.24	.28	.33	.00	2350	
4.50E-03	8.00E-03	1.07E-02	1.10E-02	1.27E-02	1.71E-02	2.00E-02	2.45E-02	2.90E-02	3.40E-02	3.90E-02	4.40E-02	4.90E-02	5.40E-02	5.90E-02	1300	
3.07E-02	3.84E-02	4.78E-02	5.67E-02	6.54E-02	7.62E-02	9.15E-02	1.00E-01	1.10E-01	1.20E-01	1.30E-01	1.40E-01	1.50E-01	1.60E-01	1.70E-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	1.18E-01	1.21E-01	1.24E-01	1.27E-01	1.30E-01	1.33E-01	1.36E-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	1.41E-02	1.16E-02	9.10E-03	6.60E-03	4.10E-03	1.60E-03	0.10E-03	10400	
1.03E-01	9.24E-02	8.28E-02	7.57E-02	7.07E-02	6.58E-02	5.56E-02	4.77E-02	3.75E-02	2.73E-02	1.71E-02	6.60E-03	1.50E-03	3.10E-04	6.20E-05	17800	
1.17E-02	7.70E-03	6.10E-03	8.50E-03	6.10E-03	3.70E-03	3.20E-03	2.70E-03	2.20E-03	1.70E-03	1.20E-03	7.00E-04	2.00E-04	5.00E-05	1.00E-05	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	0.00E-04	0.00E-04	0.00E-04	0.00E-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	9.00E-01	1.38E+01	2.00E+01	2.80E+01	3.80E+01	5.00E+01	6.50E+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	9.00E+01	1.38E+02	2.00E+02	2.80E+02	3.80E+02	5.00E+02	6.50E+02	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	3.02E+02	3.02E+02	3.02E+02	3.02E+02	3.02E+02	3.02E+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	1.20E+02	1.00E+02	8.00E+01	6.00E+01	4.00E+01	2.00E+01	0.00E+01	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	1.50E+01	1.00E+01	6.00E+00	3.00E+00	1.00E+00	0.00E+00	0.00E+00	43500	
1.57E+01	1.20E+01	1.00E+01	8.80E-00	8.30E-00	8.60E-00	9.00E-00	9.50E-00	1.00E-00	1.00E-00	1.00E-00	1.00E-00	1.00E-00	1.00E-00	1.00E-00	47500	

SPECTRAL DATA: OZONE

N<sub>2</sub> CONTINUUM

H<sub>2</sub>O

OZONE UV & VISIBLE

