

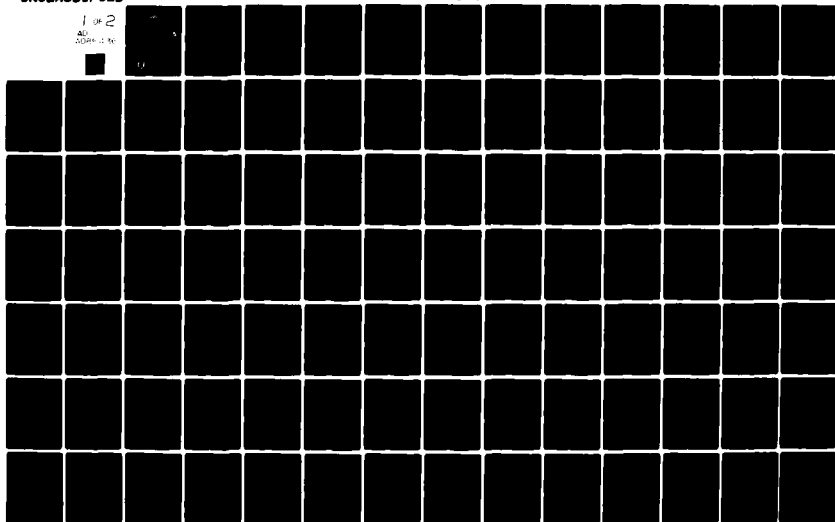
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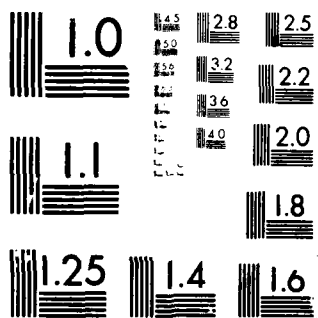
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COMPUTERIZED METHOD FOR THE GENERATION OF MOLECULAR
TRANSMITTANCE FUNCTIONS IN THE INFRARED REGION

APRIL 1980

Prepared by

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with an assumed analytical transmittance function, using the same type of data. Computerized numerical techniques are presented in connection with the first method and a generalized transmittance function is adopted for the second method. Although the methodology is generally applicable to other gaseous species, it is specifically discussed in connection with the trace gases SO_2 , NO , NO_2 , and NH_3 . As a secondary effort a structural breakdown of the Lowtran code is presented for the purpose of incorporating the band models for the trace gases. The code is separated into basic functional modules or subroutines controlled by a main program. The modularization itself was primarily performed under a separate effort through the Atmospheric Sciences Laboratory.

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I. Introduction

Following the efforts of Elsasser¹ numerous workers have attempted to arrive at computationally-simple models for gaseous molecular transmittance, averaged over narrow spectral intervals in the infrared. These efforts may be naturally divided into those involving the analytical derivation of a mean transmittance function from Beer's Law, and those involving the extraction of the transmittance function itself from transmittance data. Traditionally, the former are called "analytical" and the latter are called "empirical". The method normally used in the empirical models consists of the extraction of the transmittance function through graphical techniques, with the adoption of a relationship between spectral and absorber parameters. In the development of analytical models a transmittance function is adopted at the offset, and the spectral and absorber parameters are afterward determined through computerized numerical procedures.

In the work reported here the authors present a totally computerized version of the classical graphical methods for the extraction of the empirical transmittance function. This is followed by a presentation of a numerical method which uses a double-exponential transmittance function for the development of analytical band models. Both methods are then applied to 20 cm^{-1} averaged line-by-line

transmittance data for the atmospheric trace gases SO_2 , NO , NO_2 , and NH_3 . The model parameters are listed at 5 cm^{-1} intervals throughout the major absorption bands of these gases for the convenience of the community of band model users. Although the methodology is applied specifically to the trace gases, no restrictions are immediately evident in the extension to other gaseous absorbers in the infrared. In fact, the analytical method was successfully applied earlier² to the principal band centers of the major absorbers H_2O vapor, O_3 and the uniformly-mixed gases.

As an application of the results found through this effort, the band models for the trace gases were incorporated in the widely-used code called Lowtran. To facilitate the inclusion of these models, as well as of others, the code was broken down into separate subroutines or modules controlled by a master program. The subroutines include the evaluation of the equivalent absorber amount, the selection of the spectrally-effective attenuation model and the individual attenuation models. The principal purpose of the modularization is to assist users with the modification of the code to suit their individual requirements on transmission models.

II. The Transmittance Equation

The monochromatic transmittance τ_ν at frequency ν for the passage of infrared radiation through a path length Z in an inhomogeneous medium with pressure and temperature distributions $P(Z)$ and $T(Z)$, respectively, is given by Beer's Law in the form

$$\tau_\nu = e^{-\int K_\nu(P,T) dU(Z)} \quad (1)$$

where K_ν is the resultant absorption coefficient for all contributing lines and gaseous absorbers, and U is the absorber amount. For broadband radiation detected by an instrument of spectral response ϕ_ν , the variable of interest is the weighted mean transmittance τ , defined as

$$\tau = \int \tau_\nu \phi_\nu d\nu / \int \phi_\nu d\nu \quad (2)$$

Equation (2) has been evaluated analytically over a spectral interval $\Delta\nu$ for the special case of Lorentzian broadened lines having assumed line distributions and intensities, leading to the classical band models^{1,3}. Numerous variations of the classical band models may be found in the literature, most of which specify the analytical form of τ in terms of mean line or meteorological variables. A notable exception is the model of King⁴ which expresses the homogeneous-path transmittance as

$$\tau = g(S\alpha^n U), \quad (3)$$

where g is a function to be determined empirically, S is the mean line intensity, α is the mean line half-width and n is an absorber parameter with the physical constraints of zero and one in the weak-line and strong-line limits, respectively. The path inhomogeneity may be accounted for in Eq. (3) through the Curtis-Godson equivalences

$$S\alpha^n U = \int S(Z)\alpha^n(Z)dU(Z). \quad (4)$$

From practical considerations, it is often desirable to transform the argument in Eq.(3) with the known relations

$$S = S_o \left(\frac{T_o}{T}\right)^a \quad (5)$$

$$\alpha = \alpha_o \left(\frac{P}{P_o}\right) \left(\frac{T_o}{T}\right)^{\frac{1}{2}} \quad (6)$$

in order to obtain

$$\tau = g \left\{ C \left(\frac{P}{P_o}\right)^n \left(\frac{T_o}{T}\right)^m U \right\}, \quad (7)$$

where C is a spectral parameter combining S_o and α_o^n , m is an absorber parameter combining the temperature exponents of S and α , a is an absorber constant, and the subscript "o" denotes standard conditions. For computational convenience Eq. (7) may be expressed as

$$\tau = f\{x\}, \quad (8)$$

where

$$x = C' + \log_{10} W \quad (9)$$

$$C' = \log_{10} C \quad (10)$$

$$W = \left(\frac{P}{P_0} \right)^n \left(\frac{T_c}{T} \right)^m U \quad (11)$$

Here, f is the transmittance function, C' is the spectral parameter, W is the equivalent absorber amount, and n and m are the absorber parameters; all of which are to be determined from transmittance data for each absorber.

III. Computerized Method of Empirical Model Development

3.1 Introduction

Assuming the availability of equal transmittance data, which is defined below, we have developed an algorithm, called ADSET, which evaluates absorber parameters n , m , spectral parameters $C'(\nu)$ and an empirical transmission function simultaneously. In the algorithm the transmission function is linearized and a linear regression technique is utilized for parameter evaluation. In order to evaluate the band model parameters and the empirical transmission function simultaneously, a set of auxiliary variables are introduced. Each data point is identified through the auxiliary variables to an absorption band and to a transmittance 'cut'. This enables us to obtain globally optimal set of parameters and the empirical transmission function simultaneously.

Based on the derived optimal pointwise transmission function, a piecewise analytical transmission function is developed. The commonly used computer code Lowtran for the evaluation of atmospheric transmittance can be greatly simplified by the use of this piecewise analytical transmission function to model the major absorbers.

Finally, the code ADSET also contains a subroutine which can compute the spectral parameter value $C'(\nu)$ for non-major absorption bands.

3.2 Data Structure

Several transmittance values τ_j , $j=1, 2, \dots, \text{NCUT}$ are chosen a priori, where NCUT is the number of chosen transmittance values. Curves of growth data (i.e. τ versus U) for each layer of atmosphere are assumed to be given at these transmittance values. Therefore, the curves of growth have 'cut' structure, namely, all data points are on one of the transmittance cuts $\tau = \tau_j$, $j=1, 2, \dots, \text{NCUT}$ (See Fig. 1). We call a data set with this cut structure an 'equal transmittance' data in the sequel.

3.3 Linearization of Transmission Function

Since f in Eq.(8) is known to be strictly monotone decreasing from one to zero as x changes from $-\infty$ to ∞ , there exists an inverse function f^{-1} defined on $(0,1)$ such that

$$\begin{aligned} x &= f^{-1}(\tau) \\ &= C' + \log W \\ &= C' + n \log\left(\frac{P}{P_0}\right) + m \log\left(\frac{T_0}{T}\right) + \log U. \end{aligned} \quad (12)$$

Let us define x_j , $j=1, 2, \dots, \text{NCUT}$ be the inverse image of the prechosen transmittance values τ_j , $j=1, 2, \dots, \text{NCUT}$ i.e.,

$$x_j = f^{-1}(\tau_j), \quad j=1, 2, \dots, \text{NCUT}. \quad (13)$$

i-th BAND

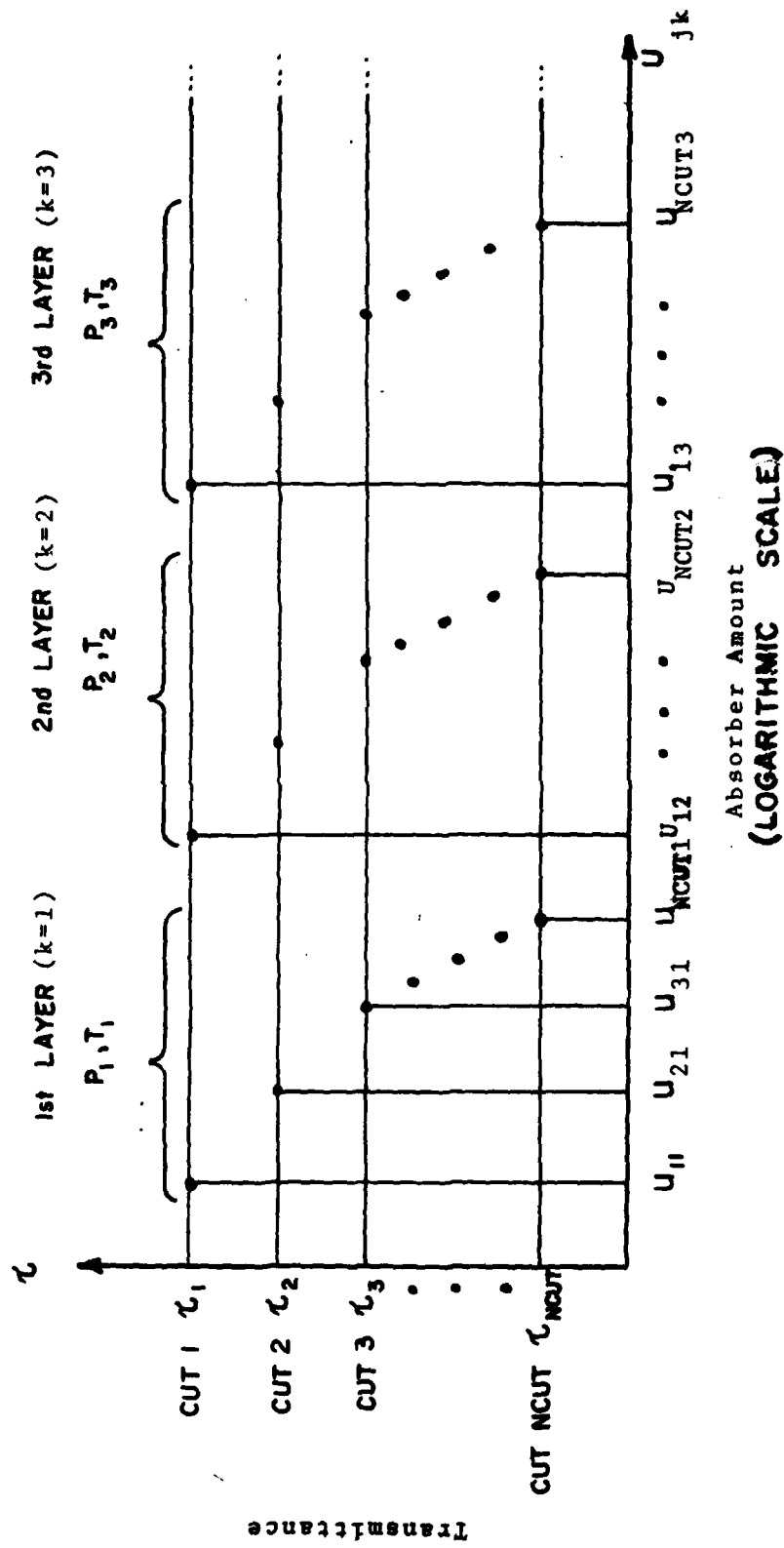


Fig. 1. Schematic representation of "equal transmittance" data structure.

Then, the set of points (x_j, τ_j) , $j = 1, 2, \dots, \text{NCUT}$ is nothing but the empirical transmission function, which is to be found. From Eq. (12), we reach the following regression equation.

$$n \log\left(\frac{P}{P_0}\right) + m \log\left(\frac{T_0}{T}\right) + C' - x = -\log U. \quad (14)$$

Note that this equation is linear in the unknown parameters n , m , C' and x . Therefore, the linear regression technique can be used to evaluate the optimum values for the parameters.

3.4 Formation of the Square Error

The square error corresponding to the k -th data point in i -th absorption band's j -th cut, denoted by E_{ijk} , is given by

$$E_{ijk} = \left\{ n \log\left(\frac{P_{ijk}}{P_0}\right) + m \log\left(\frac{T_0}{T_{ijk}}\right) + C'_i - x_j - (-\log U_{ijk}) \right\}^2 \quad (15)$$

Hence, the total square error E_{ij} for this cut is

$$E_{ij} = \sum_{k=1}^{L_{ij}} E_{ijk}, \quad (16)$$

where L_{ij} is the number of layers in this cut. Similarly, the total square error E_i for i -th band and the grand total square error E are given by

$$E_i = \sum_{j=1}^{J_i} E_{ij} = \sum_{j=1}^{J_i} \sum_{k=1}^{L_{ij}} E_{ijk}, \quad (17)$$

$$E = \sum_{i=1}^{NB} E_i = \sum_{i=1}^{NB} \sum_{j=1}^{J_i} \sum_{k=1}^{L_{ij}} E_{ijk}, \quad (18)$$

where J_i and NB are the numbers of the cuts in i -th absorption band and of the absorption bands, respectively. The final expression can be simplified if we assume that the number of layers (L_{ij}) in every cut is equal to a constant L_i . For this case

$$E = \sum_{i=1}^{NB} \sum_{j=1}^{J_i} \sum_{k=1}^{L_i} E_{ijk}. \quad (19)$$

Our objective is to find optimum set of parameters (n^* , m^* , C'_1 , C'_2 , ..., C'_{NB} , x_1 , x_2 , ..., x_{NCUT}) which minimizes this grand total error E .

3.5 Auxiliary Variables

In order to perform the minimization of E with respect to the above parameters simultaneously, we modify the square error E_{ijk} so that it contains all the parameters. This is done by introducing two sets of auxiliary variables u_i , $i=1, 2, \dots, NB$ and v_j , $j=1, 2, \dots, NCUT$. Using them, E_{ijk} is redefined as

$$E_{ijk} = \left\{ n \log \left(\frac{P_{ijk}}{P_o} \right) + m \log \left(\frac{T_o}{T_{ijk}} \right) + u_{1,ijk} C'_1 + \dots + u_{NB,ijk} C'_{NB} + v_{1,ijk} K_1 + \dots + v_{NCUT,ijk} K_{NCUT} - (-\log U_{ijk}) \right\}^2 \quad (20)$$

where $K_j = -x_j$, $j=1, 2, \dots, \text{NCUT}$. The auxiliary variables act as identifiers of the band and the cut. If a data point is for i -th band's j -th cut, then $u_i = 1$ and $u_i = 0$ for all $i \neq i$ and $v_j = 1$ and $v_j = 0$ for all $j \neq j$. Thus, only the spectral parameter C'_j and the cut parameter K_j corresponding to the current data are active and all other spectral and cut parameters disappear. Hence, Eq. (20) reduces to Eq. (15). The change from x_j to $K_j = -x_j$ is made in order to symmetrize the coefficient matrix of the resulting normal equation. This change makes it possible to utilize any specialized solution method for the symmetric normal equation when the space conservation is important.

3.6 Regression Analysis

Using the grand total error E with the redefined E_{ijk} in Eq. (20), the best parameter values n^* , m^* , $C'_1{}^*$, ..., $C'_{\text{NB}}{}^*$, $K_1{}^*$, ..., $K_{\text{NCUT}}{}^*$ are simultaneously determined by the linear regression. Setting the partial derivatives of E with respect to parameters equal to zero results in a linear normal equation of the form $AX = B$, where A , B and X are, respectively, a symmetric coefficient matrix, a constant vector and a parameter vector defined by

$$A = \begin{bmatrix} \begin{matrix} \Sigma v^2_{\text{NCUT}} & & \\ & \circ & \\ & \cdot & \\ \circ & \cdot & \Sigma v^2_1 \end{matrix} & * & * \\ * & \begin{matrix} \Sigma u^2_{\text{NB}} & & \\ & \circ & \\ & \cdot & \\ \circ & \cdot & \Sigma u^2_2 \end{matrix} & * \\ * & * & \begin{matrix} \Sigma (\log \frac{T}{T^0})^2 & * \\ * & \Sigma (\log \frac{P}{P_0})^2 \end{matrix} \end{bmatrix} \quad (21)$$

$$B = \left[\Sigma(-v_{NCUT} \log U), \dots, \Sigma(-v_1 \log U), \Sigma(-u_{NB} \log U), \dots, \right. \\ \left. \Sigma(-u_2 \log U), \Sigma(-\log(\frac{T_o}{T}) \log U), \Sigma(-\log(\frac{P}{P_o}) \log U) \right]^t, \quad (22)$$

$$X = \left[K_{NCUT}, \dots, K_1, C'_{NB}, \dots, C'_2, m, n \right]^t \quad (23)$$

The * in Eq. (21) represents some nonzero elements. Also the Σ in the above equations represents the triple sum $\sum_{i=1}^{NB} \sum_{j=1}^{J_i} \sum_{k=1}^{L_i}$ in Eq. (19). One may realize that C'_1 does not appear in Eq. (23) and hence the corresponding auxiliary variable u_1 is also absent from Eqs. (21) and (22). This is because one of $C'_1, \dots, C'_{NB}$ is dependent on other C'_i so that $C'_1, \dots, C'_{NB}$ cannot be determined uniquely. It is necessary that one of C'_i s be given a number *a priori*. Here C'_1 is chosen and is given the value zero, and therefore is eliminated from the parameter vector X . This choice calls for some explanation. On τ vs. $\log W$ diagram the optimum empirical transmission function can be placed anywhere. What it amounts to is that a different placement results in a different set of C'_i values which is a linear shift (addition or subtraction of a constant) of another set of C'_i values. Only the relative relationship among C'_i is unique. This is clearly indicated in Fig. 2.

Since the placement of the empirical transmission function is arbitrary, we may position it on the data points corresponding to the first absorption band. In other words, the first absorption band is taken as the

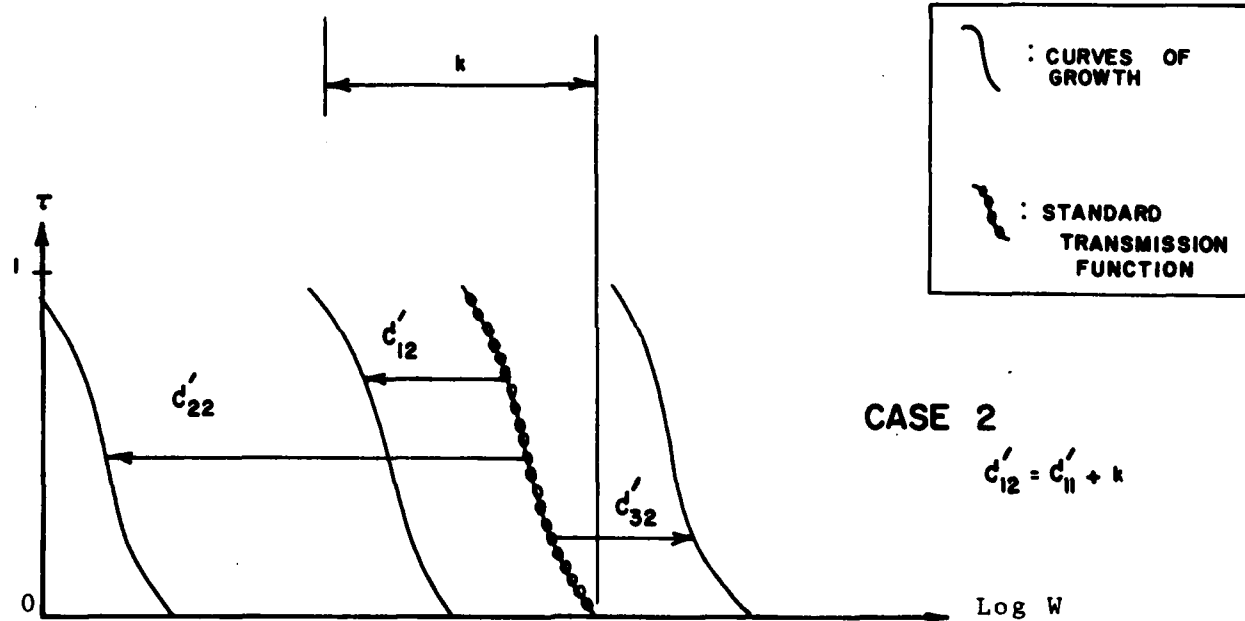
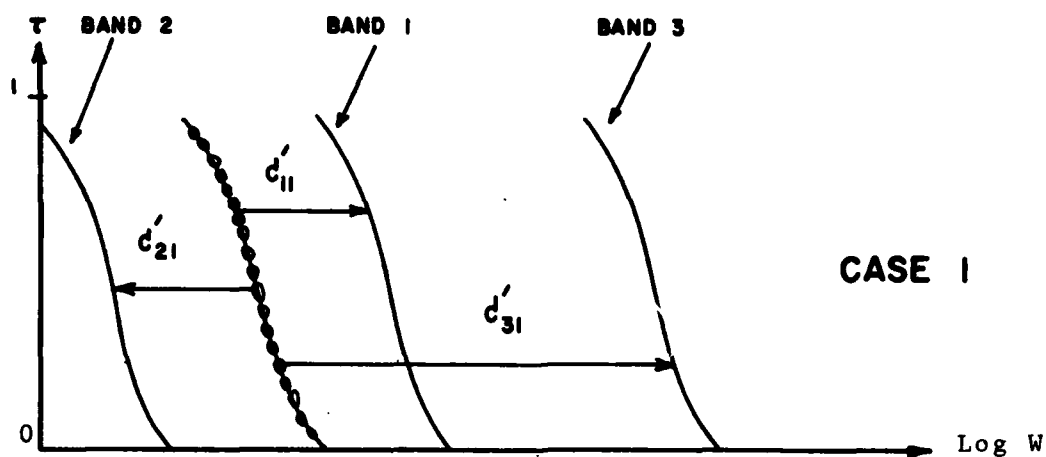


Fig. 2. Schematic representation of linear shift accounting for spectral dependence of transmittance.

reference band and the corresponding spectral parameter C_1' is set to be zero.

The queuing of parameters in X vector is determined in such a way that as many upper principal minor matrices as possible become diagonal (See Eq. (21)). This arrangement can reduce the amount of computation in the early stage of Gauss elimination steps when the normal equation is solved, and can result in less computational error.

3.7 Piecewise Analytical Transmission Function

After the best parameter values are computed, the piecewise analytical transmission function is generated by the piecewise interpolation. The transmittance region $(0,1)$ is divided into $NCUT - 1$ subregions by the transmittance cuts $\tau_2, \tau_3, \dots, \tau_{NCUT-1}$. Let $\tau_1 > \tau_2 > \dots > \tau_{NCUT}$, then the subregions are given by

Subregion 1	$[\tau_2, 1)$,
Subregion 2	$[\tau_3, \tau_1]$,
.	.
.	.
.	.
Subregion $NCUT-2$	$[\tau_{NCUT-1}, \tau_{NCUT-2}]$,
Subregion $NCUT-1$	$(0, \tau_{NCUT-1}]$.

The top and bottom subregions contain τ_1 and τ_{NCUT} as an inner point, respectively. The interpolation in each

subregion is done by the double exponential function defined by

$$\tau(x) = \exp \{-10^{a_1 + a_2 x + a_3 x^2}\}. \quad (24)$$

The generally-used linear interpolation is not used here since subregions cannot be assumed small enough for the linear approximation to be valid. Furthermore, the linear interpolation is totally inadequate for the top and bottom subregions. On the other hand, the double exponential function takes the values between and is asymptotic to one and zero as the argument varies from $-\infty$ to ∞ . It is also known that this function closely approximates the standard empirical transmission function used in the Lowtran code.^{2,16}

The parameters a_1 , a_2 , and a_3 for each subregion are determined by two different methods. The first method assumes that $a_3 = 0$ and uses no further data to compute a_1 and a_2 . They are simply determined by the condition that the interpolation function in each subregion passes through the end points. In the top and bottom subregions, the function is required to pass through two points; (τ_1, x_1) and (τ_2, x_2) for the top and $(\tau_{\text{NCUT}-1}, x_{\text{NCUT}-1})$ and $(\tau_{\text{NCUT}}, x_{\text{NCUT}})$ for the bottom subregions.

The second method does not assume that $a_3 = 0$ and requires additional data to compute parameter values. The same condition that each interpolation function passes

through two points reduces the number of unknown parameters to one. The last parameter is determined by minimizing the subregional square error E_i defined by

$$E_i = \sum_{j=1}^{L_i} (\tau_{ij} - \exp \{-10^{a_1 + a_2 x_{ij} + a_3 x_{ij}^2}\})^2 \quad (25)$$

for those data points in respective subregions.

3.8 C' for Non-major Bands

Finally, the spectral parameters C' for non-major bands are computed by a straightforward method. The discrepancies between x_{ij}^* and $\log W_{ij}$ values computed for all cuts for one band are averaged to obtain the spectral parameter $C'(v)$ for that band, i.e.,

$$C' = \frac{1}{N} \sum_{i=1}^N (x_i^* - \log W_i), \quad (26)$$

where W_i are computed by Eq. (11) with optimal n^* and m^* .

IV. Computerized Method of Analytical Model Development

4.1 Introduction

In the last chapter, we assumed no analytical form for the transmission function $\tau = f(x)$ when the standard transmission function was computed. Here, by assuming the double exponential form given by Eq. (24) as the transmission function for the entire transmittance range, we derive an algorithm which can evaluate the best function parameter values a_1 , a_2 , and a_3 ; together with the band model parameters n , m , and C'_1 . Note that the double exponential function was used for the piecewise interpolation in the last chapter. But the computation of the function parameters was performed after the band model parameters and the empirical transmission function were obtained. In other words, the computation in the last chapter was sequential but not simultaneous. The algorithm we present in this chapter is, on the contrary, the simultaneous evaluation of all parameters. The preliminary development of this algorithm can be found in Ref. 5.

4.2 Basic Equations

The basic equations are Eq. (8) and Eq. (24) of the last chapter, which are cited here for the ease of reference.

$$\tau = f(x) \quad (27)$$

$$f(x) = \exp \{-10^{a_1 + a_2 x + a_3 x^2}\}. \quad (28)$$

Now, since we have assumed the function form, we can compute the transmittance if we have the value of x . Hence, we do not have to take the inverse function as we did before to perform the regression analysis. Instead, we take the square difference of the given and computed τ directly from this expression. Thus, we get

$$E_{ij} = [\tau_{ij} - \exp\{-10^{a_1 + a_2 x_{ij} + a_3 x_{ij}^2}\}]^2, \quad (29)$$

for i -th absorption band's j -th data point, where, as before, x_{ij} is given by

$$x_{ij} = C'_i + n \log\left(\frac{P_{ij}}{P_o}\right) + m \log\left(\frac{T_o}{T_{ij}}\right) + \log U_{ij}. \quad (30)$$

By summing this individual error for all data in i -th band, we have the total error for this band as

$$E_i = \sum_{j=1}^{J_i} E_{ij}, \quad (31)$$

where J_i is the number of data in i -th band.

Again, we introduce auxiliary variables u_i , $i=1,2,\dots,NB$ in order to introduce all C'_i , $i=1,2,\dots,NB$ into the x_{ij} expression Eq.(30). By this we get

$$x_{ij} = \sum_{k=1}^{NB} u_{k,ij} C'_k + n \log\left(\frac{P_{ij}}{P_o}\right) + m \log\left(\frac{T_o}{T_{ij}}\right) + \log U_{ij}, \quad (32)$$

We use this expression for x_{ij} in the following total error E

$$E = \sum_{i=1}^{NB} E_i = \sum_{i=1}^{NB} \sum_{j=1}^J E_{ij}. \quad (33)$$

Now, we are ready to take partial derivatives with respect to the parameters n , m , C_1^i , ..., C_{NB}^i , a_1 , a_2 , and a_3 to form the normal equation for this regression problem. Theoretically speaking, we can evaluate the 'best' parameter values by solving the normal equation. But obviously the grand total Eq. (33), which is to be minimized, is not a quadratic function of the unknown parameters and, therefore, the resulting normal equation is not a linear function of them. Hence, we need to adopt a different numerical method for the evaluation of the 'optimal' parameter values.

4.3 Nonlinear Optimization Method

The computational technique we use here is a recursive technique which is referred to as the conjugate gradient method¹⁷. In essence, this technique improves a set of guesses of the parameter values recursively by locating a new set of guesses which yields smaller error. For a given guess $(\alpha^n, \beta^n, \dots, \gamma^n)$ of the minimizing parameter vector, at which the error is minimized, the best direction of the search in the parameter space for a new guess is first determined using up to second order derivatives of the error. Then the one-dimensional search for the minimizing point is performed along this direction from $(\alpha^n, \beta^n, \dots, \gamma^n)$ to find a new guess $(\alpha^{n+1}, \beta^{n+1}, \dots, \gamma^{n+1})$.

which yields locally the smallest error. Now this procedure is repeated recursively to obtain a sequence of guesses until the gradients become less than a small positive number which is chosen *a priori*.

Actual computation was done by utilizing the packaged subroutine FMCG in SSP library available from IBM¹⁸. The necessary gradients are

$$\begin{aligned}
 \frac{\partial J}{\partial a_1} &= -2 \sum D_j \delta f_j, \\
 \frac{\partial J}{\partial a_2} &= -2 \sum D_j \delta f_j x_j, \\
 \frac{\partial J}{\partial a_3} &= -2 \sum D_j \delta f_j x_j^2, \\
 \frac{\partial J}{\partial n} &= -2 \sum D_j \delta f_j (a_2 + 2a_3 x_j) \log\left(\frac{P_j}{P_o}\right), \\
 \frac{\partial J}{\partial m} &= -2 \sum D_j \delta f_j (a_2 + 2a_3 x_j) \log\left(\frac{T_o}{T_j}\right), \\
 \frac{\partial J}{\partial C'_1} &= -2 \sum D_j \delta f_j (a_2 + 2a_3 x_j) u_1,
 \end{aligned} \tag{34}$$

where, Σ represents $\sum_{i=1}^{NB} \sum_{j=1}^{J_1}$ and D_j and δf_j are given by

$$D_j = \{E_{ij}\}^{\frac{1}{2}}, \tag{35}$$

$$\delta f_j = (\ln 10) 10^{a_1 + a_2 x_j + a_3 x_j^2} f(x_j), \quad (36)$$

and $f(x)$ is given by Eq. (28).

Note that there exists a linear dependence among the gradients which is

$$a_2 \frac{\partial J}{\partial a_1} + 2a_3 \frac{\partial J}{\partial a_2} = \sum_{i=1}^{NB} \frac{\partial J}{\partial C_i'} \quad (37)$$

Therefore, the parameter set $\{n, m, C_1', \dots, C_{NB}', a_1, a_2, a_3\}$ cannot be determined uniquely. As it was explained in the previous section, this is due to the arbitrariness in the positioning of the standard transmission function. Hence, the spectral parameter C_1' is again set to be zero, so that we can evaluate unique set of optimal parameters.

V. Comparison of the Two Methods

5.1 Introduction

Both methods can evaluate the optimal n , m and $C'(v)$ values for major and non-major bands and also a standard transmission function. But there are some basic differences which are discussed in the sequel.

5.2 Final Products

The final product of the ADSET code is a piecewise analytical standard transmission function together with the band model parameters. Each analytical piece of the standard transmission function covers only one of the pre-chosen subintervals of $(0,1)$ transmittance range. On the other hand, SIMMIN produces only one analytical transmission curve for the entire range. Therefore, ADSET has more flexibility to adjust to the transmittance curve variations. This feature of ADSET can be very valuable for the gases with non-standard curves of growth.

This difference is amplified when the number of the transmittance sub-regions used in ADSET is increased. However, as the number of subregions increase, the requirement on the usable data becomes severer and more spaces are necessary to store the computed results. Hence, the determination of the number of subregions should be resorted to compromise.

5.3 Installation of the Results in Lowtran

The final products of two codes ADSET and SIMMIN were installed in the widely-used Lowtran code, as discussed in Section VII of this report. The SIMMIN results require less memory space, less time for transmittance computation and simpler coding than the ADSET result. In fact, for the SIMMIN result, all that have to be stored are the five band model parameters n , m , a_1 , a_2 , and a_3 , and a set of spectral parameters $C'(\nu_1)$ for each absorber. Furthermore, the computation of τ can be done by only one FORTRAN statement. On the other hand, the ADSET result requires the storage of NCUT-1 of a_1 , a_2 , and a_3 values, n and m and a set of $C'(\nu)$ values for each absorber. There can be a large difference in the number of the sets of a_1 , a_2 , and a_3 values to be stored. Moreover, some judging statements are necessary to select the right set of a_1 , a_2 , and a_3 for each transmittance computation.

5.4 Data Requirements

The ADSET code requires the cut structured data such that the transmittance of each data point must fall in one of prechosen values. But the SIMMIN code does not impose any conditions on the data set.

Some considerations on the requirement of equal transmittance data for ADSET are due here. Even if the available data do not have equal transmittance structure,

it can be transformed into the required form using interpolation/extrapolation. This constitutes the pre-processing of the raw data. Curves of growth data τ vs. $\log U$ with τ values not necessarily coinciding with the prechosen values can be locally interpolated/extrapolated using an analytical function. This procedure is indicated in Fig. 3. Again, the double exponential function is an excellent choice for the interpolation function. We note that an almost exact technique as the one used in obtaining a piecewise analytical transmission function can be used for this purpose. In fact, only a minor modification of the interpolation subroutine used in ADSET can accomplish this task.

5.5 Computation Time

The numerical methods used in ADSET and SIMMIN for solving normal equations are essentially different. The method in SIMMIN is a recursive algorithm and the other in ADSET is a non-iterative one. Therefore, the computation time for ADSET is determined by the size of the data set only, whereas, the one for SIMMIN depends on both the actual data values and the initial guesses. It is difficult to estimate the computation time for SIMMIN due to this dependence. One way of controlling the time is to limit the number of iterations performed. This feature is included in the packaged subroutine FMCG which is used for actual

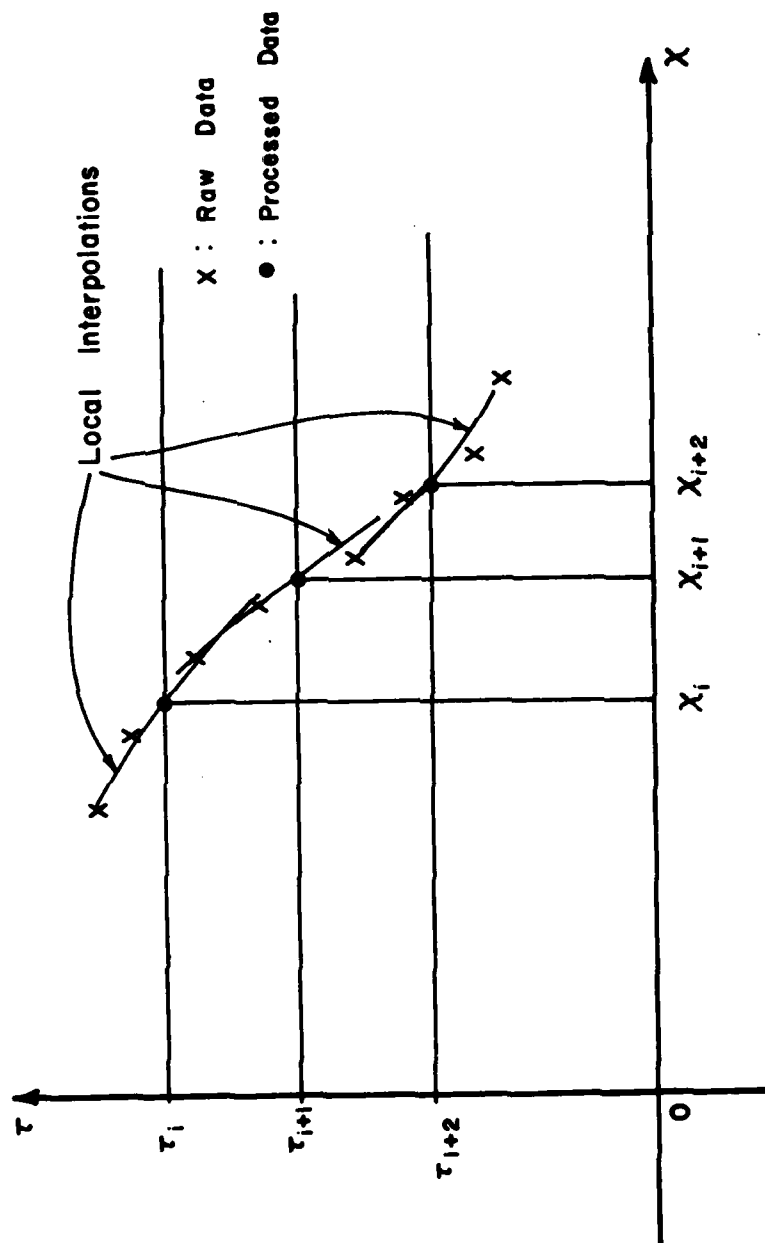


Fig. 3. Pre-processing of Data
 (τ_j, x_j) , and the derived equal transmission data.

computations. Actual time ranges required for ADSET and
SIMMIN computations will be given in a later section.

VI. Lowtran Capabilities and Functions

6.1 Introduction

The Lowtran code consists of a computer model for the calculation of transmittance through atmospheres containing absorbing and scattering molecules and aerosols. The models used in the code were for the most part developed in 1972⁶ but later editions incorporated computational changes and other capabilities⁷⁻¹⁰. It covers the spectral range from 0.25 to 28.5 μm at intervals of 5 cm^{-1} with a resolution for the major absorbers of 20 cm^{-1} . The transmittance calculation is made on six model atmospheres and two haze models on a 33-level basis for altitude, pressure, temperature and density from sea-level to 100 km. The path of the transmission is considered to be refracted by changes in atmospheric density, a fact taken into account in an optional subroutine. In its present form the Lowtran code consists of a single main program that inputs the path data and model parameters, computes the equivalent absorber amount, and performs the transmittance calculations. The only present subroutines are associated with the path, and are optional. The difficulties of understanding and, especially, updating such a program structure are considerable.

The principal objective of this effort is to modify the program structure of the Lowtran code in accordance

with the following criteria:

1. The basic functions, calculations and print-outs remain nearly identical to the original.
2. The basic operations involving the reading of data, the calculation of the equivalent path and the transmittance calculations are all separate, independent programs, but are connected as subroutines to a main control program.
3. The structure modification is performed on the latest version of the code, i.e., Lowtran 4.

As an exercise in the use of the modularized version, the present authors added empirical band models for transmittance through the trace gases. Also, continuous functions were made to replace their transmission tables for the principal molecular absorbing species.

6.2 General Features

In this section an effort is made to summarize the basic structure, fundamental calculations and models used in the Lowtran code for estimating atmospheric attenuation by gases and aerosols. Reference is specifically made to the latest fourth version, although at the present time the authors are aware of a recent effort by AFGL on a fifth version. From the authors' evaluation of their recent efforts, it appears that the modularization presented here may be incorporated in their latest version. For instance, the latter is known to have a single separate subroutine for the emission and transmission calculations. The major contribution of the work presented here lies in the separation of that emission and transmission loop into a subroutine for model selection, a subroutine for the equivalent path and individual subroutines for all of the attenuation models in the code.

The Lowtran code is designed for the specific purpose of calculating at low resolutions either atmospheric radiance or transmittance between any two locations in the Earth's atmosphere at frequencies ranging from the ultraviolet (UV) to the infrared (IR). This is accomplished through the use of band models accounting for

resonant gaseous absorption (e.g. H_2O vapor, O_3 , HNO_3 vapor and the uniformly-mixed gases), resonant aerosol absorption, non-resonant gaseous absorption (e.g. N_2 and H_2O vapor continua) and scattering by molecules and aerosols. The spectral intervals over which the band models are provided vary from 5 cm^{-1} to 500 cm^{-1} , as shown in Table 1. It should be pointed out that the spectral resolution is generally much lower than the interval over which they are defined. For instance, the models for the principal absorbers are given at 5 cm^{-1} intervals, while their spectral resolution is 20 cm^{-1} . The spectral resolutions for the remaining models is not specified anywhere in the available literature on the code. In this table the spectral definition of the models for aerosol absorption, and for aerosol and molecular scattering are not shown because they are spectrally continuous.

The spectral regions over which the attenuation models are effective are summarized in Table 2. It may be seen in this table that over some regions only a few species attenuate and, therefore, a transmittance of unity may be specified in the calculation of the total transmittance. This table forms the basis for the model selection subroutine introduced in the modularized version for the purpose of simplifying the code structure.

In the discussion that follows, the individual

ATTENUATING SPECIES	MODEL FREQUENCY INTERVAL (cm ⁻¹)			
	5	50	200	500
H ₂ O				
UNIFORMLY- MIXED GASES				
O ₃				
N ₂ CONTINUUM				
H ₂ O CONTINUUM				
HNO ₃				
VISIBLE O ₃				
ULTRA VIOLET O ₃				

Table 1. Frequency interval of the attenuation band models in the Lowtran code. The models for aerosol absorption and aerosol and molecular scattering are spectrally continuous and, therefore, not shown.

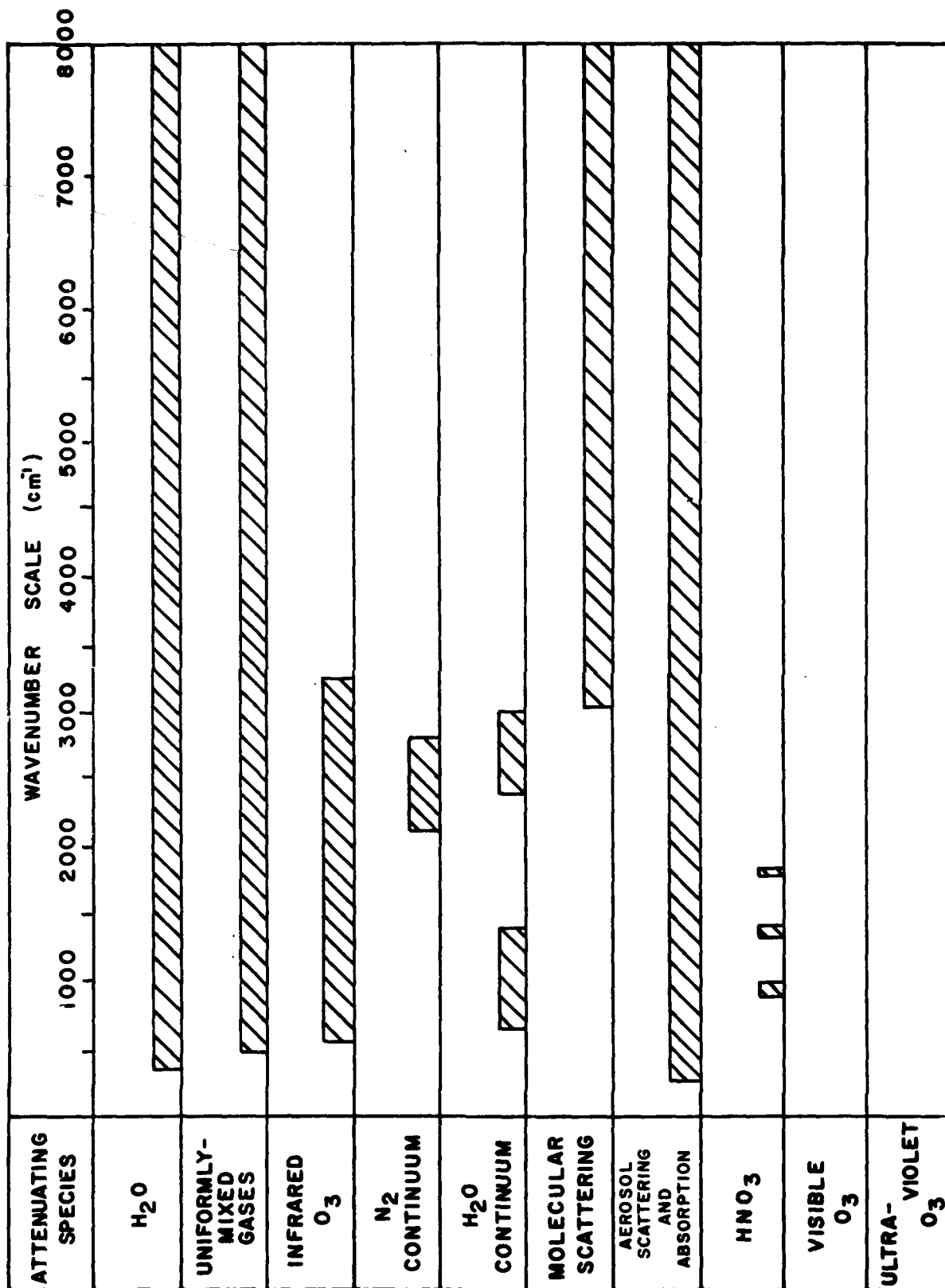


Table 2. Spectral region over which the attenuation models in LOWTRAN are effective.

ATTENUATING SPECIES	WAVENUMBER SCALE (cm ⁻¹)
H ₂ O	9000 10000 11000 12000 13000 14000 15000 16000
UNIFORMLY-MIXED GASES	
INFRARED O ₃	
N ₂ CONTINUUM	
H ₂ O CONTINUUM	
MOLECULAR SCATTERING	
AEROSOL SCATTERING AND ABSORPTION	
HNO ₃	
VISIBLE O ₃	
ULTRA-VIOLET O ₃	

Table 2. (Continued)

ATTENUATING SPECIES	WAVENUMBER SCALE (cm ⁻¹)
H ₂ O	50000 45000 40000 35000 30000 25000 20000
UNIFORMLY-MIXED GASES	
INFRARED O ₃	
N ₂ CONTINUUM	
H ₂ O CONTINUUM	
MOLECULAR SCATTERING	
AEROSOL SCATTERING AND ABSORPTION	
HNO ₃	
VISIBLE O ₃	
ULTRA-VIOLET O ₃	

Table 2. (Continued)

attenuation models are grouped together in certain classes and are briefly discussed. Generally speaking, the discussion is restricted to the extent of illustrating the function and parameters which had to be identified in Lowtran for the modularization purpose that followed. An exception is made in the case of the major molecular absorption models (i.e. H_2O vapor, infrared O_3 and the uniformly-mixed gases) because they are replaced with continuous functions in the modularized version. For a comprehensive discussion on the theory of all of the original models the reader is encouraged to study the series of AFGL reports⁶⁻¹⁰ on the code, as well as the references therein.

6.3 Resonant Molecular Absorption Models

Molecular resonant absorption is modeled in the code for H_2O vapor, infrared O_3 , the uniformly-mixed gases, and HNO_3 vapor. Different approaches are used for the first three listed as compared with the approaches used in connection with O_3 in the visible and ultraviolet regions and with HNO_3 vapor in the infrared.

The models used to account for gaseous absorption by the molecules of H_2O vapor, infrared O_3 , and the uniformly-mixed gases are based on Eq.(8), namely

$$\tau = f(x). \quad (8)$$

The developers of Lowtran obtained the parameters n , m , the function f and the spectral constant C' at 5 cm^{-1} intervals using experimental and calculated transmittance data of 20 cm^{-1} resolution. Table 3 shows the values of the parameters, as well as, the equations for the calculation of the absorber amount. The spectral constant C' over the entire spectrum of definition may be found as part of the data input presented in the Appendix. The transmission model for the uniformly-mixed gases was obtained by combining the data for all of these gases in the proportions listed in Table 4. It should be pointed out that the temperature and pressure exponents used in Lowtran for the major absorbers and listed in Table 3 are not the same as the ones developed from the original transmission data. This inconsistency was introduced during the digitizing of the curves for inclusion in the computer code, in order to account more accurately for the temperature dependence².

The method used for modeling HNO_3 vapor and the visible and ultraviolet O_3 is similar to the one described above for the major absorbers, except that the function f was specified *a priori* to be an exponential. Thus,

$$\tau = \exp(-CW), \quad (38)$$

where for HNO_3

$$W = \left(\frac{P}{P_o}\right) \left(\frac{T_o}{T}\right) U, \quad (39)$$

$$U = M Z \times 10^5, \quad (40)$$

and for O_3

$$W = U = 46.667 \rho Z. \quad (41)$$

In Eq. (40) M is the mixing ratio profile as tabulated in the Appendix together with the C 's, and ρ is the absorber density.

The last of the molecular absorption models is the one for the resonant absorption by atmospheric aerosols. The exponential function in Eq. (38) is assumed

$$\tau = \exp(-CW),$$

where

$$W = U = 3.5336 \times 10^{-6} NZ, \quad (42)$$

and N is the vertical distribution of the number of haze particles. Tabulations are provided of distributions for 5 Km and 23 km visibility, as listed in the Appendix. Other visibilities are treated in the code itself through linear interpolation.

6.4 Non-Resonant Molecular Absorption Models

Non-resonant gaseous molecular absorption is represented by the N_2 and H_2O vapor continuums. The same

modeling approach is used for N_2 as for resonant molecular absorption, that is

$$\tau = \exp(-CW),$$

where

$$W = \left(\frac{P}{P_0}\right)^2 \left(\frac{T_0}{T}\right)^{1.5} U \quad (43)$$

$$U = 0.8 Z. \quad (44)$$

For the H_2O vapor continuum an exponential function is also used, but with a more elaborate exponent. Thus,

$$\tau = \exp(-\gamma), \quad (45)$$

where

$$\gamma = C_s \left[P_w + \frac{C_n}{C_s} (P - P_w) \right] U. \quad (46)$$

Here, P_w is the partial pressure of water and C_s and C_n are the self-broadening and nitrogen-broadening spectral constants. The values of these spectral constants depend on the spectral region where the continuum is effective.

In the 8 to 14 μm region

$$C_s = C_0 \exp\left[6.08 \left(\frac{296}{T} - 1\right)\right], \quad (47)$$

and

$$\frac{C_n}{C_s} = 0.002, \quad (48)$$

while in the 3.5 to 4.2 μm region

$$C_s = C_o \exp[4.56 (\frac{296}{T} - 1)], \quad (49)$$

and

$$\frac{C_n}{C_s} = 0.120. \quad (50)$$

In these equations the value of C_o is given by

$$C_o = 4.18 + 5578 \exp(-7.87 \times 10^{-3} v). \quad (51)$$

ATTENUATING SPECIE	SPECTRAL REGION (cm^{-1})	PRESSURE EXPONENT n	TEMPERATURE EXPONENT m	ABSORBER AMOUNT U
H ₂ O Vapor	350- 9,195 9,875-12,795 13,400-14,520	0.90	0.45	0.1 ρZ
Uniformly-Mixed Gases	500- 8,070 12,950-13,245	1.75	1.375	Z
Infrared O ₃	575- 3,270	0.40	0.20	46.667 ρZ
N ₂ Continuum	2,080- 2,740	2.00	1.50	0.8 Z
Aerosol Absorption	333-50,000	0.00	0.00	3.5336×10^{-6} NZ
Aerosol Scattering	333-50,000	0.00	0.00	3.5336×10^{-4} NZ
Molecular Scattering	3,000-50,000	1.00	1.00	9.87×10^{-20} Z
HNO ₃ Vapor	850- 920 1,275- 1,350 1,675- 1,735	1.00	1.00	1×10^5 MZ
Visible and Ultraviolet O ₃	13,000-24,000 27,500-50,000	0.00	0.00	46.667 ρZ

Table 3. Absorber parameters in Lowtran for the attenuation models, where ρ is the density, Z the range and M the mixing ratio. The H₂O continuum model is excluded because of its different functional form.

GAS	MOLECULAR WEIGHT	PARTS PER MILLION BY VOLUME (ppm)
CO ₂	44	330.0
N ₂ O	44	0.28
CO	28	0.075
CH ₄	16	1.60
O ₂	32	2.095 x 10 ⁵

Table 4. Concentrations of the uniformly-mixed gases used in the combined model.

6.5 Scattering Models

In order to account for atmospheric scattering exponential functions were used again. For scattering by molecules the model is defined as in Eq. (38)

$$\tau = \exp(-CW)$$

where

$$W = \left(\frac{P}{P_0}\right) \left(\frac{T_0}{T}\right) U \quad (52)$$

$$U = 9.87 \times 10^{-20} Z \quad (53)$$

$$C = v^4 \quad (54)$$

For aerosol scattering the argument of the assumed exponential function is

$$W = U = 3.5336 \times 10^{-4} NZ \quad (55)$$

VII. Modularization of Lowtran Including the Trace Gases

7.1 Introduction

Considering the generality and broadness in scope of this code it is not surprising that the program structure shows in its present form great complexity. Although the program user is not normally interested in aspects of the code other than the input and output, there are many cases where a basic understanding helps in specific applications. Situations are likely to occur, for instance, where a replacement of one of the several attenuation models is highly desirable. To assist in the implementation of model additions or changes as well as in the extension to other spectral regions and media, the concept of the modularized version was conceived. This version¹⁵ was designed to represent exactly the same calculations as the original, except for the simplification of the program structure into modules or subroutines. However, upon the termination of that task the authors proceeded to add models for the trace gases, as developed during the present scientific effort.

7.2 Structure of Modularized Version

The basic design used was that of a main program which reads input data, computes total transmittance and radiance and generates outputs, and a series of subroutines

which select individual models and compute individual transmittances and absorber amounts. This is shown in Fig. 4. The main operational flow chart follows in Fig. 5. Excluding the four subroutines for the trace gases, the modularized version breaks down the original into one program with 11 subroutines. The flow chart for subroutine ABSORB is shown in Fig. 6. This subroutine computes the equivalent absorber amount for all of the attenuation models according to Eq.(4), which in terms of the meteorological variables becomes

$$W = \int \left(\frac{P(Z)}{P_0} \right)^n \left(\frac{T_0}{T(Z)} \right)^m dU \quad (56)$$

Figure 7 gives details of the Transmittance/Radiance Loop of program Main. It is worth noting that the modularized version of Lowtran being done by AFGL separates this loop into a subprogram. The modularization discussed in this text leaves the loop as part of the main program, but extracts individual subroutines for the calculation of the equivalent absorber amount, the frequency selection, and the attenuation models.

The flow chart for FREQSL subroutine is shown in Fig. 8. This subroutine is designed to simplify the process of arriving at the individual models effective at the frequency of interest. It should also assist the

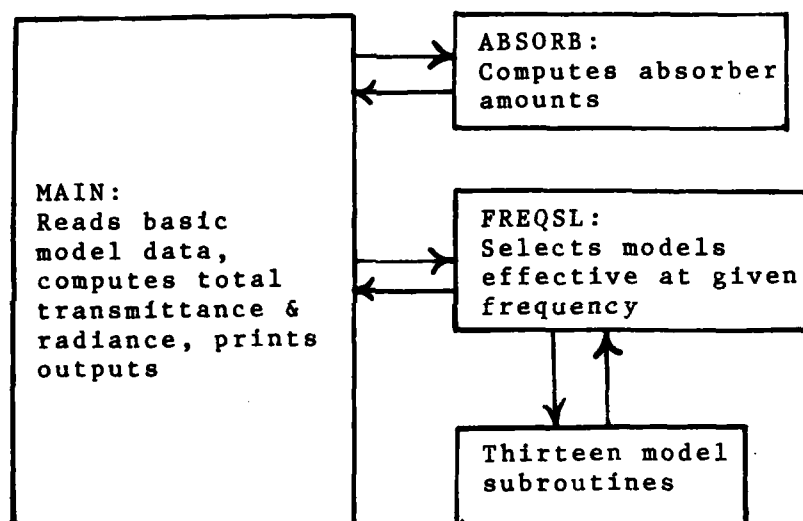


Fig. 4. Conceptual flow chart of modularized Lowtran.

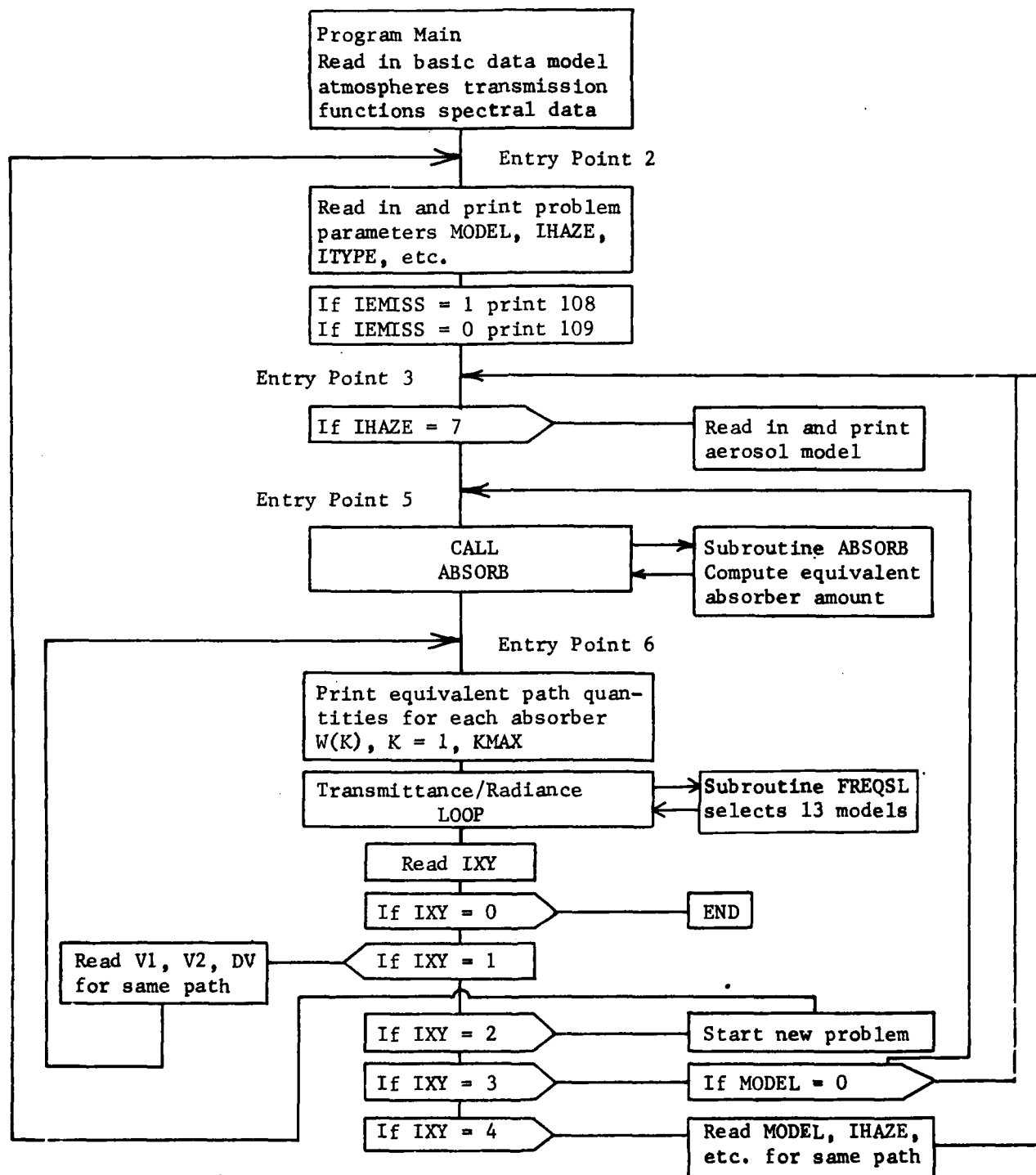


Fig. 5. General flow chart for Modularized Lowtran 4

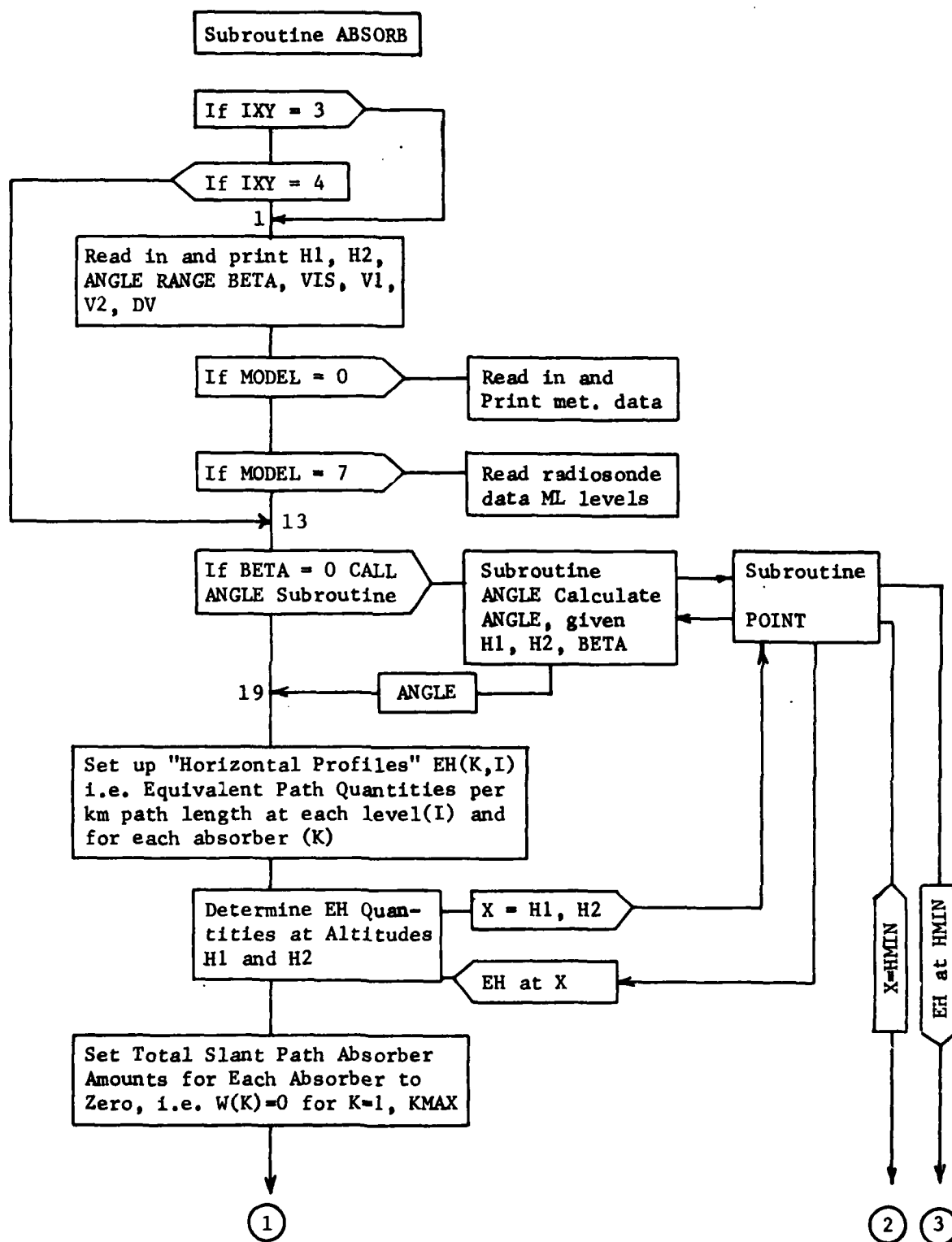


Fig. 6.

Flow chart for subroutine
ABSORB, computing equivalent
path quantities

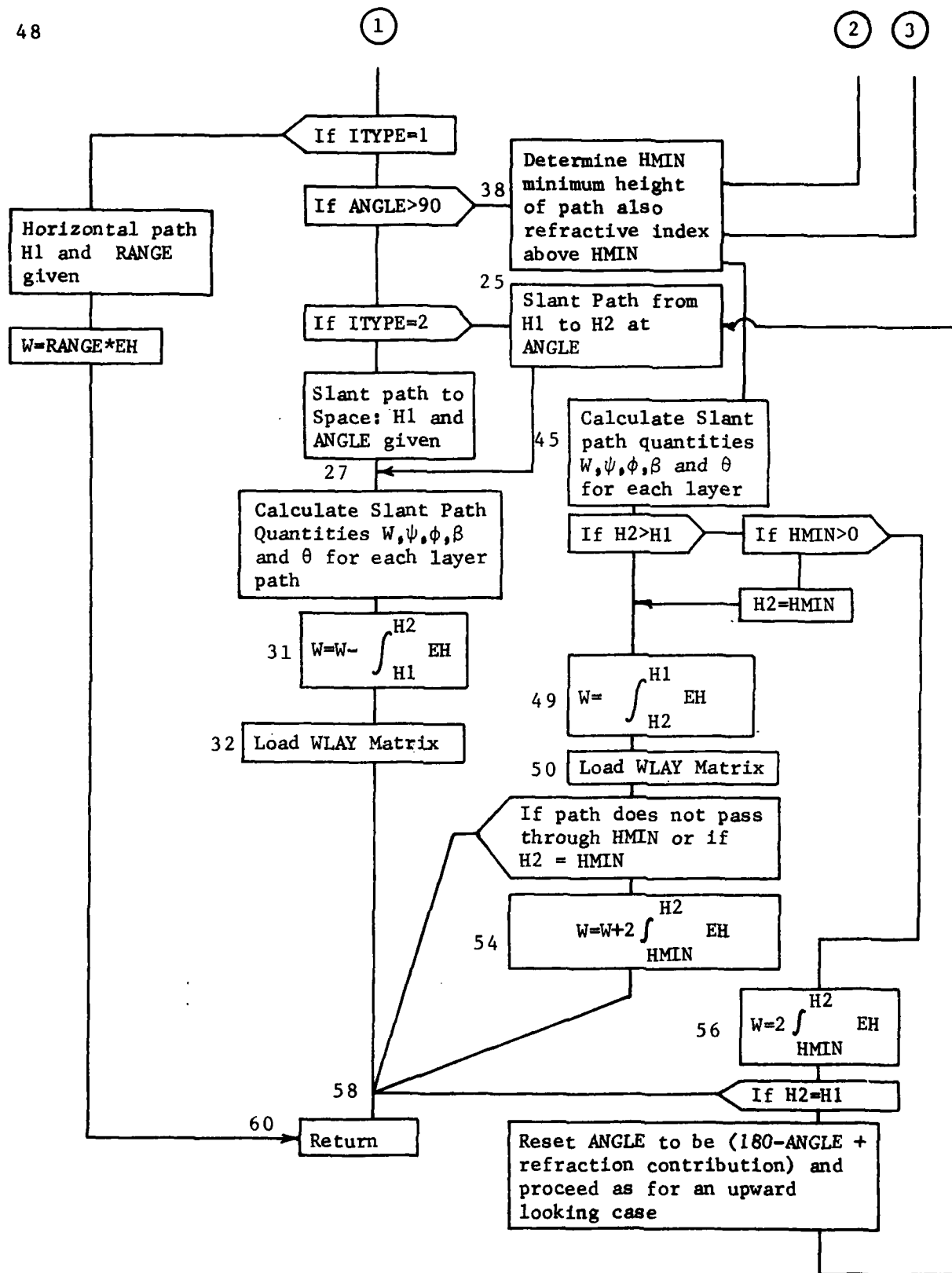


Fig. 6. (cont'd)

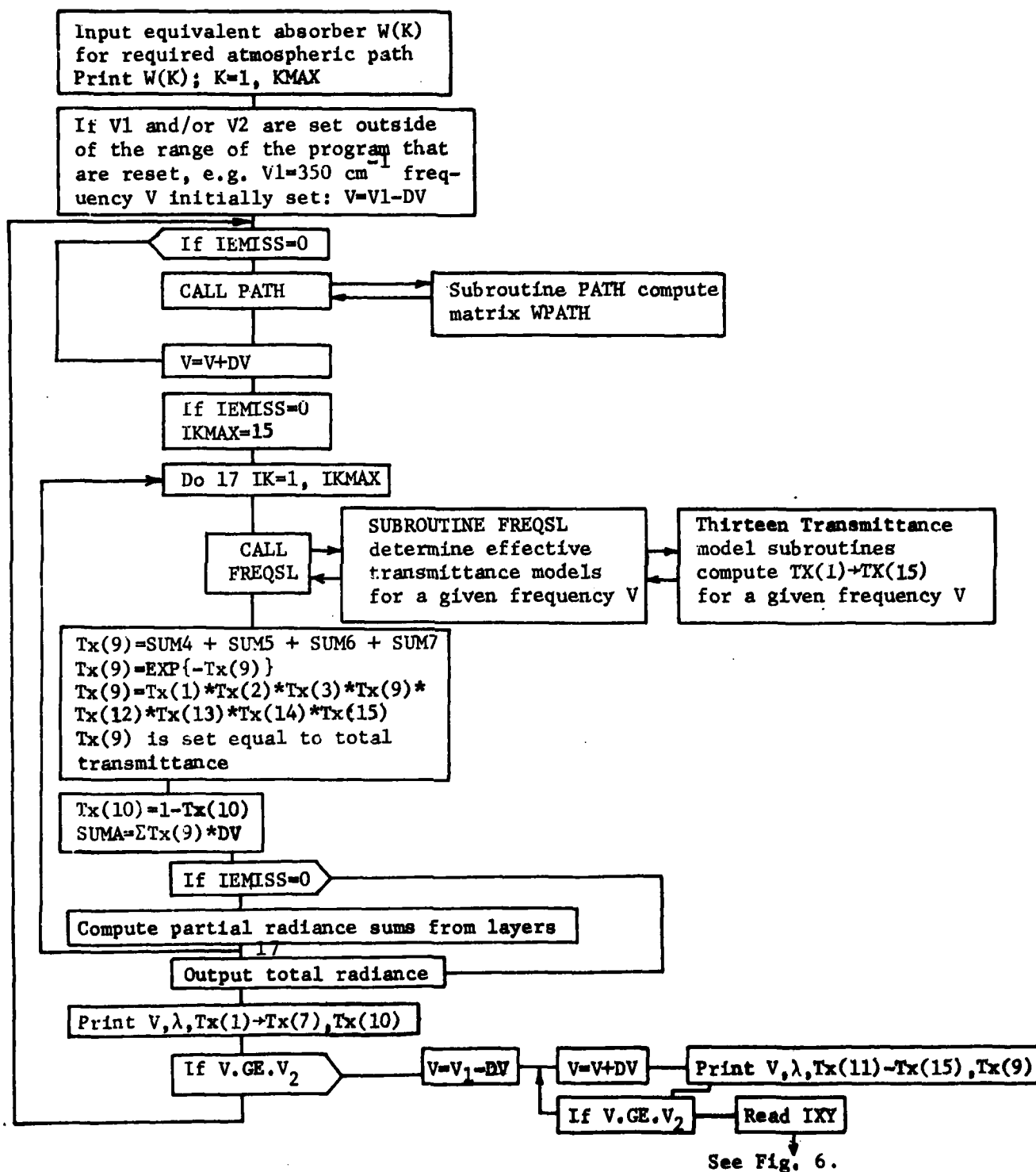


Fig. 3. Flow chart for transmittance/radiance loop.

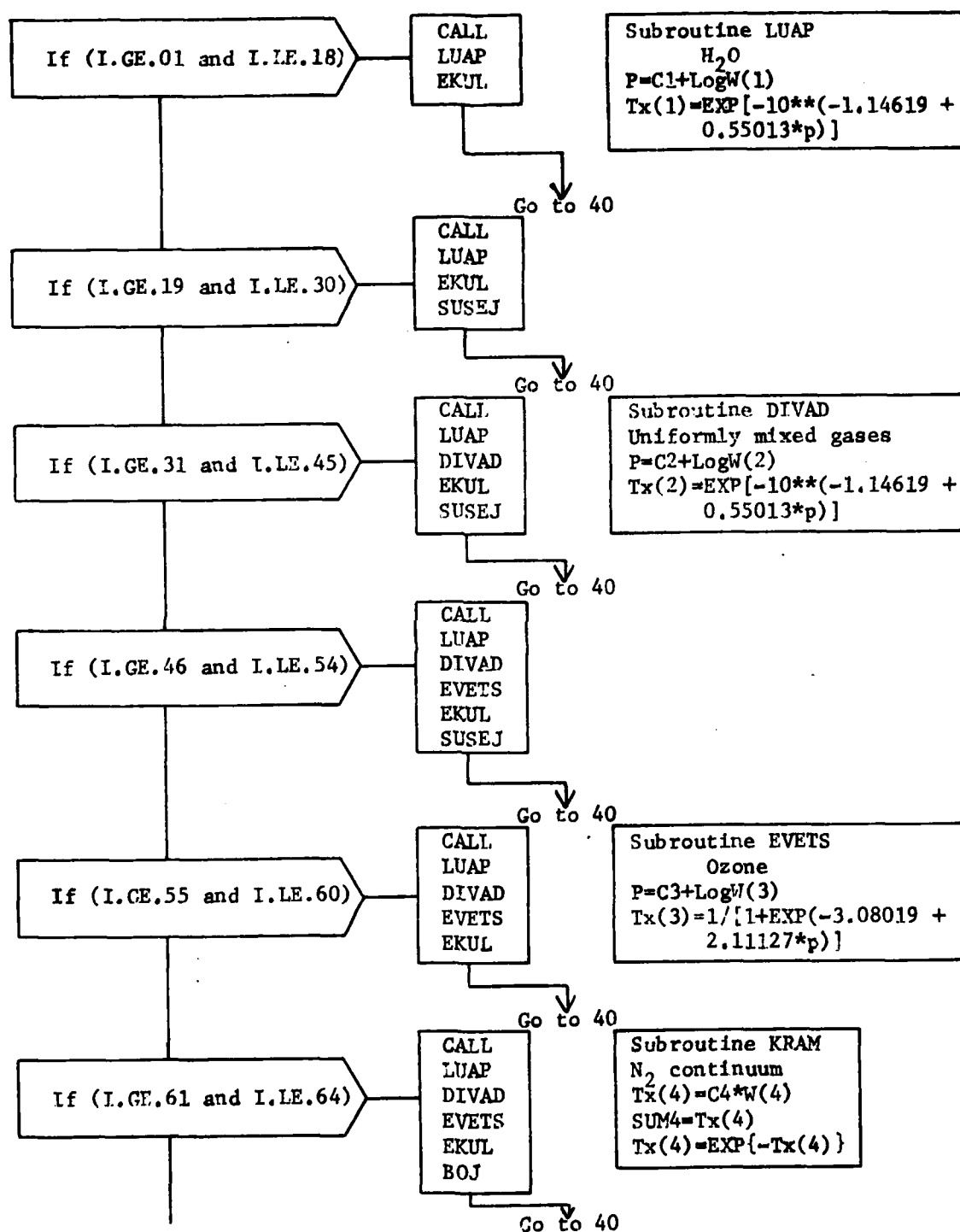


Fig. 8. Flow chart for subroutine FREQSL and thirteen transmittance model subroutines.

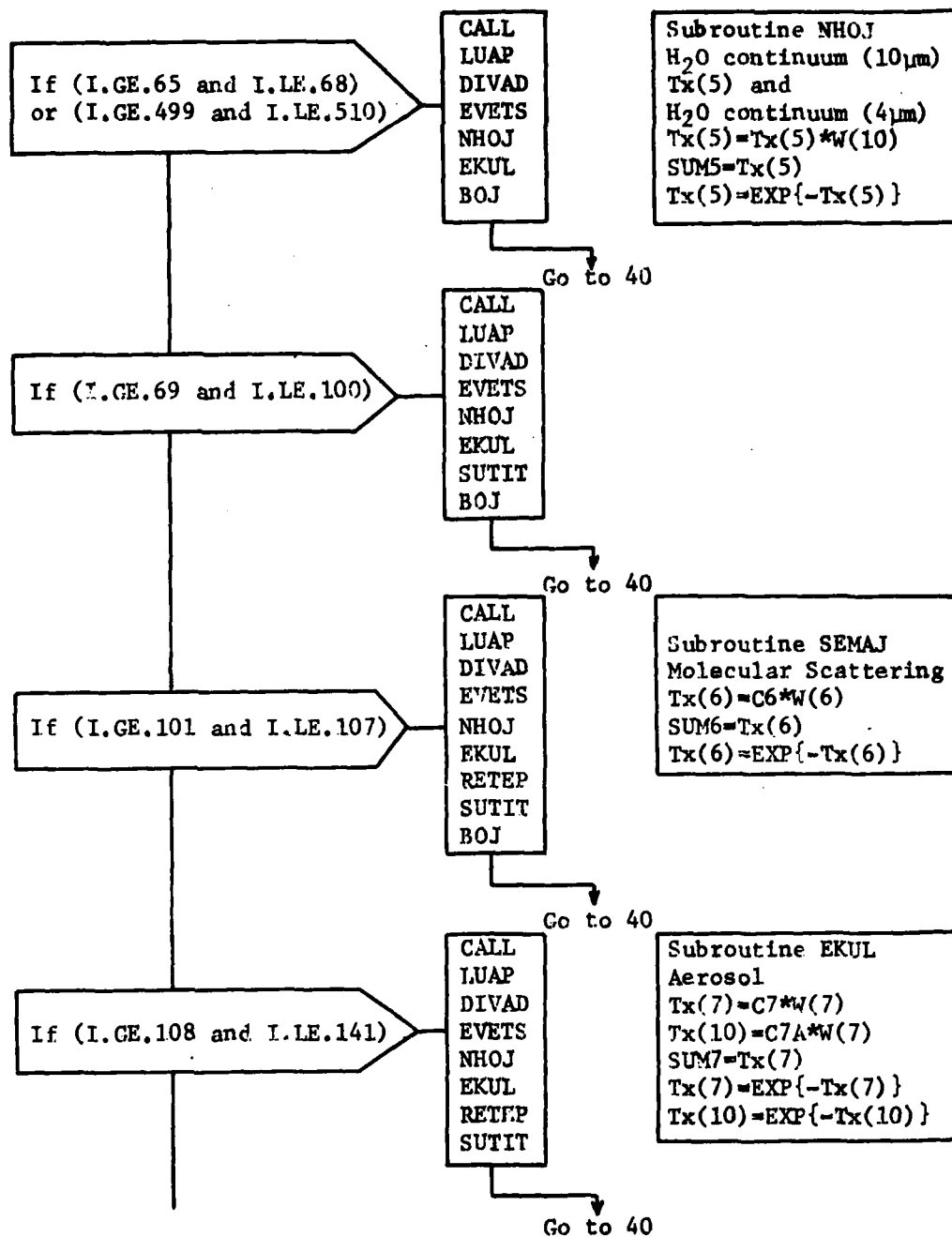


Fig. 8.

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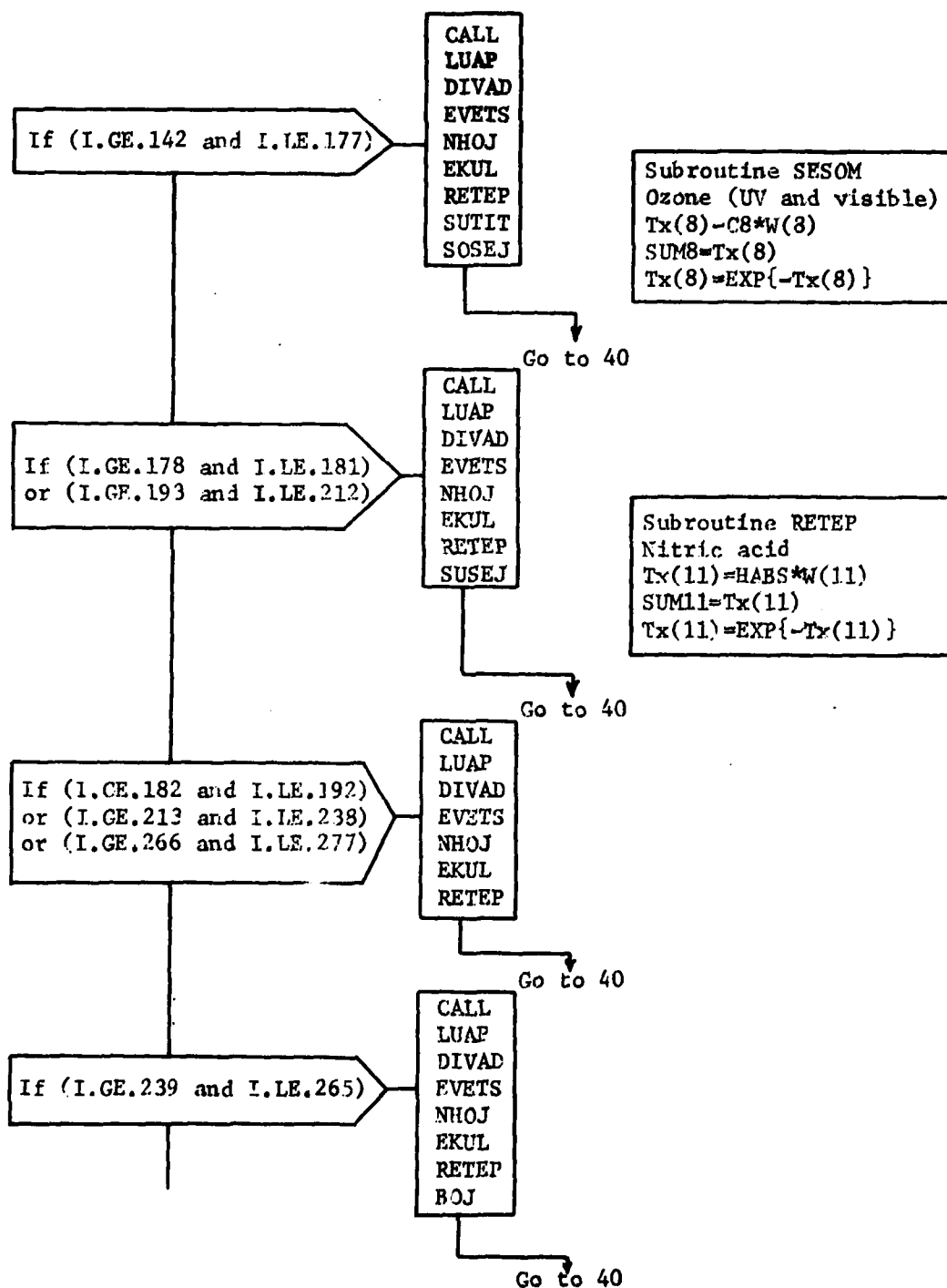


Fig. 8.

Continued

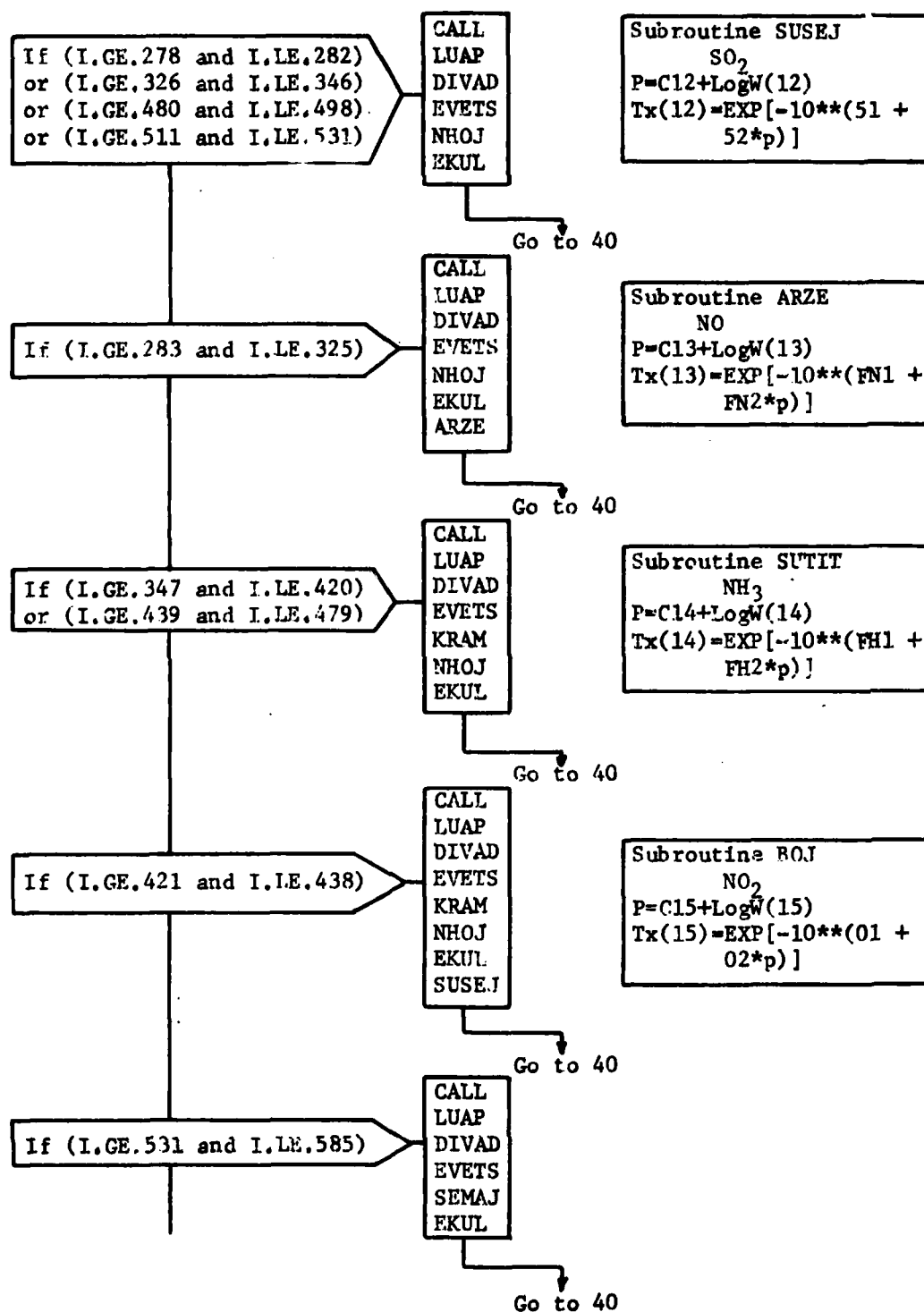


Fig. 8. Continued

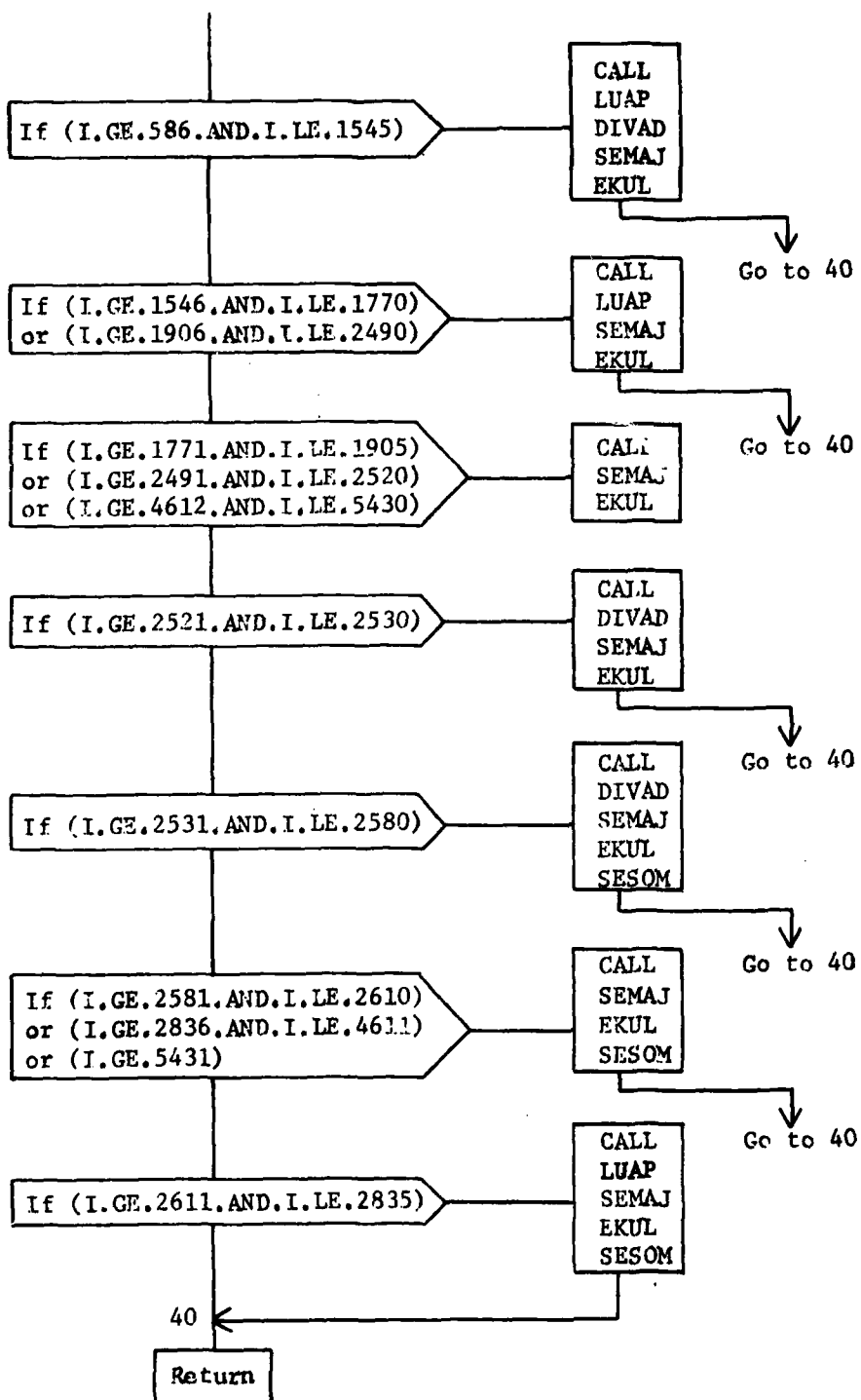


Fig. 8. Continued

user who desires to replace or add models to the program and it should reduce the overall computational time. This subroutine is based on Tables 2 and 8,

7.3 Models for H₂O Vapor, Infrared O₃ and the Uniformly-Mixed Gases

As indicated above, all the attenuation models were extracted from the main program and placed into subroutines. The models were left basically in the same structural form except for the models for HNO₃ and H₂O vapor, infrared O₃ and the uniformly-mixed gases. The change in the first was to arrange it along the same form as in the other models originally available in Lowtran. That is, the spectral parameters were extracted from the subroutine and read at the beginning of program MAIN. The changes in the latter three gases (i.e. H₂O vapor, O₃ in the infrared and the uniformly-mixed gases) were based on a previous work by Pierluissi et al.² on the representation of the tabulated transmission functions by analytical functions. The other principal change consisted of adding models for the trace gases SO₂, NO, NO₂ and NH₃.

To arrive at the analytical function for modeling H₂O vapor and the uniformly-mixed gases the double exponential expression

$$\tau = \exp(-10^{a_0 + a_1 x}) \quad (57)$$

where x is as in Eq. 9 and a_0 and a_1 are absorber

constants, was curve-fitted to the 134 values of τ and x tabulated in Lowtran. The values found are $a_0 = -1.14619$ and $a_1 = 0.55013$, and it reproduced the tabulated transmittance with a standard deviation of 0.005. For O_3 the function adopted is given by

$$\tau = \frac{1}{1 + e^{a_0 + a_1 x}} \quad (58)$$

where $a_0 = -3.08019$, $a_1 = 2.11127$, and the tabulated data is reproduced with a standard deviation of 0.007. Note in each one of these functions that the 134 tabulated values are replaced with two and, hence, their adoption reduces the computer storage requirements. Also, they inherently offer exponential interpolation while with the present tabulation linear interpolation is being used. Finally, there is no need for the small optical thickness (i.e. $0.999 \leq \tau \leq 1$) correction inserted in Lowtran 4, as required by its radiance calculational scheme.

7.4 Models for Trace Gases SO_2 , NO , NO_2 , and NH_3

Absorption by the trace gases was incorporated in Lowtran using a somewhat similar procedure. Empirical transmission functions were first obtained from a computerized procedure which replaced the classical manual graphical techniques. The procedure is explained in Chapter III of this report and has been proposed to the scientific community¹¹.

Instead of either representing the transmission function by a table or by a single function, it was divided into nine segments for each absorber. The individual curve segments are summarized in Table 5, each one being represented by the function

$$\tau = \exp(-10^{a_0 + a_1 x}) \quad (59)$$

For each absorber x is computed with Eqs. (8) through (11) and the relation

$$U = 0.772 \times 10^{-4} \text{ ppm } \rho_a Z \quad (60)$$

where ppm is the parts per million by volume, ρ_a is the air density in gm/m^3 and Z is the range in kilometers.

Table 6 lists the ppm and temperature and pressure exponents used in the modularized code for the individual trace gases. The ppm values are read as input through a separate card which may be easily changed according to the needs of the user. The constants C' are tabulated in Table 7. The spectral coverage for each gas is depicted in Table 8. The models are for a resolution of 20 cm^{-1} and are defined at 5 cm^{-1} through their spectral regions of effectiveness. Their mean standard deviation in fitting the original line-by-line data is about 0.008. Figure 9 depicts the transmission functions for the four trace gases considered.

CURVE SEGMENT	TRANSMITTANCE INTERVAL	x- INTERVAL	FUNCTION CONSTANTS	
			a_0	a_1
1	1.000 ~ 0.900	$x \leq -1.057$	0.0682	0.9894
2	0.900 ~ 0.800	-1.057 ~ -0.725	0.0594	0.9811
3	0.800 ~ 0.700	-0.725 ~ -0.514	0.0492	0.9670
4	0.700 ~ 0.600	-0.514 ~ -0.350	0.0408	0.9506
5	0.600 ~ 0.500	-0.350 ~ -0.208	0.0343	0.9319
6	0.500 ~ 0.400	-0.208 ~ -0.074	0.0295	0.9091
7	0.400 ~ 0.300	-0.074 ~ 0.061	0.0273	0.8792
8	0.300 ~ 0.200	0.061 ~ 0.212	0.0300	0.8353
9	0.200 ~ 0.0	$x \geq 0.212$	0.0466	0.7568

Table 5a. Constants for the curve segments in the empirical transmission function for SO_2 .

CURVE SEGMENT	TRANSMITTANCE INTERVAL	x- INTERVAL	FUNCTION CONSTANTS	
			a_0	a_1
1	1.000 ~ 0.900	$x \leq -1.158$	-0.0228	0.8240
2	0.900 ~ 0.800	-1.158 ~ -0.684	-0.1822	0.6864
3	0.800 ~ 0.700	-0.684 ~ -0.333	-0.2537	0.5818
4	0.700 ~ 0.600	-0.333 ~ -0.047	-0.2660	0.5450
5	0.600 ~ 0.500	-0.047 ~ 0.199	-0.2663	0.5388
6	0.500 ~ 0.400	0.199 ~ 0.419	-0.2685	0.5497
7	0.400 ~ 0.300	0.419 ~ 0.626	-0.2785	0.5737
8	0.300 ~ 0.200	0.626 ~ 0.833	-0.3000	0.6080
9	0.200 ~ 0.0	$x \geq 0.833$	-0.3373	0.6528

Table 5b. Constants for the curve segments in the empirical transmission function for NO.

CURVE SEGMENT	TRANSMITTANCE INTERVAL	x- INTERVAL	FUNCTION CONSTANTS	
			a_0	a_1
1	1.000 ~ 0.900	$x \leq 0.215$	-1.1877	0.9771
2	0.900 ~ 0.800	0.215 ~ 0.556	-1.1835	0.9577
3	0.800 ~ 0.700	0.556 ~ 0.775	-1.1668	0.9277
4	0.700 ~ 0.600	0.775 ~ 0.949	-1.1416	0.8952
5	0.600 ~ 0.500	0.949 ~ 1.104	-1.1063	0.8580
6	0.500 ~ 0.400	1.104 ~ 1.252	-1.0615	0.8174
7	0.400 ~ 0.300	1.252 ~ 1.406	-1.0055	0.7727
8	0.300 ~ 0.200	1.406 ~ 1.579	-0.9400	0.7260
9	0.200 ~ 0.0	$x \geq 1.579$	-0.8683	0.6807

Table 5c. Constants for the curve segments in the empirical transmission function for NO₂.

CURVE SEGMENT	TRANSMITTANCE INTERVAL	x - INTERVAL	FUNCTION CONSTANTS	
			a ₀	a ₁
1	1.000 ~ 0.900	$x \leq -1.444$	0.2775	0.8692
2	0.900 ~ 0.800	-1.444 ~ -1.005	0.0962	0.7436
3	0.800 ~ 0.700	-1.005 ~ -0.661	-0.0570	0.5913
4	0.700 ~ 0.600	-0.661 ~ -0.340	-0.1261	0.4867
5	0.600 ~ 0.500	-0.340 ~ -0.033	-0.1450	0.4312
6	0.500 ~ 0.400	-0.033 ~ 0.267	-0.1459	0.4037
7	0.400 ~ 0.300	0.267 ~ 0.575	-0.1409	0.3852
8	0.300 ~ 0.200	0.575 ~ 0.921	-0.1290	0.3645
9	0.200 ~ 0.0	$x \geq 0.921$	-0.1224	0.3573

Table 5d. Constants for the curve segments in the empirical transmission function for NH₃.

TRACE GAS	SPECTRAL REGION (cm^{-1})	PRESSURE EXPONENT n	TEMPERATURE EXPONENT m	PARTS PER MILLION BY VOLUME ppm
SO_2	440- 615 1,055-1,250 1,310-1,410	0.07122	0.06159	0.221
NO	1,760-1,970	0.90098	1.01192	0.250
NO_2	655- 880 1,540-1,670 2,840-2,895	0.18066	0.20911	0.090
NH_3	670-1,230	0.52125	-0.60438	0.200

Table 6. Absorber parameters in Modularized Lowtran used with the models for the trace gases.

WAVENUMBER (cm^{-1})	C'	WAVENUMBER (cm^{-1})	C'	WAVENUMBER (cm^{-1})	C'
440	-2.987	1070	-1.653	1320	-1.237
445	-2.330	1075	-1.443	1325	-0.494
450	-1.791	1080	-1.252	1330	0.139
455	-1.370	1085	-1.080	1335	0.613
460	-1.041	1090	-0.926	1340	0.899
465	-0.795	1095	-0.787	1345	1.043
470	-0.613	1100	-0.661	1350	1.090
475	-0.469	1105	-0.544	1355	1.097
480	-0.346	1110	-0.434	1360	1.104
485	-0.233	1115	-0.329	1365	1.093
490	-0.126	1120	-0.230	1370	1.118
495	-0.037	1125	-0.139	1375	1.088
500	0.0	1130	-0.073	1380	0.926
505	-0.008	1135	-0.047	1385	0.534
510	-0.052	1140	-0.057	1390	-0.067
515	-0.102	1145	-0.083	1395	-0.804
520	-0.102	1150	-0.098	1400	-0.768
525	-0.044	1155	-0.071	1405	-1.687
530	0.013	1160	-0.020	1410	-2.469
535	0.039	1165	0.014	2450	-3.669
540	0.014	1170	0.011	2455	-2.855
545	-0.056	1175	-0.040	2460	-2.131
550	-0.141	1180	-0.123	2465	-1.528

Table 7a. The spectral coefficient $C'(\nu)$ for SO_2 .

WAVENUMBER (cm ⁻¹)	C'	WAVENUMBER (cm ⁻¹)	C'	WAVENUMBER (cm ⁻¹)	C'
555	-0.221	1185	-0.213	2470	-1.076
560	-0.294	1190	-0.301	2475	-0.805
565	-0.366	1195	-0.388	2480	-0.647
570	-0.442	1200	-0.481	2485	-0.571
575	-0.529	1205	-0.586	2490	-0.549
580	-0.635	1210	-0.707	2495	-0.539
585	-0.766	1215	-0.843	2500	-0.536
590	-0.934	1220	-0.996	2505	-0.517
595	-1.157	1225	-1.165	2510	-0.528
600	-1.457	1230	-1.351	2515	-0.691
605	-1.862	1235	-1.554	2520	-1.073
610	-2.420	1240	-1.777	2525	-1.673
615	-3.094	1245	-2.033	2530	-2.414
1055	-2.604	1250	-2.369	2535	-2.207
1060	-2.156	1310	-3.010		
1065	-1.884	1315	-2.080		

Table 7a,

(Continued)

WAVENUMBER	C'	WAVENUMBER	C'	WAVENUMBER	C'
1760	-2.691	1835	-0.231	1910	0.003
1765	-2.521	1840	-0.176	1915	-0.032
1770	-2.328	1845	-0.144	1920	-0.105
1775	-2.115	1850	-0.143	1925	-0.211
1780	-1.894	1855	-0.188	1930	-0.352
1785	-1.685	1860	-0.244	1935	-0.529
1790	-1.485	1865	-0.342	1940	-0.742
1795	-1.296	1870	-0.434	1945	-0.992
1800	-1.117	1875	-0.471	1950	-1.282
1805	-0.947	1880	-0.483	1955	-1.610
1810	-0.792	1885	-0.392	1960	-1.975
1815	-0.649	1890	-0.266	1965	-2.374
1820	-0.519	1895	-0.151	1970	-2.806
1825	-0.407	1900	-0.046		
1830	-0.311	1905	-0.001		

Table 7b. The spectral coefficient $C'(\nu)$ for NO.

WAVENUMBER	C'	WAVENUMBER	C'	WAVENUMBER	C'
655	-0.844	800	-0.255	1,600	2.616
660	-0.760	805	-0.286	1,605	2.616
665	-0.676	810	-0.315	1,610	2.606
670	-0.608	815	-0.334	1,615	2.608
675	-0.543	820	-0.352	1,620	2.643
680	-0.496	825	-0.366	1,625	2.682
685	-0.450	830	-0.396	1,630	2.672
690	-0.414	835	-0.423	1,635	2.576
695	-0.383	840	-0.459	1,640	2.350
700	-0.326	845	-0.498	1,645	1.955
705	-0.289	850	-0.541	1,650	1.346
710	-0.217	855	-0.586	1,655	0.596
715	-0.140	860	-0.630	1,660	-0.258
720	-0.097	865	-0.676	1,665	-1.214
725	-0.034	870	-0.720	1,670	-1.951
730	-0.031	875	-0.766	2,840	-1.220
735	-0.082	880	-0.809	2,845	-0.644
740	-0.139	1,540	-2.428	2,850	-0.253
745	-0.216	1,545	-1.494	2,855	0.052
750	-0.249	1,550	-0.647	2,860	0.326
755	-0.207	1,555	0.122	2,865	0.574
760	-0.117	1,560	0.756	2,870	0.792

Table 7c. The spectral coefficient $C'(\nu)$ for NO_2 .

WAVENUMBER	C'	WAVENUMBER	C'	WAVENUMBER	C'
765	-0.047	1,565	1.230	2,875	0.978
770	0.000	1,570	1.568	2,880	1.122
775	0.009	1,575	1.855	2,885	1.216
780	-0.046	1,580	2.104	2,890	1.252
785	-0.100	1,585	2.310	2,895	1.249
790	-0.148	1,590	2.469		
795	-0.214	1,595	2.573		

Table 7c.

(Continued)

WAVENUMBER	C'	WAVENUMBER	C'	WAVENUMBER	C'
690	-2.603	875	-1.124	1,060	-0.589
695	-2.456	880	-1.155	1,065	-0.565
700	-2.290	885	-1.161	1,070	-0.537
705	-2.128	890	-1.143	1,075	-0.510
710	-1.980	895	-1.139	1,080	-0.512
715	-2.225	900	-1.117	1,085	-0.528
720	-1.823	905	-1.107	1,090	-0.575
725	-1.744	910	-0.844	1,095	-0.625
730	-1.674	915	-0.558	1,100	-0.668
735	-1.577	920	-0.238	1,105	-0.694
740	-1.481	925	-0.042	1,110	-0.717
745	-1.372	930	-0.002	1,115	-0.740
750	-1.284	935	-0.157	1,120	-0.774
755	-1.207	940	-0.436	1,125	-0.834
760	-1.128	945	-0.610	1,130	-0.905
765	-1.061	950	-0.548	1,135	-0.977
770	-1.004	955	-0.352	1,140	-1.042
775	-0.947	960	-0.139	1,145	-1.133
780	-0.886	965	-0.095	1,150	-1.219
785	-0.876	970	-0.365	1,155	-1.301
790	-0.872	975	-0.729	1,160	-1.383
795	-0.869	980	-1.048	1,165	-1.488
800	-0.872	985	-1.275	1,170	-1.594

Table 7d. The spectral coefficient $C'(\nu)$ for NH_3 .

WAVENUMBER	C'	WAVENUMBER	C'	WAVENUMBER	C'
805	-0.848	990	-1.257	1,175	-1.696
810	-0.811	995	-1.142	1,180	-1.796
815	-0.772	1,000	-1.053	1,185	-1.873
820	-0.773	1,005	-0.963	1,190	-1.936
825	-0.793	1,010	-0.920	1,195	-1.991
830	-0.825	1,015	-0.944	1,200	-2.080
835	-0.869	1,020	-0.889	1,205	-2.183
840	-0.894	1,025	-0.829	1,210	-2.292
845	-0.890	1,030	-0.736	1,215	-2.404
850	-0.873	1,035	-0.644	1,220	-2.529
855	-0.868	1,040	-0.596	1,225	-2.639
860	-0.907	1,045	-0.569	1,230	-2.732
865	-0.965	1,050	-0.572		
870	-1.045	1,055	-0.590		

Table 7d.

(Continued)

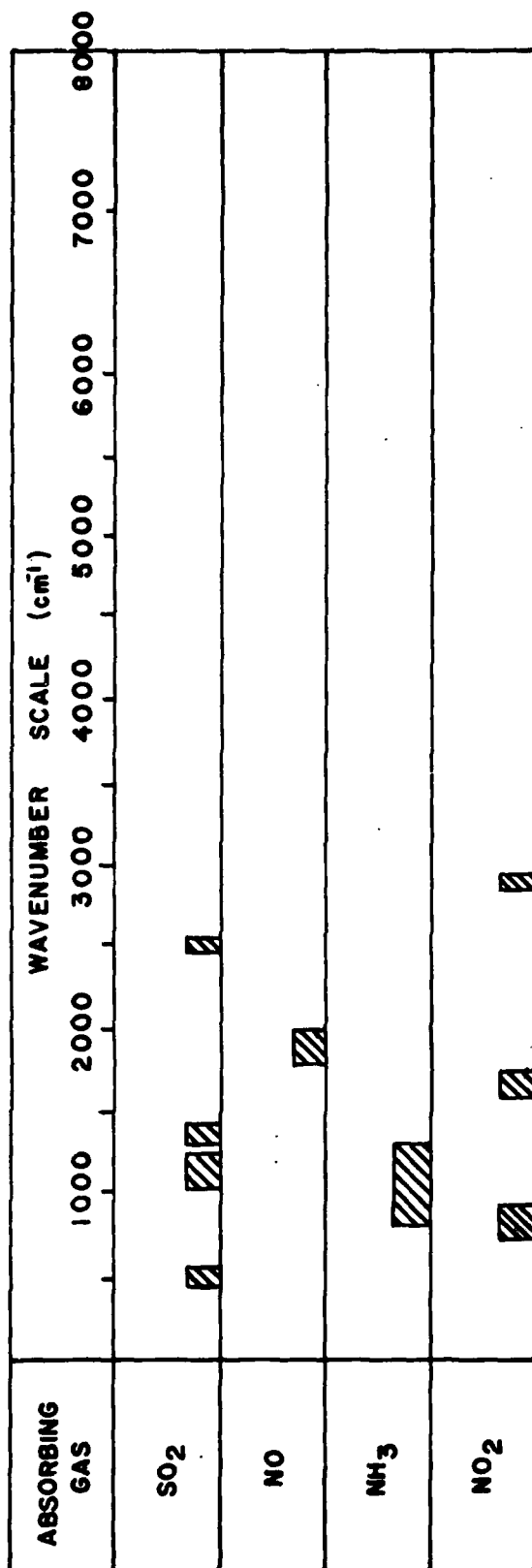


Table 8. Absorption frequency region of the trace gases in the atmosphere.

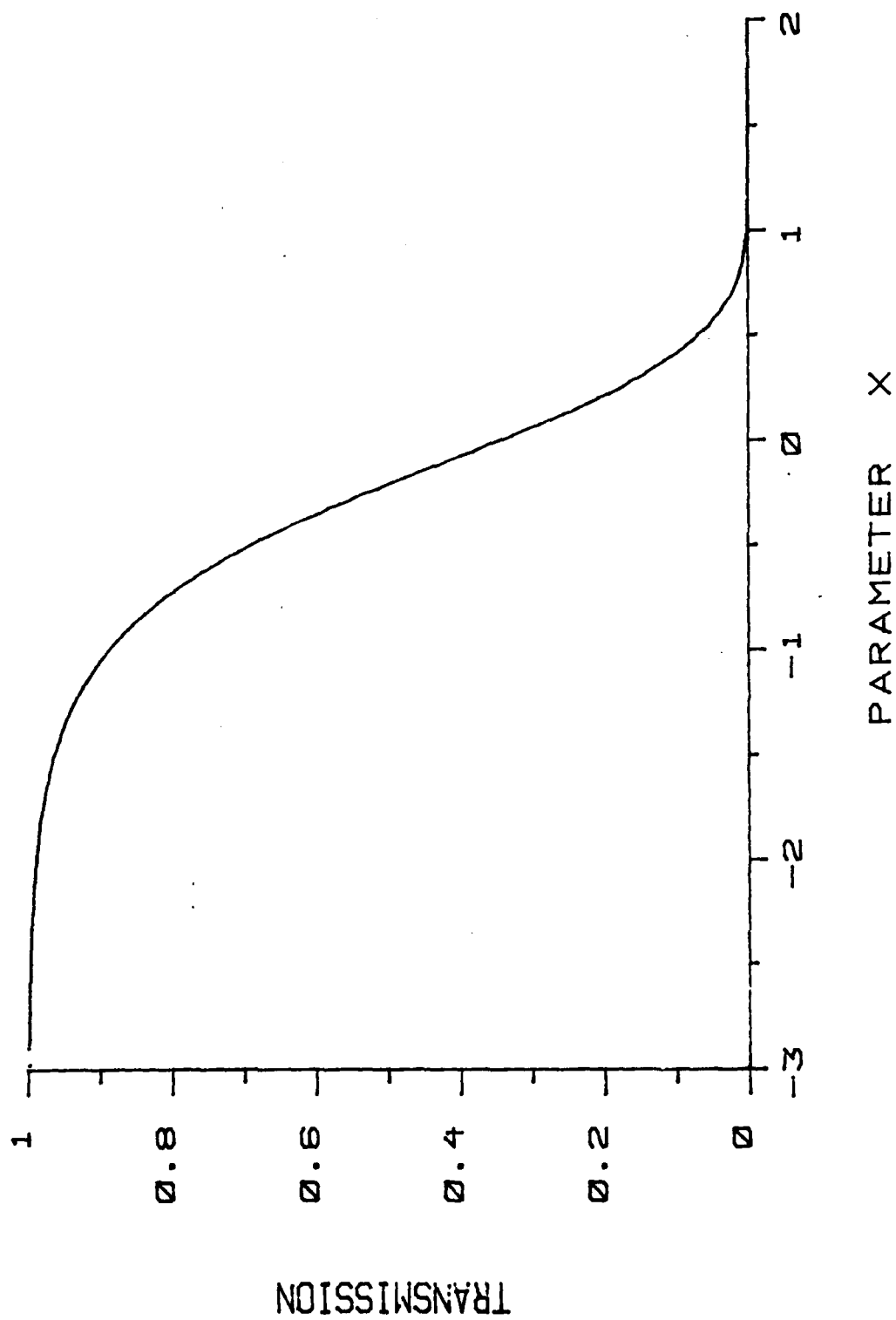


Fig. 9a. Empirical transmission function for SO_2 .

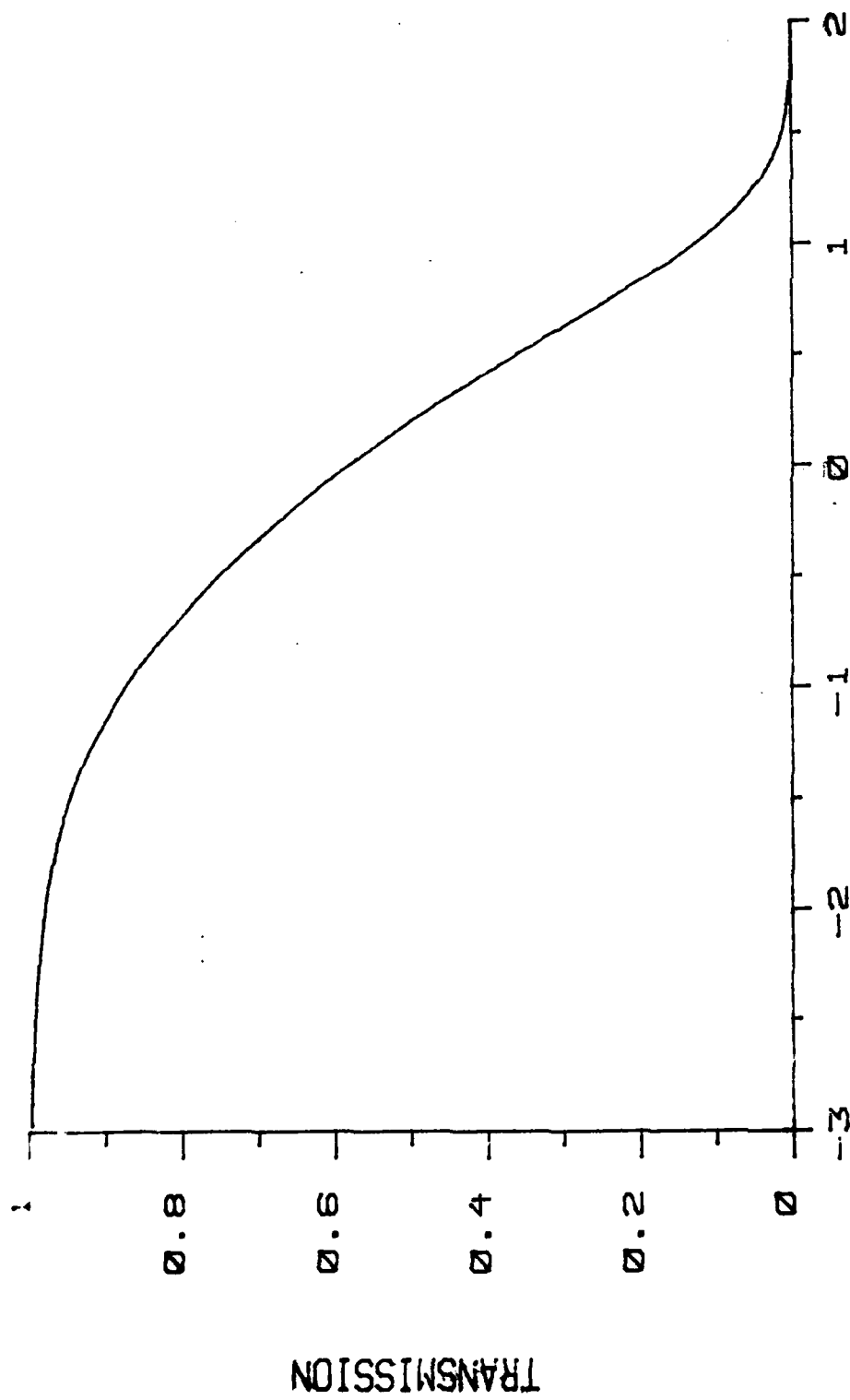


Fig. 9b. Empirical transmission function for NO.

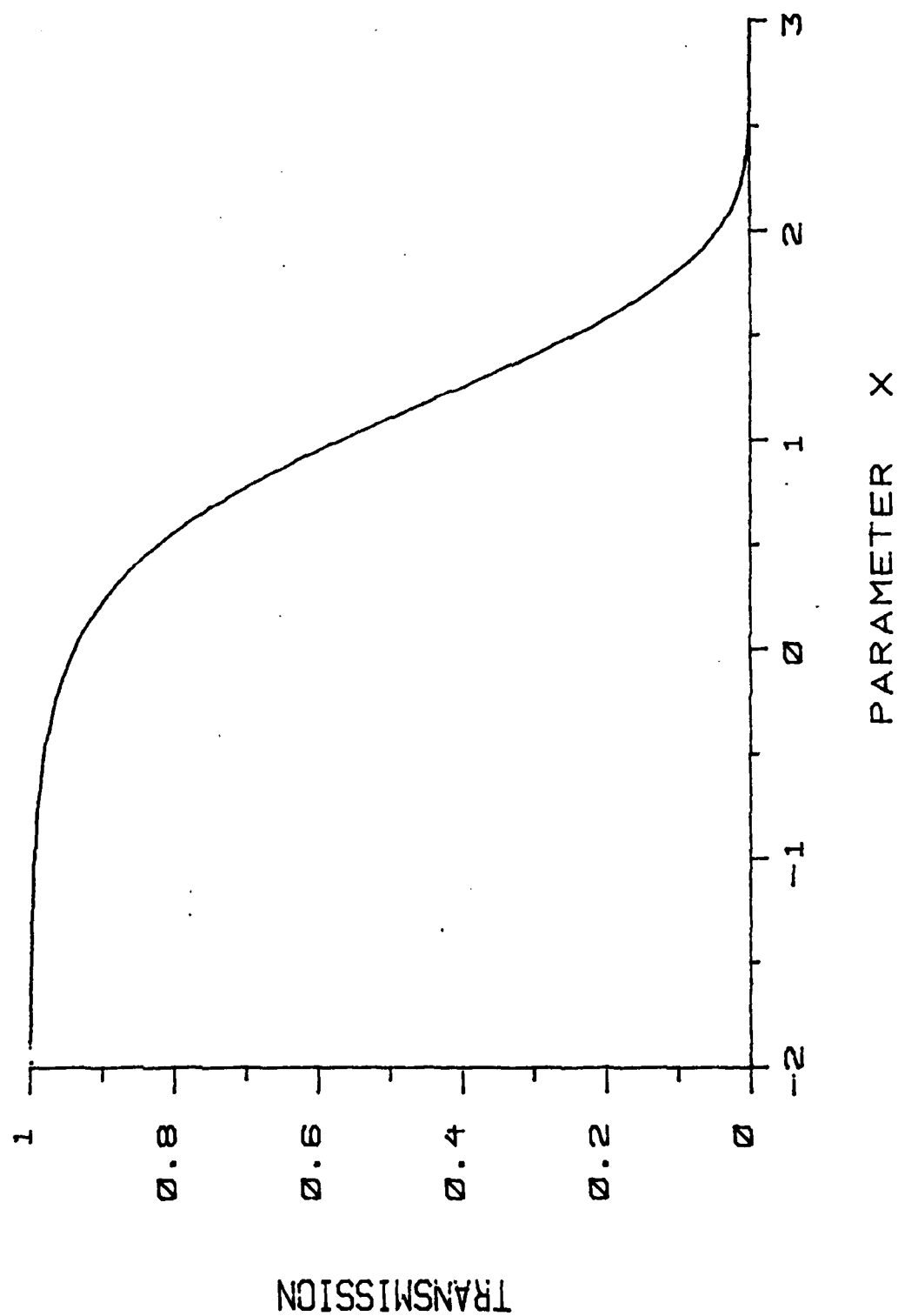


Fig. 9c. Empirical transmission function for NO_2 .

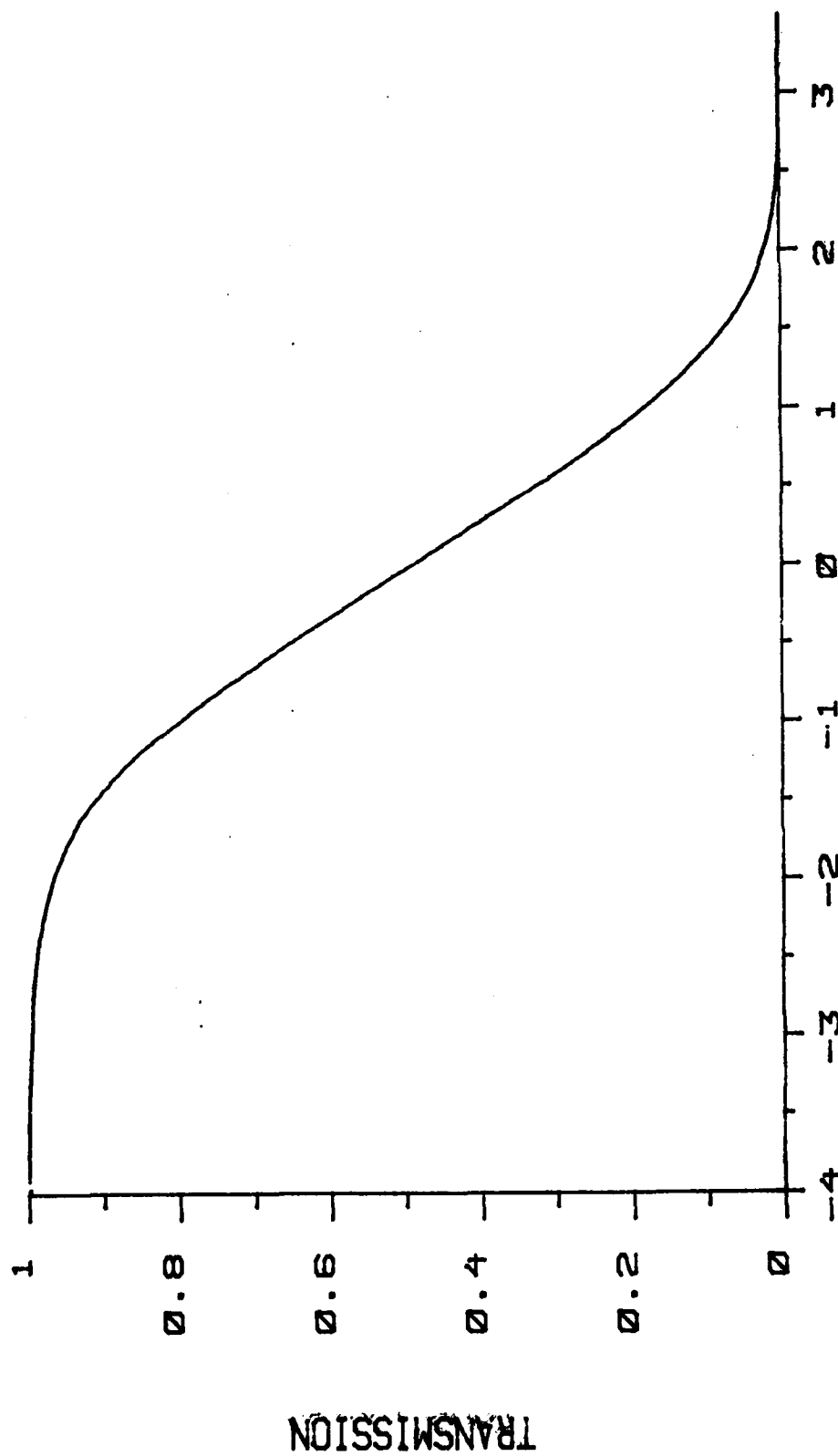


Fig. 9d. Empirical transmission function for NH_3 .

VIII. Calculations and Results

8.1 Introduction

The procedure for the use of the Modularized Lowtran in calculations is identical to that of the original and, hence, deserves no further explanation. There are some input and output alterations that deserve some explanatory remarks. Changes in the input format include:

1. Reading of the spectral constants for all band models at the beginning of the main program rather than in the subroutines.
2. Elimination of the transmittance tables for H_2O vapor, infrared O_3 and the uniformly-mixed gases.
3. Reading of the spectral constants for the newly added band models for the trace gases.
4. Reading of the air density profile for the U.S. Standard atmosphere, and of the ppm for the calculation of the equivalent amounts of the trace gases.
5. Changes in the dimension statements to include the additional subscripted variables.

Changes in the output format include:

1. Modification of the print out of the input data.
2. Modification of the output table of computations to include the transmittance for the trace gases.

It should be stressed, however, that the code is operated using exactly the same four control cards as in the original code.

8.2 Testing of Modularized Version

The first step in the testing of the modularization consisted of running identical calculations using the original code and the modularized code before the replacement of the transmittance tables and before the addition of the trace gases. Numerous cases were considered during this effort. A particular case in which the spectral range varied from 2350 to 2450 cm^{-1} for a path at 65° from a height of 2.5 km to a height of 8.5 km and a 23 km visual range, is shown in the Appendix. This output is identical to the output obtained from the original Lowtran.

The second step in the testing procedure consisted of running calculations using the original code and the modularized version with the transmittance tables replaced with the continuous functions, but before the addition of the trace gases. For this purpose, 10 frequencies were selected such that different combinations of models would be effective in the calculation of the total transmittance. The calculations were for a 5 km path at sea level in a sub-arctic winter atmosphere with a 23 km visibility. The results are summarized in Table 9. The columns listed under Transmittance Deviations represent the differences between the calculations using the tabulated and the continuous functions. Note that the average total transmittance deviation is 0.0034, which is below the standard deviation obtained in the curve fitting of

TRANSMITTANCE DEVIATIONS

WAVENUMBER (cm ⁻¹)	H ₂ O VAPOR	INFRARED O ₃	UNIFORMLY- MIXED GASES	TOTAL TRANSMITTANCE
455	0.0022	0.0000	0.0000	0.0021
555	0.0035	0.0000	0.0026	0.0018
655	0.0041	0.0003	0.0000	0.0000
755	0.0007	0.0003	0.0047	0.0038
955	0.0057	0.0002	0.0050	0.0096
1155	0.0026	0.0003	0.0050	0.0058
1355	0.0044	0.0000	0.0013	0.0006
1855	0.0007	0.0001	0.0034	0.0007
2455	0.0015	0.0000	0.0054	0.0045
3155	0.0037	0.0001	0.0027	0.0053

Table 9. Transmittance difference between calculations using the tabulation of the transmittance functions and calculations using the continuous function representation for a 5 km path at sea level in a sub-arctic winter atmosphere.

the functions to the individual transmittance tables. This deviation amounts to an error of about 0.7% in the middle of the curve-of-growth, which far exceeds the accuracy of Lowtran (between 10 to 20%). The following are attractive features of the continuous functions:

1. They inherently provide for continuous exponential interpolation in transmittance, which is superior to the linear interpolation used in connection with the transmittance tables.
2. They provide for analytical operations such as differentiation and interpolation often needed in radioactive transfer problems.
3. They can be used easily for curve fitting to new transmittance data using computerized procedures.
4. Their use reduces significantly the computer storage requirements for the individual models.
5. They continuously provide for transmittance calculations for small argument values where $0.9999 \leq \tau \leq 1$, for which range Lowtran 4 includes an additional exponential function.

It should be pointed out that the deviations listed in Table 9, although insignificant, do not represent errors solely attributed to the analytical functions. Since they are smaller than the uncertainties in the original data used to develop the tabulated transmittances, they primarily represent differences in the calculational procedures. In fact, in the region between the tabulations the use of the analytical functions are likely to provide more accurate results than the use of the original method in Lowtran.

The last effort in the testing of the modularized code consisted of calculations involving the newly added trace gases. For this purpose ten frequencies were run at which the trace gas models are effective. The same frequencies were run with the modularized Lowtran without these models. The results are summarized in Table 10. The table is primarily intended to show the absorptive effects of the trace gases.

MOLECULAR TRANSMITTANCE

WAVENUMBER (cm ⁻¹)	SO ₂	NO	NO ₂	NH ₃	TOTAL (with T.G.)	TOTAL (without T.G.)
455	0.9948	1.0000	1.0000	1.0000	0.0000	0.0000
555	0.9308	1.0000	1.0000	1.0000	0.0185	0.0199
655	1.0000	1.0000	0.9997	1.0000	0.0000	0.0000
755	1.0000	1.0000	0.9995	0.9783	0.0029	0.0030
955	1.0000	1.0000	1.0000	0.8878	0.1155	0.1300
1155	0.8929	1.0000	1.0000	0.9820	0.1657	0.1890
1355	0.2728	1.0000	1.0000	1.0000	0.0000	0.0000
1855	1.0000	0.9034	1.0000	1.0000	0.0000	0.0000
2455	0.9998	1.0000	1.0000	1.0000	0.5734	0.5735

Table 10. Calculations of trace gas (T.G.) transmittances for a 5 km path at sea level in a tropical atmosphere with a 23 km visual range. The columns on total transmittance include all the attenuators and the trace gases, except for the rightmost column which excludes the trace gases.

Table 11: (a) Atmospheric regions included in the data calculations

Model	P (mbar)	T (°K)
Standard	1013	288.1
	898.6	281.6
	795.0	275.1
	701.2	268.7
	616.6	262.2
Tropical	805.0	288.0
Subarctic Winter	1013	257.1

(b) Transmittance cuts chosen from the curve of growth

τ_1	0.99
τ_2	0.95
τ_3	0.9
τ_4	0.8
τ_5	0.7
τ_6	0.6
τ_7	0.5
τ_8	0.4
τ_9	0.3
τ_{10}	0.2
τ_{11}	0.1
τ_{12}	0.065

	Absorber Parameters		Spectral Parameter C' (cm ⁻¹)				Coefficients of Analytical Function				Standard Deviation
	n	m	v ₁	v ₂	v ₃	v ₄					
	0.07844	0.06037	0.0	0.019	1.108	-0.566	a ₁ = 0.83392 a ₂ = 0.86759 a ₃ = -0.08578				0.006259
Band Model Parameters	0.07130	0.06186	0.0	0.014	1.104	-0.571					
Empirical											
τ _i =	0.95	0.9	0.8	0.7	0.6	0.5	0.4	0.3	0.2	0.1	
x _i =	-1.3727	-1.0569	-0.7246	-0.5140	-0.3498	-0.2076	-0.0742	0.0606	0.2115	0.4170	
Piece-Wise Analytical											
a ₁ =	0.0682	0.0594	0.0492	0.0408	0.0343	0.0295	0.0273	0.0300	0.0466		
(1st order)	a ₂ =	0.9894	0.9811	0.9670	0.9319	0.9091	0.8792	0.8353	0.7568	0.005749	
a ₃ =	0	0	0	0	0	0	0	0	0		
a ₁ =	0.0755	0.2247	0.2099	0.1356	0.0590	0.0285	0.0299	0.0151	0.0296		
(2nd order)	a ₂ =	1.0016	1.3653	1.5013	1.1214	0.8897	0.8715	1.1520	0.8781	0.005604	
a ₃ =	0.0050	0.2157	0.4314	0.5273	0.3400	-0.0689	-0.8641	-1.1634	-0.1931		

Table 12a. Band model parameters for SO₂.

	Absorber Parameters		Spectral Parameter C' (cm ⁻¹)								Coefficients of Analytical Function	Standard Deviation	
	n	m	ν_1	ν_2	ν_3	ν_4							
SIMIN	1.05084	1.08785	0.0								$a_1 = -0.26287$ $a_2 = 0.58035$ $a_3 = -0.00926$	0.008667	
Band Model Parameters			0.90099	1.01192	0.0								
A	Empirical												
	$\tau_1 =$ $x_1 =$	0.95 -1.5380	0.9 -1.1585	0.8 -0.6838	0.7 -0.3334	0.6 -0.0473	0.5 0.1988	0.4 0.4193	0.3 0.6260	0.2 0.8333	0.1 1.0715		
D	Piece-Wise Analytical												
S	$a_1 =$ $\left(\begin{smallmatrix} \text{1st} \\ \text{order} \end{smallmatrix} \right)$ $a_2 =$ $a_3 =$	-0.0228 0.8240 0	-0.1822 0.6864 0	-0.2537 0.5818 0	-0.2660 0.5450 0	-0.2663 0.5388 0	-0.2685 0.5497 0	-0.2785 0.5737 0	-0.3000 0.6080 0	-0.3373 0.6528 0	0.005563		
E													
T	$a_1 =$ $\left(\begin{smallmatrix} \text{2nd} \\ \text{order} \end{smallmatrix} \right)$ $a_2 =$ $a_3 =$	-0.1770 0.5906 -0.0866	-0.1867 1.0667 0.2064	-0.2710 0.5046 -0.0759	-0.2709 0.4258 -0.3133	-0.2615 0.6162 -0.5107	-0.3293 1.0007 -0.7296	-0.4937 1.4307 -0.8199	-0.6837 1.6815 -0.7357	-0.2321 0.4283 0.1179	0.0055635		

Table 12b. Band model parameters for NO.

	Absorber Parameters	Spectral Parameter C' (cm ⁻¹)							Coefficients of Analytical Function	Standard Deviation	
		n	m	v ₁	v ₂	v ₃	v ₄				
SIMMIN		0.19941	0.22631	0.0	2.697	1.271		a ₁ = -1.2203 a ₂ = 1.0908 a ₃ = -0.1188	0.015395		
Band Model Parameters		0.17830	0.22484	0.0	2.689	1.259					
A	Empirical										
	$\tau_1 =$ $x_1 =$	0.95 -0.1059	0.9 0.2140	0.8 0.5543	0.7 0.7739	0.6 0.9483	0.5 0.1028	0.4 1.2511	0.3 1.4046	0.2 1.5784	0.1 1.8074
D	Piece-Wise Analytical										
	$a_1 =$ $a_2 =$ $a_3 =$ $\left(\begin{smallmatrix} 1st \\ order \end{smallmatrix}\right)$	-1.1865 0.9770 0	-1.1824 0.9578 0	-1.1656 0.9276 0	-1.1404 0.8950 0	-1.1052 0.8579 0	-1.0604 0.8172 0	-1.0042 0.7723 0	-0.9381 0.7252 0	-0.8656 0.6793 0	0.015555
E											
	$a_1 =$ $a_2 =$ $a_3 =$ $\left(\begin{smallmatrix} 2nd \\ order \end{smallmatrix}\right)$	-1.1864 0.9777 -0.0065	-1.0810 0.3013 0.8544	-0.4268 -1.3600 1.7222	0.0792 -1.9671 1.6619	0.1053 -1.5164 1.1576	-0.9289 0.5929 0.0953	-3.6587 4.7838 -1.5105	-5.3854 6.7090 -2.0059	-0.9659 0.7984 -0.0352	0.015620
T											

Table 12c. Band model parameters for NO₂.

	Absorber Parameters		Spectral Parameter C' (cm ⁻¹)					Coefficients of Analytical Function	Standard Deviation		
			n	m	v ₁	v ₂	v ₃			v ₄	
	SIRMIN					930				a ₁ = -0.14141 a ₂ = 0.44740 a ₃ = -0.06716 0.010536	
0.58876		-0.71406	0.0								
0.52125		-0.60437	0.0								
A	Band Model Parameters										
	Empirical										
	$\tau_1 =$ $x_1 =$	0.95 -1.8032	0.9 -1.4438	0.8 -1.0054	0.7 -0.6608	0.6 -0.3403	0.5 -0.0330	0.4 0.2673	0.3 0.5751	0.2 0.9210	0.1 1.3562
D	Piece-Wise Analytical										
	$a_1 =$	0.2775	0.0962	-0.0570	-0.1261	-0.1450	-0.1459	-0.1409	-0.1290	-0.1224	
	$a_2 =$	0.8692	0.7436	0.5913	0.4867	0.4312	0.4037	0.3852	0.3645	0.3573	0.005237
S	$a_3 =$	0	0	0	0	0	0	0	0	0	
E											
	$a_1 =$	0.0894	0.9846	0.2095	-0.1135	-0.1475	-0.1419	-0.2291	-0.3829	-0.0196	
	$a_2 =$	0.6347	2.2425	1.2594	0.5427	0.3457	0.5098	0.8682	1.0818	0.1698	0.005484
T	$a_3 =$	-0.0722	0.6120	0.4010	0.0559	-0.2290	-0.4530	-0.5734	-0.4794	0.0785	

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TEXAS UNIV AT EL PASO DEPT OF ELECTRICAL ENGINEERING F/G 7/4
COMPUTERIZED METHOD FOR THE GENERATION OF MOLECULAR TRANSMITTANCE--ETC(U)
APR 80 J H PIERLUISSI, K TOMIYAMA DAAG29-79-C-0067
ERADCOM/ASL-CR-80-0067-1 NL

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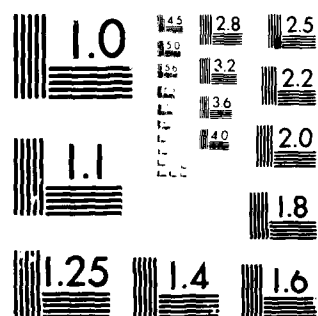
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8.3 Band Model Development

Two sets of curves of growth data for each major absorption band for four trace gases SO_2 , NO , NO_2 , and NH_3 were generated by the line-by-line calculation from the AFGL trace gas parameter tape. One of them consists of 12-cut data for several layers of atmosphere and the other consists of 65-cut data for the standard atmosphere only. Considering the wide range of applications, we included not only the standard atmospheric conditions but also one condition each from the tropical and subarctic winter climates. They are listed in Table 11 together with the 12 chosen transmittance values. The major absorption bands for the four trace gases are given in Table 12 together with the corresponding computed C' values.

Ten middle cuts were chosen from the 12-cut data and used in both ADSET and SIMMIN for the computation of the band model parameters and the standard transmission function. Depending on the number of major absorption bands, the total numbers of data used differ but are in the range of 60-210. The 65-cut data was used in ADSET for the piecewise interpolation to compute piecewise analytical transmission functions.

The ADSET computations were done first. The obtained band model parameter values n , m , and C'_1 and nine sets of coefficients a_1 , a_2 , and a_3 are tabulated in

Table 12 for SO_2 , NO , NO_2 , and NH_3 in this order. The corresponding standard deviations are also listed in these tables.

We also have generated standard atmospheric condition data for non-major bands of each trace gases. These data were used to evaluate non-major $C'(v)$ values. The computed $C'(v)$ values were listed in Table 5. As we have discussed, these $C'(v)$ values and the band model parameters together with the first order piecewise-analytical standard transmission function were implemented in the modularized Lowtran.

We recall that the SIMMIN computation is a recursive one and we need a set of initial guesses of the parameter values to start the computation. For the band model parameters n , m , and C'_1 , we used the values computed by ADSET. For a_1 and a_2 , the respective averages of the first order piecewise interpolation results of ADSET were used. Finally, a_3 was set to be zero. We note that our initial guesses are fairly accurate, since these values were optimal or optimal in average for ADSET computation. A small number ϵ which was used for the check of convergence was chosen to be 10^{-6} . Since the parameter values are expected to be in the range $-10 \sim 10$, $\epsilon = 10^{-6}$ gives the limit of numerical accuracy of numbers in the computer. The SIMMIN results are also listed in Table 12.

Typical curve-fits by piecewise analytical standard transmission functions to actual data are shown in Fig. 10 for SO_2 at 500 wavenumber. The corresponding analytical standard transmission function are also compared to the data in Fig. 10. In all of the three graphs in this Figure, the 65-cut data were also plotted to show the fitness of the standard curves.

The computation was repeated using two smaller data sets with 6 and 4 cuts only. The chosen cuts were (0.95, 0.9, 0.8, 0.6, 0.4, and 0.1) for 6 cut data and (0.95, 0.9, 0.6, and 0.2) for 4 cut data. The derived band model parameter values were similar to those in Table 12 and, hence, were not repeated here. Instead, the corresponding standard deviations were listed and compared with the 10 cut cases in Table 13.

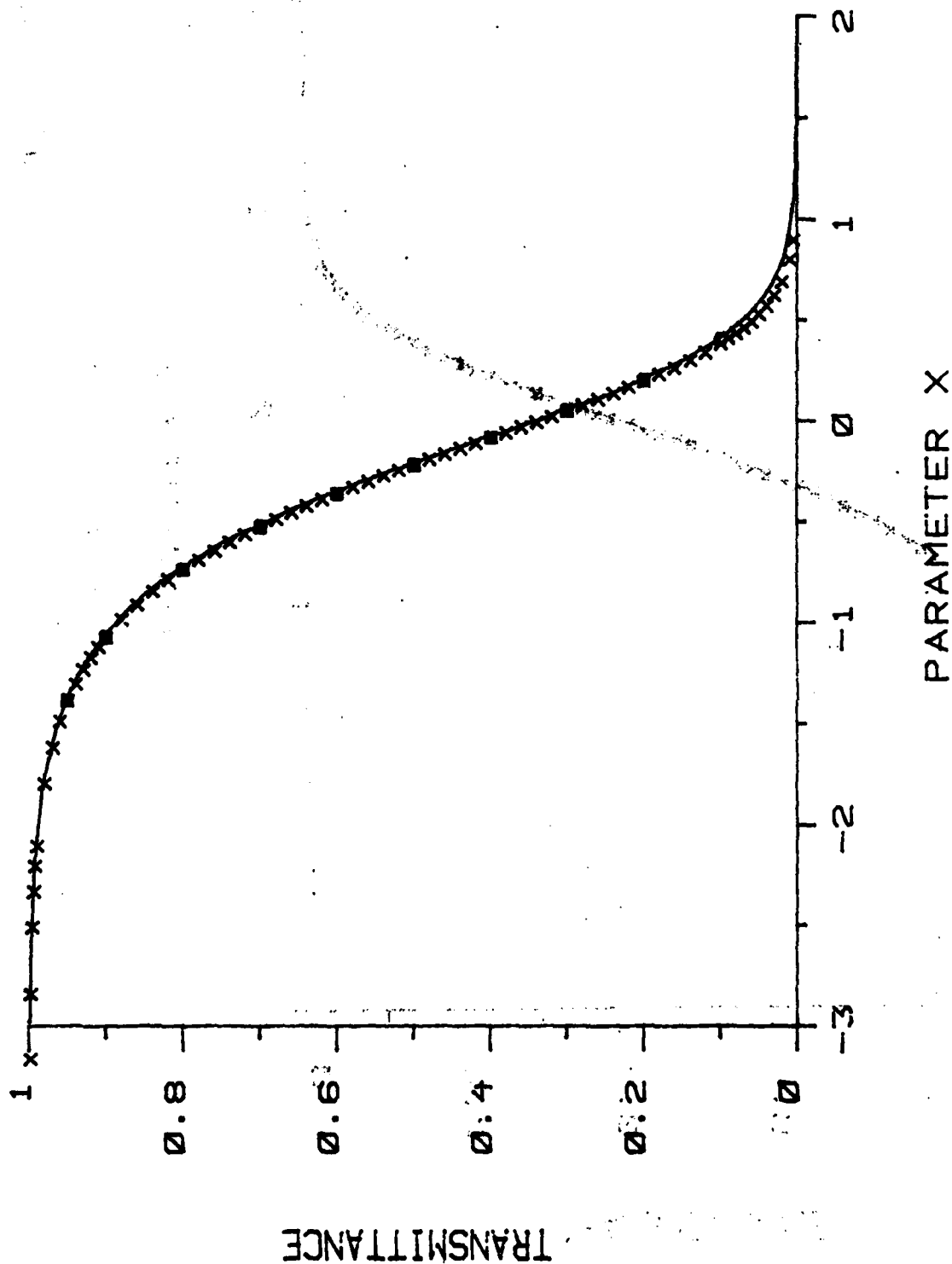
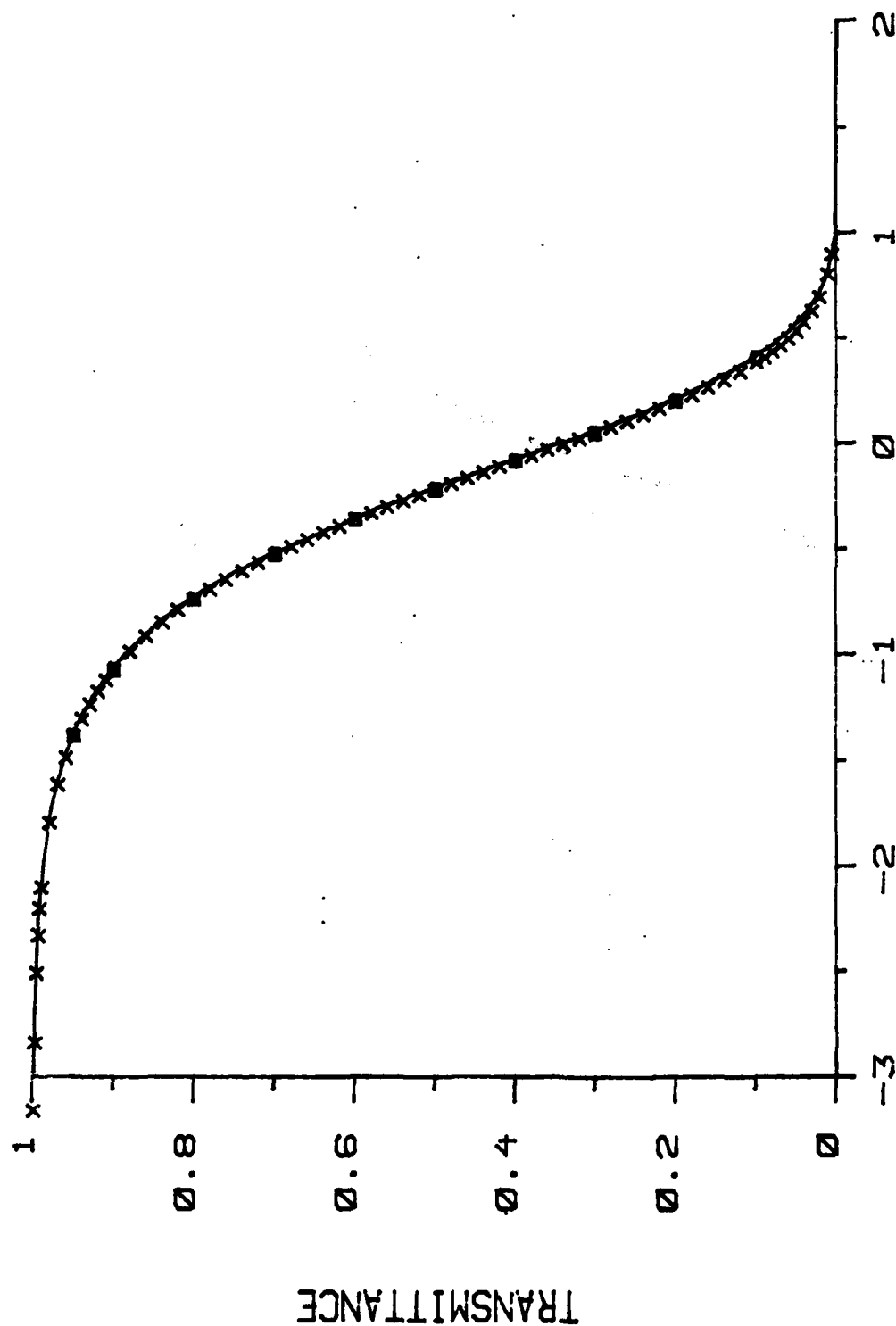


Fig. 10. (a) Standard transmittance function from
ADSET with $a_3 = 0$ for SO_2 at 500 cm^{-1}

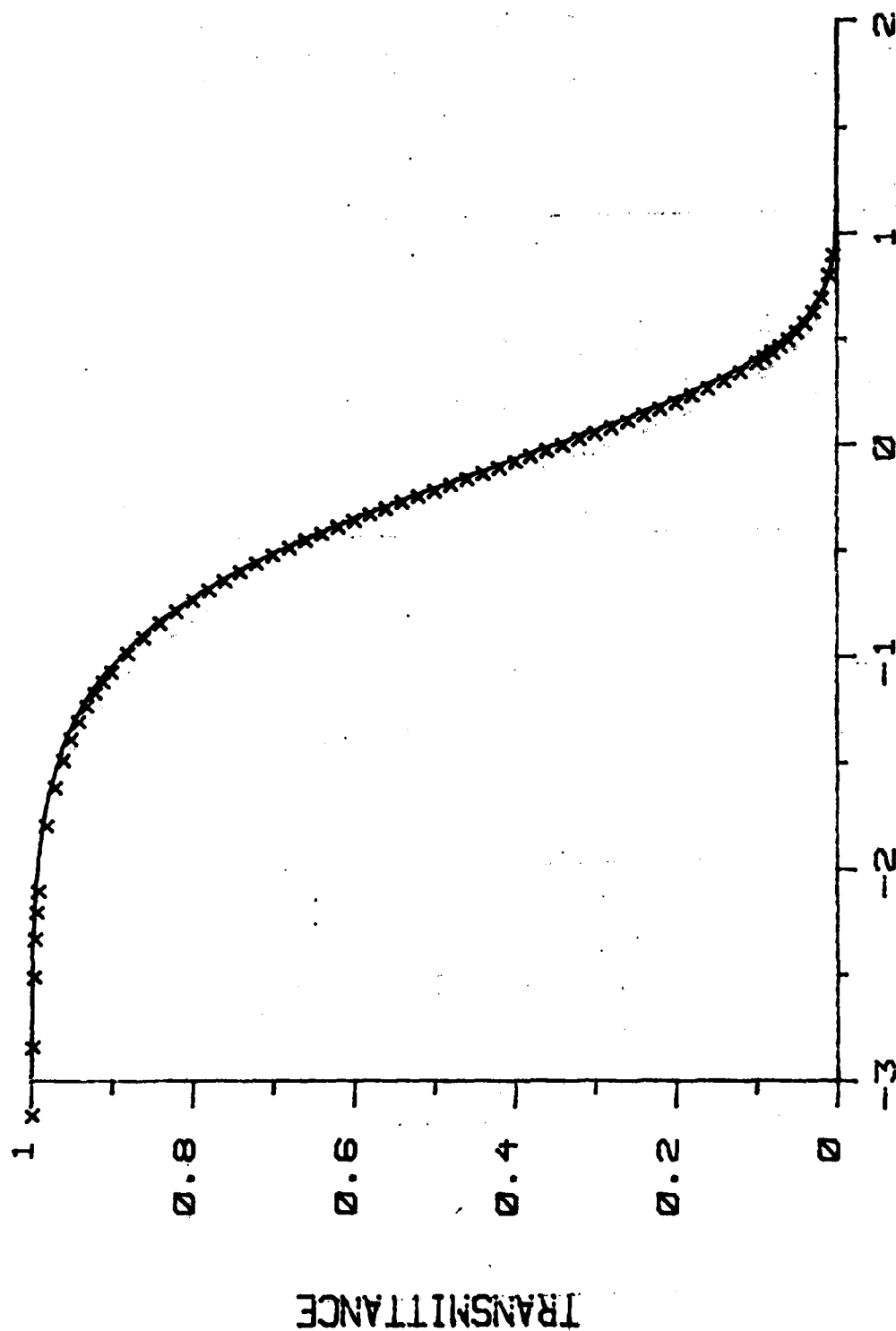
ADSET $a_3=0$
— piecewise analytic
□ empirical
x 65 data



PARAMETER X

Fig. 10. (b) Standard transmission function from
ADSET with $a_3 \neq 0$ for SO_2 at 500 cm^{-1}

ADSET $a_3 \neq 0$
— piecewise analytic
O empirical
x 65 data



PARAMETER X

Fig. 10. (c) Standard transmission function from SIMMIN

for SO_2 at 500 cm^{-1}

SIMMIN

—: Computed
x: 65 data

ABSORBER	CODES	STANDARD DEVIATIONS IN τ		
		4 Cut Data	6 Cut Data	10 Cut Data
SO ₂	SIMMIN	0.004450	0.006636	0.006259
	ADSET	0.005344	0.006551	0.005749
NO	SIMMIN	0.004830	0.006036	0.005604
	ADSET	0.005349	0.009345	0.008667
NO ₂	SIMMIN	0.009310	0.006934	0.005563
	ADSET	0.009210	0.006764	0.005635
NH ₃	SIMMIN	0.015009	0.014051	0.015395
	ADSET	0.01863	0.015355	0.015555
	SIMMIN	0.017377	0.014780	0.015620
	ADSET	0.004661	0.010423	0.010558
	SIMMIN	0.006455	0.005454	0.005237
	ADSET	0.006594	0.005400	0.005484

Table 13. Comparison of standard deviations in τ . The two rows, ADSET 1 and 2 are, respectively, for the piecewise analytical transmission functions and linear and quadratic exponents.

IX Discussion and Conclusions

9.1 Introduction

The modularized version presented here is fundamentally the same Lowtran code except for the separation of its computation structure into separate modules or subroutines. Although it is based on the 4th version, it can be adapted with little modification to any future versions, such as the 5th version now in progress. In fact, this latter version already has been structured by AFGL such that the emission/radiance loop is in a subroutine. The modularized code presented here breaks down that loop into a frequency selection subroutine, an equivalent absorber amount subroutine and separate subroutines for each one of the attenuation codes. The use of modules in a complex code such as Lowtran has numerous advantages, among which the amenability for updating by individual users to suit their specific needs is at the top of the list. In the ever changing field of modeling it is highly desirable to be able to easily modify the code for changes in the spectral coverage, the spectral resolution, the absorber concentrations in abnormal environments, the original transmission data used in the development and in the models used for the individual attenuators. The modularized version presented here, although is not the final answer to all conceivable needs, it is a first basic step

in that direction. Practicing this predicament, the authors added transmission models for the trace gases to the code.

9.2 Changes

The following are the basic changes introduced in The Modularized Lowtran:

1. The original main program was separated into a central program and subroutines for the absorber amount and the individual attenuation models.
2. In the interest of efficiency and clarity, a new subroutine FGQSL was added for the selection of the attenuation model effective at the given frequency.
3. The subroutine HNO_3 was re-structured to the form of the other previously incorporated subroutines in Lowtran.
4. Continuous analytical models were provided to replace the transmittance curves for H_2O vapor, O_3 and the uniformly-mixed gases.
5. New subroutines for the trace gases SO_2 , NO , NO_2 and NH_3 were added.

A copy of the modularized version is found in the Appendix.

9.3 Model Development

The values of band model parameters n and m and spectral parameters C'_1 obtained by ADSET and SIMMIN agreed very well. Furthermore, as it was shown in Table 13, the standard deviations corresponding to different cases followed a same pattern for the ADSET and SIMMIN results. This consistency proves the validity of both methods.

In general, the SIMMIN and ADSET computations resulted in similar standard deviations. It was expected that the ADSET computation should result in lower standard deviations since it contained more parameters to adjust. However, for a half of the cases, the SIMMIN code produced lower standard deviations. This is due to the large computational error for the ADSET computations in solving the normal equation $AX = B$. When the condition number of the coefficient matrix A becomes large (i.e., A becomes close to be singular), the computational error becomes so large that it can exceed the directly minimized error of the SIMMIN computation.

We note that this reversal occurred for all four cut data cases. This suggests that the advantage for ADSET of having more parameters to be adjusted is not significant for these cases. Hence, we recommend the use of SIMMIN if the available data contains less than five or six cuts.

A comparison of the standard deviations for two

piecewise interpolation results in the ADSET computation showed no significant difference. Furthermore, the results with the second method using quadratic form of x on the exponent of the double exponential function were 'bumpy' for some cases. Since the nature of the transmittance does not predict this behavior, we conclude that the first method using linear function of x is accurate enough to be used in the actual application.

The standard deviations were much higher for NO_2 cases than the cases for the rest of absorbers. By inspecting each curve of growth in detail, it was found that this was mainly due to the difference in the steepness of the curves of growth for three absorption bands. This difference cannot be compensated by C_1' values since they only shift the curves of growth linearly. In fact, within the current band model structure, it is impossible to compensate this difference. Hence, it may be necessary to modify some of the basic assumptions regarding the band model structure, if lower standard deviations are required.

As a side-effect of this discrepancy in the tangent of curves of growth, the SIMMIN computation took far more time for NO_2 cases than the rest. Most of the computations of ADSET were completed by 26-36 CPU seconds. The fluctuations in the computation time were very small. On the other hand, the SIMMIN computation time varied from 14 seconds to 270 seconds. NO_2 cases consumed about 200-270

seconds, which were about four times as much as that for the other cases. This is because the minimizing point in the parameter space is not well defined for NO_2 cases. In other words, the error surface in the parameter space has a very shallow bottom so that the updating step cannot produce large enough changes in the parameter guesses in order to have a rapid convergence.

Thus, it was found that the accuracy of the computed results and the time of execution depend heavily on the actual data. Hence, it is very important to give enough consideration for the data structure. This will be discussed in the next section.

9.4 Data Structure

As it was expressed earlier, we assumed that the number of layers (= the number of data points) in each cut is the same for an absorption band. This was done for the sake of easier coding in data handling. However, this assumption need not be valid. Especially in weaker absorption bands, it is required to use very large range values to have high enough equivalent absorber amounts in order to realize lower transmittances. In some cases the range becomes enormous (in the order of the radius of the earth) so that the corresponding data no longer possess physical significance. The ADSET code has a criterion that if the logarithm of the equivalent absorber, $\log W$, exceeds a certain critical value, then the corresponding data will be set aside and will not be used in the later computation. The critical value was set to be 2 for the actual computation, which corresponds approximately to a vertical path through the atmosphere.

In connection with this, if data are not available at some layers, then the data values are set at 0 to flag the nonavailability of data. ADSET can also detect this and will ignore the data.

A caution must be executed in choosing combinations of pressures and temperatures, i.e., atmospheric conditions. If a data set contains either the standard pressure or the

standard temperature or both only, then both ADSET and SIMMIN fail because of the fact that the coefficient of n or m or both in Eq.(12) becomes zero, since

$$\log \left(\frac{P_o}{P_o} \right) = \log 1 = 0, \quad (61)$$

$$\log \left(\frac{T_o}{T_o} \right) = \log 1 = 0. \quad (62)$$

For this case, the coefficient matrix A of the normal equation in ADSET becomes singular and the gradient corresponding to n or m or both in SIMMIN becomes zero all the time. Hence, the normal equation cannot be solved in ADSET and the initial guess of n or m or both cannot be changed in SIMMIN.

Another consideration which should be pointed out is to include different climate conditions. The standard climate condition for several layers of atmosphere contains sequence of pressures and temperatures both of which are monotone decreasing. Therefore, if only these conditions are used, then it is very difficult to distinguish the cause of changes in the transmittance due to the changes in pressure and in temperature. This leads to the shallow bottom of the error surface and hence, large computational error results in ADSET caused by the large condition number of the coefficient matrix and slow convergence in SIMMIN due to the small gradient. In the actual computation,

we included not only the standard climate conditions but also one condition each from the tropical and subarctic winter climates in consideration of wide applicability of the results. Numerically speaking, this also resulted in making the regression problem well-posed by breaking the monotonousness of the pressure and temperature combinations of the standard conditions. In fact, several computations were done for ADSET and SIMMIN with standard condition data only. SIMMIN took 10-45 minutes of CPU time to converge if it were convergent and ADSET resulted in a set of absurd values for n and m . Thus, the importance of the numerical consideration, which is ignored in many cases, is clearly indicated. The proper care should be taken when selecting controllable data values.

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C (GM,M=3),03 DENSITY(CM,M=3), VIS(KM),RANGE(KM) WITH FORMAT 103 IN
C SUBROUTINE ARS08.
C MODEL=7 WHEN NEW MODEL ATMOSPHERE (E.G. RADIOSONDE DATA) USED.
C DATA CARDS ARE READ IN BETWEEN CARDS 1 AND 2, AND SHOULD CONTAIN:
C ALTITUDE(KM),PRESSURE,TEMP,DEW PT,TEMP,REL. HUMIDITY,M20 DENSITY,
C M3 DENSITY,AEROSOL N7, DENSITY(CM=3) ACCORDING TO FORMAT 103 IN
C SUBROUTINE ARS08.
C NOTE THAT EITHER DEW PT, TEMP,OR REL. HUMIDITY CAN BE USED.
C M1,M2,M3, ARE USED TO CHANGE TEMP,M20, AND M3 ALTITUDE PROFILES.
C TEMISS=0=TRANSMISSION MODE / TEMISS=1=EMISSION MODE
C TACOND=TEMPERATURE OF EARTH IN DEGREES KELVIN
C IF TACOND=ZERO, ASSUMES AIR TEMPERATURE OF MODEL ATMOS.
C IF IM20=0 NO AEROSOL SCATTERING IS COMPUTED
C IM20=1 IF AEROSOL ATTENUATION REQUIRED (THIS IS USED IN
C CONJUNCTION WITH VISUAL RANGE (SEE CARD 2))
C IM20=1 OR 2 ALSO GIVE AEROSOL ATTENUATION FOR 23KM AND 5KM VIS.
C MAKE MODELS RESPECTIVELY IF VIS= 0 ON CARD 2
C IM20=7 FOR OTHER AEROSOL MODELS (E.G. MARITIME ECT) WHICH ARE
C READ INTO PROGRAM
C
C ITYPE= 1,2 OF 3 INDICATES THE TYPE OF ATMOSPHERIC PATH
C ITYPE= 3, VERTICAL OR SLANT PATH TO SPACE
C ITYPE= 2, VERTICAL OR SLANT PATH BETWEEN TWO ALTITUDES
C ITYPE= 1, CORRESPONDS TO A HORIZONTAL (CONSTANT PRESSURE) PATH
C
C M1 = OBSERVED ALTITUDE (KM)
C MPX(9)=MIX(29)
C M2 = SOURCE ALTITUDE (KM)
C ANGLE = ZENITH ANGLE AT M1 (DEGREES)
C RANGE = PATH LENGTH (KM)
C BETA = EARTH CENTRE ANGLE
C VIS = VISUAL RANGE AT SEA LEVEL (KM)
C ( IF ITYPE=1 READ M1 AND RANGE; IF ITYPE=3 READ M1 AND ANGLE;
C IF ITYPE=2 READ M1 AND TWO OTHER PARAMETERS E.G. M2 AND ANGLE)
C
C V1 = INITIAL FREQUENCY (HAVENUMBER CM-1) INTEGER VALUE
C V2 = FINAL FREQUENCY (HAVENUMBER CM-1) INTEGER VALUE
C DV = FREQUENCY INTERVALS AT WHICH TRANSMITTANCE IS PRINTED
C NOTE: DV MUST BE A MULTIPLE OF 5 CM-1
C
C IXY = 0 TO END DATA, = 1 FOR NEW VI,V2,IV ONLY, = 2 TO CONTINUE
C DATA, = 3 FOR NEW CARD 2 ONLY, = 4 FOR NEW CARD 1 ONLY.
C *****
C IXY=0
C K43=15
C READ (5,100) IATM,NL
C READ (5,101) (M21(I),I=1,NL)
C READ (5,101) (M22(I),I=1,5)
C M22(6)=M21(6)
C DO 1 J=1,3
C K2=20J
C K1=K2-1
C DO 1 I=1,NL
C READ (5,102) Z(I),IPK(I),TK(I),MAIK(I),MHK(I),MOIK(I),K=K1,K2)
C READ (5,132) PPMSC2,PPMNO,PPMH1,PPMH2
C READ (5,103) (VX(I),CT(I),CTA(I),I=1,44)

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0038 READ (5,105) (C1(1),I=1,250)
0039 READ (5,105) (C2(1),I=1,1575)
0040 READ (5,105) (C3(1),I=1,540)
0041 READ (5,105) (C4(1),I=1,133)
0042 READ (5,105) (C5(1),I=1,15)
0043 READ (5,105) (C6(1),I=1,102)
0044 READ (5,107) (C11(1),I=1,44)
0045 READ (5,124) (C12(1),I=1,115)
0046 READ (5,125) (C3(1),I=1,52(1),I=1,9)
0047 READ (5,126) (C13(1),I=1,43)
0048 READ (5,126) (C14(1),I=1,109)
0049 READ (5,126) (C15(1),I=1,85)
0050 READ (5,127) (C16(1),I=1,62(1),I=1,4)
0051 READ (5,127) (C17(1),I=1,62(1),I=1,9)
0052 READ (5,127) (C18(1),I=1,62(1),I=1,9)
0053 C5(1)=0
0054 C5(1)=0
0055 C5(1)=0
0056 C5(1)=0
0057 C5(1)=0
0058 C5(1)=0
0059 C5(1)=0
0060 C5(1)=0
0061 C5(1)=0
0062 C5(1)=0
0063 C5(1)=0
0064 C5(1)=0
0065 C5(1)=0
0066 C5(1)=0
0067 C5(1)=0
0068 C5(1)=0
0069 C5(1)=0
0070 C5(1)=0
0071 C5(1)=0
0072 C5(1)=0
0073 C5(1)=0
0074 C5(1)=0
0075 C5(1)=0
0076 C5(1)=0
0077 C5(1)=0
0078 C5(1)=0
0079 C5(1)=0
0080 C5(1)=0
0081 C5(1)=0
0082 C5(1)=0
0083 C5(1)=0
0084 C5(1)=0
0085 C5(1)=0
0086 C5(1)=0
0087 C5(1)=0
0088 C5(1)=0
0089 C5(1)=0
0090 C5(1)=0
0091 C5(1)=0
0092 C5(1)=0
0093 C5(1)=0
0094 C5(1)=0
0095 C5(1)=0

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0096          ICOUNT=0
0097          IF(IEMISS.EQ.0) GO TO 7
0098          PADSUM=0.0
0099          FACT=0.5
0100          CALL PATHWLAY.WPATH,YESY)
0101          PRINT 113
0102          PRINT 114
0103          IF(IEMISS.EQ.0) IKMAX=IKLO
0104          C===== BEGINNING OF TRANSMITTANCE CALCULATIONS
0105          IV=V*V*IV
0106          AX=RX+1
0107          SUMV=0.
0108          TGLD=1.
0109          YSGLD=1.
0110          IKLO=1
0111          IF(IEMISS.EQ.0) IKLC=IKMAX
0112          PC 17 IK=IKLC,IKMAX
0113          IF(IEMISS.EQ.0) GO TO 9
0114          GO 9 K=IKMAX
0115          WK=1-WPATH(IK,K)
0116          CONTINUE
0117          LJ=IK
0118          IF(LJ.NE.0) GO TO 11
0119          IF (ICOUNT.EQ.0) GO TO 10
0120          IF (ICOUNT.EQ.5) GO TO 10
0121          GO TO 11
0122          ICOUNT=0
0123          IF(IEMISS.EQ.0) PRINT 115
0124          GO 12 K=1,KMAX
0125          TX(K)=1.0
0126          CONTINUE
0127          ICOUNT=ICOUNT+1
0128          V=IV
0129          I=1/(V-350)/5+1
0130          SUM4=0.
0131          SUM5=0.
0132          SUM6=0.
0133          SUM7=0.
0134          SUM8=0.
0135          SUM11=0.
0136          CALL FREQL(1,IV,W,IMAZE,TX,ALAM)
0137          TX(9)=SUM4+SUM5+SUM6+SUM7+SUM8+SUM11
0138          IF (TX(9).EQ.0.0) GO TO 14
0139          IF (TX(9).LE.0.1) GO TO 13
0140          IF (TX(9).GT.20.) GO TO 15
0141          TX(9)=EXP(-TX(9))
0142          GO TO 16
0143          TX(9)=1.0-TX(9)+0.5-TX(9)*TX(9)
0144          TX(9)=1.0
0145          GO TO 16
0146          TX(9)=0.
0147          TX(9)=TX(11)*TX(12)*TX(13)*TX(14)*TX(15)
0148          IF (IV.GE.1300) TX(3)=TX(8)
0149          IF(IEMISS.EQ.0) GO TO 19
0150          ALAM=1.0E+04/V
0151          BBI=COFFITRAY(IK,V)
0152          TLJFW=TX(9)*TX(10)/(TX(7)*TX(6))

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0153 TSUM=TX12+TX13+TX14+TX15
0154 TSUM=TSUM*TX16
0155 IF (TX16.LT.0.05) GO TO 18
0156 SUMV=SUMV+TSUM*TX16
0157 TSUM=TSUM*TX16
0158 TSUM=TSUM*TX16
0159 CONTINUE
0160 CONTINUE
0161 TAUS=0.
0162 IF (TAUS.LT.0.001) GO TO 19
0163 TAUS=TAUS*TX16
0164 IF (TAUS.LT.0.001) GO TO 19
0165 TAUS=TAUS*TX16
0166 IF (TAUS.LT.0.001) GO TO 19
0167 SUMV=SUMV+TAUS
0168 IF (SUMV.LT.0.001) GO TO 19
0169 SUMV=SUMV*TX16
0170 SUMV=SUMV*TX16
0171 SUMV=SUMV*TX16
0172 IF (SUMV.LT.0.001) GO TO 19
0173 SUMV=SUMV*TX16
0174 SUMV=SUMV*TX16
0175 SUMV=SUMV*TX16
0176 SUMV=SUMV*TX16
0177 SUMV=SUMV*TX16
0178 SUMV=SUMV*TX16
0179 SUMV=SUMV*TX16
0180 SUMV=SUMV*TX16
0181 SUMV=SUMV*TX16
0182 SUMV=SUMV*TX16
0183 SUMV=SUMV*TX16
0184 SUMV=SUMV*TX16
0185 SUMV=SUMV*TX16
0186 SUMV=SUMV*TX16
0187 SUMV=SUMV*TX16
0188 SUMV=SUMV*TX16
0189 SUMV=SUMV*TX16
0190 SUMV=SUMV*TX16
0191 SUMV=SUMV*TX16
0192 SUMV=SUMV*TX16
0193 SUMV=SUMV*TX16
0194 SUMV=SUMV*TX16
0195 SUMV=SUMV*TX16
0196 SUMV=SUMV*TX16
0197 SUMV=SUMV*TX16
0198 SUMV=SUMV*TX16
0199 SUMV=SUMV*TX16
0200 SUMV=SUMV*TX16
0201 SUMV=SUMV*TX16
0202 SUMV=SUMV*TX16
0203 SUMV=SUMV*TX16
0204 SUMV=SUMV*TX16
0205 SUMV=SUMV*TX16
0206 SUMV=SUMV*TX16
0207 SUMV=SUMV*TX16
0208 SUMV=SUMV*TX16
0209 SUMV=SUMV*TX16

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0210 IF(IATV.FO.O) GO TO 25
0211 GO TO (22,23,24,25),IATV
0212 READ 122,VI,V2,DV
0213 AVA=10000./VI
0214 ALA=10000./V2
0215 PRINT 123,VI,V2,DV,ALA,AVM
0216 SUM=0.0
0217 GO TO 6
0218 IF(MODEL.FO.O) GO TO 3
0219 GO TO 5
0220 READ 100,MODEL,IMATF,ITYPE,LEA,JP,IM,VL,V2,M3,ML,IEMISS,PO,TROND
0221 IF(IEMISS.FO.O) PRINT 108
0222 IF(IEMISS.FO.O) PRINT 109
0223 LFNTR=LEN
0224 PRINT 100,MODEL,IMATF,ITYPE,LEA,JP,IM,VL,V2,M3,ML,IEMISS,PO,TROND
0225 GO TO 3
0226 STOP
0227 FCNAT(113,2F10.3)
0228 FCNAT(18,10.3)
0229 FCNAT(15,1,2F9.3,F5,1,F9.3,2F7.1)
0230 FCNAT(4,5,2,2F7.5)
0231 FCNAT(15F5,2)
0232 FCNAT(3E9,2)
0233 FCNAT(12,6,3)
0234 FCNAT(1,1) PROGRAM WILL BE EXECUTED IN THE EMISSION MODE
0235 FCNAT(1,1) PROGRAM WILL BE EXECUTED IN THE TRANSMISSION MODE
0236 FCNAT(1/10X,38H EQUIVALENT SEA LEVEL ABSORBER AMOUNTS//21X10HAT
1FP VAPOR C02 STC C27N NITROGEN (CONT) H2C (CONT)
2 NOL SCAT AEROSOL 07N=(V-VIS)/24X,7HGM CM=2,10X,2HGM,13X,2HGM,10X,6HATM CM
30X,6HATM CM,10X,2HGM,9X,7HGM CM=2,10X,2HGM,13X,2HGM,10X,6HATM CM
FCNAT(1/21X,64H NITRIC ACID S02 N3
1 NC27)
111
112 FCNAT(1/10X,8H W(1-3)=3E14,3)
113 FCNAT(1H1,50X,RADIANCE(WATTS/CM2=STER-XXX))
114 FCNAT(10X,PER(CM=1) WVL(MICRON) PER CM=1 PER MICRON,
1 INTEGRAL TRANS)
115 FCNAT(1H1,1/10X,23H FREQ WAVELENGTH H2O,5X4HCO2,5X,52HCL2H2O
1H2 CONT H2O CONT WOL SCAT AEROSOL AEROSOL /11X,14H CM=1 MICRON
1S,714XSTRANS,4X,5H ARS)
116 FCNAT(10X,FR,1,F13,6,3E13,5,F13,6)
117 FCNAT(10X,16,9F9,4)
118 FCNAT(10X,16,9F9,4)
119 FCNAT(1 RADMIN ,F12,3,5E12,5,1 RADMAX ,F12,3,5E12,5)
120 FCNAT(1 INTEGRATED ABSORPTION FROM,15,1 TO,15,1 CM=1 ,F10,2,
1 AVERAGE TRANSMITTANCE ,F6,4)
121 FCNAT(1 INTEGRATED RADIANCE ,F12,5,1WATT CM =2 SP)
122 FCNAT(17F10,3)
123 FCNAT(1/10X,21H FREQUENCY RANGE VLF ,F7,1,13H CM=1 TO VLF ,F7,1,1
14H CM=1 FOR PV ,F6,1,9H CM=1 (F6,2,1 ,F5,2,1 MICRONS )
124 FCNAT(10F8,4)
125 FCNAT(10F8,4)
126 FCNAT(10F8,3)
127 FCNAT(10F8,4)
128 FCNAT(1/10X,10H W(1-15)=5(F14,3))
129 FCNAT(1/10X,23H FREQ WAVELENGTH S02,6X2HNO,7X,31HNO3
1 INTEGRATED TOTAL/11X,14H CM=1 MICRON,5,414XSTRANS,1X,10H4-SURP
210N,2X,5HTRANS)
130 FCNAT(10X,16,7F9,4)
132 FCNAT(14F8,3)
0237
0238
0239
0240
0241
0242
0243
0244
0245
0246
0247
0248
0249
0250
0251
0252
0253
0254
0255
0256

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0001 SURROUTINE ABSORB(I1XV,LENTOR,M2,MIX,M1,X,V1,V2,DV,ALAM,SUMAM,LAV)
0002 COMMON /MD1/ Z(34),P(7,34),T(7,34),E(15,34),W(7,34),M,NL,PE,CH,C
0003 IC,P1,W(7,34)
0004 COMMON /MD2/ IFIND,CA,IP,JSTOP
0005 COMMON /MD3/ MZ(34),MZ2(16),WC(7,34)
0006 COMMON /MD4/ THAZE,JP,IM,M1,M2,M3,ML,PC,TROUND
0007 COMMON /MD5/ RACMAX,RACMIN,VPMAX,VPMIN
0008 COMMON /MD14/ PPMQ02,PPMQ03,PPMQ04,PPMQ05
0009 COMMON /EN1/ IEMISS,KMAX,ANGLE,LEN,MXIN,IJ,J1,J2,MJN,JEXTFA,IITYPE
0010 COMMON /EN7/ M1,M2,M3,MODEL
0011 DIMENSION AMZE(34),JSTOR(34),MZ2(2),MLAV(34),VH(15),W(15),E(
0012 115),TX(15),MMIX(34),W(2)
0013 *****
0014 C THIS SURROUTINE CALCULATES THE EQUIVALENT ABSORBER AMOUNT FOR EACH
0015 C GAS AND FOR ANY PATH GEOMETRY
0016 C
0017 C F(1-15) ARE ABSORBER AMOUNTS PER KV AT LEVEL 1, W(1-15) ARE
0018 C EQUIVALENT ABSORBER AMOUNTS AT A GIVEN ALTITUDE.
0019 *****
0020 F(1)=EXP(19.9766-14.2595*A-2.43982*A*A)*A
0021 IF(I1XV.EQ.3) GO TO 1
0022 IF(4.EQ.7.AND.P1.NE.JIGD) GO TO 3
0023 IF(I1XV.GT.3) GO TO 13
0024 IF(MODEL.EQ.0) GO TO 3
0025 READ 100,M1,M2,ANGLE,RANGE,BETA,VIS
0026 PRINT 101,M1,M2,ANGLE,RANGE,BETA,VIS
0027 C ***** CONSTRUCT THE PARAMETER FOR CALCULATING CONSTANT PRESSURE PATH QU
0028 X1=RE+1
0029 IF (IITYPE.EQ.3) GO TO 8
0030 IF (IITYPE.EQ.1) GO TO 13
0031 X2=RE+2
0032 IF (RANGE.EQ.0.) GO TO 10
0033 PRINT 102,M1,M2,ANGLE,RANGE,BETA,VIS
0034 IF (I42.EQ.0.AND.ANGLE.NE.0) GO TO 2
0035 ANGLE=ASCOS(0.5*(M2-M1)*(1.+X2/X1)/RANGE-RANGE/X1)/CA
0036 GO TO 12
0037 X2=SQRT((X1/RANGE+RANGE/X1)+2.*COS(ANGLE*CA))*X1/RANGE
0038 M2=X2+1
0039 GO TO 12
0040 CONTINUE
0041 IF(M1.EF.0)M1=1
0042 GO TO 7,K1,ML
0043 THAZE(1)=0.0
0044 IF(I1.EQ.0)DEAD 103,M1,P(7,1),TMO,PP,PMAX,M(7,K1),W(7,K1),VIS,RANGE
0045 IF(I1.EQ.0)PRINT 104,M1,P(7,1),TMO,PP,PMAX,M(7,K1),W(7,K1),VIS,RANGE
0046 IF(M1.GT.0)DEAD 103,Z(K1),P(7,K1),TMO,PP,PMAX,M(7,K1),W(7,K1),THAZE(K1)
0047 IF(M1.EQ.0)Z(K1)=M1
0048 J=IC+TX(K1)+1,OF=61+1.
0049 IF(I7(K1).GE.25.0) J=(Z(K1)-25.0)/5.0+26.
0050 IF(I7(K1).GE.50.0) J=(Z(K1)-50.0)/20.0+31.
0051 IF(I7(K1).GE.70.0) J=(Z(K1)-70.0)/30.0+32.
0052 IF(J.GT.33)J=33
0053 FAC=Z(K1)=FLOAT(J=1)
0054 IF(J.LT.26) GO TO 4
0055 FAC=(Z(K1)-5.0)*FLOAT(I=26)=25.1/5.
0056 IF(J.GE.31) FAC=(Z(K1)-50.0)/20.

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0047 IF(J,GE,32) FAC=1Z(KI=70,01)/30.
0048 IF(FAC,GT,1.0) FAC=1.0
0049 L=J+1
0050 T(7,K)=74P+273.15
0051 IF(4,GT,0)T(7,K)=T(41,J)=T(41,L1)/T(41,J))**FAC
0052 T(7,K)=15/T(7,K)
0053 T(7,K)=15/T(7,K)
0054 IF(4,LE,0.0) T(7,K)=15/T(7,K)
0055 IF(4,GT,0)T(7,K)=T(41,J)=T(41,L1)/T(41,J))**FAC
0056 IF(4,GT,0.0) T(7,K)=0.01*H(7,K)
0057 IF(4,GT,0)T(7,K)=0.01*H(7,K)
0058 H(7,K)=0.
0059 IF(4,GT,0)T(7,K)=0.01*H(7,K)
0060 H(7,K)=0.
0061 CONTINUE
0062 IF(7,K)=5.5,01G TO 6
0063 IF(AHAZE(K1,FO,0.0)A422(K)=H22(L1)/H22(LJ))**FAC
0064 IF(AHAZE(K1,FO,0.0)A422(K)=H22(LJ)/H22(LJ))**FAC
0065 IF(4,GT,0)T(7,K)=T(41,J)=T(41,L1)/T(41,J))**FAC
0066 IF(4,GT,0.0) T(7,K)=0.01*H(7,K)
0067 PRINT 103,Z(K),P(7,K),T(7,K),H(7,K),H(7,K),A422(K)
0068 CONTINUE
0069 T(7,K)=0
0070 NL=4L
0071 M1=0
0072 M2=0
0073 M3=0
C NOTE THAT 2111 MAY NOT CORRESPOND TO THE VALUES GIVEN FOR STANDARD
C MODEL ATMOSPHERES
0074 GO TO 1
0075 IF (11V,GE,31) GO TO 13
0076 IF (RANGE,GT,0.0) GO TO 9
0077 IF (H2,GT,0.0,AND,H2,LT,M1) IFIND=1
0078 GO TO 13
0079 ITYPE=2
0080 RETA=ACOS(10.5*(RANGE/RANGE/(X1*X2)-X2/X1-X1/X2))/CA
0081 IF (BETA,FO,0.0) GO TO 11
0082 IFIND=1
0083 RET=CA*RETA
0084 X2=RETA*H2
0085 ANGLE=ATAN(X2/SIN(RET)/(X2*CCOS(RET)-X1))/CA
0086 RANGE=X2/SIN(RET)/SIN(ANGLE-CA)
0087 RET=RETA
0088 GO TO 13
0089 RANGE=(X2/X1)*2-(1+(X1*ANGLE-CA))/2
0090 IF (RANGE,GT,0.0) RANGE=X1/(SIN(RET)-RANGE)*2
0091 IF (ANGLE,GE,0.0,AND,ANGLE,NE,180.0) RET=ASIN(RANGE/SIN(ANGLE-CA)/X2)
0092 IF (ANGLE,LT,0.0) ANGLE=ANGLE+PI
0093 IF (RANGE,LT,0.0) RANGE=RANGE
0094 RET=RET/CA
0095 PRINT 102, M1,M2,ANGLE,RANGE,RET,VIS
0096 CONTINUE
0097 DO 14 I=1,34
0098 M1=J+1,MAX
0099 M1=J+1,MAX
0100 SUMA=0.
0101 IF(11V,LE,21) READ 100,V1,V2,DV
0102 IF(11V,LE,21)PRINT 100,V1,V2,DV

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0103 IF (I*TYPE.EQ.1) PRINT 136, H1, RANGE
0104 IF (I*TYPE.EQ.2) PRINT 137, H1, H2, ANGLE
0105 IF (I*TYPE.EQ.3) PRINT 138, H1, ANGLE
0106 IF (I*TYPE.EQ.4) PRINT 139, H1, ANGLE
0107 IF (I*TYPE.EQ.5) PRINT 140, H1, ANGLE
0108 IF (I*TYPE.EQ.6) PRINT 141, H1, ANGLE
0109 IF (I*TYPE.EQ.7) PRINT 142, H1, ANGLE
0110 IF (I*TYPE.EQ.8) PRINT 143, H1, ANGLE
0111 IF (I*TYPE.EQ.9) PRINT 144, H1, ANGLE
0112 IF (I*TYPE.EQ.10) PRINT 145, H1, ANGLE
0113 IF (I*TYPE.EQ.11) PRINT 146, H1, ANGLE
0114 IF (I*TYPE.EQ.12) PRINT 147, H1, ANGLE
0115 IF (I*TYPE.EQ.13) PRINT 148, H1, ANGLE
0116 IF (I*TYPE.EQ.14) PRINT 149, H1, ANGLE
0117 IF (I*TYPE.EQ.15) PRINT 150, H1, ANGLE
0118 IF (I*TYPE.EQ.16) PRINT 151, H1, ANGLE
0119 IF (I*TYPE.EQ.17) PRINT 152, H1, ANGLE
0120 IF (I*TYPE.EQ.18) PRINT 153, H1, ANGLE
0121 IF (I*TYPE.EQ.19) PRINT 154, H1, ANGLE
0122 IF (I*TYPE.EQ.20) PRINT 155, H1, ANGLE
0123 IF (I*TYPE.EQ.21) PRINT 156, H1, ANGLE
0124 IF (I*TYPE.EQ.22) PRINT 157, H1, ANGLE
0125 IF (I*TYPE.EQ.23) PRINT 158, H1, ANGLE
0126 IF (I*TYPE.EQ.24) PRINT 159, H1, ANGLE
0127 IF (I*TYPE.EQ.25) PRINT 160, H1, ANGLE
0128 IF (I*TYPE.EQ.26) PRINT 161, H1, ANGLE
0129 IF (I*TYPE.EQ.27) PRINT 162, H1, ANGLE
0130 IF (I*TYPE.EQ.28) PRINT 163, H1, ANGLE
0131 IF (I*TYPE.EQ.29) PRINT 164, H1, ANGLE
0132 IF (I*TYPE.EQ.30) PRINT 165, H1, ANGLE
0133 IF (I*TYPE.EQ.31) PRINT 166, H1, ANGLE
0134 IF (I*TYPE.EQ.32) PRINT 167, H1, ANGLE
0135 IF (I*TYPE.EQ.33) PRINT 168, H1, ANGLE
0136 IF (I*TYPE.EQ.34) PRINT 169, H1, ANGLE
0137 IF (I*TYPE.EQ.35) PRINT 170, H1, ANGLE
0138 IF (I*TYPE.EQ.36) PRINT 171, H1, ANGLE
0139 IF (I*TYPE.EQ.37) PRINT 172, H1, ANGLE
0140 IF (I*TYPE.EQ.38) PRINT 173, H1, ANGLE
0141 IF (I*TYPE.EQ.39) PRINT 174, H1, ANGLE
0142 IF (I*TYPE.EQ.40) PRINT 175, H1, ANGLE
0143 IF (I*TYPE.EQ.41) PRINT 176, H1, ANGLE
0144 IF (I*TYPE.EQ.42) PRINT 177, H1, ANGLE
0145 IF (I*TYPE.EQ.43) PRINT 178, H1, ANGLE
0146 IF (I*TYPE.EQ.44) PRINT 179, H1, ANGLE
0147 IF (I*TYPE.EQ.45) PRINT 180, H1, ANGLE
0148 IF (I*TYPE.EQ.46) PRINT 181, H1, ANGLE
0149 IF (I*TYPE.EQ.47) PRINT 182, H1, ANGLE
0150 IF (I*TYPE.EQ.48) PRINT 183, H1, ANGLE
0151 IF (I*TYPE.EQ.49) PRINT 184, H1, ANGLE
0152 IF (I*TYPE.EQ.50) PRINT 185, H1, ANGLE
0153 IF (I*TYPE.EQ.51) PRINT 186, H1, ANGLE
0154 IF (I*TYPE.EQ.52) PRINT 187, H1, ANGLE
0155 IF (I*TYPE.EQ.53) PRINT 188, H1, ANGLE
0156 IF (I*TYPE.EQ.54) PRINT 189, H1, ANGLE
0157 IF (I*TYPE.EQ.55) PRINT 190, H1, ANGLE
0158 IF (I*TYPE.EQ.56) PRINT 191, H1, ANGLE
0159 IF (I*TYPE.EQ.57) PRINT 192, H1, ANGLE

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0160 PT=PSORSORT(TSI)
0161 D=0.1*MMH(4,1)
0162 IF(M2.GT.0.AND.M.LT.7) D=0.1*MMH(42,1)
0163 FM(1,1)=D*EXP(0.9
0164 FM(2,1)=EXP(0.75
0165 FM(6,1)=0.3*PTX
0166 PPM=4.56E-5*E+273.15/TS
0167 TS1=(296.0/273.15)*TS
0168 FM(5,1)=D*PPM*EXP(6.08*(TS1-1.0))+0.302*DE(P5=PPM)
0169 FM(10,1)=D*(PPM+0.12*(P5=PPM))*EXP(4.56*(TS1-1.0))
0170 FM(6,1)=X
0171 MAZE=MZ1(1)
0172 IF(M.EQ.7) MAZE=MAZE(1)
0173 IF(1211.GE.5.0) GO TO 20
0174 IF(M.NE.7.AND.1*MAZE.EQ.2) MAZE=MZ2(1)
0175 IF(1*MAZE.EQ.2.AND.M.EQ.7) MAZE=MAZE(1)
0176 IF(VIS.LE.0.0) GO TO 20
0177 IF(M.NE.7) MAZE=6.38*E(MZ2(1)-MZ1(1))/VIS+MZ1(1)/5.0+MZ2(1)/23.0
0178 IF(M.NE.7) GO TO 20
0179 MAZE=6.38*E(MZ2(1)-MAZE(1))/VIS+MAZE(1)/5.0+MZ2(1)/23.0
0180 IF(MAZE.LT.0.0) MAZE=0.0
0181 FM(7,1)=MAZE/MZ1(1)
0182 IF(MCDEL.EQ.7) EM(7,1)=MAZE/MAZE(1)
0183 FM(9,1)=46.6667*EM(7,1)
0184 IF(M3.GT.0.AND.M.LT.7) EM(8,1)=46.667*EM(7,1)
0185 FM(3,1)=EM(8,1)*E+3
0186 C FM(11,1)=MNO3*ABSORDER*AMOUNT*(ATM=C4)/KM
0187 FM(11,1)=46*TS*SHMX(1)+1.0E-04
0188 IF(MCDEL.EQ.0.OR.MCDEL.EQ.7) FM(11,1)=P5*TS*HSTCR(1)+1.0E-04
0189 C*****FM(12,1)=S02*ABSORDER*AMOUNT*(ATM=C4)/KM
0190 FM(13,1)=0.772E-04*PPM*52*W(1,M,1)*P5*E(0.07122*TS*E+0.06159
0191 FM(16,1)=0.772E-04*PPM*W(1,M,1)*P5*E(0.93098*TS*E+1.01192
0192 FM(15,1)=0.772E-04*PPM*W(1,M,1)*P5*E(0.52125*TS*E+(-0.60438)
0193 C FM(9,1)=1.0
0194 RE=1.0E-04*(C0+E(1013.7/273.15-P5*E+CM)
0195 IF(11.EQ.NL) GO TO 21
0196 IF(MCDEL.EQ.0.AND.1.GE.1) GO TO 30
0197 T2=(P1+1)
0198 W2=WM(4,1)
0199 IF(M1.GT.0) T2=T(1,1)+1
0200 IF(M7.GT.0) W2=WM(2,1)+1
0201 P0=...56E-04*W2*E2
0202 CM(9,1)=0.501*E*E+1.0E-04*(C0*E(1,1)+1)/T2*PPM*CM(1)
0203 TS=(11.72*NL)*EM(9,1)+0.
0204 TS=(11.72*NL)*EM(9,1)+1
0205 I=11*FM(10,1)*E(0.08*PPM*E(0.0)) *PRINT 123, I, Z(1), (P-M(1,1)*K+1)/12)
0206 FM(9,1)=EM(9,1)+1.0
0207 CONTINUE
0208 IF(11*FM(10,1) GO TO 15
0209 IF(P=1
0210 K=0
0211 X1=X1
0212 CALL POINT (M1,YN,N,NP1,TR,IP)
0213 J1=J1
0214 TX1=TX1(9)
0215 DO 20 K=1,NMAX
0216 E(K)=E(K)

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0216 C=1 TYPE=1 MEANS HORIZONTAL PATH *****
0217 IF (I,TYPE,EO,1) GO TO 35
0218 C=2 TYPE=2 MEANS VERTICAL PATH *****
0219 IF (I,TYPE,EO,2) GO TO 35
0220 C=3 TYPE=3 MEANS DOWNWARD TRAJECTORY *****
0221 IF (I,TYPE,EO,3) GO TO 35
0222 C=4 TYPE=4 MEANS UPWARD TRAJECTORY *****
0223 IF (I,TYPE,EO,4) GO TO 35
0224 IF (I,TYPE,EO,5) GO TO 35
0225 IF (I,TYPE,EO,6) GO TO 35
0226 IF (I,TYPE,EO,7) GO TO 35
0227 IF (I,TYPE,EO,8) GO TO 35
0228 IF (I,TYPE,EO,9) GO TO 35
0229 IF (I,TYPE,EO,10) GO TO 35
0230 IF (I,TYPE,EO,11) GO TO 35
0231 IF (I,TYPE,EO,12) GO TO 35
0232 IF (I,TYPE,EO,13) GO TO 35
0233 IF (I,TYPE,EO,14) GO TO 35
0234 IF (I,TYPE,EO,15) GO TO 35
0235 IF (I,TYPE,EO,16) GO TO 35
0236 IF (I,TYPE,EO,17) GO TO 35
0237 IF (I,TYPE,EO,18) GO TO 35
0238 IF (I,TYPE,EO,19) GO TO 35
0239 IF (I,TYPE,EO,20) GO TO 35
0240 IF (I,TYPE,EO,21) GO TO 35
0241 IF (I,TYPE,EO,22) GO TO 35
0242 IF (I,TYPE,EO,23) GO TO 35
0243 IF (I,TYPE,EO,24) GO TO 35
0244 IF (I,TYPE,EO,25) GO TO 35
0245 IF (I,TYPE,EO,26) GO TO 35
0246 IF (I,TYPE,EO,27) GO TO 35
0247 IF (I,TYPE,EO,28) GO TO 35
0248 IF (I,TYPE,EO,29) GO TO 35
0249 IF (I,TYPE,EO,30) GO TO 35
0250 IF (I,TYPE,EO,31) GO TO 35
0251 IF (I,TYPE,EO,32) GO TO 35
0252 IF (I,TYPE,EO,33) GO TO 35
0253 IF (I,TYPE,EO,34) GO TO 35
0254 IF (I,TYPE,EO,35) GO TO 35
0255 IF (I,TYPE,EO,36) GO TO 35
0256 IF (I,TYPE,EO,37) GO TO 35
0257 IF (I,TYPE,EO,38) GO TO 35
0258 IF (I,TYPE,EO,39) GO TO 35
0259 IF (I,TYPE,EO,40) GO TO 35
0260 IF (I,TYPE,EO,41) GO TO 35
0261 IF (I,TYPE,EO,42) GO TO 35
0262 IF (I,TYPE,EO,43) GO TO 35
0263 IF (I,TYPE,EO,44) GO TO 35
0264 IF (I,TYPE,EO,45) GO TO 35
0265 IF (I,TYPE,EO,46) GO TO 35
0266 IF (I,TYPE,EO,47) GO TO 35
0267 IF (I,TYPE,EO,48) GO TO 35
0268 IF (I,TYPE,EO,49) GO TO 35

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0269 32 WLAVID,K3=EV+M(K)
0270 WIKI=0.
0271 GO TO 34
0272 33 WIKI=EV
0273 IF (J1-NE-J2) GO TO 34
0274 WLAVIDJ2+1,K3=M(K)
0275 WIKI=0.
0276 JETRA=1
0277 CONTINUE
0278 IF (JP-EQ-QJ) P4INT 125, I,K1,(VH(L),L=1,8),PSI,PHI,DETA,THETA,SR
0279 IF (I1-GE-NL) GO TO 35
0280 IF (I1+EQ-J2) FM(9,I+1)=V.
0281 IF (I1-EQ-J1) FM(9,I)=TX1
0282 RM=FM(9,I+1)/FM(9,I)
0283 SMJ=SMJ+RM/EN
0284 IF (SALR-GE-PN) SPH(J)=SALP
0285 CONTINUE
0286 GO TO 59
0287 C===== INTERPOL PATH
0288 DO 36 I1=1,M*MAX
0289 K(K)=F2+GESEMIK(I)
0290 IF (NGDEL-GE-OL M(K)=DAVGE+TX(K)
0291 WIKI=RM
0292 CONTINUE
0293 GO TO 60
0294 38 CONTINUE
0295 C===== DOANARD TOAJECTORY
0296 K7P0 =
0297 IF (M2-EQ-0) J1=J1+1
0298 J2=J1+1
0299 J=J1+1
0300 WNA=VN
0301 IF (M2-ST-Z(J1+1),CA,M1,FQ,M2) GO TO 40
0302 RM=FM(1,EQ,1,AND,M2-GE-Z(J1+1)) GO TO 40
0303 CALL POINT (M2,VNA,NP2,TK,TP)
0304 N1=39 K=1,M*MAX
0305 WIKI=TX(K)
0306 TX2=TX(9)
0307 VN2=VN
0308 IF (M2-LT-M1) M=M2
0309 J2=N
0310 IF (J1-EQ-J2) TX2=TX1+V2-EH(9,N)
0311 IF (M2-ST-M1) TX1=TX2
0312 TX (J1-EQ-J2,AND,M2-LT-M1,VN1)=TX2
0313 AC=SEEM+1)SCPH19VNI
0314 IF (M2-ST-M1) VY2=VNI
0315 DC 41 I=1,J1
0316 MM=N*AO/EH(9,I)=RE
0317 IF (I1-EQ-J1) MM=N*AO/VH1=SE
0318 JMI=N+1
0319 IF (MMIN-LE-Z(I+1)) GO TO 42
0320 GO TO 41E
0321 X=MMK
0322 IF (MMIN-LE-0) GO TO 44
0323 CALL P2IV (X,VN,NP,TK,TP)
0324 JMI=N
0325 TX3=TX(9)
0326 IF (J2-EQ-N,OR-J1-EQ-N) TX3=VN2+TX(9)=EH(9,N)

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0325 IF (TX3.LT.0.0) TX3=TX(9)
0326 IF (J1.EQ.N.AND.M2.GE.M1) GO TO 43
0327 HMIN=AD/TX3=PE
0328 IF (ABS(K-MIN).GT.0.0001) GO TO 42
0329 IF (J1.EQ.N.AND.M2.GE.M1) YN1=TX3
0330 IF (J2.EQ.N.AND.J1.NE.J2) VN2=TX3
0331 IF (M2.GE.M1) TX2=TX3
0332 IF (M2.GE.M1) J2=N
0333 IF (M2.GE.M1.OR.M2.LT.MMIN) H=HMIN
0334 PRINT 126, HMIN
0335 IF (M2.LT.MMIN) J2=N
0336 IF (M2.LT.MMIN) PRINT 127, HMIN
0337 GO TO 45
0338 PRINT 126, HMIN
0339 IF (M2.LT.M1) GO TO 45
0340 IF (ITYPE.EQ.3.OR.M2.GE.M1) PRINT 129
0341 ITYPE=2
0342 TX2=FM(9,1)
0343 JMIN=0
0344 J2=1
0345 M2=0.0
0346 M=0.0

C==== NJM CEFIMF VERTICAL PATH QUANTITIES VHI=0)
0347 IF (J2.EQ.0) PRINT 124
0348 JSTOR=J-1
0349 DO 51 I=1,NL
0350 J=J-1
0351 RF=EM(9,J) REF=YNI
0352 IF (I.EQ.1) REF=YNI
0353 IF (I.EQ.1.AND.M2.EQ.1) REF=YV2
0354 IF (J.EQ.J2.AND.K2.EQ.0) REF=TX2
0355 IF (I.NE.1) X1=Z(J-1)
0356 X2=Z(J)
0357 IF (J.EQ.J2.AND.K2.EQ.0) X2=M
0358 IF (J.EQ.JMIN.AND.K2.EQ.1) X2=HMIN
0359 MM=(RF-X1)*SPH/RE
0360 IF (MM.GT.Z(J).AND.MM.GT.X2) X2=MM
0361 RX=(RE-X1)/(RE+X2)
0362 DS=X1-X2
0363 ALP=90.0
0364 THET=ARCSIN(SPH1/CA
0365 SCLP=ARCSIN(SPH1/CA
0366 IF (ABS(K2-M2).GT.1.3E-5) ALP=ARCSIN(SCLP)/CA
0367 HET=ALP-THET
0368 IF (SPH1.GT.1.3E-10) DS=(R2-X2)*SIN(HET*CA)/CPH1
0369 THETA=180.0-THET
0370 BET=HET*ABET
0371 PSI=HET*ALP*ANGLE*180.0
0372 SP=SRONS
0373 DO 50 K=1,KMAX
0374 AJ=EM(K,J)
0375 RJ=FM(K,J+1)
0376 IF (J.EQ.J2) BJ=E(K)
0377 IF (J.EQ.J2.AND.M2.LT.M1.AND.P2.GT.0.0) AJ=W(K)
0378 IF (J.EQ.JMIN.AND.M2.GE.M1) AJ=TX(K)
0379 IF (J.EQ.JMIN.AND.ABS(M2-M1-LT.1.0E-5) AJ=TX(K)
0380 IF (K2.EQ.0) GO TO 46
0381 IF (J.EQ.J2) BJ=W(K)

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0382 IF (J-FQ-JMIN) AJ=TX(K)
0383 IF (AJ-EQ.0.0) (R-AJ-EQ.0.0) GO TO 48
0384 IF (AJ-FQ-9J) GO TO 47
0385 FV=DS*(AJ-9J)/ALOG(AJ/9J)
0386 GO TO 49
0387 FV=DS*9J
0388 GO TO 49
0389 EV=0.0
0390 VHXI=VHX(K)+FV
0391 WLAY(J,K)=EV
0392 IF (JP-50.0) PRINT 125, J,XI,(VHXI),L=1,A),PSI,ALP,RETA,T,ETA,SP
0393 IF (J-EQ.02-AND-K2-GE-M1) GO TO 56
0394 IF (J-EQ.02-AND-K2-GE-M1) GO TO 56
0395 IF (J-EQ.02-AND-K2-GE-M1) GO TO 54
0396 IF (J-EQ.02-AND-K2-GE-M1) GO TO 54
0397 IF (J-EQ.02-AND-K2-GE-M1) GO TO 54
0398 IF (J-EQ.02-AND-K2-GE-M1) GO TO 54
0399 IF (J-EQ.02-AND-K2-GE-M1) GO TO 54
0400 IF (J-EQ.02-AND-K2-GE-M1) GO TO 54
0401 IF (J-EQ.02-AND-K2-GE-M1) GO TO 54
0402 IF (J-EQ.02-AND-K2-GE-M1) GO TO 54
0403 IF (J-EQ.02-AND-K2-GE-M1) GO TO 54
0404 IF (J-EQ.02-AND-K2-GE-M1) GO TO 54
0405 IF (J-EQ.02-AND-K2-GE-M1) GO TO 54
0406 IF (J-EQ.02-AND-K2-GE-M1) GO TO 54
0407 IF (J-EQ.02-AND-K2-GE-M1) GO TO 54
0408 IF (J-EQ.02-AND-K2-GE-M1) GO TO 54
0409 IF (J-EQ.02-AND-K2-GE-M1) GO TO 54
0410 IF (J-EQ.02-AND-K2-GE-M1) GO TO 54
0411 IF (J-EQ.02-AND-K2-GE-M1) GO TO 54
0412 IF (J-EQ.02-AND-K2-GE-M1) GO TO 54
0413 IF (J-EQ.02-AND-K2-GE-M1) GO TO 54
0414 IF (J-EQ.02-AND-K2-GE-M1) GO TO 54
0415 IF (J-EQ.02-AND-K2-GE-M1) GO TO 54
0416 IF (J-EQ.02-AND-K2-GE-M1) GO TO 54
0417 IF (J-EQ.02-AND-K2-GE-M1) GO TO 54
0418 IF (J-EQ.02-AND-K2-GE-M1) GO TO 54
0419 IF (J-EQ.02-AND-K2-GE-M1) GO TO 54
0420 IF (J-EQ.02-AND-K2-GE-M1) GO TO 54
0421 IF (J-EQ.02-AND-K2-GE-M1) GO TO 54
0422 IF (J-EQ.02-AND-K2-GE-M1) GO TO 54
0423 IF (J-EQ.02-AND-K2-GE-M1) GO TO 54
0424 IF (J-EQ.02-AND-K2-GE-M1) GO TO 54
0425 IF (J-EQ.02-AND-K2-GE-M1) GO TO 54
0426 IF (J-EQ.02-AND-K2-GE-M1) GO TO 54
0427 IF (J-EQ.02-AND-K2-GE-M1) GO TO 54
0428 IF (J-EQ.02-AND-K2-GE-M1) GO TO 54
0429 IF (J-EQ.02-AND-K2-GE-M1) GO TO 54
0430 IF (J-EQ.02-AND-K2-GE-M1) GO TO 54
0431 IF (J-EQ.02-AND-K2-GE-M1) GO TO 54
0432 IF (J-EQ.02-AND-K2-GE-M1) GO TO 54
0433 IF (J-EQ.02-AND-K2-GE-M1) GO TO 54
0434 IF (J-EQ.02-AND-K2-GE-M1) GO TO 54
0435 IF (J-EQ.02-AND-K2-GE-M1) GO TO 54
0436 IF (J-EQ.02-AND-K2-GE-M1) GO TO 54
0437 IF (J-EQ.02-AND-K2-GE-M1) GO TO 54
0438 IF (J-EQ.02-AND-K2-GE-M1) GO TO 54

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POINT

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0001 SURFUTIME POINT (X,VN,NP,TP,TP)
0002 COMMON /ND1/ 7134).D17.34).T(7.34).FM15.34).NM(7.34).M.NL.FE.CM.C
0003 10.01.MA(7.34)
0004 DIMENSION TX(15)
*****
P SURFUTIME 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 X IS THE HEIGHT IN QUESTON
C TX(9) AND VN 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
*****
N=1
NP=0
IF (XLT,0.0) X=0.
IF (XST,7134) GO TO 4
DO 1 I=1,NL
N=I
IF (XZ(I)) 2,4,1
CONTINUE
1
2
N=1
C X=1/(7(N1)/12(J2)-Z(N1))
PR1=PR(N1)D14.J21/2(P.N1)FAC
TX1=TX(N1)D14.J21/2(P.N1)FAC
N1=NM(N1)D14.J21/2(P.N1)FAC
TX31=COPR1/TX1-4.56E-06X1+TX1C
TX12=COPR1/J21/TM.J21-4.56E-06NM(N1)J21ATM.J21C
TX11=COPR1/J21/TM.N1-4.56E-06NM(N1)J21ATM.N1C
VN=0.5E-06(TX11+TX31)
IF (IP,EO,0) GO TO 9
DO 3 K=1,KMAX
TX(K,EO,9) GO TO 3
TX(K)=0.0
IF (FMK,N1)EQ,7,0) GO TO 3
IF (FMK,N1)GT,1000,0) GO TO 3
TX(K)=FMK,N1DCEH(P,J21)/FMK,N1)FAC
CONTINUE
GO TO 9
N=1
IF (IP,EO,0) GO TO 6
DO 5 K=1,KMAX
TX(K)=FMK,N1
TX(K)=FMK,N1-1.
VN=2.0
***** CARDS 8 24 AND 50 THROUGH 59 ARE NO LONGER REQUIRED
9
CONTINUE
IF (N,GT,1) VN=EM(N,1)-1.0
IF (IP,EO,1) PRINT 100, X,N,NP,TP(9),VN,IP,(TX(K),K=1,8)
TX(9)=TX(9)+1.
VN=VN+1.
0005
0006
0007
0008
0009
0010
0011
0012
0013
0014
0015
0016
0017
0018
0019
0020
0021
0022
0023
0024
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 0044 RETURN
 0045 100 FORMAT 1/0 FROM POINT: HEIGHT=0.000000 K4,N=0.000000 NP=0.000000 REF
 0046 1. INDEX ABOVE & BELOW X=0.000000 10=0.000000 13=0.000000 EQUIV. ANSWER
 2. AMOUNTS PER KM AT X=0.000000
 END

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PATH

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0001      SURPTIME PATH(LAY,WPATH,TRAP)
0002      COMMON /MOL/ Z(34),P(7,34),T(7,34),FM(15,34),WM(7,34),VNL,FE,CM,C
          LC,PI,MA(7,34)
0003      DIMENSION LAY(34,15),TBY(68),WPATH(68,15)
0004      COMMON /EM1/ TEMISS,KMAX,ANGLE,LEN,MTIN,IJ,J1,J2,JMIN,JEXT4A,ITYPE
0005      COMMON /EM2/ IL,IKMAX /LENTOR,MLL,W(15),E(15)
0006      COMMON /EM3/ M1,M2,NP1,MODEL
0007      IF (ITYPE.EQ.1) GO TO 13
0008      IF (ITYPE.EQ.2.AND.M1.EQ.M2) J2=J1
0009      IF (M2.GT.M1.AND.ANGLE.GT.90.AND.VPL.EQ.1) J1=J1-1
0010      IF (JEXT4A.EQ.1) J2=J2+1
0011      IF (ITYPE.EQ.2) AND.(M1.GT.M2).AND.(LENTOR.EQ.1) J2=J2-1
0012      IF (ITYPE.EQ.3) J2=NL
0013      PRINT 100, J1,J2
0014      PRINT 101
0015      DO 1 IK=1,68
0016      TBY(IK)=0.
0017      DO 1 K=1,KMAX
0018      WPATH(IK,K)=0.
0019      CONTINUE
0020      LEV=0
0021      MLL=NL-1
0022      IL=NL-1
0023      IJ=IL*VLL
0024      DO 2 K=1,KMAX
0025      ESK=0.
0026      CONTINUE
0027      IF (ANGLE.GT.90.0) GO TO 3
0028      IF=1.
0029      IL=IJ-1
0030      MNTN(1)=OF=4
0031      IJ=NL
0032      CONTINUE
0033      DO 4 K=1,68
0034      IF (LEV.EQ.0) IL=IL-1
0035      IF (LEV.EQ.1) IL=IL+1
0036      IJ=IJ-1
0037      IF (IL.EQ.0) GO TO 5
0038      DO 4 K=1,KMAX
0039      WPATH(IK,K)=LAY(IL,K)
0040      CONTINUE
0041      IF (IL.EQ.0.OR.IL.GE.NL) GO TO 5
0042      TBY(IK)=IL+TIN,IL+1)=0.5
0043      JPKTR=1 (ONLY WHEN PROGRAM NIVES LEAVES THE LAYER
          IF (JEXT4A.EQ.1) TBY=IT(M,J1)+T(M,J1+1)*0.5
          CONTINUE
0044      TBY(IK)=TRAP
0045      DO 6 K=1,KMAX
0046      SIN=WKI
0047      CONTINUE
0048      SIN=WKI
0049      IF (ANGLE.LE.90.0.AND.IL.EQ.NL) GO TO 9
0050      IF (ITYPE.EQ.3.AND.ANGLE.LE.90.0) GO TO 7
0051      IF (ITYPE.EQ.3.AND.LEN.EQ.1.AND.IL.EQ.J2) GO TO 9
0052      IF (ITYPE.EQ.2.AND.LENTOR.EQ.0.AND.IL.EQ.J2) GO TO 9
0053      IF (IL.EQ.JMIN.AND.MTIN.GT.0) LEV=1
0054      IF (IL.EQ.1.AND.MTIN.LE.0.0) GO TO 9
0055      IF (LEV.EQ.0) GO TO 7
0056

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0044 TX1=TX1(9)
0045 CALL POINT (M2,VN,N,NP,TK,IP)
0046 IF (NP.FO.1) N=N+1
0047 J2=N
0048 IF (J1.FO.J2) TX1=TX1+VN-EM(9,J1)
0049 DO 7 J=J1,J2
0050 X1=SE+Z(IJ)
0051 X2=SE+Z(IJ+1)
0052 IF (J.EQ.J1) X1=RE+M1
0053 IF (J.EQ.J2) X2=RE+M2
0054 SALP=X1*SPH1/X2
0055 ALP=ARSIN(SALP)
0056 PN=EM(9,J+1)/EM(9,J)
0057 IF (J+1).EQ.J2) RN=VN/EM(9,J)
0058 IF (J.EQ.J1) RN=EM(9,J+1)/TX1
0059 IF ((J+1).EQ.J2.AND.(J.FO.J1) RN=VN/TK1
0060 RET=TM*ALP
0061 FR=TAN(ALP)
0062 IF (J.NE.J1) F3=FR+TAN(THET)
0063 FR=FR*FR
0064 RET=BETA+FR
0065 TH1=THET/CA
0066 RE=RET/CA
0067 C=ALP/CA
0068 PRINT 502, J,Z(IJ),THET,ALP,RET,RETA,EST,FR,TH1,RE,C
0069 IF (X2.FO.RE+M2) C=PI-ALP
0070 IF (SALP.GE.PN) RN=1.
0071 SPH1=SALP/RN
0072 TH1=ARSIN(SPH1)
0073 CONTINUE
0074 IF (91.LE.O.O) GO TO 29
0075 GO TO 26
0076 CONTINUE
0077 TANG=TANG
0078 ANGLE=PI-ANGLE
0079 TN=ANGLE
0080 ANG=ANGLE/CA
0081 PRINT 504, R1,ANG,TANG
0082 IF (41.LE.O.O) GO TO 3
0083 C=CA*INUP
0084 IP=101
0085 CALL POINT (M1,VN,N,NP1,TK,IP)
0086 TX1=TX1(9)
0087 VN1=VN
0088 IF (NP1.EQ.1) N=N+1
0089 J2=N
0090 IF (N.EQ.7) J2=N1
0091 J=J1+1
0092 IF (M2.GE.M1) GO TO 13
0093 CALL POINT (M2,VN,N,NP,TK,IP)
0094 TX2=TX1(9)
0095 VN2=VN
0096 J2=N
0097 IF (J1.FO.J2) TX2=VN1+TX1(9)-FR*(9,J1)
0098 J=J+1
0099 X1=SE+Z(IJ+1)
0099 X2=SE+Z(IJ)

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ANGL

FORMTRAN IV G LEVEL 21

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0100 IF (J.EQ.J1) X1=RE+M1
0101 IF (J.EQ.J2) X2=RE+M2
0102 SALP=X1*SPH1/X2
0103 HM1=X1*SPH1*RE
PRINT 402, J,X1,Z(J),SPH1,SALP,HM1,RE
IF (SALP.LE.1.0) GO TO 11
SALP=SPH1
IF (HM1.NGT.M2) GO TO 18
ALP=AP*IN(SALP)
THET=AP*IN(SPH1)
BET=ALP-THET
MET1=RET1+BET
FB=TAN(ALP)
IF (J.NE.J1) FB=FB-TAN(THET)
FAT1=FB*THET+FB
TH1=THET/CA
RE=RET/CA
AL=ALP/CA
PRINT 402, J,X2,THET,ALP,RET1,RET,RM1N,MM1N,FAT1,TH1,RE,AL
IF (X2.EQ.RE+M2) C=PI-ALP
RE=RE+M2
IF (J.EQ.J1) RE=VN1
IF (J.EQ.J2) RE=TX2
IF (J.FQ.1) GO TO 12
IF (J.FQ.1) GO TO 12
RN=EM19,J1/EM19,J=1
IF (J.EQ.J1) RN=VN1/EM19,J=1
IF (J.FQ.1) RN=PCF/TX2
IF (J.EQ.J2) RN=REF/V12
IF (SEL'.GF'.RN) RN=1.
SPH1=SA*PCRN
IF (Z(J).LE.M2) GO TO 12
GO TO 10
X1=X2
12 IF (ABS(Z(J)-M2).LT.1.0E-13.FAQ.J.NE.1) GO TO 13
GO TO 14
13 J=J-1
X1=RE+Z(J+1)
IF (J.EQ.J1) X1=RE+M1
IF (J.FQ.J2.AND.J.NE.J1) X1=RE+M2
X2=RE+Z(J)
HM1=X1*SPH1*RE
IF (HM1.LE.0.1) GO TO 25
IF (Z(J).LT.HM1) GO TO 18
RE=RE+M2
IF (J.FQ.J2) RE=V1
SALP=X1*SPH1/X2
ALP=AP*IN(SALP)
THET=AP*IN(SPH1)
BET=ALP-THET
FB=TAN(ALP)-TAN(THET)
FAT2=FB*THET+FB
RET2=RET1+BET
RM1N=RET1+RET2
AL=ALP/CA
TH1=THET/CA
PRINT 402, J,X2,THET,ALP,RET2,RET,MM1N,MM1N,FAT2,TH1,RE,AL
RN=RE/EM19,J=1
IF (SALP.GE.M1) RN=1.0

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FORTRAN IV G LEVEL 21          ANGL          DATE = 79218          PAGE 0004
0155      SPH1=SPALPORN
0156      GO TO 13
0157      TX3=VNI+TX(9)=EH(9,J1)
0158      VNI=TX3
0159      IF (ABS(M2-Z(J+1))-LE-1.OF-5) VNI=TX(9)
0160      IF (ABS(M1-Z(J+1))-LE-1.OF-5) VNI=TX(9)
0161      RN=1.0
0162      GO TO 19
0163      CALL POINT (HMIN,VN,N,MP,TX,IF)
0164      IP=102
0165      TX3=TX(9)
0166      IF (J.EQ.J1.AND.M2.GE.M1) GO TO 17
0167      IF (J.EQ.J1.OR.J.EQ.J2) TX3=VN2+TX(9)=EH(9,J1)
0168      IF (HMIN.GT.M2) TX3=TX(9)
0169      IF (J1.EQ.J1.AND.HMIN.GT.M2) GO TO 17
0170      RN=REF/TX3
0171      IF (SALP.GE.PN) RN=1.
0172      SPH1=SPALPORN
0173      X=X1+SPH1*PE
0174      C1F=ABS(HMIN-X)
0175      HMIN=X
0176      IF (C1F-1.OF-5) 19,19,18
0177      X2=REF*HMIN
0178      PRINT 403, HMIN,C1F,XN
0179      TMET=ABS(SIN(SPH1))
0180      IF (RN.EQ.1.0) FRT3=-YAI(TMET)
0181      DNR=(TX3-1.0)*ALOG((TX3-1.0)/(FRT3-1.01)/(FRT3-1.01)/(TX2-X1))
0182      FRT3=-YAI(TMET)*(1.0-1.0/11.0+TX3/(TX2-DNRX1))
0183      RET=0.5*PI-TMET
0184      RET2=RET2+RET
0185      AMIN=RET1+RET2
0186      IF (M2.GE.-41) GO TO 23
0187      RET=RET1+2.*RET2
0188      CRI=X1-BET1
0189      CRI2=RET1-CRI
0190      .083=ABS(AMIN-91)
0191      IF (CRI.GT.CRI1.AND.CRI2.GT.CRI1) GO TO 25
0192      IF (CRI2.GT.CRI1) GO TO 22
0193      IF (CRI2.GT.CRI1) GO TO 25
0194      HETA=BET
0195      FRT=RET1+2.0*(FRT2+FRT3)
0196      LEN=1.
0197      GO TO 26
0198      FRT=RET1+RET2
0199      FRT2=RET1+FRT2+FRT3
0200      PRINT 401, J,BETA,FRT,FRT1,FRT2,FRT3,TX1,VNI
0201      GO TO 26
0202      FRTA=2.0*(BET1+BET2)
0203      LPA=1.
0204      FRT2.0=(FRT1+FRT2+FRT3)
0205      PRINT 401, J,BETA,FRT,FRT1,FRT2,FRT3,TX1,VNI
0206      IF (M2.EQ.M1) GO TO 26
0207      IP=103
0208      IF (NPL.EQ.1) J1=J1+1
0209      SPH1=SIN(ANGLE)
0210      IF (Z(J1+1)-LE-M2) GO TO 24
0211      PN=TX1/VNI

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FORTRAN IV G LEVEL 21      ANGL      DATE = 79218      10/22/49      PAGE 0005

0211 IF (SPH1-GE-RN) RN=1.
0212 SPH1=SPH1/RN
0213 THEY=ARSIN(SPH1)
0214 GO TO 5
0215 CALL POINT (M2,VN,NP,TX,TP)
0216 TX=TX1+VN=FH(Q,J1)
0217 CN=TX1/VN1
0218 J2=J1
0219 IF (SPH1-GE-FN) RN=1.
0220 SPH1=SPH1/RN
0221 THEY=ARSIN(SPH1)
0222 GO TO 5
0223 BETA=REY1
0224 LFN=0.
0225 FB=REY1
0226 THEY=ANGLE+(BI-RETA)/(1.+FB/TANG)
0227 CN=FB*RETA/CA
0228 FB=REY1/CA
0229 YN1=THEY/CA
0230 PRINT 404, BETA, DBETA, FB, TH1, TANG
0231 IF (THEY-GT-TN.DR.THEY.LT.TN) THEY=(TN+THEY)/2.
0232 THEY=THEY/CA
0233 PRINT 404, REY1, B, FB, TH1
0234 YN1=TN/CA
0235 YN1=TN/CA
0236 PRINT 405, TN, TM, TN1, TM1
0237 SPH1=SIGN(THEY)
0238 TAN=GTAN(THEY)
0239 IT=IT+1
0240 DB=ARSIN(RETA)
0241 OTM=ABS(ANGLE-THEY)
0242 IF (IT-EQ-10) THEY=3.5*(ANGLE+THEY)
0243 IF (IT-FQ-10) GO TO 28
0244 IF (DBE-GT-1.0E-7.AND-OTM-GT-1.0E-7) GO TO 1
0245 ANGLE=THEY/CA
0246 PRINT 406, ANGLE, IT
0247 RETURN
0248
0249 ANGLE=C/CA
0250 PRINT 406, ANGLE, IT
0251 RETURN

C
0252 FORMAT (//, ITERATION NUMBER, 13.//)
0253 F10=16.7, F11=3
0254 F10=14.5, F11=13.4, F12=4.7
0255 FORMAT (14, F10, 4, F11, 4, F12, 4, //)
0256 FORMAT (1, TOTAL BETA = 16.7, 4, F11, 4, F12, 4, //, THEY = 10.6, 1, 6, //, TANG = 10.6)
0257 FORMAT (5F12.6)
0258 FORMAT (8X, 1M, //, ZENITH ANGLE = 17.3, 3, DEGREES : RECOMPUTED
0259 1 FROM SUBROUTINE ANGL (ITERATION, 13, //)
0260 FN)

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FORTMAN IV G LEVEL 21 FREQSL

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0047 GO TO 6
0048 CALL NHOJ(I,IV,M,C5,TX,SUM5)
0049 GO TO 9
0050 CALL SUTY(I,M,C14,TX)
0051 GO TO 9
0052 CALL PFTEPI(I,M,C11,SJM11,TX)
0053 GO TO 10
0054 CALL SUTY(I,M,C14,TX)
0055 CALL REYEP(I,M,C11,SJM11,TX)
0056 CALL NHOJ(I,IV,M,C5,TX,SUM5)
0057 GO TO 6
0058 CALL SUSEJI(I,M,C12,TX)
0059 GO TO 12
0060 CALL SJCFJI(I,M,C12,TX)
0061 GO TO 13
0062 CALL PJJI(I,M,C15,TX)
0063 GO TO 13
0064 CALL AZEJI(I,M,C13,TX)
0065 GO TO 14
0066 CALL KRAM(I,M,C4,TX,SUM4)
0067 GO TO 14
0068 CALL SUSEJI(I,M,C12,TX)
0069 GO TO 19
0070 CALL SEWJJI(I,IV,M,TX,SUM6)
0071 GO TO 5
0072 CALL SEWJJI(I,IV,M,TX,SUM6)
0073 GO TO 7
0074 CALL SEWJJI(I,IV,M,TX,SUM6)
0075 GO TO 4
0076 CALL SEWJJI(I,IV,M,TX,SUM6)
0077 GO TO 5
0078 CALL DIVAD(I,M,C2,TX)
0079 GO TO 24
0080 CALL SESOM(I,M,C8,TX,SUM8)
0081 GO TO 25
0082 CALL SESOM(I,M,C8,TX,SUM8)
0083 GO TO 24
0084 CALL LUAP(I,M,C1,TX)
0085 GO TO 27
0086 RETURN
0087 END

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FORTRAN IV G LEVEL 21          LUAP          DATE = 79218          16/22/49          PAGE 0001

0001      SUBROUTINE LUAP(I,M,C1,IX)
0002      DIMENSION C1(2580),TX(I),WS(I),W(I)
0003      C.....
0004      C TRANSMITTANCE FOR WATER VAPEP
0005      C
0006      C THIS SUBROUTINE USES A CONTINUOUS FUNCTION FOR THE ORIGINAL
0007      C TRANSMITTANCE TABLE.
0008      C.....
0009      IF (W(I)).LT.1.-9F-20) GO TO 5
0010      IF (I.LE.1170) I1=1
0011      IF (I.GT.1905.AND.I.LE.2490) I1=I-135
0012      IF (I.GT.2610) I1=I-555
0013      WS(I)=C1(OG10(W(I))+C1(I1))
0014      TX(I)=EXP(-10**(-1.15619*O.55013*WS(I)))
0015      RETURN
0016      END

```

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FORTRAN IV G LEVEL 21          DIVAD          DATE = 79218          16/22/49          PAGE 0001
0001      SUBROUTINE DIVAD(I1,M,C2,TX1
0002      DIMENSION C2(1575),TX(2),MS(2),M(2)
0003      C
0004      C TRANSMITTANCE FOR UNIFORMLY MIXED GASES
0005      C
0006      C THIS SUBROUTINE USES A CONTINUOUS FUNCTION FOR THE ORIGINAL
0007      C TRANSMITTANCE TABLE.
0008      C
0009      IF (M(2).LT.1.0E-20) GO TO 5
0010      I1=1-30
0011      IF (I1.GT.2520) I1=1-1905
0012      MS(2)=1.061014*(2)+.72(1)
0013      TX(2)=EXP(1-10*(1-1.14619+0.55C1)*MS(2))
0014      RETURN
0015      END

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PORTMAN IV G LEVEL 21          EVETS          DATE = 79218          16/22/49          PAGE 0001

0001      SUMROUTINE EVETS(1,M,C3,TX)
0002      DIMENSION C3(540),TX(3),MS(3),W(3)
C*****
C      TRANSMITTANCE FOR OPTONE
C
C      THIS SUBROUTINE USES A CONTINUOUS FUNCTION FOR THE ORIGINAL
C      TRANSMITTANCE TABLE.
C*****
C      IF (W(3).LT.1.0E-20) GO TO 5
C      T1=1-W5
C      MS(3)=ALOG10(W(3))+C3(111)
C      TX(3)=1/(1+EXP(-3.08319+2.11127*W5(3)))
C      RETURN
C      END
5
0003
0004
0005
0006
0007
0008

```

PORTMAN IV 6 LEVEL 21 NHOJ DATE = 79218 16/22/49 PAGE 0001
 0001 SUBROUTINE NHOJ(I,IV,M,CS,TR,SUMS)
 0002 C-----TRANSMITTANCE FOR WATER VAPOR CONTINUUM 4 MICRON AND 10 MICRON REGION
 0003 DIMENSION CS(15),TX(5),W(10)
 0004 IF(I,LY,65,OP,1,GT,53)) GO TO 2
 0005 IF(I,GT,20)) GO TO 1
 0006 TX(5)=14.18+5578.0*EXP(-7.87E-3*IV)*W(5)
 0007 GO TO 3
 0008 1 IF(I,LY,40)) GO TO 2
 0009 XI=11-401.01/13.0+1.3
 0010 NM=XI+1.001
 0011 XM=XI*ELGA*(NM)
 0012 TX(5)=CS(NM)
 0013 TX(5)=TX(5)+XM*(CS(NM)-CS(NM-1))
 0014 TX(5)=TX(5)*W(10)
 0015 GO TO 3
 0016 2 TX(5)=0.0
 0017 SUMS=TX(5)
 0018 IF (TX(5)-EQ,0.0) GO TO 5
 0019 IF (TX(5)-LE,0.1) GO TO 4
 0020 IF (TX(5)-GT,20.1) GO TO 6
 0021 TX(5)=EXP(-TX(5))
 0022 GO TO 7
 0023 4 TX(5)=1.0-TX(5)+0.5*TX(5)*TX(5)
 0024 GO TO 7
 0025 5 TX(5)=1.0
 0026 GO TO 7
 0027 6 TX(5)=0.0
 0028 RETURN
 0029 END

```

FORTRAN IV G LEVED 21      KRAM      DATE = 79218      16/22/49      PAGE 3001

0001      SURROUNDING KRAM(I,M,C4,TX,SUM4)
0002      C*****TRANSMITTANCE FOR NITROGEN CONTINUUM*****
0003      DIMENSION C4(133),TX(4),M(4)
0004      IF (I.LT.307) GO TO 4
0005      I1=1-346
0006      TX(4)=C4(I1)M(4)
0007      SUM4=TX(4)
0008      IF (TX(4).EQ.0.0) GO TO 4
0009      IF (TX(4).LE.0.1) GO TO 3
0010      IF (TX(4).GT.20.) GO TO 5
0011      TX(4)=EXP(-TX(4))
0012      GO TO 4
0013      3 TX(4)=1.0-TX(4)+0.5*TX(4)*TX(4)
0014      GO TO 5
0015      4 TX(4)=1.0
0016      GO TO 6
0017      5 TX(4)=3.0
0018      6 PETHA
      END

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FMTRAN IV G LEVEL 21          SENAJ          DATE = 79218          16/22/49          PAGE 0001

0001      SUBROUTINE SENAJ(I,IV,M,TX,SUM6)
0002      *****TRANSMITTANCE FOR MOLECULAR SCATTERING *****
0003      DIMENSION TX(6),M(6)
0004      V=IV
0005      C6=9.807E-20*(V**4.0/117)
0006      TX(6)=C6*M(6)
0007      SUM6=TX(6)
0008      IF (TX(6).EQ.0.0) GO TO 4
0009      IF (TX(6).LE.0.1) GO TO 3
0010      IF (TX(6).GT.20.1) GO TO 5
0011      TX(6)=EXP(-TX(6))
0012      GO TO 5
0013      TX(6)=1.-0.5*TX(6)+0.5*TX(6)*TX(6)
0014      GO TO 4
0015      TX(6)=1.0
0016      GO TO 6
0017      TX(6)=0.0
0018      RETURN
0019      END

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EKUL

PORTRAM IV G LEVEL 21

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0001 SUBROUTINE EKUL(I,J,V,M,THAZE,TX,SUM7,ALAM)
0002 C***** TRANSMITTANCE FOR AEROSOL *****
0003 COMMON /M06/ VX(45),C7(45),C7A(45)
0004 DIMENSION TX(10),M(7)
0005 V=TV
0006 ALAM=1.0E+4/V
0007 XX=0.0
0008 VV=0.0
0009 I=1,44
0010 DO=ALAM-VX(I)
0011 IF(XD) 2,1,1
0012 CONTINUE
0013 XX=C7(I)-C7(N-1)*XJ/(VX(N)-VX(N-1))+C7(N)
0014 TX(I)=XX*(7)
0015 SUM7=TX(7)
0016 IF (TX(7).EQ.0.0) GO TO 5
0017 IF (TX(7).LE.0.1) GO TO 4
0018 IF (TX(7).GT.20.) GO TO 6
0019 TX(7)=EXP(-TX(7))
0020 GO TO 7
0021 TX(7)=1.-TX(7)+0.5*TX(7)*TX(7)
0022 GO TO 7
0023 TX(7)=1.0
0024 GO TO 7
0025 TX(7)=0.0
0026 CONTINUE
0027 I=THAZE,EO.0) GO TO 12
0028 VV=C7A(I)-C7A(N-1)*XJ/(VX(N)-VX(N-1))+C7A(N)
0029 TX(10)=VV*(7)
0030 IF (TX(10).EQ.0.0) GO TO 9
0031 IF (TX(10).LE.0.1) GO TO 8
0032 IF (TX(10).GT.20.) GO TO 10
0033 TX(10)=EXP(-TX(10))
0034 GO TO 11
0035 TX(10)=1.-TX(10)+0.5*TX(10)*TX(10)
0036 GO TO 11
0037 TX(10)=1.0
0038 GO TO 11
0039 TX(10)=0.0
0040 RETURN
0041 END

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FORTRAN IV 6 LEVEL 21          SESOM          DATE = 79218          PAGE 0001

0001      SUBROUTINE SESOM(I,M,CR,TX,SUPR)
0002      ***** TRANSMITTANCE FOR UV RNONE *****
0003      DIMENSION CR(102),TX(8),M(8)
0004      AT=1
0005      IF(I).LE.4611) GO TO 1
0006      IF(I).GE.5431) GO TO 2
0007      XX=40.0
0008      XI=(A1-2531.01)/XX+1.0
0009      LI=1
0010      L2=53
0011      GO TO 3
0012      XX=100.0
0013      XI=(A1-5431.01)/XX+57.0
0014      LI=57
0015      L2=102
0016      DO 4 N=1,L2
0017      XD=XI-FLDAT(N)
0018      IF (XD) 6,5,4
0019      CONTINUE
0020      TX(8)=D(8)+CR(N)
0021      GO TO 9
0022      TX(8)=CR(N)+XD*ICR(N)-CR(N-1)
0023      TX(8)=D(8)+TX(8)
0024      SUM8=TX(8)
0025      IF (TX(8).EQ.0.0) GO TO 10
0026      IF (TX(8).LE.0.1) GO TO 9
0027      IF (TX(8).GT.20.01) GO TO 11
0028      TX(8)=EXP(-TX(8))
0029      GO TO 12
0030      TX(8)=1.0-TX(8)+0.5*TX(8)+TX(8)
0031      GO TO 12
0032      TX(8)=1.0
0033      GO TO 12
0034      TX(8)=0.0
0035      RETURN
0036      END

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FORTRAN IV G LEVEL 21                                DATE = 79218                                16/22/49                                PAGE 0001

0001 SUBROUTINE PETER11(W,C11,TX,SUM11)
0002 C***** TRANSMITTANCE FOR NITRIC ACID*****
0003 DIMENSION C11(40),TX(11),W(11)
0004 MASS=0.
0005 IF (1.LT.100.CR.1.GT.2761) GO TO 1
0006 IF (1.GT.116.AND.1.LT.186) GO TO 1
0007 IF (1.GT.201.AND.1.LT.266) GO TO 1
0008 IF (1.LT.116) I1=100
0009 IF (1.GT.186.AND.1.LE.201) I1=170
0010 IF (1.GE.266) I1=234
0011 MASS=C11(I1)
0012 CONTINUE
0013 TX(I1)=MASS*W(I1)
0014 SUM11=TX(I1)
0015 IF (TX(I1).EQ.0.) GO TO 6
0016 IF (TX(I1).LE.3.) GO TO 5
0017 IF (TX(I1).GT.29.) GO TO 7
0018 TX(I1)=EXP(-TX(I1))
0019 GO TO 9
0020 TX(I1)=1.-TX(I1)*0.5*TX(I1)+TX(I1)
0021 GO TO 8
0022 TX(I1)=1.0
0023 GO TO 9
0024 TX(I1)=0.0
0025 RETURN
      END

```

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FORTRAN IV 6 LEVEL 21          SUSEJ          DATE = 79218          16/22/49          PAGE 0001

0001      SUBROUTINE SUSEJ(I,W,C12,TX)
0002      COMMON /M10/ FS(I9),SI(I9),SZ(S)
0003      DIMENSION C12(11),TA(12),WS(12),W(12)
C.....
C      THIS SUBROUTINE CALCULATES THE TRANSMITTANCE BY S02 ( PPM READ IN
C      THE MAIN PROGRAM).
C.....
0004      IF (W(12).LT.1.0E-20) GO TO 5
0005      IF (1.0E.19.AND.1.0E.54) II=I-18
0006      IF (1.0E.142.AND.1.0E.181) I=I-104
0007      IF (1.0E.193.AND.1.0E.213) I=I-116
0008      IF (1.0E.421) II=I-323
0009      WS(12)=ALOG10(W(12))+C12(II)
0010      DO 1 J=1,9
0011      IF WS(12)=FS(J) 2,2,1
0012      CONTINUE
0013      TX(12)=EXP(-10*(SI(IJ)+SZ(J)+WS(12)))
0014      RETURN
0015      END

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FORTRAN IV G LEVEL 21          ARZE          DATE = 79218      16/22/49      PAGE 0001

0001      SUBROUTINE AP2E(I,M,C13,TX)
0002      COMMON /M011/ FNC(19),FNI(19),FA2(19)
0003      DIMENSION C13(-3),TX(13),WS(13),W(13)
C*****
C      THIS SUBROUTINE CALCULATES THE TRANSMITTANCE BY NO ( PPM LEAD IN
C      THE MAIN PROGRAM).
C*****
0004      I1=I-282
0005      IF (W(13)-LT.1.0E-20) GO TO 3
0006      WS(13)=ALOG10(W(13))+C13(I1)
0007      DO 1 J=1,6
0008      IF (WS(13)-FNI(J)) 2,2,1
0009      CONTINUE
0010      TX(13)=EXP(-10*(FNI(J)+FNI(J)+FNI(J)+WS(13)))
0011      RETURN
0012      END

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FORTRAN IV G LEVEL 21          SUTIT          DATE = 79216          16/22/49          PAGE 0001

0001      SUBROUTINE SUTIT(I1,W,C14,TX)
0002      COMMON /NM12/ FMH3(9),PHI(9),PH2(9)
0003      DIMENSION C14(109),TX(14),WS(14),W(14)
0004      *****
0005      C THIS SUBROUTINE CALCULATES THE TRANSMITTANCE BY NM3 ( PPM READ IN
0006      C THE MAIN PROGRAM).
0007      C *****
0008      I1=I-68
0009      IF (M14).LT.1.DF=20) GO TO 3
0010      WS(14)=ALOG10(W(14))+C14(I1)
0011      DO 1 J=1,9
0012      IF (WS(14)-FMH3(J)) 2,2,1
0013      CONTINUE
0014      TX(14)=EXP(-10**((FMH1(J)+FMH2(J)+WS(14)))
0015      RETURN
0016      END

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FORTRAN IV G LEVEL 21      BOJ      DATE = 79218      16/22/49      PAGE 0001

0001      SUBROUTINE BOJ(I,W,C15,TR)
0002      COMMON /MO13/ FN02(I),OI(I),C2(I)
0003      DIMENSION C15(15),TX(15),WS(15),W(15)
C *****
C      THIS SUBROUTINE CALCULATES THE TRANSMITTANCE BY NO2 ( PPM READ IN
C      THE MAIN PROGRAM).
C *****
C *****
C *****
0004      IF (I.LE.106) I1=I-105
0005      IF (I1.GE.239.AND.I1.LE.265) I1=I-192
0006      IF (I1.E.499.AND.I1.LE.510) I1=I-425
0007      IF (W(I1).LT.1.0E-20) GO TO 3
0008      WS(I5)=ALOG10(W(I5))+C15(I1)
0009      DO 1 J=1,9
0010      IF (WS(I5)-FN02(IJ)) 2,2,1
0011      CONTINUE
0012      TX(I5)=EXPI=-10**((OI(IJ)+C2(IJ))+S(I5))
0013      RETURN
0014      END

```

PROGRAM WILL BE EXECUTED IN THE TRANSMISSION MODE
 1 1 0 0 0 0 0 0 0 0.0 0.0
 0.0 2.500 65.000 5.000 0.0 0.0
 450.000 455.000 5.000

HORIZONTAL PATH, ALTITUDE = 0.0 KM, RANGE = 5.000 KM

MODEL ATMOSPHERE 1 = TROPICAL

HAZE MODEL 1 = 23KM VISUAL RANGE

FREQUENCY RANGE V1= 450.0 CM-1 TO V2= 455.0 CM-1 FOR DV = 5.0 CM-1 (21.98 - 22.22 MICRONS)

HORIZONTAL PROFILES

1	0.0	0.182E-01	0.379E-00	0.256E-02	0.695E-00	0.492E-01	0.910E-00	0.100E-01	0.261E-02	0.249E-03	0.255E-00	0.0	0.0	0.198E-01	
2	1.0	0.114E-01	0.741E-00	0.246E-02	0.571E-00	0.259E-01	0.829E-00	0.440E-00	0.261E-02	0.227E-03	0.164E-00	0.0	0.0	0.179E-01	
3	2.0	0.738E-01	0.422E-00	0.277E-02	0.467E-00	0.149E-01	0.754E-00	0.190E-00	0.252E-02	0.205E-03	0.112E-00	0.0	0.0	0.162E-01	
4	3.0	0.338E-00	0.515E-00	0.235E-02	0.376E-00	0.436E-02	0.679E-00	0.794E-01	0.238E-02	0.186E-03	0.513E-01	0.0	0.0	0.145E-01	
5	4.0	0.143E-00	0.431E-00	0.181E-02	0.306E-00	0.120E-02	0.616E-00	0.422E-01	0.219E-02	0.169E-03	0.233E-01	0.0	0.0	0.131E-01	
6	5.0	0.883E-01	0.759E-00	0.166E-02	0.248E-00	0.652E-03	0.558E-00	0.318E-01	0.210E-02	0.152E-03	0.158E-01	0.0	0.0	0.118E-01	
7	6.0	0.451E-01	0.296E-00	0.111E-02	0.199E-00	0.264E-03	0.503E-00	0.224E-01	0.201E-02	0.137E-03	0.874E-02	0.0	0.0	0.106E-01	
8	7.0	0.224E-01	0.245E-00	0.118E-02	0.159E-00	0.110E-03	0.453E-00	0.208E-01	0.191E-02	0.124E-03	0.485E-02	0.0	0.0	0.944E-02	
9	8.0	0.107E-01	0.201E-00	0.125E-02	0.127E-00	0.409E-04	0.408E-00	0.215E-01	0.182E-02	0.111E-03	0.261E-02	0.408E-04	0.0	0.0	0.841E-02
10	9.0	0.459E-02	0.163E-00	0.119E-02	0.999E-01	0.136E-04	0.364E-00	0.206E-01	0.182E-02	0.993E-04	0.124E-02	0.364E-05	0.0	0.0	0.747E-02
11	10.0	0.171E-02	0.133E-00	0.113E-02	0.789E-01	0.405E-05	0.325E-00	0.201E-01	0.182E-02	0.893E-04	0.578E-03	0.107E-04	0.0	0.0	0.601E-02
12	11.0	0.516E-03	0.107E-00	0.113E-02	0.616E-01	0.133E-05	0.290E-00	0.198E-01	0.191E-02	0.784E-04	0.184E-03	0.232E-04	0.0	0.0	0.583E-02
13	12.0	0.161E-03	0.953E-01	0.112E-02	0.476E-01	0.278E-06	0.256E-00	0.197E-01	0.201E-02	0.693E-04	0.656E-04	0.308E-04	0.0	0.0	0.513E-02
14	13.0	0.426E-04	0.800E-01	0.111E-02	0.365E-01	0.678E-07	0.226E-00	0.182E-01	0.210E-02	0.613E-04	0.204E-04	0.317E-04	0.0	0.0	0.449E-02
15	14.0	0.209E-04	0.543E-01	0.105E-02	0.281E-01	0.320E-07	0.200E-00	0.168E-01	0.210E-02	0.538E-04	0.120E-04	0.320E-04	0.0	0.0	0.391E-02
16	15.0	0.138E-04	0.422E-01	0.103E-02	0.210E-01	0.230E-07	0.174E-00	0.169E-01	0.219E-02	0.469E-04	0.929E-05	0.314E-04	0.0	0.0	0.340E-02
17	16.0	0.101E-04	0.327E-01	0.967E-03	0.157E-01	0.148E-07	0.152E-00	0.163E-01	0.219E-02	0.434E-04	0.832E-05	0.289E-04	0.0	0.0	0.293E-02
18	17.0	0.765E-05	0.247E-01	0.133E-02	0.113E-01	0.110E-07	0.130E-00	0.158E-01	0.322E-02	0.340E-04	0.660E-05	0.259E-04	0.0	0.0	0.246E-02
19	18.0	0.580E-05	0.177E-01	0.161E-02	0.780E-02	0.823E-08	0.107E-00	0.153E-01	0.420E-02	0.241E-04	0.431E-05	0.225E-04	0.0	0.0	0.200E-02
20	19.0	0.443E-05	0.128E-01	0.233E-02	0.540E-02	0.690E-08	0.885E-01	0.129E-01	0.633E-02	0.233E-04	0.312E-05	0.203E-04	0.0	0.0	0.164E-02
21	20.0	0.379E-05	0.937E-02	0.295E-02	0.377E-02	0.529E-08	0.736E-01	0.943E-02	0.887E-02	0.194E-04	0.214E-05	0.221E-04	0.0	0.0	0.134E-02
22	21.0	0.368E-05	0.866E-02	0.348E-02	0.265E-02	0.512E-08	0.613E-01	0.884E-02	0.112E-01	0.162E-04	0.182E-05	0.227E-04	0.0	0.0	0.111E-02
23	22.0	0.316E-05	0.505E-02	0.380E-02	0.187E-02	0.437E-08	0.513E-01	0.514E-02	0.131E-01	0.136E-04	0.138E-05	0.215E-04	0.0	0.0	0.915E-03
24	23.0	0.290E-05	0.380E-02	0.407E-02	0.135E-02	0.430E-09	0.435E-01	0.394E-02	0.149E-01	0.116E-04	0.118E-05	0.226E-04	0.0	0.0	0.765E-03
25	24.0	0.270E-05	0.286E-02	0.406E-02	0.977E-03	0.386E-09	0.349E-01	0.312E-02	0.159E-01	0.981E-05	0.106E-05	0.222E-04	0.0	0.0	0.641E-03
26	25.0	0.270E-05	0.216E-02	0.381E-02	0.704E-03	0.376E-09	0.314E-01	0.263E-02	0.159E-01	0.654E-05	0.959E-06	0.119E-04	0.0	0.0	0.538E-03
27	30.0	0.726E-06	0.548E-03	0.198E-02	0.148E-02	0.940E-09	0.142E-01	0.791E-03	0.112E-01	0.299E-05	0.163E-06	0.369E-05	0.0	0.0	0.230E-03
28	35.0	0.115E-06	0.149E-03	0.365E-03	0.334E-04	0.133E-09	0.666E-02	0.708E-03	0.429E-02	0.142E-05	0.211E-07	0.146E-06	0.0	0.0	0.103E-03
29	40.0	0.239E-07	0.429E-04	0.190E-03	0.809E-05	0.265E-10	0.324E-02	0.548E-04	0.191E-02	0.697E-06	0.330E-08	0.324E-06	0.0	0.0	0.474E-04
30	45.0	0.577E-08	0.129E-04	0.461E-04	0.206E-05	0.605E-11	0.162E-02	0.144E-04	0.607E-03	0.355E-06	0.610E-09	0.0	0.0	0.226E-04	
31	50.0	0.108E-08	0.424E-05	0.119E-04	0.579E-06	0.107E-11	0.853E-03	0.381E-05	0.201E-03	0.113E-06	0.989E-10	0.0	0.0	0.114E-04	
32	70.0	0.235E-11	0.509E-07	0.842E-07	0.364E-08	0.162E-14	0.713E-04	0.196E-07	0.401E-05	0.103E-07	0.477E-12	0.0	0.0	0.794E-06	
33	100.0	0.150E-15	0.340E-11	0.518E-11	0.104E-12	0.604E-19	0.385E-06	0.696E-11	0.201E-08	0.553E-10	0.230E-16	0.0	0.0	0.297E-08	
34	*****	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

FROM POINT: HEIGHT= 0.0 KM, P= 1.4EE, INDEX ABOVE 6. RELCM X= 0.2489E-03 0.0 PIP= 1
 EQUIV. ASPOPER AMOUNTS PER KM AT X= 0.192E 01 0.870E 00 0.256E-02 0.695E 00 0.492E-01 0.910E 00 0.100E 01 0.261E-02

EQUILAVENT SEA LEVEL ASPOPER AMOUNTS

W(1-8)=	0.91E 01	0.440E 01	0.124E-01	0.348E 01	0.246E 00	0.455E 01	0.509E 01	0.131E-01
W(11-15)=	0.0	0.990E-01	0.102E 00	0.953E-01	0.394E-01			
ALTER VAPOR	CM CM-2	CO2 ETC.	ZONE	NITROGEN	H2O	SCAT	AEROSOL	CZONE(UV-VIS)
		KM	CM CM-2	KM	CM CM-2	KM	KM	ATM CM
NITRIC ACID		SO2	NO	NH3	NO2			

WAVELENGTH H2O CO2+ OZONE N2 CONT H2O CONT MCL SCAT AEROSOL AEROSOL
CM-1 MICRONS TRANS TRANS TRANS TRANS TRANS TRANS TRANS TRANS
450 22-222 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 0.9331 0.9370
455 21-780 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 0.9324 0.9376

WAVELENGTH SC2 NC NH3 NO2 INTEGRATED TOTAL
CM-1 MICRONS TRANS TRANS TRANS TRANS ANSRIPTION TRANS
450 22-222 1.0000 1.0000 1.0000 1.0000 2.5000 0.0000
455 21-780 1.0000 1.0000 1.0000 1.0000 4.9999 0.0000
INTEGRATED ABSORPTION FROM 450 TO 455 CM-1 = 5.00, AVERAGE TRANSMITTANCE = 0.0000

FREQUENCY RANGE V1 = 550.0 CM-1 TO V2 = 555.0 CM-1 FOR TV = 5.0 CM-1 (18.02 - 18.18 MICRONS)

EQUILIVANT SEA LEVEL ABSORBER AMOUNTS

WATER VAPOUR CO2 ETC. OZONE NITROGEN (CLNT) H2O (CONT) WFL SCAT AEROSOL OZONE(JV-VIS)
CM CM-2 K4 ST# C" K4 CM CM-2 K4
W1-91= 0.911F 01 0.440E 01 0.128E-01 0.348E 01 0.246E 00 0.455E 01 0.500E 01 0.131E-01

NITRIC ACID SO2 NH3 NO2
W11-151= 0.0 0.900E-01 0.102E 00 0.933E-01 0.398E-01

FREQ WAVELENGTH CM-1 MICRONS H2O TRANS CO2+ TRANS N2 CONT H2O CONT MOL SCAT AEROSOL AEROSOL
 550 18.1818 0.0211 0.9365 1.0000 1.0000 1.0000 1.0000 0.9332 0.0343
 555 18.0180 0.0232 0.9190 1.0000 1.0000 1.0000 1.0000 0.9124 0.0349

FREQ WAVELENGTH CM-1 MICRONS SO2 TRANS NO TRANS NH3 TRANS NO2 INTEGRATED TOTAL
 550 18.1818 0.9175 1.0000 1.0000 1.0000 2.4577 0.0169
 555 18.0180 0.9338 1.0000 1.0000 1.0000 4.9113 0.0185
 INTEGRATED ABSORPTION FROM 550 TO 555 CM-1 = 4.9113 AVERAGE TRANSMITTANCE = 0.0177

FREQUENCY RANGE V1 = 650.0 CM-1 TO V2 = 655.0 CM-1 FOR UV = 5.0 CM-1 (15.27 = 15.38 MICRONS)

EQUILAVANT SEA LEVEL ABSORBER AMOUNTS

WATER VAPOR CM CM-2 CO2 ETC. KM OZONE NITROGEN (CONT) H2O (CONT) MOL SCAT AEROSOL CZONE(UV-VIS)
 550 18.1818 0.9175 1.0000 1.0000 1.0000 2.4577 0.0169
 555 18.0180 0.9338 1.0000 1.0000 1.0000 4.9113 0.0185

NITRIC ACID SO2 NH3 NO2

W(11-15) = 0.0 0.990E-01 0.102E 00 0.953F-01 0.398E-01

FREQ WAVELENGTH H2O CO2+ OZONE N2 CONT H2O CONT H2O SCAT AEROSOL
CM-1 MICRONS TRANS TRANS TRANS TRANS TRANS TRANS AER
650 15.3866 0.2465 0.000 0.9983 1.0000 1.0000 1.0000 0.9337 0.0360
655 15.2672 0.2866 0.0000 0.9975 1.0000 1.0000 1.0000 0.9338 0.0396

FREQ WAVELENGTH CO2 NO NH3 N2 INTEGRATED TOTAL
CM-1 MICRONS TRANS TRANS TRANS TRANS ABSORPTION TRANS
650 15.3866 1.0000 1.0000 1.0000 0.9995 2.5000 0.0000
655 15.2672 1.0000 1.0000 1.0000 0.9997 5.0000 0.0000
INTEGRATED ABSORPTION FROM 650 TO 655 CM-1 = 5.00-AVERAGE TRANSMITTANCE = 0.0000

FREQUENCY RANGE VL= 750.0 CM-1 TO V2= 755.0 CM-1 FOR DV = 5.0 CM-1 (13.25 - 13.33 MICRONS)

EQUILIVANT SEA LEVEL ABSORBER AMOUNTS

WATER VAPOR CO2 ETC. OZONE NITROGEN (CONT) H2O (CONT) H2O SCAT AEROSOL SIGNATURE-VIS)
GM CM-2 KW ATM CM KW GM CM-2 GM CM-2 KM KM AEROSOL
W11-81= 0.911F 01 0.440E 01 0.128F-01 0.348F 01 0.246E 00 0.455E 01 0.500E 01 0.131E-01

NITRIC ACID SO2 NO NH3 NO2
W11-151= 0.0 0.940E-01 0.102E 00 0.953E-01 0.349E-01

FREQ WAVELENGTH H2O CO2+ OZONE N2 CNT H2O CNT MOL SCAT AEROSOL
 CM-1 MICRONS TRANS TRANS TRANS TRANS TRANS TRANS AEROSOL
 950 10-5263 0.8800 0.9603 0.9994 1.0000 0.1642 1.0000 0.9231 0.0341
 955 10-4712 0.9681 0.9612 0.9988 1.0000 0.1692 1.0000 0.9226 0.0347

FREQ WAVELENGTH SO2 NO3 N2O INTEGRATED TOTAL
 CM-1 MICRONS TRANS TRANS TRANS TRANS ABSORPTION TRANS
 950 10-5263 1.0000 1.0000 0.9212 1.0000 2.2052 0.1179
 955 10-4712 1.0000 1.0000 0.8878 1.0000 4.4165 0.1155
 INTEGRATED ABSORPTION FROM 950 TO 955 CM-1 = 4.42, AVERAGE TRANSMITTANCE = 0.1167

FREQUENCY RANGE V1 = 1150.0 CM-1 TO V2 = 1155.0 CM-1 FOR PV = 5.0 CM-1 (8.66 - 8.70 MICRONS)

EQUIVALENT SEA LEVEL ABSORBER AMOUNTS

WATER VAPOR CO2 ETC. OZONE NITROGEN (CNT) H2O (CNT) MOL SCAT AEROSOL OZONE(UV-VIS)
 CM CM-2 KM KM KM GP CM-2 KM KM ATM CM
 W(1-4) = 0.911E 01 0.440E 01 0.128E-01 0.348E 01 0.266E 00 0.455E 01 0.500E 01 0.131E-01

NITRIC ACID SO2 NO NH3 NO2
 W(11-15) = 0.0 0.900E-01 0.102E 00 0.953E-01 0.398E-01

FREQ WAVELENGTH H2O CO2+ OZONE N2 CONT H2O CONT MOL SCAT AEROSOL AEROSOL
CM-1 MICRONS TRANS TRANS TRANS TRANS TRANS TRANS ABS
750 13.3333 0.4889 0.4739 0.9980 0.0000 0.0084 1.0000 0.9361 0.0261
755 13.2450 0.5450 0.5962 0.9983 1.0000 0.0097 1.0000 0.9359 0.0260

FREQ WAVELENGTH SO2 NO NO2 INTEGRATED TOTAL
CM-1 MICRONS TRANS TRANS TRANS ABSORPTION TRANS
750 13.3333 1.0000 1.0000 0.9814 0.9994 2.4956 0.0018
755 13.2450 1.0000 1.0000 0.9783 0.9995 4.9884 0.0029
INTEGRATED ABSORPTION FROM 750 TO 755 CM-1 = 4.99-AVERAGE TRANSMITTANCE = 0.0023

FREQUENCY RANGE VL= 950.0 CM-1 TO V2= 955.0 CM-1 FOR DV = 5.0 CM-1 (10.47 - 10.53 MICRONS)

EQUILIVANT SEA LEVEL ABSORBER AMOUNTS

WATER VAPOUR GM CM-2	CO2 ETC. KM	OZONE ATM CM	NITROGEN (CONT) KM	H2O (CONT) GM CM-2	MOL SCAT KM	AEROSOL KM	OZONE(UV-VIS) ATM CM
0.911E 01	0.440E 01	0.128E-01	0.348E 01	0.246E 00	0.455E 01	0.500E 01	0.131E-01

NITRIC ACID SO2 NO NH3 NO2

W11-151* 0.0 0.990E-01 0.102E 00 0.953E-01 0.398E-01

FREQ WAVELENGTH CM-1 MICRONS	H2O TRANS	CO2+ TRANS	OZONE TRANS	N2 CONT TRANS	H2O CONT TRANS	MOL SCAT TRANS	AEROSOL TRANS	AEROSOL ABS
1150	0.7275	0.9622	0.9973	1.0000	0.3041	1.0000	0.9055	0.0548
1155	0.7094	0.9612	0.9980	1.0000	0.3060	1.0000	0.9373	0.0560

FREQ WAVELENGTH CM-1 MICRONS	SO2 TRANS	NO TRANS	NH3 TRANS	N2O TRANS	INTEGRATED TOTAL ABSORPTION
1150	0.9040	1.0000	0.9768	1.0000	0.1701
1155	0.8929	1.0000	0.9820	1.0000	0.1657

INTEGRATED ABSORPTION FROM 1150 TO 1155 CM-1 = 4.16 AVERAGE TRANSMITTANCE = 0.1679

FREQUENCY RANGE V1 = 1350.0 CM-1 TO V2 = 1355.0 CM-1 FOR V = 5.0 CM-1 (7.38 = 7.61 MICRONS)

EQUILIVANT SEA LEVEL ABSORBER AMOUNTS

WATER VAPOUR GM CM-2	CO2 ETC. GM	OZONE ATM CM	NITROGEN (CONT) GM CM-2	H2O (CONT) GM CM-2	MOL SCAT KM	AEROSOL KM	OZONE (UV-VIS) ATM CM
0.911E 01	0.440E 01	0.128E-01	0.348E 01	0.246E 00	0.455E 01	0.500E 01	0.131E-01

NITRIC ACID	SO2	NO	NH3	N2O
0.0	0.590E-01	0.102E 00	0.953E-01	0.398E-01

FREQ WAVELENGTH H2O CO2+ OZONE N2 CONT H2O CONT MPL SCAT AEROSOL AEROSOL
CM-1 MICRONS TRANS TRANS TRANS TRANS TRANS TRANS ARE
2450 4.0816 0.9822 0.9617 1.0000 0.7664 0.8288 1.0000 0.9212 0.0119
2455 4.0733 0.9914 0.9645 1.0000 0.7827 0.8320 1.0000 0.9211 0.0119

FREQ WAVELENGTH SO2 NO3 NH3 NO2 INTEGRATED TOTAL
CM-1 MICRONS TRANS TRANS TRANS TRANS ABSORPTION TRANS
2450 4.0816 1.0000 1.0000 1.0000 1.0000 1.1041 0.5584
2455 4.0733 0.9998 1.0000 1.0000 1.0000 2.1705 0.5734
INTEGRATED ABSORPTION FROM 2450 TO 2455 CM-1 = 2.17, AVERAGE TRANSMITTANCE = 0.5659

FREQUENCY RANGE V1= 3150.0 CM-1 TO V2= 3155.0 CM-1 FOR CV = 5.0 CM-1 (3.17 = 3.17 MICELNS)

EQUILAVENT SEA LEVEL ABSORBER AMOUNTS

WATER VAPOUR CM CM-2 CO2 ETC. KM OZONE ATM CM NITROGEN (CONT) H2O (CONT) MWL SCAT AEROSOL CZONE (UV-VIS)
CM CM-2 KM KM GW CM-2 KM KM KM ATM CM

W(1-8)= 0.911E 01 0.440E 01 0.123E-01 0.348E 01 0.246E 00 0.455E 01 0.500E 01 0.131E-01

NITRIC ACID SO2 NO NH3 NO2

W(11-15)= 0.0 0.990E-01 0.102E 00 0.953E-01 0.398E-01

FREQ WAVELENGTH H2O CO2+ OZONE N2 CONT H2O CONT MOL SCAT AEROSOL AEROSOL
CM-1 MICRONS TRANS TRANS TRANS TRANS TRANS TRANS ABS
1850 5.4054 0.0000 0.9955 0.9999 1.0000 1.0000 1.0000 0.9283 0.0186
1855 5.3908 0.0000 0.9948 0.9999 1.0000 1.0000 1.0000 0.9282 0.0185

FREQ WAVELENGTH SO2 NO3 NO2 INTEGRATED TOTAL
CM-1 MICRONS TRANS TRANS TRANS TRANS ABSORPTION TRANS
1850 5.4054 1.0000 0.8961 1.0000 2.5000 0.0000
1855 5.3908 1.0000 0.9034 1.0000 5.0000 0.0000
INTEGRATED ABSORPTION FROM 1850 TO 1855 CM-1 = 5.00, AVERAGE TRANSMITTANCE = 0.0000

FREQUENCY RANGE V1 = 2450.0 CM-1 TO V2 = 2455.0 CM-1 FOR DV = 5.0 CM-1 (4.07 = 4.06 MICRONS)

FOHILAVENT SEA LEVEL ABSORBER AMOUNTS

WATER VAPOR CO2 ETC. OZONE NITROGEN (CONT) H2O (CONT) MOL SCAT AEROSOL OZONE(UV-VIS)
GM CM-2 KM ATM CM KM GM CM-2 KM KM ATM CM
W(1-0) = 0.911E 01 0.440E 01 0.128E-01 0.348E 01 0.246E 00 0.455E 01 0.500E 01 0.131E-01

NITRIC ACID SO2 NO3 NO2

W(1-15) = 0.0 0.590E-01 0.102E 00 0.953E-01 0.398E-01

FREQ	WAVELENGTH	H2O	CO2+	OZONE	N2	H2O	CMNT	MOL	SCAT	AEROSOL	AEROSOL
CM-1	MICRONS	TRANS	TRANS	TRANS	TRANS	TRANS	TRANS	TRANS	TRANS	TRANS	ABS
3150	3.1746	0.4800	0.9190	0.9998	1.0000	1.0000	1.0000	1.0000	0.9116	0.0231	
3155	3.1696	0.5021	0.9373	0.9998	1.0000	1.0000	1.0000	1.0000	0.9116	0.0233	

FREQ	WAVELENGTH	SO2	NO	NH3	N2	INTEGRATED	TOTAL
CM-1	MICRONS	TRANS	TRANS	TRANS	TRANS	ABSORPTION	TRANS
3150	3.1746	1.0000	1.0000	1.0000	1.4951	0.4020	
3155	3.1696	1.0000	1.0000	1.0000	2.9229	0.4289	

INTEGRATED ABSORPTION FROM 3150 TO 3155 CM-1 = 2.92-AVERAGE TRANSMITTANCE = 0.4154

ADSET V 1-3

EVALUATION OF ABSORBER PARAMETERS AND STANDARD EMPIRICAL AND
PIECEWISE-ANALYTICAL TRANSMISSION FUNCTIONS

THIS CODE USES THE SUBROUTINE SIMQ IN SSP LIBRARY

THIS CODE CONSISTS OF

MAIN: COMPUTATIONS OF BAND PARAMETERS N,M,C'
AND EMPIRICAL STANDARD TRANSMISSION FUNCTION
NMBC: COMPUTATION OF NON-MAJOR BANDS' C-VALUES
INTPL1: COMPUTATION OF THE PIECEWISE-ANALYTICAL
STANDARD TRANSMISSION FUNCTION GIVEN BY
 $\tau = \exp(-10^{**}(A1+A2*X))$
INTPL2: COMPUTATION OF THE PIECEWISE-ANALYTICAL
STANDARD TRANSMISSION FUNCTION GIVEN BY
 $\tau = \exp(-10^{**}(A1+A2*X+A3*X**2))$
SDTAU: COMPUTATION OF THE ERROR STANDARD DERIVATIONS
BETWEEN PIECEWISE ANALYTICAL STANDARD
TRANSMISSION FUNCTION AND THE ORIGINAL DATA
USED IN THE MAIN PROGRAMME

DATA SET-UP

1. 1ST CARD TITLE IN 20A4
(ABSORBER TYPE,ETC)
2. 2ND CARD FOUR CONTROL NUMBERS IN 4I5
MAXRPT MAXIMUM NUMBER OF REPETITION OF
THE COMPUTATION IN MAIN
INDX(1) SUBROUTINE NMBC IS CALLED IF > 0
INDX(2) SUBROUTINE INTPL1 IS CALLED IF > 0
INDX(3) SUBROUTINE INTPL2 IS CALLED IF > 0
3. DATA SET FOR MAIN
CONSISTS OF SEVERAL SUBSETS (MAX.6) OF DATA
CORRESPONDING TO INDIVIDUAL MAJOR BANDS
FIRST CARD FOR EACH SUBSET IS A CONTROL CARD WHICH
CONTAINS BAND#, WAVE NUMBER, # OF CUTS AND # OF LEVELS
IN THIS ORDER BY THE FORMAT (I5,F10.3,2I5)
REFER TO THE READ(5,105) AND FORMAT 105 FOR THE
CONTENTS OF EACH CARD.
END OF DATA IS DEFINED BY A BLANK CONTROL CARD
4. DATA SET FOR NMBC
INDIVIDUAL DATA FORMAT - SAME AS FOR MAIN
END OF EACH DATA SET FOR A BAND IS MARKED BY
A BLANK CARD
END OF ALL DATA IS MARKED BY -1 (I2) IN ADDITION TO
A BLANK CARD
IF NO DATA BUT A BLANK CARD IS SUPPLIED, THEN
THIS SUBROUTINE IS SKIPPED.
5. DATA SET FOR INTPL1
FORMATION OF THE DATA IS THE SAME AS THAT FOR MAIN
DATA (IF SUPPLIED) WILL BE USED FOR S.D. COMPUTATION
ONLY.
IF NO DATA BUT A BLANK CARD IS SUPPLIED, THEN THE
S.D. COMPUTATION IS SKIPPED.
6. DATA SET FOR INTPL2

C FORMATION OF THE DATA IS THE SAME AS THAT FOR MAIN
 C IF NO DATA BUT A BLANK CARD IS SUPPLIED, THEN
 C THIS SUBROUTINE IS SKIPPED.
 C NOTE: DATA SET MUST HAVE A CUT STRUCTURE SUCH THAT EQUAL
 C TRANSMITTANCE DATA ARE GROUPED TOGETHER AND THESE GROUPS
 C ARE QUEUED IN THE DECENDING ORDER IN TAU. THE QUEUING OF
 C THE LEVELS WITHIN EVERY GROUP MUST BE THE SAME.

```

C
C      DIMENSION V(19),A(19,19),X(361),B(19),RI(6,12,10)
C      DIMENSION P(10),WWW(12,10),STANDV(12),TSD(6),NDATA(6),INDX(3)
C      COMMON /PARM1/ TSTD(12),PW(12),WN(6),CSTD(6),NCUT,NC,NAME(20),
C      *              AN,AM,CF,ICONST(6),NEL
C      COMMON /PARM2/ PRES(6,12,10),TEMP(6,12,10),UGAS(6,12,10),
C      *              TAU(6,12),NTC(6),NLV(6)
C      CF=1.0
C      LOOPCT=1
C      WCRIT=2.
C      M=0
C      READ(5,100) (NAME(I),I=1,20)
100  FORMAT(20A4)
C      READ(5,101) MAXRPT,(INDX(I),I=1,3)
101  FORMAT(4I5)
C
C      COMPUTATION OF ABSORBER PARAMETERS N, M & C-VALUES IS REPEATED
C      MAXRPT TIMES, WHERE 1 < MAXRPT < 10 IS READ IN BY I5 FORMAT
C      (SUGGESTED VALUE IS 5)
C
C      DATA READ-IN ROUTINE
C
1000 CONTINUE
C      READ(5,102) IC,W,JM,KM
102  FORMAT(I5,F10.3,2I5)
C      IF(IC.LE.0) GO TO 2000
C      IF(M.GT.0) GO TO 10
C      CALL DATE (MONTH,IDAY,IYEAR)
C      WRITE(6,111)MONTH,IDAY,IYEAR
111  FORMAT(1H1,T60,I4,' / ',I2,' / ',I2,/)
C      WRITE(6,200) (NAME(I),I=1,20)
200  FORMAT(1H ,T25,20A4)
C      GO TO 11
10  CONTINUE
C      WRITE(6,201)
201  FORMAT(1H1)
11  CONTINUE
C      M=M+1
C      WN(M)=W
C      NTC(M)=JM
C      NLV(M)=KM
C      WRITE(6,202) M,WN(M),NTC(M),NLV(M)
202  FORMAT(1H0,T15,'*** BAND',I3,' (WAVE NUMBER =',F10.3,') ***',
C      *   ///,T20,'TOTAL # OF CUTS'  =',I3,///,T20,'TOTAL # OF LEVELS =',I3,
C      *   ///)
C      WRITE(6,203)
203  FORMAT(1H ,T5,'( DATA FORMAT )',//,T9,'GAS#',T15,'WAVE #',T24,
C      *   'PRESSURE',T36,'TEMP.',T46,'PPM',T58,'RANGE',T70,'UGAS',T78,
C      *   'TRANSM.',/)

```

```

DO 12 J=1,JM
WRITE(6,204) J
204 FORMAT(1H0,T5,'< CUT',I3,' >',/)
T=0.
IT=0
DO 13 K=1,KM
READ(5,103) KGAS,FREQ,RPRES,RTEMP,PPM,RANGE,RUGAS,TX
103 FORMAT(I2,F10.3,E11.4,F9.3,E11.4,E13.6,E11.4,F7.4)
RUGAS=RUGAS/CF
WRITE(6,205) KGAS,FREQ,RPRES,RTEMP,PPM,RANGE,RUGAS,TX
205 FORMAT(T10,I2,F10.3,E11.4,F9.3,E11.4,E13.6,E11.4,F8.4)

C      PRES, TEMP & UGAS ARE CONVERTED TO THE LOG OF THE NORMALIZED
C      VALUES. IF RPRES=0 (INDICATES NO DATA), THEN UGAS(M,J,K) IS SET
C      AT AN IMPOSSIBLE VALUE , ALSO RI(M,J,K) IS SET TO ZERO.
C
      IF(RPRES.GT.0.) GO TO 14
      PRES(M,J,K)=0.
      TEMP(M,J,K)=0.
      UGAS(M,J,K)=10.
      RI(M,J,K)=0.
      GO TO 15
14 CONTINUE
      PRES(M,J,K)=ALOG10(RPRES/1013.)
      TEMP(M,J,K)=ALOG10(273.15/RTEMP)
      UGAS(M,J,K)=ALOG10(RUGAS)
15 CONTINUE

C      T=T+TX
      IT=IT+1
      RI(M,J,K)=1.0
13 CONTINUE
      TAU(M,J)=T/FLOAT(IT)
12 CONTINUE
      GO TO 1000

C      END OF DATA INPUT

C      CONSTANTS USED IN LATER COMPUTATION ARE INITIALIZED
C      FROM 2000 TO 3000.
C      NCUT = MAXIMUM # OF CUTS USED IN COMPUTATION
C      NDIM = DIMENSION OF THE COEFFICIENT MATRIX
C
2000 CONTINUE
      IF(M.GT.0) GO TO 20
      WRITE(6,206)
206 FORMAT(1H0,/,T10,'$$$ NO INPUT DATA $$$')
      STOP
20 CONTINUE
      NC=M
      CSTD(1)=0.
      NCUT=NTC(1)
      NPTS=NTC(1)*NLV(1)
      IF(NC.LE.1) GO TO 21
      DO 22 I=2,NC
      NCUT=MAX0(NCUT,NTC(I))

```

```

      NPTS=NPTS+NTC(I)*NLV(I)
22  CONTINUE
21  CONTINUE
      FNC=FLOAT(NC)
      RIT=FLOAT(NPTS)
      DO 23 J=1,NCUT
      TC=0.
      DO 24 M=1,NC
      TC=TC+TAU(M,J)
24  CONTINUE
      TSTD(J)=TC/FNC
23  CONTINUE
      NDIM=NC+1+NCUT
C
C *****
C      COMPUTATION OF THE ABSORBER PARAMETERS.
C      THIS LOOP WILL BE REPEATED MAXRPT TIMES.
C
C      FORMATION OF THE NORMAL EQUATION  $AX = B$  , A IS SYMMETRIC
C
3000 CONTINUE
      DO 30 I=1,19
      B(I)=0.
      DO 31 J=1,19
      A(I,J)=0.
31  CONTINUE
30  CONTINUE
C
      DO 1 M=1,NC
      JM=NTC(M)
      KM=NLV(M)
      DO 2 J=1,JM
      DO 3 K=1,KM
      IF(RI(M,J,K).LT.0.5.) GO TO 3
      DO 4 IC=1,19
      V(IC)=0.
4  CONTINUE
      V(NDIM-M)=1.
      V(NDIM)=PRES(M,J,K)
      V(NDIM-1)=TEMP(M,J,K)
      VV=-UGAS(M,J,K)
      V(NCUT+1-J)=1.
      DO 5 II=1,NDIM
      DO 6 IJ=1,NDIM
      A(II,IJ)=V(II)*V(IJ)*RI(M,J,K) + A(II,IJ)
6  CONTINUE
      B(II)=V(II)*VV*RI(M,J,K) + B(II)
5  CONTINUE
3  CONTINUE
2  CONTINUE
1  CONTINUE
C
C      IF J-TH ROW OF "A" IS ZERO, A(J,J) IS CHANGED TO -1
C      WHICH IS DONE IN ORDER TO MAKE "A" NON-SINGULAR
C      THIS HAPPENS WHEN ALL OF THE DATA FOR BAND J-1 FAIL TO SATISFY
C      THE CRITERION  $W < WCRIT$ .  THE BAND J-1 WILL BE IGNORED IF THIS

```

HAPPENS, AND THE C-VALUE FOR BAND J-1 WILL BE COMPUTED SEPARATELY.

C
C

```

ICONST(1)=1
IF(NC.EQ.1) GO TO 40
DO 41 M=2,NC
ICONST(M)=1
I=NDIM-M
IF(A(I,I).NE.0.) GO TO 41
A(I,I)=-1.0
ICONST(M)=0
41 CONTINUE
40 CONTINUE

```

C
C

```

NCOL=0
DO 42 J=1,NDIM
DO 43 I=1,NDIM
NCOL=NCOL+1
X(NCOL)=A(I,J)
43 CONTINUE
42 CONTINUE

```

C
C
C

PRINTING OF THE HEADING FOR EACH TRIAL AND THE NORMAL EQUATION

```

IF(LOOPCT.GT.1) GO TO 50
WRITE(6,207) MAXRPT,LOOPCT
207 FORMAT(1H1,T20,'***' ABSORBER PARAMETER COMPUTATION '***',///,
* T15,'NOTE: THE COMPUTATION WILL BE REPEATED MAXRPT =',I2,
* ' TIMES.',///,T10,'TRIAL #',I1,5X,'(ALL DATA WERE USED)')
GO TO 51
50 CONTINUE
WRITE(6,208) LOOPCT
208 FORMAT(1H1,T10,'TRIAL #',I1,5X,'(PARTIAL DATA WERE USED WITH',
* ' CUT-OFF CRITERION : W < 2 )')
51 CONTINUE
WRITE(6,209) NDIM,NDIM
209 FORMAT(//,1H0,'< NORMAL EQUATION : AX = B >',//,T10,'WHERE THE',
* ' COEFFICIENT MATRIX A(',I3,' ',I3,' ) AND THE CONSTANT VECTOR',
* ' B ARE',//)
IF(NDIM.LE.17) GO TO 52
WRITE(6,210) NDIM
210 FORMAT(1H , '***' WARNING : DIMENSION OF THE MATRIX IS TOO LARGE',
* ' (',I3,' ) TO BE PRINTED IN A MATRIX FORM '***',/)
52 CONTINUE
DO 53 I=1,NDIM
WRITE(6,211) (A(I,J),J=1,NDIM),B(I)
211 FORMAT(1H ,18F7.3)
53 CONTINUE

```

C
C
C

***** MATRIX INVERSION SUBROUTINE SIMQ IN SSP IS CALLED *****

C

CALL SIMQ(X,B,NDIM,KS)

C
C
C

PRINTING OF THE SOLUTION FOR THE NORMAL EQUATION

```

      IF(KS.EQ.1) WRITE(6,212)
212  FORMAT(1H0,T10,'WARNING:  THE COEFFICIENT MATRIX IS SINGULAR.')
      AN=B(NDIM)
      AM=B(NDIM-1)
      IF(NC.LE.1) GO TO 54
      DO 55 M=2,NC
      CSTD(M)=B(NDIM-M)
55  CONTINUE
54  CONTINUE
      DO 56 J=1,NCUT
      PW(J)=-B(NCUT+1-J)
56  CONTINUE
      WRITE(6,213) AN,AM,(CSTD(M),M=1,NC)
213  FORMAT(/,1H0,' < RESULTS >',///,T7,'N',T17,'M',T27,'C1',T37,'C2',
* T47,'C3',T57,'C4',T67,'C5',T77,'C6',//,2F10.5,6F10.3)
      WRITE(6,214) (PW(I),I=1,NCUT)
214  FORMAT(/,1H0,T7,'X*1',T17,'X*2',T27,'X*3',T37,'X*4',T47,'X*5',
* T57,'X*6',T67,'X*7',T77,'X*8',T87,'X*9',T97,'X*10',T107,'X*11',
* T117,'X*12',//,12F10.3)
      NEL=NPTS-INT(RIT)
      WRITE(6,215) NEL
215  FORMAT(/,1H0,T4,'# OF ELIMINATED POINTS  =',I5)

```

```

C
C      CHECKING OF THE CRITERION ( W < WCRIT ) AND THE COMPUTATION
C      OF C-VALUES FOR THE IGNORED BANDS.
C      RI(M,J,K) = 0 IF W IS GREATER THAN OR EQUAL TO WCRIT
C      RI(M,J,K) = 1 IF W IS LESS THAN WCRIT
C

```

```

      RIT=0.
      DO 60 M=1,NC
      JM=NTC(M)
      KM=NLV(M)
      CAVG=0.0
      DO 61 J=1,JM
      DO 62 K=1,KM
      W=AN*PRES(M,J,K)+AM*TEMP(M,J,K)+UGAS(M,J,K)
      IF(W.GE.WCRIT) RI(M,J,K)=0.
      RIT=RIT+RI(M,J,K)
      CAVG=CAVG+(PW(J)-W)
62  CONTINUE
61  CONTINUE
      IF(ICONST(M).EQ.1) GO TO 60
      CSTD(M)=CAVG/FLOAT(JM*KM)
      WRITE(6,216) M,M,M,CSTD(M)
216  FORMAT(/,1H ,T7,'** WARNING **',T25,'NO DATA FOR BAND',I2,
* ' SATISFIES THE CRITERION ( W < 2 ).',//,T25,'THE C',I1,
* ' VALUE IS SEPARATELY COMPUTED BY AVERAGING.',//,T30,'C',I1,
* ' =',F10.3)
50  CONTINUE

```

```

C
C      COMPUTATIONS OF STANDARD DEVIATIONS IN X
C

```

```

      NGDATA=0
      GTSD=0.
      ICST=NC
      DO 70 M=1,NC

```

```

JM=NTC(M)
KM=NLV(M)
NDATA(M)=0
TSD(M)=0.
WRITE(6,201)
WRITE(6,202) M,WN(M),NTC(M),NLV(M)
WRITE(6,217) AN,AM,M,CSTD(M)
217 FORMAT(1H ,T10,'N  =' ,F10.5,/,T10,'M  =' ,F10.5,/,T10,'C',I1,
* '  =' ,F10.5)
WRITE(6,218)
218 FORMAT(/,1H0,T7,'RECOMPUTED X-VALUES AND STANDARD DEVIATIONS',
* ' IN X-VALUES',/,1H0,T2,'CUT',T11,'TAU',T20,'X*',T30,'X1',T39,
* 'X2',T48,'X3',T57,'X4',T66,'X5',T75,'X6',T84,'X7',T93,'X8',
* T102,'X9',T111,'X10',T121,'CUTWISE-SD',/)

```

C
C
C

COMPUTATION OF THE CUTWISE STANDARD DEVIATIONS IN X

```

DO 71 J=1,JM
DN=0.
WW=0.
DO 72 K=1,KM
P(K)=CSTD(M)+AN*PRES(M,J,K)+AM*TEMP(M,J,K)+UGAS(M,J,K)
WWW(J,K)=(PW(J)-P(K))*2*RI(M,J,K)
WW=WW+WWW(J,K)
DN=DN+RI(M,J,K)
72 CONTINUE
WW=SQRT(WW/DN)
NDATA(M)=NDATA(M)+IFIX(DN)
WRITE(6,219) J,TAU(M,J),PW(J),(P(K),K=1,KM)
219 FORMAT(1H ,I5,F9.3,F9.4,1X,10F9.4)
WRITE(6,220) WW
220 FORMAT(1H+,T121,F10.5)
71 CONTINUE

```

C
C
C

COMPUTATION OF THE LEVELWISE STANDARD DEVIATIONS IN X

```

DO 73 K=1,KM
WW=0.
DN=0.
DO 74 J=1,JM
WW=WW+WWW(J,K)
DN=DN+RI(M,J,K)
74 CONTINUE
TSD(M)=TSD(M)+WW
STANDV(K)=SQRT(WW/DN)
73 CONTINUE
WRITE(6,221) (STANDV(K),K=1,KM)
221 FORMAT(1H0,T4,'LEVELWISE-SD :',T26,10F9.5)
NGDATA=NGDATA+NDATA(M)*ICONST(M)
GTSD=GTSD+TSD(M)*FLOAT(ICONST(M))
ICST=ICST-ICONST(M)
TSD(M)=SQRT(TSD(M)/FLOAT(NDATA(M)))
WRITE(6,222) TSD(M)
222 FORMAT(/,1H0,T4,'TOTAL STANDARD DEVIATION FOR THIS BAND  :',
* F15.6)
70 CONTINUE

```

C
C
C
C
C
C

PRINTOUT OF THE SUMMARY.
ALL VITAL INFORMATIONS ARE PRINTED OUT HERE.

```

GTSD=SQRT(GTSD/LOAT(NGDATA))
WRITE(6,223) LOOPCT,AN,AM
223 FORMAT(1H1,T15,'*** SUMMARY OF THE ABSORBER PARAMETER',
* ' COMPUTATION FOR TRIAL #',I2,' ***',///,T20,
* 'PRESSURE EXPONENT      N =',F10.5,///,T20,
* 'TEMPERATURE EXPONENT M =',F10.5,///,T5,'CASE #',3X,
* 'WAVE NUMBER',5X,'C-VALUE',5X,'TOTAL # OF DATA',3X,
* 'CASEWISE S.D. IN P')
WRITE(6,224) (M,WN(M),CSTD(M),NDATA(M),TSD(M),M=1,NC)
224 FORMAT(1H0,T6,I3,6X,F9.2,5X,F8.3,10X,I3,12X,F12.6)
WRITE(6,225) NGDATA,NEL,GTSD
225 FORMAT(//,1H0,T15,'GRAND TOTAL # OF DATA =',I5,///,T15,'# OF',
* ' ELIMINATED DATA =',I5,///,T15,'GLOBAL STANDARD DEVIATION IN P',
* ' =',F12.6,/)
IF(ICST.LE.0) GO TO 75
DO 76 M=1,NC
IF(ICONST(M).EQ.1) GO TO 76
WRITE(6,226) M
226 FORMAT(1H ,T15,'NOTE: THE BAND',I3,' IS NOT INCLUDED IN THE',
* ' FINAL STANDARD DEVIATION')
76 CONTINUE
75 CONTINUE
WRITE(6,227) LOOPCT,(TSTD(J),PW(J),J=1,NCUT)
227 FORMAT(///,1H0,T15,'*** STANDARD EMPIRICAL TRANSMISSION',
* ' FUNCTION FOR TRIAL #',I2,' ***',///,T20,'TAU',T35,'X*',/,
* (1H0,T17,F7.3,T30,F8.4))

C
C
IF(RIT.GT.0.) GO TO 80

C
C
IF NO INPUT DATA SATISFIES THE CRITERION, THE COMPUTATION IS
TERMINATED. THE MOST RECENT RESULTS WILL BE USED IN THE SEQUAL.

C
C
WRITE(6,228)
228 FORMAT(1H1,///,T15,'$$$ NO INPUT DATA SATISFIES THE CRITERION OF',
* ' ( W < 2 ) $$$',///,T15,'$$$ THE COMPUTATION FOR THIS STEP IS',
* ' TERMINATED $$$')
GO TO 4000
80 CONTINUE
LOOPCT=LOOPCT+1
IF(LOOPCT.GT.MAXRPT) GO TO 4000
GO TO 3000

C
4000 CONTINUE

C
C
SUBROUTINE COMPUTATIONS FOLLOW

C
IF(INDX(1).LE.0) GO TO 90

C
CALL NMBC

```

```

C
90 CONTINUE
  IF(INDX(2).LE.0) GO TO 91
C
  CALL INTPL1
C
91 CONTINUE
  IF(INDX(3).LE.0) GO TO 92
C
  CALL INTPL2
C
92 CONTINUE
  STOP
  END
  SUBROUTINE NMBC
C
C      COMPUTATION OF C'-VALUES FOR NON-MAJOR BANDS
C
  DIMENSION B(15),CS(15),FS(15)
  COMMON /PARM1/ TSTD(12),PW(12),WN(6),CSTD(6),NCUT,NC,NAME(20),
  *             AN,AM,CF,ICONST(6),NEL
  WRITE(6,5) (NAME(I),I=1,20)
5  FORMAT(1H1,T15,20A4)
  WRITE(6,10)
10 FORMAT(1H0,T15,' *** CALCULATION OF THE SPECTRAL PARAMETERS',
  * 'FOR NON-MAJOR BANDS ***'///)
  DF=1.E30
11 CONTINUE
  NFREQ=0
12 CONTINUE
  C=0.
  I=0
15 CONTINUE
  READ(5,20) KGAS,FREQ,P,T,UGAS,TX
20 FORMAT(I2,F10.3,E11.4,F9.3,24X,E11.4,F7.4)
  IF(KGAS.EQ.0) GO TO 25
  IF (KGAS.LT.0) GO TO 35
C
C      THE FOLLOWING IF-STATEMENT IS INSERTED TO DETECT
C      AND TO IGNORE THE INVALID DATA POINTS.
C
  IF(UGAS.GE.DF) GO TO 15
  I=I+1
  WX=FREQ
  UGAS=UGAS/CF
  C=C+(PW(I)-AN*ALOG10(P/1013.)-AM*ALOG10(273.15/T)-ALOG10(UGAS))
  GO TO 15
25 C=C/FLOAT(I)
  NFREQ=NFREQ+1
  CS(NFREQ)=C
  FS(NFREQ)=WX
  DO 27 M=1,NC
  IF(ABS(WX-WN(M)).LE.0.1) CS(NFREQ)=CSTD(M)
27 CONTINUE
  IF(NFREQ.EQ.10) GO TO 30
  GO TO 12

```

```

30 CONTINUE
   WRITE(6,31) (FS(K),K=1,NFREQ)
31 FORMAT(1H0,2X,'WAVE NUMBER',2X,10F11.0)
   WRITE(6,32) (CS(K),K=1,NFREQ)
32 FORMAT(1H0,5X,'C VALUES',2X,10F11.3//)
   GO TO 11
35 CONTINUE
   IF(NFREQ.EQ.0) GO TO 40
   WRITE(6,31) (FS(K),K=1,NFREQ)
   WRITE(6,32) (CS(K),K=1,NFREQ)
40 CONTINUE
   RETURN
   END

```

```

C
C   SUBROUTINE INTPL1
C
C       COMPUTATION OF THE STANDARD PIECEWISE-ANALYTICAL TRANSMISSION
C       FUNCTION
C
C       VERSION 1 - 1  ** A3(I) = 0 **
C       TAU = EXP(-10** ( A1(I)+A2(I)*X ))
C

```

```

   DIMENSION SDCUT(15),ICUT(15),SDTCUT(15),ITCUT(15)
   COMMON /PARM1/ TSTD(12),PW(12),WN(6),CSTD(6),NCUT,NC,NAME(20),
*           AN,AM,CF,ICONST(6),NEL
   COMMON /PARM3/ A1(11),A2(11),A3(11)
   SSD=0.
   ITOTAL=0
   IM=NCUT-1
   JM=NCUT-2

```

```

C
C
C       COMPUTATION OF THE COEFFICIENTS A1(I), A2(I) AND A3(I)
C
   CTX1=ALOG10(-ALOG(TSTD(1)))
   DO 50 I=1,IM
   PDIF=PW(I)-PW(I+1)
   CTX2=ALOG10(-ALOG(TSTD(I+1)))
   A1(I)=(PW(I)*CTX2-PW(I+1)*CTX1)/PDIF
   A2(I)=(CTX1-CTX2)/PDIF
   A3(I)=0.
   CTX1=CTX2

```

```

C
   SDTCUT(I)=0.
50 ITCUT(I)=0

```

```

C
C       THE FIRST AND LAST VALUES OF TSTD AND PW ARE CHANGED
C       FOR THE TABLE OUTPUT. TRUE VALUES ARE TEMPORARY STORED
C       IN THE RESERVE.
C

```

```

   TRES1=TSTD(1)
   TRES2=TSTD(NCUT)
   PWRES1=PW(1)
   PWRES2=PW(NCUT)
   TSTD(1)=1.0
   TSTD(NCUT)=0.0

```

PW(1)=-1.E70
PW(NCUT)=1.E70

C
C
C

PRINT OUT OF THE RESULTS

```
WRITE(6,2) (NAME(I),I=1,20)
2 FORMAT(1H1,T25,20A4,/,T15,'PIECEWISE-ANALYTICAL STANDARD',
* 'TRANSMISSION FUNCTION',/,T20,'TAU(X) =',
* ' EXP(-10** ( A1 + A2*X ) )',/,T15,'DATA:',T23,'FROM ( TAU ',
* 'X-VALUE) TO ( TAU ,X-VALUE) WITH ( A1 , A2 )')
WRITE(6,3) (TSTD(I),PW(I),TSTD(I+1),PW(I+1),A1(I),A2(I),I=1,IM)
3 FORMAT(1H0,T28,(' ',F6.3,' ',',F7.3,') (' ',F6.3,' ',',F7.3,')',T74,
* (' ',F7.4,' ',',F7.4,')')
WRITE(6,4) (I,WN(I),CSTD(I),I=1,NC)
4 FORMAT(1H0,/,T15,'ABSORPTION BANDS:',T40,
* '# WAVENUMBER C-VALUE'/(1H0,T39,I2,5X,F7.1,F11.5))
```

C
C
C
C
C
C

CHECK IF ANY DATA IS AVAILABLE FOR S.D. COMPUTATION
DATA FORMAT IS THE SAME AS THAT FOR MAIN PROGRAMME
ONE CONTROL CARD IS READ-IN FIRST FOR BRANCHING
IFQ > 0 DATA SET FOLLOWS, READ-IN DATA
IFQ = 0 END OF DATA, GO TO THE FINAL PRINTING

```
READ(5,11,END=42) FQ,IFQ
11 FORMAT(5X,F10.3,T41,I4)
IF(IFQ.GT.0) GO TO 18
42 WRITE(6,41)
41 FORMAT(///,1H0,T5,'$$$ NO DATA FOR STANDARD DEVIATION COMPUTATION
* $$$')
GO TO 40
8 READ(5,11,END=30) FQ,IFQ
IF(IFQ.LE.0) GO TO 30
18 CONTINUE
ST=0.
DO 51 I=1,IM
SDCUT(I)=0.
51 ICUT(I)=0
CLOG=100.
DO 52 I=1,NC
52 IF(ABS(FQ-WN(I)).LT.1.) CLOG=CSTD(I)
IF(CLOG.LT.99.) GO TO 13
```

C
C
C
C

THE READ-IN WAVENUMBER DOES NOT MATCH THE MAJOR BAND
WAVENUMBER (WN(I)).THE DATA IN THIS BAND ARE IGNORED.

```
WRITE(6,12) FQ
12 FORMAT(1H0,T10,'** ERROR IN WAVENUMBER **',
* ' (READ-IN WAVENUMBER =',F10.5,',')')
DO 61 IDUM=1,IFQ
READ(5,60) DUMMY
60 FORMAT(F1.0)
61 CONTINUE
GO TO 8
```

C
C
C

VALID DATA INPUTS,READ-IN OF THE DATA AND STANDARD
DEVIATION COMPUTATION ARE PERFORMED SIMULTANEOUSLY.

```

C
13 CONTINUE
  WRITE(6,17) FQ
17 FORMAT(1H1,T15,'( WAVE NUMBER =',F8.1,' )',///,6X,'WAVEN.',3X,
  * 'PRESS.',4X,'TEMP.',7X,'U',8X,'TRANSM. - T(COMP) = DIFF',6X,
  * 'DIFF**2',4X,'X-VALUE',/)
  DO 9 M=1,NDATA
    READ(5,10) KGAS,FQ,PRES,TEMP,UG,TX
10 FORMAT(I2,F10.3,E11.4,F9.3,24X,E11.4,F7.4)
    UG=UG/CF
    X=CLOG+AN*ALOG10(PRES/1013.)+AM*ALOG10(273.15/TEMP)+ALOG10(UG)
    DO 14 J=1,JM
      IF(X.LE.PW(J+1)) GO TO 15
14 CONTINUE
    J=IM
C
15 TC=EXP(-10**(A1(J)+A2(J)*X))
C
    D=TX-TC
    SD=D*D
    ST=ST+SD
    SDCUT(J)=SDCUT(J)+SD
    ICUT(J)=ICUT(J)+1
    WRITE(6,16) FQ,PRES,TEMP,UG,TX,TC,D,SD,X
16 FORMAT(1H ,3X,F8.1,F10.2,F9.2,E13.4,F9.4,F12.4,F13.6,E12.3,F9.3)
    9 CONTINUE
C
    END OF DATA READ-IN FOR THIS BAND.
C
    TOTAL STANDARD DEVIATIONS ARE COMPUTED AND PRINTED.
C
20 SSD=SSD+ST
  ITOTAL=ITOTAL+IFQ
  ST=SQRT(ST/FLOAT(IFQ))
  DO 21 I=1,IM
    SDTCUT(I)=SDTCUT(I)+SDCUT(I)
    ITCUT(I)=ITCUT(I)+ICUT(I)
21 SDCUT(I)=SQRT(SDCUT(I)/FLOAT(ICUT(I)))
    WRITE(6,22) (I,TSTD(I),TSTD(I+1),ICUT(I),SDCUT(I),I=1,IM)
22 FORMAT(1H0,///,T10,'CUTWISE STANDARD DEVIATION',//,T15,'#',T20,
  * '( FROM, TO ) ',T40,'# OF DATA',T53,'CUTWISE SD',//,(T14,I2,
  * T20,'( ',F5.2,' ',F5.2,' ) ',T43,I4,T52,F10.6,/)
    WRITE(6,23) IFQ,ST
23 FORMAT(1H0,T10,'TOTAL # OF DATA FOR THIS BAND =',I5,9X,
  * ' STANDARD DEVIATION =',F12.6,/)
    GO TO 8
C
    END OF THE STANDARD DEVIATION COMPUTATION FOR ALL DATA.
C
    GRAND TOTAL STANDARD DEVIATION IS COMPUTED AND PRINTED OUT
C
    TOGETHER WITH VITAL INFORMATIONS.
C
30 SSD=SQRT(SSD/FLOAT(ITOTAL))
  DO 31 I=1,IM
31 SDTCUT(I)=SQRT(SDTCUT(I)/FLOAT(ITCUT(I)))
    WRITE(6,32) (I,TSTD(I),PW(I),TSTD(I+1),PW(I+1),A1(I),A2(I),
  * ITCUT(I),SDTCUT(I),I=1,IM)
32 FORMAT(1H1,T20,'*** PIECEWISE-ANALYTICAL STANDARD TRANSMISSION',

```

```

* ' FUNCTION ***',///,T10,'TOTAL CUTWISE STANDARD DEVIATION',//,
* T15,'CURVE #',3X,'FROM ( TAU ,X-VALUE) TO ( TAU ,X-VALUE)',
* ' WITH ( A1 , A2 )',3X,'# OF DATA',4X,'CUTWISE SD',//,
* (T18,I2,T30,'(,F6.3,',',F7.3,') (,F6.3,',',F7.3,')',T76,
* '(,F7.4,',',F7.4,')',7X,I3,5X,F10.6,/)
WRITE(6,33) ITOTAL,SSD
33 FORMAT(1H0,T10,'GLOBAL RESULTS',//,T15,'TOTAL NUMBER OF DATA',
* ' USED',I5,//,T15,'GLOBAL STANDARD DEVIATION',F12.6)

```

C

```
40 CONTINUE
```

C

C

C

C

C

C

```
END OF ALL COMPUTATION.
```

```
RESERVED TRUE VALUES OF THE FIRST AND LAST TSTD
AND PW ARE RETURNED.
```

```

TSTD(1)=TRES1
TSTD(NCUT)=TRES2
PW(1)=PWRES1
PW(NCUT)=PWRES2

```

C

```
CALL SDTAU
```

C

```
RETURN
```

```
END
```

```
SUBROUTINE INTPL2
```

C

C

C

C

C

C

C

```
COMPUTATION OF THE PIECEWISE-ANALYTICAL STANDARD TRANSMISSION
FUNCTION
```

```
VERSION 2 - 1
```

```
TAU=EXP(-10**((A1+A2*X+A3*X**2)))
```

```

COMMON /PARM1/ TSTD(12),PW(12),WN(6),CSTD(6),NCUT,NC,NAME(20),
* AN,AM,CF,ICONST(6),NEL

```

```
COMMON /PARM3/ A1(11),A2(11),A3(11)
```

```
DIMENSION T(10),TD(6,74),PD(6,74),JI(6,10),
```

```
* SDK(7),SDE(7,9),SUME(2,9),DE(6,9)
```

```
NWC=0
```

```
K=0
```

```
READ(5,2,END=80) FREQ,MAXDAT
```

```
IF(MAXDAT.GT.0) GO TO 3
```

```
80 CONTINUE
```

```
WRITE(6,99)
```

```
99 FORMAT(///,1H0,T5,'$$$ NO DATA FOR STANDARD DEVIATION COMPUTATION
* $$$')
```

```
GO TO 77
```

```
1 CONTINUE
```

```
READ(5,2,END=21) FREQ,MAXDAT
```

```
2 FORMAT(5X,F10.5,T41,I4)
```

```
IF(MAXDAT.EQ.0) GO TO 21
```

```
3 CLOG=1.E 10
```

```
DO 5 L=1,NC
```

```
IF(ABS(FREQ-WN(L)).LE. .01) CLOG=CSTD(L)
```

```
5 CONTINUE
```

```
IF(ABS(CLOG-1.E10).GE..01) GO TO 9
```

```
WRITE(6,100) FREQ
```

```

100 FORMAT('1',////////,' ERROR IN INPUT DATA ; WAVE NUMBER ',F10.3,
* ' NOT USED IN COMPUTATION OF CONSTANTS.')
DO 6 J=1,MAXDAT
  READ(5,101) KGAS,FREQ,PRES,TEMP,PPM,RANGE,UGAS,TX
6 CONTINUE
  GO TO 1
9 CONTINUE
  K=K+1
  NWC=NWC+1
  JI(K,1)=0
  JI(K,NCUT)=MAXDAT
  J=2
  DO 20 I=1,MAXDAT
    READ(5,101) KGAS,FREQ,PRES,TEMP,PPM,RANGE,UGAS,TX
101 FORMAT('2',F10.3,E11.4,F9.3,E11.4,E13.6,E11.4,F7.4)
    TD(K,I)=TX
    PD(K,I)= AN *ALOG10(PRES/1013.)+ AM *ALOG10(273.15/TEMP)+ALOG10
    * (UGAS/CF)+CLOG
    IF(TD(K,I).GE.TSTD(J)) GO TO 20
    IF(J.EQ.NCUT) GO TO 20
    JI(K,J)=I-1
    J=J+1
20 CONTINUE
  GO TO 1
21 CONTINUE
  IF(NWC.LE.0) RETURN
  DO 30 J=1,NCUT
    T(J)=ALOG10(-ALOG(TSTD(J)))
30 CONTINUE
  SUMT=0.
  DT=0.0
  NCC=NCUT-1
  DO 45 I=1,NCC
    SA=0.
    TA=0.
    UA=0.
    DO 41 K=1,NWC
      SUME(K,I)=0.0
      M=JI(K,I)+1
      N=JI(K,I+1)
      DO 40 J=M,N
        TC=ALOG10(-ALOG(TD(K,J)))
        SA=SA+ TC *PW(I)*PW(I+1)*(PD(K,J)-PW(I))*(PD(K,J)-PW(I+1))
        TA=TA+((PD(K,J)-PW(I))*(PD(K,J)-PW(I+1))*((PD(K,J)**2)*(PW(I+1)
        * T(I)-PW(I)*T(I+1))+PD(K,J)*((PW(I)**2)*T(I+1)-(PW(I+1)**2)*T(I)
        * )))/(PW(I)-PW(I+1))
        UA=UA+((PD(K,J)-PW(I))*(PD(K,J)-PW(I+1)))**2
41 CONTINUE
40 CONTINUE
    A1(I)=(SA-TA)/UA
    A2(I)=(T(I)-T(I+1))/(PW(I+1)*(PW(I)-PW(I+1)))-(T(I)-A1(I))/(PW(I)*
    * PW(I+1))
    A3(I)=(T(I)-T(I+1))/(PW(I)-PW(I+1))-A3(I)*(PW(I)+PW(I+1))
    A4(I)=A3(I)-A2(I)
  END DO
  NWC=NWC+1

```

```

M=JI(K,I)+1
N=JI(K,I+1)
DE(K,I)=FLOAT(1+N-M)
DO 43 J=M,N
  SUME(K,I)=SUME(K,I)+(TD(K,J)-EXP(-10.**(A3(I)*PD(K,J)*PD(K,J)+
    * A2(I)*PD(K,J)+A1(I))))**2
43 CONTINUE
  SDE(K,I)=SQRT(SUME(K,I)/DE(K,I))
  SUMI=SUMI+SUME(K,I)*FLOAT(ICONST(K))
  DI=DI+DE(K,I)*FLOAT(ICONST(K))
44 CONTINUE
  SUMT=SUMT+SUMI
  DT=DT+DI
  SDE(NWC+1,I)=SQRT(SUMI/DI)
45 CONTINUE
  DO 51 K=1,NWC
    SUMK=0.0
    DK=0.0
    DO 50 I=1,NCC
      SUMK=SUMK+SUME(K,I)
      DK=DK+DE(K,I)
50 CONTINUE
    SDK(K)=SQRT(SUMK/DK)
51 CONTINUE
    SDK(NWC+1)=SQRT(SUMT/DT)
    DUM1=PW(1)
    DUM2=PW(NCUT)
    DUM3=TSTD(1)
    DUM4=TSTD(NCUT)
    PW(1)=-1000000.
    PW(NCUT)=1000000.
    TSTD(1)=1.0
    TSTD(NCUT)=0.0
    DO 60 K=1,NWC
      WRITE(6,102)(NAME(J),J=1,20),WN(K),NCC,(I,TSTD(I),TSTD(I+1),PW(I),
        * PW(I+1),A1(I),A2(I),A3(I),SDE(K,I),I=1,NCC)
102 FORMAT ('1',/,35X,'RENDITION OF EMPIRICAL TRANSMITTANCE FUNCTION
  *FOR : '//,20A4,/,40X,'WAVE NUMBER : ',F15.4,////,20X,'THE TRANSMI
  *SSION CURVE IS DIVIDED INTO',I3,' SEPARATE CURVES.',/20X,'EACH CU
  *RVE IS EXPRESSED BY A FUNCTION OF THE FORM " TAU = EXP(-10**(A3*P
  *#P+A2*P+A1)) ".',/20X, 'THE FUNCTION COEFFI
  *CIENTS AND RESULTING STANDARD DEVIATION FOR EACH CURVE ARE AS FOL
  *LOWS: ',////22X,'TAU',20X,'P',24X,'A1',13X,'A2',13X,'A3',11X,'STAND
  *ARD DEVIATION',///, (5X,'CURVE #',I3,3X,'(',F4.2,'-',F4.2,')',5X,
  *('(',F9.5,'-',F9.5,')',5X,3F15.6, 6X,F15.6 /))
    WRITE(6,401) SDK(K)
401 FORMAT(1X,/,87X,'TOTAL STANDARD DEVIATION',F15.6)
60 CONTINUE
    K=K+1
    WRITE(6,104) (NAME(J),J=1,20),NCC, (I,TSTD(I),TSTD(I+1),PW(I),
      * PW(I+1),A1(I),A2(I),A3(I),SDE(K,I),I=1,NCC)
104 FORMAT ('1',/,35X,'RENDITION OF EMPIRICAL TRANSMITTANCE FUNCTION
  *FOR : '//,20A4,/,40X,'TOTAL PROFILE AVERAGED OVER ALL WAVE NUMBER
  *S',////,20X,'THE TRANSMI
  *SSION CURVE IS DIVIDED INTO',I3,' SEPARATE CURVES.',/20X,'EACH CU
  *RVE IS EXPRESSED BY A FUNCTION OF THE FORM " TAU = EXP(-10**(A3*P

```

```

      #*P+A2*P+A1)) ".',20X,          'THE FUNCTION COEFFI
      *CIENTS AND RESULTING STANDARD DEVIATION FOR EACH CURVE ARE AS FOL
      *LWS:',////22X,'TAU',20X,'P',24X,'A1',13X,'A2',13X,'A3',11X,'STAND
      *ARD DEVIATION',///, (5X,'CURVE #',I3,3X,'(',F4.2,'-',F4.2,')',5X,
      *('F9.5,'-',F9.5,')',5X,3F15.6, 6X,F15.6 /))
      WRITE(6,402) SDK(K)
402  FORMAT(1X,/,81X,'GRAND TOTAL STANDARD DEVIATION',F15.6)
C    WRITE(7,201)(A1(I),A2(I),A3(I),I=1,NCC)
C 201  FORMAT(3F10.6)
C
      IDT=IFIX(DT)
      WRITE(6,225)IDT,NEL,SDK(K)
225  FORMAT(/,1H0,T15,'GRAND TOTAL # OF DATA =',I5,/,T15,'# OF',
      * ' ELIMINATED DATA =',I5,/,T15,'GLOBAL STANDARD DEVIATION IN',
      * ' TAU =',F12.6,/)
      DO 76 M=1,NWC
      IF(ICONST(M).EQ.1) GO TO 76
      WRITE(6,226) M
226  FORMAT(1H ,T15,'NOTE: THE BAND',I3,' IS NOT INCLUDED IN THE',
      * ' FINAL STANDARD DEVIATION')
76  CONTINUE
      PW(1)=DUM1
      PW(NCUT)=DUM2
      TSTD(1)=DUM3
      TSTD(NCUT)=DUM4
C
      CALL SDTAU
C
77  CONTINUE
      RETURN
      END
      SUBROUTINE SDTAU
C
C      COMPUTATIONS OF STANDARD DEVIATIONS IN TAU USING THE ORIGINAL
C      DATA USED IN MAIN
C
      DIMENSION NDATA(6),TSD(6),WWW(12,10),STANDV(12),P(10),T(10)
      COMMON /PARM1/ TSTD(12),PW(12),WN(6),CSTD(6),NCUT,NC,NAME(20),
      *              AN,AM,CF,ICONST(6),NEL
      COMMON /PARM2/ PRES(6,12,10),TEMP(6,12,10),UGAS(6,12,10),
      *              TAU(6,12),NTC(6),NLV(6)
      COMMON /PARM3/ A1(11),A2(11),A3(11)
C
      NGDATA=0
      GTSD=0.
      ICST=NC
      DO 70 M=1,NC
      JM=NTC(M)
      KM=NLV(M)
      NDATA(M)=JM*KM
      NGDATA=NGDATA+NDATA(M)*ICONST(M)
      TSD(M)=0.
      WRITE(6,214)
214  FORMAT('1',////,45X,'RECOMPUTATION OF TAU',////)
      IF(M.GT.1) GO TO 77
      WRITE(6,215)

```

```

215 FORMAT(20X,'A TAU VALUE , T , IS RECOMPUTED FOR THE ORIGINAL DATA
* USING THE PIECEWISE-ANALITICAL TRANSMISSION FUNCTION.'//20X,
* 'STANDARD DEVIATIONS BETWEEN THE ACTUAL TAU AND THE RECOMPUTED',
* 'TAU VALUES ARE COMPUTED.'////)
77 CONTINUE
WRITE(6,202) M,WN(M),NTC(M),NLV(M)
202 FORMAT(1H0,T15,'*** CASE',I3,' (WAVE NUMBER =',F10.3,') ***',
* ///,T20,'TOTAL # OF CUTS' =',I3,///,T20,'TOTAL # OF LEVELS' =',I3,
* ///)
WRITE(6,216) AN,AM,M,CSTD(M)
216 FORMAT(10X,'N' =',F10.5,///10X,'M' =',F10.5,///,10X,'C',I1,' =',
* F10.5,////)
WRITE(6,217)
217 FORMAT(//,1H0,T7,'RECOMPUTED TAU AND STANDARD DEVIATIONS',
* ' IN TAU ',/,1H0,T2,'CUT',T11,'TAU',T20,'X*',T30,'X1',T39,
* 'X2',T48,'X3',T57,'X4',T66,'X5',T75,'X6',T84,'X7',T93,'X8',
* T102,'X9',T111,'X10',T121,'CUTWISE-SD',/)

```

C
C
C

COMPUTATION OF THE CUTWISE STANDARD DEVIATIONS IN X

```

DO 71 J=1,JM
WW=0.
DO 72 K=1,KM
P(K)=CSTD(M)+AN*PRES(M,J,K)+AM*TEMP(M,J,K)+UGAS(M,J,K)
IM=JM-1
DO 75 I=1,IM
IF(PW(I+1).GT.P(K)) GO TO 76
75 CONTINUE
I=IM
76 CONTINUE
T(K)=EXP(-10**(A3(I)*P(K)*P(K)+A2(I)*P(K)+A1(I)))
WWW(J,K)=(TAU(M,J)-T(K))**2
WW=WW+WWW(J,K)
72 CONTINUE
WW=SQRT(WW/FLOAT(KM))
WRITE(6,218) J,PW(J),TAU(M,J),(T(K),K=1,KM)
218 FORMAT(1H ,I5,F9.4,F9.4,1X,10F9.4)
WRITE(6,219) WW
219 FORMAT(1H+,T121,F10.5)
71 CONTINUE

```

C
C
C

COMPUTATION OF THE LEVELWISE STANDARD DEVIATIONS IN X

```

DO 73 K=1,KM
WW=0.
DO 74 J=1,JM
WW=WW+WWW(J,K)
74 CONTINUE
TSD(M)=TSD(M)+WW
STANDV(K)=SQRT(WW/FLOAT(JM))
73 CONTINUE
WRITE(6,220) (STANDV(K),K=1,KM)
220 FORMAT(1H0,T4,'LEVELWISE-SD :',T26,10F9.5)
GTSD=GTSD+TSD(M)*FLOAT(ICONST(M))
ICST=ICST-ICONST(M)
TSD(M)=SQRT(TSD(M)/FLOAT(NDATA(M)))

```

```

      WRITE(6,221) TSD(M)
221 FORMAT(1H0, '//, T15, 'TOTAL STANDARD DEVIATION FOR THIS CASE  :',
      * F15.6)
70 CONTINUE
      GTSD=SQRT(GTSD/FLOAT(NGDATA))
      WRITE(6,223) AN,AM
223 FORMAT('1', T15, '**** SUMMARY OF THE TRANSMITTANCE RECOMPUTATION *
      * **', ///, T20, 'PRESSURE EXPONENT      N =', F10.5, //, T20,
      * 'TEMPERATURE EXPONENT M =', F10.5, ///, T5, 'CASE #', 3X,
      * 'WAVE NUMBER', 5X, 'C-VALUE', 5X, 'TOTAL # OF DATA', 3X,
      * 'CASEWISE S.D. IN TAU')
      WRITE(6,224) (M, WN(M), CSTD(M), NDATA(M), TSD(M), M=1, NC)
224 FORMAT(1H0, T6, I3, 6X, F9.2, 5X, F8.3, 10X, I3, 12X, F12.6)
      WRITE(6,225) NGDATA, NEL, GTSD
225 FORMAT(//, 1H0, T15, 'GRAND TOTAL # OF DATA =', I5, //, T15, '# OF',
      * 'ELIMINATED DATA =', I5, //, T15, 'GLOBAL STANDARD DEVIATION IN',
      * 'TAU =', F12.6, //)
      IF(ICST.LE.0) RETURN
      DO 78 M=1, NC
      IF(ICONST(M).EQ.1) GO TO 78
      WRITE(6,226) M
226 FORMAT(1H , T15, 'NOTE: THE BAND', I3, ' IS NOT INCLUDED IN THE',
      * ' FINAL STANDARD DEVIATION')
78 CONTINUE
      RETURN
      END

```

```

C
C***** COMPUTER CODE SIMMIN *****
C      VERSION ( 6 - 3 ) TRACE GASSES
C
C      COMPUTATION OF ABSORBER PARAMETERS AND ANALYTICAL STANDARD
C      TRANSMISSION FUNCTION
C
C      THIS CODE USES THE SUBROUTINE FMCG IN SSP LIBRARY
C
C      THIS CODE CONSISTS OF
C      MAIN: DATA READ-IN AND CONTROL OF COMPUTATION
C      FUNCT: COMPUTATION OF THE COST AND ITS DERIVATIVES
C      TITLE: PRINTING OF HEADINGS AND INITIAL CONDITIONS
C      PRINT1: PRINTOUT OF RESULTS AND COMPUTATION/PRINTING OF S.D.S
C      NMBC: COMPUTATION OF NON-MAJOR BANDS' C-VALUES
C
C      DATA SET-UP
C      1. INITIAL GUESSES X(I) (9 CARDS WITH T12,F10.7)
C          X(1)=A1, X(2)=A2, X(3)=A3, X(4)=N, X(5)=M, X(5+I)=LOG(C(I))
C          (NEED DUMMY INPUTS FOR PROBLEMS WITH DIMENSION < 9)
C      2. SIGNAL VARIABLES S(I) (9 CARDS WITH T12,F10.7)
C          S(I) = 0 ... X(I) IS KEPT CONSTANT
C          S(I) = 1 ... X(I) IS VARIED
C          (NEED DUMMY INPUTS FOR PROBLEMS WITH DIMENSION < 9)
C      3. COMMENT CARD (20A4) FOR TITLE AND ABSORBER TYPE ETC.
C      4. DATA SETS (MAX. 4 SETS) - ONE FOR EACH ABSORPTION BAND
C          EACH SET CONSISTS OF
C              1ST(CONTROL) CARD: WAVENUMBER, # OF DATA AND COMMENTS
C                                  (SEE FORMAT 101)
C              DATA CARDS: P, T, U, TAU ETC.
C                                  (SEE FORMAT 102)
C              (TOTAL # OF DATA SHOULD NOT EXCEED 900)
C      5. BLANK CARD - FOR THE TERMINATION OF DATA INPUT FOR MAIN
C      6. DATA SETS FOR NMBC - ONE FOR EACH ABSORPTION BAND
C          EACH SET CONSISTS OF
C              DATA CARDS: SAME AS MAIN
C              FINAL CARD: BLANK
C              TERMINATION A CONTROL CARD WITH -1 IN FIRST TWO COLUMNS
C                          THIS COMES AFTER THE FINAL BLANK CARD
C              (IF NO DATA BUT A BLANK CARD IS SUPPLIED, NMBC IS SKIPPED)
C
C      DIMENSION X(9),G(9),Y(9),H(72),WN(4)
C      COMMON /PARM1/ NC,ND(5),RW(4)
C      COMMON /PARM2/ IC,PLOG(900),TLOG(900),ULOG(900),TAU(900),S(9)
C      COMMON /PARM3/ P(900),T(900),U(900),L(20)
C      COMMON /PARM4/ PO,TO,NDIM,ID(5,9)
C      EXTERNAL FUNCT
C
C      CONSTANTS
C      PO=1.013E+03
C      TO=273.15
C      CF=2.69E+19
C      N=9
C      V=0.
C      IC=0
C      MAXNC=4

```

```

C
C      DATA INPUT
C
      READ(5,100) (X(I),I=1,N)
      READ(5,100) (S(I),I=1,N)
100  FORMAT (T12,F10.7)
C
C      COMMENT CARD (THIS INCLUDES THE ABSORBER TYPE)
C      READ(5,500) (L(I),I=1,20)
500  FORMAT(20A4)
C
C      NC = # OF MAJOR ABSORPTION BANDS
C      ND(1)=0, ND(2)=N1, ND(3)=N1+N2, ND(4)=N1+N2+N3, ...
C      WHERE N1, N2, N3, ... ARE #S OF DATA IN BANDS 1, 2, 3, ...
C      ND(NC+1)= TOTAL # OF DATA
C
      NC=0
      ND(1)=0
      DO 10 M=1,MAXNC
      READ(5,101) WN(M),IX,(ID(NC+1,I),I=1,9)
101  FORMAT(5X,F10.3,T41,I4,9A4)
      IF(IX.LE.0) GO TO 11
      NC=NC+1
      IM=ND(NC)+1
      IN=ND(NC)+IX
      ND(NC+1)=IN
      DO 12 I=IM,IN
      READ(5,102) P(I),T(I),U(I),TAU(I)
102  FORMAT (12X,E11.4,F9.3,24X,E11.4,F7.4)
      U(I)=U(I)/CF
C
C      DATA ARE CONVERTED TO THE LOG OF THE NORMALIZED VALUES
C
      PLOG(I)=ALOG10(P(I)/PO)
      TLOG(I)=ALOG10(T0/T(I))
      ULOG(I)=ALOG10(U(I))
C
      12 CONTINUE
      10 CONTINUE
      11 CONTINUE
C
C      END OF DATA INPUT
C
      IF(NC.GT.0) GO TO 13
      WRITE(6,110)
110  FORMAT (1H0,'ERROR IN DATA INPUT')
      GO TO 1000
      13 CONTINUE
C
      NDIM=0
      N=5+NC
      DO 14 I=1,N
      IF(S(I).NE.0.) NDIM=NDIM+1
14  CONTINUE
      DO 15 I=1,NC
      RW(I)=FLOAT(ND(NC+1))/(FLOAT(ND(I+1)-ND(I))*FLOAT(NC))

```

```

      RW(I)=1.0
15  CONTINUE
C
      DO 16 I=1,N
      Y(I)=X(I)
16  CONTINUE
C
      EST=1.E-6
      EPS=1.E-6
      LIMIT=1
      IER=0
C
C***** FMCG SEARCH ***** START *****
C
      CALL FMCG(FUNCT,N,X,V,G,EST,EPS,LIMIT,IER,H)
C
C***** FMCG SEARCH ***** END *****
C
      CALL TITLE(N,Y,LIMIT,EPS)
C
      CALL PRINT1(N,X,V,G,IER)
C
      CALL NMBC(X,L,NC,WN,CF,PO,TO)
C
1000 CONTINUE
      STOP
      END
      SUBROUTINE FUNCT(N,X,V,G)
C
C      COMPUTATION OF THE FUNCTION VALUE AND DERIVATIVES
C
C      (DOUBLE EXPONENTIAL FUNCTION)
C
      DIMENSION X(9),G(9),F(9)
      COMMON /PARM1/ NC,ND(5),RW(4)
      COMMON /PARM2/ IC,PLOG(900),TLOG(900),ULOG(900),TAU(900),S(9)
C
      IC=IC+1
      V=0.
      DO 20 K=1,N
      G(K)=0.
20  CONTINUE
C
      DO 21 J=1,NC
      JJ=J+5
      SQER=0.
      DO 22 L=1,5
      F(L)=0.
22  CONTINUE
      F(JJ)=0.
      IM=ND(J)+1
      IN=ND(J+1)
      DO 23 I=IM,IN
      W1=X(JJ)+X(4)*PLOG(I)+X(5)*TLOG(I)+ULOG(I)
      R=X(1)+X(2)*W1+X(3)*W1*W1
      R=10.**R

```

```

      IF(R.LE.70.) GO TO 24
      TC=0.
      GO TO 25
24  CONTINUE
      TC=EXP(-R)
25  CONTINUE
      E=TAU(I)-TC
      R=R*E*TC
      SQER=SQER+E**2
      F(1)=F(1)+R
      F(2)=F(2)+R*W1
      F(3)=F(3)+R*W1*W1
      R=R*(X(2)+2.*X(3)*W1)
      F(4)=F(4)+R*PLOG(I)
      F(5)=F(5)+R*TLOG(I)
      F(JJ)=F(JJ)+R
23  CONTINUE
      V=V+SQER*RW(J)
      DO 26 K=1,5
      G(K)=G(K)+F(K)*RW(J)
26  CONTINUE
      G(JJ)=F(JJ)*RW(J)
21  CONTINUE
C
      DO 27 I=1,N
      G(I)=4.60517*G(I)*S(I)
27  CONTINUE
C
      RETURN
      END
      SUBROUTINE TITLE(N,X,LIMIT,EPS)
C
C      PRINTING OF THE TITLE AND INITIAL VALUES
C
      DIMENSION X(9),L(4)
      COMMON /PARM1/ NC,ND(5),RW(4)
      COMMON /PARM4/ PO,TO,NDIM,ID(5,9)
C
      DO 40 I=1,NC
      L(I)=ND(I+1)-ND(I)
40  CONTINUE
C
      CALL DATE (MONTH,IDAY,IYEAR)
      WRITE(6,111)MONTH,IDAY,IYEAR
111  FORMAT(1H1,T60,I4,' / ',I2,' / ',I2,/)
      WRITE(6,400) NC,NDIM
400  FORMAT (1H ,T14,'*** SIMULTANEOUS PARAMETER EVALUATION ***',///,
* ' PARAMETERS : ( N , M , A1 , A2 , A3 , C(I), I=1,',I2,' )',
* 8X,'( DIMENSION =',I3,' )',///,' DATA :')
      WRITE(6,401) ((ID(K,J),J=1,9),L(K),K=1,NC)
401  FORMAT(1H+,T11,'(',I9A4,' )',5X,'# OF POINTS =',I5,/)
C
      WRITE(6,402) ND(NC+1),PO,TO,LIMIT,EPS
402  FORMAT (1H+,T51,'TOTAL # OF DATA =',I5,///,
* ' FUNCTION : TAU ( W ) = EXP ( -10 ** ( A1 + A2 * W +',
* ' A3 * W**2 + A4 * W**3 ) )',//,T15,'WHERE, ',

```

```
* ' W = LOG(C) + LOG( U * (P/PO)**N * (TO/T)**M ) ',
* ' , A4 = 0. ', ///,
* ' CONSTANTS : PO =',F8.2,7X,'TO =',F8.2,7X,
* ' LIMIT =',I5,7X,'EPS =',1PE10.1,/)

```

```
C
      IF(NC.EQ.1) WRITE(6,403) X(1),X(6),X(2),X(3),X(4),X(5)
      IF(NC.EQ.2) WRITE(6,404) X(1),X(6),RW(1),X(2),X(7),RW(2),X(3),
*                               X(4),X(5)
      IF(NC.EQ.3) WRITE(6,405) X(1),X(6),RW(1),X(2),X(7),RW(2),X(3),
*                               X(8),RW(3),X(4),X(5)
      IF(NC.EQ.4) WRITE(6,406) X(1),X(6),RW(1),X(2),X(7),RW(2),X(3),
*                               X(8),RW(3),X(4),X(9),RW(4),X(5)
403 FORMAT (1H0,'INITIAL VALUES :',T22,'A1 =',F12.7,9X,'LOG(C1) =',
* F12.7,/,T22,'A2 =',F12.7,/,T22,'A3 =',F12.7,/,T22,'N =',
* F12.7,/,T22,'M =',F12.7,/)
404 FORMAT (1H0,'INITIAL VALUES :',T22,'A1 =',F12.7,9X,'LOG(C1) =',
* F12.7,4X,'( WEIGHT =',F8.4,' )',/,T22,'A2 =',F12.7,9X,
* 'LOG(C2) =',F12.7,4X,'( WEIGHT =',F8.4,' )',/,T22,'A3 =',
* F12.7,/,T22,'N =',F12.7,/,T22,'M =',F12.7,/)
405 FORMAT (1H0,'INITIAL VALUES :',T22,'A1 =',F12.7,9X,'LOG(C1) =',
* F12.7,4X,'( WEIGHT =',F8.4,' )',/,T22,'A2 =',F12.7,9X,
* 'LOG(C2) =',F12.7,4X,'( WEIGHT =',F8.4,' )',/,T22,'A3 =',
* F12.7,9X,'LOG(C3) =',F12.7,4X,'( WEIGHT =',F8.4,' )',/,T22,
* 'N =',F12.7,/,T22,'M =',F12.7,/)
406 FORMAT (1H0,'INITIAL VALUES :',T22,'A1 =',F12.7,9X,'LOG(C1) =',
* F12.7,4X,'( WEIGHT =',F8.4,' )',/,T22,'A2 =',F12.7,9X,
* 'LOG(C2) =',F12.7,4X,'( WEIGHT =',F8.4,' )',/,T22,'A3 =',
* F12.7,9X,'LOG(C3) =',F12.7,4X,'( WEIGHT =',F8.4,' )',/,T22,
* 'N =',F12.7,9X,'LOG(C4) =',F12.7,4X,'( WEIGHT =',F8.4,' )',/,
* T22,'M =',F12.7,/)

```

```
C
      RETURN
      END
      SUBROUTINE PRINT1(N,X,V,G,IER)

```

```
C
      PRINTING OF THE RESULTS AND COMPUTATION/PRINTING OF ERRORS
      AND STANDARD DEVIATIONS

```

```
C
      DIMENSION X(9),G(9),E(900),PD(900),TC(900),W(900)
      COMMON /PARM1/ NC,ND(5),RW(4)
      COMMON /PARM2/ IC,PLOG(900),TLOG(900),ULOG(900),TAU(900),S(9)
      COMMON /PARM3/ P(900),T(900),U(900),L(20)
      COMMON /PARM4/ PO,TO,NDIM,ID(5,9)
      EQUIVALENCE (E,PLOG),(PD,TLOG),(TC,ULOG)

```

```
C
      EQUIVALENCE IS FOR SPACE CONSERVATION

```

```
C
      IT=0
      TTD=0.
      TV=0.
      V=SQRT(V/FLOAT(ND(NC+1)))

```

```
C
      WRITE(6,510) IER,IC,(X(I),G(I),I=1,5)
510 FORMAT (1H0,'** RESULTS OF COMPUTATION : IER =',I3,4X,
* 'SUBROUTINE FUNCT WAS CALLED',I6,' TIMES **',
* '///,' FINAL VALUES AND GRADIENTS :',

```

```

* T35,'A1      =',F12.7,T65,'D/D(A1)      =',E15.6,/,/,
* T35,'A2      =',F12.7,T65,'D/D(A2)      =',E15.6,/,/,
* T35,'A3      =',F12.7,T65,'D/D(A3)      =',E15.6,/,/,
* T35,'N       =',F12.7,T65,'D/D(N)       =',E15.6,/,/,
* T35,'M       =',F12.7,T65,'D/D(M)       =',E15.6
  WRITE(6,511) (I,X(I+5),I,G(I+5),I=1,NC)
511 FORMAT(1H0,T35,'LOG(C',I1,')=',F12.7,T65,'D/D(LOG(C',I1,'))=',
  * E15.6)
  WRITE(6,512) V
512 FORMAT(/,1H0,'FINAL STANDARD DEVIATION  : ',F15.7)
C
  WRITE(6,513) (L(I),I=1,20)
513 FORMAT(1H0,T5,'( COMMENT : ',20A4,' )')
C
  DO 50 J=1,NC
    JJ=J+5
    V=0.
    TD=0.
    IM=ND(J)+1
    IN=ND(J+1)
    K=ND(J+1)-ND(J)
    RK=FLOAT(K)
C
  DO 51 I=IM,IN
    W(I)=X(JJ)+X(4)*PLOG(I)+X(5)*TLOG(I)+ULOG(I)
    R=10.**(X(1)+X(2)*W(I)+X(3)*W(I)**2)
    IF(R.LE.70) GO TO 52
    TC(I)=0.
    GO TO 53
52 CONTINUE
    TC(I)=EXP(-R)
53 CONTINUE
    E(I)=TAU(I)-TC(I)
    PD(I)=100.*E(I)/TAU(I)
    TD=TD+ABS(E(I))
    V=V+E(I)**2
51 CONTINUE
C
    TTD=TTD+TD
    TV=TV+V
    TD=TD/RK
    V=V/RK
    SF=SQRT(V)
    WRITE(6,514) (ID(J,I),I=1,9),K,(X(I),I=1,5),J,X(JJ),TD,V,SF
514 FORMAT (1H1,T15,'ACTUAL/COMPUTED TRANSMITTANCES',/,/,/,
  * T10,'DATA  : ',9A4,5X,'# OF POINTS =',I4,/,/,/,T10,
  * 'A1 =',F12.7,8X,'A2 =',F12.7,8X,'A3 =',F12.7,/,/,T10,'N  =',F12.7,
  * 8X,'M  =',F12.7,8X,'LOG(C',I1,') =',F12.7,/,/,/,
  * T15,'AVERAGE DISCREPANCY =',F12.7,/,/,
  * T15,'MEAN SQUARE ERROR   =',F12.7,/,/,
  * T15,'STANDARD DEVIATION  =',F12.7,/,/,/,
  * T5,'#',T11,'U =',T26,'P =',T36,'T =',T46,'X =',T56,'ACTUAL',
  * T65,'COMPUTED',T76,'DIFFERENCE',T90,'% DIFF.',/)
  WRITE(6,515) (I,U(I),P(I),T(I),W(I),TAU(I),TC(I),E(I),PD(I),
  * I=IM,IN)
515 FORMAT (1H ,I5,T10,E11.4,T24,F8.2,T34,F8.2,T43,F9.4,T53,F9.4,T63,

```

```
* F9.4,T74,F11.6,T87,F10.4)
```

```
50 CONTINUE
```

```
C
```

```
FK=FLOAT(ND(NC+1))
```

```
TTD=TTD/FK
```

```
TV=TV/FK
```

```
TSD=SQRT(TV)
```

```
WRITE(6,516) ND(NC+1),TTD,TV,TSD
```

```
516 FORMAT (1H1,///,T10,'TOTAL # OF POINTS USED',I6,///,T10,
```

```
* 'GLOBAL AVERAGE DISCREPANCY',F12.7,///,T10,
```

```
* 'GLOBAL MEAN SQUARE ERROR',F12.7,///,T10,
```

```
* 'GLOBAL STANDARD DEVIATION',F12.7)
```

```
RETURN
```

```
END
```

```
SUBROUTINE NMBC(X,NAME,NC,WN,CF,PO,TO)
```

```
C
```

```
C
```

```
C
```

```
COMPUTATION OF THE C'-VALUES FOR NON-MAJOR BANDS
```

```
DIMENSION X(9),NAME(20),WN(4)
```

```
DIMENSION CS(10),FS(10)
```

```
DF=1.E30
```

```
SGN=1.
```

```
IF(X(3).LT.0.) SGN=-1.
```

```
C
```

```
C
```

```
C
```

```
IF THE QUADRATIC TERM IS TOO SMALL, THEN IT WILL BE IGNORED
```

```
SMI=-2.*X(3)/X(2)
```

```
IF(ABS(SMI).LE.1.E-6) GO TO 50
```

```
SYM=1./SMI
```

```
50 CONTINUE
```

```
C
```

```
WRITE(6,5)(NAME(I),I=1,20)
```

```
5 FORMAT(1H1,T15,20A4)
```

```
WRITE(6,10)
```

```
10 FORMAT(1H0,T15,' *** CALCULATION OF THE SPECTRAL PARAMETER FOR',
```

```
* ' NON-MAJOR BANDS ***',///)
```

```
C
```

```
11 CONTINUE
```

```
NFREQ=0
```

```
12 CONTINUE
```

```
C=0.
```

```
I=0
```

```
15 CONTINUE
```

```
READ(5,20,END=40) KGAS,FREQ,P,T,UGAS,TX
```

```
20 FORMAT(I2,F10.3,E11.4,F9.3,24X,E11.4,F7.4)
```

```
IF(KGAS.EQ.0) GO TO 25
```

```
IF(KGAS.LT.0) GO TO 35
```

```
IF(UGAS.GE.DF) GO TO 15
```

```
C
```

```
I=I+1
```

```
WX=FREQ
```

```
UGAS=UGAS/CF
```

```
IF(SMI.LE.1.E-6) GO TO 51
```

```
C
```

```
C
```

```
C
```

```
CASE 1 QUADRATIC TERM IS LARGE AND USED
```

```

      XS=SYM+SGN*ABS(SQRT(X(2)**2-4.*X(3)*(X(1)-ALOG10(-ALOG(TX))))
      *  /(2.*X(3)))
      GO TO 52
51  CONTINUE
C
C      CASE 2  QUADRATIC TERM IS SMALL AND IGNORED
C
      XS=(ALOG10(-ALOG(TX))-X(1))/X(2)
52  CONTINUE
      XC=X(4)*ALOG10(P/P0)+X(5)*ALOG10(T0/T)+ALOG10(UGAS)
      C=C+(XS-XC)
      GO TO 15
C
25  C=C/FLOAT(I)
      NFREQ=NFREQ+1
      CS(NFREQ)=C
      FS(NFREQ)=WX
      DO 27 M=1,NC
      IF(ABS(WX-WN(M)).LE.0.1) CS(NFREQ)=X(5+M)
27  CONTINUE
      IF(NFREQ.EQ.10) GO TO 30
      GO TO 12
30  CONTINUE
      WRITE(6,31)(FS(K),K=1,NFREQ)
31  FORMAT(1H0,2X,'WAVE NUMBER',2X,10F11.0)
      WRITE(6,32)(CS(K),K=1,NFREQ)
32  FORMAT(1H0,5X,'C VALUES',2X,10F11.3//)
      GO TO 11
C
35  CONTINUE
      IF(NFREQ.EQ.0) GO TO 40
      WRITE(6,31)(FS(K),K=1,NFREQ)
      WRITE(6,32)(CS(K),K=1,NFREQ)
40  CONTINUE
      RETURN
      END

```

ED
80