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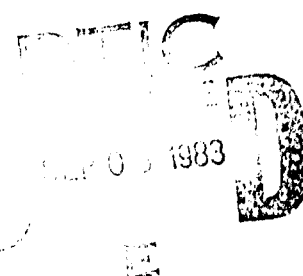# Air Mass Computer Program for Atmospheric Transmittance/Radiance Calculation: FSCATM

W. O. GALLERY
F. X. KNEIZYS
S. A. CLOUGH

9 March 1983

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AIR FORCE GEOPHYSICS LABORATORY
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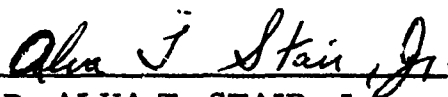
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Chief Scientist

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

Calculations of atmospheric transmittance and radiance require the knowledge of the integrated amounts of the absorbing gases along the path. This report describes the calculation of the integrated amounts ("air mass" or "column density") for various infrared absorbing gases for an arbitrary slant path through the atmosphere, including the effects of both curvature and refraction, and presents a Fortran program, FSCATM, to perform the calculation. Among the features of FSCATM are: → cont

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20. Abstract (Contd)

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1. It calculates the layer-by-layer integrated absorber amounts and density-weighted pressure and temperature for an arbitrary slant path through the atmosphere.

2. It assumes a spherically symmetric atmosphere with exponential profiles of density and refractivity between layer boundaries.

3. It allows a variety of options for specifying the slant path.

4. It includes six representative atmospheric profiles of pressure and temperature, and of density for the gases H_2O, CO_2, O_3, N_2O, CO, CH_4, and O_2 and has provision for user-supplied profiles of up to 20 gases.

5. The output layering may either be generated internally or supplied by the user.

6. It is portable to 32 bit word computers in single precision and compatible with both ANSI Standard FORTRAN 66 and 77.

7. It is modular and easily modified to suit the users' particular needs. A discussion of atmospheric profile data and a survey of the literature are included in appendices.

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Air Mass Computer Program for Atmospheric Transmittance/Radiance Calculation: FSCATM

1. INTRODUCTION

Calculations of atmospheric transmittance and radiance require knowledge of the amount and distribution of the absorbing gases along the optical path. The integrated amount of gas along a path compared to the amount for a vertical path from ground to space is generally referred to as "air mass". Under some circumstances, air mass can be calculated simply by assuming a plane parallel atmosphere and using the secant approximation. For other cases, for example, large zenith angles or tangent paths, curvature and refraction must be taken into account, requiring a more elaborate integration along the path.

This report presents the Fortran program FSCATM, which calculates the integrated absorber amounts for an arbitrary slant path through the atmosphere, including the effects of both curvature and refraction. FSCATM is specifically designed to create the atmosphere inputs to the AFGL line-by-line atmospheric transmittance and radiance program FASCODE,[1] but the program is general enough to be useful to others working in the field of infrared radiative transfer in the atmosphere.

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1. Clough, S.A., Kneizys, F.X., Rothman, L.S., and Gallery, W.O. (1981) Atmospheric spectral transmittances and radiance: FASCOD1B, SPIE, Atmospheric Transmission 277:152-166.

Among the features of FSCATM are:

1. It calculates the layer-by-layer integrated absorber amounts and density-weighted pressure and temperature for an arbitrary slant path through the atmosphere,

2. It assumes a spherically symmetric atmosphere with exponential profiles of density and refractivity between layer boundaries,

3. It allows a variety of options for specifying the slant path,

4. It includes six representative atmospheric profiles of pressure and temperature, and of density for the gases H_2O, CO_2, O_3, N_2O, CO, CH_3 and O_2, and has provision for user-supplied profiles of up to 20 gases,

5. The output layering may either be generated internally or supplied by the user,

6. It is portable to 32 bit word computers in single precision and compatible with both ANSI Standard FORTRAN 66 and 77, and

7. It is modular and easily modified to suit the users' particular needs.

As distributed FSCATM is a subroutine called by FASCODE. However, it may very easily be converted to a self-contained program (see Section 3.4 for details). References to FSCATM in this report will assume that it is being run in the stand-alone mode. FSCATM is available as part of the FASCOD1C package (see Section 3.5 for details).

Section 2 of this report provides background on the calculation of air mass, including atmospheric refraction, the numerical algorithm used here, and some examples of the effects of curvature and refraction on air mass. Section 3 documents the program FSCATM, including usage and sample input and output.

Appendix A discusses the six standard atmospheric profiles included in FSCATM and describes other sources of atmospheric profile data. Appendix B describes the formula for the index of refraction of air used in FSCATM. Finally, Appendix C gives a brief survey of the literature on air-mass calculation and atmospheric refraction.

2. AIR MASS

2.1 Definitions

The integrated absorber amount, m, along a slant path through the atmosphere is given by

$$m = \int \rho \, ds \ , \tag{1}$$

where ρ is the mass or number density of the gas and ds is the element of length along the path (m is also sometimes referred to as the "column density"). For vertical path from ground to space for the U.S. Standard Atmosphere 1962, m for the total air density is 2.15×10^{25} molecules $cm^{-2} = m_o$. This quantity m_o is sometimes referred to as "one air mass". The term air mass is somewhat ambiguous; in this report the term air mass for a particular path will refer to the relative air mass or m/m_o. For example, the air mass for a path from ground to space, where the zenith angle at the ground is 90.0^o, is 38.1. The term air mass applies specifically to total amount of air along the path. For non-uniformly mixed gases, such as H_2O or O_3, the relative amount of gas along a slant path compared to a vertical path may differ greatly from the (total) air mass.

These calculations assume a spherically-symmetric layered atmosphere with the pressure, temperature, and absorbing gas densities defined at a suitable number of layer boundaries. For any path through the atmosphere, the integrated absorber amounts, m, are calculated individually for each layer and summed over the layers. This discussion will be confined to the calculation for a single layer.

Figure 1 illustrates the geometry of a path through a single layer. The layer is bounded by the radii r_1 and r_2, α and ϕ are the zenith angles at r_1 and r_2 respectively, s is the curved path length, β is the earth centered angle, and ψ is the bending along the path. The radius of the earth is r_e while the radius to any point is r. The height z above the lower boundary equals $r - r_e$.

The pressure P, temperature T, and absorbing gas density ρ are given at r_1 and r_2. Inside the layer, temperature is interpolated linearly, while pressure and density are assumed to follow an exponential distribution. For pressure,

$$P(z) = P_1 \exp [-z/H_p] \tag{2}$$

$$H_p = -(\Delta z)/\ell n(P_2/P_1) \ , \tag{3}$$

where H_p is called the pressure scale height and Δz is $r_2 - r_1$. Equation (2) is exact for an isothermal layer and is an excellent approximation for a non-isothermal layer if the layer is thin compared to a scale height.

Similarly, the density is given by:

$$\rho(z) = \rho_1 \exp [-z/H_\rho] \tag{4}$$

$$H_\rho = -\Delta z/\ell n(\rho_2/\rho_1) \ . \tag{5}$$
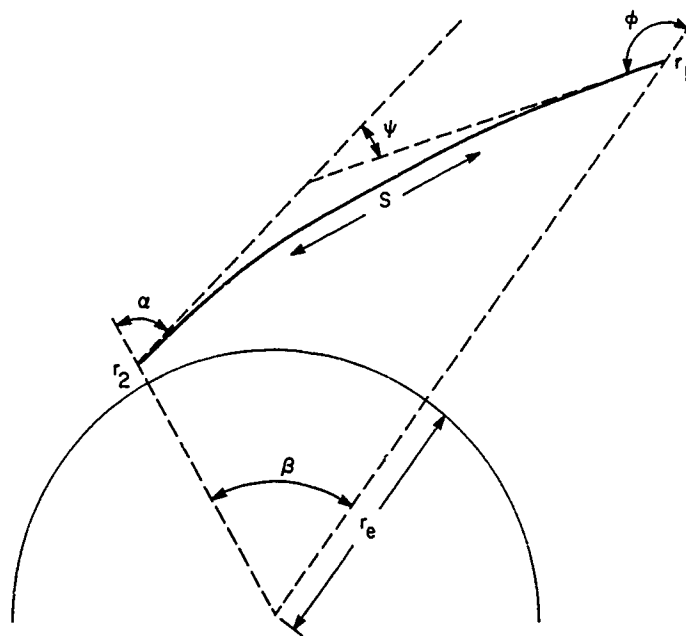
Figure 1. Geometry of the Refracted Path Through a
Single Layer

For a uniformly mixed gas in an isothermal layer, Eq. (4) is again exact and for a
non-isothermal layer is a good approximation. For a non-uniformly mixed gas,
the density will not follow an exponential distribution. In such cases it is neces-
sary to make the spacing between boundaries small enough so that the calculated
density between layers does not depend significantly upon the particular interpola-
tion scheme used.

The integrated amount m of the absorbing gas for the layer can be rewritten
from Eq. (1) as

$$m = \int_1^2 \rho(z) \frac{ds}{dz} \, dz \quad . \tag{6}$$

From small zenith angles, ds/dz is essentially constant over the layer and equals
sec θ, where θ is the incident angle of the path at z (see Figure 2). In this case,
Eq. (6) can be approximated as:

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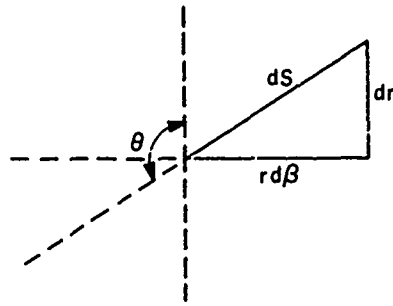
Figure 2. The Differential Path
Quantities at a Point

$$m = \sec \theta \int_1^2 \rho \, dz \quad . \tag{7}$$

This approximation is the same as assuming a plane parallel atmosphere. The vertical integral of the density has a particularly simple analytic solution when the profile is exponential:

$$\int_1^2 \rho \, dz = H_\rho (\rho_1 - \rho_2) \quad . \tag{8}$$

For larger zenith angles where the earth's curvature is important but where refraction is still not significant, Eq. (6) can be solved analytically using the Chapman functions. (See Appendix C for references to the Chapman functions.) For even larger zenith angles, refraction must be taken into account. In this later case the layer can be divided into a number of sublayers bounded by z_1, z_2, $\cdots$ z_J, which need not be uniformly spaced. The spacing between sublayers $\Delta z_j = z_j + 1 - z_j$ is determined by the requirement that the integral in Eq. (6) can be adequately represented by the sum over the sublayers j:

$$m = \sum \rho_j \frac{ds}{dz_j} \Delta z_j \quad , \tag{9}$$

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where

$$\overline{\rho_j} = \frac{1}{\Delta z_j} \int_j^{j+1} \rho \, dz = \frac{1}{\Delta z_j} H_\rho \left(o(z_j) - \rho(z_j + 1) \right) \tag{10}$$

$$\overline{\frac{ds}{dz_j}} = \frac{1}{\Delta z_j} \int_j^{j+1} ds = \frac{\Delta s_j}{\Delta z_j} \tag{11}$$

$$\Delta z_j = z_{j+1} - z_j \quad . \tag{12}$$

The problem now is to determine the number and spacing of the sublayers and the path length Δs_j through each sublayer, including the effects of refraction. This problem is discussed in the next section.

In addition to the absorber amount, atmospheric transmittance calculations require an effective pressure and temperature for a layer. The effective pressure is required to calculate the halfwidth and the effective temperature is used to calculate the line intensity halfwidth, and, in emission, blackbody source function for a layer. The effective values are those that make the absorption and/or emission of an equivalent homogeneous layer equal to that of the non-homogeneous layer. There is no single definition of the effective pressure or temperature: the effective values depend upon many factors such as the path, the density distribution, and the spectral region, and will in general be different for different absorbing gases. The most generally applicable definition, however, is the density weighted average:

$$\overline{P} = \int P \rho^* ds / \int \rho^* ds \tag{13}$$

$$\overline{T} = \int T \rho^* ds / \int \rho^* ds \quad , \tag{14}$$

where ρ^* is the total air density. For a uniformly mixed gas with no temperature dependence in the line intensities, the mean pressure given by Eq. (13) is essentially the Curtis-Godson approximation.

The effective pressure $\overline{P}$ and temperature $\overline{T}$ are calculated in a way similar to the absorber amount in Eq. (9), using

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$$\overline{P}m^* = \int P\rho^* ds = \sum \frac{\overline{\Delta s_i}}{\Delta z_i} \int_i^{i+1} P(z)\,\rho^*(z)dz \qquad (15)$$

$$\overline{T}m^* = \int T\rho^* ds = \sum \frac{\overline{\Delta s_i}}{\Delta z_i} \int_i^{i+1} T(z)\,\rho^*(z)dz \qquad (16)$$

$$m^* = \int \rho^* ds = \sum \frac{\overline{\Delta s_i}}{\Delta z_i} \int_i^{i+1} \rho^* dz \quad . \qquad (17)$$

The pressure and total air density are both assumed to follow an exponential profile with scale heights H_p and H_ρ^* respectively. The integral in Eq. (15) can be written as

$$\int_i^{i+1} P\rho^* dz = \frac{H_p H_\rho^*}{H_p + H_\rho^*} \left(P(z_i)\,\rho^*(z_i) - P(z_{i+1})\,\rho^*(z_{i+1}) \right) \qquad (18)$$

From the ideal gas law

$$P = G\rho^* T \quad , \qquad (19)$$

where G is the gas constant for air. Using this equation, the integral in Eq. (16) becomes

$$\int_i^{i+1} T\rho^* dz = \frac{1}{G} \int_i^{i+1} P dz = \frac{H_p}{G} \left(P(z_i) - P(z_{i+1}) \right) \quad . \qquad (20)$$

The density integral in Eq. (17) is the same as in Eq. (10):

$$\int_i^{i+1} \rho^* dz = H_\rho^* (\rho^*(z_i) - \rho^*(z_{i+1})) \quad . \qquad (21)$$

The next section will describe the method used to calculate the refracted path Δs_j through each sublayer.

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2.2 Atmospheric Refraction

The refraction of a light ray is due to the gradient of the index of refraction n, with the ray refracted in the direction of increasing n. To a close approximation, the refractivity N = n - 1 is proportional to the air density. See Appendix B for a discussion of the index of refraction of air. In a spherically symmetric atmosphere, grad n is directed radially, and except in unusual circumstances, downward. The trajectory of the ray is determined by Snells law for a spherically symmetric medium:[2]

$$n(r) \ r \ \sin \theta = c \ , \tag{22}$$

where θ is the angle of incidence at r and c is a constant that depends upon the particular path. If the ray is horizontal at r_T then $z_T = r_T - r_e$ is the tangent height and $c = n(r_T) r_T$. The curvature K of the refracted ray can be shown to be[3]

$$K = - \sin \theta \ \frac{n'}{n} \ , \tag{23}$$

where $n' = dn/dr$.

It is useful to define the quantity R(r) as

$$R(r) = - \frac{r}{n/n'} \ . \tag{24}$$

R is simply the ratio of r to the radius of curvature of a ray tangent at r. R is a property of the atmospheric profile (not the particular path) and is a good measure of the importance of refraction at a given altitude. For example, for the U.S. Standard Atmosphere 1962, R is 0.16 at the ground and decreases approximately exponentially with a scale height of about 10 km. As an extreme example, if R = 1.0, a ray tangent at r will continue indefinitely to follow a circular path of radius r.

Consider now a point moving along the path within the layer defined by r_1 and r_2 as shown in Figure 1. At a point defined by the radius r and with an incidence angle θ as shown in Figure 2, the differential path length ds is

$$ds = - \frac{1}{\cos \theta} \ dr \ . \tag{25}$$

2. Born, M., and Wolf, E. (1964) Principals of Optics, Pergamon Press, Inc., N.Y., pp 121-123.

3. Meyer-Arendt, J.R., and Emmanuel, C.B. (1965) Optical Scintillation: A Survey of the Literature, National Bureau of Standards, Tech Note 225.

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Eq. (22) can be used to eliminate θ in Eq. (25) giving:

$$ds = \left(1 - \frac{c^2}{n^2 r^2}\right)^{-1/2} dr \quad . \tag{26}$$

Eq. (26) can be integrated numerically to obtain s for a layer or sublayer.

The drawback with using Eq. (26) is that in the region near a tangent height (that is, $\sin \theta = c/nr$ approaches 1), the right-hand side of Eq. (26) goes to infinity and a different numerical algorithm must be used. An alternative formulation of this equation that avoids this problem is as follows. Define a new independent variable x as

$$x = - r \cos \theta \tag{27}$$

$$dx = - \left(\cos \theta - r \sin \theta \frac{d\theta}{dr}\right) dr \quad . \tag{28}$$

Differentiating Eq. (22) and using Eq. (24) gives

$$\frac{d\theta}{dr} = - \frac{\tan \theta}{r} (1 - R) \quad . \tag{29}$$

Substituting Eq. (29) into Eq. (28) gives

$$dx = - (1 - R \sin^2 \theta) \frac{dr}{\cos \theta} \quad . \tag{30}$$

Comparing Eq. (30) with Eq. (25) gives

$$ds = (1 - R \sin^2 \theta)^{-1} dx \quad . \tag{31}$$

In this form of the equation for ds, the right-hand side is a well-behaved function of r for all paths, including vertical and horizontal paths (except in the unusual circumstances that $R \geq 1$). The intermediate variable x is related to r by

$$x = - r \cos \theta = r \left(1 - \frac{c^2}{n^2 r^2}\right)^{1/2} \tag{32}$$

which is also a well-behaved function of r for all paths. In practice, the numerical integration of Eq. (31) is driven in terms of steps in r, from r to $r + \Delta r$. The

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corresponding increment in x is calculated using Eq. (32). The integration of s from Eq. (31) is then straightforward.

It is also useful to calculate the values of the earth centered angle β and the bending ψ for the layer. From Figure 2, again,

$$\frac{d\beta}{dr} = \frac{\tan \theta}{r} \quad . \tag{33}$$

In terms of x:

$$\frac{d\beta}{dx} = \frac{d\beta}{dr} \frac{dr}{dx}$$

$$\frac{d\beta}{dx} = \cdots \cdot R \sin^2 \theta)^{-1} \frac{\sin \theta}{r} \quad . \tag{34}$$

ψ is related to the other path quantities by

$$\psi = \pi + \beta - \alpha - \theta \tag{35}$$

so that

$$\frac{d\psi}{dx} = \frac{d\beta}{dx} - \frac{d\theta}{dx} \tag{36}$$

giving

$$\frac{d\psi}{dx} = (1 - R \sin^2 \theta)^{-1} \frac{R}{r} \sin \theta \quad . \tag{37}$$

In practice ψ is integrated along the path along with s and β is calculated from Eq. (35).

It is useful to examine Eq. (31) in some detail. It can be shown geometrically that dx equals ds in the case of a straight line, that is, no refraction. Correspondingly, the right-hand side of Eq. (31) approaches 1 as refraction becomes less important, that is, as either R or sin θ goes to zero. At the other extreme, in the case of very strong refraction of a horizontal ray where the curvature due to refraction equals the curvature of the earth, R and sin θ both equal 1 and the right-hand side of Eq. (31) becomes infinite. The path in this case is a circle for which x = r cos θ is constant. For even stronger refraction where R > 1, the light ray is bent back toward the earth and the right-hand side of Eq. (31) becomes negative.

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In this case, dx is also negative along the p.h. Finally, in the presence of a density inversion (n' > 0), R is negative and the ray is bent upwards.

2.3 Numerical Algorithm

This section will describe the numerical algorithm used to calculate the slant path and the absorber amounts through a single layer.

The integration of the slant path parameters s, β, and ψ and the absorber amounts is performed by dividing the layer into sublayers bounded by the altitudes z_j, $j = 1$ to J. The spacing of the sublayers is chosen so that the path increments are approximately equal to a nominal path increment $\Delta\tilde{s}$, where $\Delta\tilde{s}$ is determined by the required accuracy of the results. The integration always proceeds from the bottom of the layer to the top: the incidence angle θ at the bottom of the layer is assumed known as is the value of c [Eq. (22)].

The values of N, P, ρ, and $\rho*$ are interpolated exponentially from the values at the layer boundaries with scale heights H_N, H_p, H_ρ, and $H_\rho*$ respectively.

R is given by

$$R = \frac{r}{n/n'}$$

$$= \frac{r\, N_1\, e^{-z/H_N}}{H_N\left(1 + N_1\, e^{-z/H_N}\right)} \quad , \tag{38}$$

where N_1 is the value of N at $z = 0$.

The numerical integration scheme proceeds as follows:

1. $\Delta r_j = \Delta\tilde{s}\, \cos\, \theta_{j-1}$

2. $r_j = r_{j-1} + \Delta r_j$

3. $\sin\, \theta_j = c/(n(r_j)r_j)$

4. $\cos\, \theta_j = -(1 - \sin^2\, \theta_j)^{1/2}$

5. $x_j = -r_j\, \cos\, \theta_j$

6. $\Delta x_j = x_j - x_{j-1}$

7. $\left.\dfrac{ds}{dx}\right|_j = (1 - R_j\, \sin^2\, \theta_j)$

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8. $s_j = s_{j-1} + \dfrac{1}{2} \left(\dfrac{ds}{dx} \bigg|_{j-1} + \dfrac{ds}{dx} \bigg|_{j} \right) \Delta x_j$

9. $\dfrac{d\psi}{dx} \bigg|_{j} = \dfrac{ds}{dx} \bigg|_{i} \dfrac{R_j}{r_j} \sin \theta_j$

10. $\psi_j = \psi_{j-1} + \dfrac{1}{2} \left(\dfrac{d\psi}{dx} \bigg|_{j-1} + \dfrac{d\psi}{dx} \bigg|_{j} \right) \Delta x_j$

11. $m_j = m_{j-1} + \dfrac{\Delta s_j}{\Delta r_j} H_\rho \left(\rho(r_j) - \rho(r_{j-1}) \right)$

12. $j = j + 1$

13. Go to 1.

Near a tangent height where $\cos \theta$ approaches zero, this scheme must be modified. First, Step 1 breaks down for $\cos \theta_1 = 0$ and is replaced by

$$\Delta r_1 = \frac{\Delta \tilde{s}^2}{2 r_1} \ . \tag{39}$$

Secondly, the truncation error for $\cos \theta_j$ in Step 4 is excessive for computers with seven decimal digits of precision when $\sin \theta_j$ is greater than about 0.99999. To avoid this problem, $\cos \theta_j$ is calculated for $\sin \theta_j > 0.99999$ from:

$$\cos \theta(r) = -(2 \, y(r) - y^2(r))^{1/2} \tag{40}$$

and

$$y(r) = \int_{r_T}^{r} (1 - R(r)) \, \frac{\sin \theta}{r} \, dr \ , \tag{41}$$

where r_T is the radius at the tangent height. [Eq. (40) and Eq. (41) are obtained by integrating Eq. (29).]

Note that the steps are driven in increments of r although the nominal independent variable is x. There are two reasons for this procedure. First, it is necessary to stop the integration at the upper boundary; this is done most conveniently when r drives the integration. Secondly, x is an analytic function of r

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so that x_j can be calculated simply from r_j. The opposite is not true; an iterative scheme would be required to calculate r_j given x_j.

2.4 Examples of Air Mass Calculations

This section will present some examples of air mass calculations for total air, water vapor, and ozone for various geometries and atmospheric profiles using the program FSCATM. The cases were chosen to broadly represent the range of conditions likely to meet in spectroscopic observations of the atmosphere. In general, the results are presented both with and without the effects of refraction so that the reader may judge for himself under which circumstances refraction can be neglected.

The three atmosphere profiles used here are taken from McClatchey et al[4][*] and were chosen to represent mean and extremes of temperature and of water-vapor and ozone concentrations found in the atmosphere. The profiles of temperature, total air density, water-vapor density, and ozone density up to 70 km are shown in Figure 3. The surface pressure for all three profiles is the same, 1013 mb.

The paths are described in terms of the following parameters: H1 is the observer's altitude, ANGLE is the zenith angle at the observer, and H2 is the altitude of the other end of the path. For a path out to space, H2 is the top of the atmospheric profile (here 100 km). Three geometries are presented here: (1) H1 = 0, H2 = 100 km, ANGLE varies from 0 to 90°, (2) H2 = 100 km, ANGLE = 90°, H1 varies from 0 to 50 km, and (3) H1 = 30 km, H2 = 100 km, ANGLE varies from 85° to about 95.5° at which point the path intersects the earth. Path 1 is relevant for ground-based observations, while paths 2 and 3 correspond to observations from balloon or aircraft. Path 2 is also relevant to satellite observations scanning the limb, where H1 is the tangent height and the integrated absorber amounts must, of course, be doubled.

These calculations were all performed with the index of refraction calculated at 2000 cm^{-1} (5 μm). The effect on air mass of variations of the index of refraction with wavenumber are negligible between 500 and 20,000 cm^{-1} (20 to 0.5 μm).

Although the term air mass refers properly only to the amount of air along a path, it will be applied here loosely to water vapor and ozone to refer to the integrated amount relative to a vertical path from ground to space for the same

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[*]See Appendix A regarding the water vapor profiles.

4. McClatchey, R.A., Fenn, R.W., Selby, J.E.A., Volz, F.E., and Garing, J.S. (1972) Optical Properties of the Atmosphere (Third Edition), AFCRL-TR-72-0497, AD 679996.
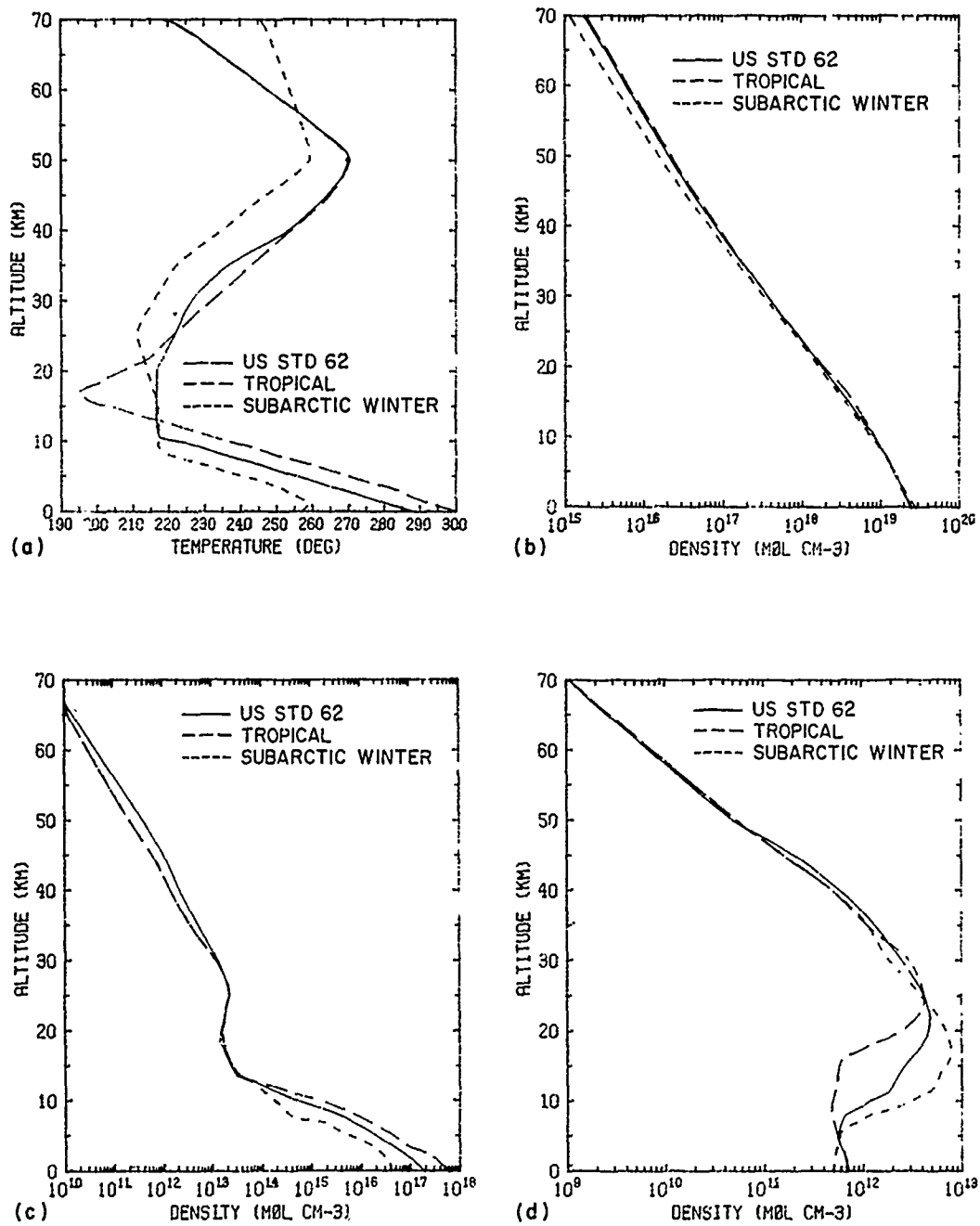
Figure 3. Profiles of Three Atmospheric Models of (a) Temperature, (b) Total Air Density, (c) Water Vapor, and (d) Ozone

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vertical distribution. For the U.S. Standard Atmosphere 1962, one air mass refers to the following integrated absorber amounts:

air 2.15×10^{25} molecules cm^{-2}

water vapor 4.74×10^{22} molecules cm^{-2}

ozone 9.24×10^{18} molecules cm^{-2} .

In the following graphs, U and $\tilde{U}$ will represent the air mass for a refracted path and an unrefracted path respectively.

Figures 4 and 5 show the effect of the earth's curvature on air mass for a ground-based observer by comparing the air mass computed without refraction with the secant of the zenith angle. Figure 5 shows that the secant approximation is good to within 1 percent up to a zenith angle of 72° for a uniformly mixed gas, up to 80° for water vapor, but only up to 60° for ozone.

Figure 6 shows the same calculations as Figure 4 except that refraction is included. At 90° the air mass values for the three components are:

	With Refraction	No Refraction
air	38.1	35.1
H_2O	72.2	66.1
O_3	14.4	13.8

These values depend upon the atmospheric profile used; in this case it is the U.S. Standard Atmosphere 1962. Water vapor has the highest value since it is concentrated near the ground where the effective secant [ds/dz in Eq. (6)] is the highest. Conversely, ozone has the smallest air mass value since the ozone density profile peaks near 20 km, where the effective secant is relatively small.

Comparing Figure 7 with Figure 5 shows that the effect of refraction is smaller than that of the earth's curvature. At 90°, refraction increases the air mass by less than 10 percent, and the air mass can be computed neglecting refraction to better than 1 percent up to 86° for water vapor, 84° for a uniformly mixed gas, and 82° for ozone.

The air mass vs altitude for an observer looking out horizontally is shown in Figure 8. These curves mimic the density profiles of the components themselves, since for this path the bulk of the absorber is located within a few kilometers (vertically) of the observer's altitude. From Figure 9, the effect of refraction an air mass becomes less than 1 percent at 20 km for all three components.
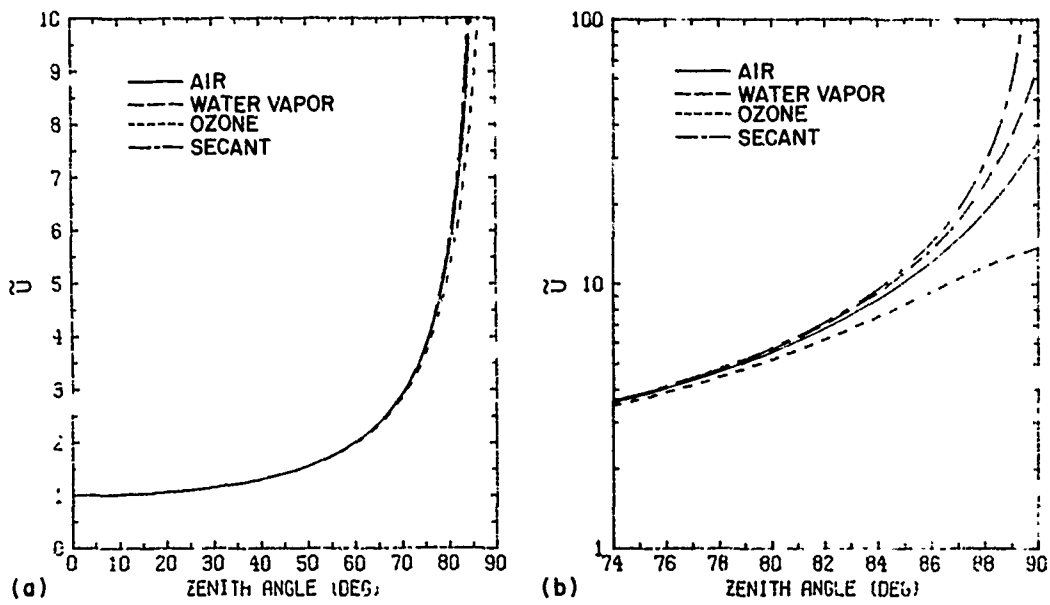
Figure 4. Air Mass ($\tilde{U}$) vs Zenith Angle for the Case: H1 = 0, H2 = 100 km U.S. Standard Atmosphere 1962, No Refraction. For reference, the secant of the angle is also shown: (a) 0 to 90° and (b) 74 to 90°
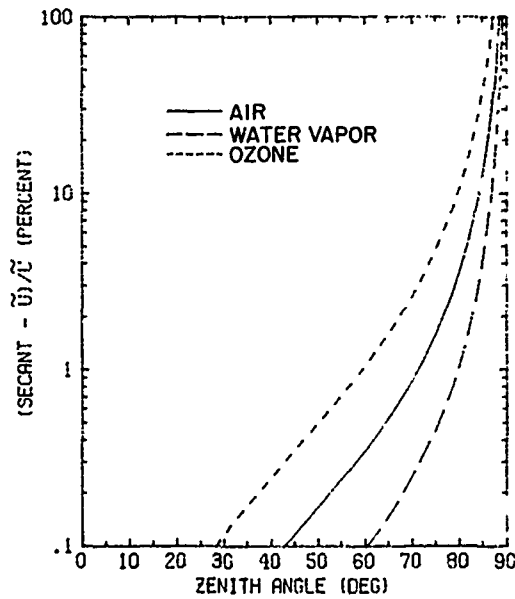
Figure 5. Relative Air Mass Error Due to the Secant Approximation vs Zenith Angle for the Case Shown in Figure 4
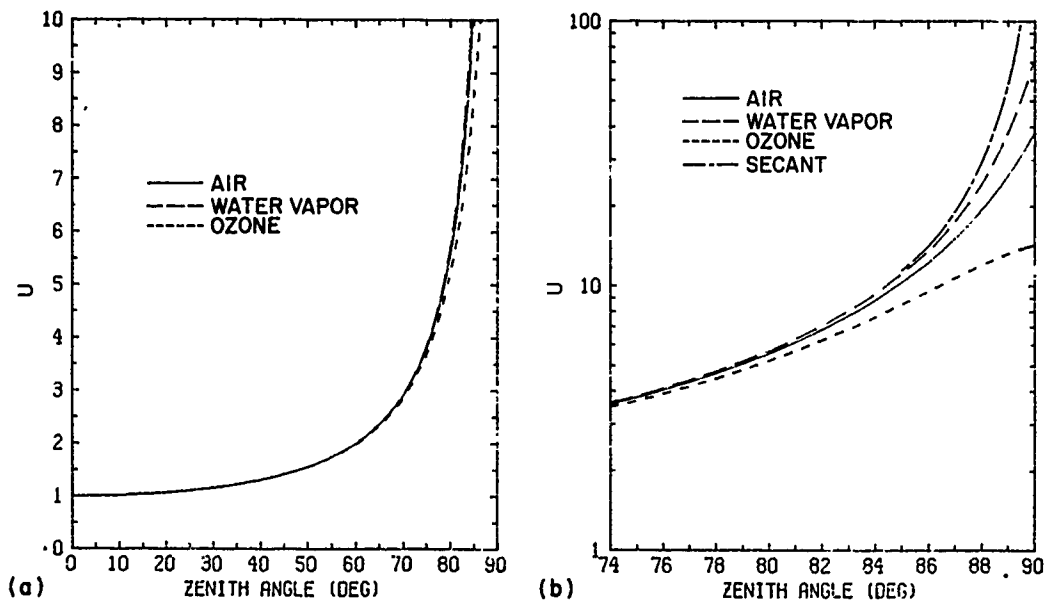
Figure 6. Air Mass (U) vs Zenith Angle for the Case H1 = 0, H2 = 100 km,
U.S. Standard Atmosphere 1962, Including Refraction: (a) 0 to 90° and
(b) 74 to 90°
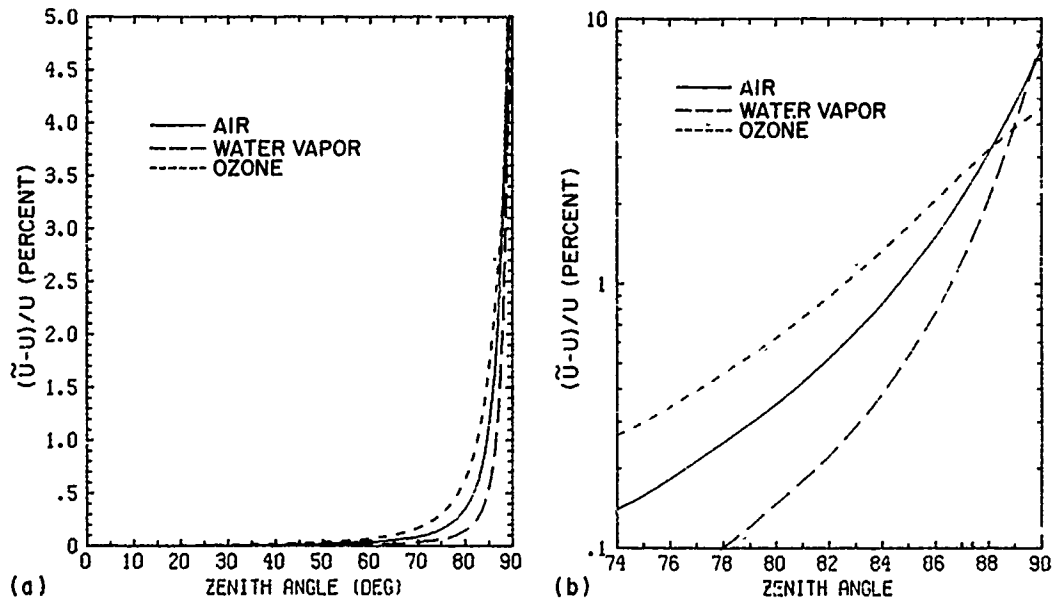
Figure 7. Relative Air Mass Error Due to Neglecting Refraction vs Zenith
Angle for the Case in Figure 6: (a) 0 to 90° and (b) 74 to 90°

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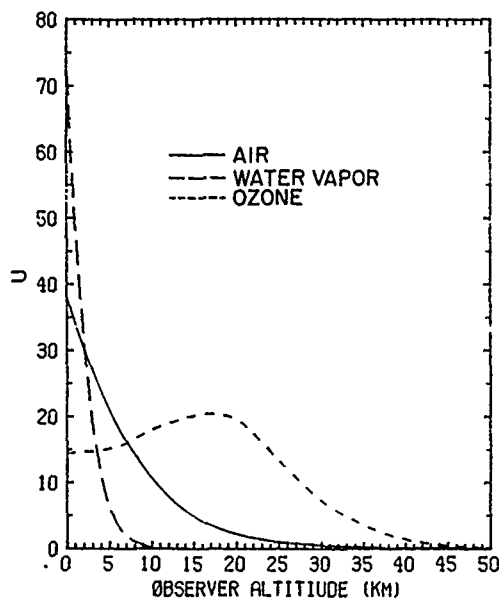
Figure 8. Air Mass (U) vs Observer Altitude (H1) for the Case H2 = 100 km, ZENITH ANGLE = 90°, U.S. Standard Atmosphere 1962, Including Refraction
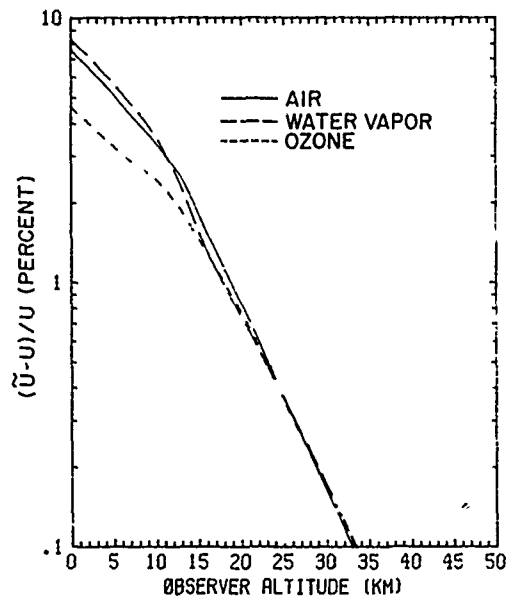
Figure 9. Relative Air Mass Error Due to Neglecting Refraction vs Observer Altitude for the Case in Figure 8

The variation of air mass with zenith angle for a typical stratospheric balloon-borne spectroscopic experiment is shown in Figure 10, with the error due to neglecting refraction in Figure 11.   The zenith angle shown is the apparent zenith angle of the refracted ray such as would be measured at the observer.   The tangent height vs zenith angle is shown on the right-hand axis of Figure 10.   Also shown on Figure 10 is the sun's angular diameter for comparison (after Sneider[5]).   If the sun is used as a source for a measurement, the air mass to different points in the sun can vary by more than a factor of 2 for large zenith angles.   This effect is due to curvature: by comparison of the effect of refraction shown in Figure 11 is much less.   The variation in air mass due to this effect can be the major source of uncertainty in a measurement and must be considered carefully.

Sneider's[5] Figures 4 and 5 show comparisons similar to Figures 10 and 11 here; however, they are not directly comparable since his refracted and unrefracted paths do not have the same zenith angle at the observer.   His calculations involve an observer looking at the sun: the unrefracted path follows a straight line to the sun with the zenith angle at the observer equal to the astronomical

5. Sneider, D. (1975) Refractive effects in remote sounding of the atmosphere with infrared transmission spectroscopy, J. Atmos. Sci. 32:2178-2184.

OBSERVER AT 30 KM
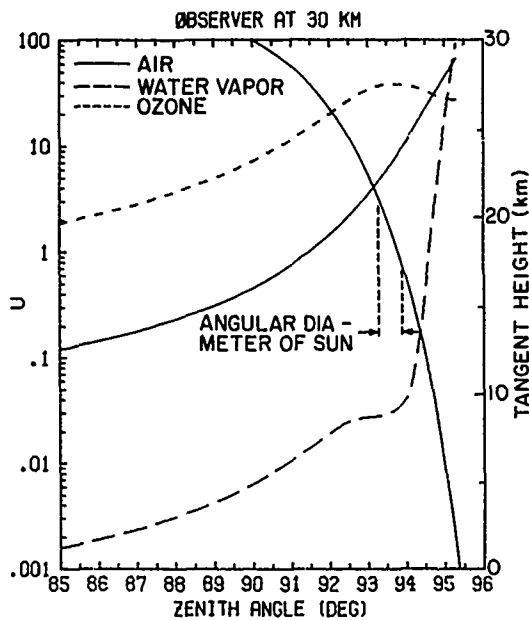
Figure 10. Air Mass (U) vs Zenith Angle for the Case H1 = 30 km, H2 = 100 km, U.S. Standard Atmosphere 1962, Including Refraction. Also shown are the tangent height vs zenith angle and the angular diameter of the sun
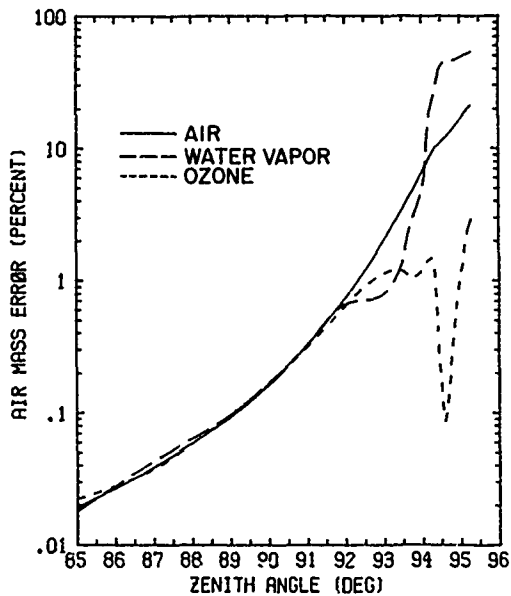
Figure 11. Relative Air Mass Error Due to Neglecting Refraction vs Zenith Angle for the Case in Figure 10

zenith angle. For the refracted path, the zenith angle at the observer is the apparent zenith angle, which is less than the astronomical zenith angle. It turns out that the effect of refraction appears greater for the geometry presented in Sneider's report than in this one.

Figures 12 and 13 demonstrate the effect of different atmospheric profiles on the absorber amount for two different paths. In Figure 12(a) the integrated amount for a uniformly mixed gas for a path from ground to space at $90°$ varies only 10 percent from a tropical to a Subarctic Winter atmosphere (assuming the same surface pressure). The water vapor amount, however, differs by a factor of 10 and the ozone amount by a factor of 2, due to different density profiles. For the path in Figure 13 (tangent height to space) the pressure at a given altitude is different for the three profiles so that the amounts for a uniformly mixed gas become equal at 3 km. The water amounts above 13 km become equal because the water vapor profiles above that altitude are about the same [see Figure 3(c)].

Different atmospheric profiles also produce different amounts of refraction. The difference in the tangent height between a refracted and an unrefracted ray coming in from space is shown as a function of the refracted tangent height in

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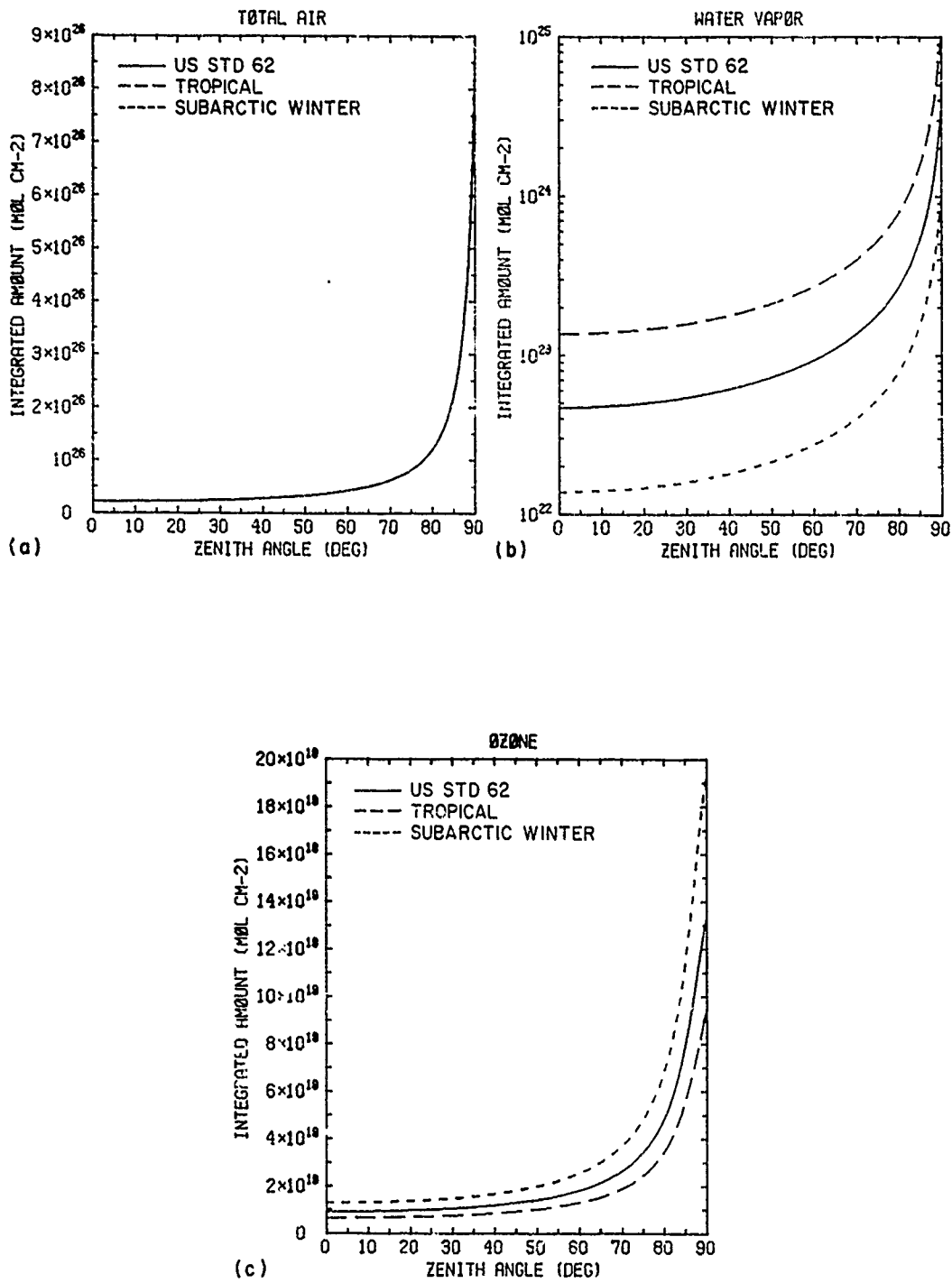
Figure 12. Integrated Absorber Amounts vs Zenith Angle for Three Atmospheric Profiles for the Case of H1 = 0, H2 = 100 km, Including Refraction: (a) Total Air (the Three Curves are Indistinguishable), (b) Water Vapor, and (c) Ozone

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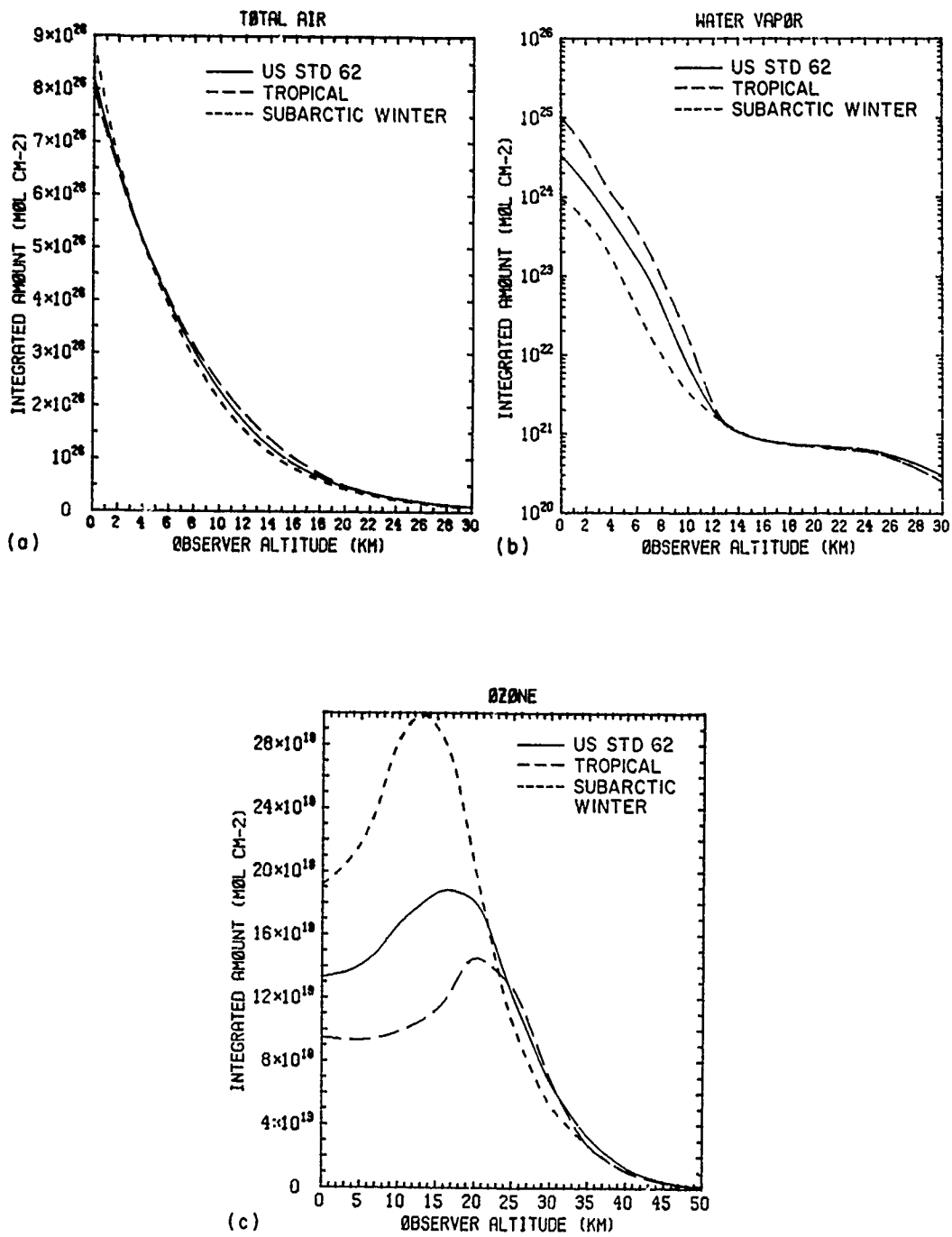
Figure 13. Integrated Absorber Amounts vs Observer Altitude for Three Atmospheric Profiles for the Case of ZENITH ANGLE = 90, H2 = 100 km, Including Refraction: (a) Total Air, (b) Water Vapor, and (c) Ozone

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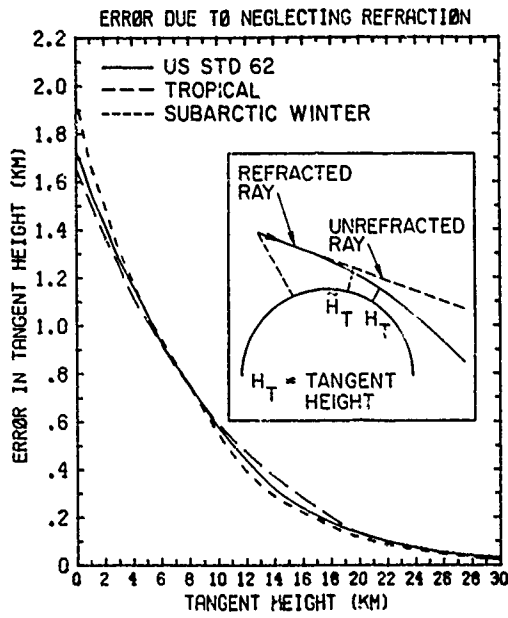
Figure 14. Unrefracted Tangent Height Minus Refracted Tangent Height vs Refracted Tangent Height for Three Atmospheric Profiles. The diagram illustrates the geometry involved
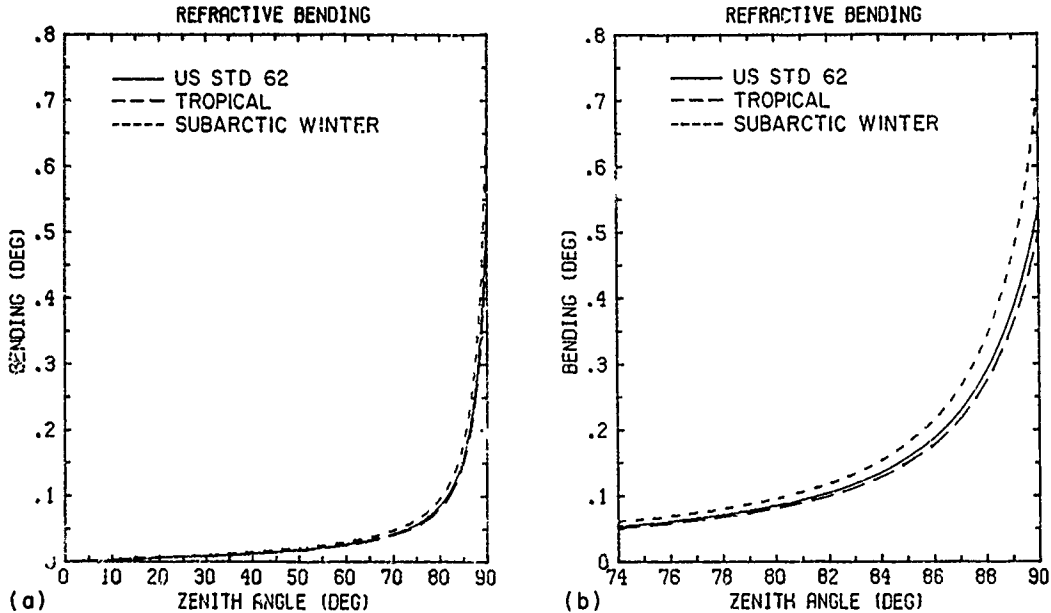
Figure 15. Refractive Bending vs Zenith Angle for Three Atmospheric Profiles for the Case H1 = 0, H2 = 100 km: (a) 0 to 90° and (b) 74 to 90°

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Figure 14 for the three atmospheric profiles (the geometry is shown schematically in the inset). The total refractive bending is shown in Figure 15 vs zenith angle for a path from ground to space and in Figure 16 vs observer altitude for a path tangent at that altitude. Note that the total bending for a path from the ground at 90° for the U.S. Standard Atmosphere 1962 and for the tropical atmosphere is about 0.5°, which is the same as the solar diameter of 0.5°.
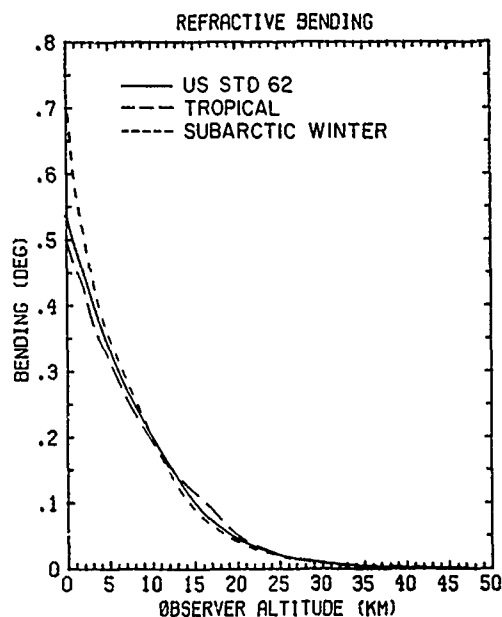
Figure 16. Refractive Bending vs Observer Altitude for Three Atmospheric Profiles for the Case H2 = space, ZENITH ANGLE = 90°

3. FSCATM: A PROGRAM TO CALCULATE AIR MASS

FSCATM calculates the integrated absorber amounts and density-weighted pressure and temperature for an arbitrary slant path through the atmosphere. FSCATM is specifically designed to calculate and format the atmospheric inputs for the atmospheric transmittance/radiance program FASCODE.[2] The form of the input parameters mimics as closely as possible the input parameters to the well known low resolution atmospheric transmittance/radiance program

LOWTRAN.[6] In fact, the core subroutines from FSCATM will replace the geometry subroutines in the next version of LOWTRAN. The six representative atmospheric profiles included in FSCATM are the same as in LOWTRAN although the densities are in different units.

3.1 Program Usage

Four standard control cards control the operation of FSCATM while other cards may be required to define non-standard conditions. The program input consists of a set of control cards read in on UNIT = 5 defining the atmospheric profile, the path, and the output layer boundaries. Output consists of a report written to UNIT = 6 providing a complete description of the profile, path, and absorber amounts and describing any error conditions encountered. Optionally, the mean pressure and temperature and the integrated absorber amounts for each layer are written to UNIT = 7. Examples of program input and output will be shown later in this section.

3.1.1 INPUT

The four standard atmospheric input control cards are shown in Table 1 and are discussed below.

3.1.1.1 Card 1 Model Parameters: MODEL, ITYPE, IBND, NOZERO, NOPRNT, KMAX, IPUNCH, RE

The parameter MODEL selects one of the six standard atmospheric profiles (1 to 6)[*] or allows the user to read in either a profile (MODEL = 7) or a set of horizontal path parameters (MODEL = 0). (See the section on non-standard conditions for the use of MODEL = 0 or 7.) ITYPE selects one of three types of path: (1) a horizontal path at constant temperature and pressure, (2) a slant path from H1 to H2, (3) a slant path from H1 to space (equal to the highest level in the atmospheric profile, 100 km for MODEL = 1 to 6). IBND controls the layering of the final output: If IBND = 0, the program automatically selects a set of output layers based on user-supplied parameters from Card 4. If IBND is greater than 0, the user directly inputs the output layer boundaries on Card 4.

Normally, the program will zero out the absorber amounts of a gas for a layer if the amount for that layer and those above it are less than 0.1 percent of the total amount. NOZERO = 1 suppresses this option. This option is used to

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[*]See Appendix A for a discussion of these atmospheric profiles.

6. Kneizys, F.X., Shettle, E.P., Gallery, W.O., Chetwynd, J.H., Jr., Abreu, L.W., Selby, J.E.A., Fenn, R.W., and McClatchey, R.A. (1980) Atmospheric Transmittance/Radiance: Computer Code LOWTRAN 5, AFGL-TR-80-0067, AD A088215.

Table 1. FSCATM Control Cards

```
Control Card 1:  MODEL, ITYPE, IBND, NOZERO, NOPRNT, KMAX,
                 IPUNCH, RE
                 (7I5, 5X, F10. 4)
```

MODEL = 0: user-supplied horizontal path parameters
        1: tropical atmospheric model
        2: midlatitude summer
        3: midlatitude winter
        4: subarctic summer
        5: subarctic winter
        6: U.S. Standard Atmosphere 1962
        7: user-supplied atmospheric profile

ITYPE = 1: horizontal path (constant pressure)
        2: slant path from H1 to H2
        3: slant path from H1 to space

IBND   number of boundary altitudes for the FAS0CD1 layers:
         IF IBND .GT. 0, user-supplied boundaries
         IF IBND . EQ. 0, auto layering is selected

NOZERO = 1: suppresses zeroing of small amounts
         Default = 0

NOPRNT = 1: selects short printout. Default = 0

KMAX   number of molecular species. Default = 7, max = 20.
         IF KMAX . LT. 0, a ray trace is done but no amounts are
         calculated.

IPUNCH = 1: write layer amounts to unit IPU=7. Default = 0.

RE   radius of the earth, defaults:
         MODEL = 1, RE = 6378.39 km
               2,3,6,7, RE = 6371.23 km
               4,5, RE = 6356.91 km

The formats for the remaining control cards are different depending on whether the path is horizontal (ITYPE=1) or slant (ITYPE=2 or 3).

For a slant path (ITYPE=2 or 3):

```
Control Card 2:  H1, H2, ANGLE, RANGE, BETA, LEN
                 (5F10. 4, I5)
```

H1   altitude of the observer or receiver (km)

H2   altitude of the other endpoint of the path (ITYPE=2) or
         the tangent height (ITYPE=3)

ANGLE   zenith angle at H1 (degrees)

RANGE   length of the path from H1 to H2 (km):

BETA   earth centered angle for the path H1 to H2 (deg)

LEN   =0, short path; =1, long path through a tangent height.
         LEN is used only when ANGLE is greater than 90.0 and
         H1 is greater than H2. Default = 0.

```
Control Card 3:  V1, V2
                 (2F10. 3)
```

V1, V2   initial and final wavenumbers for use in calculating the
         Doppler halfwidth used in creating the FASCODE layers
         and in calculating the index of refraction (cm^{-1})

Table 1. FSCATM Control Cards (Contd)

Control Card 4:

    IF IBND . EQ. 0 (autolayering selected)

      AVTRAT, TDIFF1, TDIFF2 (3F10.3)
      AVTRAT = max Voigt width ratio across a layer. Default = 2.0
      TDIFF1 = max temp difference (K) across a layer at HMIN
             (=lowest altitude along the path). Default = 15.0 K
      TDIFF2 = max temp difference (K) across a layer at HMAX
             (=highest altitude along the path). Default = 30.0 K

    IF IBND . NE. 0 (user-supplied FASCOD1 layer boundaries)

      (ZBND(IB), IB=1, IBND) (8F10.3)
      ZBND   altitudes of FASCOD1 layer boundaries

If MODEL=7, the input atmospheric profile is read in after Control
Card 4 in the following format:

    IMOD, HEADER(I5, /, 3A8)
    IMOD   = number of levels in the profile
    HEADER = 24-character describing the profile

    Z, P, T, TD, RH, PPH20, DENH10, AMSMIX (8F10.3)
    (VMIX(K), K=1, KMAX) (8E10.3)
      two (or more) card images for each of the IMOD levels. See the
      text for the definition and usages of TP, RH, PPH20, DENH20,
      AMSMIX, and VMIX.

For a horizontal path (ITYPE=1):

Control Card 2:

    For MODEL = 1 to 7:
    Z, RANGE   (2F10.3)

    For MODEL = 0:
    RANGE, P, T, TD, RH, PPH20, DENH20, AMSMIX (8F10.3)
    (VMIX(K), K=1, KMAX) (8E10.3)
      where Z and RANGE are the altitude and range of the path, both
      in km. For MODEL = 1 to 7, the pressure, temperature, and
      densities are interpolated from the model atmosphere. For
      MODEL = 0, see the text for the definition and usages of TP, RH,
      PPH20, DENH20, AMSMIX, and VMIX. If the volume mixing
      ratio of O_3 is not supplied for MODEL = 0, it is computed using
      a value for the volume mixing ratio of 40.E-9.

Control Cards 3 and 4: not used

    For MODEL = 7, the input atmospheric profile is read in after
    Control Card 2 as for a slant path.

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save computation time in the line-by-line computation since the computation time is proportional to the number of spectral lines in the calculation. NOPRNT = 1 selects a short form of the output on UNIT = 6 by suppressing the printing of the tables of the atmospheric profile, the slant path, and the layer amounts. KMAX is the number of molecular species for which the amounts are calculated and defaults to 7. The order of the molecules corresponds to the order on the AFGL Atmospheric Line Parameters Compilation[7]* and the Trace Gas Compilation[8] and is listed in Table 2. To calculate amounts for molecules other than the first seven, the user must select the MODEL = 7 option and read in an atmospheric profile including the profiles of the desired molecules, up to at most 20. If KMAX is less than zero, a ray trace is performed but no amounts are calculated. RE is the radius of the earth in KM. It can be changed to account for variations in the radius with latitude or to model the atmosphere of other planets.

3.1.1.2 Card 2 Slant Path Parameters: H1, H2, ANGLE, RANGE, BETA, LEN

The format for Card 2 and following are different depending on whether ITYPE is 1 (horizontal path) or 2 or 3 (slant paths). The slant paths will be discussed first.

The slant path parameters are illustrated in Figure 17. Only two or three of the first five parameters on Card 2 need be specified to define the slant path. See Table 3 for the allowable combinations of slant path parameters. The distinction between H1 and H2 is important when calculating radiance, since the radiance for the path from H1 to H2 is not the same as that from H2 to H1. ANGLE is the apparent or measured zenith angle at H1 and is different from the astronomical or unrefracted zenith angle. Note from Table 3 that when RANGE is a supplied parameter, H2 or ANGLE is calculated assuming no refraction and the refracted path is followed using that value. The resulting path will have a value of RANGE different from the input value, and if the path goes through a tangent height, the difference can be substantial. The parameter LEN is demonstrated in Figure 18.

Certain combinations of slant path parameters represent impossible geometries, for example, H1 = 10 km, H2 = 5 km, ANGLE = 60 deg. These cases are flagged as errors and the program stops. If a slant path intersects the earth, for

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*For current version see Rothman, L.S. (1981) AFGL atmospheric absorption line parameters compilation: 1980 version, Appl. Opt. 20:791.

7. McClatchey, R.A., Benedict, W.S., Clough, S.A., Burch, D.E., Calfee, R.F., Fox, K., Rothman, L.S., and Garing, J.S. (1973) AFCRL Atmospheric Absorption Line Parameters Compilation, AFCRL-TR-73-0096, AD 762904.

8. Rothman, L.S., Goldman, A., Gillis, J.R., Tipping, R.H., Brown, L.R., Margolis, J.S., Maki, A.G., and Young, L.D.G. (1981) AFGL trace gas compilation: 1980 version, Appl. Opt. 20:1323-1328.

Table 2. Molecular Species

	Molecule	Mwt*	$v^\dagger$		Molecule	Mwt*	$v^\dagger$
1	H_2O	18.015	0	11	NH_3	17.03	0
2	CO_2	44.010	322	12	HNO_3	63.01	0
3	O_3	47.998	0	13	OH	17.00	0
4	N_2O	44.01	0.27	14	HF	20.01	0
5	CO	28.011	0.19	15	HCl	36.46	0
6	CH_4	16.043	1.5	16	HBr	80.92	0
7	O_2	31.999	2.0948×10^5	17	HI	127.91	0
8	NO	30.01	0	18	ClO	51.45	0
9	SO_2	64.06	0	19	OCS	60.08	0
10	NO_2	46.01	0	20	H_2CO	30.03	0

*Molecular weight, from CRC, Handbook of Chemistry and Physics, 1971. The molecular weight is the average for the various isotopes weighted by their natural abundance.

$\dagger$Default volume-mixing ratio in parts per million used for MODEL = 7 from U.S. Standard Atmosphere 1976.[9]

BENDING = 180 + BETA - ANGLE - PHI
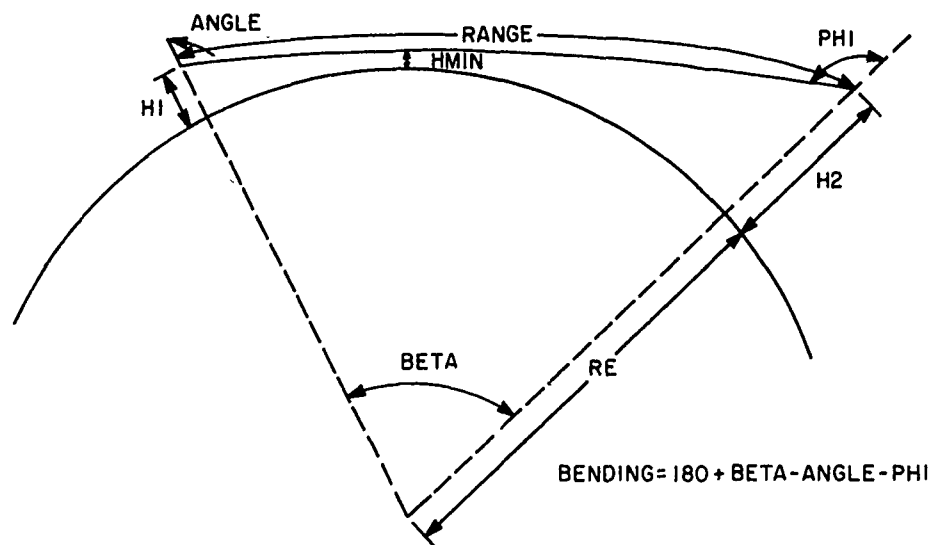
Figure 17. The Slant Path Parameters H1, H2, ANGLE, PHI, RANGE, BETA, and HMIN

9. (1976) U.S. Standard Atmosphere 1976, NOAA - S/T 76-1562, U.S. Government Printing Office.

Table 3. Allowable Combinations of Slant Path Parameters

Case	ITYPE	H1	H2	ANGLE	RANGE	BETA	LEN (Optional)
2A	2	*	*	*			(*)
2B	2	*		*	*		
2C	2	*	*		*		
2D	2	*	*			*	
3A	3	*		*			
3B	3	*	* (HMIN)				

2A: LEN option is available only when H1 > H2 and ANGLE > 90. Otherwise, LEN is set in the program.

2B: H2 calculated assuming no refraction. Calculated RANGE will differ from the input value.

2C: ANGLE calculated assuming no refraction. Calculated RANGE will differ from the input value.

2D: Exact ANGLE is calculated by iteration of the path calculation.

3B: H2 is interpreted as HMIN = tangent height. H2 is reset to highest profile boundary.
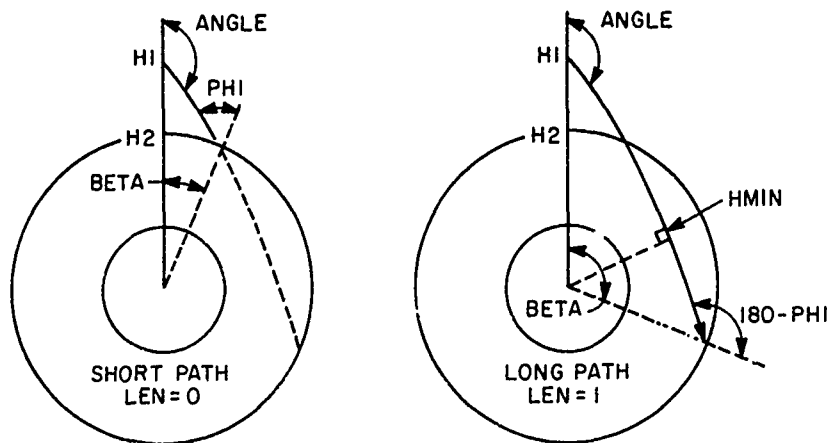
Figure 18. Demonstration of the Parameter LEN

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example, H1 = 10 km, H2 = 20 km, ANGLE = 100 deg, the action of the program depends upon ITYPE. If ITYPE = 2, an error is flagged and the program stops. If ITYPE = 3, H2 is reset to 0, a message is printed, and the program continues.

It is possible to specify a value for H1 and/or H2 that is greater than the highest altitude in the atmospheric profile, for example, H1 might be a satellite altitude (for MODEL = 1 through 6, the highest boundary is at 100 km). In this case, the program resets H1 and/or H2 to the highest profile altitude ZMAX and recomputes ANGLE at ZMAX, assuming no refraction. This procedure is necessary because the density profiles above the top of the atmosphere are poorly defined and because the calculation time for the path above the atmosphere may be excessive (for example, for geosynchronous altitudes). Note also that for the Case 2D in Table 2 (H1, H2, BETA) H1 and H2 are not reset in the iterative calculation of ANGLE so this case can be relatively time-consuming.

3.1.1.3 Card 3 Frequency Range: V1, V2

The average of V1 and V2 is used to calculate the Doppler halfwidth used in creating the output layers and to calculate the index of refraction. V1 and V2 need not correspond to the range of the spectral calculation, if for example the user wants to run cases in two different spectral regions with identical paths and output layers.

3.1.1.4 Card 4 Output Layering

If IBND = 0 on Card 1, the program generates its own set of output layer boundaries based on the values of AVTRAT, TDIFF1, and TDIFF2. AVTRAT specifies the maximum allowable ratio of the Voigt halfwidth from one output boundary to the next highest for a molecule of molecular weight 36 and Lorentz halfwidth at 1013 mb and 296K of 0.1 cm^{-1}. TDIFF1 and TDIFF2 define the maximum allowable temperature difference across an output layer for a layer at HMIN and HMAX respectively. The actual temperature difference for a particular layer is determined by exponentially interpolating TDIFF1 and TDIFF2 to the altitude of bottom of the layer. The layers produced by this procedure will satisfy approximately both constraints. The defaults provided (AVTRAT = 2.0, TDIFF1 = 15K and TDIFF2 = 30K) will produce a set of output layers generally suitable for general survey calculations. The user should, however, experiment with finer layering and critically examine the results in view of his accuracy requirements.

If IBND is greater than zero, the user supplies its own output layer boundaries. These need not include the path endpoints and may extend above and below the endpoints. The program will edit this set of output boundaries to one that extends from the lowest to the highest altitude along the path and includes H1 or H2 if they

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fall in the middle. The zeroing option on Card 1 may further reduce this set of layers under certain circumstances.

3.1.1.5 Horizontal Path: Z, RANGE, P, T, TD, PPH20, DENH20, AMSMIX, VMIX

For a horizontal path (ITYPE = 1, MODEL = 0 or MODEL = 1 to 7), Card 2 contains the only remaining parameters that need be specified and the format is different for the two cases. For an ITYPE = 1, MODEL = 1 through 7 case, only the altitude Z and path length RANGE need be specified. The program will interpolate the pressure, temperature, and densities to the given altitude. For a MODEL = 0 case, the user must supply the path length, pressure P, temperature T, water vapor amount, and volume mixing ratios for the other gases. See the next section on non-standard profiles for the definitions and usages of the various water vapor parameters and the conventions regarding the uniformly mixed gases. If no value for the ozone volume-mixing ratio is supplied, the surface value of 40×10^{-9} ppmv is assumed, taken from U.S. Standard Atmosphere 1976.[9]

3.1.1.6 Non-Standard Profiles

The MODEL = 7 option on Card 1 allows the user to read in an atmospheric profile, for example, from a radiosonde ascent. The profile is read in after Card 4 for ITYPE = 2 or 3 and after Card 2 for ITYPE = 1. The necessary parameters for each level are: the altitude, pressure, temperature, water vapor amount, and volume mixing ratios of the other gases. The water vapor amount can be specified in any one of six ways: VMIX = volume mixing ratio (ppm), AMSMIX = mass mixing ratio (gm kg^{-1}), DENH20 = mass density (gm m^{-3}), PPH20 = partial pressure (mb), RH = relative humidity (percent), or TD = dew point (^{O}C). If more than one of these values is given for the same level, the first non-zero value in the above list is used. A dew-point temperature of zero is a valid input and is assumed if all the water vapor parameters are left zero. To specify no water vapor, specify any negative value for the volume mixing ratio. (The dew point temperature should not be confused with the wet bulb temperature of a wet and dry bulb thermometer.)

If the volume mixing ratios for the uniformly mixed gases (K = 2 = CO_2, 4 = N_2O, 5 = CO, 6 = CH_4, 7 = O_2) are not supplied, then the following values are used:

Default Volume-mixing Ratios

CO_2	N_2O	CO	CH_4	O_2
322×10^{-6}	0.27×10^{-6}	0.19×10^{-6}	1.5×10^{-6}	0.20948

These default values, especially for CO, are different from those used to calculate the densities for models 1 through 6 taken from Optical Properties of the Atmosphere, Third Edition. [4] If no profile for ozone is supplied, the ozone density is left at zero. To specify a zero density for a gas, read in any negative value for the volume mixing ratio.

3.1.2 OUTPUT

The program output consists of a descriptive report written to UNIT = 6 and optionally, the layer-by-layer results written to UNIT = 7. See the sample output following for examples of both outputs. The report on UNIT = 6 is largely self-explanatory. It should be noted, however, that the absorber amounts for a layer are for a single pass through the layer even if the path passes through the layer twice, as for a tangent path. The total amount listed does account for the two passes through a layer. Also, the parameter ZETA in the table of FASCODE output layer boundaries is defined as the ratio of the Lorentz to the Lorentz plus Doppler halfwidths (at half height).

The file written to UNIT = 7 consists of, first of all, a card with the number of layers to follow and 70 characters describing the atmospheric profile and the path. Next is the layer-by-layer data on two cards or more per layer. Card 1 contains the mean pressure, temperature, ICNTRL, and a 20-character layer description field. Card 2 contains the molecular absorber amounts in the order shown in Table 2 with the following exception. The amount in the eighth position is for N_2, which is used by FASCODE to calculate foreign broadened water-vapor continuum. The amounts for the remaining molecules start in position 9 beginning with molecule number 8 (NO). The ICNTRL parameter is used to describe the relationship between that layer and the rest of the path and is illustrated in Figure 19. For a tangent path, the layers that the path traverses twice (the symmetric layers) have ICNTRL = 2. The asymmetric layers (if any) on the near side of H1 have ICNTRL = 1, while the asymmetric layers (if any) on the far side
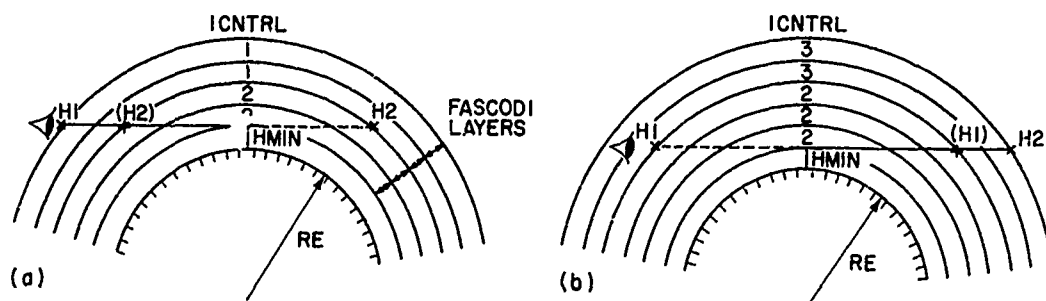
Figure 19. The Parameter ICNTRL for Two Tangent Paths

of H1 have ICNTRL = 3. For a path that is not a tangent path, then for a looking up case (H1 less the H2) ICNTRL = 3 and for a looking down case, ICNTRL = 1. For a horizontal path ICNTRL = 0.

3.2 Sample Input and Output

The input and output for four sample cases is listed in Table 4. Case 1, shown in Table 4a, models the conditions of a set of measurements taken at the South Pole. [10] These measurements were taken by a ground based instrument at 2.9 km elevation looking at the sun, with a solar zenith angle of 67.7°. On Card 1, the Subarctic Winter Atmosphere (MODEL = 5) was selected because it contains the least amount of water vapor. ITYPE = 3 selects a slant path from H1 to the top of the atmosphere profile, here 100 km. The remaining parameters on Card 1 are left zero to select the defaults. In particular, IBND = 0 causes the program to generate its own output layers on the basis of the parameters on Card 4.

On Card 2, H1 is the altitude of the observer, here 2.9 km, and ANGLE is the measured zenith angle at H1. The other parameters are left blank and are calculated by the program. On Card 3, the initial and final wavenumbers are simply averaged and the average value is used to calculate the index of refraction and to produce the output layering. Card 4 is left blank to select the defaults that are 2.0, 15.0, and 30.0 for AVTRAT, TDIFF1 and TDIFF2 respectively.

The first page of the output for this case simply echoes the input cards and shows the supplied default values. A list of the atmospheric profiles follows. Next the path parameters are shown reduced to the standard form H1, H2, ANGLE, PHI, HMIN, and LEN: any allowed set of parameters (see Table 3) is reduced to this form. The output layer boundaries generated internally are shown next. These boundaries satisfy the requirements that: (1) the ratio of the average Voigt width across a layer is less than AVTRAT and, (2) the temperature difference across a layer is less than TDIFF. The value of TDIFF at any altitude is found by exponentially interpolating TDIFF1 and TDIFF2 to that altitude. A selected boundary is always rounded down to the nearest 0.1 km. In this case the temperature criterion determines the thickness of the first two layers while the Voigt ratio determines the next five. The Voigt ratio algorithm is only approximate so that the actual Voigt ratio may be slightly more than AVTRAT. The parameter ZETA is the ratio of the Lorentz to the Lorentz plus Doppler halfwidths.

10. Blatherwick, R.D., Murcray, F.J., Murcray, F.H., Goldman, A., and Murcray, D.G. (1982) Atlas of south pole IR solar spectra, _Appl. Opt._ 21:2658-2659.

Table 4a. Sample Input and Output - Case 1

```
****INPUT CASE 1****************************************************************
  5   3
  2.9         890.0         67.7
880.0           0.0          0.0
  0.0           0.0

****OUTPUT CASE 1***************************************************************

                    ****PROGRAM FSCATM****      01/11/83      11.03.08.
1


CONTROL CARD 1: MODEL AND OPTIONS

               MODEL   =      5
               ITYPE   =      3
               IBND    =      0
               NOZERO  =      0
               NOPRNT  =      0
               KMAX    =      0
               IPUNCH  =      0
               RE      =          0.000 KM


CONTROL CARD 1 PARAMETERS WITH DEFAULTS:

               MODEL   =      5
               ITYPE   =      3
               IBND    =      0
               NOZERO  =      0
               NOPRNT  =      0
               KMAX    =      7
               IPUNCH  =      0
               RE      =   6356.910 KM


SLANT PATH SELECTED, ITYPE =      3


CONTROL CARD 2:   SLANT PATH PARAMETERS

               H1      =      2.9000 KM
               H2      =      0.0000 KM
               ANGLE   =     67.7000 DEG
               RANGE   =      0.0000 KM
               BETA    =      0.0000 DEG
               LEN     =           0
```

40

Table 4a. Sample Input and Output – Case 1 (Contd)

```
CONTRCL CARD 3

     V1   =   880.000 CM-1
     V2   =   890.000 CM-1
     VBAR =   885.000 CM-1


AUTOLAYERING SELECTED

     AVTRAT =    2.00
     TDIFF1 =   15.00
     TDIFF2 =   30.00

1ATMOSPHERIC PROFILE SELECTED IS:  M = 5    SUBARCTIC WINTER
```

				REFRACT		DENSITY (MOLS CM-3)							
I	Z	P	T	INDEX-1	AIR	H2O	CO2	O3	N2O	CO	CH4	O2
	(KM)	(MB)	(K)	*1.0E6								
1	0.000	1013.000	257.100	305.153	2.85E+19	4.01E+16	9.41E+15	5.15E+11	7.98E+11	2.14E+12	4.56E+13	5.97E+18
2	1.000	887.800	259.100	265.366	2.48E+19	4.01E+16	8.18E+15	5.15E+11	6.94E+12	1.86E+12	3.97E+13	5.19E+18
3	2.000	777.500	255.900	235.010	2.20E+19	3.14E+16	7.25E+15	5.15E+11	6.16E+12	1.65E+12	3.52E+13	4.07E+18
4	3.000	679.800	252.700	208.354	1.95E+19	2.27E+16	6.43E+15	4.05E+11	5.45E+12	1.46E+12	3.12E+13	4.08E+18
5	4.000	593.200	247.700	185.492	1.73E+19	1.37E+16	5.72E+15	5.65E+11	4.86E+12	1.30E+12	2.77E+13	3.53E+18
6	5.000	515.800	240.900	165.351	1.55E+19	6.69E+15	5.12E+15	5.90E+11	4.34E+12	1.16E+12	2.48E+13	3.25E+18
7	6.000	446.700	234.100	147.803	1.36E+19	3.28E+15	4.56E+15	6.15E+11	3.87E+12	1.04E+12	2.21E+13	2.90E+18
8	7.000	385.300	227.300	131.307	1.23E+19	1.81E+15	4.05E+15	6.91E+11	3.44E+12	9.21E+11	1.97E+13	2.57E+18
9	8.000	330.800	220.600	116.450	1.09E+19	3.68E+14	3.59E+15	1.13E+12	3.04E+12	8.15E+11	1.74E+13	2.28E+18
10	9.000	282.900	217.200	100.895	9.43E+18	2.81E+14	3.11E+15	2.01E+12	2.64E+12	7.08E+11	1.51E+13	1.36E+18
11	10.000	241.800	217.200	80.237	8.06E+18	1.84E+14	2.65E+15	3.01E+12	2.26E+12	6.05E+11	1.29E+13	1.69E+18
12	11.000	206.700	217.200	73.719	6.83E+18	1.27E+14	2.28E+15	4.32E+12	1.93E+12	5.17E+11	1.10E+13	1.45E+18
13	12.000	176.600	217.200	62.984	5.89E+18	8.69E+13	1.94E+15	5.40E+12	1.65E+12	4.42E+11	9.43E+12	1.23E+18
14	13.000	151.000	217.200	53.454	5.04E+18	6.02E+13	1.66E+15	5.20E+12	1.41E+12	3.78E+11	8.06E+12	1.06E+18
15	14.000	129.100	217.200	46.543	4.31E+18	3.34E+13	1.42E+15	6.15E+12	1.21E+12	3.23E+11	6.89E+12	9.02E+17
16	15.000	110.350	217.200	39.438	3.68E+18	2.54E+13	1.21E+15	7.03E+12	1.03E+12	2.76E+11	5.89E+12	7.71E+17
17	16.000	94.310	215.600	33.728	3.15E+18	2.14E+13	1.04E+15	7.78E+12	8.83E+11	2.37E+11	5.05E+12	5.61E+17
18	17.000	80.580	216.600	28.893	2.70E+18	1.87E+13	3.92E+14	7.78E+12	7.57E+11	2.03E+11	4.33E+12	5.66E+17
19	18.000	68.820	215.400	24.749	2.31E+18	1.64E+13	7.64E+14	7.79E+12	6.48E+11	1.74E+11	3.70E+12	4.85E+17
20	19.000	58.750	214.800	21.187	1.98E+18	1.64E+13	6.54E+14	7.53E+12	5.55E+11	1.49E+11	3.17E+12	4.15E+17
21	20.000	50.140	214.100	18.141	1.70E+18	1.51E+13	5.60E+14	7.03E+12	4.75E+11	1.27E+11	2.72E+12	3.56E+17
22	21.000	42.770	213.600	15.511	1.45E+18	1.71E+13	4.79E+14	6.40E+12	4.06E+11	1.09E+11	2.32E+12	3.04E+17
23	22.000	36.470	213.000	13.263	1.24E+18	1.71E+13	4.09E+14	5.40E+12	3.47E+11	9.30E+10	1.99E+12	2.60E+17
24	23.000	31.090	212.400	11.329	1.06E+18	1.81E+13	3.50E+14	4.52E+12	2.97E+11	7.95E+10	1.70E+12	2.22E+17
25	24.000	26.490	211.000	9.680	9.06E+17	2.01E+13	2.99E+14	4.02E+12	2.54E+11	6.80E+10	1.45E+12	1.90E+17
26	25.000	22.560	211.200	8.274	7.74E+17	2.24E+13	2.55E+14	4.02E+12	2.17E+11	5.80E+10	1.24E+12	1.62E+17
27	30.000	10.200	216.000	3.558	3.42E+17	1.20E+13	1.13E+14	1.66E+12	9.58E+10	2.57E+10	5.47E+11	7.17E+16
28	35.000	4.701	222.200	1.639	1.53E+17	3.68E+12	5.06E+13	1.16E+12	4.29E+10	1.15E+10	2.45E+11	3.21E+16
29	40.000	2.243	234.700	.740	6.92E+16	1.44E+12	2.29E+13	1.15E+12	1.94E+10	5.19E+09	1.11E+11	1.45E+16
30	45.000	1.113	247.000	.349	3.26E+16	6.35E+11	1.08E+13	1.63E+11	9.14E+09	2.45E+09	5.22E+10	6.94E+15
31	50.000	.572	259.300	.171	1.60E+16	2.11E+11	5.27E+12	5.40E+10	4.47E+09	1.26E+09	2.56E+10	3.35E+15
32	70.000	.040	245.700	.013	1.18E+15	4.69E+09	3.91E+11	1.04E+09	3.32E+08	8.88E+07	1.90E+09	2.49E+14
33	100.000	.000	210.000	.000	1.03E+13	3.34E-07	3.42E+09	5.40E+05	2.90E+06	7.76E+05	1.66E+07	2.17E+12

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Table 4a. Sample Input and Output - Case 1 (Contd)

CASE 3A: GIVEN H1,H2=SPACE,ANGLE

SLANT PATH PARAMETERS IN STANDARD FORM

```
H1     =     2.900 KM
H2     =   100.000 KM
ANGLE  =    67.700 DEG
PHI    =   114.288 DEG
HMIN   =     2.900 KM
LEN    =     0
```

FASCODE LAYER BOUNDARIES PRODUCED BY THE AUTOMATIC LAYERING ROUTINE AUTLAY
THE USER SHOULD EXAMINE THESE BOUNDARIES AND MODIFY THEM IF APPROPRIATE
THE FOLLOWING PARAMETERS ARE USED:

```
VTRAT  =     2.00       = MAX RATIO OF VOIGT WIDTHS
TDIFF1 =    15.00       = MAX TEMP DIFF AT HMIN
TDIFF2 =    30.00       = MAX TEMP DIFF AT HMAX
ALZERO =     .100 CM-1  = AVERAGE LORENTZ WIDTH AT STP
AVMWT  =    36.00       = AVERAGE MOLECULAR WEIGHT
VBAR   =   885.00 CM-1  = AVERAGE WAVENUMBER
```

I	Z (KM)	P (MB)	T (K)	LORENTZ (CM-1)	DOPPLER (CM-1)	ZETA	VOIGT (CM-1)	VOIGT RATIO	TEMP DIFF (K)
1	2.900	638.930	253.020	.07355	.00064	.989	.07356	1.37	14.8
2	5.400	486.962	236.160	.05358	.00092	.985	.05359	1.34	14.9
3	7.600	351.608	225.280	.03995	.00079	.981	.03997	1.99	6.1
4	12.100	173.856	217.200	.02013	.00078	.963	.02016	1.98	.9
5	16.500	87.175	216.300	.01006	.00078	.928	.01012	1.99	2.7
6	21.000	42.770	213.600	.00497	.00077	.866	.00509	2.02	1.5
7	25.900	19.556	212.064	.00228	.00077	.748	.00252	2.04	7.7
8	33.000	6.408	219.720	.00073	.00078	.434	.00123	1.33	18.4
9	41.400	1.843	232.144	.00020	.00082	.199	.00092	1.05	19.7
10	49.400	.619	257.824	.00007	.00085	.072	.00036	1.08	20.8
11	77.300	.012	237.013	.00000	.00091	.002	.00008	1.06	25.5
12	98.700	.000	211.547	.00000	.00077	.000	.00077	1.00	1.5
13	100.000	.000	210.000	.00000	.00077	.000	.00077	0.00	0.0

1CALCULATION OF THE REFRACTED PATH THROUGH THE ATMOSPHERE

I	ALTITUDE FROM (KM)	TO (KM)	THETA (DEG)	DRANGE (KM)	RANGE (KM)	DBETA (DEG)	BETA (DEG)	PHI (DEG)	DBEND (DEG)	BENDINC (DEG)	PBAR (MB)	TSAR (K)	RHOBAR (MOL CM-3)
	H1 TO H2												
1	2.900	3.000	67.700	.264	.264	.002	.002	112.302	.000	.000	684.394	252.860	1.96E+19
2	3.000	4.000	67.698	2.634	2.898	.022	.024	112.321	.003	.004	636.356	250.240	1.84E+19

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Table 4a.   Sample Input and Output – Case 1 (Contd)

	FROM	TO	AIR	H2O	CO2	O3	N2O	CO	CH4	O2			
3	4.000	5.000	67.679	2.632	5.530	.022	.046	112.340	.003	.006	554.321	244.548	1.64E+19
4	5.000	5.400	67.660	1.532	6.582	.009	.055	112.348	.001	.007	501.354	239.548	1.52E+19
5	5.400	6.000	67.652	1.578	8.153	.013	.068	112.359	.001	.009	466.773	236.158	1.43E+19
6	6.000	7.000	67.641	2.628	10.787	.022	.090	112.379	.002	.011	415.849	230.750	1.30E+19
7	7.000	7.600	67.621	1.576	12.363	.013	.103	112.391	.001	.012	368.404	225.309	1.18E+19
8	7.600	8.000	67.609	1.050	13.413	.009	.112	112.399	.001	.013	341.183	221.948	1.11E+19
9	8.000	9.000	67.601	2.623	16.036	.022	.134	112.418	.002	.015	305.788	218.936	1.01E+19
10	9.000	10.000	67.582	2.621	18.657	.022	.155	112.438	.002	.017	262.350	217.200	8.73E+18
11	10.000	11.000	67.562	2.619	21.276	.022	.177	112.458	.002	.019	224.250	217.200	7.46E+18
12	11.000	12.000	67.542	2.617	23.892	.022	.199	112.478	.001	.021	191.650	217.200	6.38E+18
13	12.000	12.100	57.522	.252	24.154	.002	.201	112.480	.001	.021	175.228	217.200	5.84E+18
14	12.100	13.000	57.520	2.353	26.507	.020	.221	112.499	.001	.022	162.428	217.200	5.41E+18
15	13.000	14.000	67.501	2.612	29.119	.022	.242	112.519	.001	.023	140.050	217.200	4.66E+18
16	14.000	15.000	67.481	2.610	31.729	.022	.264	112.540	.001	.024	119.700	217.200	3.98E+18
17	15.000	16.000	67.460	2.608	34.336	.022	.286	112.561	.000	.025	102.301	216.908	3.41E+18
18	16.000	16.500	67.439	1.303	35.639	.011	.296	112.571	.000	.025	90.742	216.452	3.03E+18
19	16.500	17.000	67.429	1.302	36.942	.011	.307	112.582	.000	.025	83.877	216.152	2.81E+18
20	17.000	18.000	67.418	2.603	39.545	.022	.329	112.603	.001	.026	74.697	215.708	2.50E+18
21	18.000	19.000	67.397	2.601	42.145	.022	.350	112.624	.000	.026	63.783	215.108	2.14E+18
22	19.000	20.000	67.376	2.598	44.744	.022	.372	112.645	.000	.027	54.443	214.459	1.83E+18
23	20.000	21.000	67.355	2.596	47.340	.022	.394	112.666	.000	.027	46.454	213.856	1.57E+18
24	21.000	22.000	67.334	2.594	49.934	.021	.415	112.698	.000	.027	39.619	213.308	1.34E+18
25	22.000	23.000	67.312	2.592	52.525	.021	.436	112.709	.000	.028	33.779	212.708	1.15E+18
26	23.000	24.000	67.291	2.589	55.114	.021	.458	112.730	.000	.028	28.789	212.108	9.81E+17
27	24.000	25.000	67.270	2.587	57.701	.021	.479	112.751	.000	.028	24.524	211.508	8.38E+17
28	25.000	25.900	67.249	2.336	60.027	.019	.499	112.770	.000	.028	21.059	211.621	7.20E+17
29	25.900	30.000	67.230	10.574	70.602	.087	.586	112.857	.000	.029	14.894	213.807	4.87E+17
30	30.000	33.000	67.143	7.713	78.315	.064	.650	112.921	.000	.029	8.310	217.705	2.71E+17
31	33.000	35.000	67.079	5.131	83.446	.042	.692	112.963	.000	.029	5.556	220.391	1.81E+17
32	35.000	40.000	67.037	12.788	96.234	.105	.798	113.068	.000	.029	3.484	227.571	1.06E+17
33	40.000	41.400	66.932	3.571	99.805	.029	.827	113.098	.000	.029	2.044	236.357	6.24E+16
34	41.400	45.000	66.902	9.162	108.967	.075	.902	113.173	.000	.029	1.481	242.146	4.33E+16
35	45.000	49.400	66.827	11.160	120.127	.092	.994	113.265	.000	.029	.868	251.807	2.42E+16
36	49.400	50.000	66.735	1.519	121.646	.012	1.007	113.278	.000	.029	.596	258.551	1.67E+16
37	50.000	70.000	66.722	50.191	171.837	.411	1.418	113.689	.000	.029	.305	255.121	5.70E+15
38	70.000	77.300	66.311	18.117	189.954	.148	1.565	113.836	.000	.029	.026	242.153	7.02E+14
39	77.300	98.700	66.164	52.512	242.465	.426	1.992	114.263	.000	.029	.006	230.191	1.07E+14
40	98.700	100.000	65.737	3.162	245.627	.026	2.017	114.288	.000	.020	.000	210.799	1.15E+13

1INTEGRATED ABSORBER AMOUNTS BY LAYER

I	LAYER BOUNDARIES		INTEGRATED AMOUNTS (MOL CM-2)							
	FROM	TO	H2O	CO2	O3	N2O	CO	CH4	O2	
			AIR							
1	2.000	3.000	5.166E+23	6.001E+20	1.703E+20	1.419E+16	1.445E+17	3.871E+16	8.259E+17	1.075E+23
2	3.000	4.000	4.045E+24	4.701E+21	1.508E+21	1.454E+17	1.356E+17	3.631E+18	7.747E+18	1.014E+24
3	4.000	5.000	4.319E+24	2.575E+21	1.425E+21	1.519E+17	1.209E+17	3.238E+17	6.908E+18	9.046E+23
4	5.000	5.400	5.595E+24	5.121E+20	5.262E+20	6.258E+16	4.465E+17	1.196E+17	2.551E+18	3.341E+23
5	5.400	6.000	2.257E+24	6.452E+20	7.450E+20	9.581E+16	6.321E+17	1.694E+17	3.613E+18	4.730E+23
6	6.000	7.000	3.425E+24	6.487E+20	1.130E+21	1.956E+17	9.590E+17	2.569E+17	5.481E+18	7.177E+23
7	7.000	7.600	1.865E+24	1.833E+20	6.155E+20	1.508E+20	5.223E+17	1.399E+17	2.985E+18	3.908E+23
8	7.600	8.000	1.169E+24	5.309E+19	3.858E+20	1.31E+17	3.273E+17	6.768E+16	1.870E+18	2.449E+23
9	8.000	9.000	2.658E+24	8.455E+19	7.772E+20	4.005E+17	7.443E+17	1.994E+17	4.253E+16	5.569E+23
10	9.000	10.000	2.283E+24	6.002E-19	7.554E+20	6.490E+17	6.408E+17	1.717E+17	3.663E+18	4.796E+23
11	10.000	11.000	1.954E+24	4.027E-13	6.451E+20	9.140E+17	5.474E+17	1.466E+17	3.128E+18	4.095E+23
12	11.000	12.000	1.669E+24	2.767E+19	5.508E+20	1.223E+18	4.674E+17	1.252E+17	2.671E+18	3.496E+23

Table 4a. Sample Input and Output – Case 1 (Contd)

	FROM (KM)	TO (KM)									
13	12.000	12.100	1.528E+23	2.232E+18	5.045E+19	1.418E+17	4.279E+16	1.146E+16	2.446E+17	3.202E+22
14	13.000	13.100	1.272E+24	1.678E+19	4.200E+20	1.334E+18	3.563E+18	9.546E+18	2.036E+18	2.666E+23
15	14.000	14.000	1.217E+24	1.189E+19	4.018E+20	1.573E+18	3.410E+17	9.134E+16	1.948E+18	2.551E+23
15	15.000	15.000	1.040E+24	7.632E+18	3.431E+20	1.717E+18	2.912E+17	7.800E+16	1.664E+18	2.179E+23
17	15.000	16.000	8.890E+23	6.088E+18	2.934E+20	1.929E+18	2.490E+17	6.670E+16	1.423E+18	1.863E+23
18	16.000	16.500	3.954E+23	2.697E+18	1.305E+20	1.014E+18	1.108E+17	2.967E+16	6.328E+17	8.287E+22
19	16.500	17.000	3.659E+23	2.521E+18	1.208E+20	1.013E+18	1.025E+17	2.745E+16	5.856E+17	7.668E+22
20	17.000	18.000	6.515E+23	4.608E+18	2.151E+20	2.025E+18	1.825E+17	4.868E+16	1.043E+18	1.366E+23
21	18.000	19.000	5.574E+23	4.304E+18	1.840E+20	1.991E+18	1.561E+17	4.181E+16	8.922E+17	1.168E+23
22	19.000	20.000	4.766E+23	4.081E+18	1.574E+20	1.691E+18	1.335E+17	3.577E+16	7.632E+17	9.993E+22
23	20.000	21.000	4.076E+23	4.161E+18	1.345E+20	1.742E+18	1.142E+17	3.058E+16	6.524E+17	8.542E+22
24	21.000	22.000	3.482E+23	4.422E+18	1.149E+20	1.594E+18	9.752E+16	2.612E+16	5.573E+17	7.297E+22
25	22.000	23.000	2.975E+23	4.549E+18	9.820E+19	1.462E+18	8.330E+16	2.232E+16	4.761E+17	6.234E+22
26	23.000	24.000	2.540E+23	4.931E+18	8.385E+19	1.280E+18	7.113E+16	1.906E+16	4.066E+17	5.323E+22
27	24.000	25.000	2.168E+23	5.486E+18	7.156E+19	1.103E+18	6.072E+16	1.625E+16	3.470E+17	4.542E+22
28	25.000	25.500	1.674E+23	4.330E+18	5.525E+19	8.733E+17	4.688E+16	1.256E+16	2.678E+17	3.507E+22
29	25.500	30.000	5.150E+23	1.660E+19	1.700E+20	2.760E+18	1.442E+17	3.863E+16	8.241E+17	1.079E+23
30	30.000	33.000	2.094E+23	6.645E+18	6.911E+19	1.258E+18	5.864E+16	1.571E+16	3.351E+17	4.388E+22
31	33.000	35.000	9.271E+22	2.415E+18	3.060E+19	5.544E+17	2.597E+16	6.958E+15	1.484E+17	1.943E+22
32	35.000	40.000	1.352E+23	3.051E+18	4.464E+19	1.013E+18	3.788E+16	1.015E+16	2.165E+17	2.834E+22
33	40.000	41.400	2.229E+22	4.590E+17	7.357E+18	1.571E+17	6.243E+15	1.672E+15	3.568E+16	4.672E+21
34	41.400	45.000	3.968E+22	7.925E+17	1.310E+19	2.325E+17	1.112E+16	2.977E+15	6.352E+16	8.317E+21
35	45.000	49.400	2.704E+22	4.537E+17	8.925E+18	1.164E+17	7.574E+15	2.029E+15	4.329E+16	5.668E+21
36	49.400	50.000	2.533E+21	3.420E+16	8.361E+17	8.763E+15	7.094E+14	1.900E+14	4.055E+15	5.309E+20
37	50.000	70.000	2.862E+22	2.727E+17	9.447E+18	6.814E+16	8.016E+15	2.147E+15	4.581E+16	5.998E+21
38	70.000	77.300	1.272E+21	4.965E+15	4.204E+17	8.914E+14	3.567E+14	9.554E+13	2.038E+15	2.669E+20
39	77.300	98.700	5.617E+20	2.042E+15	1.858E+17	1.645E+14	1.576E+14	4.222E+13	9.007E+14	1.179E+20
40	98.700	100.000	3.631E+18	1.179E+13	1.199E+15	2.021E+11	1.017E+12	2.725E+11	5.813E+12	7.610E+17
OTOTAL	2.900	100.000	3.834E+25	1.036E+22	1.265E+22	3.307E+19	1.074E+21	2.876E+18	6.136E+19	8.033E+24

1 SUMMARY OF THE GEOMETRY CALCULATION

```
MODEL    =  SUBARCTIC WINTER
H1       =    2.900 KM
H2       =  100.000 KM
ANGLE    =   57.700 DEG
RANGE    =  245.627 KM
BETA     =    2.017 DEG
PHI      =  114.298 DEG
HMIN     =    2.900 KM
BENDING  =     .029 DEG
LEN      =        0
AIRMAS   =     1.78    RELATIVE TO A VERTICAL PATH , GROUND TO SPACE
```

OFINAL SET OF LAYERS FOR INPUT TO FASCOD1
A LAYER AMOUNT MAY BE SET TO ZERO IF THE CUMULATIVE AMOUNT FOR THAT LAYER AND ABOVE IS LESS THAN 0.1 PERCENT
OF THE TOTAL AMOUNT. THIS IS DONE ONLY FOR THE FOLLOWING CASES
  1. IEMIT = 0 (TRANSMITTANCE)
  2. IEMIT = 1 (RADIANCE) AND ICNTRL = 3 (PATH LOOKING UP)
O2 IS NOT INCLUDED
IF THE AMOUNTS FOR ALL THE MOLECULES BUT O2 ARE ZEROED, THE REMAINING LAYERS ARE ELIMINATED

L	LAYER BOUNDARIES		ICNTRL	PBAR	TBAR	INTEGRATED AMOUNTS (MOLS CM-2)							
	FROM (KM)	TO (KM)		(MB)	(K)	AIR	H2O	CO2	N2O	O3	CO	CH4	O2

Table 4a. Sample Input and Output – Case 1 (Contd)

1	2.900	5.400	3	589.04	246.59	1.13E+25	8.50E+21	3.72E+21	3.74E+17	3.16E+18	8.45E+17	1.80E+19	2.36E+24
2	5.400	7.600	3	419.36	231.02	7.55E+24	1.48E+21	2.49E+21	4.42E+17	2.11E+18	5.66E+17	1.21E+19	1.56E+24
3	7.600	12.100	3	262.80	218.23	9.89E+24	2.69E+20	3.26E+21	3.44E+18	2.77E+18	7.42E+17	1.58E+13	2.07E+24
4	12.100	16.500	3	130.55	217.08	4.81E+24	4.51E+19	1.59E+21	7.57E+18	1.35E+18	3.61E+17	7.70E+13	1.01E+24
5	16.500	21.000	3	64.98	215.09	2.46E+24	1.97E+19	8.12E+20	8.66E+18	6.89E+17	1.84E+17	3.94E+13	5.15E+23
6	21.000	25.900	3	31.15	212.41	1.28E+24	2.43E-19	4.24E+20	6.31E+18	3.60E+17	9.63E-16	2.05E+13	2.69E+23
7	25.900	33.000	3	12.99	214.93	7.24E-23	2.32E+19	2.39E+20	4.02E+18	2.03E+17	5.43E+16	1.16E+13	1.52E+23
8	33.000	41.400	3	4.12	225.88	2.50E+23	0.	8.26E+19	1.82E+18	7.01E+16	1.88E+16	4.01E+17	5.24E+22
9	41.400	49.400	3	1.23	246.06	6.67E+22	0.	2.20E+19	3.49E+17	1.87E+16	5.01E+15	1.07E+17	1.40E+22
10	49.400	77.300	3	.32	254.88	3.24E+22	0.	0.	7.78E-16	0.	0.	0.	6.80E+21

Table 4b. Sample Input and Output – Case 2

```
****INPUT CASE 2********************************************************************
   7    3                                         20
     33.0                                       94.87
    820.0      830.0                             50.0
      2.0       50.0

  36
S    7G + TRACE GASES
  0.0000 1012.2500  288.1500   .320E+00  .150E+00  .170E-01  .209E+06  .300E-03
 .100E+05  .322E+03  .330E-01   .300E-04  .440E-07  .100E-07  .100E-03  .170E-05
 .300E-03  .300E-03  .130E-02   .240E-02
 .300E-05  .100E-06  .600E-03
  2.0000  795.0100  275.1540   .320E+00  .140E+00  .170E+01  .209E+06  .300E-03
 .970E+04  .322E+03  .330E-01   .400E-04  .440E-07  .100E-07  .650E-04  .170E-05
 .250E-03  .300E-03  .120E-02   .300E-03
 .300E-05  .100E-06  .580E-03
  4.0000  616.6000  262.1660   .320E+00  .130E+00  .170E+01  .209E+06  .300E-03
 .380E+04  .322E+03  .340E-01   .500E-04  .440E-07  .300E-07  .330E-04  .170E-05
 .140E-03  .300E-03  .100E-02   .130E-03
 .300E-05  .100E-06  .500E-03
  6.0000  472.1700  249.1870   .320E+00  .130E+00  .170E+01  .209E+06  .300E-03
 .150E+04  .322E+03  .410E-01   .700E-04  .440E-07  .900E-07  .260E-04  .170E-05
 .950E-04  .300E-03  .850E-03   .700E-04
 .300E-05  .150E-06  .550E-03
  8.0000  356.5100  236.2150   .320E+00  .120E+00  .160E+01  .209E+06  .300E-03
 .650E+03  .322E+03  .600E-01   .800E-04  .440E-07  .230E-06  .220E-04  .170E-05
 .700E-04  .300E-03  .700E-03   .500E-04
 .300E-05  .150E-06  .530E-03
 10.0000  264.9900  223.2520   .310E+00  .100E+00  .160E+01  .209E+06  .300E-03
 .200E+02  .322E+03  .130E+00   .100E-03  .470E-07  .600E-06  .240E-04  .170E-05
 .600E-04  .300E-03  .700E-03   .330E-04
 .300E-05  .200E-06  .520E-03
 12.0000  193.9900  216.6500   .300E+00  .800E-01  .160E+01  .209E+06  .300E-03
 .600E+01  .322E+03  .310E+00   .200E-03  .490E-07  .200E-05  .300E-04  .170E-05
 .550E-04  .300E-03  .400E-03   .370E-04
 .300E-05  .200E-06  .500E-03
 14.0000  141.7000  216.6500   .290E+00  .500E-01  .150E+01  .209E+06  .300E-03
 .290E+01  .322E+03  .500E+00   .300E-03  .530E-07  .450E-05  .100E-04  .170E-05
 .560E-04  .350E-03  .300E-03   .360E-04
 .300E-05  .130E-05  .470E-03
 16.0000  1C3.5200  216.6500   .270E+00  .300E-01  .150E+01  .209E+06  .270E-03
 .320E+01  .322E+03  .850E+00   .290E+00  .810E-07  .100E-06  .100E-04  .170E-05
 .600E-04  .400E-03  .100E-03   .340E-04
 .300E-05  .250E-05  .390E-03
 18.0000   75.6520  216.6500   .240E+00  .200E-01  .140E+01  .209E+06  .230E-03
 .340E+01  .322E+03  .160E+01   .115E-02  .130E-06  .250E-06  .400E-03  .170E-05
 .500E-04  .400E-03  .100E-04   .340E-04
 .300E-05  .250E-05  .310E-03
 20.0000   55.2930  216.6500   .150E-01  .150E-01  .130E+01  .209E+06  .250E-03
 .350E+01  .322E+03  .260E+01   .200E-02  .190E-06  .600E-06  .500E-03  .170E-05
 .310E-04  .900E-03  .100E-05   .330E-04
 .300E-05  .600E-05  .240E-03
 22.0000   40.4750  218.5740
```

Table 4b. Sample Input and Output – Case 2 (Contd)

.350E+01	.322E-03	.360E+01	.200E+00	.160E-01	.110E-01	.209E+06	.300E-03
.220E-04	.120E-02	.100E-06	.300E-02	.520E-06	.100E-03	.550E-03	.170E-05
.300E-05	.100E-04	.90E-03	.400E-04				
24.0000	29.7170	220.5600					
.350E+01	.322E+03	.470E+01	.160E+00	.170E-01	.100E+01	.209E+06	.400E-03
.220E-04	.220E-02	.100E-06	.400E-02	.100E-05	.150E-03	.600E-03	.170E-05
.300E-05	.200E-04	.140E-03	.50CE-04				
26.0000	21.8830	222.5440					
.370E+01	.322E+03	.570E+01	.130E+00	.180E-01	.930E+00	.209E+06	.800E-03
.170E-04	.310E-02	.10uE-06	.350E-02	.290E-05	.200E-03	.650E-03	.170E-05
.300E-05	.500E-04	.110E-03	.600E-04				
23.0000	16.1610	224.5270					
.390E+01	.322E+03	.620E+01	.110E+00	.190E-01	.800E+00	.209E+06	.150E-02
.150E-04	.450E-02	.100E-06	.300E-02	.610E-05	.250E-03	.700E-03	.170E-05
.300E-05	.100E-03	.700E-04	.800E-04				
30.0C00	11.9700	226.5090					
.410E+01	.322E+03	.660E+01	.900E-01	.200E-01	.800E+00	.209E+06	.250E-02
.130E-04	.750E-02	.100E-06	.200E-02	.100E-04	.300E-03	.100E-02	.180E-05
.300E-05	.200E-03	.300E-04	.900E-C4				
32.0000	8.8910	228.49C0					
.420E+01	.322E+03	.720E+01	.700E-01	.220E-01	.730E+00	.209E+06	.400E-02
.120E-04	.700E-02	.100E-06	.100E-02	.280E-04	.320E-03	.120E-02	.210E-05
.300E-05	.400E-03	.170E-04	.100E-02				
34.0000	6.6340	233.7430					
.430E+0'	.322E-02	.770E+01	.500E-01	.240E-01	.660E+00	.209E+06	.700E-02
.110E-04	.550E-02	.100E-06	.600E-03	.580E-04	.340E-03	.160E-02	.240E-05
.30CE-05	.500E-03	.600E-05	.110E-03				
36.0000	4.9950	239.2820					
.440E+01	.322E+03	.810E+01	.320E-01	.270E-01	.570E+00	.209E+06	.900E-02
.110E-04	.500E-02	.100E-06	.350E-03	.130E-03	.360E-03	.180E-02	.310E-05
.300E-05	.600E-03	.250E-05	.120E-03				
38.0000	3.7710	244.8180					
.440E+01	.322E+03	.780E+01	.220E-01	.300E-01	.480E+00	.209C+06	.100E-01
.120E-04	.450E-02	.100E-06	.200E-03	.220E-03	.380E-03	.170E-02	.390E-05
.300E-05	.700E-03	.100E-05	.120E-03				
40.0000	2.8710	250.3500					
.450E+01	.322E+03	.730E+01	.160E-01	.300E-01	.400E+00	.209E+06	.120E-01
.130E-04	.350E-02	.100E-06	.100E-03	.310E-03	.400E-03	.150E-02	.510E-05
.300E-05	.720E-03	.500E-06	.110E-03				
42.0000	2.1200	255.8780					
.450E+01	.322E+03	.640E+01	.100E-01	.300E-01	.320E+00	.209E+06	.110E-01
.150E-C4	.300E-02	.100E-06	.700E-04	.400E-03	.410E-03	.140E-02	.640E-05
.300E-05	.600E-03	.200E-06	.950E-04				
44.0000	1.6950	261.4030					
.450E+0:	.322E+03	.580E+01	.700E-02	.300E-01	.250E+00	.209E+06	.100E-01
.190E-04	.250E-02	.100E-06	.400E-04	.500E-03	.420E-03	.130E-02	.700E-05
.300E-05	.300E-03	.800E-07	.800E-04				
46.0000	1.3130	266.9250					
.460E+01	.322E+03	.470E+01	.400E-02	.30CE-01	.200E+00	.209E+06	.100E-01
.230E-04	.200E-02	.100E-06	.200E-04	.600E-03	.430E-03	.130E-02	.730E-05
.30CE-05	.170E-03	.250E-07	.650E-04				
48.0000	1.C230	270.6500					
.490E+01	.322E+03	.380E+01	.200E-02	.300E-01	.150E+00	.205E+06	.100E-01
.31CE-04	.150E-02	.100E-06	.100E-04	.700E-03	.440E-03	.130E-02	.740E-05
.300E-05	.130E-03	.100E-07	.510E-04				

Table 4b. Sample Input and Output – Case 2 (Contd)

```
50.0000    .798C    270.6500   .100E-02   .300E-01   .100E+00   .209E+06   .100E-01
.500E+01   .322E+03 .310E+01   .500E-05   .800E-03   .450E-03   .130E-02   .740E-05
.350E-04   .100E-02 .100E-06   .100E-07
.300E-05   .10CE-03 .100E-07
55.0000    .4253    260.7710   .400E-04
    5.0    0.       0.         0.   0.   0.   0.   0.   0.
    0.     0.       0.         0.   0.
60.0000    .2196    247.0210
    5.0    0.       0.         0.   0.   0.   0.   0.   0.
    0.     0.       0.         0.   0.
65.0000    .1093    233.2920
    5.0    0.       0.         0.   0.   0.   0.   0.   0.
    0.     0.       0.         0.   0.
70.0000    .0522    219.5850
    5.0    0.       0.         0.   0.   0.   0.   0.   0.
    0.     0.       0.         0.   0.
75.0000    .0239    208.3990
    5.0    0.       0.         0.   0.   0.   0.   0.   0.
    0.     0.       0.         0.   0.
80.0000    .C105    198.6390
    5.0    0.       0.         0.   0.   0.   0.   0.   0.
    0.     0.       0.         0.   0.
85.0000    .0045    188.8930
    5.0    0.       0.         0.   0.   0.   0.   0.   0.
    0.     0.       0.         0.   0.
90.0000    .0018    196.8700
    5.0    0.       0.         0.   0.   0.   0.   0.   0.
    0.     0.       0.         0.   0.
95.0000    .0008    188.4200
    5.0    0.       0.         0.   0.   0.   0.   0.   0.
    0.     0.       0.         0.   0.
100.0000   .0003    195.0800
    5.0    0.       0.         0.   0.   0.   0.   0.   0.
    0.     0.       0.         0.   0.
```

*****OUTPUT CASE 2**

*****PROGRAM FSCATM*****   01/11/83   11.03.37.

1

CONTROL CARD 1: MODEL AND OPTIONS

MODEL   =   7

48

Table 4b. Sample Input and Output – Case 2 (Contd)

```
ITYPE     =     3
IEND      =     0
NOPRNT    =     0
KMAX      =    20
IPUNCH    =     0
RE        =        0.000 KM


CONTROL CARD 1 PARAMETERS WITH DEFAULTS:

MODEL     =     7
ITYPE     =     3
IBND      =     0
NOZERO    =     0
NOPRNT    =     0
KMAX      =    20
IPUNCH    =     0
RE        =     6371.230 KM


SLANT PATH SELECTED, ITYPE =     3


CONTROL CARD 2:   SLANT PATH PARAMETERS

H1        =    33.0000 KM
H2        =     0.0000 KM
ANGLE     =    94.8700 DEG
RANGE     =     0.0000 KM
BETA      =     0.0000 DEG
LEN       =          0


CONTROL CARD 3

V1        =    820.000 CM-1
V2        =    830.000 CM-1
VBAR      =    825.000 CM-1


AUTOLAYERING SELECTED

AVTRAT    =      2.00
TDIFF1    =     50.00
TDIFF2    =     50.00


READING IN USER SUPPLIED MODEL ATMOSPHERE
```

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Table 4b. Sample Input and Output – Case 2 (Contd)

IMOD = 36
PROFILE = US 76 + TRACE GASES

I	Z (KM)	P (MB)	T (K)	TD (C)	RH (PERCNT)	PH2O (MB)	DENH2O (GM M-3)	AMSMIX (GM/KG)
VOL MIX RAT (PPMV)	H2O / SO2 / HI	CO2 / NO2 / CLO	O3 / NH3 / OCS	N2O / HNO3 / H2CO	CO / OH	CH4 / HF	O2 / HCL	NO / HBR
1	0.000	1013.250	288.150	-0.000	0.000	0.000	0.000	0.000
	1.000E+04	3.220E+02	3.300E-02	3.200E-01	1.500E-01	1.700E+00	2.090E+05	3.000E-04
	3.000E-04	3.000E-04	1.300E-03	3.000E-05	4.400E-08	1.000E-08	1.000E-04	1.700E-06
	3.000E-06	1.000E-07	6.000E-04	2.400E-03				
2	2.000	795.010	275.154	0.000	0.000	0.000	0.000	0.000
	9.700E+03	3.220E+02	3.300E-02	3.200E-01	1.400E-01	1.700E+00	2.090E+05	3.000E-04
	2.500E-04	3.000E-04	1.200E-03	4.000E-05	4.400E-08	1.000E-08	6.500E-05	1.700E-06
	3.000E-06	1.000E-07	5.800E-04	3.000E-04				
3	4.000	616.600	262.166	0.000	0.000	0.000	0.000	0.000
	3.800E+03	3.220E+02	3.400E-02	3.200E-01	1.300E-01	1.700E+00	2.090E+05	3.000E-04
	1.400E-04	3.000E-04	1.000E-03	5.000E-05	4.400E-08	3.000E-08	3.300E-05	1.700E-06
	3.000E-06	1.000E-07	5.600E-04	1.300E-04				
4	6.000	472.170	249.187	0.000	0.000	0.000	0.000	0.000
	1.500E+03	3.220E+02	4.100E-02	3.200E-01	1.300E-01	1.700E+00	2.090E+05	3.000E-04
	9.500E-05	3.000E-04	3.500E-04	7.000E-05	4.400E-08	9.000E-08	2.600E-05	1.700E-06
	3.000E-06	1.200E-07	5.500E-04	7.000E-05				
5	8.000	356.510	236.215	0.000	0.000	0.000	0.000	0.000
	6.500E+02	3.220E+02	6.000E-02	3.200E-01	1.200E-01	1.600E+00	2.090E+05	3.000E-04
	7.000E-05	3.000E-04	7.000E-04	8.000E-05	4.400E-08	2.300E-07	2.200E-05	1.700E-06
	3.000E-06	1.200E-07	5.300E-04	5.000E-05				
6	10.000	264.990	223.252	0.000	0.000	0.000	0.000	0.000
	2.000E+01	3.220E+02	1.300E-01	3.200E-01	1.000E-01	1.600E+00	2.090E+05	3.000E-04

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Table 4b. Sample Input and Output – Case 2 (Contd)

```
6.000E-05 3.000E-04 5.500E-04 9.000E-05 4.700E-08 6.000E-07 2.400E-05 1.700E-06
3.000E-06 2.000E-07 5.200E-04 3.400E-05
7  12.000 193.990                          0.000     0.000     0.000
6.000E+00 3.220E+02 3.100E-01 8.000E-02 1.600E+00 2.090E+05 3.000E-04
5.500E-05 3.000E-04 1.000E-04 4.900E-08 2.000E-06 3.000E-05 1.700E-06
3.000E-06 4.000E-07 5.000E-04 3.300E-05
8  14.000 141.700                          0.000     0.000     0.000
2.900E+00 3.220E+02 5.000E-01 3.000E-01 5.000E-02 1.500E+00 2.090E+05 3.000E-04
5.600E-05 3.300E-04 2.000E-04 5.300E-08 4.500E-06 1.000E-05 1.700E-06
3.000E-06 7.000E-07 4.700E-04 3.700E-05
9  16.000 103.520                          0.000     0.000     0.000
3.200E+00 3.270E+02 8.500E-01 2.900E-01 3.000E-02 1.500E+00 2.090E+05 2.700E-04
6.000E-05 3.500E-04 1.000E-04 3.000E-04 8.100E-08 1.000E-05 2.500E-04 1.700E-06
3.000F-06 1.300E-06 3.900E-04 3.600E-05
10 18.000  75.652                          0.000     0.000     0.000
3.400E+00 3.220E+02 1.600E+00 2.700E-01 2.000E-02 1.400E+00 2.090E-05 2.300E-04
5.000E-05 4.000E-04 1.000E-05 1.100E-03 1.300E-07 2.500E-05 4.000E-04 1.700E-06
3.000E-06 2.500E-06 3.100E-04 3.400E-05
11 20.000  55.293                          0.000     0.000     0.000
3.500E+00 3.220E+02 2.600E+00 2.400E-01 1.500E-02 1.300E+00 2.090E+05 2.500E-04
3.100E-05 9.000E-04 1.000E-06 2.000E-03 1.300E-07 6.000E-05 5.000E-04 1.700E-06
3.000E-06 6.000E-06 2.400E-04 3.300E-05
12 22.000  40.475                          0.000     0.000     0.000
3.500E+00 3.220E+02 3.600E+00 2.000E-01 1.600E-02 1.100E+00 2.090E+05 3.000E-04
2.200E-05 1.200E-03 1.000E-07 3.000E-03 5.200E-07 1.000E-04 5.500E-04 1.700E-06
3.000E-06 1.000E-05 1.900E-04 4.000E-05
13 24.000  29.717 220.560                  0.000     0.000     0.000
```

Table 4b. Sample Input and Output – Case 2 (Contd)

```
      3.500E+00 3.220E+02 4.700E+00 1.600E-01 1.700E-02 1.000E+00 2.090E+05 4.000E-04
      1.900E-05 2.200E-03 1.000E-07 4.000E-03 1.000E-06 1.500E-04 6.000E-04 1.700E-06
      3.000E-06 2.000E-05 1.400E-04 5.000E-05

14    26.000 222.544    0.000     0.000     0.000     0.000
      3.700E+00 3.220E+02 5.700E+00 1.300E-01 1.800E-02 9.300E-01 2.090E+05 8.000E-04
      1.700E-05 3.100E-03 1.000E-07 3.500E-03 2.900E-06 2.000E-04 6.500E-04 1.700E-06
      3.000E-06 5.000E-05 1.100E-04 6.000E-05

15    28.000 224.527    0.000     0.000     0.000     0.000
      3.900E+00 3.220E+02 6.200E+00 1.100E-01 1.900E-02 8.600E-01 2.090E+05 1.500E-03
      1.500E-05 4.500E-03 1.000E-07 3.000E-03 6.100E-06 2.500E-04 7.000E-04 1.700E-06
      3.000E-06 1.000E-04 7.000E-05 8.000E-05

16    30.000 226.509    0.000     0.000     0.000     0.000
      4.100E+00 3.220E+02 6.600E+00 9.000E-02 2.000E-02 8.000E-01 2.090E+05 2.500E-03
      1.300E-05 7.500E-03 1.000E-07 2.000E-03 1.000E-05 3.000E-04 1.000E-03 1.800E-06
      3.000E-06 2.000E-04 3.000E-05 9.000E-05

17    32.000 228.490    0.000     0.000     0.000     0.000
      4.200E+00 3.220E+02 7.200E+00 7.000E-02 2.200E-02 7.300E-01 2.090E+05 4.000E-03
      1.200E-05 7.000E-03 1.000E-07 1.000E-03 2.800E-05 3.200E-04 1.200E-03 2.100E-06
      3.000E-06 4.000E-04 1.700E-05 1.000E-04

18    34.000 233.743    0.000     0.000     0.000     0.000
      4.300E+00 3.220E+02 7.700E+00 5.000E-02 2.400E-02 6.600E-01 2.090E+05 7.000E-03
      1.100E-05 5.500E-03 1.000E-07 6.000E-04 5.800E-05 3.400E-04 1.600E-03 2.400E-06
      3.000E-06 5.000E-04 6.000E-06 1.100E-04

19    36.000 239.282    0.000     0.000     0.000     0.000
      4.400E+00 3.220E+02 8.100E+00 3.200E-02 2.700E-02 5.700E-01 2.090E+05 9.000E-03
      1.100E-05 5.000E-03 1.000E-07 3.500E-04 1.300E-04 3.600E-04 1.800E-03 3.100E-06
      3.000E-06 6.000E-04 2.500E-06 1.200E-04

20    38.600 244.818    0.000     0.000     0.000     0.000
```

Table 4b. Sample Input and Output – Case 2 (Contd)

```
       4.400E+00 3.220E+02 7.800E+00 2.200E-02 3.000E-02 4.800E-01 2.050E+05 1.000E-02
       1.200E-05 4.500E-03 1.000E-07 2.000E-04 2.200E-04 3.800E-04 1.700E-03 3.900E-06
       3.000E-06 7.000E-04 1.000E-06 1.200E-04

21     40.000    2.871   250.350      0.000     0.000     0.000     0.000
       4.500E+00 3.220E+02 7.300E+00 1.600E-02 3.000E-02 4.000E-01 2.090E+05 1.200E-02
       1.300E-05 3.500E-03 1.000E-07 1.000E-04 3.100E-04 4.000E-04 1.500E-03 5.100E-06
       3.000E-06 7.200E-04 5.000E-07 1.100E-04

22     42.000    2.120   255.878      0.000     0.000     0.000     0.000
       4.500E+00 3.220E+02 6.400E+00 1.000E-02 3.000E-02 3.200E-01 2.090E+05 1.100E-02
       1.500E-05 3.000E-03 1.000E-07 7.000E-05 4.000E-04 4.100E-04 1.400E-03 6.400E-06
       3.000E-06 6.000E-04 2.000E-07 9.500E-05

23     44.000    1.695   261.403      0.000     0.000     0.000     0.000
       4.500E+00 3.220E+02 5.800E+00 7.000E-03 3.000E-02 2.500E-01 2.090E+05 1.000E-02
       1.300E-05 2.500E-03 1.000E-07 4.000E-05 5.000E-04 4.200E-04 1.300E-03 7.000E-06
       3.000E-06 3.000E-04 3.000E-08 8.000E-05

24     46.000    1.313   266.925      0.000     0.000     0.000     0.000
       4.600E+00 3.220E+02 4.700E+00 4.000E-03 3.000E-02 2.000E-01 2.090E+05 1.000E-02
       2.300E-05 2.000E-03 1.000E-07 2.000E-05 6.000E-04 4.300E-04 1.300E 03 7.300E-06
       3.000E-06 1.700E-04 2.500E-08 6.500E-05

25     48.000    1.023   270.650      0.000     0.000     0.000     0.000
       4.800E+00 3.220E+02 3.800E+00 2.000E-03 3.000E-02 1.500E-01 2.090E+05 1.000E-02
       3.100E-05 1.500E-03 1.000E-07 1.000E-05 7.000E-04 4.400E-04 1.300E-03 7.400E-06
       3.000E-06 1.300E-04 1.000E-08 5.100E-05

26     50.000     .798   270.650      0.000     0.000     0.000     0.000
       5.000E+00 3.220E+02 3.100E+00 1.000E-03 3.000E-02 1.000E-01 2.090E+05 1.000E-02
       3.500E-05 1.000E-03 1.000E-07 5.000E-06 8.000E-04 4.500E-04 1.300E-03 7.400E-06
       3.000E-06 1.000E-04 1.000E-08 4.000E-05
```

Table 4b. Sample Input and Output – Case 2 (Contd)

27	55.000	.425	260.771	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	5.000E+00	0.	0.	0.	0.	0.	0.	0.	0.	0.
	0.	0.	0.							
	0.	0.	0.							
28	60.000	.220	247.021	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	5.000E+00	0.	0.	0.	0.	0.	0.	0.	0.	0.
	0.	0.	0.							
	0.	0.	0.							
29	65.000	.109	233.292	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	5.000E+00	0.	0.	0.	0.	0.	0.	0.	0.	0.
	0.	0.	0.							
	0.	0.	0.							
30	70.000	.052	219.585	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	5.000E+00	0.	0.	0.	0.	0.	0.	0.	0.	0.
	0.	0.	0.							
	0.	0.	0.							
31	75.000	.024	209.399	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	5.000E+00	0.	0.	0.	0.	0.	0.	0.	0.	0.
	0.	0.	0.							
	0.	0.	0.							
32	80.000	.011	198.639	0.000	0.000	0.000	0.000	0.000	0.300	0.000
	5.000E+00	0.	0.	0.	0.	0.	0.	0.	0.	0.
	0.	0.	0.							
	0.	0.	0.							
33	85.000	.005	188.893	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	5.000E+00	0.	0.	0.	0.	0.	0.	0.	0.	0.
	0.	0.	0.							
	0.	0.	0.							

Table 4b. Sample Input and Output – Case 2 (Contd)

	Z							
34	90.000	.002	166.873	0.000	0.000	0.000	0.000	0.000
	5.000E+00	0.	0.	0.	0.	0.		
	0.	0.	0.	0.	0.	0.		
	0.	0.	0.	0.	0.	0.		
35	95.000	.001	188.420	0.000	0.000	0.000	0.000	0.000
	5.000E+00	0.	0.	0.	0.	0.		
	0.	0.	0.	0.	0.	0.		
	0.	0.	0.	0.	0.	0.		
36	100.000	.000	195.080	0.000	0.000	0.000	0.000	0.000
	5.000E+00	0.	0.	0.	0.	0.		
	0.	0.	0.	0.	0.	0.		
	0.	0.	0.	0.	0.	0.		

1ATMOSPHERIC PROFILE SELECTED IS: M = 7   US 76 + TRACE GASES

DENSITY (MOLS CM-3)

I	Z (KM)	P (MB)	T (K)	REFRACT INDEX-1 *1.0E6	AIR	H2O / SO2 / HI	CO2 / NO2 / CLO	O3 / NH3 / OCS	N2O / HNO3 / H2CO	CO / OH	CH4 / HF	O2 / HCL	NO. / HBR
1	0.000	1013.250	288.150	271.956	2.55E+19	2.55E+17 7.64E+09 7.64E-07	8.20E+15 7.64E+09 2.55E+06	8.40E+11 3.31E+10 1.53E+10	8.15E+12 7.64E+08 6.11E+10	3.82E+12 1.12E+06	4.33E+13 2.55E+05	5.32E+18 2.55E+09	7.64E+09 4.33E+07
2	2.000	795.010	275.154	223.485	2.09E+19	2.03E+17 5.23E+09 6.28E+06	6.74E+15 6.28E+09 2.09E+06	6.91E+11 2.51E+10 1.21E+10	6.70E+12 8.37E+08 5.28E+09	2.93E+12 9.21E+05	3.56E+13 2.09E+05	4.37E+18 1.36E+09	6.28E+09 3.56E+07
3	4.000	616.600	262.166	182.088	1.70E+19	6.47E+16 2.38E+09 5.11E+07	5.49E+15 5.11E+09 1.70E+06	5.79E+11 1.70E+10 1.70E+10	5.45E+12 8.52E+08 5.11E+05	2.21E+12 7.50E+05	2.90E+13 5.11E+05	3.56E+18 5.62E+08	5.11E+09 2.90E+07
4	6.000	472.170	249.187	146.750	1.37E+19	2.06E+16 1.30E+09 4.12E+09	4.42E+15 4.12E+09 1.17E+09	5.63E+11 1.17E+10 1.17E+09	4.39E+12 9.61E+08 1.24E+06	1.78E+12 6.04E+05	2.33E+13 1.24E+06	2.87E+18 3.57E+08	4.12E+09 2.33E+07
5	8.000	356.510	236.215	116.902	1.09E+19	7.11E+15 7.65E+08 3.28E+07	3.52E+15 3.28E+09 7.55E+06	6.56E+11 7.55E+09 9.61E+08	3.50E+12 8.75E+08 2.51E+06	1.31E+12 4.81E+05	1.75E+13 2.51E+06	2.28E+18 2.40E+08	3.28E+09 1.86E+07
6	10.000	264.990	223.252	91.945	8.60E+18	1.64E+06 2.58E+07	2.77E+15 2.58E+09 1.72E+06	4.73E+11 1.12E+12 7.65E+08	2.75E+12 7.74E+08 5.16E+06	8.60E+11 4.04E+05	1.38E+13 5.16E+06	1.80E+18 2.06E+08	2.58E+09 1.46E+07
7	12.000	193.990	216.650	69.361	6.49E+18	3.89E+13 3.57E+08 1.95E+07	2.09E+15 1.95E+09 2.01E+12	2.59E+11 2.59E+09 6.49E+08	2.01E+12 6.49E+08 1.30E+07	5.19E+11 3.18E+05	1.04E+13 1.30E+07	1.36E+18 1.95E+08	1.95E+09 1.10E+07
8	14.000	141.700	216.650	50.665	4.74E+18	1.37E+13 3.24E+09 2.14E+08	1.53E+15 2.37E+15	2.35E+11	1.42E+12	2.37E+11	7.11E+12	9.90E+17	1.42E+09

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Table 4b. Sample Input and Output - Case 2 (Contd)

#													
9	16.000	103.520	216.650	37.014	3.46E+18	2.65E-08	1.56E+09	1.42E+09	9.47E+08	2.51E+05	2.13E+07	4.74E+07	8.95E+06
10	18.000	75.652	216.650	27.049	2.53E+13					5.19E+12	7.23E+17	9.34E+08	5.52E+08
11	20.000	55.293	216.650	19.770	1.85E+18					3.46E+07	3.65E+08	5.88E+06	4.30E+06
12	22.000	40.475	218.574	14.344	1.34E+18								4.62E+08
13	24.000	29.717	220.560	10.437	9.76E+17								3.14E+06
14	26.000	21.883	222.544	7.617	7.12E+17								4.02E+08
15	28.000	16.161	224.527	5.576	5.21E+17								2.28E+06
16	30.000	11.970	226.509	4.094	3.83E+17								3.90E+08
17	32.000	8.891	228.490	3.314	2.82E+17								1.66E+06
18	34.000	6.634	233.743	2.199	2.06E+17								5.70E+08
19	36.000	4.985	239.282	1.614	1.51E+17								1.21E+06
20	38.000	3.771	244.818	1.193	1.12E+17								7.82E+08
21	40.000	2.871	250.350	.888	8.31E+16								8.86E+05
22	42.000	2.120	255.878	.642	6.00E+16								9.57E+08
23	44.000	1.695	261.403	.502	4.70E+16								6.89E+05
24	46.000	1.313	266.925	.381	3.56E+16								1.13E+09
25	48.000	1.023	270.650	.293	2.74E+16								5.92E+05
26	50.000	.7??	270.650	.228	2.14E+16								1.44E+09

Table 4b. Sample Input and Output - Case 2 (Contd)

					6.41E-04	2.14E+06	2.14E+02			8.54E+05				
27	55.000	260.771	.425	.126	1.18E+16	5.91E+10	3.80E+12	0.	0.	3.19E+09	2.24E+09	1.77E+10	2.47E+15	0. 0.
28	60.000	247.021	.220	.069	6.44E+15	3.22E+10	2.07E+12	0.	0.	.74E+09	1.22E+09	9.66E+09	1.35E+15	0. 0.
29	65.000	233.292	.109	.036	3.39E+15	1.70E+10	1.09E+12	0.	0.	9.16E+08	6.45E+08	5.09E+09	7.11E+14	0. 0.
30	70.000	219.585	.052	.018	1.72E+15	8.61E+09	5.54E+11	0.	0.	4.65E+08	3.27E+08	2.58E+09	3.61E+14	0. 0.
31	75.000	208.399	.024	.009	8.31E+14	4.15E+09	2.67E+11	0.	0.	2.24E+08	1.58E+08	1.25E+09	1.74E+14	0. 0.
32	80.000	198.630	.011	.004	3.83E+14	1.91E+09	1.23E+11	0.	0.	1.03E+08	7.27E+07	5.74E+08	8.02E+13	0. 0.
33	85.000	188.893	.005	.002	1.73E+14	8.63E+08	5.56E+10	0.	0.	4.66E+07	3.28E+07	2.59E+08	3.61E+13	0. 0.
34	90.000	186.870	.002	.001	6.98E+13	3.49E+08	2.25E+10	0.	0.	1.88E+07	1.33E+07	1.05E+08	1.46E+13	0. 0.
35	95.000	188.420	.001	.000	3.08E+13	1.54E+08	9.90E+09	0.	0.	8.30E+06	5.84E+06	4.61E+07	5.44E+12	0. 0.
36	100.000	195.080	.000	.000	1.11E+13	5.57E+07	3.59E+09	0.	0.	3.01E+06	2.12E+06	1.67E+07	2.33E+12	0. 0.

CASE 3A: GIVEN H1,H2=SPACE,ANGLE

SLANT PATH PARAMETERS IN STANDARD FORM

```
H1     =   33.000 KM
H2     =  100.000 KM
ANGLE  =   94.870 DEG
PHI    =   99.572 DEG
HMIN   =    9.255 KM
LEN    =    1
```

FASCODE LAYER BOUNDARIES PRODUCED BY THE AUTOMATIC LAYERING ROUTINE AUTLAY
THE USER SHOULD EXAMINE THESE BOUNDARIES AND MODIFY THEM IF APPROPRIATE
THE FOLLOWING PARAMETERS ARE USED:

```
AVTRAT  =   2.00   = MAX RATIO OF VOIGT WIDTHS
TDIFF1  =  50.00   = MAX TEMP DIFF AT HMIN
TDIFF2  =  50.00   = MAX TEMP DIFF AT HMAX
```

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Table 4b. Sample Input and Output – Case 2 (Contd)

```
ALZERO  =     .100 CM-1  = AVERAGE LORENTZ WIDTH AT STP
AVMWT   =   36.00        = AVERAGE MOLECULAR WEIGHT
VBAR    =  825.00 CM-1   = AVERAGE WAVENUMBER
```

I	Z (KM)	P (MB)	T (K)	LORENTZ (CM-1)	DOPPLER (CM-1)	ZETA	VOIGT (CM-1)	VOIGT RATIO	TEMP DIFF (K)
1	9.255	295.960	228.082	.03327	.00074	.978	.03329	1.97	11.4
2	13.800	146.221	216.650	.01687	.00072	.959	.01690	1.98	0.0
3	18.200	73.317	216.650	.00646	.00072	.921	.00652	1.99	2.6
4	22.700	36.326	219.269	.00417	.00073	.851	.00429	2.00	5.1
5	27.800	16.658	224.329	.00189	.00074	.719	.00214	2.00	15.5
6	36.200	4.848	239.836	.00074	.00076	.411	.00107	1.58	50.0
7	84.500	.005	189.868	.00000	.00068	.001	.00068	.99	5.2
8	100.000	.000	195.080	.00000	.00069	.000	.00069	0.00	0.0

1CALCULATION OF THE REFRACTED PATH THROUGH THE ATMOSPHERE

I	ALTITUDE FROM (KM)	TO (KM)	THETA (DEG)	DRANGE (KM)	RANGE (KM)	DBETA (DEG)	BETA (DEG)	PHI (DEG)	DBEND (DEG)	BENDING (DEG)	PBAR (MB)	TBAR (K)	RHOBAR (MOL CM-3)
	TANGENT HEIGHT H1												
1	9.255	10.000	90.000	101.441	101.441	.911	.911	90.843	.068	.063	285.647	226.502	9.13E+18
2	10.000	12.000	89.157	93.235	194.677	.837	1.748	91.618	.061	.129	233.072	220.435	7.60E+18
3	12.000	13.800	88.382	55.690	250.367	.500	2.247	92.087	.030	.160	171.107	216.650	5.68E+18
4	13.800	14.000	87.913	5.431	255.798	.049	2.296	92.134	.003	.162	143.963	216.650	4.81E+18
5	14.000	16.000	87.866	48.925	304.723	.439	2.735	92.553	.019	.181	123.174	216.650	4.08E+18
6	16.000	18.000	87.447	41.922	346.644	.376	3.110	92.917	.012	.193	89.890	216.650	2.98E+18
7	18.000	18.200	87.083	3.908	350.552	.035	3.145	92.951	.001	.194	74.485	216.650	2.49E+18
8	18.200	20.000	87.049	33.325	383.877	.298	3.443	93.242	.007	.201	64.443	216.650	2.14E+18
9	20.000	22.000	86.758	33.816	417.693	.303	3.746	93.539	.005	.207	48.001	217.546	1.58E+18
10	22.000	22.700	86.461	11.183	428.876	.100	3.846	93.638	.001	.208	38.410	218.914	1.27E+18
11	22.700	24.000	86.252	20.002	448.878	.179	4.025	93.815	.002	.210	33.049	219.887	1.08E+18
12	24.000	26.000	86.185	29.081	477.959	.260	4.285	94.072	.002	.212	25.847	221.488	8.39E+17
13	26.000	27.800	85.928	24.684	502.643	.220	4.505	94.291	.001	.214	19.296	223.386	6.22E+17
14	27.800	29.000	85.709	2.665	505.308	.024	4.529	94.315	.000	.214	16.410	224.427	5.30E+17
15	29.000	30.000	85.685	25.893	531.201	.231	4.760	94.545	.001	.215	14.086	225.457	4.49E+17
16	30.000	32.000	85.455	24.646	555.847	.220	4.980	94.764	.001	.216	10.444	227.440	3.30E+17
17	32.000	33.000	85.236	11.908	567.755	.106	5.086	94.870	.000	.216	8.289	229.762	2.61E+17
0	DOUBLE RANGE, BETA, BENDING FOR SYMMETRIC PART OF PATH				1135.511		10.172			.432			
	H1 TO H2												
18	33.000	34.000	85.130	11.656	1147.166	.104	10.276	94.974	.000	.432	7.160	232.389	2.23E+17
19	34.000	36.000	85.026	22.613	1169.779	.201	10.478	95.175	.000	.432	5.818	236.342	1.77E+17
20	36.000	36.200	84.825	2.213	1171.992	.020	10.497	95.194	.000	.433	4.916	239.557	1.49E+17
21	36.200	38.000	84.806	19.555	1191.548	.174	10.671	95.368	.000	.433	4.314	242.193	1.28E+17
22	38.000	40.000	84.632	21.013	1212.561	.187	10.858	95.555	.000	.433	3.325	247.423	9.67E+16
23	40.000	42.000	84.445	20.331	1232.892	.181	11.039	95.726	.000	.433	2.499	252.941	7.10E+16
24	42.000	44.000	84.264	19.712	1252.604	.175	11.214	95.911	.000	.434	1.909	258.505	5.33E+16

25	44.000	46.000	84.089	19.147	1271.751	.170	11.394	96.081	.000	.434	1.506	264.015	4.11E+16
26	46.000	48.000	83.919	18.628	1290.379	.165	11.550	96.246	.000	.434	1.169	268.694	3.13E+16
27	48.000	50.000	83.754	13.150	1308.529	.161	11.711	95.407	.000	.434	.911	270.650	2.43E+16
28	50.000	55.000	83.593	43.504	1352.033	.385	12.096	96.792	.000	.434	.612	266.211	1.62E+16
29	55.000	60.000	83.208	41.176	1393.209	.364	12.460	97.157	.000	.434	.322	254.583	8.88E+15
30	60.000	65.000	82.843	39.191	1432.401	.346	12.807	97.503	.000	.434	.164	240.871	4.77E+15
31	65.000	70.000	82.497	37.472	1469.872	.330	13.137	97.833	.000	.434	.081	227.186	2.47E+15
32	70.000	75.000	82.167	35.964	1505.836	.317	13.454	98.150	.000	.434	.038	214.652	1.23E+15
33	75.000	80.000	81.850	34.528	1540.464	.304	13.758	98.454	.000	.434	.017	204.132	5.79E+14
34	80.000	84.500	81.546	30.140	1570.603	.265	14.023	98.719	.000	.434	.008	194.762	2.74E+14
35	84.500	85.000	81.281	3.293	1573.896	.029	14.052	98.748	.000	.434	.005	189.386	1.80E+14
36	85.000	90.000	81.252	32.356	1606.252	.284	14.335	99.031	.000	.434	.003	188.035	1.14E+14
37	90.000	95.000	80.969	31.379	1637.631	.275	14.610	99.306	.000	.434	.001	187.536	4.77E+13
38	95.000	100.000	80.694	30.488	1668.119	.266	14.876	99.572	.000	.434	.001	191.163	1.94E+13

1INTEGRATED ABSORBER AMOUNTS BY LAYER

INTEGRATED AMOUNTS (MOL CM-2)

I	FROM (KM)	TO (KM)	AIR	H2O / SO2 / HI	CO2 / NO2 / CLO	O3 / NH3 / OCS	N2O / HNO3 / H2CO	CO / OH	CH4 / HF	O2 / HCL	NO / HBR
1	9.255	10.000	9.258E+25	4.747E+21	2.982E+22	9.949E+18	2.963E+19	9.696E+18	1.482E+20	1.935E+25	2.778E+16
				5.776E+15	2.778E+16	5.413E+16	8.092E+16	4.281E+12	4.392E+13	2.174E+15	1.574E+14
				2.778E+14	1.724E+13	4.838E+16	3.472E+15				
2	10.000	12.000	7.089E+25	4.004E+20	2.283E+22	1.375E+19	2.238E+19	6.462E+18	1.134E+20	1.482E+25	2.127E+16
				4.100E+15	2.127E+16	3.420E+16	6.675E+15	3.391E+12	7.533E+13	1.874E+15	1.205E+14
				2.127E+14	1.941E+13	3.626E+16	2.380E+15				
3	12.000	13.800	3.165E+25	1.434E+20	1.019E+22	1.203E+19	9.680E+18	2.103E+18	4.932E+19	6.614E+24	9.494E+15
				1.754E+15	9.376E+15	1.128E+16	4.274E+15	1.602E+12	9.024E+13	6.294E+14	5.380E+13
				9.494E+13	1.609E+13	1.543E+16	1.095E+15				
4	13.800	14.000	2.614E+24	7.863E+18	8.415E+20	1.276E+18	7.853E+17	1.338E+17	3.933E+18	5.462E+23	7.841E+14
				1.462E+14	8.583E+14	7.955E+14	5.049E+14	1.380E+11	1.129E+13	2.763E+13	4.443E+12
				7.841E+12	1.779E+12	1.232E+15	9.615E+13				
5	14.000	16.000	1.998E+25	6.066E+19	6.435E+21	1.290E+19	5.903E+18	7.987E+17	2.998E+19	4.177E+24	5.715E+15
				1.155E+15	6.776E+15	3.800E+15	5.049E+14	1.297E+12	1.332E+14	1.327E+15	3.307E+13
				5.995E+13	1.889E+13	8.633E+15	7.302E+14				
6	16.000	18.000	1.250E+25	4.113E+19	4.024E+21	1.447E+19	5.507E+18	3.128E+18	1.816E+19	2.612E+24	3.136E+15
				6.900E+14	4.656E+15	5.275E+14	3.339E+15	1.272E+12	1.978E+14	3.919E+15	2.124E+13
				3.749E+13	2.238E+13	4.392E+15	4.382E+14				
7	18.000	18.200	9.730E+23	3.313E+18	3.133E+20	1.595E+18	2.612E+17	1.918E+16	1.357E+18	2.034E+23	2.247E+14
				4.751E+13	4.053E+14	8.666E+12	1.103E+15	1.289E+11	2.542E+13	3.936E+14	1.554E+12
				2.919E+12	2.542E+12	2.978E+14	3.303E+13				
8	18.200	20.000	7.132E+24	2.462E+19	2.297E+21	1.492E+19	1.812E+18	1.231E+17	3.608E+18	1.491E+24	1.714E+15
				2.800E+14	4.454E+15	2.536E+13	1.085E+16	1.136E+12	2.890E+14	3.211E+15	1.213E+13
				2.140E+13	2.890E+13	1.939E+15	2.388E+14				
9	20.000	22.000	5.360E+24	1.876E+19	1.725E+21	1.629E+19	1.183E+18	8.286E+16	6.453E+18	1.120E+24	1.461E+15
				1.608E+14	5.535E+15	2.247E+12	1.304E+16	1.698E+12	4.125E+14	2.803E+15	9.111E+12
				1.423E+13	1.725E+13	1.156E+15	1.938E+14				
10	22.000	22.700	1.420E+24	4.969E+18	4.571E+20	5.351E+18	2.734E+17	2.295E+16	1.537E+18	2.967E+23	4.476E+14
				3.046E+13	1.893E+14	1.420E+11	4.476E+15	8.275E+11	1.523E+14	7.926E+14	2.414E+12
				4.259E+12	1.602E+13	2.561E+14	5.901E+13				
11	22.700	24.000	2.170E+24	7.595E+18	9.987E+20	9.350E+18	3.748E+17	3.614E+16	2.242E+18	4.535E+23	7.386E+14
				4.334E+13	3.913E+14	2.170E+11	7.886E+15	1.752E+12	2.846E+14	1.264E+15	3.669E+12
				6.510E+12	3.461E+13	3.374E+14	1.007E+14				
12	24.000	26.000	2.438E+24	8.761E+18	7.852E+20	1.256E+19	3.545E+17	4.258E+16	2.357E+18	5.096E+23	1.377E+15

Table 4b. Sample Input and Output – Case 2 (Contd)

13	26.000	1.535E+24							
14	27.800	1.411E+23							
15	28.000	1.163E+24							
16	30.000	8.136E+23							
17	32.000	3.105E+23							
18	33.000	2.596E+23							
19	34.000	4.002E+23							
20	36.000	3.290E+22							
21	36.200	2.509E+23							
22	38.000	2.032E+23							
23	40.000	1.443E+23							
24	42.000	1.050E+23							
25	44.000	7.862E+22							
26	46.000	5.838E+22							
27	48.000	4.402E+22							
28	50.000	7.031E+22							
29	55.000	3.656E+22							
30	60.000	1.868E+22							

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Table 4b. Sample Input and Output – Case 2 (Contd)

```
 L   FROM     TO      AIR        H2O        CO2        O3         N2O        CO         CH4/O2
(KM)  (KM)
31  65.000  70.000  9.254E+21  4.627E+16  2.980E+18  2.499E+15  1.758E+15  1.388E+16  1.939E+21   0.
                    0.         0.         0.         0.          0.        0.         0.           0.
32  70.000  75.000  4.407E+21  2.204E+16  1.419E+18  1.190E+15  8.373E+14  6.611E+15  9.232E+20   0.
                    0.         0.         0.         0.          0.        0.         0.           0.
33  75.000  80.000  2.007E+21  1.003E+16  6.461E+17  5.418E+14  3.812E+14  3.010E+15  4.203E+20   0.
                    0.         0.         0.         0.          0.        0.         0.           0.
34  80.000  84.500  8.250E+20  4.125E+15  2.656E+17  2.227E+14  1.567E+14  1.237E+15  1.728E+20   0.
                    0.         0.         0.         0.          0.        0.         0.           0.
35  84.500  85.000  5.914E+19  2.957E+14  1.904E+16  1.597E+13  1.124E+13  8.872E+13  1.239E+19   0.
                    0.         0.         0.         0.          0.        0.         0.           0.
36  85.000  90.000  3.681E+20  1.841E+15  1.185E+17  9.939E+13  6.994E+13  5.522E+14  7.711E+19   0.
                    0.         0.         0.         0.          0.        0.         0.           0.
37  90.000  95.000  1.497E+20  7.487E+14  4.821E+16  4.043E+13  2.845E+13  2.246E+14  3.137E+19   0.
                    0.         0.         0.         0.          0.        0.         0.           0.
38  95.000 100.000  5.901E+19  2.951E+14  1.900E+16  1.593E+13  1.121E+13  8.852E+13  1.236E+19   0.
                    0.         0.         0.         0.          0.        0.         0.           0.

OTOTAL 33.000 100.000
       AIR  = 5.090E+26
       H2O  = 1.198E+22   SO2 = 2.856E+16   HI  = 1.527E+15
       CO2  = 1.639E+23   NO2 = 2.362E+17   CLO = 2.728E+15
       O3   = 1.532E+20   NH3 = 2.096E+17   OCS = 2.377E+15
       N2O  = 3.106E+20   HNO3= 1.767E+17   H2CO= 1.875E+16
       CO   = 3.988E+19   OH  = 5.206E+14
       CH4  = 7.806E+20   HF  = 4.917E+16
       O2   = 1.064E+26   HCL = 6.968E+15
       NO   = 1.792E+17   HBR = 8.701E+14
```

1 SUMMARY OF THE GEOMETRY CALCULATION

```
     MODEL    =   US 76 + TRACE GASES
     H1       =     33.000  KM
     H2       =    100.000  KM
     ANGLE    =     94.870  DEG
     RANGE    =   1668.119  KM
     BETA     =     14.876  DEG
     PHI      =     99.572  DEG
     HMIN     =      9.255  KM
     BENDING  =       .434  DEG
     LEN      =          1
     AIRMAS   =       23.6   RELATIVE TO A VERTICAL PATH , GROUND TO SPACE
```

OFINAL SET OF LAYERS FOR INPUT TO FASCOD1
A LAYER AMOUNT MAY BE SET TO ZERO IF THE CUMULATIVE AMOUNT FOR THAT LAYER AND ABOVE IS LESS THAN 0.1 PERCENT
OF THE TOTAL AMOUNT. THIS IS DONE ONLY FOR THE FOLLOWING CASES
  1. IEMIT = 0 (TRANSMITTANCE)
  2. IEMIT = 1 (RADIANCE) AND ICNTRL = 3 (PATH LOOKING UP)
O2 IS NOT INCLUDED
IF THE AMOUNTS FOR ALL THE MOLECULES BUT O2 ARE ZEROED, THE REMAINING LAYERS ARE ELIMINATED

L	LAYER BOUNDARIES		ICNTRL	PBAR	TBAR	INTEGRATED AMOUNTS (MOLS CM-2)								
	FROM (KM)	TO (KM)		(MB)	(K)	AIR	H2O SO2 HI	CO2 NO2 CLO	O3 NH3 OCS	N2O HNO3 H2CO	CO OH	CH4 HF	O2 HCL	NO HBR

Table 4b. Sample Input and Output – Case 2 (Contd)

```
1   9.255  13.800  247.97  2  222.70  1.95E+26  5.79E+21 6.28E+22 3.57E+19 6.17E+19 1.83E+19 3.11E+20 4.08E+25 5.85E+16
                                                 1.16E+16 5.89E+16 9.96E+16 1.90E+16 9.27E+12 2.09E+14 4.68E+15 3.32E+14
                                                 5.85E+14 5.27E+13 1.00E+17 6.95E+15

2  13.800  18.200  111.83  2  216.65  3.61E+25  1.13E+20 1.16E+22 3.02E+19 1.05E+19 1.26E+18 5.34E+19 7.54E+24 9.86E+15
                                                 2.04E+15 1.27E+16 5.13E+15 1.38E+16 2.84E+12 3.68E+14 5.67E+15 6.13E+13
                                                 1.08E+14 4.56E+13 1.46E+16 1.30E+15

3  18.200  22.700   55.45  2  217.23  1.39E+25  4.83E+19 4.48E+21 3.65E+19 3.27E+18 2.29E+17 1.76E+19 2.91E+24 3.62E+15
                                                 4.53E+14 1.19E+16 0.       2.84E+16 3.66E+12 8.54E+14 6.81E+15 2.37E+13
                                                 4.17E+13 8.62E+13 3.35E+15 4.92E+14

4  22.700  27.800   26.75  2  221.40  6.14E+24  2.22E+19 1.98E+21 3.10E+19 9.15E+17 1.07E+17 5.98E+19 1.28E+24 3.79E+15
                                                 1.12E+14 1.58E+16 0.       2.21E+16 1.22E+13 1.04E+15 3.81E+15 1.04E+13
                                                 1.84E+13 2.17E+14 7.83E+14 3.38E+14

5  27.800  33.000   12.26  2  226.61  2.43E+24  9.88E+18 7.82E+20 1.62E+19 2.18E+19 4.93E+16 1.93E+18 5.07E+23 6.44E+15
                                                 3.23E+13 1.53E+16 0.       4.80E+15 3.41E+13 7.05E+14 2.35E+15 4.52E+12
                                                 7.28E+12 5.39E+14 2.18E+14

6  33.000  36.200    6.28  3  235.01  6.93E+23  0.       2.23E+20 5.39E+18 0.       1.71E+16 4.41E+17 1.45E+23 5.04E+15
                                                 3.79E+15 0.       5.18E+13 2.39E+14 1.12E+15 1.79E+12
                                                 2.08E+12 3.61E+14 0.       7.77E+13

7  36.200  84.500    2.54  3  252.50  1.03E+24  0.       3.30E+20 6.12E+18 0.       0.       0.       2.15E+23 9.65E+15
                                                 0.       3.14E+15 0.       3.73E+14 1.41E+15 4.97E+12
                                                 2.79E+12 4.86E+14 0.       9.05E+13
```

Table 4c. Sample Input and Output – Case 3

```
****INPUT CASE 3***************************************************************
 6    2   25    1    1
100.0     0.0   180.0
690.0   700.0
  2.0     4.0     6.0     8.0    10.0    12.0    14.0    16.0
 18.0    20.0    22.0    24.0    26.0    26.0    30.0    32.0
 34.0    36.0    38.0    40.0    42.0    44.0    46.0    48.0
 50.0
****OUTPUT CASE 3**************************************************************

1
              ****PROGRAM FSCATM****       01/11/83       11.03.55.


CONTROL CARD 1: MODEL AND OPTIONS

          MODEL  =   6
          ITYPE  =   2
          ISND   =  25
          NOZERO =   1
          NOPRNT =   1
          KMAX   =   0
          IPUNCH =   0
          RE     =   0.000 KM


CONTROL CARD 1 PARAMETERS WITH DEFAULTS:

          MODEL  =   6
          ITYPE  =   2
          IBND   =  25
          NOZERO =   1
          NOPRNT =   1
          KMAX   =   7
          IPUNCH =   0
          RE     =  6371.230 KM


SLANT PATH SELECTED. ITYPE =   2


CONTROL CARD 2:  SLANT PATH PARAMETERS

          H1    =  100.0000 KM
          H2    =    0.0000 KM
          ANGLE =  180.0000 DEG
          RANGE =    0.0000 KM
```

Table 4c. Sample Input and Output – Case 3 (Contd)

```
BETA    =    0.0000 DEG
LEN     =         0


CONTROL CARD 3

V1    =    690.000 CM-1
V2    =    700.000 CM-1
VBAR  =    695.000 CM-1


USER DEFINED BOUNDARIES FOR FASCOD1 LAYERS
I     Z (KM)

1      2.0000
2      4.0000
3      6.0000
4      8.0000
5     10.0000
6     12.0000
7     14.0000
8     16.0000
9     18.0000
10    20.0000
11    22.0000
12    24.0000
13    26.0000
14    28.0000
15    30.0000
16    32.0000
17    34.0000
18    36.0000
19    38.0000
20    40.0000
21    42.0000
22    44.0000
23    46.0000
24    48.0000
25    50.0000

1ATMOSPHERIC PROFILE SELECTED IS: M =    6      U. S. STANDARD, 1962


CASE 2A: GIVEN H1, H2, ANGLE

EITHER A SHORT PATH (LEN=0) OR A LONG PATH THROUGH A TANGENT HEIGHT (LEN=1) IS POSSIBLE: LEN  =    0


SLANT PATH PARAMETERS IN STANDARD FORM

H1    =    100.000 KM
H2    =      0.000 KM
```

Table 4c. Sample Input and Output – Case 3 (Contd)

```
ANGLE  =  180.000 DEG
PHI    =   -.000 DEG
HMIN   =   0.000 KM
LEN    =       0
```

HALFWIDTH INFORMATION ON THE USER SUPPLIED FASCOD1 BOUNDARIES
THE FOLLOWING VALUES ARE ASSUMED:
ALZERO = .100 CM-1 = AVERAGE LORENTZ WIDTH AT STP
AVMWT = 36.00 = AVERAGE MOLECULAR WEIGHT
VBAR = 695.00 CM-1 = AVERAGE WAVENUMBER

I	Z (KM)	P (MB)	T (K)	LORENTZ (CM-1)	DOPPLER (CM-1)	ZETA	VOIGT (CM-1)	VOIGT RATIO	TEMP DIFF (K)
1	2.000	795.000	275.100	.08139	.00069	.992	.08139	1.26	12.9
2	4.000	616.600	262.200	.06466	.00067	.990	.06466	1.27	13.0
3	6.000	472.200	249.200	.05079	.00065	.987	.05080	1.29	13.0
4	8.000	356.500	236.200	.03939	.00064	.904	.03940	1.31	13.0
5	10.000	265.000	223.200	.03012	.00062	.980	.03013	1.35	6.6
6	12.000	194.000	216.600	.02236	.00061	.973	.02240	1.37	0.0
7	14.000	141.700	216.600	.01635	.00061	.964	.01637	1.37	0.0
8	16.000	103.500	216.600	.01194	.00061	.951	.01197	1.37	0.0
9	18.000	75.650	216.600	.00873	.00061	.935	.00877	1.36	0.0
10	20.000	55.290	216.600	.00638	.00061	.913	.00644	1.36	2.0
11	22.000	40.470	218.600	.00465	.00061	.883	.00473	1.35	2.0
12	24.000	29.720	220.600	.00340	.00062	.846	.00351	1.33	2.0
13	26.000	21.914	222.580	.00249	.00062	.801	.00264	1.30	2.0
14	28.000	16.196	224.540	.00184	.00062	.747	.00203	1.27	2.0
15	30.000	11.970	226.500	.00135	.00062	.684	.00159	1.22	4.0
16	32.000	8.925	230.500	.00100	.00063	.613	.00130	1.19	4.0
17	34.000	6.654	234.500	.00074	.00064	.537	.00110	1.13	5.4
18	36.000	5.001	239.880	.00055	.00064	.460	.00097	1.10	6.8
19	38.000	3.789	246.640	.00041	.00065	.386	.00089	1.07	6.8
20	40.000	2.871	253.400	.00031	.00066	.317	.00083	1.05	4.3
21	42.000	2.209	257.720	.00023	.00067	.260	.00079	1.03	4.3
22	44.000	1.700	262.040	.00018	.00067	.210	.00077	1.02	3.4
23	46.000	1.316	265.430	.00014	.00068	.169	.00075	1.02	2.6
24	48.000	1.025	268.040	.00011	.00068	.135	.00073	1.01	2.6
25	50.000	.798	270.600	.00008	.00068	.108	.00072	0.00	0.0

1 SUMMARY OF THE GEOMETRY CALCULATION

```
MODEL    =  U. S. STANDARD, 1962
H1       =  100.000 KM
H2       =    0.000 KM
ANGLE    =  180.000 DEG
RANGE    =  100.000 KM
BETA     =    .000 DEG
PHI      =   -.000 DEG
HMIN     =  0.000 KM
BENDING  =   -.000 DEG
LEN      =       0
AIRMAS   =  1.00   RELATIVE TO A VERTICAL PATH , GROUND TO SPACE
```

Table 4c. Sample Input and Output – Case 3 (Contd)

OFINAL SET OF LAYERS FOR INPUT TO FASCOD·
A LAYER AMOUNT MAY BE SET TO ZERO IF THE CUMULATIVE AMOUNT FOR THAT LAYER AND ABOVE IS LESS THAN 0.1 PERCENT
OF THE TOTAL AMOUNT. THIS IS DONE ONLY FOR THE FOLLOWING CASES
  1. IEMIT = 0 (TRANSMITTANCE)
  2. IEMIT = 1 (RADIANCE) AND ICNTRL = 3 (PATH LOOKING UP)
O2 IS NOT INCLUDED
IF THE AMOUNTS FOR ALL THE MOLECULES BUT O2 ARE ZEROED, THE REMAINING LAYERS ARE ELIMINATED

L	LAYER BOUNDARIES FROM (KM)	TO (KM)	ICNTRL	PBAR (MB)	TBAR (K)	INTEGRATED AMOUNTS (MOLS CM-2) AIR	H2O	CO2	O3	N2O	CO	CH4	O2
1	0.000	2.000	1	903.76	281.80	4.63E+24	2.85E+22	1.52E+21	1.36E+17	1.29E+18	3.45E+17	7.36E+13	9.64E+23
2	2.000	4.000	1	705.62	268.88	3.78E+24	1.25E+22	1.25E+21	1.25E+17	1.06E+18	2.83E+17	6.04E+13	7.91E+23
3	4.000	6.000	1	544.24	255.92	3.07E+24	4.51E+21	1.01E+21	1.15E+17	8.57E+17	2.30E+17	4.90E+13	6.42E+23
4	6.000	8.000	1	414.24	242.93	2.46E+24	1.50E+21	8.11E+20	1.22E+17	6.88E+17	1.84E+17	3.93E+13	5.15E+23
5	8.000	10.000	1	310.64	229.94	1.95E+24	3.58E+20	6.42E+20	1.77E+17	5.45E+17	1.46E+17	3.11E+13	4.09E+23
6	10.000	12.000	1	229.45	218.49	1.51E+24	6.06E+19	4.98E+20	3.18E+17	4.23E+17	1.13E+17	2.42E+13	3.16E+23
7	12.000	14.000	1	167.85	216.60	1.11E+24	1.30E+19	3.67E+20	4.33E+17	3.12E+17	8.35E+16	1.78E+13	2.33E+23
8	14.000	16.300	1	122.60	216.60	8.13E+23	4.62E+18	2.68E+20	5.33E+17	2.28E+17	6.10E+16	1.30E+13	1.70E+23
9	16.030	18.000	1	89.58	216.60	5.94E+23	3.49E+18	1.96E+20	7.02E+17	1.66E+17	4.46E+16	9.51E+12	1.25E+23
10	18.000	20.000	1	65.47	216.60	4.34E+23	2.94E+18	1.43E+20	8.78E+17	1.22E+17	3.26E+16	6.95E+12	9.10E+22
11	20.000	22.000	1	47.88	217.55	3.16E+23	3.21E+18	1.04E+20	9.60E+17	8.86E+16	2.37E+16	5.06E+12	6.63E+22
12	22.000	24.000	1	35.10	219.55	2.30E+23	3.79E+18	7.58E+19	9.47E+17	6.43E+16	1.72E+16	3.68E+12	4.81E+22
13	24.000	26.000	1	25.81	221.54	1.67E+23	4.21E+18	5.53E+19	8.44E+17	4.69E+16	1.26E+16	2.68E+12	3.51E+22
14	26.000	28.000	1	19.06	223.51	1.23E+23	3.55E+18	4.05E+19	6.91E+17	3.43E+16	9.20E+15	1.96E+12	2.57E+22
15	28.000	30.000	1	14.09	225.47	8.98E+22	2.04E+18	2.97E+19	5.59E+17	2.51E+16	6.74E+15	1.44E+12	1.88E+22
16	30.000	32.000	1	10.45	228.39	6.50E+22	2.15E+18	2.17E+19	4.46E+17	1.84E+16	4.94E+15	1.05E+12	1.38E+22
17	32.000	34.000	1	7.79	232.39	4.82E+22	1.52E+18	1.59E+19	3.51E+17	1.35E+16	3.62E+15	7.72E+15	1.01E+22
18	34.000	36.000	1	5.82	236.71	3.54E+22	1.08E+18	1.17E+19	2.74E+17	9.90E+15	2.65E+15	5.66E+15	7.41E+21
19	36.000	38.000	1	4.40	243.0	.60E+22	7.59E+17	8.60E+18	2.01E+17	7.29E+15	1.95E+15	4.17E+15	5.46E+21
20	38.000	40.000	1	3.33	249.83	1.92E+22	5.36E+17	6.34E+18	1.45E+17	5.37E+15	1.44E+15	3.07E+15	4.02E+21
21	40.000	42.000	1	2.54	255.45	1.43E+22	3.80E+17	4.73E+18	1.00E+17	4.01E+15	1.07E+15	2.29E+16	3.00E+21

Table 4c.   Sample Input and Output – Case 3 (Contd)

22	42.000	44.000	1	1.96	259.77	1.08E+22	2.89E+17	3.58E+18	6.56E+16	3.04E+15	8.13E+14	1.73E+15 2.27E+21
23	44.000	46.000	1	1.51	263.90	8.22E+21	2.12E+17	2.71E+18	4.23E+16	2.30E+15	6.17E+14	1.32E+16 1.72E+21
24	46.000	48.000	1	1.17	266.70	6.32E+21	1.45E+17	2.09E+18	2.43E+16	1.77E+15	4.74E+14	1.01E+15 1.33E+21
25	48.000	50.000	1	.91	269.26	4.88E+21	9.83E+16	1.61E+18	1.36E+16	1.37E+15	3.66E+14	7.81E+15 1.02E+21
26	50.000	100.000	1	.39	251.62	1.69E+22	1.84E+17	5.58E+18	2.60E+16	4.74E+15	1.27E+16	2.71E+16 3.55E+21

Table 4d. Sample Input and Output - Case 4

```
****INPUT CASE 4*******************************************************************
  2   2          10.0         1        1          450.0
  800.0      1200.0        15.0
  1.6         10.0
```

```
****OUTPUT CASE 4*****************************************************************
1                        ****PROGRAM FSC/TM*****       01/11/83       11.04.18.


CONTROL CARD 1: MODEL AND OPTIONS

          MODEL    =       2
          ITYPE    =       2
          IBND     =       0
          NOZERO   =       0
          NOPRNT   =       1
          KMAX     =       0
          IPUNCH   =       1
          RE       =       0.000 KM


CONTROL CARD 1 PARAMETERS WITH DEFAULTS:

          MODEL    =       2
          ITYPE    =       2
          IBND     =       0
          NOZERO   =       0
          NOPRNT   =       1
          KMAX     =       7
          IPUNCH   =       1
          RE       =    6371.230 KM


SLANT PATH SELECTED, ITYPE =       2


CONTROL CARD 2:  SLANT PATH PARAMETERS

          H1       =       8.0000 KM
          H2       =      10.0000 KM
          ANGLE    =       0.0000 DEG
          RANGE    =     450.0000 KM
          BETA     =       0.0000 DEG
          LEN      =            0
```

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Table 4d. Sample Input and Output - Case 4 (Cont'd)

```
CONTROL CARD 3

     V1   =     800.000 CM-1
     V2   =    1200.000 CM-1
     VBAR =    1000.000 CM-1


AUTOLAYERING SELECTED

     AVTRAT =    1.60
     TDIFF1 =   10.00
     TDIFF2 =   15.00

1ATMOSPHERIC PROFILE SELECTED IS: M =   2    MIDLATITUDE SUMMER


CASE 2C: GIVEN H1, H2, RANGE

     NOTE: ANGLE IS COMPUTED FROM H1, H2, AND RANGE ASSUMING NO REFRACTION


SLANT PATH PARAMETERS IN STANDARD FORM

     H1    =    8.000 KM
     H2    =   10.000 KM
     ANGLE =   91.786 DEG
     PHI   =   92.241 DEG
     HMIN  =    4.647 KM
     LEN   =        1


FASCODE LAYER BOUNDARIES PRODUCED BY THE AUTOMATIC LAYERING ROUTINE AUTLAY
THE USER SHOULD EXAMINE THESE BOUNDARIES AND MODIFY THEM IF APPROPRIATE
THE FOLLOWING PARAMETERS ARE USED:

     AVTRAT =    1.60           = MAX RATIO OF VOIGT WIDTHS
     TDIFF1 =   10.00           = MAX TEMP DIFF AT HMIN
     TDIFF2 =   15.00           = MAX TEMP DIFF AT HMAX
     ALZERO =     .100 CM-1     = AVERAGE LORENTZ WIDTH AT STP
     AVMWT  =   36.00           = AVERAGE MOLECULAR WEIGHT
     VBAR   = 1000.00 CM-1      = AVERAGE WAVENUMBER
```

I	Z (KM)	P (MB)	T (K)	LORENTZ (CM-1)	DOPPLER (CM-1)	ZETA	VOIGT (CM-1)	VOIGT RATIO	TEMP DIFF (K)
1	4.647	579.076	269.119	.05994	.00098	.984	.05995	1.21	9.9
2	6.300	467.835	259.200	.04934	.00096	.981	.04936	1.23	11.2
3	8.000	372.000	248.000	.04011	.00094	.977	.04013	1.27	12.3
4	9.900	285.030	235.700	.03152	.00092	.972	.03155	1.01	.7
5	10.000	281.000	235.000	.03112	.00091	.971	.03115	0.00	0.0

Table 4d. Sample Input and Output – Case 4 (Contd)

1 SUMMARY OF THE GEOMETRY CALCULATION

```
        MODEL   =    MIDLATITUDE SUMMER
        H1      =    8.000 KM
        H2      =    10.000 KM
        ANGLE   =    91.766 DEG
        RANGE   =    494.451 KM
        BETA    =    4.441 DEG
        PHI     =    92.241 DEG
        HMIN    =    4.647 KM
        BENDING =    .434 DEG
        LEN     =    1
        AIRMAS  =    30.9     RELATIVE TO A VERTICAL PATH , GROUND TO SPACE
```

OFINAL SET OF LAYERS FOR INPUT TO FASCOD1
A LAYER AMOUNT MAY BE SET TO ZERO IF THE CUMULATIVE AMOUNT FOR THAT LAYER AND ABOVE IS LESS THAN 0.1 PERCENT
OF THE TOTAL AMOUNT. THIS IS DONE ONLY FOR THE FOLLOWING CASES
   1. IEMIT = 0 (TRANSMITTANCE)
   2. IEMIT = 1 (RADIANCE),AND ICNTRL = 3 (PATH LOOKING UP)
O2 IS NOT INCLUDED
IF THE AMOUNTS FOR ALL THE MOLECULES BUT O2 ARE ZEROED, THE REMAINING LAYERS ARE ELIMINATED

L	LAYER BOUNDARIES		ICNTRL	PBAR	TBAR	INTEGRATED AMOUNTS (MOLS CM-2)							
	FROM (KM)	TO (KM)		(MB)	(K)	AIR	H2O	CO2	O3	N2O	CO	CH4	O2
1	4.647	6.300	2	542.59	265.96	2.26E+26	4.89E+23	7.46E+22	1.29E+19	6.33E+19	1.69E+19	3.62E+20	4.73E+25
2	6.300	8.000	2	422.54	254.30	7.79E+25	7.77E+22	2.57E+22	6.12E+18	2.18E+19	5.84E+18	1.25E+20	1.63E+25
3	8.000	9.900	3	330.11	242.52	5.36E+25	2.39E+22	1.77E+22	5.81E+18	1.50E+19	4.02E+18	8.58E+13	1.12E+25
4	9.900	10.000	3	283.01	235.35	2.24E+24	0.	7.39E+20	2.89E+17	6.27E+17	1.68E+17	3.58E+13	4.69E+23

```
***TAPE7  CASE4**************************************************************
    4  MIDLATITUDE SUMMER        H1=  8.00 H2=  10.00 ANGLE= 91.766 LEN= 1
5.426E+02   265.96               2                        4.65 TO    6.30 KM
4.89E+23  7.46E+22  1.29E+19  6.33E+19  3.62E+20  4.73E+25
4.225E-02   254.30               2                        6.30 TO    8.00 KM
7.77E+22  2.57E+22  6.12E+18  2.18E+19  1.25E+20  1.63E+25
3.301E-02   242.52               3                        8.00 TO    9.90 KM
2.39E+22  1.77E+22  5.81E+18  1.50E+19  1.12E+25
2.830E+02   235.35               3                        9.90 TO   10.00 KM
0.        7.39E+20  2.89E+17  6.27E+17  4.69E+23
```

The following two pages trace the refracted path through the atmosphere, starting from the lowest point along the path. The layer boundaries for this calculation are the result of merging the atmospheric profile boundaries with the output layer boundaries, from HMIN to HMAX. The column labeled THETA shows the path zenith angle at the bottom of that layer, while DRANGE is the curved path length through the layer. DBETA is the earth-centered angle subtended by that layer. PHI is the arrival angle at the top of the layer, while DBEND is the refractive bending in the layer. PBAR and TBAR are the density-weighted pressure and temperatures for the layer, while RHOBAR is the average density. The next table lists the amounts for each gas for each layer, plus the total for the path.

The last page prints a summary of the path calculation then the amounts for the output layers. Note that the amounts for H_2O are zeroed out above 32.3 km because less than 0.1 percent of the total H_2O amount for this path lies above 32.3 km. The amounts for all the other molecules except O_3 are zeroed out above 49.0 km for the same reason. Finally, the layers above 78.1 km are eliminated entirely since 99.9 percent of the amounts for all the molecules lie below this altitude. This zeroing option can reduce the computation time for a line-by-line calculation. The option can be suppressed by specifying NOZERO = 1 on Card 1.

Case 2, shown in Table 4b, models the conditions of a stratospheric balloon-borne experiment looking at the sun as it sets.[11] On Card 1, MODEL = 7 selects a user-supplied atmospheric profile, ITYPE = 3 selects a slant path to space, and KMAX = 20 selects 20 molecular species, the maximum allowed. On Card 2, H1 = 33 km is the altitude of the balloon and ANGLE = 94.88 deg is the apparent or measured zenith angle of the sun. The reported zenith angle of 95.3 deg is the astronomical zenith angle for a straight line to the sun. The apparent zenith angle was found by iteration of the program until the apparent zenith angle (ANGLE) plus the total bending (BENDNG) equaled the astronomical zenith angle.

Autolayering is again selected but now the parameters AVTRAT, TDIFF1, and TDIFF2 are supplied on Card 4 as 2.0, 50.0, and 50.0 respectively. The large values of TDIFF1 and TDIFF2 will generate a relatively small number of thick output layers. This layering is useful for initial or survey line-by-line calculations since the time of the calculation is related to the number of layers. More accurate calculations may require more layers: the user must experiment with different layerings to determine the minimum number of layers consistent with his accuracy requirements.

---

11. Goldman, A., Blatherwick, R.D., Murcray, F.J., Van Allen, J.W., Murcray, F.H., and Murcray, D.G. (1982) Atlas of stratospheric IR absorption spectra, Appl. Opt. 21:1163-1164.

Using a value of AVTRAT larger than 2.0 will also generate thick output layers. However, due to the layer to layer merging scheme used in FASCODE, layers generated by a value of AVTRAT greater than 2.0 may be inconsistent with FASCODE.

The user-supplied atmospheric profile is read in after Card 4. In this case, the temperature profile is from the U.S. Standard Atmosphere 1976 while the volume mixing ratios up to 50 km for the various gases, except CO_2, are from Smith[12] (see also Appendix A). Above the 50 km only a water vapor concentration is given: the mixing ratios for the "uniformly mixed gases" CO_2, N_2O, CO, CH_4, and O_2 revert to their default values. Note: the program does not check whether the atmosphere is in hydrostatic equilibrium.

Following the atmospheric profile are the slant path parameters in standard form. This path passes through a tangent height of 9.152 km. Next comes the internally-generated FASCODE output layer boundaries; note that the ratio of the Voigt halfwidths controls the layering up to 40 km. The rest of the output is straight forward and self-explanatory.

Case 3, shown in Table 4c, illustrates the use of user-supplied output layers, the NOZERO option, and of the short form of the output. On Card 1, IBND is set to the number of user-supplied output boundaries, 25 in this case. The altitudes are then read in after Card 3. The NOPRNT = 1 option suppresses the printing of the tables of the atmospheric profile and ray trace calculation. The NOZERO = 1 option preserves the amounts for all the molecules for all the layers. This option is important, for example, when calculating the radiance measured looking down from space, where the contribution from a high but sparse layer can be significant. The particular case run here applies to calculating weighting functions for temperature sounding from a satellite looking straight down from space. Note also that the program resets H1 from the input value 500 km to 100 km, which is the altitude of the highest boundary in the atmospheric profile.

The last case, shown in Table 4d, illustrates the use of H1, H1, and RANGE to describe the path. The program calculates ANGLE from H1, H2, and RANGE assuming no refraction, and then traces out the path using H1, H2, and ANGLE. Due to refraction the resultant RANGE is significantly larger than the input value. Also shown is the output on TAPE7 selected by the IPU=1 option on Card 1. This output is in a form suitable for direct input to FASCODE.

---

12. Smith, M.A.H. (1982) Compilation of Atmospheric Gas Concentration Profiles From 0 to 50 km, NASA TM-83289.

3.3 Program Structure

The program consists of a simple driver program, called FSCATM, and 20 subroutines. Table 5 lists the program units and their functions and Figure 20 shows the relationship among the principal ones. Each subroutine contains comment cards describing its function. The comments in ATMPTH contain a concise description of the program usage. The program is modular so that the user may easily modify it to suit any particular needs.

Table 5. Program Units and Their Functions

Program Unit	Function
FSCATM	Interface between FASCODE and ATMPTH
ATMCON	Block data: Initializes various program constants
ATMPTH	Main subroutine: Handles I/O
MLATMB	Block data: Stores reference profiles
MLATM	Model atmosphere: Sets up atmospheric profile
NSMDL	Non-standard model: Inputs user profiles
WATVAP	Calculates the water vapor number density for non-standard conditions
GEOINP	Reduces the input slant path parameters to the standard form: H1, H2, ANGLE, LEN
REDUCE	Eliminates slant path segments that extend about the highest profile altitude
FDBETA	Calculates angle given the input parameters H1, H2, BETA
EXPINT	Exponential interpolation
FNDHMN	Calculates HMIN = Minimum altitude along the path (Tangent altitude if any)
FINDSH	Finds the layer containing a given altitude
SCALHT	Calculates the scale height of the refractivity
ANDEX	Calculates the index of refraction at a given altitude
RADREF	Calculates the radius of curvature due to refraction
RFPATH	Drives the path calculation over all the layers
FILL	Sets up a profile extending from HMIN to HMAX
ALAYER	Calculates the path and the amounts through one layer
AUTLAY	Layers the atmosphere from HMIN to HMAX based on AVTRAT, TDIFF1, and TDIFF2
HALFWD	Calculates LORENTZ, DOPPLER, and VOIGT half-widths and ZETA given P, T, and VBAR

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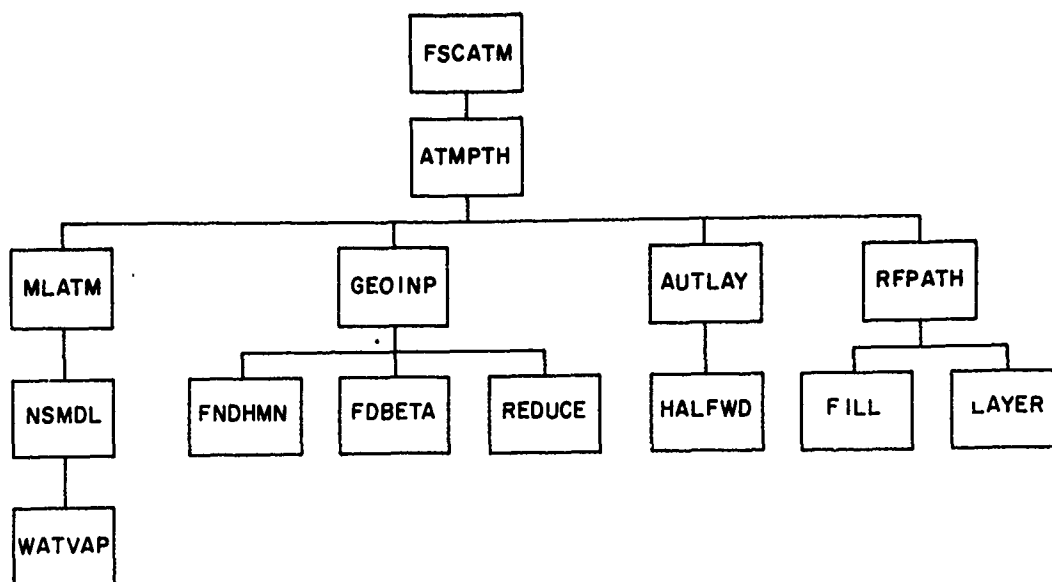
Figure 20. Structure Chart Showing the Major Subroutines

3.4 Portability

The program FSCATM runs on a CDC 6600 computer (a 60 bit word computer) with a FORTRAN 77 (FORTRAN V) compiler. It is also designed to be compatible with minor modifications with 32 bit word computer in single precision and with FORTRAN 66 (FORTRAN IV). To run on a 32 bit word computer, variables containing character data must be declared DOUBLE PRECISION (CHARACTER *8 will not work since some of these variables are carried in COMMON along with non-character variables). The required statements for this are supplied in the program with the characters 'C&' in Columns 1 to 3. To compile under CDC FORTRAN IV, all single quotes ' must be replaced with double quotes ". To convert the subroutine FSCATM to a stand-along program, enable the statements in FSCATM with the characters 'CP' in Columns 1 and 2, and include the subroutines from ATMPTH to HALFWD. The user must also supply subroutines DATE and TIME, which return the date and time in A8 format.

When the sample cases described in Section 3.2 are run on a 32 bit word computer in single precision, the results may be different in the third or fourth decimal place compared with the sample output. This precision is generally sufficient considering the accuracy of the models and of the data.

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3.5 Availability

FSCATM is available as a part of the FASCOD1C package. This package includes the program FASCOD1C plus various other associated programs and sample input and output. The package is available on tape from

National Climatic Center, NOAA
Environmental Data Service
Federal Building
Asheville, NC 28801
(704)-258-2850, ex 682 (Ms Yolanda Goodge)

and presently costs $98.00. The users guide for FASCOD1C is available from

S. A. Clough
AFGL/OPI
Hanscom AFB MA 01731

An earlier version of FSCATM, called FSCDATM, was distributed as a part of the FASCOD1B package. FSCATM is a revision of FSCDATM with a number of improvements and fixes. In particular, FSCDATM would not work properly on a 32 bit word computer in single precision for tangent paths. This bug has been fixed in FSCATM.

3.6 Errata for FSCATM

As distributed with FASCOD1C, FSCATM contained six known errors. The corrections are as follows:

1. Line 24740 (line 420 of ATMPTH)

    IF(VMIX(I).GT.0.0) DENSTY(K, 1) = VMIX(K)*RHOBAR*1.0E-6

    should read

    IF(VMIX(K).GT.0.0) DENSTY(K, 1) = VMIX(K)*RHOBAR*1.0E-6

2. After line 25300 (line 476 of ATMPTH), insert

    NLAYERS = 1

    WN2L(1) = AMTAIR * VMIXN2 * 1.0 E-6

3. Line 25240 (line 488 of ATMPTH)

    1   (AMOUNT(K, 1), K=1, KMAX)

        should read

    1   (AMOUNT(K, 1), K=1, 7), WN2L(1), (AMOUNT(K, 1), K=8, KMAX)

4. Lines 28540 to 28550 (lines 800 to 801 of ATMPTH)

    IF(IPUNCH. EQ. 1) WRITE(IPU, 70)(AMOUNT(K, L), K=1, KMAX)

    70 FORMAT(1P8E10. 2)

      should read

    IF(IPUNCH. NE. 1) GO TO 470

    WRITE(IPU, 70)(AMOUNT(K, L), K=1, 7), WN2L(L)

    70 FORMAT (1P8E10. 2)

    IF(KMAX. GT. 7)WRITE(IPU, 70)(AMOUNT(K, L), K=8, KMAX)

5. In FORMAT statements 30, 35, and 37 of ATMPTH, the '20X' should be changed to 'T20'.

6. Line 44970 (line 143 of ALAYER)

    TPSUM(J) = TPSUM(J) + 0. 5*DS*(PA+PB)

      should read

    TPSUM(J) = TPSUM(J) + 0. 5*DS*(PA+PB)/GCAIR

Corrections 1 and 2 are required for the program to run a horizontal path properly. Corrections 3 and 4 are required to write the proper layer information to TAPE7. Correction 5 affects only the printed output of the total air amounts. Correction 6 fixes an error in the calculation of the average temperature for a very thin layer: most paths are unaffected by this error. These corrections have been incorporated into the listing contained in this report, with an '!' in column 74.

3.7 Program Listing

```
        SUBROUTINE FSCATM                                                020000
CP      PROGRAM FSCATM                                                 CP020010
C*****************************************************************************  020020
C                                                                        020030
C       FSCATM IS AN ATMOSPHERIC RAY TRACE PROGRAM.                      020040
C       IT CREATES AND FORMATS THE ATMOSPHERIC INPUTS FOR THE AFGL       020050
C       LINE-BY-LINE TRANSMITTANCE/RADIANCE PROGRAM FASCODE.             020060
C                                                                        020070
C       SEE THE COMMENTS IN SUBROUTINE ATMPTH FOR DETAILED INSTRUCTIONS ON C20080
C       THE USAGE OF THE ATMOSPHERIC INPUTS.                            020090
C                                                                        020100
C       TO CONVERT THE AIR MASS MODULE TO A STAND ALONE PROGRAM,         020110
C       INCLUDE THE SUBROUTINES FROM FSCATM TO HALFWD, AND               020120
C       ENABLE THE CARDS THAT BEGIN WITH 'CP '.                          020130
C                                                                        020140
C       TO RUN THE PROGRAM ON A 32 BIT WORD MACHINE, ENABLE THE CARDS    020150
C       THAT BEGIN WITH 'C& '.                                           020160
C                                                                        020170
C*****************************************************************************  020180
        COMMON /PATHD/ PBAR(37),TBAR(37),AMOUNT(20,37),WN2L(37),         020190
C          DVL(37),WTOTL(37),ALBL(37),ADBL(37),AVBL(37),H2OSL(37),       020200
C          ICNTRL(37),ITYL(37),SECNTA(37),ALTB(37),ALTT(37),HT1,HT2      020210
        COMMON /MAIN/ NWDFIL,KFILE,KPANEL,LINFIL,PO,TEMPO,NLAYRS,        020220
C                H2OSLF,WTOT,ALBAR,ADBAR,AVBAR,AVFIX,LAYRFX,SECNTO,       020230
C       SAMPLE,ALFALO,AVMASS                                             020240
C&      DOUBLE PRECISION XID,SECANT,HMOLID,YID ,HMOL                    C&020250
        COMMON /FILHDR/ XID(10),SECANT,PAVE,TAVE,HMOLID(20),WK(20),WN2,  020260
C                DV,V1,V2,TBOUND,EMISIV,FSCDID(17),NMOL,LAYER,           020270
C                YI1,YID(10)                                             020280
        EQUIVALENCE (FSCDID(5),IEMIT)                                    020290
C&      DOUBLE PRECISION HMOLS                                          C&020300
        COMMON /HMOLS/ HMOLS(20)                                         020310
        COMMON /IFIL/ IRD,IPR,IPU                                        020320
        COMMON /PARMTR/ PI,DEG,GCAIR,RE,DELTAS,ZMIN,ZMAX,IMAX,IMOD,IBMAX, 020330
     1      ICU1MX,IPATH,IMODMX,IDIM,KDIM,KMXNOM,KMAX,NOPRNT             020340
C&      DOUBLE PRECISION HDATE,HTIME                                    C&020350
C*****IRD, IPR, IPU ARE UNIT NUMBERS FOR INPUT, OUTPUT, PUNCH            020360
CP      DATA IRD/5/,IPR/6/,IPU/7/,IEMIT/0/                             CP020370
CP      OPEN(UNIT=5,FILE='INPUT',STATUS='OLD')                         CP020380
CP      OPEN(UNIT=6,FILE='OUTPUT')                                     CP020390
        CALL DATE(HDATE)                                                020400
        CALL TIME(HTIME)                                                020410
        WRITE(IPR,900)  HDATE,HTIME                                     020420
900     FORMAT('1',20X,'*****PROGRAM FSCATM*****      ',A10,5X,A10,///)  020430
C*****                                                                   020440
        CALL ATMPTH(IEMIT)                                              020450
C*****                                                                   020460
        SECANT = 1.0                                                    020470
        NMOL = KMAX                                                     020480
        DO 30 M=1,KMAX                                                  020490
30      HMOLID(M)=HMOLS(M)                                             020500
        RETURN                                                         020510
CP      STOP                                                          CP020520
C                                                                        020530
        END                                                            020540
```

```
      SUBROUTINE ATMPTH(IEMIT)                                                   020550
C***********************************************************************        C20560
C                                                                               020570
C                                                                               020580
C                                                                               020590
C                                                                               020600
C                ATMPTH    (ATMOSPHERIC PATH)                                   020610
C                                                                               020620
C                                                                               020630
C                                                                               020640
C                                                                               020650
C                     WILLIAM O. GALLERY                                        020660
C                     FRANCIS X. KNEIZYS                                        020670
C                     SHEPARD A. CLOUGH                                         020680
C                                                                               020690
C                                                                               020700
C                                                                               020710
C                              AIR FORCE GEOPHYSICS LAB                         020720
C                              OPTICAL PHYSICS DIVISION                         020730
C                              HANSCOM AFB                                      020740
C                              BEDFORD, MA.   01731                             020750
C                              617-861-4774                                     020760
C                                                                               020770
C                                                                               020780
C .                            REVISED    JULY, 1982                            020790
C                                                                               020800
C***********************************************************************        020810
C                                                                               020820
C                                                                               020830
C        USER INSTRUCTIONS:                                                     C20840
C                                                                               020850
C        ATMPTH CALCULATES THE DENSITY WEIGHTED MEAN TEMPERATURE AND            020860
C        PRESSURE AND THE INTEGRATED ABSORBER AMOUNTS (IN MOLECULES             020870
C        CM-2) FOR EACH LAYER ALONG A PATH THROUGH A LAYERED                    020880
C        ATMOSPHERE, INCLUDING THE EFFECTS OF REFRACTION AND THE  EARTH'S       020890
C        CURVATURE.   ATMPTH IS DESIGNED TO PREPARE THE ATMOSPHERIC INPUTS      020900
C        TO THE PROGRAM FASCOD1 WHICH DOES A LINE-BY-LINE CALCULATION OF        020910
C        ATMOSPHERIC TRANSMITTANCE OR RADIANCE AND IS DESCRIBED IN              020920
C        REFERENCE (1).   THE CONTROL CARDS REQUIRED TO RUN ATMPTH ARE          020930
C        DESCRIBED LATER IN THESE COMMENTS.   A DETAILED DESCRIPTION OF         020940
C        OF THE ALGORITHM USED HERE AND A DISCUSSION OF THE EFFECTS OF          020950
C        THE EARTH'S CURVATURE AND REFRACTION ARE GIVEN IN REFERENCE (2).       020960
C                                                                               020970
C        THE DEFINITIONS AND USES OF THE PATH PARAMETERS ITYPE, H1, H2,         020980
C        ANGLE, RANGE, BETA, AND LEN ARE THE SAME AS THOSE DESCRIBED IN         020990
C        REFERENCE (3): HOWEVER THE SUBROUTINES WHICH CALCULATE THE             021000
C        REFRACTED PATH ARE COMPLETELY DIFFERENT FROM THOSE IN THE              021010
C        VERSIONS OF LOWTRAN, UP TO LOWTRAN 5.                                  021020
C                                                                               021030
C        THERE ARE SIX BUILT IN ATMOSPHERIC PROFILES WHICH DEFINE THE           021040
C        PRESSURE, TEMPERATURE, AND THE DENSITIES OF THE SEVEN MOLECULAR        021050
C        SPECIES H2O, CO2, O3, N2O, CO, CH4, AND O2 ON THE AFGL                 021060
C        ATMOSPHERIC LINE PARAMETERS COMPILATION AT 33 STANDARD                 021070
C        ALTITUDES.   THESE MODEL ATMOSPHERES ARE THE SAME AS THOSE             021080
C        DESCRIBED IN REFERENCE (4), ALTHOUGH THE DENSITIES ARE IN              021090
C        DIFFERENT UNITS.   THE USER MAY ALSO INPUT AN ATMOSPHERIC              021100
C        PROFILE AS DESCRIBED LATER (SEE ALSO THE COMMENTS IN                   021110
C        THE SUBROUTINE NSMOL) AND INCLUDE UP TO 13 ADDITIONAL                  021120
C        SPECIES CORRESPONDING TO THE MOLECULES ON THE AFGL TRACE GAS           021130
C        COMPILATION.                                                           021140
```

```
C                                                                   021150
C     THE PRINCIPAL OUTPUT CONSISTS OF THE INTEGRATED ABSORBER AMOUNTS  021160
C     FOR A SET OF LAYERS TO BE INPUT TO THE LINE-BY-LINE CALCULATION.  021170
C     THE NUMBER OF THESE LAYERS REPRESENTS A TRADEOFF BETWEEN ACCURACY 021180
C     AND COMPUTATIONAL SPEED OF THE LINE-BY-LINE CALCULATION.   THE    021190
C     USER HAS THE OPTION OF INPUTTING HIS OWN SET OF LAYER BOUNDARIES  021200
C     OR OF LETTING THE SUBROUTINE AUTLAY GENERATE THESE LAYERS         021210
C     AUTOMATICALLY.  IF THE USER INPUTS HIS OWN BOUNDARIES,  THEY NEED 021220
C     NOT FALL ON THE ATMOSPHERIC PROFILE BOUNDARIES OR INCLUDE THE     021230
C     PATH ENDPOINTS. IF AUTOMATIC LAYERING IS SELECTED, THE USER MAY   021240
C     SPECIFY THE MAXIMUM HALFWIDTH RATIO ACROSS A LAYER AND THE        021250
C     MAXIMUM TEMPERATURE DIFFERENCE ACROSS A LAYER.                    021260
C                                                                       021270
C     IT IS DIFFICULT TO SPECIFY APRIORI THE RELATIONSHIP BETWEEN       021280
C     THE NUMBER OF LAYERS AND THE ACCURACY:  THE ACCURACY DEPENDS UPON 021290
C     SUCH FACTORS AS THE SPECTRAL REGION, THE DISTRIBUTION OF THE      021300
C     MOLECULES OF INTEREST, THE PARTICULAR PATH TAKEN, AND WHETHER     021310
C     TRANSMITTANCE OR RADIANCE IS CALCULATED. THE LAYERING CREATED     021320
C     BY THE DEFAULT VALUES OF AVTRAT (2.0) AND TDIFF1 (15.0 K) AND     021330
C     TDIFF2 (30.0 K) SHOULD BE CONSIDERED A POINT OF DEPARTURE FOR     021340
C     SUBSEQUENT CALCULATIONS. THE USER SHOULD THEN EXPERIMENT WITH     021350
C     DIFFERENT LAYERING UNTIL THE RESULTS ARE CONSISTENT WITH          021360
C     HIS ACCURACY REQUIREMENTS.                                        021370
C                                                                       021380
C     TO SAVE COMPUTER TIME IN FASCOD1, THE LAYER AMOUNTS ARE ZEROED    021390
C     OUT WHEN                                                          021400
C          1.   THE CUMULATIVE AMOUNT FOR THAT LAYER AND ABOVE IS LESS  021410
C               THAN 0.1 PERCENT OF THE TOTAL,                          021420
C          AND                                                          021430
C          2.   A. TRANSMITTANCE IS CALCUALTED (IEMIT = 0)              021440
C               OR                                                      021450
C               B. RADIANCE IS CALCULATED (IEMIT = 1) AND THE PATH IS   021460
C                  LOOKING UP (ICNTRL = 3)                              021470
C     O2 IS  NOT CONSIDERED IN THIS SCHEME.  IF THE ABSORBER            021480
C     FOR A LAYER FOR ALL THE MOLECULES (EXCEPT O2) ARE ZEROED          021490
C     OUT, THEN THAT LAYER AND THOSE ABOVE ARE ELIMINATED               021500
C                                                                       021510
C     TO CALCULATE THE AMOUNTS FOR THE TRACE GASES (MOLECULES 8 THROUGH 021520
C     20) THE USER MUST INCREASE KMAX ON CARD 1 AND READ IN AN          021530
C     ATMOSPHERIC PROFILE (MODEL = 7) INCLUDING THE VOLUME MIXING RATIOS 021540
C     OF THE ADDITIONAL MOLECULES.                                      021550
C                                                                       021560
C----------------------------------------------------------------------021570
C     CONTROL CARDS:                                                    021580
C                                                                       021590
C     FOUR  CONTROL CARDS CONTROL THE OPERATION OF THE PROGRAM WHILE    021600
C     OTHER CARDS MAY BE READ IN TO DEFINE NON-STANDARD CONDITIONS. THE 021610
C     FORMATS OF THESE CARDS AND THE MEANING OF THE PARAMETERS ARE      021620
C     DESCRIBED AS FOLLOWS:                                             021630
C                                                                       021640
C          CONTROL CARD 1: MODEL, ITYPE, IBND, NOZERO, NOPRNT, KMAX,    021650
C                          IPUNCH, RE                                   021660
C                          (7I5,5X,F10.4)                               021670
C               MODEL = 0: USER SUPPLIED HORIZONTAL PATH PARAMETERS     021680
C                       1: TROPICAL MODEL ATMOSPHERE                    021690
C                       2: MIDLATITUDE SUMMER                           021700
C                       3: MIDLATITUDE WINTER                           021710
C                       4: SUBARCTIC SUMMER                             021720
C                       5: SUBARCTIC WINTER                             021730
C                       6: U.S. STANDARD, 1962                          021740
```

```
C                 7: USER SUPPLIED ATMOSPHERIC PROFILE          021750
C        ITYPE = 1: HORIZONTAL PATH (CONSTANT PRESSURE)          021760
C                2: SLANT PATH FROM H1 TO H2                     021770
C                3: SLANT PATH FROM H1 TO SPACE                  021780
C        IBND    NUMBER OF BOUNDARY ALTITUDES FOR THE FASCOD1    021790
C                LAYERS: IF IBND GT 0, USER SUPPLIES BOUNDARIES  021800
C                     IF IBND = 0, AUTO LAYERING IS SELECTED     021810
C        NOZERO =1: SUPRESSES ZEROING OF SMALL AMOUNTS.          021820
C                DEFAULT = 0                                     021830
C        NOPRNT =1: SELECTS SHORT PRINTOUT. DEFAULT = 0          021840
C        KMAX    NUMBER OF MOLECULAR SPECIES. DEFAULT = 7        021850
C                IF KMAX LT 0, A RAY TRACE IS DONE BUT NO AMOUNTS 021860
C                ARE CALCULATED                                  021870
C        IPUNCH =1: WRITE LAYER AMOUNTS TO UNIT IPU=7. DEFAULT = 0 021880
C        RE      RADIUS OF THE EARTH. DEFAULTS:                  021890
C                MODEL = 1, RE = 6378.39 KM                      021900
C                      2,3,6,7, RE = 6371.23 KM                  021910
C                      4,5, RE = 6356.91 KM                      021920
C                                                                021930
C    THE FORMATS FOR THE REMAINING CONTROL CARDS ARE DIFFERENT   021940
C    DEPENDING ON WHETHER THE PATH IS HORIZONTAL (ITYPE = 1)     021950
C    OR SLANT (ITYPE = 2 OR 3)                                   021960
C                                                                021970
C--------------------------------------------------------------  021980
C                                                                021990
C    FOR A SLANT PATH (ITYPE = 2 OR 3):                          022000
C                                                                022010
C        CONTROL CARD 2: H1,H2,ANGLE,RANGE,BETA,LEN              022020
C                (5F10.4,I5)                                     022030
C            H1      ALTITUDE OF THE OBSERVER OR RECIEVER (KM)    022040
C            H2      ALTITUDE OF THE OTHER ENDPOINT OF THE PATH (KM): 022050
C            ANGLE   ZENITH ANGLE AT H1 (DEGREES)                022060
C            RANGE   LENGTH OF THE PATH FROM H1 TO H2 (KM):      022070
C            BETA    EARTH CENTERED ANGLE FOR THE PATH H1 TO H2 (DEG) 022080
C            LEN     =0, SHORT PATH; =1, LONG PATH THROUGH A TANGENT: 022090
C                    HEIGHT.  LEN IS USED ONLY WHEN ANGLE IS GT 90.0 022100
C                    AND H1 IS GT H2.  DEFAULT = 0.              022110
C                                                                022120
C    ONLY THREE OF THE FIRST FIVE PARAMETERS NEED BE SPECIFIED:  022130
C    FOR EXAMPLE, H1, H2, ANGLE. OR H1, H2, BETA. OR H1, ANGLE, RANGE. 022140
C    SEE THE COMMENTS IN THE SUBROUTINE GEOINP OR SEE REFERENCE (2) 022150
C    FOR MORE DETAILS ON THE POSSIBLE COMBINATIONS OF THESE PARAMETERS 022160
C                                                                022170
C        CONTROL CARD 3: V1, V2                                  022180
C                (2F10.3)                                        022190
C            V1,V2   INITIAL AND FINAL WAVENUMBERS FOR USE       022200
C                    IN CALCULATING THE DOPPLER HALFWIDTH USED IN 022210
C                    CREATING THE FASCODE LAYERS AND IN CALCULATING 022220
C                    THE INDEX OF REFRACTION  (CM-1)             022230
C                                                                022240
C        CONTROL CARD 4: (LAYERING)                              022250
C                                                                022260
C        IF IBND = 0 (AUTOLAYERING SELECTED)                     022270
C                                                                022280
C            AVTRAT,TDIFF1,TDIFF2  (3F10.3)                      022290
C            AVTRAT = MAX VOIGT WIDTH RATIO ACROSS A LAYER       022300
C                    DEFAULT - 2.0                               022310
C            TDIFF1 = MAX TEMP DIFFERENCE (K) ACROSS A LAYER AT HMIN 022320
C                    (=LOWEST ALTITUDE ALONG THE PATH).          022330
C                    DEFAULT - 15.0 K                            022340
```

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```
C                TDIFF2 = MAX TEMP DIFFERENCE (K) ACROSS A LAYER AT HMAX      022350
C                         (=HIGHEST ALTITUDE ALONG THE PATH).                 022360
C                         DEFAULT = 30.0 K                                    022370
C                                                                             022380
C           IF IBND NE 0 (USER SUPPLIED FASCOD1 LAYER BOUNDARIES)             022390
C                                                                             022400
C                (ZBND(IB),IB=1,IBND)  (8F10.3)                               022410
C                ZBND     ALTITUDES OF FASCOD1 LAYER BOUNDARIES               022420
C                                                                             022430
C           IF MODEL = 7, THE INPUT ATMOSPHERIC PROFILE IS READ IN AFTER      022440
C           CONTROL CARD 4 IN THE FOLLOWING FORMAT:                           022450
C                                                                             022460
C                IMOD, HEADER   (I5,/,3A8)                                    022470
C                   IMOD   = NUMBER OF LEVELS IN THE PROFILE                  022480
C                   HEADER = 24 CHARACTER HEADER DESCRIBING THE PROFILE       022490
C                                                                             022500
C                Z,P,T,TD,RH,PPH2O,DENH2O,AMSMIX     (8F10.3)                 022510
C                (VMIX(K),K=1,KMAX)      (8E10.3)                             022520
C                         TWO (OR MORE) CARD IMAGES FOR EACH OF THE IMOD      022530
C                         LEVELS.  SEE COMMENTS  FOR THE SUBROUTINE NSMDL     022540
C                       ' REGARDING  THE DEFINITIONS AND USAGES OF THESE      022550
C                         PARAMETERS.                                         022560
C                                                                             022570
C------------------------------------------------------------------          022580
C                                                                             022590
C           FOR A HORIZONTAL PATH (.TYPE = 1):                                022600
C              CONTROL CARD 2:                                                022610
C                 FOR MODEL = 1 TO 7:                                         022620
C                 Z,RANGE    (2F10.3)                                         022630
C                                                                             022640
C                 FOR MODEL = 0:                                              022650
C                 RANGE,P,T,TD,RH,PPH2O,DENH2O,AMSMIX  (8F10.3)               022660
C                 (VMIX(K),K=1,KMAX)     (8E10.3)  '                          022670
C                         WHERE Z AND RANGE ARE THE ALTITUDE AND RANGE OF     022680
C                         THE PATH, BOTH IN KM.  FOR MODEL = 1 TO 7, THE      022690
C                         PRESSURE, TEMPERATURE, AND DENSITIES ARE            022700
C                         INTERPOLATED FROM THE MODEL ATMOSPHERE.  FOR        022710
C                         MODEL = 0, SEE THE NOTES FOR THE SUBROUTINE         022720
C                         NSMDL FOR THE DEFINITIONS AND USAGES OF THE         022730
C                         PARAMETERS IN THIS CASE.  IF THE VOLUME MIXING      022740
C                         RATIO OF O3 IS NOT SUPPLIED FOR MODEL = 0, IT IS    022750
C                         COMPUTED USING A VALUE FOR THE VOLUME               022760
C                         MIXING RATIO OF 40.E-9.                             022770
C                                                                             022780
C              CONTROL CARDS 3 AND 4: NOT USED                                022790
C                                                                             022800
C           FOR MODEL 7, THE INPUT ATMOSPHERIC PROFILE IS READ IN AFTER       022810
C           CONTROL CARD 2 AS FOR A SLANT PATH.                               022820
C                                                                             022830
C------------------------------------------------------------------          022840
C                                                                             022850
C           OUTPUT :                                                          022860
C                                                                             022870
C           THE PRINTED OUTPUT IS ON FILE IPR (DEFAULT=6). SELECTING          022880
C           NOPPNT=1 SUPRESSES THE PRINTING OF THE ATMOSPHERIC PROFILES       022890
C           AND THE LAYER-BY-LAYER RESULTS FOR THE REFRACTED PATH.            022900
C           IF IPUNCH = 1, THEN THE FASCOD1 INPUT DATA IS ALSO PUT ON FILE    022910
C           IPU (DEFAULT=7) AND CONSISTS OF A SINGLE CARD IMAGE GIVING THE    022920
C           NUMBER OF LAYERS LMAX AND A 70 CHARACTER FIELD DESCRIBING THE     022930
C           PROFILE AND THE PATH, FOLLOWED BY TWO (OR MORE) CARD IMAGES FOR   022940
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C      EACH OF THE LMAX LAYERS                                           022950
C                                                                       022960
C         CARD 1: LMAX,LABEL  (I5,5X,A70)                               022970
C                 LMAX   = NUMBER OF FASCOD1 LAYERS, MAY DIFFER FROM    022980
C                          IBND DEPENDING ON THE PATH.                  022990
C                 LABEL  = 70 CHARACTER FIELD.                          023000
C                                                                       023010
C         CARD 2: PAVE,TAVE,ICNTRL,LAYRID                               023020
C                 (2F10.4,10X,I5,25X, A20)                              023030
C                 PAVE   =  AVERAGE PRESSURE (MB)                       023040
C                 TAVE   =  AVERAGE TEMPERATURE (K)                     023050
C                 ICNTRL : IF THE PATH DOES NOT GO THROUGH A TANGENT HEIGHT, 023060
C                             IF H1.LT.H2   ICNTRL = 3                  023070
C                             IF H1.GT.H2   ICNTRL = 1                  023080
C                          IF THE PATH GOES THROUGH A TANGENT HEIGHT, THEN  023090
C                             FOR THE LAYERS FROM THE TANGENT HEIGHT TO 023100
C                             MIN(H1,H2),  ICNTRL = 2                   023110
C                             FOR THE LAYERS (IF ANY) FROM MIN(H1,H2)   023120
C                             TO H1, ICNTRL = 1                         023130
C                             FOR THE LAYERS (IF ANY) FROM MIN(H1,H2)   023140
C                             TO H2, ICNTRL = 3                         023150
C                          FOR A HORIZONTAL PATH, ICNTRL = 0            023160
C                 LAYRID:  20 CHARACTER FIELD GIVING THE BOUNDARY       023170
C                          ALTITUDES (ITYPE 2 OR 3) OR RANGE AND        023180
C                          ALTITUDE (ITYPE 1)                           023190
C                                                                       023200
C         CARD 3: (AMOUNT(K),K=1,KMAX)                                  023210
C                 (1P8E10.2)                                            023220
C                 AMOUNT(K)   INTEGRATED ABSORBER AMOUNT FOR THE K'TH   023230
C                             MOLECULAR SPECIES (MOLECULES CM-2)        023240
C                                                                       023250
C         CARDS 2 AND 3 ARE REPEATED UNTIL LMAX LAYERS ARE SPECIFIED.   023260
C                                                                       023270
C------------------------------------------------------------------    023280
C                                                                       023290
C      REFERENCES:                                                      023300
C                                                                       023310
C      (1)   FASCOD1 - A USERS' GUIDE (AVAILABLE FROM S.A. CLOUGH AT    023320
C                      THE ABOVE ADDRESS)                               023330
C            SEE ALSO:                                                  023340
C            FASCODE - FAST ATMOSPHERIC SIGNATURE CODE                  023350
C            (SPECTRAL TRANSMITTANCE AND RADIANCE)                      023360
C                                              AFGL-TR-78-008'          023370
C                                                                       023380
C      (2)   FSCATM - A FORTRAN PROGRAM TO CALCULATE AIR MASS FOR       023390
C            INFRARED RADIATIVE TRANSFER (AFGL REPORT- IN PREPERATION)  023400
C                                                                       023410
C                                                                       023420
C      (3)   ATMOSPHERIC TRANSMITTANCE/RADIANCE:                        023430
C            COMPUTER CODE LOWTRAN 5                                    023440
C                                              AFGL-TR-80-0067          023450
C                                                                       023460
C      (4)   OPTICAL PROPERTIES OF THE ATMOSPHERE (THIRD EDITION)       023470
C                                              AFGL-TR-72-0497          023480
C                                                                       023490
C                                                                       023500
C*********************************************************************  023510
C                                                                       023520
       COMMON /IFIL/ IRD,IPR,IPU                                        023530
       COMMON /PARMTR/ PI,DEG,GCAIR,RE,DELAS,ZMIN,ZMAX,IMAX,IMOD,IBMAX, 023540
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      1     IOUTMX,IPATH,IMODMX,IDIM,KDIM,KMXNOM,KMAX,NOPRNT            023550
      COMMON /CONSTN/ PZERO,TZERO,AVOGAD,ALOSMT,GASCON,PLANK,BOLTZ,     023560
   '  1    CLIGHT,ADCON,ALZERO,AVMWT,AIRMWT,AMWT(20),VMIXST(20),VMIXN2  023570
C&    DOUBLE PRECISION HMOD                                            C&023580
      COMMON HMOD(3),ZM(50),PM(50),TM(50),RFNDXM(50),DENM(20,50)        023590
      COMMON ZP(71),PP(71),TP(71),RFNDXP(71),SP(71),                   023600
      1    PPSUM(71),TPSUM(71),RHOPSM(71),DENP(20,71),AMTP(20,71)       023610
      COMMON Z(71),P(71),T(71),RFNDX(71),DENSTY(20,71)                 023620
C&    DOUBLE PRECISION HMOLS                                           C&023630
      COMMON /HMOLS/ HMOLS(20)                                          023640
      COMMON /PATHD/ PBAR(37),TBAR(37),AMOUNT(20,37),WN2L(37),          023650
     C    DVL(37),WTOTL(37),ALBL(37),ADBL(37),AVBL(37),H2OSL(37),       023660
     C    ICNTRL(37),ITYL(37),SECNTA(37),ALTB(37),ALTT(37),HT1,HT2      023670
      COMMON /MAIN/ NWDFIL,KFILE,KPANEL,LINFIL,PO,TEMPO,NLAYRS,         C23680
     C         H2OSLF,WTOT,ALBAR,ADBAR,AVBAR,AVFIX,LAYRFX,SECNTO,       023690
     C    SAMPLE,ALFALO,AVMASS                                          023700
      COMMON /BNDRY/ ZBND(34),PBND(34),TBND(34),ALORNZ(34),ADOPP(34),   023710
      1    AVOIGT(34)                                                   023720
      COMMON /ZOUTP/ ZOUT(37),SOUT(37),RHOSUM(37),AMTTOT(20),AMTCUM(20),023730
     C ISKIP(20)                                                        023740
      DIMENSION VMIX(20)                                                023750
      DIMENSION XZM(6312),XPBAR(1258),XZOUT(171)                        023760
      EQUIVALENCE (ZM(1),XZM(1)),(PBAR(1),XPBAR(1)),(ZOUT(1),XZOUT(1))  023770
C&    DOUBLE PRECISION HORIZ                                           C&023780
      DIMENSION HORIZ(3)                                                023790
      DATA AVRATS/2.0/,TDIF1S/15.0/,TDIF2S/30.0/                        023800
      DATA HORIZ/8HHORIZONT, 8HAL PATH , 8H        /                    023810
      DATA HT1HRZ/4H AT /,HT2HRZ/4H KN /,HT1SLT/4H TO /,HT2SLT/4H KM /  023820
      DATA IERROR/0/                                                    023830
C*****IAMT = 1:CALCULATE AMOUNTS, IAMT = 2:DO NOT CALCULATE AMOUNTS    023840
      DATA IAMT/1/                                                      023850
C*****O3VMIX IS THE MEAN SURFACE VOLUME MIXING RATIO OF OZONE,         023860
C*****PARTS PER MILLION, FROM U. S. STANDARD ATMOSPHERE, 1976          023870
      DATA O3VMIX/40.0E-3/                                              023880
C*****AIRMS1 IS ONE AIRMASS OR THE TOTAL AMOUNT FOR A VERTICAL PATH    023890
C*****FROM GROUND TO SPACE                                             023900
      DATA AIRMS1/2.153E25/                                             023910
      PI = ASIN(1.0)*2.0                                                023920
      DEG = 180.0/PI                                                    023930
C*****GCAIR IS THE GAS CONSTANT FOR RHO IN MOL CM(-3), P IN MB, AND    023940
C*****T IN K                                                           023950
      GCAIR = 1.0E-3*GASCON/AVOGAD                                      023960
C*****ADCON IS THE CONSTANT FOR THE DOPPLER HALFWIDTH                  023970
      ADCON = SORT(2.0*ALOG(2.0)*GASCON/CLIGHT**2)                      023980
C*****ZERO OUT COMMON BLOCKS                                           023990
      NXZM = IMODMX*(4+KDIM)+IDIM*(12+3*KDIM)                           024000
      NXPBAR = IOUTMX*(14+KDIM)                                         024010
      NXZOUT = IOUTMX*3+KDIM*3                                          024020
      DO 90 N=1,NXZM                                                    024030
   90 XZM(N) = 0.0                                                      024040
      DO 91 N=1,NXPBAR                                                  024050
   91 XPBAR(N) = 0.0                                                    024060
      DO 92 N=1,NXZOUT                                                  024070
   92 XZOUT(N) = 0.0                                                    024080
C*****                                                                 024090
C*****                                                                 024100
C*****READ CONTROL CARD 1                                              024110
      READ(IRD,20) MODEL,ITYPE,IBND,NOZERO,NOPRNT,KMAX,IPUNCH,RE        024120
   20 FORMAT(7I5,5X,F10.3)                                             024130
      WRITE(IPR,21)                                                     024140
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   21 FORMAT(' CONTROL CARD 1: MODEL AND OPTIONS ')                   024150
      WRITE(IPR,22) MODEL,ITYPE,IBND,NOZERO,NOPRNT,KMAX,IPUNCH,RE      024160
   22 FORMAT(/,10X,'MODEL   = ',I5,/,10X,'ITYPE   = ',I5,/,            024170
     1    10X,'IBND    = ',I5,/,10X,'NOZERO  = ',I5,/,                 024180
     2    10X,'NOPRNT  = ',I5,/,10X,'KMAX    = ',I5,/,                 024190
     3    10X,'IPUNCH  = ',I5,/,                                       024200
     3    10X 'RE      = ',F10.3,' KM')                                024210
      M = MODEL                                                        024220
      IF(ITYPE.LT.1 .OR. ITYPE.GT.3) GO TO 900                        024230
      IF(M.LT.0 .OR. M.GT.7)  GO TO 900                               024240
      IF(IBND.GT.IBMAX) GO TO 900                                     024250
      IF(KMAX.GT.KDIM) GO TO 900                                      024260
      IF(KMAX.EQ.0) KMAX = KMXNOM                                     024270
      IF(IPUNCH.EQ.1) OPEN(UNIT=IPU,FILE='TAPE7')                     024280
      IF(RE.NE.0.0) GO TO 95                                          024290
      RE = 6371.23                                                    024300
      IF(M.EQ.1) RE = 6378.39                                         024310
      IF(M.EQ.4 .OR. M.EQ.5) RE = 6356.91                            024320
   95 CONTINUE                                                         024330
      WRITE(IPR,24)                                                    024340
   24 FORMAT(///,' CONTROL CARD 1 PARAMETERS WITH DEFAULTS:')          024350
      WRITE(IPR,22) MODEL,ITYPE,IBND,NOZERO,NOPRNT,KMAX,IPUNCH,RE      024360
      IF(ITYPE.NE.1) GO TO 200                                        024370
C*****                                                                 024380
C*****                                                                 024390
C*****HORIZONTAL PATH SELECTED                                        024400
C*****                                                                 024410
C*****                                                                 024420
      WRITE(IPR,25)                                                    024430
   25 FORMAT(///,' HORIZONTAL PATH SELECTED')                          024440
      DO 103 I=1,3                                                     024450
      HMOD(I) =  HORIZ(I)                                             024460
  103 CONTINUE                                                         024470
      IF(M.NE.0)  GO TO 120                                           024480
C*****READ IN PARAMETERS FOR A HORIZONTAL PATH, MODEL 0               024490
      READ(IRD,26) RANGE,PH,TH,TD,RH,PPH2O,DENH2O,AMSMIX,             024500
     1    (VMIX(K),K=1,KMAX)                                          024510
   26 FORMAT(8F10.3,/,(8E10.3))                                       024520
      WRITE(IPR,27) RANGE,PH,TH,TD,RH,PPH2O,DENH2O,AMSMIX,(HMOLS(K),  024530
     1    K=1,KMAX)                                                   024540
   27 FORMAT(//,' ECHO INPUT PARAMETERS FOR MODEL 0',//,              024550
     1    10X,'RANGE   = ',F10.3,' KM',/,10X,'P       = ',F10.3,' MB',/, 024560
     2    10X,'T       = ',F10.3,' K',/,10X,'DEW PT  = ',F10.3,' C',/, 024570
     3    10X,'REL HUM = ',F10.3,' %',/,10X,'PART PR = ',F10.3,' MB',/, 024580
     4    10X,'MASS DEN= ',F10.3,' GM/M3',/,                          024590
     5    10X,'MASS MIX= ',F10.3,' GM/KG',//,                         024600
     6    40X,'VOLUME MIXING RATIO ( PARTS PER MILLION)',/,           024610
     7    10X,8A10)                                                   024620
      WRITE(IPR,28) (VMIX(K),K=1,KMAX)                                024630
   28 FORMAT(10X,1P8E10.3)                                            024640
      ZH = -9.9.0                                                     024650
      RHOBAR = ALOSMT*(PH/PZERO)*(TZERO/TH)                          024660
      DENSTY(1,1) = 0.0                                              024670
      IF(VMIX(1).EQ.0.0)  CALL WATVAP(PH,TH,TD,RH,PPH2O,DENH2O,       024680
     1    AMSMIX,DENSTY(1,1))                                        024690
      IF(VMIX(1).GT.0 C) DENSTY(1,1) = VMIX(1)*RHOBAR*1.0E-6          024700
      DO 105 K=2,KMAX                                                 024710
      DENSTY(K,1) = 0.0                                              024720
      IF(VMIX(K).EQ.0.0) DENSTY(K,1) = VMIXST(K)*RHOBAR*1.0E-6        024730
      IF(VMIX(K).GT.0.0) DENSTY(K,1) = VMIX(K)*RHOBAR*1.0E-6         !024740
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      105 CONTINUE                                                        024750
          IF(VMIX(3).EQ.0.0)  DENSTY(3,1) = O3VMIX*RHOBAR*1.0E-6          024760
          WRITE(IPR,29)RANGE,PH,TH,(HMOLS(K),K=1,KMAX)                    024770
       29 FORMAT(///,' PARAMETERS FOR A HORIZONTAL PATH, MODEL 0:',//     024780
          1    10X,'RANGE    = ',F10.3,' KM',/,10X,'P       = ',F10.3,' KM',/,  024790
          2    10X,'T        = ',F10.3,' K',//,                          024800
          3    10X,'DENSITY ',T26,'AIR',(T33,8A10))                      024810
          WRITE(IPR,30) RHOBAR,(DENSTY(K,1),K=1,KMAX)                     024820
       30 FORMAT(T63,'(MOL CM-3)',//,(T20,1PE10.3,(T30,8E10.3)))          !024830
          GO TO 160                                                       024840
C*****MODEL 1 TO 7                                                        024850
      120 CONTINUE                                                        024860
C*****READ IN CONTROL CARD 2                                              024870
          READ(IRD,31)  ZH,RANGE                                          024880
       31 FORMAT(F10.3,F10.3)                                             024890
          WRITE(IPR,32) ZH,RANGE                                          024900
       32 FORMAT(///,' CONTROL CARD 2:',//,10X,'Z      = ',F10.3,' KM',/, 024910
          1    10X,'RANGE = ',F10.3,' KM')                               024920
C*****SET UP THE ATMOSPHERIC PROFILE                                      024930
          CALL MLATM(M)                                                   024940
C*****INTERPOLATE ATMOSPHERIC PROFILE DENSITIES TO ZH                     024950
          DO 130 IM= 2,IMOD                                               024960
          IF(ZH.LT.ZM(IM))  GO TO 140                                     024970
      130 CONTINUE                                                        024980
          IM = IMOD                                                       024990
      140 CONTINUE                                                        025000
          A = (ZH-ZM(IM-1))/(ZM(IM)-ZM(IM-1))                             025010
          CALL EXPINT(PH,PM(IM-1),PM(IM),A)                               025020
          TH = TM(IM-1)+(TM(IM)-TM(IM-1))*A                               025030
          RHOBAR = ALOSMT*PH*TZERO/(PZERO*TH)                             025040
          DO 150 K=1,KMAX                                                 025050
          CALL EXPINT(DENSTY(K,1),DENM(K,IM-1),DENM(K,IM),A)              025060
      150 CONTINUE                                                        025070
          WRITE(IPR,34)  HMOD,ZH,PH,TH,(HMOLS(K),K=1,KMAX)                025080
       34 FORMAT(///' PRESSURE, TEMPERATURE, AND DENSITIES INTERPOLATED', 025090
          1     ' FROM THE FOLLOWING ATMOSPHERIC MODEL: ',//,10X, 3A8,//  025100
          2    10X,'Z       = ',F10.3,' KM',/,10X,'P       = ',F10.3,' MB'./, 025110
          3    10X,'T       = ',F10.3,' K',//,                          025120
          4    10X,'DENSITIES :',T26,'AIR',(T30,8A10))                   025130
          WRITE(IPR,35) RHOBAR,(DENSTY(K,1),K=1,KMAX)                     025140
       35 FORMAT(T63,'(MOL CM-3)',//,T20,1PE10.3,(T30,8E10.3))            !025150
      160 CONTINUE                                                        025160
C*****COMPUTE AMOUNTS FOR A HORIZONTAL PATH                               025170
          DO 170 K=1,KMAX                                                 025180
          AMOUNT(K,1) = DENSTY(K,1)*RANGE*1.0E+5                          025190
      170 CONTINUE                                                        025200
          AMTAIP = RHOBAR*RANGE*1.0E-5                                    025210
          WRITE(IPR,36) HMOD,ZH,PH,TH,RANGE,(HMOLS(K),K=1,KMAX)           025220
       36 FORMAT('0SINGLE LAYER INPUT TO FASCOD1',//,10X,'MODEL = ',3A8,/, 025230
          1    10X,'Z       = ',F10.3,' KM',/,10X,'P       = ',F10.3,' MB',/, 025240
          2    10X,'T       = ',F10.3,' K',/,10X,'RANGE = ',F10.3,' KM',//, 025250
          4    10X,'AMOUNTS:',T26, AIR',(T30,8A10))                      025260
          WRITE(IPR,37) AMTAIR, (AMOUNT(K,1),K=1,KMAX)                    025270
       37 FORMAT(T63,'(MOL CM-2)',//,T20,1PE10.2,(T30,8E10.2))            !025280
          ICNTRL(1)=0                                                     025290
          LMAX = 1                                                        025300
          NLAYRS = 1                                                      !025303
          WN2L(1) = AMTAIR*VMIXN2*1.0E-6                                  !025306
          PBAR(1)=PH                                                      025310
          TBAR(1)=TH                                                      025320
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          ALTB(1)=RANGE                                                 025330
          ZOUT(1)=ZH                                                    025340
          SECNTA(1)=1.                                                  025350
          ALTT(1)=ZH                                                    025360
          HT1 = HT1HRZ                                                  025370
          HT2 = HT2HRZ                                                  025380
          IF(IPUNCH.EQ.1) WRITE(IPU,38)  LMAX,HMOD                      025390
       38 FORMAT(I5,5X,3A8)                                             025400
          IF(IPUNCH.EQ.1) WRITE(IPU,39)  PH,TH,ICNTRL(1),RANGE,ZH,      025410
         1    (AMOUNT(K,1),K=1,7),WN2L(1),(AMOUNT(K,1),K=8,KMAX)        !025420
       39 FORMAT(2F10.4,10X,I5,25X,F7.2,' AT',F7.2,' KM',/,             025430
         1    (1P8E10.2))                                               025440
          RETURN                                                        025450
    C*****                                                              025460
    C*****                                                              025470
    C*****SLANT PATH SELECTED                                           025480
    C*****                                                              025490
    C*****                                                              025500
      200 CONTINUE                                                      025510
    C*****ITYPE = 2 OR 3: SLANT PATH THROUGH THE ATMOSPHERE             025520
          WRITE(IPR,40) ITYPE                                           025530
       40 FORMAT(///,' SLANT PATH SELECTED, ITYPE = ',I5)               025540
    C***** READ IN CONTROL CARD 2 CONTAINING SLANT PATH PARAMETERS      025550
          READ(IRD,46)  H1,H2,ANGLE,RANGE,BETA,LEN                      025560
       46 FORMAT(5F10.4,I5)                                             025570
          WRITE(IPR,48)  H1,H2,ANGLE,RANGE,BETA,LEN                     025580
       48 FORMAT(////' CONTROL CARD 2:  SLANT PATH PARAMETERS',//,      025590
         1    10X,'H1        = ',F10.4,' KM',/,10X,'H2        = ',F10.4,' KM',/, 025600
         2    10X,'ANGLE     = ',F10.4,' DEG',/,10X,'RANGE     = ',F10.4,' KM',/ 025610
         3    10X,'BETA      = ',F10.4,' DEG',/,10X,'LEN        = ',I10)  025620
    C*****READ IN CONTROL CARD 3 GIVING THE FREQUENCY RANGE IN WAVENUMBERS 025630
          READ(IRD,50) V1,V2                                            025640
       50 FORMAT(2F10.3)                                                025650
          VBAR = 0.5*(V1+V2)                                            025660
          WRITE(IPR,51) V1,V2,VBAR                                      025670
       51 FORMAT(///,' CONTROL CARD 3',//,10X,'V1    = ',F10.3,' CM-1',/, 025680
         1    10X,'V2    = ',F10.3,' CM-1',/,10X,'VBAR = ',F10.3,' CM-1') 025690
    C*****GENERATE OR READ IN FASCOD1 BOUNDARY LAYERS                   025700
          IF(IBND.NE.0) GO TO 210                                       025710
    C*****SELECT AUTOMATIC LAYERING                                     025720
          READ(IRD,56) AVTRAT,TDIFF1,TDIFF2                             025730
       56 FORMAT(3F10.3)                                                025740
          IF(AVTRAT.EQ.0.0) AVTRAT = AVRATS                             025750
          IF(TDIFF1.EQ.0.0) TDIFF1 = TDIF1S                             025760
          IF(TDIFF2.EQ.0.0) TDIFF2 = TDIF2S                             025770
          WRITE(IPR,57) AVTRAT,TDIFF1,TDIFF2                            025780
       57 FORMAT(///,' AUTOLAYERING SELECTED',//,                       025790
         1    10X,'AVTRAT.    = ',F8.2,/,10X,'TDIFF1    = ',F8.2,/,     025800
         2    10X,'TDIFF2    = ',F8.2)                                  025810
          IF(AVTRAT.LE.1.0 .OR. TDIFF1.LE.0.0 .OR. TDIFF2.LE.0.0) GO TO 906 025820
          GO TO 220                                                     025830
      210 CONTINUE                                                      025840
    C*****READ IN FASCOD1 BOUNDARY LAYERS                               025850
          READ(IRD,58) (ZBND(IB),IB=1,IBND)                            025860
       58 FORMAT(8F10.3)                                                025870
          WRITE(IPR,59) (IB,ZBND(IB),IB=1,IBND)                        025880
       59 FORMAT(///,' USER DEFINED BOUNDARIES FOR FASCOD1 LAYERS',/,  025890
         1    10X,'I',4X,'Z (KM)',//,(10X,I2,F10.4))                    025900
          IF(ZBND(1).LT.0) GO TO 902                                    025910
          DO 215 IB=2,IBND                                              025920
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      IF(ZBND(IB).LE.ZBND(IB-1)) GO TO 902                        025930
  215 CONTINUE                                                     025940
  220 CONTINUE                                                     025950
C*****SET UP ATMOSPHERIC PROFILE                                   025960
      CALL  MLATM(M)                                               025970
C*****COMPUTE THE REFRACTIVE INDEX PROFILE                         025980
C*****RFNDXM IS 1.0-INDEX                                          025990
C*****EQUATION FOR RFNDXM IS FROM LOWTRAN (REF 3)                  026000
      DO 225 IM=1,IMOD                                             026010
      PPH2O = DENM(1,IM)*PZERO*TM(IM)/(TZERO*ALOSMT)               026020
      RFNDXM(IM) = ((77.46+0.459E-8*VBAR**2)*PM(IM)/TM(IM)         026030
     1   -(PPH2O/1013.0)*(43.49-0.347E-8*VBAR**2))*1.0E-6          026040
  225 CONTINUE                                                     026050
C*****PRINT ATMOSPHERIC PROFILE                                    026060
      WRITE(IPR,52) M,HMOD                                         026070
   52 FORMAT('1ATMOSPHERIC PROFILE SELECTED IS: M = ',I3,5X, 3A8)  026080
      IF(NOPRNT.NE.0)  GO TO 230                                   026090
      WRITE(IPR,53) (HMOLS(K),K=1,KMAX)                            026100
   53 FORMAT(/,T5,'I',T12,'Z',T22,'P',T32,'T',T38,'REFRACT',       026110
     1   T70,'DENSITY   (MOLS CM-3)',/,                            026120
     2   T38,'INDEX*1',T50,/,                                      026130
     3   T11,'(KM)',T21,'(MB)',T31,'(K)',T38,'*1.0E6',             026140
     4   T50,'AIR',(T55,8A9))                                      026150
      WRITE(IPR,55)                                                026160
   55 FORMAT(/)                                                    .26170
      DO 228 IM=1,IMOD                                             026180
      DENAIR = ALOSMT*(PM(IM)/PZERO)*(TZERO/TM(IM))                026190
      WRITE(IPR,54)    IM,ZM(IM),PM(IM),TM(IM),RFNDXM(IM),DENAIR,  026200
     1    (DENM(K,IM),K=1,KMAX)                                    026210
   54 FORMAT(I4,3F10.3,6PF10.3,1P9E9.2,/,(53X,1P8E9.2))            026220
  228 CONTINUE                                                     026230
  230 CONTINUE                                                     026240
C*****REDUCE SLANT PATH PARAMETERS TO STANDARD FORM                026250
      CALL GEOINP(H1,H2,ANGLE,RANGE,BETA,ITYPE,LEN,HMIN,PHI,IERROR)026260
      IF(IERROR.NE.0) GO TO 904                                    026270
C*****SET UP FASCOD1 LAYER BOUNDARIES                              026280
      IF(IBND.NE.0)  GO TO 235                                     026290
C*****AUTOMATIC LAYERING SELECTED                                  026300
      HMAX = AMAX1(H1,H2)                                          026310
      CALL AUTLAY(HMIN,HMAX,VBAR,AVTRAT,TDIFF1,TDIFF2,IBND,IERROR) 026320
      GO TO 238                                                    026330
  235 CONTINUE                                                     026340
C*****USER SUPPLIED LAYERING                                       026350
      WRITE(IPR,80)                                                026360
   80 FORMAT(///,' HALFWIDTH INFORMATION ON THE USER SUPPLIED ',   026370
     1    'FASCOD1 BOUNDARIES',/,' THE FOLLOWING VALUES ARE ASSUMED:')026380
      DO 237 IB=1,IBND                                            026390
      CALL HALFWD(ZBND(IB),VBAR,PBND(IB),TBND(IB),ALORNZ(IB),ADOPP(IB),026400
     1    AVOIGT(IB))                                              026410
  237 CONTINUE                                                     026420
  238 CONTINUE                                                     026430
      WRITE(IPR,82) ALZERO,AVMWT,VBAR                             026440
   82 FORMAT(10X,'ALZERO    = ',F9.3,' CM-1 = AVERAGE LORENTZ WIDTH ',026450
     1    'AT STP',/,                                              026460
     2    10X,'AVMWT    = ',F8.2,'      = AVERAGE  MOLECULAR WEIGHT',/,026470
     3    10X,'VBAR     = ',F8.2,'  CM-1 = AVERAGE WAVENUMBER',///,  026480
     4    T5,'I',T12,'Z',T22,'P',T32,'T',T38,'LORENTZ',            026490
     5    T49,'DOPPLER',T61,'ZETA',T70,'VOIGT',T80,'VOIGT',T90,'TEMP',/,026500
     6    T11,'(KM)',T21,'(MB)',T31,'(K)',T40,'(CM-1)',            026510
     7    T50,'(CM-1)',T70,'(CM-1)',T80,'RATIO',T90,'DIFF (K)',/)  026520
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            DO 239 IB=1,IBND                                           026530
            ZETA = ALORNZ(IB)/(ALORNZ(IB)+ADOPP(IB))                   026540
            RATIO = 0.0                                                026550
            DTEMP = 0.0                                                026560
            IF(IB.NE.IBND) RATIO = AVOIGT(IB)/AVOIGT(IB+1)             026570
            IF(IB.NE.IBND) DTEMP = ABS(TBND(IB)-TBND(IB+1))            026580
            WRITE(IPR,84) IB,ZBND(IB),PBND(IB),TBND(IB),ALORNZ(IB),ADOPP(IB), 026590
           1     ZETA,AVOIGT(IB),RATIO,DTEMP                           026600
         84 FORMAT(I5,3F10.3,2F10.5,F10.3,F10.5,F10.2,F10.1)           026610
        239 CONTINUE                                                   026620
            IF(IERROR.NE.0)  STOP  06                                  026630
      C*****MERGE FASCOD1 LAYER BOUNDARIES WITH ATMOSPHEREIC PROFILE LEVELS 026640
            I = 0                                                      026650
            IM = 1                                                     026660
            IB = 1                                                     026670
        240 CONTINUE                                                   026680
            I = I+1                                                    026690
            IF(I.GT.IDIM) GO TO 908                                    026700
            IF(IB.GT.IBND)  GO TO 250                                  026710
            IF(ZBND(IB).LT.ZM(IM)) GO TO 260                           026720
      C*****INSERT A LEVEL FROM THE ATMOSPHERIC PROFILE                026730
            IF(ZBND(IB).EQ.ZM(IM)) IB = IB+1                           026740
        250 CONTINUE                                                   026750
            Z(I) = ZM(IM)                                              026760
            P(I) = PM(IM)                                              026770
            T(I) = TM(IM)                                              026780
            RFNDX(I) = RFNDXM(IM)                                      026790
            DO 255 K=1,KMAX                                            026800
            DENSTY(K,I) = DENM(K,IM)                                   026810
        255 CONTINUE                                                   026820
            IF(IM.GE.IMOD)  GO TO 270                                  026930
            IM = IM+1                                                  026840
            GO TO 240                                                  026850
        260 CONTINUE                                                   026860
      C*****INSERT A LEVEL FROM THE FASCOD1 BOUNDARIES AND INTERPOLATE 026870
      C*****PRESSURE, TEMPERATURE, AND DENSITIES                       026880
            Z(I) = ZBND(IB)                                            026890
            IF(IM.EQ.1)  IM = 2                                        026900
            A = (Z(I)-ZM(IM-1))/(ZM(IM,-ZM(IM-1))                      026910
            CALL EXPINT(P(I),PM(IM-1),PM(IM),A)                        026920
            T(I) = TM(IM-1)+(TM(IM)-TM(IM-1))*A                        026930
            CALL EXPINT(RFNDX(I),RFNDXM(IM-1),RFNDXM(IM),A)            026940
            DO 265 K=1,KMAX                                            026950
            CALL EXPINT(DENSTY(K,I),DENM(K,IM-1),DENM(K,IM),A)         026960
        265 CONTINUE                                                   026970
            IB = IB+1                                                  026980
            GO TO 240                                                  026990
        270 CONTINUE                                                   027000
            IMAX = I                                                   027010
      C*****CALCULATE THE REFRACTED PATH THROUGH THE ATMOSPHERE        027020
            CALL RFPATH(H1,H2,ANGLE,PHI,LEN,HMIN,IAMT,RANGE,BETA,BENDNG) 027030
      C*****PRINT AMOUNTS BY LAYER AND ACCUMULATE TOTALS               027040
            IF(NOPRNT.NE.1) WRITE(IPR,60) (HMOLS(K),K=1,KMAX)          027050
         60 FORMAT('1INTEGRATED ABSORBER AMOUNTS BY LAYER',///,        027060
           1     T5,'I  LAYER BOUNDARIES',T55,'INTEGRATED AMOUNTS (MOL CM-2)', 027070
           2     /,T11,'FROM',T22,'TO',T30,'AIR',T36,8(1X,A8,1X),/,    027080
           4     T11,'(KM)',T21,'(KM)',(T37,8A10))                     027090
            I2 = IPATH-1                                               027100
            AIRTOT = 0.0                                               027110
            DO 280 K=1,KMAX                                            027120
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  280 AMTTOT(K) = 0.0                                                     027130
      HMID = AMIN1(H1,H2)                                                027140
      DO 290 I=1,I2                                                      027150
      FAC = 1.0                                                          027160
      IF(LEN.EQ.1 .AND. ZP(I+1).LE.HMID)  FAC = 2.0                      027170
      AMTAIR = RHOPSM(I)*1.0E5                                           027180
      AIRTOT = AIRTOT+FAC*AMTAIR                                         027190
      DO 285 K=1,KMAX                                                    027200
      AMTTOT(K) = AMTTOT(K)+FAC*AMTP(K,I)                                027210
  285 CONTINUE                                                           027220
      IF(NOPRNT.NE.1) WRITE(IPR,61) I,ZP(I),ZP(I+1),AMTAIR,(AMTP(K,I),   027230
     1   K=1,KMAX)                                                       027240
   61 FORMAT(I5,2F10.3,1P9E10.3,/,(35X,1P8E10.3))                        027250
  290 CONTINUE                                                           027260
      IF(NOPRNT.NE.1) WRITE(IPR,62) H1,H2,AIRTOT,(AMTTOT(K),K=1,KMAX)    027270
   62 FORMAT('0TOTAL',F9.3,F10.3,1P9E10.3,/,(35X,1P8E10.3))              027280
  300 CONTINUE                                                           027290
C****PRINT SUMMARY OF PATH                                               027300
      AIRMAS = AIRTOT/AIRMS1                                             027310
      WRITE(IPR,63) HMOD,H1,H2,ANGLE,RANGE,BETA,PHI,HMIN,BENDNG,LEN,     027320
     1    AIRMAS                                                         027330
   63 FORMAT('1 SUMMARY OF THE GEOMETRY CALCULATION',//,                 027340
     1    10X,'MODEL   = ',4X,3A8,/                                      027350
     1    10X,'H1      = ',F10.3,' KM',/,10X,'H2      = ',F10.3,' KM',/,  027360
     2 10X,'ANGLE   = ',F10.3,' DEG',/,10X,'RANGE   = ',F10.3,' KM',/,   027370
     3 10X,'BETA    = ',F10.3,' DEG',/,10X,'PHI     = ',F10.3,' DEG',/,  027380
     4    10X,'HMIN    = ',F10.3,' KM',/,10X,'BENDING = ',F10.3,' DEG',/ 027390
     5    10X,'LEN     = ',I10,/,10X,'AIRMAS  = ',G10.3,                 027400
     6    'RELATIVE TO A VERTICAL PATH , GROUND TO SPACE')               027410
C****RETRIEVE THE LAYERS FROM HMIN TO MAX(H1,H2)' DEFINED BY THE         027420
C****BOUNDARIES HMIN,H1,H2 AND ZBND                                      027430
      I = 1                                                              027440
      I2 = IPATH-1                                                       027450
      ZOUT(I) = ZP(I)                                                    027460
C****FIND SMALLEST ZBND.GT.HMIN                                          027470
      DO 305 IB=1,IBND                                                   027480
      IF(ZBND(IB).GT.HMIN)  GO TO 310                                    027490
  305 CONTINUE                                                           027500
      IB = IBND                                                          027510
  310 CONTINUE                                                           027520
      DO 360 IP=1,I2                                                     027530
      PBAR(I) = PBAR(I)+PPSUM(IP)                                        027540
      TBAR(I) = TBAR(I)+TPSUM(IP)                                        027550
      RHOSUM(I) = RHOSUM(I)+RHOPSM(IP)                                   027560
      SOUT(I) = SOUT(I)+SP(IP)                                           027570
      DO 320 K=1,KMAX                                                    027580
      AMOUNT(K,I) = AMOUNT(K,I)+AMTP(K,IP)                               027590
  320 CONTINUE                                                           027600
      IF(ZOUT(I).EQ.HMID)  IHMID = I                                     027610
      IF(IP.EQ.I2)  GO TO 360                                            027620
C*****TEST FOR JUMP UP TO THE NEXT LAYER OF ZOUT                         027630
      IF(ZP(IP+1).EQ.ZBND(IB))  GO TO 330                                027640
      IF(LEN.EQ.1 .AND. ZP(IP+1).EQ.HMID)  GO TO 340                     027650
      GO TO 360                                                          027660
C****JUMP TO THE NEXT LAYER OF ZBND                                      027670
  330 IB = IB+1                                                          027680
      IF(IB.GT.IBND)  IB = IBND                                          027690
C****JUMP TO THE NEXT LAYER IN ZOUT                                      027700
  340 I = I+1                                                            027710
      ZOUT(I) = ZP(IP+1)                                                 027720
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      360 CONTINUE                                                         027730
          IOUTMX = I+1                                                     027740
          ZOUT(IOUTMX) = ZP(IPATH)                                         027750
          IF(ZOUT(IOUTMX).EQ.HMID)   IHMID = IOUTMX                        027760
C*****CALCULATE THE DENSITY WIEGHTED PRESSURE AND TEMPERATURE AND          027770
C*****ZERO OUT LAYER AMOUNTS AFTER 99.9 PERCENT OF THE TOTAL               027780
          DO 405 K=1,KMAX                                                  027790
          AMTCUM(K) = 0.0                                                  027800
          ISKIP(K) = 0                                                     027810
          IF(AMTTOT(K).EQ.0.0) ISKIP(K) = 1                                027820
      405 CONTINUE                                                         027830
          L2 = IOUTMX-1                                                    027840
          LMAX = L2                                                        027850
          DO 450 L=1,L2                                                    027860
          PBAR(L) = PBAR(L)/RHOSUM(L)                                      027870
          TBAR(L) = TBAR(L)/RHOSUM(L)                                      027880
C*****ADJUST RHOSUM FOR THE PATH LENGTH IN CM NOT KM                       027890
          RHOSUM(L) = RHOSUM(L)*1.0E+5                                     027900
C*****CALCULATE THE AMOUNT OF N2 TO DETERMINE THE PRESSURE BROADENING      027910
          WN2L(L) = RHOSUM(L)*VMIXN2*1.0E-6                                027920
C*****CALCULATE 'EFFECTIVE SECANT' SECNTA                                  027930
          SECNTA(L) = SOUT(L)/(ZOUT(L+1)-ZOUT(L))                         027940
          ALTB(L) = ZOUT(L)                                               027950
          ALTT(L) = ZOUT(L+1)                                             027960
C*****SET ICNTRL                                                           027970
          IF(LEN.EQ.1) GO TO 410                                          027980
              IF(H1.LT.H2)   ICNTRL(L) = 3                                027990
              IF(H1.GT.H2)   ICNTRL(L) = 1                                028000
              GO TO 415                                                   028010
      410 CONTINUE                                                        028020
              IF(ZOUT(L).LT.HMID) ICNTRL(L) = 2                           028030
              IF(ZOUT(L).GE.HMID .AND. H1.GT.H2) ICNTRL(L) = 1            028040
              IF(ZOUT(L).GE.HMID .AND. H1.LT.H2) ICNTRL(L) = 3            028050
      415 CONTINUE                                                        028060
C*****TEST FOR ZEROING OF AMOUNTS                                          028070
          ISKPT = 0                                                       028080
          FAC = 1                                                         028090
          IF(ICNTRL(L).EQ.2) FAC = 2                                      028100
          DO 440 K=1,KMAX                                                 028110
          IF(ISKIP(K).EQ.1)  GO TO 420                                    028120
          IF(NOZERO.EQ.1 .OR. K.EQ.7 .OR.                                 028130
         1     (IEMIT.EQ.1 .AND. ICNTRL(L).NE.3))  GO TO 430              028140
          IF(((AMTTOT(K)-AMTCUM(K))/AMTTOT(K)).GT.0.001)  GO TO 430       028150
      420 CONTINUE                                                        028160
C*****ZERO OUT THIS AMOUNT                                                 028170
          ISKIP(K) = 1                                                    028180
          AMOUNT(K,L) = 0.0                                               028190
          ISKPT = ISKPT+1                                                 028200
C*****IF ALL BUT O2 ARE ZEROED, ELIMINATE ALL HIGHER LAYERS               028210
          IF(ISKPT.GE.(KMAX-1))  GO TO 460                                028220
      430 CONTINUE                                                        028230
          AMTCUM(K) = AMTCUM(K)+FAC*AMOUNT(K,L)                           028240
      440 CONTINUE                                                        028250
          LMAX = L                                                        028260
      450 CONTINUE                                                        028270
      460 CONTINUE                                                        028280
C*****OUTPUT THE PROFILE                                                   028290
          WRITE(IPR,64) (HMOLS(K),K=1,KMAX)                               028300
       64 FORMAT('0FINAL SET OF LAYERS FOR INPUT TO FASCOD1',/,           028310
         1     ' A LAYER AMOUNT MAY BE SET TO ZERO IF THE CUMULATIVE ',   028320
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      2      'AMOUNT FOR THAT LAYER AND ABOVE IS LESS THAN 0.1 PERCENT',/,      028330
      3      ' OF THE TOTAL AMOUNT. THIS IS DONE,ONLY FOR THE ',             028340
      4      'FOLLOWING CASES',/,5X,'1.  IEMIT = 0 (TRANSMITTANCE)',/,5X,    028350
      5      '2.  IEMIT = 1 (RADIANCE) AND ICNTRL = 3 (PATH LOOKING UP)',/,  028360
      6      ' O2 IS NOT INCLUDED',/,' IF THE AMOUNTS FOR ALL THE',          028370
      7      ' MOLECULES BUT O2 ARE ZEROED, THE REMAINING LAYERS ARE ',      028380
      8      'ELIMINATED',/////,T5,'L   LAYER BOUNDARIES',T26,'ICNTRL',T34,  028390
      9      'PBAR',T43,'TBAR',T65,'INTEGRATED AMOUNTS (MOLS CM-2)',/,       028400
      *      T11,'FROM',T22,'TO',/,                                         028410
      1      T11,'(KM)',T21,'(KM)',T34,'(MB)',T44,'(K)',T52,'AIR',          028420
      2      (T57,8A9))                                                      028430
        IF(IPUNCH.EQ.1) WRITE(IPU,65) LMAX,HMOD,H1,H2,ANGLE,LEN            028440
   65 FORMAT(I5,5X,3A8,' H1=',F8.2,' H2=',F8.2,' ANGLE=',F8.3,            028450
      1      ' LEN=',I2)                                                     028460
        DO 470 L=1,LMAX                                                     028470
        WRITE(IPR,66)  L,ZOUT(L),ZOUT(L+1),ICNTRL(L),PBAR(L),TBAR(L),     028480
      1      RHOSUM(L),(AMOUNT(K,L),K=1,KMAX)                              028490
   66 FORMAT(/,I4,2F10.3,I4,2F9.2,1P9E9.2,/,(55X,1P8E9.2))               028500
        IF(IPUNCH.EQ.1) WRITE(IPU,68)  PBAR(L),TBAR(L),ICNTRL(L),         028510
      1      ZOUT(L),ZOUT(L+1)                                              028520
   68 FORMAT(1PG10.3,0PF10.2,10X,I5,25X,F7.2,' TO',F7.2,' KM')           028530
        IF(IPUNCH.NE.1) GO TO 470                                         !028540
        WRITE(IPU,70) (AMOUNT(K,L),K=1,7),WN2L(L)                         !028545
   70 FORMAT(1P8E10.2)                                                    !028550
        IF(KMAX.GT.7) WRITE(IPU,70) (AMOUNT(K,L),K=8,KMAX)               !028555
  470 CONTINUE                                                            028560
        NLAYRS = LMAX                                                      028570
        HT1 = HT1SLT                                                       028580
        HT2 = HT2SLT                                                       028590
        RETURN                                                             028600
C*****                                                                     028610
C*****                                                                     028620
C*****ERROR MESSAGES                                                       028630
C*****                                                                     028640
  900 WRITE(IPR,901) MODEL,ITYPE,KMAX                                     028650
  901 FORMAT(////,' ERROR IN INPUT, CONTROL CARD 1: ONE OF THE ',        028660
      1      'PARAMETERS MODEL, ITYPE, KMAX IS OUT OT RANGE',//,          028670
      2      10X,'MODEL   = ',I5,/,10X,'ITYPE   = ',I5,/,                 028690
      3      10X,'KMAX    = ',I5)                                          028690
        STOP 10                                                            028700
  902 WRITE(IPR,903)                                                      028710
  903 FORMAT(////,' ERROR: BOUNDARY ALTITUDES FOR FASCOD1 LAYERS '.      028720
      1      'ARE NEGATIVE OR NOT IN ASCENDING ORDER')                    028730
        STOP 12                                                            023740
  904 WRITE(IPR,905)                                                      028750
  905 FORMAT('0ERROR FLAG RETURNED FROM GEOINP:  AN ERROR OCCURED '.     028760
      1      'IN PROCESSING THE SLANT PATH PARAMETERS',/,                 028770
      2      '0PROGRAM STOP')                                             028780
        STOP 14                                                            028790
  906 WRITE(IPR,907)                                                      028800
  907 FORMAT(////,' ERROR: EITHER AVTRAT.LE.1.0 OR TDIFF.LE.0',/,        028810
      1      '0PROGRAM STOP')                                             028820
        STOP 05                                                            028830
  908 WRITE(IPR,909) IDIM                                                 028840
  909 FORMAT(//,' ERROR: THE MERGING OF THE ATMOSPHERIC PROFILE ',       028850
      1      'AND THE FASCODE BOUNDARIES ',/,T10,'EXCEEDS THE AVAILABLE', 028860
      2      ' DIMENSION IDIM = ',I3)                                      028870
        STOP 16                                                            028880
        END                                                               028890
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      BLOCK DATA ATMCON                                                   028900
C************************************************************************  028910
C     THIS SUBROUTINE INITIALIZES THE CONSTANTS  USED IN THE              028920
C     PROGRAM. CONSTANTS RELATING TO THE ATMOSPHERIC PROFILES ARE STORED  028930
C     IN BLOCK DATA MLATMB.                                               028940
C************************************************************************  028950
      COMMON /PARMTR/ PI,DEG,GCAIR,RE,DELTAS,ZMIN,ZMAX,IMAX,IMOD,IBMAX,   028960
     1    IOUTMX,IPATH,IMODMX,IDIM,KDIM,KMXNOM,KMAX,NOPRNT                 028970
      COMMON /CONSTN/ PZERO,TZERO,AVOGAD,ALOSMT,GASCON,PLANK,BOLTZ,       028980
     1    CLIGHT,ADCON,ALZERO,AVMWT,AIRMWT,AMWT(20),VMIXST(20),VMIXN2     028990
C&    DOUBLE PRECISION HMOLS                                              C&029000
      COMMON /HMOLS/ HMOLS(20)                                            029010
C*****IMODMX IS THE MAX NUMBER OF LEVELS IN THE ATMOSPHERIC PROFILE       029020
C*****     STORED IN ZM                                                   029030
C*****IOUTMX IS THE MAXIMUN NUMBER OF OUTPUT LAYERS                       029040
C*****IDIM IS THE MAXIMUM NUMBER OF LEVELS IN THE PROFILE Z OBTAINED      029050
C*****    BY MERGING ZM AND ZBND                                          029060
C*****KDIM ID THE MAXIMUM NUMBER OF MOLECULES, KMXNOM IS THE DEFAULT      029070
C*****IBMAX IS THE MAXIMUM NUMBER OF INPUT FASCODE LAYERS                 029080
      DATA IMODMX/50/,IOUTMX/37/,IDIM/71/,KDIM/20/,KMXNOM/7/              029090
      DATA IBMAX/34/                                                      029100
C*****DELTAS IS THE NOMINAL SLANT PATH INCREMENT IN KM.                   029110
      DATA DELTAS/5.0/                                                    029120
      DATA PZERO/1013.25/,TZERO/273.15/                                   029130
      DATA AVOGAD/6.022045E+23/,ALOSMT/2.68675E+19/,                      029140
     1    GASCON/8.31441E+7/,PLANK/6.626176E-27/,BOLTZ/1.380662E-16/,     029150
     2    CLIGHT/2.99792458E10/                                           029160
C*****ALZERO IS THE MEAN LORENTZ HALFWIDTH AT PZERO AND 296.0 K.          029170
C*****AVMWT IS THE MEAN MOLECULAR WEIGHT USED TO AUTOMATICALLY            029180
C*****GENERATE THE FASCOD1 BOUNDARIES IN AUTLAY                           029190
      DATA ALZERO/0.1/,AVMWT/36.0/                                        029200
C*****ORDER OF MOLECULES H2O(1), CO2(2), O3(3), N2O(4), CO(5), CH4(6),    029210
C*****    O2(7), NO(8), SO2(9), NO2(10), NH3(11), HNO3(12), OH(13),       029220
C*****    HF(14 ), HCL(15), HBR(16), HI(17), CLO(18), OCS(19), H2CO(20)   029230
      DATA HMOLS/ 8H   H2O    , 8H   CO2   , 8H   O3    ,                  029240
     1    8H   N2O   , 8H   CO    , 8H   CH4   ,                          029250
     2    8H   O2    , 8H   NO    , 8H   SO2   ,                          029260
     3    8H   NO2   , 8H   NH3   , 8H   HNO3  ,                          029270
     4    8H   OH    , 6H   HF    , 8H   HCL   ,                          029280
     5    8H   HBR   , 8H   HI    , 8H   CLO   ,                          029290
     6    8H   OCS   , 8H   H2CO  /                                       029300
C*****MOLECULAR WEIGHTS                                                   029310
      DATA AIRMWT/28.964/,AMWT/18.015,44.010,47.998,44.01,28.011,         029320
     1    16.043,31.999,30.01,64.06,46.01,17.03,63.01,17.00,20.01,        029330
     2    36.46,80.92,127.91,51.45,60.08,30.03/                          029340
C*****VMIXN2 IS THE VOLUME MIXING RATIO OF N2                             029350
      DATA VMIXN2/7.8084E5/                                               029360
C*****DEFAULT VOLUME MIXING RATIOS FOR THE UNIFORMILY MIXED GASES         029370
C*****FOR USER SUPPLIED ATMOSPHERIC PROFILES,                            029380
C*****IN PARTS PER MILLION, FROM THE U. S. STANDARD ATMOSPHERE, 1976.    029390
C*****THESE ARE NOT THE SAME VALUES AS USED IN MODELS 1 TO 6             029400
      DATA VMIXST/0.0,322., 0.0,0.27,0.19,1.5,2.0948E+5,13*0.0/           029410
      END                                                                029420
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      BLOCK DATA MLATM8                                                029430
C*********************************************************************** 029440
C     THIS SUBROUTINE INITIALIZES THE 6 BUILT-IN ATMOSPHERIC PROFILES  029450
C     (FROM 'OPTICAL PROPERTIES OF THE ATMOSPHERE, THIRD EDITION'      029460
C     AFCRL-72-0497 (AD 753 075) AND 'U.S. STANDARD ATMOSPHERE 1976)   029470
C     AND SETS OTHER CONSTANTS RELATED TO THE ATMOSPHERIC PROFILES     029480
C*********************************************************************** 029490
C&    DOUBLE PRECISION ATMNA1,ATMNA2,ATMNA3,ATMNA4,ATMNA5,ATMNA6      C&029500
      COMMON /MLATMC/ ALT(34),P1(34),P2(34),P3(34),P4(34),P5(34),P6(34) C29510
     +,T1(34),T2(34) T3(34),T4(34),T5(34),T6(34)                       029520
     +,AMOL11(34),AM  12(34),AMOL13(34),AMOL14(34),AMOL15(34),AMOL1S(34) 029530
     +,AMOL17(34),AMOL18(34)                                           029540
     +,AMOL21(34),AMOL22(34),AMOL23(34),AMOL24(34),AMOL25(34),AMOL26(34) 029550
     +,AMOL27(34),AMOL28(34)                                           029560
     +,AMOL31(34),AMOL32(34),AMOL33(34),AMOL34(34),AMOL35(34),AMOL36(34) 029570
     +,AMOL37(34),AMOL38(34)                                           029580
     +,AMOL41(34),AMOL42(34),AMOL43(34),AMOL44(34),AMOL45(34),AMOL46(34) 029590
     +,AMOL47(34),AMOL48(34)                                           029600
     +,AMOL51(34),AMOL52(34),AMOL53(34),AMOL54(34),AMOL55(34),AMOL56(34) 029610
     +,AMOL57(34),AMOL58(34)                                           029620
     +,AMOL61(34),AMOL62(34),AMOL63(34),AMOL64(34),AMOL65(34),AMOL66(34) 029630
     +,AMOL67(34),AMOL68(34)                                           029640
     +,ATMNA1(3),ATMNA2(3),ATMNA3(3),ATMNA4(3),ATMNA5(3),ATMNA6(3)     029650
      DATA ATMNA1  /8HTROPICAL,8H        ,8H        /                  029660
      DATA ATMNA2  /8HMIDLATIT,8HUDE SUMM,8HER       /                  029670
      DATA ATMNA3  /8HMIDLATIT,8HUDE WINT,8HER       /                  029680
      DATA ATMNA4  /8HSUBARCTI,8HC SUMMER ,8H       /                  029690
      DATA ATMNA5  /8HSUBARCTI,8HC WINTER ,8H       /                  029700
      DATA ATMNA6  /8HU. S. ST,8HANDARD,  ,8H1962   /                  029710
      DATA ALT /                                                       029720
     *       0.,        1.,        2.,        3.,        4.,        5.. 029730
     *       6.,        7.,        8.,        9.,       10.,       11., 029740
     *      12.,       13.,       14.,       15.,       16.,       17.. 029750
     *      18.,       19.,       20.,       21.,       22.,       23.. 029760
     *      24.,       25.,       30.,       35.,       40.,       45.. 029770
     *      50.,       70.,      100.,        0./                      029780
      DATA P1 /                                                        029790
     * 1.013E+03, 9.040E+02, 8.050E+02, 7.150E+02, 6.330E+02, 5.590E+02, 029800
     * 4.920E+02, 4.320E+02, 3.780E+02, 3.290E+02, 2.860E+02, 2.470E+02, 029810
     * 2.130E+02, 1.820E+02, 1.560E+02, 1.320E+02, 1.110E+02, 9.370E+01, 029820
     * 7.890E+01, 6.660E+01, 5.650E+01, 4.800E+01, 4.090E+01, 3.500E+01, 029830
     * 3.000E+01, 2.570E+01, 1.220E+01, 6.000E+00, 3.050E+00, 1.590E+00, 029840
     + 8.540E-01, 5.790E-02, 3.000E-04, 0.        /                    029850
      DATA P2 /                                                        029860
     * 1.013E+03, 9.020E+02, 8.020E+02, 7.100E+02, 6.280E+02, 5.540E+02, 029870
     * 4.870E+02, 4.260E+02, 3.720E+02, 3.240E+02, 2.810E+02, 2.430E+02, 029880
     * 2.090E+02, 1.790E+02, 1.530E+02, 1.300E+02, 1.110E+02, 9.500E+01, 029890
     * 8.120E+01, 6.950E+01, 5.950E+01, 5.100E+01, 4.370E+01, 3.760E+01, 029900
     * 3.220E+01, 2.770E+01, 1.320E+01, 6.520E+00, 3.330E+00, 1.760E+00, 029910
     * 9.510E-01, 6.710E-02, 3.000E-04, 0.        /                    029920
      DATA P3 /                                                        029930
     * 1.018E+03, 8.973E+02, 7.897E+02, 6.938E+02, 6.081E+02, 5.313E+02, 029940
     * 4.627E+02, 4.016E+02, 3.473E+02, 2.992E+02, 2.568E+02, 2.199E+02, 029950
     * 1.882E+02, 1.610E+02, 1.378E+02, 1.178E+02, 1.007E+02, 8.610E+01, 029960
     * 7.350E+01, 6.280E+01, 5.370E+01, 4.580E+01, 3.910E+01, 3.340E+01, 029970
     * 2.860E+01, 2.430E+01, 1.110E+01, 5.180E+00, 2.530E+00, 1.290E+00, 029980
     * 6.820E-01, 4.670E-C2, 3.000E-04, 0.        /                    029990
      DATA P4 /                                                        030000
     * 1.010E+03, 8.960E+02, 7.929E+02, 7.000E+02, 6.160E+02, 5.410E+02, 030010
     * 4.730E+02, 4.130E+02, 3.590E+02, 3.107E+02, 2.677E+02, 2.300E+02, 030020
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 * 1.977E+02, 1.700E+02, 1.460E+02, 1.250E+02, 1.080E+02, 9.280E+01,   C30030
 * 7.980E+01, 6.860E+01, 5.890E+01, 5.070E+01, 4.360E+01, 3.750E:01,   030040
 * 3.227E+01, 2.780E+01, 1.340E+01, 6.610E+00, 3.400E+00, 1.810E+00.   03005C
 * 9.870E-01, 7.070E-02, 3.000E-04, 0.         /                       030060
   DATA P5 /                                                           030070
 * 1.013E+03, 8.878E+02, 7.775E+02, 6.798E+02, 5.932E+02, 5.158E+02,   030080
 * 4.467E+02, 3.853E+02, 3.308E+02, 2.829E+02, 2.418E+02, 2.067E+02,   030090
 * 1.766E+02, 1.510E+02, 1.291E+02, 1.103E+02, 9.431E+01, 8.058E+01,   030100
 * 6.882E+01, 5.875E+01, 5.014E+01, 4.277E+01, 3.647E+01, 3.109E+01,   030110
 * 2.649E+01, 2.256E+01, 1.020E+01, 4.701E+00, 2.243E+00, 1.113E+00.   030120
 * 5.719E-01, 4.016E-02, 3.000E-04, 0.         /                       030130
   DATA P6 /                                                           030140
 * 1.013E+03, 8.986E+02, 7.950E+02, 7.012E+02, 6.166E+02, 5.405E+02,   030150
 * 4.722E+02, 4.111E+02, 3.565E+02, 3.080E+02, 2.650E+02, 2.270E+02,   030160
 ^ 1.940E+02, 1.658E+02, 1.417E+02, 1.211E+02, 1.035E+02, 8.850E+01,   03C170
 * 7.565E+01, 6.467E+01, 5.529E+01, 4.729E+01, 4.047E+01, 3.467E+01,   030180
 * 2.972E+01, 2.549E+01, 1.197E+01, 5.746E+00, 2.871E+00, 1.491E+00.   030190
 * 7.978E-01, 5.520E-02, 3.008E-04, 0.         /                       C30200
   DATA T1 /                                                           030210
 * 3.000E+02, 2.940E+02, 2.880E+02, 2.840E+02, 2.770E+02, 2.700E+02,   030220
 * 2.640E+02, 2.570E+02, 2.500E+02, 2.440E+02, 2.370E+02, 2.300E+02,   030230
 * 2.240E+02, 2.170E+02, 2.100E+02, 2.040E+02, 1.970E+02, 1.950E+02,   030240
 * 1.990E+02, 2.030E+02, 2.070E+02, 2.110E+02, 2.150E+02, 2.170E+02,   030250
 ~ 2.190E+02, 2.210E+02, 2.320E+02, 2.430E+02, 2.540E+02, 2.650E+02,   030260
 * 2.700E+02, 2.190E+02, 2.100E+02, 1.900E+02/                         030270
   DATA T2 /                                                           030280
 * 2.940E+02, 2.900E+02, 2.850E+02, 2.790E+02, 2.730E+02, 2.670E+02,   030290
 * 2.610E+02, 2.550E+02, 2.480E+02, 2.420E+02, 2.350E+02, 2.290E+02,   030300
 * 2.220E+02, 2.160E+02, 2.160E+02, 2.160E+02, 2.160E+02, 2.160E+02,   030310
 * 2.160E+02, 2.170E+02, 2.180E+02, 2.190E+02, 2.200E+02, 2.220E+02,   030320
 * 2.230E+02, 2.240E+02, 2.340E+02, 2.450E+02, 2.580E+02, 2.700E+02,   030330
 * 2.760E+02, 2.180E+02, 2.100E+02, 1.900E+02/                         030340
   DATA T3 /                                                           030350
 * 2.722E+02, 2.687E+02, 2.652E+02, 2.617E+02, 2.557E+02, 2.497E+02,   C30360
 * 2.437E+02, 2.377E+02, 2.317E+02, 2.257E+02, 2.197E+02, 2.192E+02,   030370
 * 2.187E+02, 2.182E+02, 2.177E+02, 2.172E+02, 2.167E+02, 2.162E+02,   030380
 * 2.157E+02, 2.152E+02, 2.152E+02, 2.152E+02, 2.152E+02, 2.152E+02,   030390
 * 2.152E+02, 2.152E+02, 2.174E+02, 2.278E+02, 2.432E+02, 2.585E+02,   030400
 * 2.657E+C2, 2.307E+02, 2.102E+02, 1.900E+02/                         030410
   DATA T4 /                                                           030420
 * 2.870E+02, 2.820E+02, 2.760E+02, 2.710E+02, 2.660E+02, 2.600E+02,   030430
 * 2.530E+02, 2.460E+02, 2.390E+02, 2.320E+02, 2.250E+02, 2.250E+C2,   030440
 * 2.250E+02, 2.250E+02, 2.250E+02, 2.250E+02, 2.250E+02, 2.250E+02,   030450
 * 2.250E+02, 2.250E+02, 2.250E+02, 2.250E+02, 2.250E+02, 2.250E+02,   030460
 * 2.260E+C2, 2.280E+02, 2.350E+02, 2.470E+02, 2.620E+02, 2.740E+02,   030470
 * 2.770E+02, 2.160E+02, 2.100E+02, 1.900E+02/                         030480
   DATA T5 /                                                           C30490
 * 2.571E+02, 2.591E+02, 2.559E+02, 2.527E+02, 2.477E+02, 2.409E+02,   030500
 * 2.341E+02, 2.273E+02, 2.206E+02, 2.172E+02, 2.172E+02, 2.172E+02,   030510
 * 2.172E+02, 2.172E+02, 2.172E+02, 2.172E+02, 2.166E+02, 2.160E+02,   030520
 * 2.154E+02, 2.148E+02, 2.141E+02, 2.136E+02, 2.130E+02, 2.124E+02,   030530
 * 2.118E+02, 2.112E+02, 2.160E+02, 2.222E+02, 2.347E+02, 2.470E+02.   030540
 * 2.593E+02, 2.457E+02, 2.200E+02, 1.900E+02,                         030550
   DATA T6 /                                                           030560
 * 2.881E+02, 2.816E+02, 2.751E+02, 2.687E+02, 2.622E+02, 2.557E+02,   030570
 * 2.492E+02, 2.427E+02, 2.362E+02, 2.297E+02, 2.232E+02, 2.168E+02,   03058C
 * 2.166E+C2, 2.166E+02, 2.166E+02, 2.166E+02, 2.166E+02, 2.166E+02,   030590
 * 2.166E+02, 2.166E+02, 2.166E+02, 2.176E+02, 2.186E+02, 2.196E+02,   030600
 * 2.206E+02, 2.216E+02, 2.265F' 2, 2.365E+02, 2.534E+02, 2.642E+02,   030610
 * 2.706E+02, 2.197E+02, 2.100E :. 1.900E+02/                          030620
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      DATA AMOL11 /
     * 6.353E+17, 4.347E+17, 3.110E+17, 1.571E+17, 7.356E+16, 5.015E+16,    030630
     * 2.842E+16, 1.571E+16, 8.359E+15, 4.012E+15, 1.672E+15, 5.684E+14,    030640
     * 2.006E+14, 6.018E+13, 3.344E+13, 2.541E+13, 2.140E+13, 1.872E+13,    030650
     * 1.672E+13, 1.638E+13, 1.505E+13, 1.705E+13, 1.705E+13, 1.896E+13,    030660
     * 2.006E+13, 2.240E+13, 1.204E+13, 3.678E+12, 1.438E+12, 6.353E+11,    030670
     * 2.106E+11, 4.681E+09, 3.344E+07, 0.          /                        030680
      DATA AMOL12 /                                                          030690
                                                                            030700
     * 7.864E+15, 7.208E+15, 6.580E+15, 5.968E+15, 5.440E+15, 4.934E+15,    030710
     * 4.447E+15, 4.014E+15, 3.612E+15, 3.223E+15, 2.885E+15, 2.568E+15,    030720
     * 2.273E+15, 2.005E+15, 1.776E+15, 1.547E+15, 1.347E+15, 1.149E+15,    030730
     * 9.480E+14, 7.844E+14, 6.526E+14, 5.439E+14, 4.548E+14, 3.856E+14,    030740
     * 3.275E+14, 2.780E+14, 1.257E+14, 5.903E+13, 2.871E+13, 1.435E+13,    030750
     * 7.562E+12, 6.321E+11, 3.416E+09, 0.          /                        030760
      DATA AMOL13 /                                                          030770
     * 7.028E+11, 7.028E+11, 6.777E+11, 6.400E+11, 5.898E+11, 5.647E+11,    030780
     * 5.396E+11, 5.145E+11, 4.894E+11, 4.894E+11, 4.894E+11, 5.145E+11,    030790
     * 5.396E+11, 5.647E+11, 5.647E+11, 5.898E+11, 5.898E+11, 8.659E+11,    030800
     * 1.129E+12, 1.757E+12, 2.384E+12, 3.012E+12, 3.514E+12, 4.016E+12,    030810
     * 4.267E+12, 4.267E+12, 3.012E+12, 1.155E+12, 5.145E+11, 1.631E+11,    030820
     * 5.396E+10, 1.079E+09, 5.396E+05, 0.          /                        030830
      DATA AMOL14 /                                                          030840
     * 6.672E+12, 6.116E+12, 5.583E+12, 5.063E+12, 4.615E+12, 4.186E+12,    030850
     * 3.773E+12, 3.406E+12, 3.065E+12, 2.734E+12, 2.448E+12, 2.178E+12,    030860
     * 1.929E+12, 1.701E+12, 1.507E+12, 1.313E+12, 1.143E+12, 9.748E+11,    030870
     * 8.043E+11, 6.656E+11, 5.537E+11, 4.615E+11, 3.859E+11, 3.272E+11,    030880
     * 2.779E+11, 2.359E+11, 1.067E+11, 5.009E+10, 2.436E+10, 1.217E+10,    030890
     * 6.417E+09, 5.364E+08, 2.698E+06, 0.          /                        030900
      DATA AMOL15 /                                                          030910
     * 1.787E+12, 1.638E+12, 1.496E+12, 1.356E+12, 1.236E+12, 1.121E+12,    030920
     * 1.011E+12, 9.122E+11, 8.210E+11, 7.324E+11, 6.556E+11, 5.835E+11,    030930
     * 5.167E+11, 4.558E+11, 4.037E+11, 3.516E+11, 3.062E+11, 2.611E+11,    030940
     * 2.154E+11, 1.783E+11, 1.483E+11, 1.236E+11, 1.034E+11, 8.764E+10,    030950
     * 7.444E+10, 6.319E+10, 2.857E+10, 1.342E+10, 6.525E+09, 3.260E+09,    030960
     * 1.719E+09, 1.437E+08, 7.763E+05, 0.          /                        030970
      DATA AMOL16 /                                                          030980
     * 3.813E+13, 3.495E+13, 3.191E+13, 2.893E+13, 2.637E+13, 2.392E+13,    030990
     * 2.156E+13, 1.946E+13, 1.751E+13, 1.562E+13, 1.399E+13, 1.245E+13,    031000
     * 1.102E+13, 9.723E+12, 8.612E+12, 7.501E+12, 6.532E+12, 5.570E+12,    031010
     * 4.596E+12, 3.803E+12, 3.164E+12, 2.637E+12, 2.205E+12, 1.870E+12,    031020
     * 1.588E+12, 1.348E+12, 6.096E+11, 2.862E+11, 1.392E+11, 6.955E+10,    031030
     * 3.677E+10, 3.065E+09, 1.656E+07, 0.        /                          031040
      DATA AMOL17 /                                                          031050
     * 4.992E+18, 4.576E+18, 4.178E+18, 3.789E+18, 3.453E+18, 3.132E+18,    031060
     * 2.823E+18, 2.548E+18, 2.293E+18, 2.046E+18, 1.831E+18, 1.630E+18,    031070
     * 1.443E+18, 1.273E+18, 1.128E+18, 9.822E+17, 8.553E+17, 7.294E+17,    031080
     * 6.016E+17, 4.980E+17, 4.143E+17, 3.453E+17, 2.887E+17, 2.448E+17,    031090
     * 2.079E+17, 1.765E+17, 7.982E+16, 3.748E+16, 1.823E+16, 9.107E+15,    031100
     * 4.801E+15, 4.013E+14, 2.168E+12, 0.          /                        031110
      DATA AMOL18 /                                                          031120
     * 1.861E+19, 1.706E+19, 1.557E+19, 1.412E+19, 1.287E+19, 1.167E+19,    031130
     * 1.052E+19, 9.498E+18, 8.548E+18, 7.626E+18, 6.826E+18, 6.076E+18,    031140
     * 5.380E+18, 4.715E+18, 4.203E+18, 3.661E+18, 3.188E+18, 2.719E+18,    031150
     * 2.243E+18, 1.856E+18, 1.544E+18, 1.287E+18, 1.076E+18, 9.125E+17,    031160
     * 7.750E+17, 6.579E+17, 2.975E+17, 1.397E+17, 6.794E+16, 3.395E+16,    031170
     * 1.790E+16, 1.496E+15, 8.083E+12, 0.          /                        031180
      DATA AMOL21 /                                                          031190
     * 4.681E+17, 3.110E+17, 1.973E+17, 1.103E+17, 6.353E+16, 3.344E+16,    031200
     * 2.040E+16, 1.237E+16, 7.022E+15, 4.012E+15, 2.140E+15, 7.356E+14,    031210
     * 2.006E+14, 6.018E+13, 3.344E+13, 2.541E+13, 2.140E+13, 1.872E+13,    031220
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* !.672E+13, 1.638E+13, 1.505E+13, !.705E+13, 1.705E+13, 1.606E+13,   031230
* 2.006E+13, 2.240E+13, 1.204E+13, 3.678E=12, 1.438E+12, 6.353E+11,   031240
* 2.106E+11, 4.681E+09, 3.344E+07, 0.        /                        031250
  DATA AMOL22 /                                                       031260
* 8.084E+15, 7.334E+15. 6.663E+15, 6.048E+15, 5.479E+15, 4.950E+15,   031270
* 4.455E+15, 3.99CE+15, 3.584E+15, 3.200E+15, 2.858E+15, 2.537E+15,   031280
* 2.251E+15, 1.981E+15, !.694E+15, 1.439E+15, 1.223E+15, 1.052E+15,   031290
* 8.988E+14, 7.658E+14, 6.526E+14, 5.568E+14, 4.749E+14, 4.049E+14,   031300
* 3.452E+14, 2.957E+14, 1.349E+14, 6.363E+13, 3.086E+13, 1.559E+13,   031310
* 8.238E+12, 7.359E+11, 3.416E+09, 0.        /                        031320
  DATA AMOL23 /                                                       031330
* 7.530E+11, 7.530E+11, 7.530E+11, 7.781E+11, 8.032E+11, 8.283E+11,   031340
* 8.659E+11, 9.412E+11, 9.914E+11, 1.079E+12, 1.129E+12, 1.380E+12,   031350
* 1.506E+12, 1.882E+12, 2.259E+12, 2.384E+12, 2.635E+12, 3.012E+12,   031360
* 3.514E+12, 4.016E+12, 4.267E+12, 4.518E+12, 4.518E+12, 4.267E+12,   031370
* 4.016E+12, 3.765E+12, 2.510E+12, 1.155E+12, 5.145E+11, 1.631E+11,   031380
* 5.396E+10, 1.079E+09, 5.396E+05, 0.        /                        031390
  DATA AMOL24 /                                                       031400
* 6.859E+12, 6.223E+12, 5.654E+12, 5.132E+12, 4.649E+12, 4.200E+12,   031410
* 3.780E+12, 3.386E+12, 3.041E+12, 2.715E+12, 2.425E+12, 2.153E+12,   031420
* 1.910E+12, 1.681E+12, 1.437E+12, 1.221E+12, 1.043E+12, 8.922E+11,   031430
* 7.626E+11, 6.497E+11, 5.537E+11, 4.724E+11, 4.030E+11, 3.436E+11,   031440
* 2.929E+11, 2.509E+11, 1.144E+11, 5.399E+10, 2.618E+10, 1.322E+10,   031450
* 6.990E+09, 6.244E+08, 2.898E+06, 0.        /                        031460
  DATA AMOL25 /                                                       031470
* 1.837E+12, 1.667E+12, 1.514E+12, 1.375E+12, 1.245E+12, 1.125E+12,   031480
* 1.012E+12, 9.069E+11, 8.146E+11, 7.272E+11, 6.496E+11, 5.766E+11,   031490
* 5.116E+11, 4.503E+11, 3.849E+11, 3.270E+11, 2.792E+11, 2.390E+11,   031500
* 2.043E+11, 1.740E+11, 1.483E+11, 1.265E+11, 1.079E+11, 9.203E+10,   031510
* 7.846E+10, 6.720E+10, 3.065E+10, 1.446E+10, 7.014E+09, 3.542E+09,   031520
* 1.872E+09, 1.673E+08, 7.763E+05, 0.        /                        031530
  DATA AMOL26 /                                                       031540
* 3.919E+13, 3.556E+13, 3.231E+13, 2.932E+13, 2.657E+13, 2.400E+13,   031550
* 2.160E+13, 1.935E+13, 1.738E+13, 1.551E+13, 1.386E+13, 1.230E+13,   031560
* 1.091E+13, 9.607E+12, 8.211E+12, 6.977E+12, 5.957E+12, 5.099E+12,   031570
* 4.358E+12, 3.713E+12, 3.164E+12, 2.700E+12, 2.303E+12, 1.963E+12,   031580
* 1.674E+12, 1.434E+12, 6.539E+11, 3.085E+11, 1.496E+11, 7.557E+10,   031590
* 3.994E+10, 3.568E+09, 1.656E+07, 0.        /                        031600
  DATA AMOL27 /                                                       031610
* 5.132E+18, 4.656E+18, 4.220E+18, 3.840E+18, 3.478E+18, 3.142E+18,   031620
* 2.828E+18, 2.533E+18, 2.275E+18, 2.031E+18, 1.815E+19, 1.611E+18,   031630
* 1.429E+18, 1.258E+18, 1.075E+18, 9.135E+17, 7.800E+17, 6.676E+17,   031640
* 5.706E+17, 4.861E+17, 4.143E+17, 3.535E+17, 3.015E+17, 2.571E+17,   031650
* 2.192E+17, 1.877E+17, 8.562E+16, 4.039E+16, 1.959E+16, 9.894E+15,   031660
* 5.230E+15, 4.672E+14, 2.169E+12, 0.        /                        031670
  DATA AMOL28 /                                                       031680
* 1.913E+19, 1.736E+19, 1.577E+19, 1.431E+19, 1.297E+19, 1.171E+19,   031690
* 1.054E+19, 9.442E+18, 8.481E+18, 7.572E+18, 6.764E+18, 6.003E+18,   031700
* 5.326E+18, 4.689E+18, 4.008E+18, 3.405E+18, 2.903E+18, 2.489E+18,   031710
* 2.127E+18, 1.812E+18, 1.544E+18, 1.018E+18, 1.124E+18, 9.583E+17,   03172C
* 8.170E+17, 6.996E+17, 3.192E+17, 1.506E+17, 7.302E+16, 3.688E+16,   031730
* 1.949E+16, 1.741E+15, 8.083E+12, 0.        /                        031740
  DATA AMOL31 /                                                       03175C
* 1.170E+17, 8.359E+16, 6.018E+16, 4.012E+16, 2.207E+16, 1.271E+16,   031760
* 7.022E+15, 2.842E+15, 1.170E+15, 5.350E+14, 2.508E+14, 2.307E+14,   031770
* 2.006E+14, 6.018E+13, 3.344E+13, 2.541E+13, 2.140E+13, 1.872E+13,   031780
* 1.672E+13, 1.638E+13, 1.505E+13, 1.705E+13, 1.705E+13, 1.806E+13,   031790
* 2.006E+13, 2.240E+13, 1.204E+13, 3.678E+12, 1.438E+12, 6.353E+11,   031800
* 2.106E+11, 4.681E+09, 3.344E+07, 0.        /                        031810
  DATA AMOL32 /                                                       031820
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 * 8.903E+15, 7.957E+15, 7.100E+15, 6.326E+15, 5.679E+15, 5.083E+15,   031830
 * 4.537E+15, 4.039E+15, 3.583E+15, 3.169E+15, 2.795E+15, 2.399E+15,   031840
 * 2.057E+15, 1.764E+15, 1.513E+15, 1.297E+15, 1.111E+15, 9.522E+14,   031850
 * 8.147E+14, 6.977E+14, 5.966E+14, 5.089E+14, 4.344E+14, 3.711E+14,   031860
 * 3.178E+14, 2.700E+14, 1.221E+14, 5.437E+13, 2.487E+13, 1.193E+13,   031870
 * 6.137E+12, 4.840E+11, 3.412E+09, 0.        /                        031880
   DATA AMOL33 /                                                       031890
 * 7.530E+11, 6.777E+11, 6.149E+11, 6.149E+11, 6.149E+11, 7.279E+11,   031900
 * 8.032E+11, 9.663E+11, 1.129E+12, 1.506E+12, 2.008E+12, 2.635E+12,   031910
 * 3.263E+12, 3.765E+12, 4.016E+12, 4.267E+12, 4.518E+12, 4.894E+12,   031920
 * 5.145E+12, 5.396E+12, 5.647E+12, 5.396E+12, 5.396E+12, 4.894E+12,   031930
 * 4.518E+12, 4.267E+12, 2.384E+12, 1.155E+12, 5.145E+11, 1.631E+11,   031940
 * 5.396E+10, 1.079E+09, 5.396E+05, 0.        /                        031950
   DATA AMOL34 /                                                       031960
 * 7.554E+12, 6.751E+12, 6.024E+12, 5.367E+12, 4.818E+12, 4.313E+12,   031970
 * 3.850E+12, 3.427E+12, 3.041E+12, 2.689E+12, 2.371E+12, 2.035E+12,   031980
 * 1.746E+12, 1.497E+12, 1.284E+12, 1.100E+12, 9.427E+11, 8.079E+11,   031990
 * 6.913E+11, 5.920E+11, 5.062E+11, 4.318E+11, 3.686E+11, 3.149E+11,   032000
 * 2.696E+11, 2.291E+11, 1.036E+11, 4.613E+10, 2.110E+10, 1.012E+10,   032010
 * 5.207E+09, 4.107E+08, 2.895E+06, 0.        /                        032020
   DATA AMOL35 /                                                       032030
 * 2.023E+12, 1.808E+12, 1.614E+12, 1.438E+12, 1.291E+12, 1.155E+12,   032040
 * 1.031E+12, 9.179E+11, 8.144E+11, 7.203E+11, 6.351E+11, 5.451E+11,   032050
 * 4.676E+11, 4.009E+11, 3.440E+11, 2.947E+11, 2.525E+11, 2.164E+11,   032060
 * 1.852E+11, 1.586E+11, 1.356E+11, 1.156E+11, 9.873E+10, 8.434E+10,   032070
 * 7.222E+10, 6.136E+10, 2.774E+10, 1.236E+10, 5.653E+09, 2.712E+09,   032080
 * 1.395E+09, 1.100E+08, 7.755E+05, 0.        /                        032090
   DATA AMOL36 /                                                       032100
 * 4.317E+13, 3.858E+13, 3.442E+13, 3.067E+13, 2.753E+13, 2.465E+13,   032110
 * 2.200E+13, 1.958E+13, 1.737E+13, 1.537E+13, 1.355E+13, 1.163E+13,   032120
 * 9.976E+12, 8.554E+12, 7.338E+12, 6.287E+12, 5.387E+12, 4.617E+12,   032130
 * 3.950E+12, 3.383E+12, 2.893E+12, 2.467E+12, 2.106E+12, 1.799E+12,   032140
 * 1.541E+12, 1.309E+12, 5.919E+11, 2.636E+11, 1.206E+11, 5.785E+10,   032150
 * 2.976E+10, 2.347E+09, 1.654E+07, 0.        /                        032160
   DATA AMOL37 /                                                       032170
 * 5.652E+18, 5.051E+18, 4.507E+18, 4.016E+18, 3.605E+18, 3.227E+18,   032180
 * 2.880E+18, 2.564E+18, 2.275E+18, 2.012E+18, 1.774E+18, 1.523E+18,   032190
 * 1.306E+18, 1.120E+18, 9.608E+17, 8.232E+17, 7.054E+17, 6.045E+17,   032200
 * 5.172E+17, 4.430E+17, 3.788E+17, 3.230E+17, 2.758E+17, 2.356E+17,   032210
 * 2.017E+17, 1.714E+17, 7.750E+16, 3.451E+16, 1.579E+16, 7.575E+15,   032220
 * 3.896E+15, 3.073E+14, 2.166E+12, 0.        /                        032230
   DATA AMOL38 /                                                       032240
 * 2.107E+19, 1.883E+19, 1.680E+19, 1.497E+19, 1.344E+19, 1.203E+19,   032250
 * 1.074E+19, 9.557E+18, 8.480E+18, 7.500E+18, 6.613E+18, 5.676E+18,   032260
 * 4.869E+18, 4.175E+18, 3.581E+18, 3.069E+18, 2.629E+18, 2.253E+18,   032270
 * 1.928E+18, 1.651E+18, 1.412E+18, 1.204E+18, 1.028E+18, 8.781E+17,   032280
 * 7.519E+17, 6.389E+17, 2.889E+17, 1.287E+17, 5.886E+16, 2.823E+16,   032290
 * 1.452E+16, 1.145E+15, 8.075E+12, 0.        /                        032300
   DATA AMOL41 /                                                       032310
 * 3.043E+17, 2.006E+17, 1.404E+17, 9.028E+16, 5.684E+16, 3.344E+16,   032320
 * 1.806E+16, 9.696E+15, 4.347E+15, 1.404E+15, 5.015E+14, 3.143E+14,   032330
 * 2.006E+14, 6.018E-13, 3.344E+13, 2.541E+13, 2.140E+13, 1.872E+13,   032340
 * 1.672E+13, 1.638E+13, 1.505E+13, 1.705E+13, 1.705E+13, 1.806E+13,   032350
 * 2.006E+13, 2.240E+13, 1.204E+13, 3.678E+12, 1.438E+12, 6.353E+11,   032360
 * 2.106E+11, 4.681E+09, 3.344E+07, 0.        /                        032370
   DATA AMOL42 /                                                       032380
 * 8.314E+15, 7.531E+15, 6.822E+15, 6.146E+15, 5.518E+15, 4.964E+15,   032390
 * 4.464E+15, 4.011E+15, 3.590E+15, 3.202E+15, 2.845E+15, 2.444E+15,   032400
 * 2.101E+15, 1.806E+15, 1.551E+15, 1.328E+15, 1.148E+15, 9.861E+14,   032410
 * 8.480E+14, 7.290E+14, 6.259E+14, 5.388E+14, 4.633E+14, 3.985E+14,   032420
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*  3.414E+14,  2.915E+14,  1.363E+14,  6.398E+13,  3.103E+13,  1.579E+13,   032430
*  8.519E+12,  7.826E+11,  3.416E+09,  0.          /                        032440
   DATA AMOL43 /                                                            032450
*  6.149E+11,  6.777E+11,  7.028E+11,  7.279E+11,  7.530E+11,  8.032E+11,   032460
*  8.910E+11,  9.412E+11,  9.914E+11,  1.380E+12,  1.631E+12,  2.259E+12,   032470
*  2.635E+12,  3.263E+12,  3.514E+12,  4.016E+12,  4.267E+12,  4.894E+12,   032480
*  5.145E+12,  5.145E+12,  4.894E+12,  4.518E+12,  4.016E+12,  3.765E+12,   032490
*  3.514E+12,  3.263E+12,  1.757E+12,  1.155E+12,  5.145E+11,  1.631E+11,   032500
*  5.396E+10,  1.079E+09,  5.396E+05,  0.          /                        032510
   DATA AMOL44 /                                                            032520
*  7.054E+12,  6.390E+12,  5.789E+12,  5.215E+12,  4.682E+12,  4.212E+12,   032530
*  3.788E+12,  3.403E+12,  3.046E+12,  2.716E+12,  2.414E+12,  2.074E+12,   032540
*  1.782E+12,  1.533E+12,  1.316E+12,  1.127E+12,  9.738E+11,  8.367E+11,   032550
*  7.195E+11,  6.185E+11,  5.311E+11,  4.571E+11,  3.931E+11,  3.381E+11,   032560
*  2.897E+11,  2.474E+11,  1.157E+11,  5.429E+10,  2.633E+10,  1.340E+10,   032570
*  7.229E+09,  6.640E+08,  2.898E+06,  0.          /                        032580
   DATA AMOL45 /                                                            032590
*  1.889E+12,  1.712E+12,  1.551E+12,  1.397E+12,  1.254E+12,  1.128E+12,   032600
*  1.015E+12,  9.116E+11,  8.159E+11,  7.276E+11,  6.465E+11,  5.555E+11,   032610
*  4.775E+11,  4.106E+11,  3.526E+11,  3.019E+11,  2.608E+11,  2.241E+11,   032620
*  1.927E+11,  1.657E+11,  1.422E+11,  1.224E+11,  1.053E+11,  9.057E+10,   032630
*  7.759E+10,  6.625E+10,  3.098E+10,  1.454E+10,  7.052E+09,  3.590E+09,   032640
*  1.936E+09,  1.779E+08,  7.763E+05,  0.          /                        032650
   DATA AMOL46 /                                                            032660
*  4.031E+13,  3.651E+13,  3.308E+13,  2.980E+13,  2.675E+13,  2.407E+13,   032670
*  2.164E+13,  1.945E+13,  1.741E+13,  1.552E+13,  1.379E+13,  1.185E+13,   032680
*  1.019E+13,  8.759E+12,  7.522E+12,  6.440E+12,  5.564E+12,  4.781E+12,   032690
*  4.111E+12,  3.534E+12,  3.035E+12,  2.612E+12,  2.246E+12,  1.932E+12,   032700
*  1.655E+12,  1.413E+12,  6.610E+11,  3.102E+11,  1.504E+11,  7.658E+10,   032710
*  4.131E+10,  3.794E+09,  1.656E+07,  0.          /                        032720
   DATA AMOL47 /                                                            032730
*  5.278E+18,  4.781E+18,  4.331E+18,  3.902E+18,  3.503E+18,  3.151E+18,   032740
*  2.834E+18,  2.546E+18,  2.279E+18,  2.033E+18,  1.806E+18,  1.552E+18,   032750
*  1.334E+18,  1.147E+18,  9.849E+17,  8.433E+17,  7.286E+17,  6.260E+17,   032760
*  5.383E+17,  4.628E+17,  3.973E+17,  3.420E+17,  2.941E+17,  2.530E+17,   032770
*  2.167E+17,  1.851E+17,  8.655E+16,  4.062E+16,  1.970E+16,  1.003E+16,   032780
*  5.408E+15,  4.968E+14,  2.168E+12,  0.          /                        032790
   DATA AMOL48 /                                                            032800
*  1.967E+19,  1.782E+19,  1.614E+19,  1.454E+19,  1.306E+19,  1.175E+19,   032810
*  1.056E+19,  9.491E+18,  8.495E+18,  7.576E+18,  6.731E+18,  5.783E+18,   032820
*  4.971E+18,  4.275E+18,  3.671E+18,  3.143E+18,  2.716E+18,  2.334E+18,   032830
*  2.007E+18,  1.725E+18,  1.481E+18,  1.275E+18,  1.096E+18,  9.430E+17,   032840
*  8.079E+17,  6.898E+17,  3.226E+17,  1.514E+17,  7.342E+16,  3.737E+16,   032850
*  2.016E+16,  1.852E+15,  8.083E+12,  0.          /                        032860
   DATA AMOL51 /                                                            032870
*  4.012E+16,  4.012E+16,  3.143E+16,  2.274E+16,  1.371E+16,  6.687E+15,   032880
*  3.277E+15,  1.806E+15,  3.678E+14,  2.809E+14,  1.839E+14,  1.271E-14,   032890
*  8.693E+13,  6.018E+13,  3.344E+13,  2.541E+13,  2.140E+13,  1.872E+13,   032900
*  1.672E+13,  1.638E+13,  1.505E+13,  1.705E+'3,  1.705E+13,  1.806E+13,   032910
*  2.006E+13,  2.240E+13,  1.204E+13,  3.678E+12,  1.438E+12,  6.353E+11,   032920
*  2.106E+11,  4.681E+09,  3.344E+07,  0.          /                        032930
   DATA AMOL52 /                                                            032940
*  9.407E+15,  8.179E+15,  7.254E+15,  6.425E+15,  5.721E+15,  5.117E+15,   032950
*  4.561E+15,  4.052E+15,  3.585E+15,  3.114E+15,  2.662E+15,  2.275E+15,   032960
*  1.944E+15,  1.662E+15,  1.421E+15,  1.214E+15,  1.041E+15,  8.920E+14,   032970
*  7.639E+14,  6.539E+14,  5.599E+14,  4.787E+14,  4.094E+14,  3.500E+14,   032980
*  2.990E+14,  2.554E+14,  1.129E+14,  5.058E+13,  2.285E+13,  1.077E+13,   032990
*  5.273E+12,  3.908E+11,  3.416E+09,  0.          /                        033000
   DATA AMOL53 /                                                            033010
*  5.145E+11,  5.145E+11,  5.145E+11,  5.396E+11,  5.647E+11,  5.898E+11,   033020
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 * 6.149E+11, 8.910E+11, 1.129E+12, 2.006E+12, 3.012E+12, 4.016E+12,   033030
 * 5.396E+12, 5.898E+12, 6.149E+12, 7.028E+12, 7.781E+12, 7.781E+12,   033040
 * 7.781E+12, 7.530E+12, 7.028E+12, 6.400E+12, 5.898E+12, 5.396E+12,   033050
 * 4.518E+12, 4.016E+12, 1.882E+12, 1.155E+12, 5.145E+11, 1.631E+11,   033060
 * 5.396E+10, 1.079E+09, 5.396E+05, 0.        /                        033070
   DATA AMOL54 /                                                       033080
 * 7.982E+12, 6.940E+12, 6.155E+12, 5.431E+12, 4.855E+12, 4.342E+12,   033090
 * 3.870E+12, 3.438E+12, 3.042E+12, 2.642E+12, 2.258E+12, 1.931E+12,   033100
 * 1.649E+12, 1.410E+12, 1.206E+12, 1.030E+12, 8.833E+11, 7.568E+11,   033110
 * 6.482E+11, 5.549E+11, 4.751E+11, 4.062E+11, 3.473E+11, 2.969E+11,   033120
 * 2.537E+11, 2.167E+11, 9.580E+10, 4.292E+10, 1.939E+10, 9.141E+09,   033130
 * 4.474E+09, 3.316E+08, 2.898E+06, 0.        /                        033140
   DATA AMOL55 /                                                       033150
 * 2.138E+12, 1.859E+12, 1.649E+12, 1.460E+12, 1.300E+12, 1.163E+12,   033160
 * 1.037E+12, 9.210E+11, 8.148E+11, 7.078E+11, 6.049E+11, 5.171E+11,   033170
 * 4.418E+11, 3.778E+11, 3.230E+11, 2.760E+11, 2.366E+11, 2.027E+11,   033180
 * 1.736E+11, 1.486E+11, 1.273E+11, 1.088E+11, 9.304E+10, 7.954E+10,   033190
 * 6.796E+10, 5.804E+10, 2.566E+10, 1.150E+10, 5.193E+09, 2.449E+09,   033200
 * 1.198E+09, 8.882E+07, 7.763E+05, 0.        /                        033210
   DATA AMOL56 /                                                       033220
 * 4.561E+13, 3.966E+13, 3.517E+13, 3.115E+13, 2.774E+13, 2.481E+13,   033230
 * 2.212E+13, 1.965E+13, 1.738E+13, 1.510E+13, 1.291E+13, 1.103E+13,   033240
 * 9.425E+12, 8.059E+12, 6.890E+12, 5.887E+12, 5.047E+12, 4.325E+12,   033250
 * 3.704E+12, 3.171E+12, 2.715E+12, 2.321E+12, 1.985E+12, 1.697E+12,   033260
 * 1.450E+12, 1.238E+12, 5.474E+11, 2.453E+11, 1.108E+11, 5.224E+10,   033270
 * 2.557E+10, 1.895E+09, 1.656E+07, 0.        /                        033280
   DATA AMOL57 /                                                       033290
 * 5.972E+18, 5.193E+18, 4.065E+18, 4.079E+18, 3.632E+18, 3.249E+18,   033300
 * 2.896E+18, 2.573E+18, 2.276E+18, 1.977E+18, 1.690E+18, 1.444E+18,   033310
 * 1.234E+18, 1.055E+18, 9.022E+17, 7.708E+17, 6.609E+17, 5.663E+17,   033320
 * 4.850E+17, 4.152E+17, 3.555E+17, 3.039E+17, 2.599E+17, 2.222E+17,   033330
 * 1.898E+17, 1.621E+17, 7.168E+16, 3.211E+16, 1.451E+16, 6.840E+15,   033340
 * 3.348E+15, 2.481E+14, 2.168E+12, 0.        /                        033350
   DATA AMOL58 /                                                       033360
 * 2.226E+19, 1.936E+19, 1.717E+19, 1.520E+19, 1.354E+19, 1.211E+19,   033370
 * 1.079E+19, 9.589E+18, 8.484E+18, 7.369E+18, 6.299E+18, 5.384E+18,   033380
 * 4.600E+18, 3.933E+18, 3.363E+18, 2.873E+18, 2.463E+18, 2.111E+18,   033390
 * 1.808E+18, 1.547E+18, 1.325E+18, 1.133E+18, 9.687E+17, 8.282E+17,   033400
 * 7.076E+17, 6.043E+17, 2.672E+17, 1.197E+17, 5.407E+16, 2.549E+16,   033410
 * 1.248E+16, 9.248E+14, 8.083E+12, 0.        /                        033420
   DATA AMOL61 /                                                       033430
 * 1.973E+17, 1.404E+17, 9.696E+16, 6.018E+16, 3.678E+16, 2.140E+16,   033440
 * 1.271E+16, 7.022E+15, 4.012E+15, 1.538E+15, 6.018E+14, 2.742E+14,   033450
 * 1.237E+14, 6.018E+13, 2.809E+13, 2.407E+13, 2.040E+13, 1.739E+13,   033460
 * 1.471E+13, 1.471E+13, 1.471E+13, 1.605E+13, 1.739E+13, 1.906E+13,   033470
 * 2.040E+13, 2.207E+13, 1.271E+13, 5.350E+12, 2.240E+12, 1.070E+12,   033480
 * 4.012E+11, 5.015E+09, 3.344E+07, 0.        /                        033490
   DATA AMOL62 /                                                       033500
 * 8.342E+15, 7.583E+15, 6.878E+15, 6.220E+15, 5.611E+15, 5.047E+15,   033510
 * 4.526E+15, 4.048E+15, 3.607E+15, 3.205E+15, 2.839E+15, 2.503E+15,   033520
 * 2.141E+15, 1.830E+15, 1.564E+15, 1.337E+15, 1.142E+15, 9.769E+14,   033530
 * 8.351E+14, 7.139E+14, 6.103E+14, 5.196E+14, 4.426E+14, 3.775E+14,   033540
 * 3.221E+14, 2.750E+14, 1.264E+14, 5.809E+13, 2.709E+13, 1.349E+13,   033550
 * 7.049E+12, 6.007E+11, 3.425E+09, 0.        /                        033560
   DATA AMOL63 /                                                       033570
 * 6.777E+11, 6.777E+11, 6.777E+11, 6.275E+11, 5.773E+11, 5.773E+11,   033580
 * 5.647E+11, 6.149E+11, 6.526E+11, 8.910E+11, 1.129E+12, 1.631E+12,   033590
 * 2.008E+12, 2.133E+12, 2.384E+12, 2.635E+12, 3.012E+12, 3.514E+12,   033600
 * 4.016E+12, 4.392E+12, 4.769E+12, 4.769E+12, 4.994E+12, 4.769E+12,   033610
 * 4.518E+12, 4.267E+12, 2.510E+12, 1.380E+12, 6.149E+11, 2.133E+11,   033620
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* 5.020E+10, 1.079E+09, 5.396E+05, 0.          /          033630
  DATA AMOL64 /                                            033640
* 7.078E+12, 6.434E+12, 5.836E+12, 5.277E+12, 4.760E+12, 4.282E+12,   033650
* 3.8ø1E+12, 3.434E+12, 3.061E+12, 2.720E+12, 2.408E+12, 2.124E+12,   033660
* 1.8.ˋE+12, 1.553E+12, 1.327E+12, 1.134E+12, 9.694E+11, 8.289E+11,   033670
* 7.08ˋE+11, 6.057E+11, 5.178E+11, 4.409E+11, 3.756E+11, 3.203E+11,   033680
* 2.733E+11, 2.333E+11, 1.072E+11, 4.929E+10, 2.298E+10, 1.145E+10,   033690
* 5.981E+09, 5.057E+08, 2.906E+06, 0.          /          033700
  DATA AMOL65 /                                            033710
* 1.896E+12, 1.723E+12, 1.563E+12, 1.414E+12, 1.275E+12, 1.147E+12,   033720
* 1.029E+12, 9.199E+11, 8.199E+11, 7.285E+11, 6.451E+11, 5.689E+11,   033730
* 4.867E+11, 4.160E+11, 3.555E+11, 3.038E+11, 2.597E+11, 2.220E+11,   033740
* 1.898E+11, 1.622E+11, 1.387E+11, 1.181E+11, 1.006E+11, 8.579E+10,   033750
* 7.321E+10, 6.250E+10, 2.872E+10, 1.320E+10, 6.156E+09, 3.067E+09,   033760
* 1.602E+09, 1.365E+08, 7.784E+05, 0.          /          033770
  DATA AMOL66 /                                            033780
* 4.045E+13, 3.677E+13, 3.335E+13, 3.016E+13, 2.720E+13, 2.447E+13,   033790
* 2.195E+13, 1.962E+13, 1.749E+13, 1.554E+13, 1.376E+13, 1.214E+13,   033800
* 1.038E+13, 8.874E+12, 7.584E+12, 6.481E+12, 5.539E+12, 4.737E+12,   033810
* 4.049E+12, 3.461E+12, 2.959E+12, 2.519E+12, 2.146E+12, 1.830E+12,   033820
* 1.562E+12, 1.333E+12, 6.126E+11, 2.816E+11, 1.313E+11, 6.542E+10,   033830
* 3.418E+10, 2.913E+09, 1.660E+07, 0.          /          033840
  DATA AMOL67 /                                            033850
* 5.296E+18, 4.814E+18, 4.366E+18, 3.949E+18, 3.562E+18, 3.204E+18,   033860
* 2.874E+18, 2.570E+18, 2.290E+18, 2.035E+18, 1.802E+18, 1.589E+18,   033870
* 1.359E+18, 1.162E+18, 9.930E+17, 8.486E+17, 7.253E+17, 6.202E+17,   033880
* 5.301E+17, 4.532E+17, 3.875E+17, 3.299E+17, 2.810E+17, 2.396E+17,   033890
* 2.045E+17, 1.746E+17, 8.021E+16, 3.686E+16, 1.720E+16, 8.566E+15,   033900
* 4.475E+15, 3.814E+14, 2.174E+12, 0.          /          033910
  DATA AMOL68 /                                            033920
* 1.974E+19, 1.794E+19, 1.627E+19, 1.472E+19, 1.328E+19, 1.194E+19,   033930
* 1.071E+19, 9.578E+18, 8.536E+18, 7.585E+18, 6.717E+18, 5.924E+18,   033940
* 5.067E+18, 4.331E+18, 3.701E+18, 3.163E+18, 2.704E+18, 2.312E+18,   033950
* 1.976E+18, 1.689E+18, 1.444E+18, 1.230E+18, 1.047E+18, 8.932E+17,   033960
* 7.622E+17, 6.508E+17, 2.990E+17, 1.375E+17, 6.410E+16, 3.193E+16,   033970
* 1.668E+16, 1.422E+15, 8.104E+12, 0.          /          033980
  END                                                      033990
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      SUBROUTINE  MLATM(M)                                          034000
C*****************************************************************  034010
C  ,, THIS SUBROUTINE LOADS ONE OF THE 6 BUILT IN ATMOSPHERIC PROFILES  034020
C     OR CALLS NSMDL TO READ IN A USER SUPPLIED PROFILE.           034030
C*****************************************************************  034040
      COMMON /IFIL/ IRD,IPR,IPU                                    034050
      COMMON /PARMTR/ PI,DEG,GCAIR,RE,DELTAS,ZMIN,ZMAX,IMAX,IMOD,IBMAX,  034060
     1    IOUTMX,IPATH,IMODMX,IDIM,KDIM,KMXNOM,KMAX,NOPRNT           034070
C&    DOUBLE PRECISION HMOD                                       C&034080
      COMMON HMOD(3),ZM(50),PM(50),TM(50),RFNDXM(50),DENM(20,50)    034090
      COMMON ZP(71),PP(71),TP(71),RFNDXP(71),SP(71),               034100
     1    PPSUM(71),TPSUM(71),RHOPSM(71),DENP(20,71),AMTP(20,71)    034110
      COMMON Z(71),P(71),T(71),RFNDX(71),DENSTY(20,71)             034120
C&    DOUBLE PRECISION ATMNAM                                     C&034130
      COMMON /MLATMC/ ALT(34),PMDL(34,6),TMDL(34,6),AMOL(34,8,6),   034140
     1    ATMNAM(3,6)                                               034150
      IF(M.EQ.7) GO TO 200                                         034160
      IF(M.GE.1 .OR. M.LE.6) IMOD = 33                             034170
      DO 100 I=1,IMOD                                              034180
      ZM(I) = ALT(I)                                               034190
      PM(I) = PMDL(I,M)                                            034200
      TM(I) = TMDL(I,M)                                            034210
C*****AMOL(I,8,M) IS N2 AND IS NO LONGER USED                      034220
      DO 100 K=1,7                                                 034230
      DENM(K,I) = AMOL(I,K,M)                                      034240
  100 CONTINUE                                                     034250
      DO 110 L=1,3                                                 034260
  110 HMOD(L) = ATMNAM(L,M)                                        034270
      GO TO 210                                                    034280
  200 CONTINUE                                                     034290
      CALL NSMDL                                                   034300
  210 CONTINUE                                                     034310
      ZMIN = ZM(1)                                                 034320
      ZMAX = ZM(IMOD)                                              034330
      RETURN                                                       034340
      END                                                          034350
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      SUBROUTINE NSMDL                                                  034360
C**************************************************************************  034370
C                                                                        034380
C                                                                        034390
C      NOTES TO USER:                                                    034400
C                                                                        034410
C      THIS SUBROUTINE IS FOR READING IN AN ATMOSPHERIC PROFILE         034420
C      CORRESPONDING TO MODEL = 7.  THE PROFILE IS READ IN AFTER         034430
C      CONTROL CARD 4 IN THE FOLLOWING FORMAT                            034440
C            IMOD    (I5)                                                034450
C                    THE NUMBER OF LAYER BOUNDARIES TO FOLLOW            034460
C            (HEADER(I),I=1,3)     ( 3A8)                                034470
C                    A 24 CHARACTER HEADER DESCRIBING THE PROFILE        034480
C        FOR EACH OF THE IMOD LEVELS-                                    034490
C            Z,P,T,TD,RH,PPH2O,DENH2O,AMSMIX       (8F10.3)              034500
C            (VMIX(K),K=1,KMAX)       (8E10.3)                           034510
C                    Z       ALTITUDE (KM                                034520
C                    P       PRESSURE (MB)                               034530
C                    T       TEMPERATURE (K)                             034540
C                    TD      DEW POINT (DEG C)                           034550
C                  . RH      RELATIVE HUMIDITY (PER CENT)                034560
C                    PPH2O   H2O PARTIAL PRESSURE (MB)                   034570
C                    DENH2O  H2O MASS DENSITY (GM M-3)                   034580
C                    AMSMIX  H2O MASS MIXING RATIO (GM KG-1)             034590
C                    VMIX    VOLUME MIXING RATIO OF THE ::'TH            034600
C                            MOLECULAR SPECIES, PARTS PER MILLION        034610
C                                                                        034620
C      THE WATER VAPOR DENSITY MAY BE SPECIFIED IN ANY OF 6 WAYS-       034630
C      IF VMIX(1) IS NOT SUPPLIED, THEN THE DENSITY OF H2O, DENSTY(1),  034640
C      IS COMPUTED                                                       034650
C      IN THE SUBROUTINE WATVAP FROM THE GIVEN VALUE OF TD, RH,         034660
C      PPH2O, DENH2O, OR ASMIX.  IF MORE THAN ONE OF THESE IS GIVEN,    034670
C      THEN THE LAST ONE GIVEN IS USED.  (NOTE THAT TD = 0 IS           034680
C      A VALID INPUT AND THAT TD SHOULD NOT BE CONFUSED WITH THE        034690
C      WETBULB TEMPERATURE OF A WET AND DRY BULB THERMOMETER)           034700
C      IF THE VOL MIX RATIOS OF THE UNIFORMLY MIXED GASES (K=2=CO2,     034710
C      4=N2O,5=CO,6=CH4,7=O2,8=N2) ARE NOT SUPPLIED, THEY ARE           034720
C      CALCULATED USING THE VALUE OF THE VOLUME MIXING RATIO            034730
C      VMIXST(K) TAKEN FROM THE U.S. STANDARD ATMOSPHERE, 1976.         034740
C      NOTE THAT THESE VALUES OF VMIXST (ESP FOR CO) ARE DIFFERENT      034750
C      FROM THOSE USED IN MODELS 1 TO 6, WHICH ARE TAKEN FROM           034760
C      OPTICAL PROPERTIES OF THE ATMOSPHERE (THIRD EDITION).            034770
C      IF AN O3 PROFILE IS NOT SUPPLIED, IT IS SET EQUAL TO ZERO.       034780
C**************************************************************************  034790
      COMMON /IFIL/ IRD,IPR,IPU                                         034800
      COMMON /PARMTR/ PI,DEG,GCAIR,RE,DELTAS,ZMIN,ZMAX,IMAX,IMOD,IBMAX,  034810
     1   IOUTMX,IPATH,IMODMX,IDIM,KDIM,KMXNOM,KMAX,NOPRNT               034820
      COMMON /CONSTN/ PZERO,TZERO,AVOGAD,ALOSMT,GASCON,PLANK,BOLTZ,      034830
     1   CLIGHT,ADCON,ALZERO,AVMWT,AIRMWT,AMWT(20),VMIXST(20),VMIXN2    034840
C&    DOUBLE PRECISION HMOD                                             C&034850
      COMMON HMOD(3),ZM(50),PM(50),TM(50),RFNDXM(50),DENM(20,50)        034860
      COMMON ZP(71),PP(71),TP(71),RFNDXP(71),SP(71),                    034870
     1   PPSUM(71),TPSUM(71),RHOPSM(71),DENP(20,71),AMTP(20,71)         034880
      COMMON Z(71),P(71),T(71),RFNDX(71),DENSTY(20,71)                  034890
C&    DOUBLE PRECISION HMOLS                                            C&034900
      COMMON /HMOLS/ HMOLS(20)                                          034910
      DIMENSION VMIX(20)                                                034920
C&    DOUBLE PRECISION HD1,HD2                                          C&034930
      DIMENSION HD1(9),HD2(9)                                           034940
      DATA HD1/   8H      I, 8H     Z  , 8H     P  , 8H     T    , 034950
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      1       8H     TD   ,  8H     RH   ,  8H    PPH2O  ,  8H DENH2O  ,        034960
      2       8H AMSMIX  /                                                       034970
       DATA HD2/  8H            ,  8H    (KM)  ,  8H    (MB)  ,  8H      (K)   , 034980
      1       8H    ,(C)  ,  8H(PERCNT)  ,  8H    (MB)  ,  8H(GM M-3)  ,         034990
      2       8H(GM/KG)  /                                                       035000
       WRITE(IPR,20)                                                            035010
   20 FORMAT(///,' READING IN USER SUPPLIED MODEL ATMOSPHERE')                  035020
       READ(IRD,21) IMOD                                                        035030
   21 FORMAT(I5)                                                                035040
       READ(IRD,22) HMOD                                                        035050
   22 FORMAT(3A8)                                                               035060
       WRITE(IPR,24) IMOD, HMOD                                                 035070
   24 FORMAT(//,10X,'IMOD    = ',I5,/,10X,'PROFILE = ',3A8)                     035080
       IF(IMOD.GT.IMODMX) GO TO 900                                             035090
       WRITE(IPR,26) HD1,HD2                                                    035100
   26 FORMAT(/,(3X,9(1X,A8,1X)))                                                035110
       WRITE(IPR,28) HMOLS                                                      035120
   28 FORMAT(/,' VOL MIX RAT' ,8(1X,A8,1X),/,' (PPMV)',                         035130
      1      (T14,8A10))                                                        035140
       DO 110 IM=1,IMOD                                                         035150
       READ(IRD,30) ZM(IM),PM(IM),TM(IM),TD,RH,PPH2O,DENH2O,AMSMIX             035160
   30 FORMAT(8F10.3)                                                            035170
       WRITE(IPR,32) IM,ZM(IM),PM(IM),TM(IM),TD,RH,PPH2O,DENH2O,AMSMIX         035180
   32 FORMAT(/,I11,8F10.3)                                                      035190
       READ(IRD,34)   (VMIX(K),K=1,KMAX)                                        035200
   34 FORMAT(8E10.3)                                                            035210
       WRITE(IPR,36)   (VMIX(K),K=1,KMAX)                                       035220
   36 FORMAT(/,11X,1P8E10.3)                                                    035230
       RHOAIR = ALOSMT*(PM(IM)/PZERO)*(TZERO/TM(IM))                            035240
       DENM(1,IM) = 0.0                                                         035250
       IF(VMIX(1).GT.0.0) DENM(1,IM) = VMIX(1)*RHOAIR*1.0E-6                    035260
       IF(VMIX(1).EQ.0.0) CALL WATVAP(PM(IM),TM(IM),TD,RH,PPH2O,               035270
      1    DENH2O,AMSMIX,DENM(1,IM))                                            035280
       DO 100 K=2,KMAX                                                          035290
       DENM(K,IM) = 0.0                                                         035300
       IF(VMIX(K).GT.0.0) DENM(K,IM) = VMIX(K)*RHOAIR*1.0E-6                    035310
       IF(VMIX(K).EQ.0.0) DENM(K,IM) = VMIXST(K)*RHOAIR*1.0E-6                  035320
  100 CONTINUE                                                                  035330
  110 CONTINUE                                                                  035340
       RETURN                                                                   035350
  900 CONTINUE                                                                  035360
       WRITE(IPR,902) IMOD,IMODMX                                              035370
  902 FORMAT(/,' NUMBER OF PROFILE LEVELS IMOD = ',I5,' EXCEEDS THE ',         035380
      1    'MAXIMUM ALLOWED = ',I5)                                            035390
       END                                                                      035400
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      SUBROUTINE WATVAP(P,T,TD,RH,PPH2O,DENH2O,AMSMIX,DENNUM)              035410
C************************************************************************  035420
C     THIS SUBROUTINE COMPUTES THE WATERVAPOR NUMBER DENSITY (MOL CM-3)    035430
C     GIVEN : TD = DEW POINT TEMPERATURE (DEG C), RH = RELATIVE HUMIDITY   035440
C     (PERCENT), PPH2O = WATER VAPOR PARTIAL PRESSURE (MB), DENH2O =       035450
C     WATER VAPOR MASS DENSITY (GM M-3),AMSMIX = MASS MIXING RATIO         035460
C     (GM/KG).                                                            035470
C     IF MORE THAN ONE OF THESE QUANTITIES IS GIVEN, THE LAST ONE          035480
C     GIVEN IS USED.  THE FUNCTION DENSAT FOR THE SATURATION               035490
C     WATER VAPOR DENSITY OVER WATER IS ACCURATE TO BETTER THAN 1          035500
C     PERCENT FROM -50 TO +50 DEG C. (SEE THE LOWTRAN3 OR 5 REPORT)        035510
C************************************************************************  035520
      COMMON /IFIL/ IRD,IPR,IPU                                           035530
      COMMON /PARMTR/ PI,DEG,GCAIR,RE,DELTAS,ZMIN,ZMAX,IMAX,IMOD,IBMAX,   035540
     1    IOUTMX,IPATH,IMODMX,IDIM,KDIM,KMXNOM,KMAX,NOPRNT                035550
      COMMON /CONSTN/ PZERO,TZERO,AVOGAD,ALOSMT,GASCON,PLANK,BOLTZ,       035560
     1    CLIGHT,ADCON,ALZERO,AVMWT,AIRMWT,AMWT(20),VMIXST(20),VMIXN2     035570
      DATA C1/18.9766/,C2/-14.9595/,C3/-2.4388/                          035580
      DENSAT(ATEMP) = ATEMP*B*EXP(C1+C2*ATEMP+C3*ATEMP**2)*1.0E-6         035590
C*****                                                                    035600
      RHOAIR = ALOSMT*(P/PZERO)*(TZERO/T)                                035610
      A = TZERO/T                                                        035620
      B = AVOGAD/AMWT(1)                                                 035630
      IF(AMSMIX.LE.0.0) GO TO 110                                        035640
C*****GIVEN MASS MIXING RATIO (GM KG-1)                                  035650
      DENNUM = B*AMSMIX*1.0E-3*RHOAIR                                    035660
      GO TO 200                                                         035670
  110 CONTINUE                                                          035680
      IF(DENH2O.LE.0.0) GO TO 120                                       035690
C*****GIVEN MASS DENSITY (GM M-3)                                        035700
      DENNUM = B*DENH2O*1.0E-6                                          035710
      GO TO 200                                                         035720
  120 CONTINUE                                                          035730
      IF(PPH2O.LE.0.0) GO TO 130                                        035740
C*****GIVEN WATER VAPOR PARTIAL PRESSURE (MB)                            035750
      DENNUM = ALOSMT*(PPH2O/PZERO)*(TZERO/T)                           035760
      GO TO 200                                                         035770
  130 CONTINUE                                                          035780
      IF(RH.LE.0.0) GO TO 140                                           035790
C*****GIVEN RELATIVE HUMIDITY (PERCENT)                                  035800
      DENNUM = DENSAT(A)*(RH/100.0)/(1.0-(1.0-RH/100.0)*DENSAT(A)/       035810
     1    RHOAIR)                                                       035820
      GO TO 200                                                         035830
  140 CONTINUE                                                          035840
C*****GIVEN DEWPOINT (DEG C)                                             035850
      ATD = TZERO/(TZERO+TD)                                            035860
      DENNUM = DENSAT(ATD)*(TZERO+TD)/T                                 035870
  200 CONTINUE                                                          035880
      DENST = DENSAT(A)                                                 035890
      RHP = 100.0*(DENNUM/DENST)*((RHOAIR-DENST)/(RHOAIR-DENNUM))       035900
      WRITE(IPR,12) RHP                                                 035910
   12 FORMAT('+',95X,'RH = ',F10.2)                                     035920
      IF(RHP.LE.100.0) GO TO 230                                        035930
      WRITE(IPR,10) RHP                                                 035940
   10 FORMAT(/,' ********WARNING (FROM WATVAP): RELATIVE HUMIDITY = ',   035950
     1    G10.3,' IS GREATER THAN 100 PERCENT')                         035960
  230 CONTINUE                                                          035970
      RETURN                                                            035980
      END                                                               035990
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      SUBROUTINE GEOINP(H1,H2,ANGLE,RANGE,BETA,ITYPE,LEN,HMIN,PHI,        036000
     1    IERROR)                                                          036010
C****************************************************************          036020
C        GEOINP INTERPRETS THE ALLOWABLE COMBINATIONS OF INPUT PATH        036030
C        PARAMETERS INTO THE STANDARD SET H1,H2,ANGLE,PHI,HMIN, AND LEN.   036040
C        THE ALLOWABLE COMBINATIONS OF INPUT PARAMETERS ARE- FOR ITYPE = 2,036050
C        (SLANT PATH H1 TO H2) A. H1, H2, AND ANGLE, B. H1, ANGLE, AND     036060
C        RANGE, C. H1, H2, AND RANGE, D. H1, H2, AND BETA -                036070
C        FOR ITYPE = 3 (SLANT PATH H1 TO SPACE, H2 = ZMAX(=100 KM,M=1 TO 6)036080
C        A. H1 AND ANGLE, B. H1 AND HMIN (INPUT AS H2).                    036090
C        THE SUBROUTINE ALSO DETECTS BAD INPUT (IMPOSSIBLE GEOMETRY) AND   036100
C        ITYPE = 2 CASES WHICH INTERSECT THE EARTH, AND RETURNS THESE      036110
C        CASES WITH ERROR FLAGS.                                           036120
C        THE SUBROUTINE FNDHMN IS CALLED TO CALCULATE HMIN, THE MINIMUM    036130
C        HEIGHT ALONG THE PATH, AND PHI, THE ZENITH ANGLE AT H2, USING THE 036140
C        ATMOSPHERIC PROFILE STORED IN /MDATA/                             036150
C****************************************************************          036160
      COMMON /IFIL/ IRD,IPR,IPU                                            036170
      COMMON /PARMTR/ PI,DEG,GCAIR,RE,DELTAS,ZMIN,ZMAX,IMAX,IMOD,I9MAX,    036180
     1    IOUTMX,IPATH,IMODMX,IDIM,KDIM,KMXNOM,KMAX,NOPRNT                 036190
      ITER = 0                                                             036200
      IF(ITYPE.NE.3) GO TO 120                                             036210
C*****SLANT PATH TO SPACE                                                  036220
C*****NOTE: IF BOTH HMIN AND ANGLE ARE ZERO, THEN ANGLE IS                 036230
C*****ASSUMED SPECIFIED                                                    036240
      IF(H2.NE.0.0)  GO TO 110                                             036250
C*****CASE 3A: H1,SPACE,ANGLE                                              036260
      WRITE(IPR,10)                                                        036270
   10 FORMAT(//,' CASE 3A: GIVEN H1,H2=SPACE,ANGLE')                       036280
      H2 =  ZMAX                                                           036290
      CALL FNDHMN(H1,ANGLE,H2,LEN,ITER,HMIN,PHI,IERROR)                    036300
      GO TO 200                                                            036310
  110 CONTINUE                                                             036320
C*****CASE 3B: H1,HMIN,SPACE                                               036330
      WRITE(IPR,12)                                                        036340
   12 FORMAT(//,' CASE 3B: GIVEN H1, HMIN, H2=SPACE')                      036350
      HMIN = H2                                                            036360
      H2 = ZMAX                                                            036370
      IF(H1.LT.HMIN) GO TO 9001                                           036380
      CALL FNDHMN(HMIN,90.0,H1,LEN,ITER,HMIN,ANGLE,IERROR)                 036390
      CALL FNDHMN(HMIN,90.0,H2,LEN,ITER,HMIN,PHI,IERROR)                   036400
      IF(HMIN.LT.H1) LEN = 1                                               036410
      GO TO 200                                                            036420
  120 CONTINUE                                                             036430
      IF(ITYPE.NE.2) GO TO 9002                                           036440
      IF(RANGE.NE.0.0.OR.BETA.NE.0.0) GO TO 130                           036450
C*****CASE 2A: H1, H2, ANGLE                                               036460
      WRITE(IPR,16)                                                        036470
   16 FORMAT(//, ' CASE 2A: GIVEN H1, H2, ANGLE')                         036480
      IF(H1.GE.H2.AND.ANGLE.LE.90.0) GO TO 9004                           036490
      IF(H1.EQ.0.0 .AND. ANGLE.GT.90.0) GO TO 9007                        036500
      IF(H2.LT.H1 .AND. ANGLE.GT.90.0)  WRITE(IPR,15) LEN                 036510
   15 FORMAT(//,' EITHER A SHORT PATH (LEN=0) OR A LONG PATH ',           036520
     1    'THROUGH A TANGENT HEIGHT (LEN=1) IS POSSIBLE: LEN = ',         036530
     2    I3)                                                              036540
      H2ST   H2                                                           036550
      CALL FNDHMN(H1,ANGLE,H2,LEN,ITER,HMIN,PHI,IERROR)                   036560
      IF(H2.NE.H2ST)  GO TO 9007                                          036570
      GO TO 200                                                            036580
  130 CONTINUE                                                             036590
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      IF(BETA.NE.0.0) GO TO 150                                        036600
      IF(ANGLE.EQ.0.0) GO TO 140                                       036610
C*****CASE 2B: H1, ANGLE, RANGE                                        036620
C*****ASSUME NO REFRACTION                                             036630
      WRITE(IPR,18)                                                    036640
   18 FORMAT(//,' CASE 2B:, GIVEN H1, ANGLE, RANGE',//                 036650
     1    10X,'NOTE: H2 IS COMPUTED FROM H1, ANGLE, AND RANGE ',       036660
     2     'ASSUMING NO REFRACTION')                                   036670
      R1 = RE+H1                                                       036680
      R2 = SQRT(R1**2+RANGE**2+2.0*R1*RANGE*COS(+ANGLE/DEG))           036690
      H2 = R2-RE                                                       036700
      IF(H2.GE.0.0)  GO TO 135                                         036710
      H2 = 0.0                                                         036720
      R2 = RE+H2                                                       036730
      RANGE = -R1*COS(ANGLE/DEG)-SQRT(R2**2-R1**2*(SIN(ANGLE/DEG))**2) 036740
      WRITE(IPR,17) RANGE                                              036750
   17 FORMAT(//,10X,'CALCULATED H2 IS LESS THAN ZERO:',/,              036760
     1    10X,'RESET H2 = 0.0 AND RANGE = ',F10.3)                     036770
  135 CONTINUE                                                         036780
C*****NOTE: GEOMETRIC PHI IS NEEDED TO DETERMINE LEN(0 OR 1).          036790
C*****PHI IS THEN RECOMPUTED IN FNDHMN                                 036800
      PHI = 180.0-ACOS((R2**2+RANGE**2-R1**2)/(2.0*R2*RANGE))*DEG      036810
      LEN = 0                                                          036820
      IF(ANGLE.GT.90.0.AND.PHI.GT.90.0) LEN = 1                        036830
      CALL FNDHMN(H1,ANGLE,H2,LEN,ITER,HMIN,PHI,IERROR)               036840
      GO TO 200                                                        036850
  140 CONTINUE                                                         036860
C*****CASE 2C: H1, H2, RANGE                                           036870
      WRITE(IPR,19)                                                    036880
   19 FORMAT(//,' CASE 2C: GIVEN H1, H2, RANGE',//,                    036890
     1    10X,'NOTE: ANGLE IS COMPUTED FROM H1, H2, AND RANGE ',       036900
     2     'ASSUMING NO REFRACTION')                                   036910
      IF(ABS(H1-H2).GT.RANGE) GO TO 9003                              036920
      R1 = H1+RE                                                       036930
      R2 = H2+RE                                                       036940
      ANGLE = 180.0-ACOS((R1**2+RANGE**2-R2**2)/(2.0*R1*RANGE))*DEG    036950
      PHI = 180.0-ACOS((R2**2+RANGE**2-R1**2)/(2.0*R2*RANGE))*DEG      036960
      LEN = 0.                                                         036970
      IF(ANGLE.GT.90.0.AND.PHI.GT.90.0) LEN = 1                        036980
      CALL FNDHMN(H1,ANGLE,H2,LEN,ITER,HMIN,PHI,IERROR)               036990
      GO TO 200                                                        037000
C*****CASE 2D: H1, H2, BETA                                            037010
  150 CONTINUE                                                         C37020
      CALL FDBETA(H1,H2,BETA,ANGLE,PHI,LEN,HMIN,IERROR)              037030
      GO TO 200                                                        037040
C*****END OF ALLOWED CASES                                             037050
C*****                                                                 037060
  200 CONTINUE                                                         C37070
C*****TEST IERROR AND RECHECK LEN                                      037080
      IF(IERROR.NE.0)  RETURN                                          037090
      LEN = 0                                                          037100
      IF(HMIN.LT.AMIN1(H1,H2)) LEN = 1                                037110
C*****REDUCE PATH ENDPOINTS ABOVE ZMAX TO ZMAX                         037120
      IF(HMIN.GE.ZMAX) GO TO 9003                                     037130
      IF(H1.GT.ZMAX .OR. H2.GT.ZMAX)  CALL REDUCE(H1,H2,ANGLE,PHI,ITER) C37140
C*****AT THIS POINT THE FOLLOWING PARAMETERS ARE DEFINED-              037150
C*****    H1,H2,ANGLE,PHI,HMIN,LEN                                     037160
      WRITE(IPR,20)  H1,H2,ANGLE,PHI,HMIN,LEN                         037170
   20 FORMAT(///,' SLANT PATH PARAMETERS IN STANDARD FORM',//,         037180
     1  10X,'H1      = ',F10.3,' KM',/,10X,'H2      = ',F10.3,' KM',/, 037190
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      2 10X,'ANGLE   = ',F10.3,' DEG',/,10X,'PHI      = ',F10.3,' DEG',/,    037200
     ,3    10X,'HMIN    = ',F10.3,' KM',/,10X,'LEN      = ',I10)             037210
        RETURN                                                               037220
C*****                                                                       037230
C*****ERROR MESAGES                                                          037240
C*****                                                                       037250
 9001 CONTINUE                                                               037260
        WRITE(IPR,40) H1,HMIN                                                037270
   40 FORMAT('0GEOINP: CASE 3B (H1,HMIN,SPACE): ERROR IN INPUT DATA',        037280
     1   //,10X,'H1 = ',F12.6,'    IS LESS THAN HMIN = ',F12.6)              037290
        GO TO 9900                                                           037300
 9002 WRITE(IPR,42) ITYPE,ITYPE                                              037310
   42 FORMAT('0GEOINP: ERROR IN INPUT DATA, ITYPE NOT EQUAL TO ',            037320
     1    ' 2, OR 3.   ITYPE = ',I10,E23.14)                                 037330
        GO TO 9900                                                           037340
 9003 WRITE(IPR,43) H1,H2,RANGE                                              037350
   43 FORMAT('0GEOINP: CASE 2C (H1,H2,RANGE): ERROR IN INPUT DATA',//,       037360
     110X,'ABS(H1-H2) GT RANGE:  H1 = ',F12.6,'    H2 = ',F12.6,             037370
     2    '    RANGE = ',F12.6)                                              037380
        GO TO 9900                                                           037390
 9004 CONTINUE                                                               037400
        WRITE(IPR,44)  H1,H2,ANGLE                                           037410
   44 FORMAT('0GEOINP: CASE 2A (H1,H2,ANGLE): ERROR IN INPUT DATA',          037420
     1   //,10X,'H1 = ',F12.6,'    IS GREATER THAN OR EQUAL TO H2 = ',       037430
     2    F12.6,/,10X,'AND ANGLE = ',F12.6,'    IS LESS THAN OR ',           037440
     3    'EQUAL TO 90.0')                                                   037450
        GO TO 9900                                                           037460
 9007 WRITE(IPR,48)                                                          037470
   48 FORMAT('0GEOINP: ITYPE = 2: SLANT PATH INTERSECTS THE EARTH',          037480
     1    ' AND CANNOT REACH H2')                                            037490
        GO TO 9900                                                           037500
 9008 WRITE(IPR,50) ZMAX,H1,H2,HMIN                                          037510
   50 FORMAT(' GEOINP:  THE ENTIRE PATH LIES ABOVE THE TOP ZMAX ',           037520
     1    'OF THE ATMOSPHERIC PROFILE',//,10X,'ZMAX = ',G12.6,5X,            037530
     2    '  H1 = ',G12.6,5X,'  H2 = ',G12.6,'   HMIN = ',G12.6)             037540
 9900 IERROR = 1                                                             037550
        RETURN                                                               037560
        END                                                                  037570
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      SUBROUTINE REDUCE(H1,H2,ANGLE,PHI,ITER)                           037580
C****************************************************************************  037590
C     ZMAX IS THE HIGHEST LEVEL IN THE ATMOSPHERIC PROFILE STORED IN   037600
C     COMMON /MDATA/.  IF H1 AND/OR H2 ARE GREATER THAN ZMAX, THIS     037610
C     SUBROUTINE REDUCES THEM TO ZMAX AND RESETS ANGLE AND/OR PHI      037620
C     AS NECESSARY. THIS REDUCTION IS NECESSARY,FOR EXAMPLE FOR        037630
C     SATELLITE ALTITUDES, BECAUSE (1) THE DENSITY PROFILES ARE        037640
C     POORLY DEFINED ABOVE ZMAX AND (2) THE CALCULATION TIME FOR       037650
C     PATHS ABOVE ZMAX CAN BE EXCESSIVE ( EG. FOR GEOSYNCRONOUS        037660
C     ALTITUDES)                                                       037670
C****************************************************************************  037680
      COMMON /IFIL/ IRD,IPR,IPU                                        037690
      COMMON /PARMTR/ PI,DEG,GCAIR,RF,DELAS,ZMIN,ZMAX,IMAX,IMOD,IBMAX, 037700
     1    IOUTMX,IPATH,IMODMX,IDIM,KDIM,KMANOM,KMAX,NOPRNT             037710
      IF(H1.LE.ZMAX .AND. H2.LE.ZMAX)  RETURN                          037720
      CALL FINDSH(H1,SH,GAMMA)                                         037730
      CPATH = ANDEX(H1,SH,GAMMA)*(RE+H1)*SIN(ANGLE/DEG)                037740
      CALL FINDSH(ZMAX,SH,GAMMA)                                       037750
      CZMAX = ANDEX(ZMAX,SH,GAMMA)*(RE+ZMAX)                           037760
      ANGMAX = 180.0-ASIN(CPATH/CZMAX)*DEG                             037770
      IF(H1.LE.ZMAX) GO TO 120                                         037780
      H1 = ZMAX                                                        037790
      ANGLE = ANGMAX                                                   037800
  120 CONTINUE                                                         037810
      IF(H2.LE.ZMAX)  GO TO 130                                        037820
      H2 = ZMAX                                                        037830
      PHI = ANGMAX                                                     037840
  130 CONTINUE                                                         037850
      IF(ITER.EQ.0) WRITE(IPR,20) ZMAX,ANGMAX                          037860
   20 FORMAT(////,' FROM SUBROUTINE REDUCE : ',/,                      037870
     1    10X,'ONE OR BOTH OF H1 AND H2 ARE ABOVE THE TOP OF THE ',    037880
     2    'ATMOSPHERIC PROFILE ZMAX = ',F10.3,'  AND HAVE BEEN RESET ', 037890
     3    'TO ZMAX.',/,10X,'ANGLE AND/OR PHI HAVE ALSO BEEN RESET TO ', 037900
     4    'THE ZENITH ANGLE AT ZMAX = ',F10.5,' DEG')                  037910
  200 CONTINUE                                                         037920
      RETURN                                                           037930
      END                                                              037940
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      SUBROUTINE FDBETA(H1,H2,BETA,ANGLE,PHI,LEN,HMIN,IERROR)        037950
C************************************************************************  037960
C     GIVEN H1,H2,AND BETA (THE EARTH CENTERED ANGLE) THIS SUBROUTINE   037970
C     CALCULATES THE INITIAL ZENITH ANGLE AT H1 THROUGH AN ITERATIVE    037980
C     PROCEEDURE                                                        037990
C************************************************************************  038000
      COMMON /IFIL/ IRD,IPR,IPU                                        038010
      COMMON /PARMTR/ PI,DEG,GCAIR,RE,DELTAS,ZMIN,ZMAX,IMAX,IMOD,IBMAX, 038020
     1    IOUTMX,IPATH,IMODMX,IDIM,KDIM,KMXNOM,KMAX,NOPRNT              038030
C&    DOUBLE PRECISION HMOD                                           C&038040
      COMMON HMOD(3),ZM(50),PM(50),TM(50),RFNDXM(50),DENM(20,50)        038050
      COMMON ZP(71),PP(71),TP(71),RFNDXP(71),SP(71),                   038060
     1    PPSUM(71),TPSUM(71),RHOPSM(71),DENP(20,71),AMTP(20,71)        038070
      COMMON Z(71),P(71),T(71),RFNDX(71),DENSTY(20,71)                 038080
      DATA TOLRNC/1.0E-4/,ITERMX/10/                                   038090
      IFLAG = 0                                                        038100
      IF(H1.GT.H2) GO TO 100                                           038110
      IORDER = 1                                                       038120
      HA = H1                                                          038130
      HB = H2                                                          038140
      GO TO 120                                                        038150
  100 CONTINUE                                                         038160
      IORDER = -1                                                      038170
      HA = H2                                                          038180
      HB = H1                                                          038190
  120 CONTINUE                                                         038200
C*****LOAD ATMOSPHERIC PROFILE INTO /MODEL/                            038210
      IMAX = IMOD                                                      038220
      DO 130 IM=1,IMOD                                                 038230
      Z(IM) = ZM(IM)                                                   038240
      P(IM)=PM(IM)                                                     038250
      T(IM) = TM(IM)                                                   038260
      RFNDX(IM) = RFNDXM(IM)                                           038270
  130 CONTINUE                                                         038280
C*****SET PARAMETER TO SUPRESS CALCULATION OF AMOUNTS                  038290
      IAMTB = 2                                                        038300
C*****GUESS AT ANGLE, INTEGRATE TO FIND BETA, TEST FOR                 038310
C*****CONVERGENCE, AND ITERATE                                         038320
C*****FIRST GUESS AT ANGLE: USE THE GEOMETRIC SOLUTION(NO REFRACTION)  038330
      ITER = 1                                                         038340
      RA = RE+HA                                                       038350
      RB = RE+HB                                                       038360
      SG = SQRT(RA**2+RB**2-2.0*RA*RB*COS(BETA/DEG))                   038370
      ANGLE1 = 180.0-ACOS((RA**2+SG**2-RB**2)/(2.0*RA*SG))*DEG         038380
      HMIN = HA                                                        038390
      IF(ANGLE1.GT.90.0)  HMIN = RA*SIN(ANGLE1/DEG)-RE                 038400
      IF(HMIN.GE.0.0) GO TO 310                                        038410
      IFLAG = 1                                                        038420
      HMIN = 0.0                                                       038430
      CALL FNDHMN(HMIN,90.0,HA,LEN,ITER,HMIN,ANGLE1,IERROR)            038440
  310 CONTINUE                                                         038450
      WRITE(IPR,24)                                                    038460
   24 FORMAT(///,' CASE 2D: GIVEN H1, H2,  BETA:',//,                  038470
     1     ' ITERATE AROUND ANGLE UNTIL BETA CONVERGES',//,            038480
     2     ' ITER    ANGLE',T21,'BETA',T30,'DBETA',T40,'RANGE',        038490
     3     T51,'HMIN',T61,'PHI',T70,'BENDING',/,                       038500
     4     T10,'(DEG)',T21,'(DEG)',T30,'(DEG)',T41,'(KM)',             038510
     5     T51,'(KM)',T60,'(DEG)',T71,'(DEG)',/)                       038520
      LEN = 0                                                          038530
      IF(ANGLE1.GT.90.0) LEN = 1                                       038540
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      CALL FNDHMN(HA,ANGLE1,HB,LEN,ITER,HMIN,PHI,IERROR)           038550
      LEN = 0                                                       038560
      IF(HMIN.LT.HA) LEN = 1                                        038570
      CALL RFPATH(HA,HB,ANGLE1,PHI,LEN,HMIN,IAMTB,RANGE,BETA1,BENDNG) 038580
      DBETA = BETA-BETA1                                            038590
      WRITE(IPR,26)  ITER,ANGLE1,BETA1,DBETA,RANGE,HMIN,PHI,BENDNG  038600
   26 FORMAT(I5,3F10.4,2F10.3,2F10.4)                               038610
      IF(IFLAG.EQ.1 .AND. BETA1.LT.BETA) GO TO 9005                 038620
      ITER = 2                                                      038630
      DANG = (BETA/25.0)**2                                         038640
      IF(DANG.LT.0.001) DANG = 0.001                               038650
      ANGLE2 = ANGLE1-DANG                                          038660
      IF(ANGLE2.LT.0.0)   ANGLE2 = 0.0                              038670
      LEN = 0                                                       038680
      IF(ANGLE2.GT.90.0) LEN = 1                                    038690
      CALL FNDHMN(HA,ANGLE2,HB,LEN,ITER,HMIN,PHI,IERROR)           038700
      LEN = 0                                                       038710
      IF(HMIN.LT.HA) LEN = 1                                        038720
      CALL RFPATH(HA,HB,ANGLE2,PHI,LEN,HMIN,IAMTB,RANGE,BETA2,BENDNG) 038730
      DBETA = BETA-BETA2                                            038740
      WRITE(IPR,26)  ITER,ANGLE2,BETA2,DBETA,RANGE,HMIN,PHI,BENDNG  038750
      IF(ABS(DBETA).LE.TOLRNC) GO TO 340                            038760
  320 CONTINUE                                                      038770
      ITER = ITER+1                                                 038780
      ANGLE3 = ANGLE2+(ANGLE2-ANGLE1)*(BETA-BETA2)/(BETA2-BETA1)    038790
      LEN = 0                                                       038800
      IF(ANGLE3.GT.90.0) LEN = 1                                    038810
      CALL FNDHMN(HA,ANGLE3,HB,LEN,ITER,HMIN,PHI,IERROR)           038820
      LEN = 0                                                       038830
      IF(HMIN.LT.HA) LEN = 1                                        038840
      CALL RFPATH(HA,HB,ANGLE3,PHI,LEN,HMIN,IAMTB,RANGE,BETA3,BENDNG) 038850
      DBETA = BETA-BETA3                                            038860
      WRITE(IPR,26)  ITER,ANGLE3,BETA3,DBETA,RANGE,HMIN,PHI,BENDNG  038870
      IF(BETA3.LT.BETA.AND.HMIN.LT.0.0) GO TO 9005                  038880
      ANGLE1 = ANGLE2                                               038890
      ANGLE2 = ANGLE3                                               038900
      BETA1 = BETA2                                                 038910
      BETA2 = BETA3                                                 038920
      IF(ABS(BETA-BETA3).LT.TOLRNC) GO TO 340                       038930
      IF(ITER.GT.ITERMX) GO TO 9006                                 038940
      GO TO 320                                                     038950
  340 CONTINUE                                                      038960
      IF(HMIN.LT.0.0) GO TO 9005                                    038970
C*****CONVERGED TO A SOLUTION                                       038980
      ANGLE = ANGLE3                                                038990
      BETA = BETA3                                                  039000
C*****ASSIGN ANGLE AND PHI TO PROPER H1 AND H2                      039010
      IF(IORDER.EQ.1) GO TO 350                                     039020
      TEMP = PHI                                                    039030
      PHI = ANGLE                                                   039040
      ANGLE = TEMP                                                  039050
  350 CONTINUE                                                      039060
      RETURN                                                        039070
C*****                                                              039080
C*****ERROR MESSAGES                                                039090
C*****                                                              039100
 9005 CONTINUE                                                      039110
      WRITE(IPR,45)                                                 039120
   45 FORMAT('0FDBETA, CASE 2D(H1,H2,BETA): REFRACTED TANGENT ',    039130
     1    'HEIGHT IS LESS THAN ZERO-PATH INTERSECTS THE EARTH',     039140
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      2     //,10X,'BETA IS TOO LARGE FOR THIS H1 AND H2')        039150
        GO TO 9900                                                039160
 9006 CONTINUE                                                    039170
        WRITE(IPR,46) H1,H2,BETA,ITER,ANGLE1,BETA1,ANGLE2,BETA2,  039180
      1    ANGLE3,BETA3                                           039190
   46 FORMAT('OFDBETA, CASE 2D (H1,H2,BETA): SOLUTION DID NOT ',  039200
      1    ' CONVERGE',//,10X,'H1 = ',F12.6,'    H2 = ',F12.6,    039210
      2    '    BETA = ',F12.6,'    ITERATIONS = ',I4,//,         039220
      3    10X,'LAST THREE ITERATIONS ',//,                       039230
      4    (10X,'ANGLE = ',F15.9,'    BETA = ',F15.9))            039240
 9900 IERROR = 1                                                  039250
      RETURN                                                      039260
      END                                                         039270
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      SUBROUTINE EXPINT(X,X1,X2,A)                                      039280
C***************************************************************************  039290
C     THIS SUBROUTINE EXPONENTIALLY INTERPOLATES X1 AND X2 TO X BY      039300
C     THE FACTOR A                                                      039310
C***************************************************************************  039320
      IF(X1.EQ.0.0 .OR. X2.EQ.0.0)  GO TO 100                          039330
      X = X1*(X2/X1)**A                                                 039340
      RETURN                                                            039350
  100 X = X1+(X2-X1)*A                                                  039360
      RETURN                                                            039370
      END                                                               039380
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      SUBROUTINE FNDHMN(H1,ANGLE,H2,LEN,ITER,HMIN,PHI,IERROR)              039390
C*********************************************************** ..*********   039400
C     THIS SUBROUTINE CALCULATES THE MINIMUM ALTITUDE HMIN ALONG          039410
C     THE REFRACTED PATH AND THE FINAL ZENITH ANGLE PHI.                  039420
C     THE PARAMETER LEN INDICATES WHETHER THE PATH GOES THROUGH           039430
C     A TANGENT HEIGHT (LEN=1) OR NOT (LEN=0).  IF ANGLE > 90 AND         039440
C     H1 > H2, THEN LEN CAN EITHER BE 1 OR 0, AND THE CHOICE IS           039450
C     LEFT TO THE USER.                                                   039460
C     THE (INDEX OF REFRACTION - 1.0) IS MODELED AS AN EXPONENTIAL        039470
C     BETWEEN THE LAYER BOUNDARIES, WITH A SCALE HEIGHT SH AND AN         039480
C     AMOUNT AT THE GROUND GAMMA.                                         039490
C     CPATH IS THE REFRACTIVE CONSTANT FOR THIS PATH AND                  039500
C     EQUALS   INDEX(H1)*(RE+H1)*SIN(ANGLE).                              039510
C*************************-****************************************.****** 039520
      COMMON /IFIL/ IRD,IPR,IPU                                           039530
      COMMON /PARMTR/ PI,DEG,GCAIR,RE,DELTAS,ZMIN,ZMAX,IMAX,IMOD,IBMAX,   039540
     1   IGUTMX,IPATH,IMODMX,IDIM,KDIM,KMXNOM,KMAX,IPRINT                 039550
      DATA DH/1.0/,ETA/5.0E-8/                                            039560
C*****ETA MAY BE TOO SMALL FOR SOME COMPUTERS. TRY 1.0E-7 FOR 32 BIT      039570
C*****WORD MACHINES                                                       039580
      CRFRCT(H) = (RE+H)*ANDEX(H,SH,GAMMA)                                039590
      N = 0                                                              039600
      CALL FINDSH(H1,SH,GAMMA)                                            039610
      CPATH = CRFRCT(H1)*SIN(ANGLE/DEG)                                   039620
      CALL FINDSH(H2,SH,GAMMA)                                            039630
      CH2 = CRFRCT(H2)                                                    039640
      IF(ABS(CPATH/CH2).GT.1.0) GO TO 200                                039650
      IF(ANGLE.GT.90.0)  GO TO 100                                        039660
      LEN = 0                                                            039670
      HMIN = H1                                                          039680
      GO TO 160                                                           039690
  100 CONTINUE                                                            039700
      IF(H1.LE.H2)  LEN = 1                                               039710
      IF(LEN.EQ.1)  GO TO 110                                             039720
      LEN = 0                                                            039730
      HMIN = H2                                                          039740
      GO TO 160                                                           039750
  110 CONTINUE                                                            039760
C*****LONG PATH THROUGH A TANGENT HEIGHT.                                 039770
C*****SOLVE ITERATIVELY FOR THE TANGENT HEIGHT HT.                        039780
C*****HT IS THE HEIGHT FOR WHICH  INDEX(HT)*(RE+HT) = CPATH.              039790
      CALL FINDSH(0.0,SH,GAMMA)                                           039800
      CMIN = CRFRCT(0.0)                                                  039810
C*****FOR BETA CASES (ITER>0), ALLOW FOR HT < 0.0                         039820
      IF(ITER.EQ.0 .AND. CPATH.LT.CMIN)  GO TO 150                        039830
      HT1 = (RE+H1)*SIN(ANGLE/DEG)-RE                                     039840
      CALL FINDSH(HT1,SH,GAMMA)                                           039850
      CT1 = CRFRCT(HT1)                                                   039860
      HT2 = HT1-DH                                                        039870
      CALL FINDSH(HT2,SH,GAMMA)                                           039880
      CT2 = CRFRCT(HT2)                                                   039890
C*****ITERATE TO FIND HT                                                  039900
      N = 2                                                              039910
  120 CONTINUE                                                            039920
      N = N+1                                                            039930
      HT3 = HT2+(HT2-HT1)*(CPATH-CT2)/(CT2-CT1)                           039940
      CALL FINDSH(HT3,SH,GAMMA)                                           039950
      CT3 = CRFRCT(HT3)                                                   039960
      DC = CPATH-CT3                                                      039970
      IF(ABS((CPATH-CT3)/CPATH).LT.ETA)  GO TO 130                        039980
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      IF(N.GT.15) GO TO 210                                       039990
      HT1 = HT2                                                   040000
      CT1 = CT2                                                   040010
      HT2 = HT3                                                   040020
      CT2 = CT3                                                   040030
      GO TO 120                                                   040040
  130 CONTINUE                                                    040050
      HT = HT3                                                    040060
      HMIN = HT                                                   040070
      GO TO 160                                                   040080
  150 CONTINUE                                                    040090
C*****TANGENT PATH INTERSECTS EARTH                               040100
      H2 = 0.0                                                    040110
      HMIN = 0.0                                                  040120
      LEN = 0                                                     040130
      CH2 = CMIN                                                  040140
      WRITE(IPR,22) H1,ANGLE                                      040150
   22 FORMAT(///,' TANGENT PATH WITH H1 = ',F10.3,' AND ANGLE = ',040160
     1       F10.3,' INTERSECTS THE EARTH',//,10X,'H2 HAS BEEN RESET ', C40170
     2       'TO 0.0 AND LEN TO 0')                               040180
  160 CONTINUE                                                    040190
C*****CALCULATE THE ZENITH ANGLE PHI AT H2                        040200
      PHI = ASIN(CPATH/CH2)*DEG                                   040210
      IF(ANGLE.LE.90.0 .OR. LEN.EQ.1)  PHI = 180.0-PHI            040220
      RETURN                                                      040230
C*****H2 LT TANGENT HEIGHT FOR THIS H1 AND ANGLE                  040240
  200 CONTINUE                                                    040250
      WRITE(IPR,20)                                               040260
   20 FORMAT('0H2 IS LESS THAN THE TANGENT HEIGHT FOR THIS PATH ',040270
     1      'AND CANNOT BE REACHED')                              040280
      IERROR = 2                                                  040290
      RETURN                                                      040300
  210 CONTINUE                                                    040310
      DC = CPATH-CT3                                              040320
      WRITE(IPR,24)  N,CPATH,CT3,DC,HT3                           040330
   24 FORMAT(///,'0FROM SUBROUTINE FNDHMN :',//,                  040340
     1    10X,'THE PROCEEDURE TO FIND THE TANGENT HEIGHT DID NOT ',040350
     2    'CONVERG AFTER ',I3,' ITERATIONS',//,                   040360
     3    10X,'CPATH   = ',F12.5,' KM',//,10X,'CT3     = ',F12.5,' KM', 040370
     4    //,10X,'DC      = ',E12.3,' KM',//,                     040380
     5    10X,'HT3     = ',F12.5,' KM')                           040390
      STOP 05                                                     040400
      END                                                         040410
```

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```
      SUBROUTINE FINDSH(H,SH,GAMMA)                                  040420
C***************************************************************************  040430
C     GIVEN AN ALTITUDE H, THIS SUBROUTINE FINDS THE LAYER BOUNDARIES  040440
C     Z(I1) AND Z(I2) WHICH CONTAIN H,  THEN CALCULATES THE SCALE    040450
C     HEIGHT (SH) AND THE VALUE AT THE GROUND (GAMMA+1) FOR THE      040460
C     REFRACTIVITY (INDEX OF REFRACTION -1)                          040470
C***************************************************************************  040480
      COMMON /IFIL/ IRD,IPR,IPU                                      040490
      COMMON /PARMTR/ PI,DEG,GCAIR,RE,DELTAS,ZMIN,ZMAX,IMAX,IMOD,IBMAX,  040500
     1   IOUTMX,IPATH,IMODMX,IDIM,KDIM,KMXNOM,KMAX,NOPRNT             040510
C&    DOUBLE PRECISION HMOD                                          C&040520
      COMMON  HMOD(5),ZM(50),PM(50),TM(50),RFNDXM(50),DENM(20,50)    040530
      COMMON  ZP(71),PP(71),TP(71),RFNDXP(71),SP(71),               040540
     1   PPSUM(71),TPSUM(71),RHOPSM(71),DENP(20,71),AMTP(20,71)      040550
      COMMON  Z(71),P(71),T(71),RFNDX(71),DENSTY(20,71)             040560
      DO 100 IM=2,IMOD                                               040570
      I2 = IM                                                        040580
      IF(ZM(IM).GE.H)  GO TO 110                                     040590
  100 CONTINUE                                                       040600
      I2 = IMOD                                                      040610
  110 CONTINUE                                                       040620
      I1 = I2-1                                                      040630
      CALL SCALHT(ZM(I1),ZM(I2),RFNDXM(I1),RFNDXM(I2),SH,GAMMA)      040640
      RETURN                                                         040650
      END                                                            040660
```

```
      SUBROUTINE SCALHT(Z1,Z2,RFNDX1,RFNDX2,SH,GAMMA)                      040670
C*******************************************************************************  040680
C     THIS SUBROUTINE CALCULATES THE SCALE HEIGHT SH OF THE (INDEX OF       040690
C     REFRACTION-1.0) FROM THE VALUES OF THE INDEX AT THE ALTITUDES Z1      040700
C     AND Z2 ( Z1 < Z2). IT ALSO CALCULATES THE EXTRAPOLATED VALUE          040710
C     GAMMA OF THE (INDEX-1.0) AT Z = 0.0                                   040720
C*******************************************************************************  040730
      RF1 = RFNDX1+1.0E-20                                                  040740
      RF2 = RFNDX2+1.0E-20                                                  040750
      RATIO = RF1/RF2                                                       040760
      IF(ABS(RATIO-1.0).LT.1.0E-05)  GO TO 100                             040770
      SH = (Z2-Z1)/ALOG(RATIO)                                             040780
      GAMMA = RF1*(RF2/RF1)**(-Z1/(Z2-Z1))                                 040790
      GO TO 110                                                            040800
  100 CONTINUE                                                             040810
C*****THE VARIATION IN THE INDEX OF REFRACTION WITH HEIGHT IS              040820
C*****INSIGNIFICANT OR ZERO                                                040830
      SH = 0.0                                                             040840
      GAMMA = RFNDX1                                                       040850
  110 CONTINUE                                                             040860
      RETURN                                                               040870
      END                                                                  040880
```

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```
      FUNCTION ANDEX(H,SH,GAMMA)                                    040890
C***************************************************************** 040900
C     COMPUTES THE INDEX OF REFRACTION AT HEIGHT H, SH IS THE       040910
C     SCALE HEIGHT, GAMMA IS THE VALUE AT H=0 OF THE REFRACTIVITY = 040920
C     INDEX-1                                                       040930
C***************************************************************** 040940
      IF(SH.EQ.0.0) GO TO 10                                        040950
      ANDEX = 1.0+GAMMA*EXP(-H/SH)                                  040960
      RETURN                                                        040970
   10 ANDEX = 1.0+GAMMA                                             040980
      RETURN                                                        040990
      END                                                           041000
```

```
      FUNCTION RADREF(H,SH,GAMMA)                                       041010
C*******************************************************************    041020
C     COMPUTES THE RADIUS OF CURVATURE OF THE REFRACTED RAY FOR         041030
C     A HORIZONTAL PATH.  RADREF = ANDEX/ D(ANDEX)/D(RADIUS)            041040
C*******************************************************************    041050
      DATA BIGNUM/1.0E36/                                               041060
      IF(SH.EQ.0.0) GO TO 20                                            041070
      RADREF = SH*(1.0+EXP(H/SH)/GAMMA)                                 041080
      RETURN                                                            041090
   20 RADREF = BIGNUM                                                   041100
      RETURN                                                            041110
      END                                                               041120
```

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```
      SUBROUTINE RFPATH(H1,H2,ANGLE,PHI,LEN,HMIN,IAMT,RANGE,BETA,BENDNG)   041130
C*****************************************************************************   041140
C     THIS SUBROUTINE TRACES THE REFRACTED RAY FROM H1 WITH A            041150
C     INITIAL ZENITH ANGLE ANGLE TO H2 WHERE THE ZENITH ANGLE IS PHI,    041160
C     AND CALCULATES THE ABSORBER AMOUNTS (IF IAMT.EQ.1) ALONG           041170
C     THE PATH.  IT STARTS FROM THE LOWEST POINT ALONG THE PATH          041180
C     (THE TANGENT HEIGHT HMIN IF LEN = 1 OR HA = MIN(H1,H2) IF LEN = 0) 041190
C     AND PROCEEDS TO THE HIGHEST POINT.  BETA AND RANGE ARE THE         041200
C     EARTH CENTERED ANGLE AND THE TOTAL DISTANCE RESPECTIVELY           041210
C     FOR THE REFRACTED PATH FROM H1 TO H2, AND BENDNG IS THE TOTAL      041220
C     BENDING ALONG THE PATH                                            041230
C*****************************************************************************   C41240
      COMMON /IFIL/ IRD,IPR,IPU                                          041250
      COMMON /PARMTR/ PI,DEG,GCAIR,RE,DELTAS,ZMIN,ZMAX,IMAX,IMOD,IBMAX,  041260
     1   IOUTMX,IPATH,IMODMX,IDIM,KDIM,KMXNOM,KMAX,NOPRNT               041270
C&    DOUBLE PRECISION HMOD                                             C&041280
      COMMON HMOD(3),ZM(50),PM(50),TM(50),RFNDXM(50),DENM(20,50)         041290
      COMMON ZP(71),PP(71),TP(71),RFNDXP(71),SP(71),                     041300
     1   PPSUM(71),TPSUM(71),RHOPSM(71),DENP(20,71),AMTP(20,71)          041310
      COMMON Z(71),P(71),T(71),RFNDX(71),DENSTY(20,71)                   041320
      DIMENSION HLOW(2)                                                  041330
      DATA HLOW/2HH1,2HH2/                                               041340
      IF(H1.GT.H2) GO TO 90                                              041350
      IORDER = 1                                                         041360
      HA = H1                                                            041370
      HB = H2                                                            041380
      ANGLEA = ANGLE                                                     041390
      GO TO 95                                                           041400
   90 CONTINUE                                                           041410
      IORDER = -1                                                        041420
      HA = H2                                                            041430
      HB = H1                                                            041440
      ANGLEA = PHI                                                       041450
   95 CONTINUE                                                           041460
      JNEXT = 1                                                          041470
      IF(IAMT.EQ.1 .AND. NOPRNT.NE.1)  WRITE(IPR,20)                     041480
   20 FORMAT('1CALCULATION OF THE REFRACTED PATH THROUGH THE ',          041490
     1    'ATMOSPHERE',///,                                             041500
     4    T5,'I',T14,'ALTITUDE',T30,'THETA',T38,'DRANGE',T47,'RANGE',    041510
     5    T57,'DBETA',T65,'BETA',T76,'PHI',T84,'DBEND',T91,'BENDING',    041520
     6    T102,'PBAR',T111,'TBAR',T119,'RHOBAR',/,                       041530
     7    T11,'FROM',T22,'TO',/,T11,'(KM)',T21,'(KM)',T30,'(DEG)',       041540
     8    T39,'(KM)',T48,'(KM)',T57,'(DEG)',T65,'(DEG)',T75,'(DEG)',     041550
     9    T84,'(DEG)',T92,'(DEG)',T102,'(MB)',T112,'(K)',                041560
     1    T117,'(MOL CM-3)',/)                                           041570
      IF(LEN.EQ.0) GO TO 100                                             041580
C*****LONG PATH: FILL IN THE SYMETRIC PART FROM THE TANGENT HEIGHT       041590
C*****TO HA                                                              041600
      CALL FILL(HMIN,HA,JNEXT)                                          041610
      JHA = JNEXT                                                        041620
  100 CONTINUE                                                           041630
C*****FILL IN THE REMAINING PATH FROM HA TO HB                           041640
      IF(HA.EQ.HB) GO TO 110                                             041650
      CALL FILL(HA,HB,JNEXT)                                            041660
  110 CONTINUE                                                           041670
      JMAX = JNEXT                                                       041680
      IPATH = JMAX                                                       041690
C*****INTEGRATE EACH SEGMENT OF THE PATH                                 041700
C*****CALCULATE CPATH SEPERATELY FOR LEN = 0,1                           041710
      IF(LEN.EQ.1) GO TO 115                                             041720
```

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        CALL FINDSH(HA,SH,GAMMA)                                        041730
        CPATH = (RE+HA)*ANDEX(HA,SH,GAMMA)*SIN(ANGLEA/DEG)              041740
        GO TO 116                                                       041750
   115 CONTINUE                                                         041760
        CALL FINDSH(HMIN,SH,GAMMA)                                      041770
        CPATH = (RE+HMIN)*ANDEX(HMIN,SH,GAMMA)                          041780
   116 CONTINUE                                                         041790
        BETA = 0.0                                                      041800
        S = 0.0                                                         041810
        BENDNG = 0.0                                                    041820
        IF(LEN.EQ.0) GO TO 140                                          041830
C*****DO SYMETRIC PART, FROM TANGENT HEIGHT(HMIN) TO HA                 041840
        IHLOW = 1                                                       041850
        IF(IORDER.EQ.-1)   IHLOW = 2                                    041860
        IF(IAMT.EQ.1 .AND. NOPRNT.NE.1) WRITE(IPR,24) HLOW(IHLOW)       041870
    24 FORMAT(' ',T10,'TANGENT',T20,A2,/,T10,'HEIGHT',/)                041880
        SINAI = 1.0                                                     041890
        COSAI = 0.0                                                     041900
        THETA = 90.0                                                    041910
        J2 = JHA-1                                                      041920
        DO 120 J=1,J2                                                   041930
        CALL SCALHT(ZP(J),ZP(J+1),RFNDXP(J),RFNDXP(J+1),SH,GAMMA)       041940
        CALL ALAYER(J,SINAI,COSAI,CPATH,SH,GAMMA,IAMT,DS,DBEND)         041950
        DBEND = DBEND*DEG                                               041960
        PHI = ASIN(SINAI)*DEG                                           041970
        DBETA = THETA-PHI+DBEND                                         041980
        PHI = 180.0-PHI                                                 041990
        S = S+DS                                                        042000
        BENDNG = BENDNG+DBEND                                           042010
        BETA = BETA+DBETA                                               042020
        IF(IAMT.NE.1) GO TO 118                                         042030
        PBAR = PPSUM(J)/RHOPSM(J)                                       042040
        TBAR = TPSUM(J)/RHOPSM(J)                                       042050
        RHOBAR = RHOPSM(J)/DS                                           042060
        IF(IAMT.EQ.1 .AND. NOPRNT.NE.1) WRITE(IPR,22) J,ZP(J),ZP(J+1),  042070
     1      THETA,DS,S,DBETA,BETA,PHI,DBEND,BENDNG,PBAR,TBAR,RHOBAR      042080
    22 FORMAT(' ',I4,2F10.3,10F9.3,1PE9.2)                             042090
   118 CONTINUE                                                         042100
        THETA = 180.0-PHI                                               042110
   120 CONTINUE                                                         042120
C*****DOUBLE PATH QUANTITIES FOR THE OTHER PART OF THE SYMETRIC PATH    042130
        BENDNG = 2.0*BENDNG                                             042140
        BETA = 2.0*BETA                                                 042150
        S = 2.0*S                                                       042160
        IF(IAMT.EQ.1 .AND. NOPRNT.NE.1) WRITE(IPR,26) S,BETA,BENDNG     042170
    26 FORMAT('0',T10,'DOUBLE RANGE, BETA, BENDING',/,                  042180
     1      T10,'FOR SYMMETRIC PART OF PATH',T44,F9.3,T62,F9.3,         042190
     2      T89,F9.3,/)                                                 042200
        JNEXT = JHA                                                     042210
        GO TO 150                                                       042220
   140 CONTINUE                                                         042230
C*****SHORT PATH                                                        042240
        JNEXT = 1                                                       042250
C*****ANGLEA IS THE ZENITH ANGLE AT HA IN DEG                           042260
C*****SINAI IS SIN OF THE INCIDENCE ANGLE                              042270
C*****COSAI IS CARRIED SEPERATELY TO AVOID A PRECISION PROBLEM          042280
C*****WHEN SINAI IS CLOSE TO 1.0                                        042290
        THETA = ANGLEA                                                  042300
        IF(ANGLEA.GT.45.0) GO TO 145                                    042310
        SINAI = SIN(ANGLEA/DEG)                                         042320
```

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          COSAI = -COS(ANGLEA/DEG)                                          042330
          GO TO 150                                                         042340
      145 CONTINUE                                                          042350
          SINAI = COS((90.0-ANGLEA)/DEG)                                    042360
          COSAI = -SIN((90.0-ANGLEA)/DEG)                                   042370
      150 CONTINUE                                                          042380
C*****DO PATH FROM HA TO HB                                                 042390
          IF(HA.EQ.HB) GO TO 170                                            042400
          J1 = JNEXT                                                        042410
          J2 = JMAX-1                                                       042420
          IHLOW = 1                                                         042430
          IF(IORDER.EQ.-1)  IHLOW = 2                                       042440
          IHIGH = MOD(IHLOW,2)+1                                            042450
          IF(IAMT.EQ.1 .AND. NOPRNT.NE.1) WRITE(IPR,28) HLOW(IHLOW),        042460
         1    HLOW(IHIGH)                                                   042470
       28 FORMAT(' ',T14,A2,' TO ',A2,/)                                    042480
          DO 160 J=J1,J2                                                    042490
          CALL SCALHT(ZP(J),ZP(J+1),RFNDXP(J),RFNDXP(J+1),SH,GAMMA)         042500
          CALL ALAYER(J,SINAI,COSAI,CPATH,SH,GAMMA,IAMT,DS,DBEND)           042510
          DBEND = DBEND*DEG                                                 042520
          PHI = ASIN(SINAI)*DEG                                            042530
          DBETA = THETA-PHI+DBEND                                           042540
          PHI = 180.0-PHI                                                   042550
          S = S+DS                                                          042560
          BENDNG = BENDNG+DBEND                                             042570
          BETA = BETA+DBETA                                                 042580
          IF(IAMT.NE.1) GO TO 158                                           042590
          PBAR = PPSUM(J)/RHOPSM(J)                                         042600
          TBAR = TPSUM(J)/RHOPSM(J)                                         042610
          RHOBAR = RHOPSM(J)/DS                                             042620
          IF(IAMT.EQ.1 .AND. NOPRNT.NE.1) WRITE(IPR,22) J,ZP(J),ZP(J+1),    042630
         1    THETA,DS,S,DBETA,BETA,PHI,DBEND,BENDNG,PBAR,TBAR,RHOBAR       042640
      158 CONTINUE                                                          042650
          THETA = 180.0-PHI                                                 042660
      160 CONTINUE                                                          042670
      170 CCNTINUE                                                          042680
          IF(IORDER.EQ.-1) PHI = ANGLEA                                     042690
          RANGE = S                                                         042700
          RETURN                                                            042710
          END                                                               042720
```

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      SUBROUTINE FILL(HA,HB,JNEXT)                                       042730
C**********************************************************************  042740
C     THIS SUBROUTINE DEFINES THE ATMOSPHERIC BOUNDARIES OF THE PATH     042750
C     FROM HA TO HB AND INTERPOLATES (EXTRAPOLATES) THE DENSITIES TO     042760
C     THESE BOUNDARIES ASSUMING THE DENSITIES VARY EXPONENTIALLY         042770
C     WITH HEIGHT.                                                       042780
C**********************************************************************  042790
      COMMON /IFIL/ IRD,IPR,IPU                                          042800
      COMMON /PARMTR/ PI,DEG,GCAIR,RE,DELTAS,ZMIN,ZMAX,IMAX,IMOD,IBMAX,  042810
     1    IOUTMX,IPATH,IMODMX,IDIM,KDIM,KMXNOM,KMAX,NOPRNT               042820
C&    DOUBLE PRECISION HMOD                                              C&042830
      COMMON HMOD(3),ZM(50),PM(50),TM(50),RFNDXM(50),DENM(20,50)         042840
      COMMON ZP(71),PP(71),TP(71),RFNDXP(71),SP(71),                     042850
     1    PPSUM(71),TPSUM(71),RHOPSM(71),DENP(20,71),AMTP(20,71)         042860
      COMMON Z(71),P(71),T(71),RFNDX(71),DENSTY(20,71)                   042870
      IF(HA.LT.HB) GO TO 90                                              042880
      WRITE(IPR,22) HA,HB,JNEXT                                          042890
   22 FORMAT('0SUBROUTINE FILL- ERROR, HA .GE. HB',//,                   042900
     1    10X,'HA, HB, JNEXT = ',2E25.15,I6)                             042910
      STOP 06                                                            042920
   90 CONTINUE                                                           042930
C*****FIND Z(IA)- THE SMALLEST Z(I).GT.HA                                042940
      DO 100 I=1,IMAX                                                    042950
      IF(HA.GE.Z(I)) GO TO 100                                           042960
      IA = I                                                             042970
      GO TO 110                                                          042980
  100 CONTINUE                                                           042990
      IA = IMAX+1                                                        043000
      IB = IA                                                            043010
      GO TO 130                                                          043020
C*****FIND Z(IB)- THE SMALLEST Z(I).GE.HB                                043030
  110 CONTINUE                                                           043040
      DO 120 I=IA,IMAX                                                   043050
      IF(HB.GT.Z(I)) GO TO 120                                           043060
      IB = I                                                             043070
      GO TO 130                                                          043080
  120 CONTINUE                                                           043090
      IB = IMAX+1                                                        043100
  130 CONTINUE                                                           043110
C*****INTERPOLATE DENSITIES TO HA, HB                                    043120
      ZP(JNEXT) = HA                                                     043130
      I2 = IA                                                            043140
      IF(I2.EQ.1) I2 = 2                                                 043150
      IF(I2.GT.IMAX) I2 = IMAX                                           043160
      I1 = I2-1                                                          043170
      A = (HA-Z(I1))/(Z(I2)-Z(I1))                                       043180
      CALL EXPINT(PP(JNEXT),P(I1),P(I2),A)                               043190
      TP(JNEXT) = T(I1)+(T(I2)-T(I1))*A                                  043200
      CALL EXPINT(RFNDXP(JNEXT),RFNDX(I1),RFNDX(I2),A)                   043210
      DO 140 K=1,KMAX                                                    043220
      CALL EXPINT(DENP(K,JNEXT),DENSTY(K,I1),DENSTY(K,I2),A)             043230
  140 CONTINUE                                                           043240
      IF(IA.EQ.IB) GO TO 160                                            043250
C*****FILL IN DENSITIES BETWEEN HA AND HB                                043260
      I1 = IA                                                            043270
      I2 = IB-1                                                          043280
      DO 150 I=I1,I2                                                     043290
      JNEXT = JNEXT+1                                                    043300
      ZP(JNEXT) = Z(I)                                                   043310
      PP(JNEXT) = P(I)                                                   043320
```

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        TP(JNEXT) = T(I)                                              043330
        RFNDXP(JNEXT) = RFNDX(I)                                      043340
        DO 150 K=1,KMAX                                               043350
        DENP(K,JNEXT) = DENSTY(K,I)                                   043360
  150 CONTINUE                                                        043370
  160 CONTINUE                                                        043380
C*****INTERPOLATE THE DENSITIES TO HB                                 043390
        JNEXT = JNEXT+1                                               043400
        ZP(JNEXT) = HB                                                043410
        I2 = IB                                                       043420
        IF(I2.EQ.1) I2 = 2                                            043430
        IF(I2.GT.IMAX) I2 = IMAX                                      043440
        I1 = I2-1                                                     043450
        A = (HB-Z(I1))/(Z(I2)-Z(I1))                                  043460
        CALL EXPINT(PP(JNEXT),P(I1),P(I2),A)                          043470
        TP(JNEXT) = T(I1)+(T(I2)-T(I1))*A                             043480
        CALL EXPINT(RFNDXP(JNEXT),RFNDX(I1),RFNDX(I2),A)              043490
        DO 170 K=1,KMAX                                               043500
        CALL EXPINT(DENP(K,JNEXT),DENSTY(K,I1),DENSTY(K,I2),A)        043510
  170 CONTINUE                                                        043520
        RETURN                                                        043530
        END                                                           043540
```

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      SUBROUTINE ALAYER(J,SINAI,COSAI,CPATH,SH,GAMMA,IAMT,S,BEND)        043550
C******************************************************************      043560
C     THIS SUBROUTINE TRACES THE OPTICAL RAY THROUGH ONE LAYER FROM      043570
C     Z1 TO Z2 AND IF IAMT.NE.2 CALCULATES THE INTEGRATED ABSORBER       043580
C     AMOUNTS FOR THE LAYER. SINAI IS THE SIN OF THE INITIAL INCIDENCE   043590
C     ANGLE (= 180 - ZENITH ANGLE). COSAI IS CARRIED SEPERATELY TO       C43600
C     AVOID A PRECISION PROBLEM NEAR SINAI = 1. CPATH IS THE CONSTANT    043610
C     OF REFRACTION FOR THE PATH = INDEX*RADIUS*SINAI. SH AND GAMMA ARE  043620
C     THE SCALE HEIGHT AND THE AMOUNT AT THE GROUND FOR THE REFRACTIVITY 043630
C     (= 1-INDEX OF REFRACTION). S IS THE REFRACTED PATH LENGTH THROUGH  043640
C     THE LAYER, BETA IS THE EARTH CENTERED ANGLE, AND BEND IS THE       C43650
C     BENDING THROUGH THE LAYER. IAMT CONTROLS WHETHER AMOUNTS ARE       043660
C     CALCULATED OR NOT.                                                 043670
C******************************************************************      C43680
      COMMON /IFIL/ IRD,IPR,IPU                                          043690
      COMMON /PARMTR/ PI,DEG,GCAIR,RE,DELTAS,ZMIN,ZMAX,IMAX,IMOD,IBMAX,  043700
     1    IOUTMX,IPATH,IMODMX,IDIM,KDIM,KMXNOM,KMAX,NOPRNT               043710
C&    DOUBLE PRECISION HMOD                                              C&043720
      COMMON HMOD(3),ZM(50),PM(50),TM(50),RFNDXM(50),DENM(20,50)         043730
      COMMON ZP(71),PP(71),TP(71),RFNDXP(71),SP(71),                     043740
     1    PPSUM(71),TPSUM(71),RHOPSM(71),DENP(20,71),AMTP(20,71)         043750
      COMMON Z(71),P(71),T(71),RFNDX(71),DENSTY(20,71)                   043760
      DIMENSION HDEN(20),DENA(20),DENB(20)                               043770
      DATA EPSILN/1.0E-5/                                                043780
      N = 0                                                              043790
      Z1 = ZP(J)                                                         043800
      Z2 = ZP(J+1)                                                       043810
      H1 = Z1                                                            043820
      R1 = RE+H1                                                         043830
      DHMIN = DELTAS**2/(2.0*R1)                                         043840
      SINAI1 = SINAI                                                     043850
      COSAI1 = COSAI                                                     043860
      IF((1.0-SINAI).LT.EPSILN) Y1 = COSAI1**2/2.0+COSAI1**4/8.0+        043870
     1    COSAI1**6*3.0/48.0                                             043880
      Y2 = 0.0                                                           043890
      X1 = -R1*COSAI1                                                    043900
      RATIO1 = R1/RADREF(H1,SH,GAMMA)                                    043910
      DSDX1 = 1.0/(1.0-RATIO1*SINAI1**2)                                 043920
      DBNDX1 = DSDX1*SINAI1*RATIO1/R1                                    043930
      S = 0.0                                                            043940
      BEND = 0.0                                                         043950
      IF(IAMT.EQ.2) GO TO 110                                           043960
C*****INITIALIZE THE VARIABLES FOR THE CALCULATION OF THE                043970
C*****ABSORBER AMOUNTS                                                   043980
      PA = PP(J)                                                         043990
      PB = PP(J+1)                                                       044000
      TA = TP(J)                                                         044010
      TB = TP(J+1)                                                       044020
      RHOA = PA/(GCAIR*TA)                                               044030
      RHOB = PB/(GCAIR*TB)                                               044040
      DZ = ZP(J+1)-ZP(J)                                                 044050
      HP = -DZ/ALOG(PB/PA)                                               044060
      IF(ABS(RHOB/RHOA-1.0).LT.EPSILN) GO TO 90                         044070
      HRHO = -DZ/ALOG(RHOB/RHOA)                                         044080
      GO TO 95                                                           044090
   90 HRHO = 1.0E30                                                      044100
   95 CONTINUE                                                           044110
      DO 105 K=1,KMAX                                                    044120
      DENA(K) = DENP(K,J)                                                044130
      DENB(K) = DENP(K,J+1)                                              044140
```

```
      IF(DENA(K).EQ.0.0 .OR. DENB(K).EQ.0.0)  GO TO 100          044150
      IF(ABS(1.0-DENA(K)/DENB(K)).LE.EPSILN)  GO TO 100          044160
C*****USE EXPONENTIAL INTERPOLATION                             044170
      HDEN(K, = -DZ/ALOG(DENB(K)/DENA(K))                       044180
      GO TO 105                                                 044190C
C*****USE LINEAR INTERPOLATION                                  044200
  100 HDEN(K) = 0.0                                             044210
  105 CONTINUE                                                  044220
  110 CONTINUE                                                  044230
C*****                                                          044240
C*****LOOP THROUGH PATH                                         044250
C*****INTEGRATE PATH QUANTITIES USING QUADRATIC INTEGRATION WITH 044260
C*****UNEQUALLY SPACED POINTS                                   044270
C*****                                                          044280
  115 CONTINUE                                                  044290
      N = N+1                                                   044300
      DH = -DELTAS*COSAI1                                       044310
      IF(DH.LT.DHMIN) DH = DHMIN                                044320
      H3 = H1+DH                                                044330
      IF(H3.GT.Z2) H3 = Z2                                      044340
      DH = H3-H1                                                044350
      R3 = RE+H3                                                044360
      H2 = H1+DH/2.0                                            044370
      R2 = RE+H2                                                044380
      SINAI2 = CPATH/(ANDEX(H2,SH,GAMMA)*R2)                    044390
      SINAI3 = CPATH/(ANDEX(H3,SH,GAMMA)*R3)                    044400
      RATIO2 = R2/RADREF(H2,SH,GAMMA)                           044410
      RATIO3 = R3/RADREF(H3,SH,GAMMA)                           044420
      IF((1.0-SINAI2).GT.EPSILN)  GO TO 116                     044430
C*****NEAR A TANGENT HEIGHT, COSAI = -SQRT(1-SINAI**2) LOSES    044440
C*****PRECISION. USE THE FOLLOWING ALGORITHM TO GET COSAI.      044450
      Y3 = Y1+(SINAI1*(1.0-RATIO1)/R1+4.0*SINAI2*(1.0-RATIO2)/R2+ 044460
     1    SINAI3*(1.0-RATIO3)/R3)*DH/6.0                        044470
      COSAI3 = -SQRT(2.0*Y3-Y3**2)                              044480
      X3 = -R3*COSAI3                                           044490
      DX = X3-X1                                                044500
      W1 = 0.5*DX                                               044510
      W2 = 0.0                                                  044520
      W  = 0.5*DX                                               044530
      GO TO 118                                                 044540
C*****                                                          044550
  116 CONTINUE                                                  044560
      COSAI2 = -SQRT(1.0-SINAI2**2)                             044570
      COSAI3 = -SQRT(1.0-SINAI3**2)                             044580
      X2 = -R2*COSAI2                                           044590
      X3 = -R3*COSAI3                                           044600
C*****CALCULATE WEIGHTS                                         044610
      D31 = X3-X1                                               044620
      D32 = X3-X2                                               044630
      D21 = X2-X1                                               044640
      IF(D32.EQ.0.0 .OR. D21.EQ.0.0) GO TO 117                  044650
      W1 = (2.0-D32/D21)*D31/6.0                                044660
      W2 = D31**3/(D32*D21*6.0)                                 044670
      W3 = (2.0-D21/D32)*D31/6.0                                044680
      GO TO 118                                                 044690
  117 CONTINUE                                                  044700
      W1 = 0.5*D31                                              044710
      W2 = 0.0                                                  044720
      W3 = 0.5*D31                                              044730
C*****                                                          044740
```

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      118 CONTINUE                                                     044750
          DSDX2 = 1.0/(1.0-RATIO2*SINAI2**2)                          044760
          DSDX3 = 1.0/(1.0-RATIO3*SINAI3**2)                          044770
          DBNDX2 = DSDX2*SINAI2*RATIO2/R2                             044780
          DBNDX3 = DSDX3*SINAI3*RATIO3/R3                             044790
      C****INTEGRATE                                                   044800
          DS = W1*DSDX1+W2*DSDX2+W3*DSDX3                             044810
          S = S+DS                                                    044820
          DBEND = W1*DBNDX1+W2*DBNDX2+W3*DBNDX3                       044830
          BEND = BEND+DBEND                                           044840
          IF(IAMT.EQ.2) GO TO 150                                     044850
      C*****CALCULATE AMOUNTS                                          044860
          DSDZ = DS/DH                                                044870
          PB = PA*EXP(-DH/HP)                                         044880
          RHOB = RHOA*EXP(-DH/HRHO)                                   044890
          IF((DH/HRHO).LT.EPSILN) GO TO 120                           044900
          PPSUM(J) = PPSUM(J)+DSDZ*(HP/(1.0+HP/HRHO))*(PA*RHOA-PB*RHOB) 044910
          TPSUM(J) = TPSUM(J)+DSDZ*HP*(PA-PB)/GCAIR                   044920
          RHOPSM(J) = RHOPSM(J)+DSDZ*HRHO*(RHOA-RHOB)                 044930
          GO TO 125                                                   C44940
      120 CONTINUE                                                    044950
          PPSUM(J) = PPSUM(J)+0.5*DS*(PA*RHOA+PB*RHOB)               044960
          TPSUM(J) = TPSUM(J)+0.5*DS*(PA+PB)/GCAIR                   !044970
          RHOPSM(J) = RHOPSM(J)+0.5*DS*(RHOA+RHOB)                   044980
      125 CONTINUE                                                    044990
          DO 140 K=1,KMAX                                             045000
          IF(HDEN(K).EQ.0.0) GO TO 130                                045010
          IF(ABS(DH/HDEN(K)).LT.EPSILN) GO TO 130                     045020
      C****EXPONENTIAL INTERPOLATION                                   045030
          DENB(K) = DENP(K,J)*EXP(-(H3-Z1)/HDEN(K))                   045040
      C*****1.0E5 FACTOR CONVERTS FROM KM TO CM                        045050
          AMTP(K,J) = AMTP(K,J)+DSDZ*HDEN(K)*(DENA(K)-DENB(K))*1.0E5  045060
          GO TO 140                                                   045070
      130 CONTINUE                                                    045080
      C****LINEAR INTERPOLATION                                        045090
          DENB(K) = DENP(K,J)+(DENP(K,J+1)-DENP(K,J))*(H3-Z1)/DZ      045100
          AMTP(K,J) = AMTP(K,J)+0.5*(DENA(K)+DENB(K))*DS*1.0E5        045110
      140 CONTINUE                                                    045120
          PA = PB                                                     045130
          RHOA = RHOB                                                 045140
          DO 145 K=1,KMAX                                             045150
      145 DENA(K) = DENB(K)                                           045160
      150 CONTINUE                                                    045170
          IF(H3.GE.Z2) GO TO 160                                      045180
          H1 = H3                                                     045190
          R1 = R3                                                     045200
          SINAI1 = SINAI3                                             045210
          RATIO1 = RATIO3                                             C45220
          Y1 = Y3                                                     045230
          COSAI1 = COSAI3                                             045240
          X1 = X3                                                     045250
          DSDX1 = DSDX3                                               045260
          DBNDX1 = DBNDX3                                             045270
          GO TO 115                                                   045280
      160 CONTINUE                                                    045290
          SINAI = SINAI3                                              045300
          COSAI = COSAI3                                              045310
          SP(J) = S                                                   045320
          RETURN                                                      045330
          END                                                         045340
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      SUBROUTINE AUTLAY(HMIN,HMAX,VBAR,AVTRAT,TDIFF1,TDIFF2,IBND,      045350
     1   IERROR)                                                       045360
C****************************************************************      045370
C      THIS SUBROUTINE AUTOMATICALLY SELECTS A SET OF FASCODE BOUNDARY  045380
C      LEVELS WHICH SATISFY THE FOLLOWING TWO TESTS:                    045390
C          1. THE RATIO OF THE VOIGT HALFWIDTHS BETWEEN BOUNDARIES      045400
C             IS LESS THAN OR EQUAL TO AVTRAT, AND                      045410
C          2. THE TEMPERATURE DIFFERENCE BETWEEN BOUNDARIES IS          045420
C             LESS THAN OR EQUAL TO TDIFF                               045430
C      TDIFF VARIES FROM TDIFF1 AT HMIN TO TDIFF2 AT HMAX,              045440
C      WITH EXPONENTIAL INTERPOLATION BETWEEN                           045450
C      THESE BOUNDARIES ARE ROUNDED DOWN TO THE NEAREST TENTH KM        045460
C      NOTE THAT THESE TESTS APPLY TO THE LAYER BOUNDARIES              045470
C      NOT TO THE AVERAGE VALUES FROM ONE LAYER TO THE NEXT.            045480
C****************************************************************      045490
      COMMON /IFIL/ IRD,IPR,IPU                                        045500
      COMMON /PARMTR/ PI,DEG,GCAIR,RE,DELTAS,ZMIN,ZMAX,IMAX,IMOD,IBMAX, 045510
     1   IOUTMX,IPATH,IMODMX,IDIM,KDIM,KMXNOM,KMAX,NOPRNT               045520
      COMMON /CONSTN/ PZERO,TZERO,AVOGAD,ALOSMT,GASCON,PLANK,BOLTZ,     045530
     1   CLIGHT,ADCON,ALZERO,AVMWT,AIRMWT,AMWT(20),VMIXST(20),VMIXN2    045540
C&    DOUBLE PRECISION HMOD                                            C&045550
      COMMON HMOD(3),ZM(50),PM(50),TM(50),RFNDXM(50),DENM(20,50)        045560
      COMMON ZP(71),PP(71),TP(71),RFNDXP(71),SP(71),                   045570
     1   PPSUM(71),TPSUM(71),RHOPSM(71),DENP(20,71),AMTP(20,71)         045580
      COMMON Z(71),P(71),T(71),RFNDX(71),DENSTY(20,71)                 045590
      COMMON /BNDRY/ ZBND(34),PBND(34),TBND(34),ALORNZ(34),ADOPP(34),   045600
     1   AVOIGT(34)                                                    045610
      DIMENSION AVTM(50)                                               045620
C*****FUNCTION ZROUND ROUNDS THE ALTITUDE Z DOWN TO THE                045630
C*****NEAREST TENTH KM                                                 045640
      ZROUND(ZX) = 0.1*FLOAT(IFIX(10.0*ZX))                            045650
C*****                                                                 045660
      DO 100 IM=2,IMOD                                                 045670
      IHMIN = IM                                                       045680
      IF(ZM(IM).GT.HMIN) GO TO 120                                     045690
  100 CONTINUE                                                         045700
  120 CONTINUE                                                         045710
      HTOP = HMAX                                                      045720
      IF(HTOP.GT.ZMAX) HTOP = ZMAX                                     045730
      IM = IHMIN-1                                                     045740
      ZZ = ZM(IM)                                                      045750
      CALL HALFWD(ZZ,VBAR,P,T,AL,AD,AVTM(IM))                          045760
      IB = 1                                                           045770
      ZBND(IB) = HMIN                                                  045780
      IM = IHMIN                                                       045790
      CALL HALFWD(ZBND(IB),VBAR,PBND(IB),TBND(IB),ALORNZ(IB),          045800
     1   ADOPP(IB),AVOIGT(IB))                                         045810
      IB = 2                                                           045820
C*****BEGIN LOOP                                                       045830
  200 CONTINUE                                                         045840
      IPASS = 0                                                        045850
      ZBND(IB) = ZM(IM)                                                045860
      IF(ZBND(IB).GE.HTOP)  ZBND(IB) = HTOP                            045870
      CALL HALFWD(ZBND(IB),VBAR,PBND(IB),TBND(IB),ALORNZ(IB),          045880
     1   ADOPP(IB),AVOIGT(IB))                                         045890
      AVTM(IM) = AVOIGT(IB)                                            045900
C*****TEST THE RATIO OF THE VOIGT WIDTHS AGAINST AVTRAT                045910
      IF((AVOIGT(IB-1)/AVOIGT(IB)).LT.AVTRAT)  GO TO 220               045920
C*****ZM(IM) FAILS THE HALFWIDTH RATIO TEST                           045930
      IPASS = 1                                                        045940
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      AVOIGT(IB) = AVOIGT(IB-1)/AVTRAT                                     045950
      ZBND(IB) = ZM(IM-1)+(ZM(IM)-ZM(IM-1))*ALOG(AVOIGT(IB)/AVTM(IM-1))/   045960
     1    ALOG(AVTM(IM)/AVTM(IM-1))                                        045970
      IF(ZBND(IB).NE.HTOP) ZBND(IB) = ZROUND(ZBND(IB))                     045980
      CALL HALFWD(ZBND(IB),VBAR,PBND(IB),TBND(IB),ALORNZ(IB),              045990
     1    ADOPP(IB),AVOIGT(IB))                                            046000
  220 CONTINUE                                                             046010
C*****TEST THE TEMPERATURE DIFFERENCE AGAINST TDIFF                        046020
      FAC = (ZBND(IB-1)-HMIN)/(HMAX-HMIN)                                  046030
      CALL EXPINT(TDIFF,TDIFF1,TDIFF2,FAC)                                 046040
      IF(ABS(TBND(IB)-TBND(IB-1)).LE.TDIFF)  GO TO 230                     046050
C*****ZBND(IB) FAILS THE TERPERATURE DIFFERENCE TEST                       046060
      IPASS = 2                                                            046070
      TBND(IB) = TBND(IB-1)+SIGN(TDIFF,TM(IM)-TM(IM-1))                    046080
      ZBND(IB) = ZM(IM-1)+(ZM(IM)-ZM(IM-1))*                              046090
     1    (TBND(IB)-TM(IM-1))/(TM(IM)-TM(IM-1))                            046100
      IF(ZBND(IB).NE.HTOP)  ZBND(IB) = ZROUND(ZBND(IB))                    046110
      CALL HALFWD(ZBND(IB),VBAR,PBND(IB),TBND(IB),ALORNZ(IB),              046120
     1    ADOPP(IB),AVOIGT(IB))                                            046130
  230 CONTINUE                                                             046140
      IF(ZBND(IB).GE.HTOP)  GO TO 300                                      046150
      IF(IPASS.NE.0)  GO TO 240                                            046160
C*****BOTH HALFWIDTH AND TEMPERATURE TEST PASS FOR ZBND(IB) = ZM(IM),      046170
C*****NOW TRY ZBND(IB) = ZM(IM+1)                                          046180
      IM = IM+1                                                            046190
      GO TO 200                                                            046200
  240 CONTINUE                                                             046210
C*****ONE OF THE TESTS FAILED AND A NEW BOUNDRY ZBND WAS PRODUCED          046220
C*****TEST FOR THE NEXT BOUNDARY AT THE PREVIOUS ZM(IM)                    046230
      IB = IB+1                                                            046240
      IF(IB.GT.IBMAX)  GO TO 900                                          046250
      GO TO 200                                                            046260
  300 CONTINUE                                                             046270
      IBND = IB                                                            046280
      WRITE(IPR,10)  AVTRAT,TDIFF1,TDIFF2                                  046290
   10 FORMAT(///,' FASCODE LAYER BOUNDARIES PRODUCED BY THE AUTOMATIC ',   046300
     1    'LAYERING ROUTINE AUTLAY',/,' THE USER SHOULD EXAMINE ',         046310
     2    'THESE BOUNDARIES AND MODIFY THEM IF APPROPRIATE',/,             046320
     3    ' THE FOLLOWING PARAMETERS ARE USED:',//,                       046330
     4 10X,'AVTRAT   = ',F8.2,'       = MAX RATIO OF VOIGT WIDTHS',/,      046340
     5 10X,'TDIFF1   = ',F8.2,'       = MAX TEMP DIFF AT HMIN',/,          046350
     6 10X,'TDIFF2   = ',F8.2,'       = MAX TEMP DIFF AT HMAX')            046360
      RETURN                                                               046370
  900 CONTINUE                                                             046380
      WRITE(IPR,901) IBMAX                                                 046390
  901 FORMAT(///,' ERROR IN AUTLAY:',/,5X,'THE NUMBER OF ',                046400
     1    'GENERATED LAYER BOUNDARIES EXCEEDS THE DIMENSION IBMAX ',       046410
     2    'OF THE ARRAY ZBND.   IBMAX = ',I5,/,                           046420
     3 5X,'PROBABLE CAUSE: EITHER AVTRAT AND/OF TDIFF ARE TOO SMALL',      046430
     4    /,5X,'THE GENERATED LAYERS FOLLOW')                             046440
      IBND = IBMAX                                                         046450
      IERROR = 5                                                           046460
      RETURN                                                               046470
      END                                                                  046480
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      SUBROUTINE HALFWD(Z,VBAR,P,T,ALORNZ,ADOPP,AVOIGT)                   046490
C****************************************************************************  046500
C     GIVEN AN ALTITUDE Z AND AN AVERAGE WAVENUMBER VBAR, THIS             046510
C     SUBROUTINE INTERPOLATES P AND T FROM THE PROFILE IN ZM  AND          046520
C     CALCULATES THE LORENTZ, THE DOPPLER, AND THE VOIGT HALFWIDTHS         046530
C     (AT HALFHEIGHT) ALORNZ, ADOPP, AND AVOIGT RESPECTIVELY FOR           046540
C     THE ALTITUDE Z                                                        046550
C     AN AVERAGE LORENTZ WIDTH ALZERO AND AN AVERAGE MOLECULAR             046560
C     WEIGHT AVMWT ARE ASSUMED                                             046570
C****************************************************************************  046580
      COMMON /IFIL/ IRD,IPR,IPU                                            046590
      COMMON /PARMTR/ PI,DEG,GCAIR,RE,DELTAS,ZMIN,ZMAX,IMAX,IMOD,IBMAX,    046600
     1    IOUTMX,IPATH,IMODMX,IDIM,KDIM,KMXNOM,KMAX,NOPRNT                 046610
      COMMON /CONSTN/ PZERO,TZERO,AVOGAD,ALOSMT,GASCON,PLANK,BOLTZ,        046620
     1    CLIGHT,ADCON,ALZERO,AVMWT,AIRMWT,AMWT(20),VMIXST(20),VMIXN2      046630
C&    DOUBLE PRECISION HMOD                                                C&046640
      COMMON HMOD(3),ZM(50),PM(50),TM(50),RFNDXM(50),DENM(20,50)           046650
      COMMON ZP(71),PP(71),TP(71),RFNDXP(71),SP(71),                      046660
     1    PPSUM(71),TPSUM(71),RHOPSM(71),DENP(20,71),AMTP(20,71)           046670
      COMMON ZX(71),PX(71),TX(71),RFNDX(71),DENSTY(20,71)                 046680
C*****FUNCTIONS     *                                                      046690
C*****ALZERO IS AT 1013.25 MB AND 296.0 K                                  046700
      ALPHAL(P,T) = ALZERO*(P/PZERO)*SQRT(296.0/T)                        046710
      ALPHAD(T,V) = ADCON*V*SQRT(T/AVMWT)                                 046720
      ALPHAV(AL,AD) = 0.5*(AL+SQRT(AL**2+4.0*AD**2))                      046730
C*****                                                                     046740
      DO 100 I2=2,IMOD                                                     046750
      IM = I2                                                              046760
      IF(ZM(IM).GE.Z)  GO TO 110                                          046770
  100 CONTINUE                                                             046780
      IM = IMOD                                                            046790
  110 CONTINUE                                                             046800
      FAC = (Z-ZM(IM-1))/(ZM(IM)-ZM(IM-1))                                046810
      CALL EXPINT(P,PM(IM-1),PM(IM),FAC)                                  046820
      T = TM(IM-1)+(TM(IM)-TM(IM-1))*FAC                                  046830
      ALORNZ = ALPHAL(P,T)                                                046840
      ADOPP = ALPHAD(T,VBAR)                                              046850
      AVOIGT = ALPHAV(ALORNZ,ADOPP)                                       046860
      RETURN                                                               046870
      END                                                                  046880
```

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Appendix A

Six atmospheric profiles are included in FSCATM as a convenience to the user. These profiles consist of the pressure and temperature, and the number densities of H_2O, CO_2, O_3, N_2O, CO, CH_4, and O_2, vs altitude at 1-km steps from 0 to 25 km, 5-km steps from 25 to 50 km, and at 70 and 100 km. These profiles, taken from McClatchey et al[A1] correspond to the 1962 U.S. Standard Atmosphere[A2] and five supplementary models:[A3] Tropical (15°N), Midlatitude Summer (45°N, July), Midlatitude Winter (45°, Jan), Subarctic Summer (60°N, July), and Subarctic Winter (60°N, Jan). These profiles are identical to the ones contained in LOWTRAN.[A4] The water vapor and ozone altitude profiles added to the 1962 U.S. Standard Atmosphere by McClatchey et al[A1] were obtained from Sissenwine et al[A5] and Hering et al[A6] respectively, and correspond to mean annual values. The water vapor densities for the 1962 U.S. Standard Atmosphere correspond to relative humidities of approximately 50 percent for altitudes up to 10 km, whereas the relative humidity values for the other supplementary models tend to decrease with altitude from approximately 80 percent at sea level to approximately 30 percent at 10-km altitude. Above 12 km, the water-vapor number densities of models 1 to 5 are identical and represent volume mixing ratios that reach a minimum of about 6.5 ppmv at 17 km, increase to 30 ppmv at 30 km, and then decrease to 10 ppmv at 50 km. For all models, the gases CO_2, N_2O, CO, CH_4, and O_2

Because of the large number of references cited above, they will not be listed here. See References, page 139.

are considered uniformly mixed with volume mixing ratios of 330, 0.28, 0.075, 1.6, and 2.095 $\times 10^5$ ppm respectively.

The temperature profiles as a function of altitude for the six atmospheric models are shown in Figure A1. Figure A2 shows the water-vapor density vs altitude for 0 to 100 km and an expanded profile from 0 to 30 km. Figure A3 shows similar profiles for ozone.

In the almost 20 years since these profiles were constructed, our knowledge of the state of the atmosphere has increased enormously. This is particularly true regarding the stratosphere and above, and the concentration of minor constituents. For example, the stratospheric water-vapor concentrations for the six profiles given here are now known to be too large by a factor of 5 at 30 km. Models 1 through 6 may still be considered representative of their respective conditions up to about 50 km for temperature, up to 30 km for ozone densities, and up to the tropopause (~15 km in the Tropics to 8 km in the Arctic) for water vapor. Users may still use these models for cases dominated by the conditions in the troposphere. For cases dominated by stratospheric conditions or where the distribution of minor constituents is significant, the user should supply his own profile read in under the MODEL = 7 option.
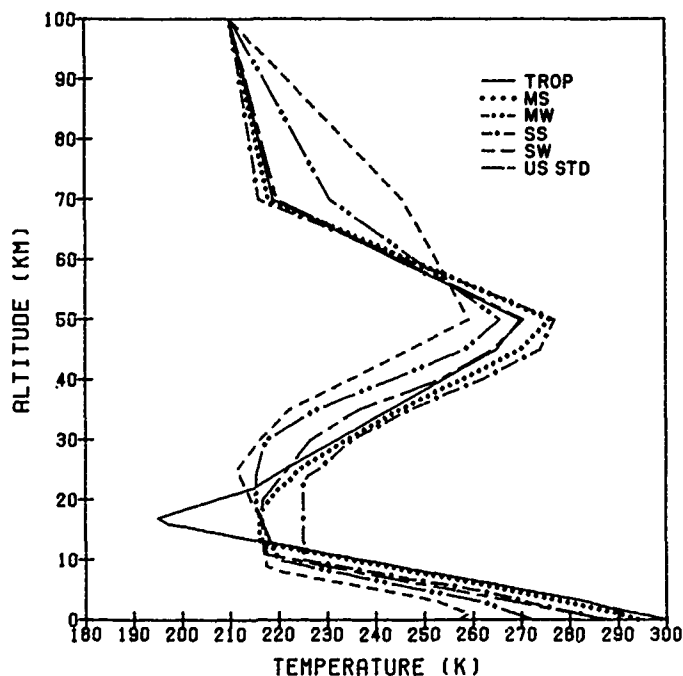
Figure A1. Temperature vs Altitude for the Six Model Atmospheres

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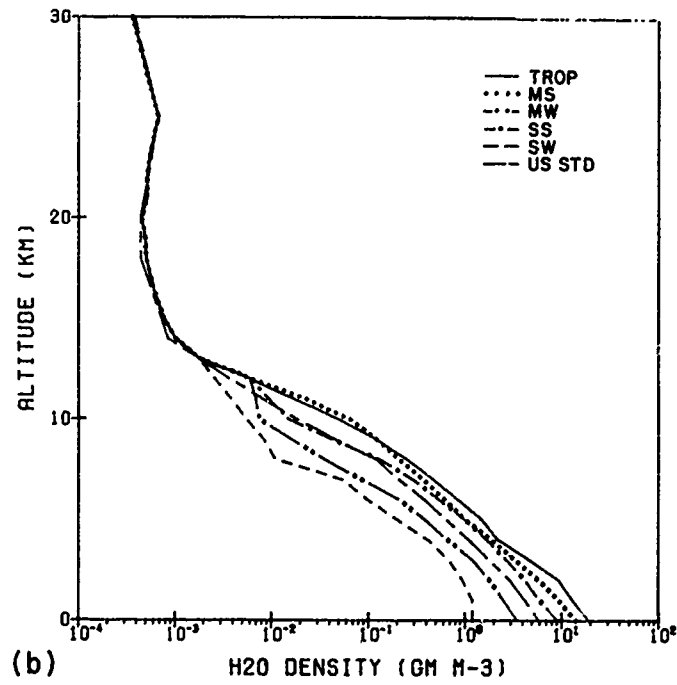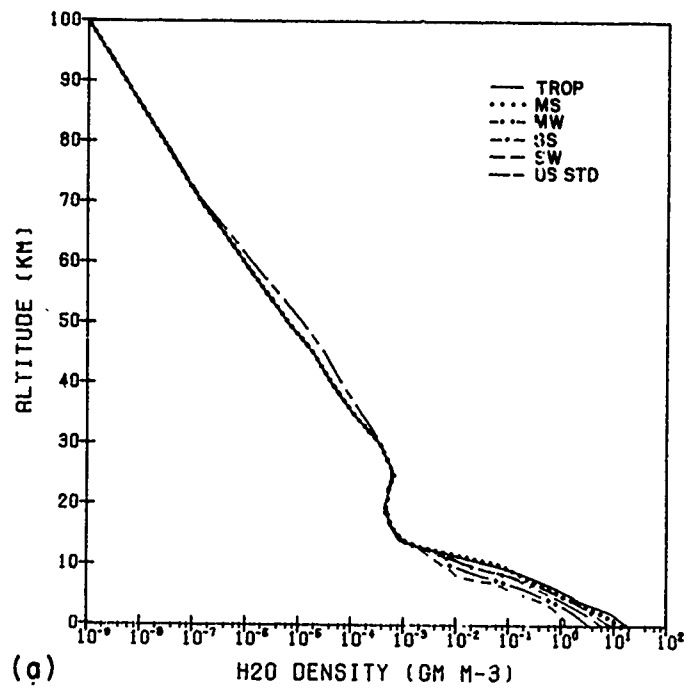
Figure A2. Water Vapor Density Profiles vs Altitude for the Six Model Atmospheres: (a) From 0 to 100 km and (b) From 0 to 30 km

135
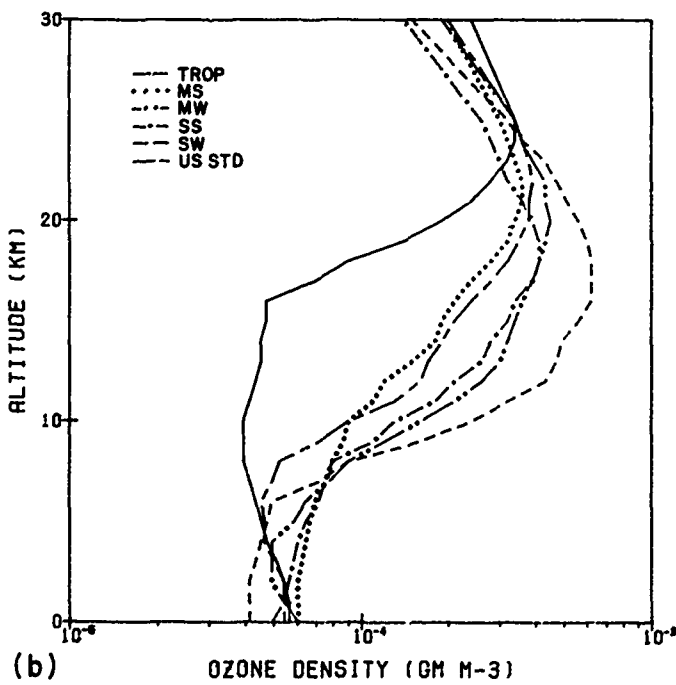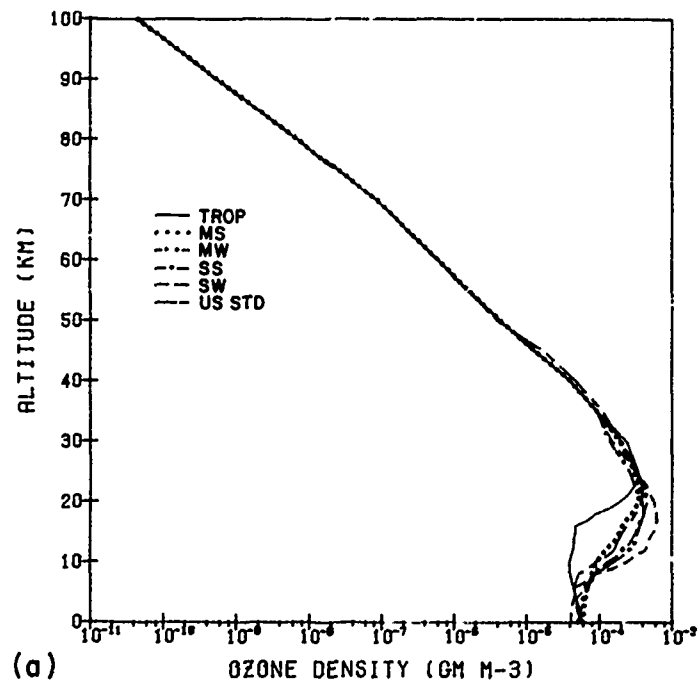
Figure A3. Ozone Profile vs Altitude for the Six
Model Atmospheres: (a) From 0 to 100 km and
(b) From 0 to 30 km

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There are several recent sources for profiles of temperature and minor constituent density. The U.S. Standard Atmosphere 1976[A7] updates the 1962 U.S. Standard Atmosphere for temperature above 50 km and provides revised estimates for the surface concentrations of what was termed previously "uniformly mixed gases". The new values for the volume mixing ratios of CO_2, N_2O, CO, and CH_4 are 322, 0.27, 0.19, and 1.50 ppmv respectively. These values are used as the default mixing ratios for MODEL = 7 if the user-supplied values are zero. Actually the concentration of these gases do show significant variations from these values, particularly with altitude in the stratosphere.

Cole and Kantor[A8] provide sets of monthly mean temperature profiles up to 90 km at 15° intervals between the Equator and the pole. Along with statistics on the variability of these profiles, they also provide models that portray the longitudinal variations in monthly mean values of temperature during winter months and the vertical variation which occurs during stratospheric warming and cooling events in the winter arctic and subarctic. Houghton[A9] provides seasonal profile temperature at 10^oN, 40^oN and 70^oN up to 105 km plus the original references for the data (this by the way is a marvelous little book that I strongly recommend as both an introduction and a refresher in atmospheric physics).

For profiles of the minor constituants including ozone and stratosphere water vapor, Hudson et al[A10] provides an up-to-date (June 1981) and exhaustive source. This volume is available from

Stratospheric Chemistry and Physics Branch
Code 963
NASA Goddard Space Flight Center
Greenbelt, MD 20771

or

Word Meteorological Center
Case Postule No. 5
Geneva 20, Switzerland

Much of the profile data from this source plus some more recent measurements have been compiled as annual averages in 2 km steps in Smith.[A11]

Finally a new edition of the Handbook of Geophysics[A12] is in preparation, which will include seasonal profiles of temperature, water vapor, and ozone plus a wealth of other data. This volume should be available in 1984.

Because of the large number of references cited above, they will not be listed here. See References, page 139.

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Appendix B

Index of Refraction

The expression for the index of refraction of air is:

$$n - 1 = 10^{-6} \times (77.46 + 0.479 \times 10^{-8} * \tilde{\nu}^2) \times \frac{P}{T}$$

$$- \frac{P_{H_2O}}{P_o} * (43.49 - 0.347 \times 10^{-8} \tilde{\nu}^2)$$

where $\tilde{\nu}$ is the wavenumber, c is the speed of light, P and T the pressure and temperature. P_{H_2O} is the water-vapor partial pressure, and P_o is 1013.25 mb. This expression is the same as is in the program LOWTRAN[B1] and is a simplified version of the expression by Edlen.[B2] For further references on the index of refraction of air, the reader is referred to References B3 and B4.

B1. Kneizys, F.X., Shettle, E.P., Gallery, W.O., Chetwynd, J.H., Jr., Abreu, L.W., Selby, J.E.A., Fenn, R.W., and McClatchey, R.A. (1980) Atmospheric Transmittance/Radiance: Computer Code LOWTRAN 5, AFGL-TR-80-0067, AD A088215.

B2. Edlen, B. (1966) The refractive index of air, Metrologia 2:12.

B3. Peck, E.R., and Reeder, K. (1972) Dispersion of air, J. Opt. Soc. Am. 62:958.

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Appendix C.

A Brief Survey of the Literature

The subject of air mass calculation and the associated subject of astronomical refraction go back to Laplace and have generated a large body of literature. This brief survey is meant only to point out a few references to which the interested reader can turn to for further references.

The theory of atmospheric refraction and of air mass calculation is discussed in some detail in Kondratyev, K. (1969) Radiation in the Atmosphere, Academic Press, New York, Chapter 4 and in Zuev, V. E. (1982) Laser Beams in the Atmosphere, Consultants Bureau, New York, Chapter 1.

The following paper has a fairly extensive list of references on the calculation of air mass along with graphs showing the effect of neglecting refraction for occultation geometries: Sneider, D. (1975) Refractive effects in remote sounding of the atmosphere with infrared transmission spectroscopy, J. Atmos. Sci. 32: 2178-2184.

Essentially the same paper but with tables of air mass for observer altitudes ranging from 10 to 50 km in steps of 1 km, with zenith angles ranging from 80° to 97° is Sneider, D. E., and Goldman, A. (1974) Refractive Effects in Remote Sensing of the Atmosphere With Infrared Transmission Spectroscopy, Ballistic Res. Labs, Report 1790, Aberdeen Md, DTIC No. AD-A011253.

A more recent paper with references is Wang, P. -H., Deepak, A., and Hong, S. -S. (1981) General formulation of optical paths or large zenith angles in the earth's curved atmosphere, J. Atmos. Sci. 38:650-658.

One of the earliest tabulations of air mass was by Bemporad and is reprinted in List, R.J. (1968) Smithsonian Meteorological Tables (6th Revised Edition), Smithsonian Institute Press, Washington.

In the case where refraction can be neglected and where the density profile is exponential, the air mass can be calculated analytically using the "Chapman function". The original reference is Chapman, S. (1931) The absorption and dissociative or ionizing effect of monochromatic radiation in an atmosphere on a rotating earth II. Grazing incidence, Proc. Phys. Soc. (London) 43:483-501.

Since then numerous simplifications and approximations to the Chapman functions have appeared. Among them are: (1) Fitzmaurice, J.A. (1964) Simplification of the Chapman function for atmospheric attenuation, Appl. Opt. 3:640; (2) Swider, W., Jr., and Gardner, M.E. (1967) On the Accuracy of Certain Approximations to the Chapman Functions, AFCRL-67-0468, AD 658826; (3) Swider, W., Jr., and Gardner, M.E. (1969) On the accuracy of Chapman function approximations, Appl. Opt. 3:1725; and (4) Smith, F.L. III, and Smith, C. (1972) Numerical evaluation of Chapman's grazing incidence integral, Ch (x, ψ), J. Geophys. Res. 77:3592-3597.

An analytic approximation to the calculation of air mass that includes the effect of earth's curvature and refraction is in Uplinger, W.G. (1981) A Simple Model for Relative Air Mass, in preprint volume for the Fourth Conference on Atmospheric Radiation, June 1981, Toronto, Canada (American Meteorological Society).

The case in which the density scale height varies with altitude (that is, temperature) is discussed in Swider, W., Jr. (1964) The determination of the optical depth at large solar zenith distances, Planet Space Sci. 12:761-782.

Another method for dealing with non-exponential density distributions is found in Green, A.E.S., and Martin, J.D. (1966) A generalized Chapman Function, The Middle Ultraviolet: Its Science and Technology, A.E.S. Green, Ed., Wiley, New York, pp 140-157.

The following paper applies the Chapman function to a solar occultation measurement of the absorption by trace gases in the stratosphere: Menzies, R.J., Rutledge, C.W., Zanteson, R.A., and Spears, D.L. (1981) Balloonborne laser heterodyne radiometer for measurements of stratospheric trace species, Appl. Opt. 20:536-544.

Astronomical refraction refers to the bending of a ray along a path from an observer to a very distant source outside the atmosphere, for instance a star. The effect was recognized in ancient times and is still the subject of active investigation among astronomers. The following paper gives a review of the subject plus an extensive list of references: Mahan, A.I. (1962) Astronomical refraction - some history and theories, Appl. Opt. 4:497-511.

The following report gives an even more complete derivation of the mathematics of refraction plus extensive references covering refraction of visible, IR, and radio waves: Meyer-Arendt, J.R., and Emmanuel, C.B. (1965) Optical Scintillation, a Survey of the Literature, National Bureau of Standards Tech Note 225.

Analyt.. solutions for astronomical refraction for several vertical distributions of the refractive index are given in White, R. (1975) New solutions to the refraction integral, J. Opt. Soc. Am. 65:676-678.

Terrestrial refraction applies to cases in which the whole path lies near the surface of the earth and is of importance in geodesy and surveying. A recent volume devoted to both astronomical and terrestrial refraction is Tengstrom, E., and Teliki, R., Ed. (1979) Refractional Influences in Astronomy and Geodesy, IAU Symposium No. 89, D. Reidel Publishing Co., Holland.

The following report describes an atmospheric ray tracing computer program capable of handling complex problems such as mirages and ducting, for frequencies from the microwave to the visible: Able, M., Mill, J.D., and Lenn, L. (1982) The Theory and Use of a Raytracing Model Developed at USAFETAC., USAFETAC-TN-82-002.

Since this report went to press, the following two papers have come to my attention: Thompson, D.A., Pepin, T.J., and Simon, F.W. (1982) Ray tracing in a spherically symmetric atmosphere, J. Opt. Soc. 72:1498-1501 and Chu, W.P. (1983) Calculation of atmospheric refraction for spacecraft remote-sensing applications, Appl. Opt. 22:721-725.