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UVTRAN
An Ultraviolet Transmission and Lidar Simulation Model

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13. ABSTRACT *(Maximum 200 words)*

UVTRAN is a user-friendly, ultraviolet and visible wavelenth, propagation and lidar model. The computer program is available as both a generic FORTRAN code and as a highly interactive Visual Basic Ver. 3, MS Windows. The transmission code currently uses a modified Koshmeider aerosol model for the aerosol attenuation. It uses a modified Rayleigh scattering model for the attenuation due to molecular scattering, and it uses average molecular absorption data for ozone, oxygen and trace gas attenuation. The wavelength range is 200 to 700 nm. The principle inputs are: range in kilometers, visibility in kilometers, and wavelength in nanometers. Other inputs are: gas concentration in parts per billion, the wavelength interval for calculations, and the range information (starting and ending ranges), and the interval for the range calculation. Default values are built into the model if the user does not know sensible values to use. The last values used in a calculation are saved and can be reused for the next calculations. A 1976 standard atmosphere is used for gas concentraion but can be user defined. The Windows version of the program has plotting capability while the FORTRAN version allows the information to be printed to a data file and plotted externally. This version also has options for viewing and printing the data. The lidar model includes the UVTRAN model for the two-way atmospheric attenuation of the beam. The lidar model performs standard elastic back scattering calculations as a function of range, and it will also perform flourescence lidar calculations. Inputs are the same for the UVTRAN model, but also include the likar inputs such as back scattering cross section (or fluorescence back scattering) and the lidar system parameters (wavelength, power, mirror size, system efficiency). Default typical values are built in if the operator does not know reasonable values.

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Executive Summary

In the last few years there has been a renewed interest in the ultraviolet (UV) spectral region. Interest is due to three things: (1) developments in laser sources that have considerably more power than was available in the past; (2) developments in new detectors with excellent quantum efficiency, speed, and the capability to almost instantaneously collect the full UV/VIS spectrum; and (3) requirements such as remote sensing of biological agents, detection of drug laboratories, combat identification of friendly forces, verification of treaties, and detection of missile plumes and secure communications.

Estimates of UV atmospheric transmission are essential to all requirements that involve propagation of UV radiation. UVTRAN is an atmospheric transmission and laser radar (lidar) model that predicts atmospheric transmission in the 186 to 700 nm spectral region using only visibility, range, and wavelength as parameters. UVTRAN includes a 1976 U.S. standard atmosphere model, a modified Koschmeider aerosol model, and trace gases (nitrogen dioxide, nitrous oxide, sulfur dioxide, and water); the standard atmosphere ozone profile may be changed by the user. The model is designed for any horizontal, vertical, or slant path for ranges up to 11 km and for visibilities less than 50 km. It is primarily for continental air mass type aerosol and is designed for altitudes up to 11 km. A lidar model for aerosol elastic scattering or for fluorescence scattering of aerosols or gases is also part of the complete model. UVTRAN is a Fortran code model for mainframe computers or IBM compatible PC's and a Microsoft Windows Program written in Visual Basic 3.0. The Windows version has considerably more user features. Both codes feature menu or prompt driven input and plotting capability.

UVTRAN is an EOSAEL 92 model and is available from the Army Research Laboratory to qualified requesters. The program is readily available in Fortran, and the Visual Basic source code is available in addition to the executable program. The Windows version comes complete with a setup routine for automatic installation.

1. Introduction

UVTRAN is an atmospheric transmission and lidar return calculation model for visible and ultraviolet (UV) wavelengths. This EOSAEL module combines a transmission code suitable for use in the visible and UV regions with a backscatter code for Mie and fluorescence lidar return calculations and a sky background radiance code into a modular, menu-driven, user friendly program for IBM PC's and compatible systems. The code is available in Fortran source code for main frame computers and as both source and executable code for IBM PC's and compatible systems. The PC version is also available as a Microsoft Windows program written in Visual Basic. The Visual Basic version has more operational features and is discussed in section 4.2.

The transmission model includes attenuation caused by molecular scattering, molecular absorption, and particulate attenuation. Gaseous absorption does not differ significantly from that in Lowtran 6; likewise, the calculated Rayleigh scattering is only slightly less than that of Lowtran. The difference is due to matching of more recent values of Rayleigh attenuation coefficients. The major difference in the UVTRAN and the Lowtran results are due to the different aerosol parameterizations in the two models. The Lowtran models are based on aerosol microphysical models. The UVTRAN model is more directly based on empirical transmission data, with the wavelength dependence of aerosol attenuation parameterized in terms of the visual range to provide an approximate match for visible and UV horizontal attenuation data. The aerosol model was compared with the AFGL standard aerosol models and with experimental data on atmospheric attenuation as a function of the visual range. Comparisons are discussed in section 3.

The lidar model calculates the lidar return signal as a function of range for six different lidar wavelengths. The model is capable of determining backscatter for nominal conditions for Mie backscatter caused by an arbitrary cloud or fluorescent backscatter caused by particles or gaseous molecules.

Default lidar system parameters are available, or the user can tailor the system parameters to any particular system. Sky background is calculated for the wavelength and set of system parameters chosen.

2. Background

Electro-optical sensor systems design requires a knowledge of the effects of the atmosphere on the received signal and on the signal levels to be expected from actively sensed atmospheric targets. Although interest traditionally focused on infrared (IR) and longer wavelength systems, the availability of improved sources and detectors and the desire to utilize the increased resolution available with shorter wavelength systems led to a renewed interest in short wavelength optical systems, extending into the solar-blind region below 290 nm.

There has been a need for a simple code for determining the parameters in the visible and UV regions. To meet this need, the UVTRAN program was developed to model atmospheric transmission and lidar return at visible and UV wavelengths. This model is unique because it combines a transmission code suitable for use in the visible and UV regions with a backscatter code for Mie and fluorescence lidar return calculations and a sky background radiance code into a modular, menu-driven, user friendly Fortran program for an IBM PC or compatible system.

The transmission model differs from the Lowtran 6 [1] or similar models because it is designed for use at visible and UV wavelengths only, so that the band models and emission calculations needed at IR wavelengths are not included. Molecular oxygen absorption is included, a feature not available on PC versions of Lowtran; absorption of trace gases nitrogen dioxide (NO_2), nitrous oxide (NO), sulfur dioxide (SO_2), and water (H_2O) are also included. In addition, the wavelength dependence of the aerosol attenuation is parameterized in terms of the visual range in this model rather than having a wavelength dependence independent of the visual range. This different aerosol parameterization was chosen, in part, because of data showing differences between the Lowtran results and short wavelength experimental data. [2] The background radiance also is parameterized in terms of a zenith angle dependence rather than being calculated on the basis of single scattering theory.

This section describes the computer program, discusses the scientific basis for the model, and compares its results with Lowtran calculations and with experimental data.

2.1 Transmission Model Description

The transmission model determines the path transmission between 185 and 700 nm caused by aerosol attenuation, molecular scattering, and molecular absorption. The model is designed to use over relatively short ranges in the troposphere; consequently, a plane parallel geometry only is assumed. The model does not include effects caused by density gradients or atmospheric turbulence. In all cases, the attenuation is assumed to be given by the Beer-Lambert attenuation law:

$$t = e^{-\sigma x} \tag{1}$$

where

σ = the attenuation coefficient
x = the path length.

The model does not include a band absorption model because of the interest in UV and visible absorption in which electronic absorption is important. No IR water bands are included in the model; therefore, the long wavelength limit for the model is approximately 700 nm.

The model is primarily designed for use in the lower troposphere. Concentrations of attenuating components are determined for altitudes of 11 km or less. Because no spherical geometry is included, the model is most appropriate for relatively short ranges.

The attenuation caused by molecular scattering is calculated by the molecular scattering formula based on a fit to data of Penndorf, [3] which was used in Lowtran 5 with a modification to take account of differences in the Lowtran

formula and more recent results in the Handbook of Geophysics and Space Environment. [4]

$$\sigma_{ms} = \frac{1}{\lambda^4} * \left[\frac{C}{9.26x10^{18} - 1.07x10^{9}\left(\frac{1}{\lambda^2}\right)} \right] * \left(\frac{N}{N_0}\right) \qquad (2)$$

where

λ	=	the wavelength of light
N	=	the number density of air molecules calculated from pressure and temperature data
N_o	=	the number density under standard conditions.

As written, the Penndorf equation requires λ with units of cm and calculates attenuation with units of km^{-1}. UVTRAN converts the entry units of nm to the wavelength units needed for the calculation. The correction term C, C = 0.987, is the modification to the Penndorf formula to bring the calculated Rayleigh scattering into agreement with the standard molecular scattering given by the Handbook of Geophysics and the Space Environment. [3,4]

Molecular absorption in the UVTRAN model is calculated for the two major absorbing species, oxygen (O_2) and ozone (O_3), and for the minor absorbing species, NO_2, NO, SO_2, and H_2O vapor. The choice of these species for inclusion into the model was made on the basis of expected concentrations of trace species from the 1976 U.S. Standard Atmosphere [5] and molecular absorption coefficients discussed in Ackerman [6] and Calvert and Pitts. [7] Under normal conditions, it is expected that the molecular absorption is almost entirely determined by the O_2 and the O_3 absorption. The other absorption coefficients are included because high concentrations of these other gaseous constituents could be present under some circumstances, leading to significant absorption.

Plots of the absorption cross sections for O_2 and O_3 used in UVTRAN are shown in figures 1 (O_2) and 2 (O_3). The model resolution is 2.5 nm for the O_2 data and for the O_3 Hartley-Huggins bands. The Chappuis band data for O_3 have resolutions of 5 to 10 nm.

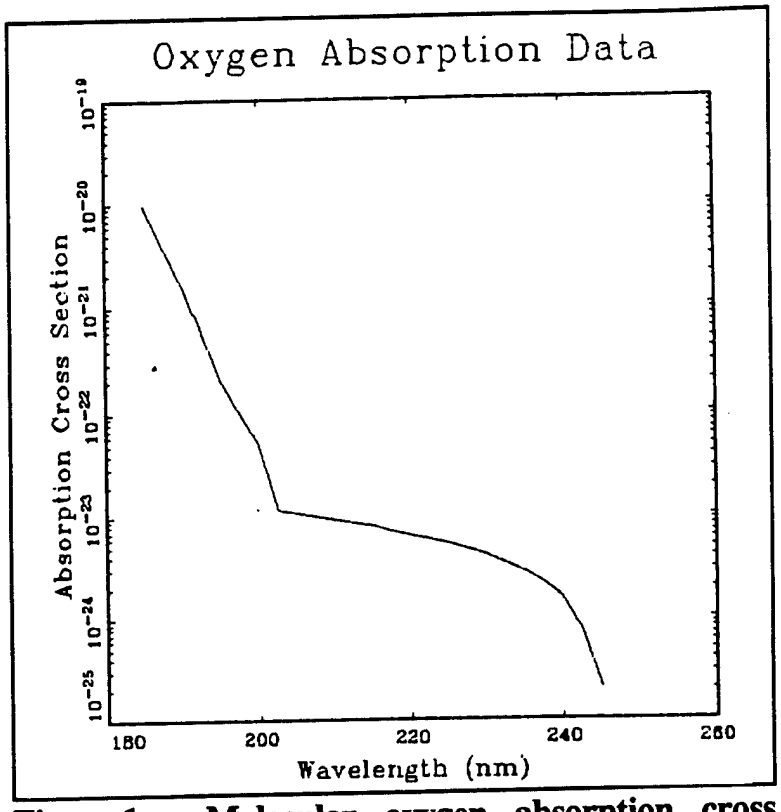

Figure 1. Molecular oxygen absorption cross sections in cm^2.

The resolution data is relatively low, but interpolation should not cause any significant deviations from actual values, except in the case of the O_2 Schumann-Runge bands between 185 and 200 nm in which the modeled values are approximate averages over the adjacent bands. In this case, the assumption was made that measurements in this region are relatively wide band, so the averaging is appropriate.

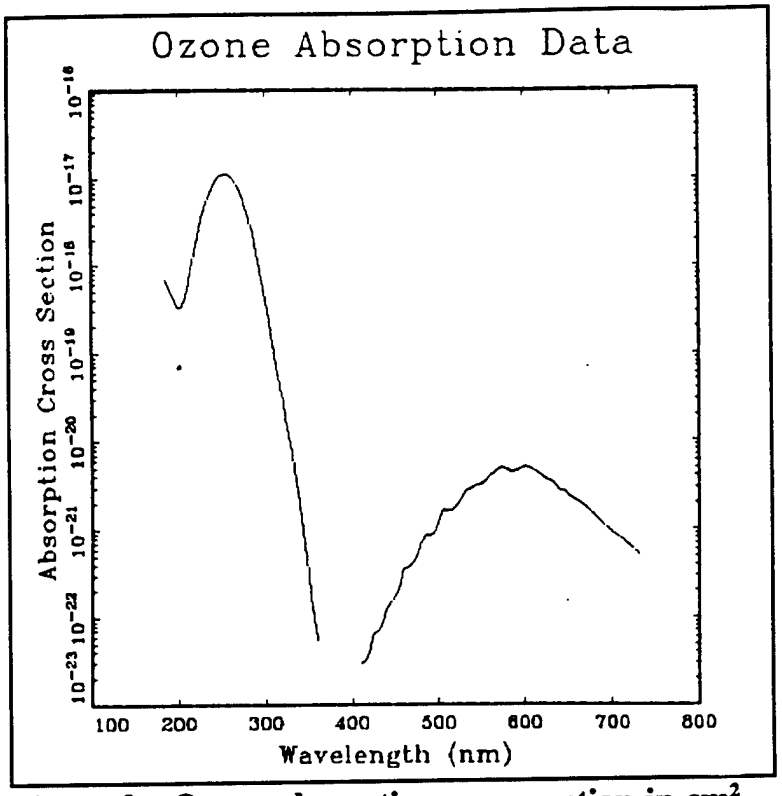

Figure 2. Ozone absorption cross section in cm^2.

Aerosol attenuation was parameterized in terms of visibility according to equation (3) with the wavelength of light [8]

$$\sigma_{aer}(\lambda) = \left[\frac{3.912}{V} - \sigma_{ms}(550)\right] * \left|\frac{\lambda}{550}\right|^{q} \qquad (3)$$

where

$\sigma_{aer}(\lambda)$	=	the desired particle extinction
$\sigma_{ms}(550)$	=	the Rayleigh extinction at 550 nm
V	=	the observed visibility
q	=	the Angstrom exponent describing the wavelength dependence of the attenuation.

q is empirically related to the visual range V for V < 24 km by

$$q = .585 V^{1/3} \tag{4}$$

and for greater visual ranges, by

$$q = 1.7. \tag{5}$$

Equation (4) is based on an empirical fit to short wavelength, relatively low visibility transmission data. [9,10] The limiting case equation (5) is based on experimental data for high visibility conditions. The relationship in equation (3) is an extension of the Koschmeider relation between visibility and atmospheric extinction at 0.55 μm, $V = 3.912/\sigma$. [10] For V in kilometers the units of σ are kilometers^{-1}.

Because the visibility depends on the total atmospheric extinction coefficient, the molecular attenuation at 550 nm has been subtracted from the total atmospheric attenuation coefficient to determine the particle extinction. The separation is made so wavelength scaling and particulate attenuation variation with height can be made in terms of aerosol effects only.

Figure 3 shows a plot of the calculated wavelength dependent aerosol attenuation for different visibilities. In figure 3, the dotted line corresponds to a visibility of V = 50 km, the solid line to V = 10 km, the dashed and dotted line to V = 2 km and the dot-dash line to V = 0.5 km. The calculated decrease in the wavelength dependence of the particle attenuation with decreasing visibility is consistent with the idea that the greatly reduced visibilities are associated with larger particles that are the background cases of high visibility.

Figure 4 shows a plot of the total attenuation coefficient as a function of wavelength and the attenuation coefficients caused by aerosol attenuation, molecular scattering, and molecular absorption for assumed standard conditions. The total attenuation coefficient is given by the solid line, the aerosol attenuation by the dotted line, the molecular scattering attenuation by

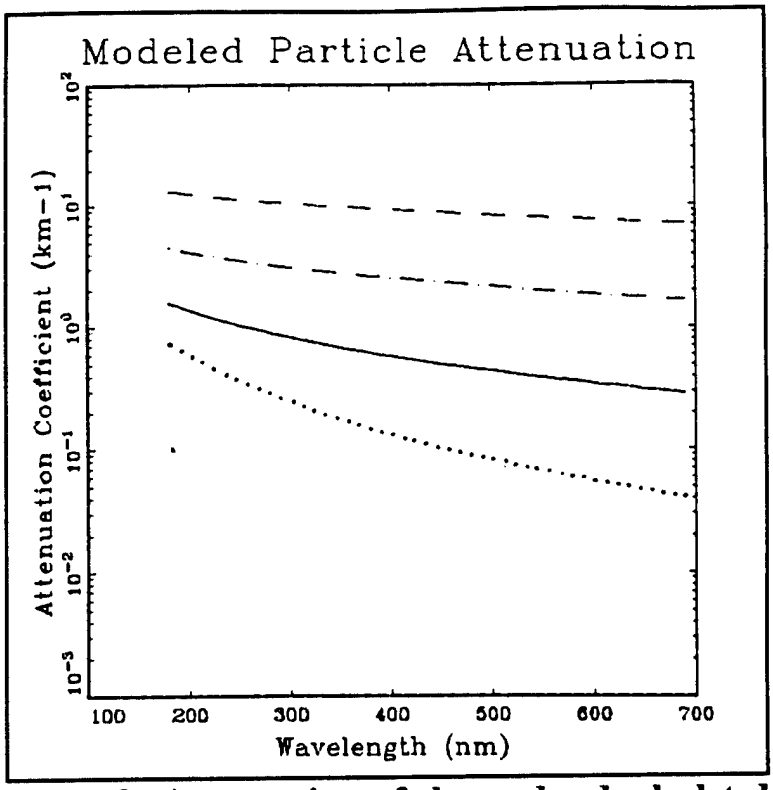

Figure 3. A comparison of observed and calculated attenuation coefficients.

the dashed and dotted line, and the O_3 and O_2 attenuations by the long and short dashed lines. The calculations are made for standard temperature and pressure conditions at sea level for an assumed visibility of 10 km and a nominal O_3 concentration. Figure 4 shows the relative importance of the individual components.

In the program, the pressure and temperature as a function of altitude are given by a standard atmosphere calculation. Concentrations of O_3, SO_2, H_2O, N_2O, and NO_2 can be varied; O_3 altitude profiles can be entered, and altitude independent values of the other gaseous constituents can be input. As discussed above, the aerosol extinction is calculated from the visual range, which is a user input. The variation of aerosol extinction with altitude is done in a manner similar to that of the Army vertical structure algorithm in Lowtran. The percent change in extinction with a given change in altitude is specified and used in subsequent calculations.

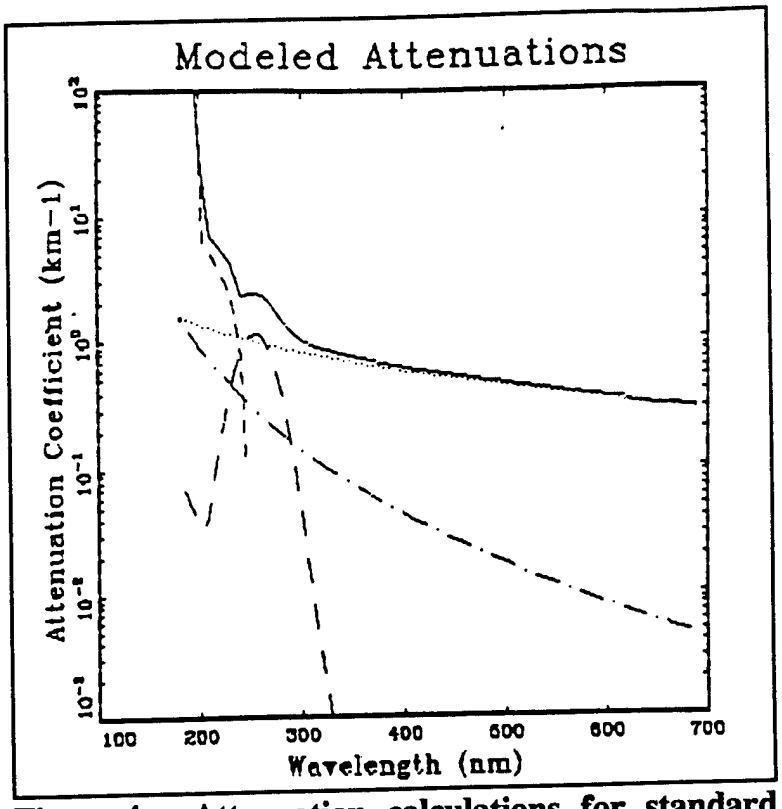

Figure 4. Attenuation calculations for standard conditions at sea level for an assumed visibility of 10 km.

The transmission is calculated for one or more ranges at a constant zenith angle. For slant or vertical ranges the extinction varies as a function of height along the path; and so the range is divided into subintervals, with each subinterval covering an altitude range of no more than 100 m. The attenuation is assumed to be constant in each subinterval. For multiple ranges, the transmission is done sequentially with the total transmission equal to the transmission of the final range times the previous transmission. Schematically,

$$t_{R_n-R_0} = t_{R_{n-1}-R_0}\, t_{R_n-R_{n-1}}. \tag{6}$$

The transmission at any level is given by the equation

$$t = e^{-\sigma' r} \tag{7}$$

where

σ' = the attenuation coefficient at some level.

σ is the sum of the attenuation caused by Rayleigh scattering, aerosol attenuation, and molecular absorption according to

$$\sigma = \sigma_{ms} + \sigma_{aer} + \sigma_{ozone} + \sigma_{mg} \tag{8}$$

where

σ_{ms} = the Rayleigh scattering of atmospheric molecules
σ_{aer} = the attenuation due to aerosol particles
σ_{ozone} = the absorption due to O_3
σ_{mg} = the absorption due to the other mixed gases
r = the incremental path length through the layer.

2.2 Lidar Return Calculations

The UVTRAN module calculates the lidar return power as a function of range for realistic lidar geometries. Nominal system parameters of transmitted energy, receiver area, receiver field of view and spectral bandwidth, and system efficiencies are provided; or alternative parameters can be input. Return calculations can be made for one of six lidar wavelengths: 532 nm (Nd-YAG doubled), 355 nm (Nd-YAG tripled), 266 nm (Nd-Yag quadrupled), 351 nm (XeF Excimer), 308 nm (XeCl Excimer), and 248 nm (KrF Excimer). Calculations can be made for elastic aerosol and molecular backscatter or for backscatter cuased by fluorescence from molecular or particulate material.

Elastic backscatter is given by the equation

$$P(R) = E_p \frac{\pi D^2}{4R^2} \epsilon_{tr} \epsilon_{rcv} \beta_M t_\lambda^2 \tag{9}$$

where

P	=	the return power as a function of range
R	=	the range
β_M	=	the Mie backscatter coefficient
D	=	the aperture diameter
E_p	=	the transmitted pulse power
ϵ	=	efficiency.

The transmission t_λ is given by

$$t_\lambda = e^{-\int_0^R \sigma'(\lambda) r dr}. \tag{10}$$

The fluorescent backscatter is given by the equation

$$P(R) = E_p \frac{\pi D^2}{4R^2} \epsilon_{tr} \epsilon_{rcv} \beta_{Fl} t_{\lambda_1} t_{\lambda_2} \tag{11}$$

with β_{Fl}, the fluorescent backscatter coefficient for particulate fluorescent materials given by

$$\beta_{Fl} = \frac{B_{Fl} C_M}{4\pi} \tag{12}$$

where

β_{fl}	=	the specific fluorescence coefficient of the fluorescent material in the lidar spectral bandwidth
C_m	=	the mass concentration of the fluorescing material,

and β_{Fl}, the fluorescent backscatter coefficient for gaseous fluorescent materials given by

$$\beta_{Fl} = \frac{F_{xc} C_v \rho_N}{4\pi} \tag{13}$$

where

F_{xc} = the fluorescence cross section per molecule for the spectral bandwidth of the lidar

C_v = is the concentration of the fluorescing material in ppbv

ρ_n = the number concentration of air molecules.

2.3 Background Radiance Calculations

The background radiance values can be calculated for three cases: daytime clear sky illumination, daytime cloudy illumination, and nighttime illumination. The values are parameterized in terms of a zenith angle dependence relative to assumed horizon radiance levels; no solar azimuth or elevation angle dependence is assumed. Sky and terrain backgrounds are considered for different zenith angles; sky for zenith angles less than or equal to 90° and terrain for zenith angles greater than 90°.

The background radiance routine radiance values for daylight conditions are contained in a table with radiance values at 20 nm intervals between 280 and 700 nm. Sky radiance values below 280 nm are assumed to be 0. The horizon brightness levels were inferred from various data sources, including the Infrared Handbook and references therein. [11] The zenith angle dependence for zenith angles of less than or equal to 90° for clear daylight conditions is given by

$$I_\theta(\lambda) = I_{hor}(\lambda)\ (0.19 + 0.81 \sin\theta) \tag{14}$$

and for overcast conditions, by

$$I_\theta(\lambda) = I_{hor}(\lambda)\ (1.0 + 2\cos\theta) \tag{15}$$

where

$I_{hor}(\lambda)$ = the nominal horizon brightness
θ = the zenith angle.

Nighttime radiance values are assumed to be 1.0×10^{-6} times the daytime values.

For zenith angles greater than 90°, the brightness of the ground for day conditions is given by

$$I_\theta(\lambda) = I_{hor}(\lambda)\ (1.0 + 0.7\cos\theta) \tag{16}$$

The night value is 1.0×10^{-6} times the daytime value.

3. Model Verification

3.1 Grade of Software

The atmospheric transmission model should be classed as developmental software; the lidar transmission calculations should be classed as fieldable software.

3.2 Model Failure

The number of ranges called for in the calculation should not exceed the maximum number specified in the interactive input file; otherwise, dimensions would be exceeded and unpredictable output results. The maximum altitude of the calculation is limited to 11 km because flat earth geometry is assumed (this should not be serious, the ranges for short wavelengths are generally short). A test of maximum altitude is included in the program, which is halted if maximum altitude is exceeded. Other incorrectly formatted input causes an error halt to the program.

3.3 Verification Tests

A comparison of our model and the Lowtran 6 calculations for standard conditions is shown in table 1. The calculations were made for wavelengths of 300, 550, and 700 nm, for the atmospheric conditions listed in the table. The visibility was specified to be 10 km, and the wavelength dependence of the aerosol attenuation is given by equation (4) for UVTRAN and by the rural aerosol model for a relative humidity of 70 percent for Lowtran. [1]

Table 1. Transmission for UVTRAN and Lowtran for standard conditions[a]

Wavelength	300 nm τ		550 nm τ		700 nm τ	
	UVT	Low	UVT	Low	UVT	Low
τ_{ms}[b]	.239	.233	.892	.890	.956	.957
τ_{O3}[c]	.773	.768	.998	.998	.999	.999
τ_{aer}[d]	.013	.064	.206	.206	.347	.307
τ_{oth}[e]	.986[f]	-----	.997[g]	-----	-----	.954[h]
τ_{tot}[i]	.0024	0.115	.182	.183	.331	.280

[a] p = 1013.25 mb, T = 288.15 K, O_3 = 25.2 ppbv, Vis = 23 km, Range = 10 km
[b] τ_{ms} = the transmittance caused by molecular scattering
[c] τ_{O3} = the transmittance caused by ozone
[d] τ_{aer} = the transmittance caused by aerosol particles
[e] τ_{oth} = the transmittance caused by any other gaseous species
[f] caused by SO_2
[g] caused by NO_2
[h] caused by water vapor
[i] τ_{tot} = the total resulting transmittance

The Rayleigh scattering attenuation is slightly less than the comparable Lowtran attenuation as discussed above, leading to slightly higher transmittance in the model. Similarly, there are no significant differences in the O_3 absorption in the different models. The calculated aerosol attenuation values are significantly different at 300 and 700 nm in the two models, with the greater differences at 300 nm. The agreement in the aerosol attenuation at 550 nm is due to the fact that the attenuation at this wavelength is determined by the assumed visual range in each of the models.

The differences in the aerosol attenuation in the two models indicate that the variation of attenuation with wavelength is less in the AFGL rural aerosol model than in UVTRAN. For the cases shown above, q = 1.7 for UVTRAN compared with q = 0.9 for Lowtran. While the experimental data on the wavelength dependence of the atmospheric attenuation is limited, data do suggest a larger value of q between 300 and 550 nm than predicted by the AFGL models except under conditions of greatly reduced visibility. Middleton [10] reported that the average value of q was 1.6 under good to

excellent seeing conditions and 1.3 under average seeing conditions. Junge [12] used a value of q = 1.3 to describe the average atmospheric conditions. The experimental data of Wolff, which were used by Loehle [9] to derive the empirical relationship in equation (3), predict a q less than 1 but are for relatively low visibility conditions.

Baum and Dunkelman [2] present a more detailed set of wavelength dependent attenuation data measuring attenuation coefficients between 250 and 550 nm in Pasadena, CA for a range of visibilities. They developed an empirical relationship between visibility and wavelength dependent atmospheric attenuation. Tables 2 and 3 show aerosol attenuation comparisons calculated by UVTRAN and Lowtran with the attenuation calculated from the empirical relation of Baum and Dunkelman [2] for visual ranges of 300 and 350 nm, respectively. It is only for visual ranges of less than 5 km that the q for UVTRAN is less than the q for the AFGL rural aerosol model. The UVTRAN and Baum and Dunkelman [2] values are closer at 350 than 300 nm suggesting that higher than standard O_3 concentrations during the Baum and Dunkelman [2] measurements may be affecting the 300 nm comparison.

Table 2. A comparison of observed and calculated attenuation coefficients at 300 nm for different visibilities

Visual Range (km)	σ_{aer} (UVTRAN) (km^{-1})	σ_{aer} (Lowtran) (km^{-1})	σ_{aer} (B & D-emp) (km^{-1})
100	.137	.047	.213
40	.284	.150	.340
20	.476	.320	.553
10	.809	.662	.978
5	1.41	1.34	1.83

Table 3. A comparison of observed and calculated attenuation coefficients at 350 nm for different visibilities

Visual Range (km)	σ_{aer} (UVTRAN) (km^{-1})	σ_{aer} (Lowtran) (km^{-1})	σ_{aer} (B & D-emp) (km^{-1})
100	.092	.042	.097
40	.212	.134	.198
20	.376	.288	.366
10	.691	.594	.702
5	1.21	1.20	1.38

The comparisons indicate that the value of q is related to the visibility and that the parameterization for q used in UVTRAN is adequate, though certainly not exact. Discussion of Woodman [13] indicates that the wavelength parameterizations of equations (2) and (3) should be adequate throughout the visible region. Although the relationship (3) was derived on the basis of low visibility data only, these comparisons with the Middleton data [10] suggest the model should be adequate for high and low visibilities.

4. Operations Guide

4.1 Fortran Version

The MS DOS version of UVTRAN is run at the prompt by typing UVTRAN {enter}. The program may also be run by typing UVTRAN < *filename.ext* {enter}. *filename.ext* is a data file containing the inputs to the UVTRAN prompts. This latter method is a property of MS DOS that allows UVTRAN to be run from a shell program in a batch file and is given as an example below.

4.1.1 Inputs

Input to the program is interactive. Choices are presented for the environmental parameters and for the test conditions to be simulated. The user must choose conditions or accept default values. In general, letters may be entered in upper or lower case (i.e., when the user is asked to enter a choice for a Mie or fluorescence lidar, if the choice is a Mie calculation, m or M may be entered).

Generally, entries are self explanatory. The aerosol, elastic scattering (Mie) lidar calculation is based on user input of excess scattering material in addition to the scattering material estimated from the visibility. The excess material is entered in terms of backscatter or attenuation; the nominal relationship may be used, or a specific backscatter to attenuation ratio may be input. For the fluorescence lidar, the backscatter is assumed to be due to fluorescence only. Inputs to determine the fluorescent backscatter depend on whether the fluorescing material is assumed to be a gas or an aerosol. If the fluorescent material is a gas, the fluorescent cross section per molecule and the concentration in ppbv must be entered. If the fluorescent material is particulate, the specific fluorescence cross section and the concentration of the fluorescent material in g/m^3 must be entered.

Section 5 presents samples of interactive sessions for the input of data to calculate transmission or lidar return power data shown in section 4.2.

4.1.2 *Output*

Two sample output listings for a transmission calculation and a LIDAR calculation follow:

Output A: Transmission Calculation Output

UV transmission calculations:

UVTRAN model ozone concentrations are:

altitude	=	0. km	O3 concentration	-	40.0 ppbv
altitude	=	1. km	O3 concentration	-	35.8 ppbv
altitude	=	2. km	O3 concentration	-	32.5 ppbv
altitude	=	3. km	O3 concentration	-	33.2 ppbv
altitude	=	4. km	O3 concentration	-	34.0 ppbv
altitude	=	5. km	O3 concentration	-	37.5 ppbv
altitude	=	6. km	O3 concentration	-	41.5 ppbv
altitude	=	7. km	O3 concentration	-	50.0 ppbv
altitude	=	8. km	O3 concentration	-	59.5 ppbv
altitude	=	9. km	O3 concentration	-	87.0 ppbv
altitude	=	10. km	O3 concentration	-	131.0 ppbv

UVTRAN model trace gas concentrations are:

1	SO2 concentration	1.0 ppbv
2	N2O concentration	270.0 ppbv
3	H2O concentration	1000000.0 ppbv
4	NO2 concentration	1.0 ppbv

visibility = 10.00 km at an altitude of 1.00 km
particle extinction changes by .0 %
per 100 meters altitude increase

initial altitude = 1.00 km zenith angle = .0 degrees

Range	=	1.00 km	Final Altitude	=	2.00 km
Wavelength	=	500.00 nm	Transmission	=	.641E+00
Wavelength	=	550.00 nm	Transmission	=	.676E+00
Range	=	2.00 km	Final Altitude	=	3.00 km
Wavelength	=	500.00 nm	Transmission	=	.411E+00
Wavelength	=	550.00 nm	Transmission	=	.458E+00

Output B: Lidar Calculation Output

Lidar return calculations for a Mie lidar:

UVTRAN modeled ozone concentrations are:

altitude	=	0. km	O3 concentration	-	40.0 ppbv
altitude	=	1. km	O3 concentration	-	35.8 ppbv
altitude	=	2. km	O3 concentration	-	32.5 ppbv
altitude	=	3. km	O3 concentration	-	33.2 ppbv
altitude	=	4. km	O3 concentration	-	34.0 ppbv
altitude	=	5. km	O3 concentration	-	37.5 ppbv
altitude	=	6. km	O3 concentration	-	41.5 ppbv
altitude	=	7. km	O3 concentration	-	50.0 ppbv
altitude	=	8. km	O3 concentration	-	59.5 ppbv
altitude	=	9. km	O3 concentration	-	87.0 ppbv
altitude	=	10. km	O3 concentration	-	131.0 ppbv

UVTRAN modeled trace gas concentrations are:

1	SO2	concentration	1.0 ppbv
2	N2O	concentration	270.0 ppbv
3	H2O	concentration	1000000.0 ppbv
4	NO2	concentration	1.0 ppbv

visibility = 10.00 km at an altitude of 1.00 km

particle extinction changes by 1.0 %
per 100 meters altitude increase

Lidar system parameters:

Pulse Energy	= 1.00 joules;	Receiver Diameter	= .600 m;
Receiver fov	= 2.00 mrad;	Spectral Width	= .50 nm;
transmit efficiency	= .55;	receiver efficiency	= .54

initial altitude = 1.00 km zenith angle = 30.0 degrees

added values:

range #	value added for beta
1	.200E-05

Lidar wavelength = 532.0 nm bkg signal = .264E-07 watts

range [km]	final alt [km]	beta(tot) [(msr)**1]	beta ratio	2xtrans	sogtot [watts]	sig(Ray) [watts]
1.00	1.87	.180E-04	.134E+00	.426E+00	.966E-04	.722E-05
2.00	2.73	.159E-04	.129E+02	.168E+05	.843E-05	.654E-06

4.2 Visual Basic for Windows Version

The purpose of the Windows version of UVTRAN is to give the end user a user friendly graphical interface and provide several operational features not available through Fortran such as online help and built-in plotting capability. This has been done by porting the Fortran source code over to Microsoft Visual Basic. UVTRAN for Windows is a complete Windows based application designed and written within the Microsoft Windows environment. UVTRAN for Windows requires Microsoft Windows version 3.0 or later to run.

For specific hardware and operating system requirements see the Microsoft Windows User's Guide. A Visual Basic runtime module, VBRUN100.DLL (or VBRUN300.DLL depending on the latest version under which UVTRAN

for windows was compiled) must be present for it to execute outside of Visual Basic. The module is supplied with UVTRAN for Windows.

4.2.1 Installation

The Windows version of UVTRAN comes with a setup program on the diskette. The user inserts the diskette into the disk drive; from Program Manager in Windows, puts the cursor on File; and from the pull down menu, clicks on Run. In the pop-up box, the user types a:setup {enter}. The program has defaults for installation and tells how much hard disk space is required. The default directory may be changed. The installation program creates a group with the appropriate icons and the appropriate directory on the hard disk and decompresses the files to the directory.

4.2.2 Initiating a Session

From Program Manager in Windows, the user opens the group containing the UVTRAN for Windows icon and executes the program by selecting the UVTRAN for Windows icon. As with all Microsoft Windows applications, UVTRAN for Windows can be minimized or quit anytime the control box is available to the user. For a complete discussion of suspending and stopping the Windows application, please refer to the Microsoft Windows user guide.

UVTRAN for Windows was designed to minimize data input errors and make the program easier to use. The major convention used is the placement of input buttons and data display. To enter new data the user simply clicks on the proper button and an input window will open for the user to input the new value. If data values are present in the current window and buttons are visible, the user clicks on the data item to be updated. Each window containing data that the user can edit or update contains an Accept Values button. This button saves the values display in the window and returns the user to the previous window. Because of the design of UVTRAN for Windows, there is no need for ordered procedures to run the model. All system parameters are set to default

values at start up, allowing the user greater flexibility to process data using a what if methodology. A discussion of each window and the data displayed in them follows:

UVTRAN for Windows Opening window. This is the main menu/window for the UVTRAN for Windows model. This window displays five buttons for the user to choose from: (1) Run it (or Process), (2) Setup Aerosol Profiles, (3) Edit/Set Default Ozone Levels, (4) Edit/Set Default Trace Gas Levels, and (5) Calculation Type. The Run it (or Process) button runs the model using the system parameters that the user sets in the other four windows accessed through the buttons available on the Opening window.

Setup Aerosol Profiles. Selecting this button displays the Aerosol Profiles window. The Aerosol Profiles window displays the parameters pertaining to the aerosol profile used in the model. The user can change and edit the aerosol profile used by selecting different actions from this window. When satisfied with the selected value, the user clicks on Accept Values to close the window and return to the previous window.

Edit/Set Default Ozone Levels. Selecting this button selects the Ozone Levels window. The user can edit any of the O_3 levels. When satisfied with the selected value, the user clicks on Accept Values to close the window and return to the previous window. The user may also click on the Reset Default Values button to return the O_3 levels to their default values.

Edit/Set Default Trace Gas Levels. Selecting this button displays the Trace Gas Concentrations window. The user can edit any of the trace gas values. When satisfied with the selected value the user clicks on Accept Values to close the window and return to the previous window. The user may also click on the Reset Default Values button to return the O_3 levels to their default values.

Calculation Type. Selecting this button displays the Calculation Type window. In this window the user selects Transmission or Lidar calculation from the model. The user sets the number of ranges for the model to compute as well as the shortest distance and length of interval of measurements. The user may

edit system parameters for the select calculation type or accept default values. If Edit Parameters is selected, the proper window appears allowing the user to set parameter values for Transmission or Lidar calculations.

Transmission Setup. If Transmission was selected in the Calculation Type window, the user will see the Transmission Setup displayed when Edit Parameters is selected from the Calculation Type window. The user may set the number of wavelengths from this window and enter specific values for the desired wavelengths.

Lidar Setup. If Lidar was selected in the Calculation Type window, the Lidar Setup is displayed when the user selects Edit Parameters from the Calculation Type window. The user may set all lidar parameters from this window, including special values for Mie or Fluorescence type lidar calculations.

Run It! (or Process). Selecting this button executes the model using the parameters set in the setup windows.

Results. When all calculations are complete the Results window is displayed showing the user the resulting calculation from the input parameters passed to the model and giving the user the choice to print the results or place them in a file.

5. Sample Data Input

The following examples show an interactive session for transmission and Lidar calculations. Computer output queries and information are shown in normal typeface; user responses are shown in bold type, and comments on the response are shown in italics. In some cases, changes are entered that are the same as the default values to illustrate procedures.

The following input generates the Fortran version sample run for the transmission calculations shown in section 4. User responses are in bold and program writes to the screen are in italics.

Do you want hard copy output? (y or n) **y**

Make sure printer is on.

present values for trace constituents are based on 1976 standard atmosphere values. Ozone data are given for each km for altitudes between 0 and 20 km. Other trace gas concentrations are representative lower tropospheric values. All values are given as number mixing ratios.

Enter return for default parameters; o to change ozone parameters, t to change any of the other trace gas concentrations; or a to change both ozone and other trace gases. **{return}**

The default visual range is 10 km
Hit s for default value
else enter the desired visual range (in km) **s**

enter altitude of receiver (in km) **1.0**

enter altitude of visibility measurement
enter s if same as receiver altitude **s**

Visual range selected is 10 km
at an altitude of 1.0 km

enter number corresponding to desired aerosol profile
1 if aerosol attenuation is constant with height
2 if aerosol attenuation increases with height
3 if aerosol attenuation decreases with height
(2 or 3 assume a change by a factor of x %/y m--
a change of -0.97%/100 m corresponds to an approximately constant mass mixing ratio) **1**

Is path horizontal (h), vertical (v), or slant (s) **v**

enter u or d for upward or downward looking systems **u**

Do you want transmission or LIDAR calculation (Enter T or L) **T**

How many ranges for calculation (< = 100) **2**

enter shortest range (km) **1.0**

enter range interval (km) **1.0**

Should transmission be high (h) or low (l) resolution
(h only for laser transmission) **l**

Enter number of wavelengths (< 20) for transmission calculations **2**

enter wavelength values in nm **500. 550.**

{The Program then calculates the transmission for the selected wavelengths and ranges. The remainder of output is an echo of the output to the printer above.}

The following Fortran version sample run will generate the sample run for the lidar calculations shown in section 4:

Do you want hard copy output? (y or n) **y**

Make sure printer is on.

present values for trace constituents are based on 1976 standard atmosphere values. Ozone data are given for each km for altitudes between 0 and 20 km. Other trace gas concentrations are representative lower tropospheric values. All values are given as number mixing ratios.

Enter return for default parameters; o to change ozone parameters, t to change any of the other trace gas concentrations; or a to change both ozone and other trace gases. **[return]**

The default visual range is 10 km
Hit s for default value
else enter the desired visual range (in km) **s**

enter altitude of receiver (in km) **1.0**

enter altitude of visibility measurement
enter s if same as receiver altitude **s**

Visual range selected is 10 km
at an altitude of 1.0 km

enter number corresponding to desired aerosol profile
1 if aerosol attenuation is constant with height
2 if aerosol attenuation increases with height
3 if aerosol attenuation decreases with height
(2 or 3 assume a change by a factor of x %/y m--

a change of -0.97%/100 m corresponds to an approximately constant mass mixing ratio) **2**

enter percent change in attenuation and vertical distance (in meters) over which change occurs (positive numbers) **1.0 100.**

Is path horizontal (h), vertical (v), or slant (s) **s**

enter zenith angle for slant path **30.0**

Do you want transmission or LIDAR calculation (Enter T or L) **L**

How many ranges for calculation (< = 100) **2**

enter shortest range (km) **1.0**

enter range interval (km) **1.0**

Enter background condition for calculation
daylight clear = 1
daylight overcast = 2
night = 3 **1**

Clear Daylight Background Selected

Lidar return calculation can
be made for 6 different laser wavelengths
1 -- 532 nm (Nd-YAG doubled)
2 -- 355 nm (Nd-YAG tripled)
3 -- 266 nm (Nd-YAG quadrupled)
4 -- 351 nm (XeF Excimer)
5 -- 308 nm (XeCl Excimer)
6 -- 248 nm (KrF Excimer)
Enter the number of the desired wavelength **1**

Number chosen is 1 wavelength chosen is 532.0 nm

Following parameters are default parameters for Lidar system:

1. *Laser Pulse Energy* -- *1.00 joules*
2. *Receiver Mirror diameter* -- *0.6 m*
3. *Receiver Field of View* -- *2.00 mrad*
4. *Spectral Bandwidth of System* -- *0.5 nm*
5. *Transmitter Efficiency* -- *.55*
6. *Receiver Efficiency* -- *.54*

Enter number of parameter to change;
or enter s if current values are used. **1**

Enter new value of parameter **2.00**

Do you want to change another parameter (y or n) **y**

Current Lidar parameters are

1. *Laser Pulse Energy* -- *2.00 joules*
2. *Receiver Mirror diameter* -- *0.6 m*
3. *Receiver Field of View* -- *2.00 mrad*
4. *Spectral Bandwidth of System* -- *0.5 nm*
5. *Transmitter Efficiency* -- *.55*
6. *Receiver Efficiency* -- *.54*

Enter number of parameter to change;
or enter s if current values are used. **1**

Enter new value of parameter **1.00**

Do you want to change another parameter (y or n) **n**

Do you want Mie or fluorescence calculations? (M or F) **M**

Mie lidar was selected
*Program assumes a beta profile(m**-1 sr**-1) determined from aerosol and molecular profiles. An additional component can be added at any point in the profile by inserting beta or extinction values for each range.*

Enter number of ranges at which excess aerosol is to be added **1**

Do you want to enter as backscatter or attenuation (b or a)? **b**

Do you want to enter a specific beta/attenuation ratio (y or n) **n**

Ranges and numbers listed below.
Enter range number and value (ordered pair) for each point
at which excess aerosol is added. Attn=[km-1] beta=[(msr)-1]

#	range	#	range	#	range	#	range
1	*1.000*	*2*	*2.000*				

1 2.0e-6

The printed output is also output to the screen. The program then calculates the lidar return for the selected ranges. The remainder of output is an echo of the output to the printer above.

6. Conclusions

UVTRAN is an effective model for quick estimates of UV transmission and lidar returns. The algorithms used to determine the transmission and the lidar returns have been verified, and UVTRAN compares favorably with the Baum and Dunkleman data and model. [2] It also compares favorably with Lowtran 6 when compatible scenarios are selected. The model is not intended to replace more complete transmission models such as Lowtran and full-blown radiative transfer models; however it can estimate transmission for situations described in this report.

UVTRAN is a very easy model to use and has a very friendly user interface--especially the Windows version. The Windows version also comes with an automatic setup installation program. This model is available through the EOSAEL library from ARL or from the authors. The Fortran source code is included, and the Visual Basic 3.0 code is available upon request.

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Appendix

UVTRAN Fortran Listing

```
      Program UVTRAN
c
c           Version 2.1    June 18, 1994
c       Program calculates uv and visible wavelength transmission,
c       and LIDAR return.  Program requires as input the wavelength(s),
c       visibility, range, zenith angle, altitude above sea level,
c       concentration of gaseous absorbers.  Program will output
c       either transmission or expected LIDAR return together with
c       an estimate of the background.
c
      common/ilas/ilas
      common/za/zref,alfapt,alfsgn,att55r
      common/o3con/o3con(21),o3prnt(21)
      common/amolcn/so2con,an2ocn,h2ocon,ano2cn,trppb(4)
      common/z1/z1(21)
      common/syspar/syspar(8)
c**********************************
c     identification of character variables
c       trflg--transmission or lidar calculation
c       pthtype--horizontal, vertical, or slant path
c       udflag--up or down looking system
c       resflg--high or low resolution transmission
c       prton--print or not flag
c       pflg--change any lidar system parameters
c       tyflg--Mie or fluorescence lidar
c       pgflg--particle or gas for fluorescence
c       dflag--change ozone, other trace, or all
c       iflg2--flag to review trace gas concentrations
c       iflg3--flag to change trace gas concentrations
c       baflg--flag to indicate wheter beta or attn is input
c       bsflg--flag to indicate whether bseta/sigma ratio is imput
c**********************************
      character trflg, pthtype, udflag,resflg,prton
      character pflg, tyflg, pgflg, baflg, bsflg
      character*50 msga(9)
      character dflag,iflg2,iflg3
      character*56 msgb(7)
      parameter(nrmax=100)

      dimension alamb(20),trans(20,nrmax)
      dimension hrlamb(6)
      dimension trcon(4)
      dimension range (nrmax), zf(nrmax),betrat(nrmax)
      dimension betadd(nrmax), attadd(nrmax),betfl(nrmax)
```

```
      dimension betray(nrmax), betpar(nrmax), betsum(nrmax)
      dimension sigsum(nrmax), sigray(nrmax), sigfl(nrmax)
      dimension tr2x(nrmax)
      dimension flcon(nrmax)
      dimension irnum(nrmax), addval(nrmax)
      equivalence(trcon(1),so2con),(trcon(2),an2ocn),(trcon(3),h2ocon)
     &,(trcon(4),ano2cn),(trppb(1),so2ppb),(trppb(2),an2opb)
     &,(trppb(3),h2oppb),(trppb(4),ano2pb)

      data cdtrad/.017453292/
      data hrlamb/532.,355.,266.,351.,308.,248./
      data vis/10.0/
      data msga/
     1' High resolution transmission calculations can   ',
     2' be made for 6 different laser wavelengths       ',
     3'  1  -- 532 nm  (Nd-Yag doubled)                 ',
     4'  2  -- 355 nm  (Nd-Yag tripled)                 ',
     5'  3  -- 266 nm  (Nd-Yag quadrupled)              ',
     6'  4  -- 351 nm  (XeF  Excimer)                   ',
     7'  5  -- 308 nm  (XeCl Excimer)                   ',
     8'  6  -- 248 nm  (KrF  Excimer)                   ',
     9' Enter the number of the desired wavelength      '/
      data msgb/
     1' enter number corresponding to desired aerosol profile  ',
     2' 1 if aerosol attenuation is constant with height       ',
     3' 2 if aerosol attenuation increases with height         ',
     4' 3 if aerosol attenuation decreases with height         ',
     5' (2 or 3 assume a change by a factor of x %/y m--       ',
     6' a change of -0.97%/100m corresponds to an approximately',
     7' constant mass mixing ratio.                            '/

c*****************************************************************
c
c       Initialize and clear screen
c
      call clear
      write(*,'(////a//a///a///)')
     &'                    PROGRAM  UVTRAN',
     &'                      Version 2.1',
     &'          Program calculates transmission or Lidar returns.'
c
c
c   Input if hard copy output is wanted.
c
      write(*,'(///a\)')'  Do you want hard copy output? (y or n)  '
      read(*,'(a1)')prton
```

```
      iprnt=0
      if(prton.eq.'y'.or.prton.eq.'Y')then
        iprnt=1
        write(*,'(///a)')'  '
        pause' Make sure printer is on. '
      endif
c*****************************************************
c  Geophysical and environmental set up
c

c*****************************************************
c  initialization routine for gaseous constituents
c
c  subroutine checks to see if default values of ozone and other
c  trace gases are ok, if not, the user is given the opportunity
c  to change the parameters in tcondata.
c
c      set up ppb values for printing
c
      do 630 i=1,21
      o3prnt(i)=o3con(i)*1.0e+9
  630 continue
      do 634 i=1,4
      trppb(i) = trcon(i)*1.0e+9
  634 continue
c
c  determine whether mods are needed in o3 or other concentrations
c
      write(*,'(/a/)')'   '
      write(*,'(a)')' present values for trace constituents are based'
      write(*,'(a)')' on 1976 standard atmosphere values.  Ozone data'
      write(*,'(a)')' are given for each km for altitudes between 0 '
      write(*,'(a)')' and 20 km.  Other trace gas concentrations are'
      write(*,'(a)')' representative lower tropospheric values.  All'
      write(*,'(a)')' values are given as number mixing ratios',
      write(*,'(/a)')' Enter return for default parameters; o to '
      write(*,'(a)')' change ozone parameters, t to change any of the'
      write(*,'(a)')' other trace gas concentrations; or a to change'
      write(*,'(a)')' both ozone and other trace gases'
  650 read(*,'(a1)')dflag
      if(dflag.eq.' ') go to 500
      if(dflag.eq.'o'.or.dflag.eq.'O')go to 660
      if(dflag.eq.'t'.or.dflag.eq.'T')go to 700
      if(dflag.eq.'a'.or.dflag.eq.'A')go to 660
      write(*,'(a\)')' Please hit return or enter o, t, or a'
      goto 650
```

```
c
c       Make ozone modifications
c
 660 write(*,'(/a/)')' current model ozone concentrations are:'
     write(*,2010)(z1(i),o3prnt(i),i=1,21)
 665 write(*,'(/a)')' enter altitude (0,1,2,...20 km) and new ozone con
    1centration (ppbv)'
 670 read(*,*)zin,o3inpt
     if (zin.ge.0.0.and.zin.le.20.) go to 680
     write(*,'(/a/a\)')' enter alt. in km increments between 0 and 20',
    1' reenter alt and new ozone concentration'
     goto 670
 680 j= int(zin+0.5)
     o3con(j+1)=o3inpt*1.0e-09
     write(*,2015)j,o3inpt
     write(*,'(a\)')' do you want to review data set?'
     read(*,'(a)')iflg2
     if(iflg2.eq.'y'.or.iflg2.eq.'Y')then
       do 674 i=1,21
       o3prnt(i)=o3con(i)*1.0e+9
 674   continue
       write(*,'(/a/)')' current model ozone concentrations are:'
       write(*,1010)(z1(i),o3prnt(i),i=1,21)
     endif
     write(*,'(a\)')' do you want to change another ozone value?'
 685 read(*,'(a)')iflg2
     if(iflg2.eq.'y'.or.iflg2.eq.'Y') goto 665
     if(iflg2.eq.'n'.or.iflg2.eq.'N') goto 690
     write(*,'(a\)')' need to enter either y or n'
     goto 685
 690 if(dflag.eq.'o'.or.dflag.eq.'O') go to 500

c
c********set up for modification of trace gas concentrations
c
 700 write(*,2020)(trppb(i),i=1,4)

 730 write(*,'(a)')' If change in assumed concentration is desired'
 735 write(*,'(a)')' enter the number of trace component and the'
     write(*,'(a)')' new concentration. Enter negative id and dummy'
     write(*,'(a)')' concentration if no changes are desired'
     read(*,*)idno,trppb(idno)
     if(idno.lt.0)go to 500
     trcon(idno)=trppb(idno)*1.0e-9
     write(*,2025)idno,trppb(idno)
```

```
      write(*,'(a\)')' do you want to review data set?'
      read(*,'(a)')iflg2
      if(iflg2.eq.'y'.or.iflg2.eq.'Y')then
        write(*,1020)(trppb(i),i=1,4)
      endif
      write(*,'(a\)')'  do you want to change another value?  '
  750 read(*,'(a)')iflg3
      if(iflg3.eq.'n'.or.iflg3.eq.'N') go to 500
      if(iflg3.eq.'y'.or.iflg3.eq.'Y') go to 735
      write(*,'(a\)')' please enter y or n'
      goto 750

 2010 format(' altitude = ',f3.0,' km  O3 concentration =',f7.1,' ppbv')
 2015 format(' new ozone data:'/' alt = ',i3,' km    O3 value =',f6.1,
     1' ppbv')
 2020 format(' current modeled trace gas concentrations are:'/
     1'  1--SO2  concentration      ',f7.1,' ppbv'//
     2'  2--N2O  concentration      ',f7.1,' ppbv'//
     3'  3--H2O  concentration    ',f9.1,' ppbv'//
     4'  4--NO2  concentration      ',f7.1,' ppbv')
 2025 format(' ID for trace gas is ',i2,' conc = ',f7.2,' ppbv')

c***********************************************
c
c  This section sets up the profile of aerosol extinction.
c  Three choices are offered:
c      1. Aerosol attenuation is assumed to be constant with height
c         in the region of interest.
c      2. Aerosol attenuation is assumed to increase with height
c         by a factor of x% per y m.
c      3. Aerosol attenuation is assumed to decrease with height
c         by a factor of X% per y m. A change of 0.97%/100m
c         will produce an aerosol profile with a roughly constant
c         mixing ratio.
c   An exponential profile is assumed. The profile exponent is
c   given by alfapt times delta z (delz).
c

  500 continue
      write(*,'(//a/a/a\)')' The default visual range is 10 km',
     &' Hit  s  for default value;',
     &' else enter desired visual range (in km).  '
      read(*,*, err=502) vis
      go to 503
  502 vis= 10.0
  503 continue
```

```
      write(*,'(///a\)')' enter altitude of receiver (in km)  '
      read(*,'(f6.0)') z0

      write(*,'(//a/a\)')' enter altitude of visibility  measurement
     1 ',' enter  s  if same as receiver altitude  '
      read(*,*,err=512)zref
      go to 513
  512 zref=z0
  513 write(*,3020)vis,zref
      call stdatm(zref,t,p,den)
      att55r = (3.912/vis)-den*4.505*1.0e-22

      write(*,'(//7(a/))')(msgb(i),i=1,7)

  520 read(*,'(i3)')iaprof
      if(iaprof.eq.1) goto 550
      if(iaprof.eq.2) goto 570
      if(iaprof.eq.3) goto 570
      write(*,'(a\)')' enter either 1,2, or 3'
      go to 520

  550 alfapt=0.0
      alfsgn=0.0
      go to 103
  570 write(*,'(/a/a\)')' enter % change in attenuation and vertical dis
     1tance (in meters)',' over which change occurs (positive numbers)'
      read(*,*)attpct,zdelt
      alfapt=(alog(1.0+0.01*attpct))/zdelt
      if(iaprof.eq.2) alfsgn= 1.0
      if (iaprof.eq.3) alfsgn= -1.0
      go to 103

  103 pct100 = (exp(alfsgn*alfapt*100.) - 1.)*100.
 3020 format(/' Visual range selected is ',f6.2,' km',/,
     1' at an altitude of ',f6.2,' km')

c*********************************************

      write(*,'(//a\)')' Is path horizontal (h), vertical (v), or slant
     & (s)?  '
  105 read(*,'(a1)') pthtype
      if (pthtype.eq.'h'.or.pthtype.eq.'H') goto 120
      if (pthtype.eq.'v'.or.pthtype.eq.'V') goto 140
      if (pthtype.eq.'s'.or.pthtype.eq.'S') goto 160
      write(*,'(//a\)')' Pathtype not identified properly.  Enter
     & s, v, or h'
```

```
      goto 105
c
c   set up for horizontal path
c
  120 thetaz = 90.0
      thetzr = thetaz*cdtrad
      go to 170
c
c  set up for vertical path
c
  140 write(*,'(//a\)')' Enter u or d for upward or downward looking
     &systems  '
      read(*,'(bn,a1)')udflag
      thetaz = 0.0
      if (udflag.eq.'d'.or.udflag.eq.'D') thetaz = 180.
      thetzr = thetaz*cdtrad
      go to 170
c
c  set up for slant path
c
  160 write(*,'(a\)')' enter zenith angle for slant path  '
      read (*,*)thetaz
      write(*,1007)thetaz
 1007 format(' zenith angle is ',f7.2)
      thetzr=thetaz*cdtrad

  170 continue
c*****************************************************************************
      write(*,'(//a)')'    '
      write(*,'(a\)')' Do you want transmission or LIDAR calculation?
     &(Enter T or L)'
  200 read(*,'(bn,a1)')trflg
      if (trflg.eq.'t'.or.trflg.eq.'T'.or.trflg.eq.'l'.or.trflg.eq.'L')
     &go to 210
      write(*,'(a\)')' a "t" or an "l" should be entered'
      goto 200

  210 write(*,'(//a\)')' How many ranges for calculation (< or = 100)'
      read(*,*)nrange
      if(nrange.eq.1) then
        write(*,'(//A\)')' enter range (km)  '
        read(*,*)range(1)
      else
        write(*,'(//A\)')' enter shortest range (km)  '
        read(*,*)range(1)
        write(*,'(//A\)')' enter range interval (km)  '
```

```
        read(*,*)delrng
      endif
      zf(1)=z0+range(1)*cos(thetzr)
      do 230 j=2,nrange
      range(j)=range(1)+(j-1)*delrng
      zf(j)=z0+range(j)*cos(thetzr)
  230 continue

      if (trflg.eq.'t'.or.trflg.eq.'T') go to 220
      if (trflg.eq.'l'.or.trflg.eq.'L') go to 400
c*************************************************************************
  220 write(*,'(//a,/a\)')' Should transmission be high(h) or low(l) re
     &solution',' (h only for laser transmission) '
      read(*,'(bn,a1)')resflg
      ires=-1
      if(resflg.eq.'l'.or.resflg.eq.'L')ires=0
      if(resflg.eq.'h'.or.resflg.eq.'H')ires=1
      if(ires.ne.0.and.ires.ne.1)go to 220

      if(ires.eq.0) then

       write(*,'(////a\)')' Enter number of wavelengths (< 20) for trans
     &mission calculations '
       read(*,*) nlamb
       write(*,'(///a\)')' enter wavelength values in nm '
       read(*,*)(alamb(i),i=1,nlamb)
c
c   calculate transmission values for each of the lambda values
c   for each of the ranges
c
       do 280 i = 1, nlamb

       if(alamb(i).lt.185.0) alamb(i)= 185.0
       if(alamb(i).gt.700.) alamb(i)= 700.0
       do 240 j = 1, nrange
       if (j.eq.1) then
       call trmod(alamb(i),z0,vis,range(1),thetzr,t,p,den,
     , trans(i,1),ires)
       else
       call trmod(alamb(i),zf(j-1),vis,delrng,thetzr,t,p,den,
     , trans(i,j),ires)
       trans(i,j) = trans(i,j) *trans(i,j-1)
       endif
  240  continue
  280  continue
```

```
      else
       write(*,'(//2(a/),/6(a/)a\)')(msga(i),i=1,9)
       read(*,*)li
       write(*,1020)li,hrlamb(li)
c
c   combine the resolution parameter with the laser id parameter so that
c   ires=o for low resolution case and ires = 1,2,... for the individual
c   laser cases
       ires=li
       nlamb=1

      do 290 j = 1, nrange
       if  (j.eq.1) then
       call trmod(hrlamb(li),z0,vis,range(1),thetzr,t,p,
     , den,trans(1,1),ires)
       else
       call trmod(hrlamb(li),zf(j-1),vis,delrng,thetzr,t,p,den,
     , trans(1,j),ires)
       trans(1,j) = trans(1,j) * trans(1,j-1)
       endif
  290  continue
      endif

c   write transmission data to printer
c
          If(iprnt.eq.1) then
  310  continue
       open(4,file='prn')
c       open(4,file = '    ',status ='new')
       write(4,'(//a//)')'  uv transmission calculations '
       write(4,'(/a/)')' current model ozone concentrations are:'
       write(4,1008)(z1(i),o3prnt(i),i=1,11)
       write(4,1009)(trppb(i),i=1,4)

       write(4,1010) vis,zref,pct100
       if (ires.ne.0) write (4,'(a/)')' high resolution data'
       write(4,1013) z0,thetaz
       Do 315 j=1, nrange
       write (4,1015) range(j), zf(j)
       if(ires.ne.0) then
         write(4,1014)hrlamb(li),trans(1,j)
       else
         write(4,1014)( alamb(i),trans(i,j), i=1,nlamb)
       endif
  315  continue
      endif
```

```
c
      write(*,1010) vis,zref,pct100
      if (ires.ne.0) write (*,'(a/)')' high resolution data'
      write(*,1013) z0,thetaz
      Do 318 j=1, nrange
      write (*,1015) range(j), zf(j)
      if(ires.ne.0) then
        write(*,1014)hrlamb(li),trans(1,j)
      else
        write(*,1014)( alamb(i),trans(i,j), i=1,nlamb)
      endif
  318 continue

 1008 format(' altitude = ',f3.0,' km    O3 concentration - ',
     1 f7.1,' ppbv')
 1009 format(/' current modeled trace gas concentrations are:'//
     1' 1--SO2 concentration      ',f7.1,' ppbv'/
     2' 2--N2O concentration      ',f7.1,' ppbv'/
     3' 3--H2O concentration    ',f9.1,' ppbv'/
     4' 4--NO2 concentration      ',f7.1,' ppbv')
 1010 format(/' visibility = ',f6.2,' km   at an altitude of ',
     &f5.2,' km'/' particle extinction changes by ',f6.1,' %'
     &/' per 100 meters altitude increase')

 1013 format(//1h ,' initial altitude = ',
     &,f5.2,' km      zenith angle = ',f5.1,' degrees'//)
 1014 format(1h ,' Wavelength = ',f7.2,' nm    Transmission = '
     &,e8.3)
 1015 format (1h ,/,' Range = ', f5.2,' km      Final Altitude =',
     &f5.2,' km'/)
 1020 format(' Number chosen is ',i2,'   wavelength chosen is ',
     & f5.1,' nm')

      stop
c*************************************************************************

c  do LIDAR calculations
c
  400 continue
c*************************************************************************
c         determine background condition: 1= clear daylight; 2= overcast
c         3= night
c
      write(*,'(/a/a/a/a\)')' Enter background condition for calculatio
     &n','      daylight clear = 1','      daylight overcast = 2',
```

```
   &'      night = 3  '
 410 read(*,*) ibkflg
     if(ibkflg.eq.1.or.ibkflg.eq.2.or.ibkflg.eq.3) goto 412
     write(*,'(//a\)')'  Please enter 1, 2, or 3     '
     goto 410
 412 if(ibkflg.eq.1) then
      write(*,'(//a/)')'  Clear Daylight Background Selected'
      endif
     if(ibkflg.eq.2) then
      write(*,'(//a/)')'  Overcast Daylight Background Selected'
      endif
     if(ibkflg.eq.3) then
      write(*,'(//a/)')'  Night Background Selected'
      endif
c*************************************************************************
c
c determine wavelength of laser source
c
     write(*,'(//a/)')'  Lidar return calculations can'
     write(*,'(a/,/6(a/)a\)')(msga(i), i=2,9)
     read(*,*)li
     write(*,1020)li,hrlamb(li)
c*************************************************************************
c determine whether default lidar parameters are ok as is or whether
c changes should be made
c
     write(*,'(//a//)')'  Following are default parameters for Lidar sy
    &stem:'
     write(*,1041)(syspar(i),i=1,6)
 1041 format('    1.    Laser Pulse energy   -- ',f4.2,' joule'/,
    2'    2.    Receiver Mirror Diameter -- ',f4.3,' m '/
    3'    3.    Receiver field of view  -- ',f4.2,' mrad'/,
    4'    4.    Spectral Bandwidth of System -- ',f4.2,' nm '/,
    5'    5.    Transmitter Efficiency   ---  ',f3.2,/,
    6'    6.    Receiver Efficiency      ---  ',f3.2,/,
    7'  Enter number of parameter to change; '/,
    8'  or enter s if current values are used.'/)
 404     read(*,*,err=406)isp
     write(*,'(//a\)')'  Enter new value of parameter  '
     read(*,*)syspar(isp)
     write(*,'(//a\)')'  Do you want to change another parameter (y or
    & n)  '
     read(*,'(a1)')pflg
     if(pflg.eq.'y'.or.pflg.eq.'Y') then
       write(*,'(//a/)')'  Current Lidar parameters are '
       write(*,1041)(syspar(i),i=1,6)
```

```
      go to 404
     else
     endif
c*************************************************************************8
c        set up Lidar eqn parameters
c
  406 continue
     enpls=syspar(1)
     colar= (syspar(2)**2)*(3.141593/4.0)
     recfov = 3.141593*(0.001*syspar(3)/2)**2
     specbw= syspar(4)
     efftot = syspar(5)*syspar(6)
     eqna = enpls*colar*efftot
c*************************************************************************
     iflg=-1
     write(*,'(//a\)')'  Do you want Mie or fluorescence calculations?
    & ( M or F)  '
  408 read(*,'(a1)')tyflg
     if(tyflg.eq.'m'.or.tyflg.eq.'M') iflg=1
     if(tyflg.eq.'f'.or.tyflg.eq.'F') iflg=0
     if(iflg.eq.-1) then
       write(*,'(//a\)')'   Please enter either  M  or F  '
       go to 408
     else
     endif

c*************************************************************************
c******For the Mie lidar, assume that the backscatter is in three parts,
c******molecular, nominal particle, and added as an additional aerosol cloud.
c******beta for the molecular is calculated from  atmospheric density, beta
c******for nominal particle is calculated from visibility, additional aerosol
c******is entered in terms of beta and extinction calculated for each.
c******Nominally, beta = 0.03 sigma**.7
c*************************************************************************
     if(iflg.eq.1) then
     write(*,'(//a/a/a/a/a//a\)')'  Mie lidar was selected.',
    &' Program assumes a beta profile (m**-1 sr**-1) determined ',
    &' from aerosol and molecular profiles.  An additional component',
    &' can be added at any point in the profile by inserting beta',
    &' or extinction values for each range.',
    &' Enter number of ranges at which excess aerosol is to be added '
     read (*,*) nadd
     if (nadd.ne.0) then
     write (*,'(/a\)') ' Do you want to enter as backscatter or attenua
    &tion (b or a)? '
  420 read(*,'(a1)' )baflg
```

```
      i3flg = -1
      if(baflg.eq.'b'.or.baflg.eq.'B') i3flg = 0
      if(baflg.eq.'a'.or.baflg.eq.'A') i3flg = 1
      if(i3flg.eq.-1) then
        write(*,'(//a\)')' Please enter an a or a b.    '
        go to 420
      endif
      write(*,'(//a\)')' Do you want to enter a specific  beta/atten
     ,ratio? ( y or n)'
  421 read(*,'(a1)')bsflg
      i4flg = -1
      if(bsflg.eq.'n'.or.bsflg.eq.'N') i4flg = 0
      if(bsflg.eq.'y'.or.bsflg.eq.'Y') i4flg = 1
      if(i4flg.eq.-1) then
        write(*,'(//a\)')' Please enter either y or n.    '
        go to 421
      endif
      if (i4flg.eq.1) then
       write(*,'(//a\)')' Enter multiplier for sigma(km**-1) to get beta
     ,  ((msr)-1) '
      read (*,*)bsrat
      endif

      write (*,'(/a/a/a/a/)')' Ranges and numbers listed below.',
     &' Enter range number and value (ordered pair) for each point',
     &' at which excess aerosol is added.  Attn=[km-1] beta=[msr-1]',
     &'    #    range    #    range    #    range    #    range '

      write (*,'(i6,f9.3,i6,f9.3,i6,f9.3,i6,f9.3)')
     & ( j,range(j), j=1, nrange)
      do 424 i=1,nadd
      if (i3flg.eq.0) then
       read (*,*) m, betadd(m)
       irnum(i)=m
       addval(i)=betadd(m)
       if (i4flg.eq.1) then
        attadd(m) = (1/bsrat)*betadd(m)
       else
        attadd(m) = 148*(betadd(m))**1.43
        attadd(m) = attadd(m)*1000.0
       endif
      else
       read(*,*) m, attadd(m)
       irnum(i) = m
       addval(i) = attadd(m)
       if (i4flg.eq.1) then
```

```
      betadd(m) = bsrat*attadd(m)
     else
      betadd(m) = 0.03*(attadd(m))**0.7
      betadd(m) = betadd(m)*0.001
     endif
    endif
424 continue

    endif
    do 428 j = 1, nrange
    call betamod(hrlamb(li),z0,vis,range(j),thetzr,t,p,den,
   &betray(j), betpar(j),li)
    betsum(j) = betray(j) + betpar(j) + betadd(j)
    betrat(j) = betsum(j)/betray(j)
428 continue

    call trmod(hrlamb(li),z0,vis,range(1),thetzr,t,p,den,tra1,li)
    tr2x(1) = tra1*tra1
    do 432 j = 2, nrange
    call trmod(hrlamb(li),zf(j-1),vis,delrng,thetzr,t,p,den,
   &tra1,li)
    if (attadd(j-1).ne.0.0) then
     deladd = attadd(j-1)*delrng
     tradd = exp(-deladd)
     tra1 = tra1 * tradd
    endif
    tra2 = tra1*tra1
    tr2x(j) = tra2*tr2x(j-1)
432 continue

c*************************************************************************
c       complete Lidar return calculations
c
     do  436 j = 1,nrange
     eqnb =(eqna*tr2x(j)/((range(j)*1000.)**2))*(1.5e+8)
     sigsum(j) = (eqnb*betsum(j))
     sigray(j) = (eqnb*betray(j))
 436 continue
     call bkgrnd(thetzr,hrlamb(li),ibkflg,bkgval)
     sigbkg = bkgval*colar*recfov*specbw

     else

c*************************************************************************
c*********For fluorescence lidar assume that the backscatter is due to
c********* fluorescence only, but that the attenuation is due to
```

```
c********* molecular and nominal aerosol.
cc*****************************************************************
      write(*,'(//a/a/a/a/a//a/a\)')' Fluorescence lidar was selected',
     &' Program assumes an extinction profile (m**-1) determined ',
     &' from aerosol and molecular profiles.  Beta is due to',
     &' fluorescence only, which must be input.  Fluorescence can',
     &' be added at any point in the profile.',
     &'  Do you want to model gas or particle fluorescence?',
     &'  Enter  g or p :   '
  440 read(*,'(a1)')pgflg
      i2flg = -1
      if(pgflg.eq.'g'.or.pgflg.eq.'G') i2flg = 0
      if(pgflg.eq.'p'.or.pgflg.eq.'P') i2flg = 1
      if(i2flg.eq.-1) then
       write(*,'(//a\)')'  Please enter a g or a p.     '
       go to 440
       else
      endif
      write(*,'(//a\)')'  What is the wavelength shift of the return?  (
     &in nm) '
      read(*,*)flshft
      alam2=hrlamb(li)+flshft

      if(i2flg.eq.0) then
      write(*,'(//a/)')
     &'  What is the cross section per nm (m**2/nm) for fluorescence?  '
      else
      write(*,'(//a/)')
     &'  What is the specific cross section per nm (m**2/g/nm) for fluor
     &escence?'
      endif

      read(*,*) flxc
      flxc2=flxc*syspar(4)
      write (*,'(/a\)') '  Enter number of ranges at which fluorescence
     &  material concentration is input    '
      read (*,*) nadd

      do 442 j = 1,nrange
      flcon(j) = 0.0
  442 continue
      write (*,'(/a/a/a/a/a//)')
     &'  Ranges and numbers are listed below.',
     &' Enter range number and concentration value (as ordered pair)',
     &' for each point.  Enter as ppbv for gas concentration or ',
     &' g/m**3 for particle concentration.',
```

```
     &' #  range   #  range   #  range   #  range '
      write (*,'(i6,f9.3,i6,f9.3,i6,f9.3,i6,f9.3)')
     & ( j,range(j), j=1, nrange)

      do 444 i=1,nadd
      read (*,*) m, flcon(m)
      irnum(i) = m
      addval(i) = flcon(m)
  444 continue


      call trmod(hrlamb(li),z0,vis,range(1),thetzr,t,p,den,tra1,li)
      call trmod(alam2,z0,vis,range(1),thetzr,t,p,den,tra2,0)
      tr2x(1) = tra1*tra2
      do 450 j = 2, nrange
      call trmod(hrlamb(li),zf(j-1),vis,delrng,thetzr,t,p,den,
     &tra1,li)
      call trmod(alam2,zf(j-1),vis,delrng,thetzr,t,p,den,tra2,0)
      tra12 = tra1*tra2
      tr2x(j) = tra12*tr2x(j-1)
  450 continue
c
c************complete fluorescence Lidar return calculations
c
      do 454 j = 1, nrange
      if(i2flg.eq.0) then
       call stdatm(zf(j),t,p,den)
       flcon2 = flcon(j)*den*1.0e-3
       betfl(j)=flxc2*flcon2/(4*3.141593)
      else
       betfl(j) = flxc2*flcon(j)/(4*3.14159)
      endif
      eqnb =eqna*tr2x(j)/((range(j)**2)*(1.5e+2))
      sigfl(j) = eqnb*betfl(j)
  454 continue

      call bkgrnd(thetzr,alam2,ibkflg,bkgval)
      sigbkg = bkgval*colar*recfov*specbw

      endif

c     write(*,1042) flsxc2,flmcon,flshft
c1042 format(//'  fluorescence cross section (in wavelength interval) =
c     & ',e10.3,'m**2/g'/'  concentration = ',e10.3,' g/m**3'
c     &/'  wavelength shift = ',f5.1,' nm'/)
```

```
c     write(*,1043) flxc2,flppb,flshft
c1043 format(//' fluorescence cross section (in wavelength interval) =
c    & ',e10.3,'m**2'/' concentration = ',e10.3,' ppbv'
c    &/' wavelength shift = ',f5.1,' nm'/)


c*********************************************************************
        If(iprnt.eq.1) then
      continue
c      open (4, file='prn')
      open (4,file = '    ', status ='new')
      write(4,'(//a\)')' Lidar return calculations'
      if(iflg.eq.1) then
       write(4,'(a/)')' for a Mie Lidar'
       else
       write(4,'(a/)')' for a fluorescence Lidar'
      endif

      write(4,'(/a/)')' current modeled ozone concentrations are:'
      write(4,1008)(z1(i),o3prnt(i),i=1,11)
      write(4,1009)(trppb(i),i=1,4)

      write(4,1010)vis,zref,pct100
      write(4,1046)(syspar(i),i=1,6)
      write(4,1047) z0,thetaz
      if (iflg.eq.1) then
      if (nadd.eq.0)then
      write (4,'(a)')' no added attenuation values'
      else
      write(4,'(a,/,a\)')' added values:',' range #   value added for'
       if (i3flg.eq.0) then
        write (4,'(a)')' beta'
        else
        write (4,'(a)')' attenuation'
        endif
        write(4,'(i5,5x,e11.3)')(irnum(i),addval(i), i = 1,nadd)
        endif
        write(4,1048) hrlamb(li), sigbkg
      write (4,'(a,a/a,a/)')' range   final alt  beta(tot) ',
     &' beta ratio  2xtrans     sigtot     sig(Ray)',
     &' [km]     [km]     [(msr)**-1]              ',
     &'              [watts]     [watts] '
      Do 456 j = 1,nrange
       write(4,1044) range(j),zf(j),betsum(j),betrat(j),tr2x(j),
     &sigsum(j), sigray(j)
  456 continue
```

```
      else
            if (nadd.eq.0)then
      write (4,'(a)')' no added attenuation values'
       else
       write(4,'(a,/,a\)')' added values:',' range     value added for
     ,fluorescence'
       write(4,'(i4,6x,e11.3)')(irnum(i),addval(i), i = 1,nadd)
       endif
       write(4,1049) hrlamb(li), alam2, sigbkg
      write(4,'(a)')' range   final alt    beta (fl)     2xtrans    ret
     &urn signal  '
       write(4,'(a/)')'  [km]      [km]        [(msr)-1]
     &[watts]     '
       do 458 j = 1,nrange
       write(4,1052) range(j),zf(j),betfl(j),tr2x(j),sigfl(j)
  458 continue
      endif

      else

      endif
  1044 format(1x,f5.2,4x,f5.2,2x,5(e12.3))
  1045 format(//'  Lidar transmitter wavelength = ',f5.1,' nm   ',/
     &'  fluorescence return wavelength = ',f5.1,' nm'/
     &'  fluorescence beta in bandwidth = ',e8.3,' m**-1 sr**-1'/
     &'  total transmission =',e8.3,///,
     &'  return fluorescence signal = ',e8.3,' watts',/
     &'  background signal = ',e8.3,' watts')
  1046  format(//'  Lidar system parameters:'/'   Pulse Energy = ',
     & f4.2,' joules;  Receiver Diameter = ',f5.3,' m;'/
     &,'   Receiver fov = ',f4.2,' mrad;  Spectral Width = ',f4.2,
     &' nm;'/'   transmit efficiency = ',f4.2,';  receiver efficiency =
     &',f4.2/)

  1047 format(/1h,'  initial altitude = ',f5.2,
     &' km       zenith angle = ',f5.1,' degrees'/)

  1048 format (/' Lidar wavelength = ',f5.1,' nm    bkg signal = '
     ,e11.3' watts'/)
  1049 format (//' source wavelength ',f5.1,' nm    return wavelength ',
     ,f5.1' nm'/' background signal = ',e11.3/)
  1052 format(1x,f5.2,4x,f5.2,2x,4(e13.3))

c      if(iflg.eq.1) then
c      endif
c
```

```
      write(*,'(//a\)')'  LIDAR return calculations'
      if(iflg.eq.1) then
        write(*,'(a/)')' for a Mie LIDAR'
        else
        write(*,'(a/)')' for a fluorescence LIDAR'
       endif

      write(*,'(/a/)')' current modeled ozone concentrations are:'
      write(*,1008)(z1(i),o3prnt(i),i=1,11)
      write(*,1009)(trppb(i),i=1,4)

      write(*,1010)vis,zref,pct100
      write(*,1047) z0,thetaz

      if(iflg.eq.1) then
       write (*,'(a,a/a,a/)')' range   final alt  beta(tot) ',
     &' beta ratio  2xtrans      sigtot     sig(Ray)',
     &' [km]     [km]     [(msr)**-1]              ',
     &'              [watts]     [watts] '
       Do 466 j = 1,nrange
        write(*,1044) range(j),zf(j),betsum(j),betrat(j),tr2x(j),
     &sigsum(j), sigray(j)
  466 continue
       else

        write(*,1049) hrlamb(li), alam2, sigbkg
       write(*,'(a)')' range   final alt    beta (fl)     2xtrans    ret
     &urn signal  '
       write(*,'(a/)')'  [km]     [km]       [(msr)-1]
     &[watts]    '

       do 468 j = 1,nrange
        write(*,1052) range(j),zf(j),betfl(j),tr2x(j),sigfl(j)
  468 continue
       endif


       end

c*******************************************************************************

       subroutine trmod(alamb,z0,vis,range,thetzr,t,p,den,trans,ires)
c
c  subroutine trmod is the transmission module that calculates transmission
c  over a given range.  Input parameters are
c        alamb--wavelength
```

```
c       z0 -- receiver altitude
c       vis--visual range
c       range--distance to target
c       thetzr--zenith angle in radians
c       t,p,den--atmospheric temperature, pressure, and density
c       trans--returned transmission
c       ires--flag for resolution and for laser type: ires=0 low;
c       ires=1, 2, 3, ... high-- for laser line designated by numbers
c
      nrngnt = int((range/0.1)*abs(cos(thetzr)))+1
      rngint = (range/nrngnt)

      sigrng = 0.0
      attrng = 0.0
      do 275 j = 1, nrngnt
      zi = z0 +((rngint/2)+((j-1)*rngint))*cos(thetzr)
      call stdatm(zi,t,p,den)
      call o3ccal(zi)
      if(ires.eq.0)then
          call absmol(alamb,den,amolab)
        else
          call hrabsm(ires,den,amolab)
        endif
      call attmol(alamb,den,amolsc)
      call attaer(zi,alamb,den,vis,partex)
c     write(*,'(3e10.4)')amolab,amolsc,partex
      sigrng =  amolab+amolsc+partex
      attrng = attrng + sigrng*rngint
  275 continue

      trans = exp(-attrng)
      return
      end

c*******************************************************************************
      subroutine betamod(alamb,z0,vis,range,thetzr,t,p,den,
     &betray, betpar,li)
c
c     subroutine calculates beta values for normal extinction and
c     molecular profiles.  Beta values are in (m sr)**-1
c
      zf = z0 + range*cos(thetzr)
      call stdatm(zf,t,p,den)
      call attmol(alamb,den,amolsc)
      betray=(amolsc/8.130)*1.0e-3
      call attaer(zi,alamb,den,vis,partex)
```

```
      betpar = (0.03*partex**0.7)*1.0e-3
      return
      end
c*******************************************************************************
      subroutine clear
c
      character clr
      clr=char(27)
      write(*,100) clr
  100 format (1x,a1,'[2J')
      return
      end
c*******************************************************************************
      subroutine bkgrnd(thetzr,alamb,ibkflg,bkgval)
c
c        Purpose is to calculate background in watts/(sr nm m**2)
c            thetzr = zenith angle in radians
c            ibkflg = flag which indicates conditions of illumination
c                1 = daylight clear sky
c                2 = daylight overcast
c                3 = night
c
c
c         Array Hbkg contains nominal daylight horizon brightness
c         values from 280 to 720 nm.  Othere values are calcualted
c         from these values
c
c****************************************
c
      dimension hbkg(23)
      data  hbkg/1.0e-8,4.0e-3,2.3e-2,3.9e-2,5.6e-2,6.5e-2,7.5e-2,
     &8.6e-2,9.5e-2,1.01e-1,1.04e-1,1.04e-1,1.01e-1,9.9e-2,9.8e-2,
     &9.2e-2,8.8e-2,8.1e-2,7.3e-2,6.5e-2,4.8e-2,3.6e-2,2.6e-2/

      if(alamb.lt.280) then
      bkgval=0.0
      return
      endif
c
c        calculate nominal horizon brightness for alamb
c
      dlamb=alamb-280.
```

```
      indx=int(dlamb/20.)+1
      indx2=indx+1
      y1=alog(hbkg(indx))
      y2=alog(hbkg(indx2))
      rat1=(amod(dlamb,20.))/20.
      yint = y1 + (y2-y1)*rat1
      hbk1 = exp(yint)
c
c         calculate actual brightness
c
      if(thetzr.lt.1.5708) then
      if(ibkflg.eq.1) then
       bkgval = hbk1*(0.19 + .81*sin(thetzr))
       else
       if(ibkflg.eq.2) then
       bkgval = hbk1*(1.0 + 2*cos(thetzr))
       else
       if(ibkflg.eq.3)then
       bkgval = 1.0e-6*(hbk1*(0.19 + .81*sin(thetzr)))
       endif
       endif
       endif
      else
      if(ibkflg.eq.1.or.ibkflg.eq.2) then
      bkgval = 0.1*hbk1*(1.0 + 0.7*cos(thetzr))
      else
      bkgval = 1.0e-6*0.1*hbk1*(1. + 0.7*cos(thetzr))
      endif
      endif
      return
      end
```

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